ARTHROPOD PREDATORS IN CABBAGE (CRUCIFERAE) AND THEIR POTENTIAL AS NATURALLY OCCURRING BIOLOGICAL CONTROL AGENTS FOR *PIERIS RAPAE* (LEPIDOPTERA: PIERIDAE)

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Abstract

The Canadian Entomologist **132**: 655 – 675 (2000)

We used three sampling methods to identify the arthropod predators most abundant and active in fields of cabbage, *Brassica oleracea* L. var. *capitata*, and determined those most likely to be important predators of the imported cabbageworm, *Pieris rapae* L., by testing the predators' abilities to forage on cabbage plants and to feed on *Pieris rapae* in small arenas in the laboratory. Abundance and activity in the field were monitored with pitfall traps, sticky traps applied directly to leaves, and plant samples. Four criteria were used to assess the species' potential value as a predator of *Pieris rapae* in cabbage: relatively high overall abundance in trap catches and plant samples, occurrence on plant foliage in the field, a high propensity to feed on *Pieris rapae* eggs and first instars, and the ability to search for larval *Pieris rapae* on cabbage plants. Four species, the wolf spider *Pardosa milvina* (Hentz) (Araneae: Lycosidae), the harvestman *Phalangium opilio* L. (Opiliones: Phalangiidae), and the lady beetles *Coleomegilla maculata lengi* Timberlake and *Hippodamia variegata* (Goeze) (Coleoptera: Coccinellidae), demonstrated these attributes, although all four species appeared unable to search for prey on some parts of the cabbage plants, owing to unsure footing on the plants' slippery cuticular wax. Linyphiids (Araneae) and syrphids (Diptera), the most abundant taxa in the plant samples, may prove better at thoroughly searching cabbage plants, but remain to be tested in future laboratory trials. Our results show that only a small portion of the predatory arthropod species that occur in cabbage fields is likely to prey on *Pieris rapae* on the plants, although important questions remain about the roles of some taxa. Future efforts to enhance biological control of *Pieris rapae* by naturally occurring predators can now focus on further elucidating and finding ways to enhance the roles of those predators that are effective.

Résumé

Nous avons identifié les prédateurs arthropodes les plus abondants et actifs sur le choux, *Brassica oleracea* L. var. *capitata*, en utilisant trois méthodes de recensement en champ. Ensuite nous avons identifié les espèces de ces arthropodes les plus susceptibles d'être des prédateurs efficaces de la piéride du chou, *Pieris rapae* L., en utilisant un examen en laboratoire de leurs aptitudes à rechercher des proies sur plantes entières et à consommer des piérides du chou (oeufs ou larves). Nous avons recensé l'abondance et l'activité de ces prédateurs potentiels au moyen de pièges à fosses, de pièges gluants déposés sur feuilles et d'échantillonages de plantes. Nous avons utilisé quatre critères pour évaluer le potentiel de chaque espèce étudiée: son abondance relative dans les pièges et sur plantes, l'efficacité de sa recherche de proies sur plantes, et sa consommation d'oeufs et de larves de *Pieris rapae*. Quatre espèces se sont avérées intéressantes : la lycose *Pardosa milvina* (Hentz) (Araneae :

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Lycosidae), l'opilion *Phalangium opilio* L. (Opiliones : Phalangiidae), et les cocci-
nelles *Coleomegilla maculata lengi* Timberlake et *Hippodamia variegata* (Goeze)
(Coleoptera : Coccinellidae). Cependant, chacune de ces espèces est incapable de
consommer des piérides sur certaines parties de la plante en raison de la présence de
cires épicuticulaires qui gênent leurs déplacements. Il est possible que les linyphii-
dés (Araneae) et les syrphides (Diptera), les prédateurs les plus abondants dans nos
échantillons de plantes entières, ne sont pas gênés par ces cires. Néanmoins, leurs
aptitudes à rechercher des proies sur plantes entières reste à être évaluée. Nos résul-
tats montrent que seule une petite proportion des prédateurs présents aux champs
ont le potentiel d'être des prédateurs efficaces de *Pieris rapae*. Le rôle de ces préda-
teurs pourrait être accentué dans un programme de lutte biologique contre *Pieris
rapae* basé sur l'utilisation de prédateurs naturellement présents dans les champs de
choux.

Introduction

As one of the most common butterflies and a serious pest of crucifer crops in
many parts of the world, *Pieris rapae* L. (Lepidoptera: Pieridae) has received a great
deal of attention from lepidopterists and agricultural entomologists (Gilbert and Singer
1975; Jones 1981; Ehrlich 1984; Courtney 1986; Lokkers and Jones 1999). Despite its
importance, little is known about the impact of predatory arthropods on *Pieris rapae*
populations, although several studies suggest it may be substantial (Dempster 1967,
1984; Parker 1970; Ashby 1974; Hasui 1977; Jones *et al*. 1987). Earlier reports have
documented high levels of mortality from arthropod predators (Schmaedick and Shelton
1999) and reported on extensive pitfall-trapping of ground-dwelling predators (Shelton
et al. 1983*a*) in fields of cabbage, *Brassica oleracea* L. var. *capitata* (Cruciferae), in
central New York State. In the current study, we used pitfall-trapping, along with other
sampling methods and laboratory predation assays, to monitor arthropod predators in
cabbage fields and assess their potential as naturally occurring biological control agents
for *Pieris rapae*.

Immature *Pieris rapae* are reported to rarely leave suitable host plants before they
disperse for pupation (Harcourt 1961; Jones 1977). This habit would likely reduce the
opportunity for predation on early stage *Pieris rapae* by the surface-active predators
typically captured by pitfall-trapping. Nevertheless, pitfall-trapping, combined with
other sampling techniques, remains an important tool for assessing the potential impact
of predators on foliar-dwelling herbivores for several reasons. First, many predators
spend time both on plants and on the soil surface, and pitfall traps may be the most ef-
fective way to monitor some of these predators. Second, studies in other crops have
shown that soil surface dwelling predators may have a significant impact on populations
of foliar-dwelling herbivores when the presence of other predators on the foliage causes
the herbivores to move off or be dislodged from the plants (Dennis and Sotherton 1994;
Losey and Denno 1998*a*, 1998*b*). Third, a great deal of information has recently be-
come available on predator–predator and predator–detritivore interactions and their ef-
fects on biological control in agricultural systems (*e.g*., Polis and Myers 1989;
Rosenheim *et al*. 1995; Settle *et al*. 1996; Fagan *et al*. 1996; Rosenheim 1998; Snyder
and Wise 1999). As a result, agricultural entomologists now recognize that they cannot
hope to understand individual predator–prey relationships in isolation from the larger
food webs of which they are a part. We therefore approached the problem of determin-
ing which predator species may be affecting *Pieris rapae* populations by first using sev-
eral sampling techniques, including pitfall traps, sticky traps, and above-ground plant
samples, to determine the relative abundance and activity of arthropod predators in cab-
bage fields. We then focused on those species most likely to affect the early stages of

Pieris rapae directly, owing to their occurrence on plants in the field, and tested their abilities to forage on cabbage plants and feed on *Pieris rapae* in the laboratory.

Materials and Methods

Field Study Sites. Trapping with pitfall traps and sticky traps was conducted at three sites in 1995 and two sites in 1996. Plant samples were taken from the two 1996 sites. The sites were 0.2 ha square plots of 'Vantage Point' transplanted 6–10 June 1995 and 'Cheers' transplanted 22–26 May 1996. The plots were located at the Fruit and Vegetable Research Farm of the New York State Agricultural Experiment Station at Geneva, New York (42°53′N, 77°02′W) and were separated by >500 m in 1995 and by 160 m in 1996. Soil at the research farm is mostly Lima silt loam (fine-loamy, mixed, mesic, Glossoboric Hapludalf) (US Department of Agriculture 1958). Precipitation averages 65 cm annually, and temperatures range from a January mean daily low of –9°C to a July mean daily high of 28°C (Vittum *et al.* 1983). Standard agronomic practices were followed in all the fields and no fungicides or insecticides were applied. The plots were bordered by a 3- to 5-m strip in which weeds were controlled by disking and rototilling, and all trapping and sampling took place >3 m from the edge of the planted areas. Surrounding areas consisted of deciduous woodlands, fallowed fields of grasses and forbs, gravel roadways, and fields planted to corn, *Zea mays* L. (Poaceae); tomatoes, *Lycopersicon esculentum* Miller (Solanaceae); cabbage; squash, *Cucurbita* L. spp. (Cucurbitaceae); alfalfa, *Medicago sativa* L. (Fabaceae); and sorghum-sudan grass, *Sorghum bicolor* L. × *Sorghum sudanense* Bailey (Poaceae).

Pitfall Traps. Dry pitfall traps, consisting of two 296-mL clear plastic cups (7.2 cm diameter opening; Solo Cup Co., Urbana, Illinois) placed one inside the other, were embedded in the soil, replacing every 13th plant in every sixth row in a 7 × 7 grid in the plot center. Each trap was protected from rain and direct sunlight by an inverted 15.2-cm-diameter white plastic disposable plate (Solo Cup Co.) held approximately 3 cm above the trap by a binder clip fastened to a 14-gauge wire inserted into the soil beside the trap. Squat 266-mL plastic cups (9 cm diameter opening; Solo Cup Co.) were inserted into the mouth of each trap to close it and were held in place by the inverted plate cover. The traps were opened for a 24-h period weekly, during which they were emptied twice, at approximately 08:00 and 20:00, before closing them until the following week. Captured arthropods were immediately placed in containers embedded in ice and were later frozen at –20 or –80°C (according to space available in freezers) until they could be examined. Trapping was conducted for 7 weeks (from 28 June to 9 August) in 1995 and 11 weeks (from 19 June to 28 August) in 1996. Predatory arthropods were identified to the lowest taxonomic level possible and the abundance of the most common species was determined for each plot and sampling time.

Sticky Traps. Sticky traps were placed on 36 plants, approximately every 13th plant in every sixth row, forming a 6 × 6 grid in the center of each plot. The traps consisted of two 8.6-cm rings of insect trap coating (Tanglefoot Co., Grand Rapids, Michigan) applied to each plant, one on the upper surface of a frame leaf and another on the lower surface of a frame leaf roughly opposite the first. On the first trapping date in 1996, when the leaves were small, the traps consisted of 5-cm-diameter circles instead of the larger rings. In 1995, the trapping began on 10 July and continued until 14 August. Predatory arthropods were collected from the traps every 3–4 d, and every week the coated leaves were removed and new trap coating applied to leaves of the same or nearby plants. In 1996, trapping was done for one 24-h period each week from 19 June

until 28 August, and traps were checked at approximately 08:00 and 20:00 during each trapping period, after which the coated leaves were removed from the fields. Trapped predatory arthropods were placed in petri dishes on ice for transport to the laboratory, where they were stored at –80°C until they could be cleaned and examined. All were identified to the lowest taxonomic level possible, and numbers of the most abundant species were determined for each plot and sampling time.

It has been shown that some natural enemies are attracted to plants that are damaged by their herbivore prey (Whitman and Nordlund 1994). It is possible that removing the leaves bearing sticky traps after each trapping period could have increased plant damage over background levels enough to increase the attractiveness of the plants to certain arthropod predators, thus increasing trap catches. We did not investigate this possibility further. Such a bias, if it existed, represents one of many potential biases associated with this or any trapping method.

Plant Sampling. On 20 June, 4 July, 18 July, and 7 August 1996, plant samples were taken from the two study plots. At eight sampling times on each of the four sampling dates, 30 randomly selected plants per plot were sampled by quickly placing a large plastic bag over the plant, closing it around the plant base, cutting the stem at ground level, and then tying the bag closed. The samples were taken at 02:00, 05:00, 08:00, 11:00, 14:00, 17:00, 20:00, and 23:00 and were held at 2°C until they could be examined leaf by leaf in the laboratory. (Median time between sampling and examination of the plants was 6 d.) Samples were taken at all times of the day, to ensure that any predators that tend to move on and off plants in a daily cycle would not be missed. All predatory arthropods were removed from the plants and stored at –80°C until they could be examined further. (Some predator pupae were not frozen but, instead, were reared to adults for identification.) Over the season, a total of 1920 plants was examined (2 plots × 8 sampling times × 4 sampling dates × 30 samples). Predators were identified to the lowest taxonomic level possible and the abundance of the most numerous predators was displayed graphically by plot and sampling date. Voucher specimens from the pitfall-trapping, sticky-trapping, and plant-sampling were placed in the Cornell University Insect Collection under lot number 1239.

Predation in Small Arenas. Selected species that were found to occur in the study plots were collected from cabbage fields and surrounding areas and tested for their ability to prey on *Pieris rapae* eggs and first instars in small arenas in the laboratory. Species were selected on the basis of their relative abundance in the trap captures and plant samples and our ability to positively identify and collect enough individuals to test. In addition, nabids and anthocorids (Insecta) were also included in this and the following experiment, despite their rarity or absence in the trapping and plant-sampling. We included these predators in the experiments, because these groups were found to be relatively abundant in cabbage by Oatman and Platner (1969) and Weires and Chiang (1973) and in preliminary sampling done by us (MA Schmaedick, unpublished data). The predators were placed individually in 473-mL white plastic "deli" containers with clear tops (Fabri-Kal Corp.) lined with filter paper and provided with a moist 2.5-cm length of cotton dental wick. The arenas containing the predators were placed in an environmental chamber at 15 L (22°C) : 9 D (17°C) and 60% RH, and starved for 24 h before adding either 10 or 20 *Pieris rapae* eggs or five first instars. These environmental conditions were chosen to approximate those occurring in central New York State during the cabbage-growing season. Eggs and first instars were used in the tests, because earlier work indicated that almost all mortality from arthropod predators occurred during these stages (Schmaedick and Shelton 1999). The eggs were presented on pieces cut from parafilm sheets used for oviposition in a laboratory colony of *Pieris rapae*

(Webb and Shelton 1988). The first instars were transferred shortly after hatching to 3.2-cm cabbage leaf disks that were then placed with the predators. After an additional 24 h, the remaining eggs or larvae were counted. At least 19 test arenas containing individual predators were used for each species – *Pieris rapae* stage combination. A minimum of five control arenas, identical to the test arenas except without predators, were included with each batch of predators tested. No eggs or larvae were damaged or disappeared in any of the control arenas.

Predation on Cabbage Plants in the Laboratory. A subset of the predator species that had been found to occur in cabbage plots and which fed on *Pieris rapae* in the small-arena assays was tested for the ability to prey on first-instar *Pieris rapae* on potted cabbage plants in cages in the laboratory. Predators were collected from cabbage fields and surrounding areas and starved for 24 h, as for the small-arena experiments. Groups of predators were then placed in clear-plastic cylinder cages with screen tops covering small (4- to 6-leaf) cabbage plants. The cabbage plants had been transplanted into 25 cm diameter pots containing a moist mason sand substrate (BR DeWitt, Inc., Phelps, New York) and infested with 10 first instar *Pieris rapae* 24 h earlier. The cylinder cages fit tightly inside the pot rims at the level of the substrate and were coated with a thin layer of fluon (Northern Products, Woonsocket, Rhode Island), which prevented the predators from climbing the sides and kept them confined to the substrate and plant. A moist 2.5-cm length of cotton dental wick was placed on the substrate surface in each pot. After 24 h at 22°C, 40% RH, and 16L:8D, the remaining larval *Pieris rapae* were counted. Three control plants, with *Pieris rapae* but no predators, were included in each trial. No larvae disappeared from any of the control plants.

Results

Pitfall Traps. The Carabidae (Insecta), Staphylinidae (Insecta), and Linyphiidae (Arachnida) comprised most of the species caught in the pitfall traps. (Table 1 presents taxonomic authorities, order, and family for all genera and species.) With a few exceptions, the most numerous taxa in the traps also belonged to these families (Fig. 1). Only five species were captured in numbers that comprised 5% or more of the total catch of arthropod predators in the pitfall traps: *Phalangium opilio* (Arachnida; 15%), *Bembidion quadrimaculatum oppositum* (Insecta; 14%), *Elaphropus anceps* (Insecta; 7%), *Stenolophus comma* (Insecta; 6%), and *Pterostichus melanarius* (Insecta; 5%). Two additional taxa that were not identified to species level also comprised >5% of total captures: centipedes (Chilopoda) [Lithobiidae (*sensu lato*)] (7%) and the Athetini (Insecta; 6%). Lithobiidae, among the most abundant predators in 1995, were relatively scarce in 1996 (Fig. 1). *Tinotus* sp. (Insecta), although relatively abundant overall, occurred almost solely in plot 1 (Fig. 1). *Lasius* sp. (Insecta) were also restricted in their occurrence, with 44% of the 2-year total being trapped on the final sample date in plot 3. Traps in plot 1 in 1995 had unusually high numbers of *Bembidion quadrimaculatum* and *Phalangium opilio* (Fig. 1). Plot 1 was by far the weediest of the five plots, Weed levels in midseason probably exceeded what would be tolerated by most commercial growers. It was also unique in being located in an area surrounded by weedy fallow land, whereas the other four plots were surrounded by unpaved access roads and cultivated areas.

Seasonal patterns were evident for some species but not for others (Figs. 2 and 3). Immature *Phalangium opilio* tended to be more abundant late in the season, while adults were more abundant early in the season (Fig. 2A). *Pardosa* sp. (Arachnida) numbers peaked in midseason in both years (Fig. 2B). The large numbers of *Tennesseellum*

TABLE 1. Predatory arthropods captured in cabbage fields in pitfall traps (PF), sticky traps (ST), and plant samples (PL).

	Order	Family	PF	ST	PL
Arachnida					
Achaearanea tepidariorum (C.L. Koch)	Araneae	Theridiidae			×
Anyphaenidae (immature, no further identification)	Araneae	Anyphaenidae			×
Araniella displicata (Hentz)	Araneae	Araneidae			×
Catabrithorax plumosus (Emerton)	Araneae	Linyphiidae	×		
Clubiona Latreille sp.	Araneae	Clubionidae		×	×
Clubiona pygmaea Banks	Araneae	Clubionidae		×	
Coriarachne versicolor Keyserling	Araneae	Thomisidae			×
Dictyna bostoniensis Emerton	Araneae	Dictynidae			×
Dictyna foliacea (Hentz)	Araneae	Dictynidae			×
Diplostyla concolor (Wider)	Araneae	Linyphiidae	×		
Drassyllus depressus (Emerton)	Araneae	Gnaphosidae	×		
Eperigone Crosby and Bishop sp.	Araneae	Linyphiidae	×		
Eperigone tridentata (Emerton)	Araneae	Linyphiidae	×		
Eperigone trilobata (Emerton)	Araneae	Linyphiidae	×		
Erigone atra Blackwall	Araneae	Linyphiidae	×		
Erigone Audouin sp.	Araneae	Linyphiidae	×		×
Erigone autumnalis Emerton	Araneae	Linyphiidae	×		
Grammonota inornata Emerton	Araneae	Linyphiidae	×		
Hadrobunus maculosus (Wood)	Opiliones	Phalangiidae	×		
Islandiana Braendegaard sp.	Araneae	Linyphiidae	×		
Islandiana flaveola (Banks)	Araneae	Linyphiidae	×		×
Islandiana longisetosa (Emerton)	Araneae	Linyphiidae	×		×
Leiobunum bracchiolum McGhee	Opiliones	Phalangiidae	×		
Linyphia pusilla Sundevall	Araneae	Linyphiidae	×		×
Meioneta unimaculata (Banks)	Araneae	Linyphiidae	×	×	×
Metaphidippus Cambridge sp.	Araneae	Salticidae		×	
Neoantistea Gertsch sp.	Araneae	Hahniidae			×
Ozyptila praticola (C.L. Koch)	Araneae	Thomisidae	×		
Pardosa milvina (Hentz)	Araneae	Lycosidae	×	×	
Pardosa saxatilis (Hentz)	Araneae	Lycosidae	×		
Phalangium opilio L.	Opiliones	Phalangiidae	×	×	×
Philodromus rufus Walckenaer	Araneae	Philodromidae			×
Pirata minutus Emerton	Araneae	Lycosidae	×		
Salticidae (immature, no further identification)	Araneae	Salticidae			×
Steatoda americana (Emerton)	Araneae	Theridiidae	×		
Tennesseellum formicum (Emerton)	Araneae	Linyphiidae	×		×
Tetragnatha laboriosa Hentz	Araneae	Tetragnathidae		×	×
Tetragnatha versicolor Walckenaer	Araneae	Tetragnathidae			×
Theridion bimaculatum (L.)	Araneae	Theridiidae			×
Theridula emertoni Levi	Araneae	Theridiidae			×
Tibellus Simon sp.	Araneae	Philodromidae			×
Trochosa ruricola (DeGeer)	Araneae	Lycosidae	×		
Walckenaeria Blackwall sp.	Araneae	Linyphiidae	×		×
Walckenaeria spiralis (Emerton)	Araneae	Linyphiidae	×		×

TABLE 1 (*continued*).

	Order	Family	PF	ST	PL
Chilopoda					
Lithobiidae (*sensu lato*) (no further identification)	Lithobiomorpha	Lithobiidae	×		×
Insecta					
Acupalpus Latreille sp.	Coleoptera	Carabidae		×	
Agonum muelleri (Herbst)	Coleoptera	Carabidae	×		
Agonum placidum (Say)	Coleoptera	Carabidae	×		
Aleochara curtula (Goeze)	Coleoptera	Staphylinidae		×	
Aleochara gracilicornis Bernhauer	Coleoptera	Staphylinidae		×	
Aleochara Gravenhorst sp.	Coleoptera	Staphylinidae	×		×
Amara avida (Say)	Coleoptera	Carabidae	×		
Amara cupreolata Putzeys	Coleoptera	Carabidae	×	×	
Amara impuncticollis (Say)	Coleoptera	Carabidae	×		
Amphasia sericea (T.W. Harris)	Coleoptera	Carabidae	×		
Anisodactylus sanctaecrucis (F.)	Coleoptera	Carabidae	×	×	
Anotylus insecatus (Gravenhorst)	Coleoptera	Staphylinidae	×		
Anotylus rugosus (F.)	Coleoptera	Staphylinidae	×	×	×
Anthicus cervinus LaFerté-Sénectère	Coleoptera	Anthicidae	×	×	×
Athetini (no further identification)	Coleoptera	Staphylinidae	×	×	×
Bembidion obscurellum (Motschulsky)	Coleoptera	Carabidae	×		
Bembidion obtusum Audinet-Serville	Coleoptera	Carabidae	×		
Bembidion quadrimaculatum oppositum Say	Coleoptera	Carabidae	×	×	
Bembidion tetracolum Say	Coleoptera	Carabidae	×		
Bembidion versicolor (LeConte)	Coleoptera	Carabidae	×		×
Brachinus Weber sp.	Coleoptera	Carabidae	×		
Bradycellus congener (LeConte)	Coleoptera	Carabidae	×	×	×
Bradycellus rupestris (Say)	Coleoptera	Carabidae	×	×	
Carabus nemoralis O.F. Müller	Coleoptera	Carabidae	×		
Cerceris Latreille sp.	Hymenoptera	Sphecidae		×	
Chlaenius pusillus Say	Coleoptera	Carabidae	×		
Chlaenius tricolor tricolor Dejean	Coleoptera	Carabidae	×		
Chrysopa oculata Say	Neuroptera	Chrysopidae	×	×	×
Chrysoperla carnea (Stephens)	Neuroptera	Chrysopidae	×	×	×
Cicindela punctulata punctulata Olivier	Coleoptera	Cicindelidae	×	×	
Clivina impressefrons LeConte	Coleoptera	Carabidae	×		
Coccinella septempunctata L.	Coleoptera	Coccinellidae	×	×	×
Coleomegilla maculata lengi Timberlake	Coleoptera	Coccinellidae	×	×	×
Colliuris pensylvanica (L.)	Coleoptera	Carabidae	×		
Condylostylus caudatus (Wiedemann)	Diptera	Dolichopodidae		×	
Condylostylus sipho (Say)	Diptera	Dolichopodidae		×	
Cordalia obscura (Gravenhorst)	Coleoptera	Staphylinidae	×		
Cosmopepla bimaculata (Thomas)	Hemiptera	Pentatomidae			×
Crabronini (no further identification)	Hymenoptera	Sphecidae		×	
Dolichopus acuminatus Loew	Diptera	Dolichopodidae		×	
Dolichopus bifractus Loew	Diptera	Dolichopodidae		×	
Drusilla canaliculata (F.)	Coleoptera	Staphylinidae	×		
Elaphropus anceps (LeConte)	Coleoptera	Carabidae	×		
Eupeodes Osten Sacken sp.	Diptera	Syrphidae		×	

TABLE 1 (*continued*).

	Order	Family	PF	ST	PL
Formica argentea W.M. Wheeler	Hymenoptera	Formicidae	×		
Gabrius Curtis sp.	Coleoptera	Staphylinidae	×	×	
Harmonia axyridis (Pallas)	Coleoptera	Coccinellidae	×		×
Harpalus affinis (Schrank)	Coleoptera	Carabidae	×		
Harpalus compar LeConte	Coleoptera	Carabidae	×		
Harpalus pensylvanicus (DeGeer)	Coleoptera	Carabidae	×		
Hippodamia glacialis glacialis (F.)	Coleoptera	Coccinellidae		×	
Hippodamia parenthesis (Say)	Coleoptera	Coccinellidae		×	
Hippodamia variegata (Goeze)	Coleoptera	Coccinellidae		×	×
Hoplandria Kraatz sp.	Coleoptera	Staphylinidae	×		
Hoplandria lateralis (Melsheimer)	Coleoptera	Staphylinidae		×	
Isohydnocera curtipennis (Newman)	Coleoptera	Cleridae		×	
Lasius F. sp.	Hymenoptera	Formicidae	×	×	×
Lathrobium Gravenhorst (*sensu lato*) sp.	Coleoptera	Staphylinidae	×	×	
Lygus lineolaris (Palisot de Beauvois)	Hemiptera	Miridae	×	×	×
Malporus formicarius (LaFerté-Sénectère)	Coleoptera	Anthicidae	×		
Meronera venustula (Erichson)	Coleoptera	Staphylinidae	×		
Microlestes linearis (LeConte)	Coleoptera	Carabidae	×	×	
Micromus Rambur sp.	Neuroptera	Hemerobiidae	×		
Mycetoporus Mannerheim sp.	Coleoptera	Staphylinidae	×		
Myrmica Latreille sp.	Hymenoptera	Formicidae	×		
Nabis americoferus Carayon	Hemiptera	Nabidae	×	×	×
Neobisnius Ganglbauer sp.	Coleoptera	Staphylinidae	×		
Neohypnus Coiffait and Saiz sp.	Coleoptera	Staphylinidae	×		
Notiobia terminata (Say)	Coleoptera	Carabidae		×	
Oxypoda Mannerheim sp.	Coleoptera	Staphylinidae	×		
Oxypselaphus pusillus (LeConte)	Coleoptera	Carabidae	×		
Patrobus longicornis (Say)	Coleoptera	Carabidae	×		
Philonthus carbonarius (Gravenhorst)	Coleoptera	Staphylinidae	×	×	
Philonthus concinnus (Gravenhorst)	Coleoptera	Staphylinidae	×	×	
Philonthus Curtis sp.	Coleoptera	Staphylinidae			×
Philonthus lomatus Erichson	Coleoptera	Staphylinidae		×	
Philonthus varians (Paykull)	Coleoptera	Staphylinidae	×		
Platycheirus Lepeletier and Serville sp.	Diptera	Syrphidae		×	
Platycheirus quadratus (Say)	Diptera	Syrphidae		×	
Poecilus chalcites (Say)	Coleoptera	Carabidae	×		
Poecilus lucublandus lucublandus (Say)	Coleoptera	Carabidae	×		
Polistes dominulus (Christ)	Hymenoptera	Vespidae		×	
Polistes fuscatus (F.)	Hymenoptera	Vespidae		×	
Pompilidae (no further identification)	Hymenoptera	Pompilidae		×	
Ponera pennsylvanica Buckley	Hymenoptera	Formicidae	×		
Prenolepis imparis Say	Hymenoptera	Formicidae	×		
Propylaea quatuordecimpunctata (L.)	Coleoptera	Coccinellidae		×	
Psyllobora vigintimaculata (Say)	Coleoptera	Coccinellidae			×
Pterostichus melanarius (Illiger)	Coleoptera	Carabidae	×		
Pterostichus permundus (Say)	Coleoptera	Carabidae	×		
Scopaeus Erichson sp.	Coleoptera	Staphylinidae	×		
Sphaerophoria asymmetrica Knutson	Diptera	Syrphidae		×	

TABLE 1 (*concluded*).

	Order	Family	PF	ST	PL
Sphaerophoria contigua Macquart	Diptera	Syrphidae		×	×
Sphaerophoria Lepeletier and Serville sp.	Diptera	Syrphidae		×	
Stenistoderus rubripennis (LeConte)	Coleoptera	Staphylinidae	×		
Stenolophus comma (F.)	Coleoptera	Carabidae	×	×	×
Stenolophus ochropezus (Say)	Coleoptera	Carabidae		×	
Stenus Latreille sp.	Coleoptera	Staphylinidae	×		×
Syrphus vitripennis Meigen	Diptera	Syrphidae		×	
Tachyporus Gravenhorst sp.	Coleoptera	Staphylinidae	×		
Tachyporus maculicollis LeConte	Coleoptera	Staphylinidae		×	
Tachyporus nitidulus (F.)	Coleoptera	Staphylinidae	×		
Tetragonoderus fasciatus (Haldeman)	Coleoptera	Carabidae	×		
Tinotus Sharp sp.	Coleoptera	Staphylinidae	×		
Toxomerus geminatus (Say)	Diptera	Syrphidae		×	
Toxomerus marginatus (Say)	Diptera	Syrphidae		×	×
Trechus quadristriatus (Schrank)	Coleoptera	Carabidae	×		×
Vespula germanica (F.)	Hymenoptera	Vespidae		×	
Vespula maculifrons (Buysson)	Hymenoptera	Vespidae		×	
Vespula vidua (Saussure)	Hymenoptera	Vespidae		×	
Xantholinus linearis (Olivier)	Coleoptera	Staphylinidae	×		

NOTE: Pitfall and sticky traps were placed in three plots in 1995 and in two plots in 1996. Plant samples were taken in two plots in 1996 only. "×" indicates presence in the sample.

formicum (Arachnida) and *Meioneta unimaculata* (Arachnida) captured in 1996 came mostly from the first two sampling dates (Fig. 2C). In 1995, trapping started later, and the peak periods of activity for these two species may have been missed. The large number of *Bembidion quadrimaculatum* caught in 1995 showed a clear peak in mid-season, but the pattern was not repeated in the 1996 plots (Fig. 3A). In both years, *E. anceps* activity was highest early and declined later in the season (Fig. 3A). Clear seasonal trends were not evident for the remaining Carabidae (Fig. 3A), nor for the most numerous Staphylinidae (Fig. 3B), Anthicidae (Fig. 3C), or Formicidae (Fig. 3C).

Substantial rainfall during the trapping periods on 3 July (10 mm) and 31 July (20 mm) in 1996 appeared to reduce the trap catch of some of the arthropods [*e.g.*, *Pardosa* sp. (Fig. 2B), *Tennesseellum formicum* and *Meioneta unimaculata* (Fig. 2C), and several of the carabid species (Fig. 3A)]. Lesser amounts of rain on 28 June 1995 (2.5 mm), 5 July 1995 (8 mm), and 19 June 1996 (4 mm) may have affected trap catches as well, although the effects are not as clear. It was observed that although covers were used over the traps, heavy rains sometimes left droplets of mud splashed on the sides of the cups that may have provided sufficient foothold for some of the predators to escape from the traps.

Sticky Traps. In general, fewer taxa and fewer individuals were captured in the sticky traps than in the pitfall traps (Table 1 and Fig. 4). As with the pitfall traps, the great majority of taxa were represented by only a few individuals. *Lygus lineolaris* (Insecta), *Stenolophus comma*, and *Coleomegilla maculata lengi* (Insecta) were relatively numerous in both years. Adult *Toxomerus marginatus* (Insecta) and *Condylostylus* sp. (Insecta) were present but not monitored in 1995, and were the most abundant taxa in the traps in 1996. In 1995, some large differences between plots were evident, with *Lygus lineolaris* and *Phalangium opilio* being more abundant and *Stenolophus comma* and *Coleomegilla maculata* being less abundant in the relatively weedy plot 1 than in
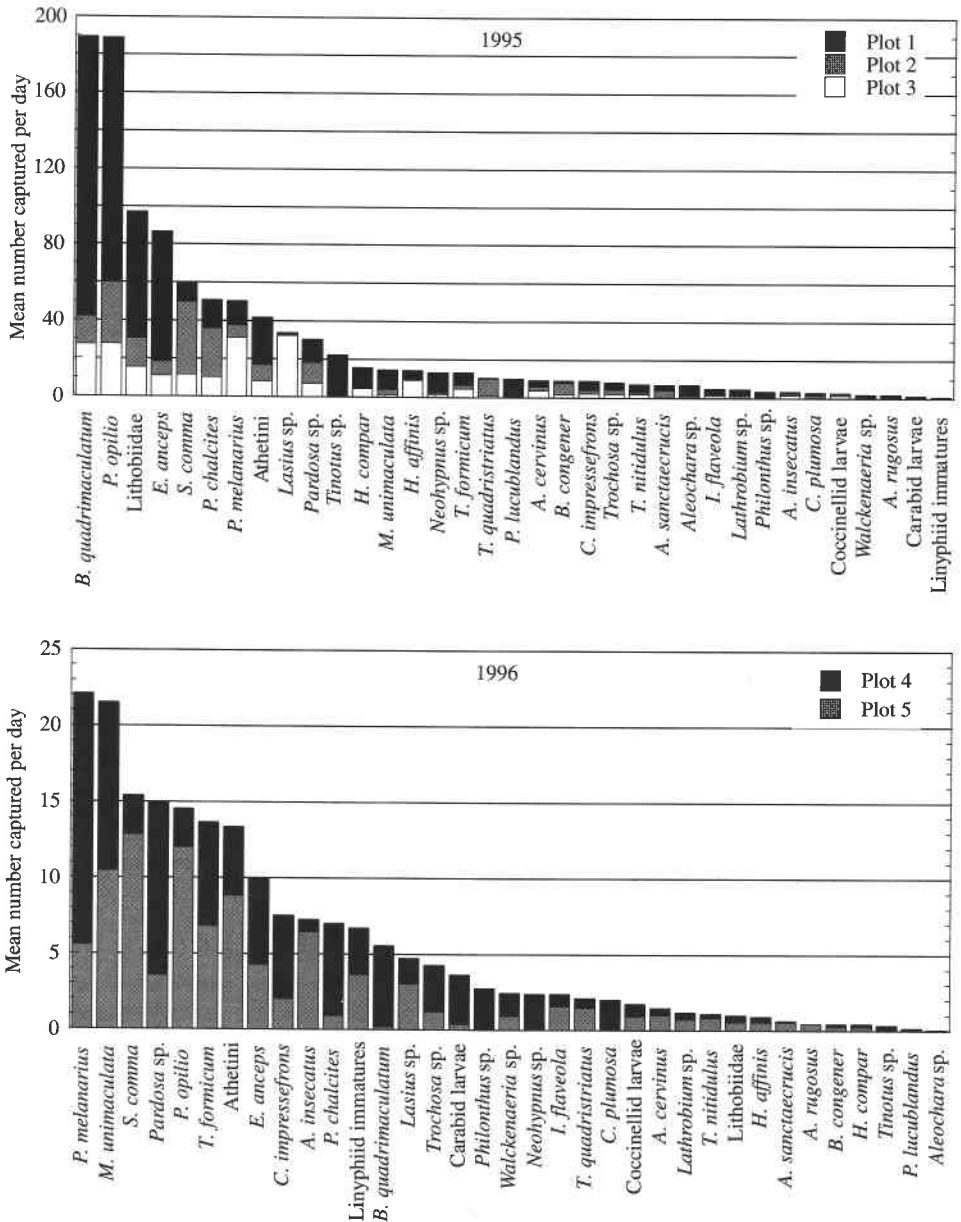
FIGURE 1. Mean number of predatory arthropods captured per day in pitfall traps in 1995 and 1996. Figure includes only groups for which total captures were >20.

the other two plots (Fig. 4). Trap catches of the most abundant taxa were more evenly distributed between the relatively weed-free plots 2 and 3 in 1995 and the two 1996 plots. The only clear seasonal trend in the sticky-trap catches was the early season buildup and midseason drop-off in numbers of *Toxomerus marginatus* in 1996 (Fig. 5).

Plant Sampling. Except for the spiders, taxonomic diversity was substantially less overall in the plant samples than in the pitfall or sticky traps (Table 1). Spiders were the
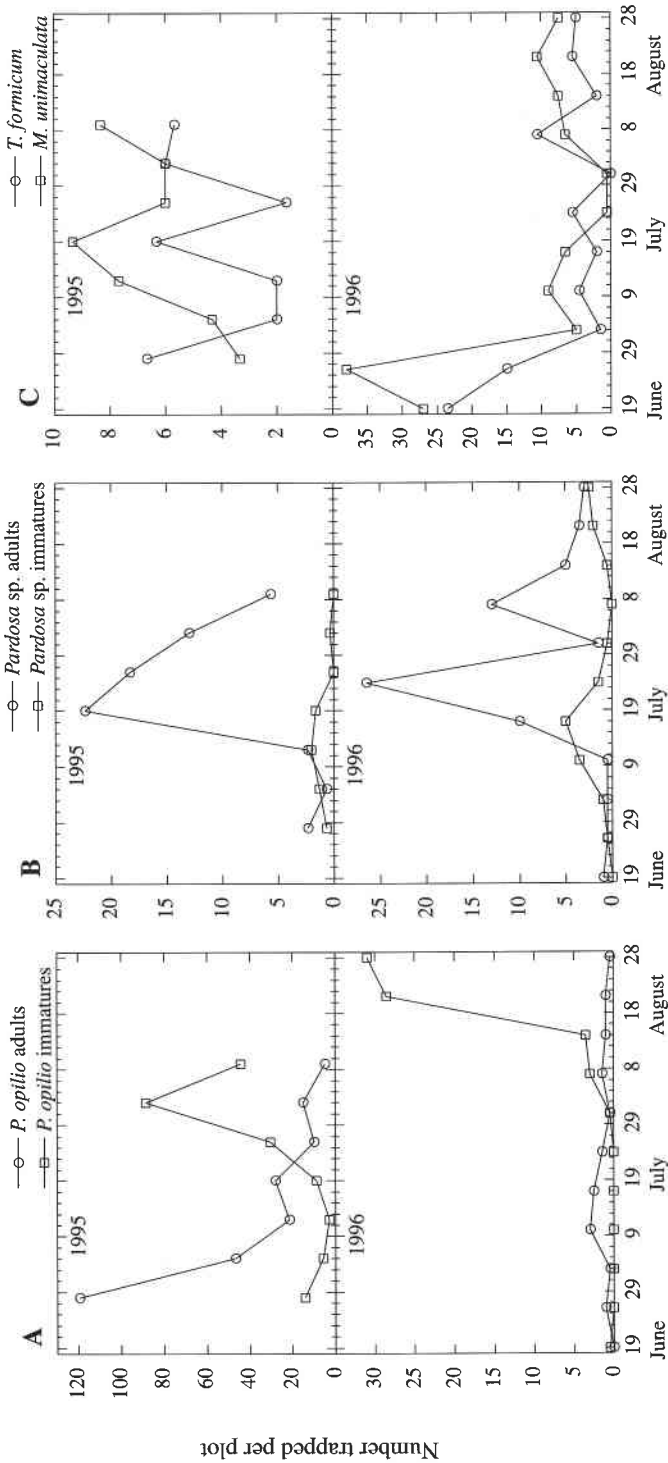
FIGURE 2. Pitfall-trap captures by date for the most commonly caught predatory arachnid taxa. Data are means of three (1995) or two (1996) plots, with a total of 49 traps per plot. Plots were planted 6–10 June 1995 and 22–26 May 1996. Note the different ordinal scales.
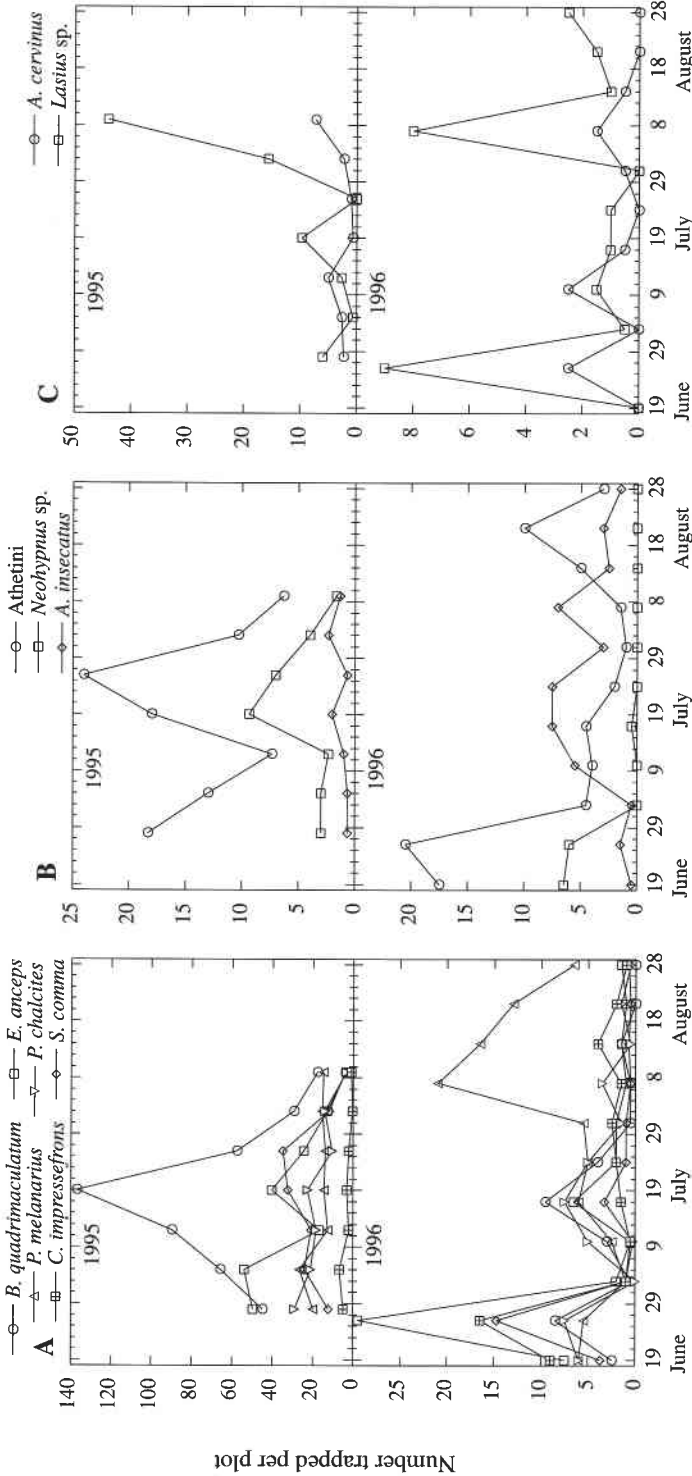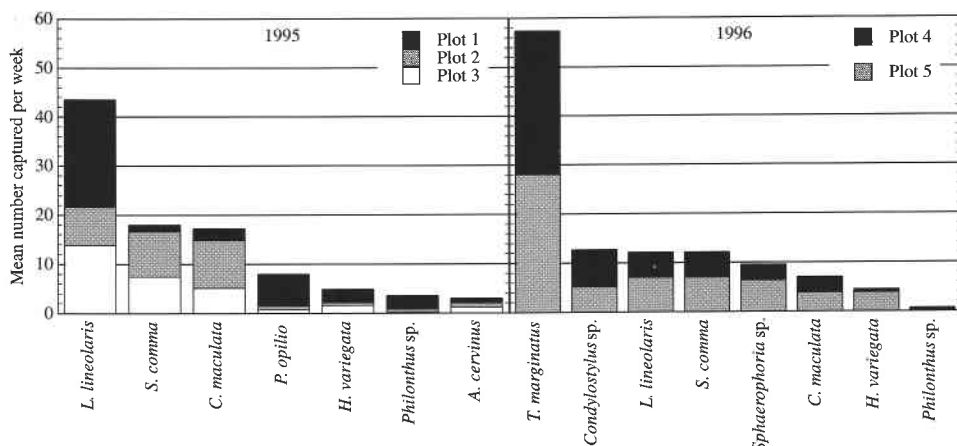
FIGURE 3. Pitfall-trap captures by date for the most commonly caught predatory insect taxa. Data are means of three (1995) or two (1996) plots, with a total of 49 traps per plot. Plots were planted 6–10 June 1995 and 22–26 May 1996. Note the different ordinal scales.

FIGURE 4. Numbers of most abundant predatory arthropods captured on sticky traps on cabbage plants, adjusted to number captured per week for five plots in 1995 and 1996. Figure includes only taxa for which total captures were ≥15. Note: *Condylostylus* sp., *Toxomerus marginatus*, and *Sphaerophoria* sp. were not monitored in 1995. No *Phalangium opilio* or *Anthicus cervinus* were caught on the traps in 1996.

most abundant group, comprising 54% of the predatory arthropods collected. Densities were low, however, averaging 0.2 spiders per plant. Most (74%) of the spiders were immatures but, in most cases, could be identified at least to family level. Of those spiders that could be determined to family level (91% of the total), 71% were linyphiids. Among the 51 adult spiders collected in the plant samples, the most numerous species were *Meioneta unimaculata* (25%) and *Tennesseellum formicum* (20% of the adults). The numbers of none of the other species reached 8% of the total adults collected.

Syrphid (Insecta) larvae were the most abundant predatory-insect group in the plant samples, accounting for 13% of the total predators and averaging 0.03 individuals per plant. Syrphid pupae were also collected, and nine of these pupae were reared to adults, yielding one specimen of *Sphaerophoria contigua* and eight of *Toxomerus marginatus*. Coccinellid larvae and adults comprised 12% of the total predators collected (mean of 0.02 per plant) and consisted mainly of *Coleomegilla maculata* (77%), of which 47% were larvae. A total of 180 coccinellid eggs was also found on the sample plants. Nymphs comprised 78% of the *Lygus lineolaris* collected in the plant samples; all the nymphs were found on the final sampling date. Altogether, *Lygus lineolaris* made up 10% of the arthropod predators in the plant samples and averaged 0.02 per plant.

Because the numbers of each taxon collected at each sampling time were low, statistical tests were not useful in evaluating the effect of time of day on predator abundance on the plants. Graphical examination of the data revealed that the time of day at which a sample was collected had no clear consistent effect on the counts of the most abundant taxa found in the plant samples. No pronounced seasonal trends were evident either, except perhaps a general tendency for numbers to increase over the course of the season.

Predation in Small Arenas. All the species tested in the small arenas, except *Meioneta unimaculata*, fed on *Pieris rapae* to some extent (Table 2). Both male and female *Meioneta unimaculata* formed sheet webs in the containers. Only three of the 62 *Anthicus cervinus* (Insecta) fed at all, one on an egg and two on larvae. Several species showed a greater tendency to feed on larvae than on eggs. The 19 *Pardosa milvina*
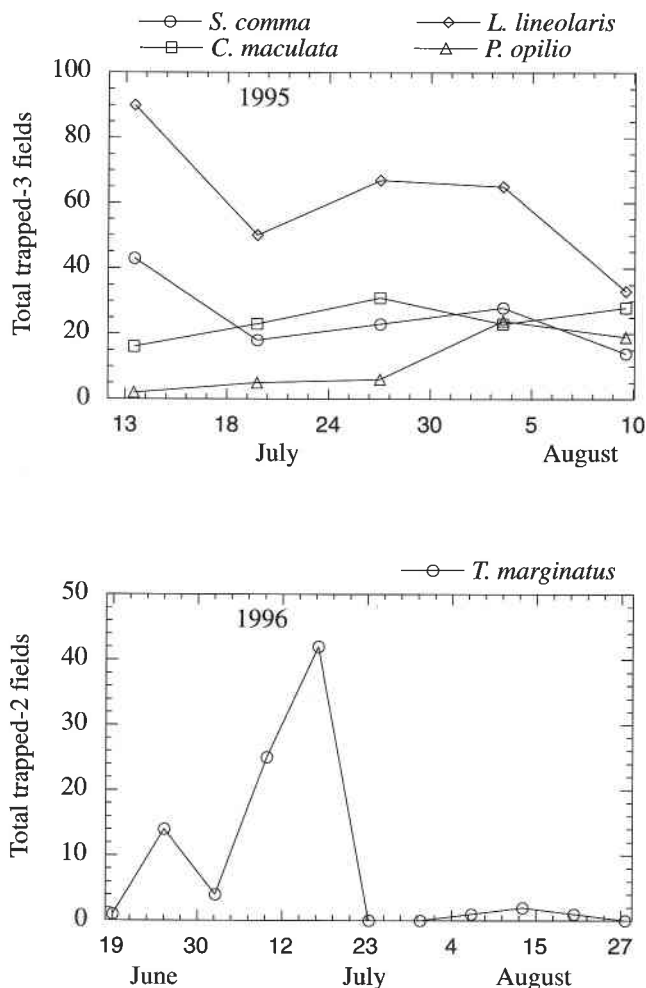
FIGURE 5. Total catch on sticky traps by date for the most abundant predatory arthropods in 1995 and 1996. Dates given in the 1995 plot are midpoints of each 7-d trapping period. In 1996, trapping was conducted only during 24-h periods starting at approximately 08:00 on the dates indicated.

(Arachnida) tested with *Pieris rapae* eggs did not consume any, but almost all those presented with first instars fed on the larvae. At least some of the *Nabis americoferus* (Insecta), *Orius insidiosus* (Say) (Coleoptera: Anthocoridae), and *Hippodamia variegata* (Insecta) fed on eggs, but all showed a much greater tendency to feed on larvae.

Predation on Cabbage Plants in the Laboratory. *Stenolophus comma* and *Lygus lineolaris* did not feed on larval *Pieris rapae* on the plants, but the other species tested did (Table 3). *Stenolophus comma* formed deep burrows in the substrate. *Lygus lineolaris* stayed mostly on the plants and some were observed feeding on the plants. *Pardosa milvina* and *O. insidiosus* consumed, on average, <1 larva per cage. Larval *Pieris rapae* were apparently much less vulnerable to these predators when on plants than when on leaf disks in the small-arena experiments. Although *Phalangium opilio*, *N. americoferus*, *Coleomegilla maculata*, and *Hippodamia variegata* all consumed some of the larvae on the plants, in all cases many larvae survived the experiment despite the

TABLE 2. Consumption of *Pieris rapae* eggs and first instars by predators in small arenas.

Predator species		Predation on eggs					Predation on first instars			
	n	No. of eggs provided	No. of eggs consumed (mean ± SE)	Percent consuming ≥1 egg	Maximum consumption	n	No. of larvae provided	No. of larvae consumed (mean ± SE)	Percent consuming ≥1 larva	Maximum consumption
*Meioneta unimaculata**	21	10	0.00	0	0	23	5	0.00	0	0
*Pardosa milvina**	19	10	0.00	0	0	66	5	3.50±0.22	92	5
*Phalangium opilio**	43	20	12.63±1.24	84	20	49	5	2.94±0.25	88	5
Lygus lineolaris[†]	20	10	3.25±1.03	40	10	23	5	0.65±0.21	43	4
Nabis americoferus[†]	20	10	4.15±1.06	50	10	22	5	4.36±0.21	100	5
Orius insidiosus[†]	23	10	0.09±0.06	9	1	29	5	2.38±0.26	86	5
Stenolophus comma[†]	20	20	13.90±2.07	75	20	22	5	4.00±0.38	86	5
Coleomegilla maculata[†]	20	10	5.95±1.10	65	10	23	5	4.26±0.32	96	5
Hippodamia variegata[†]	23	10	0.26±0.26	4	6	21	5	1.76±0.45	57	5
Anthicus cervinus[†]	35	20	0.03±0.03	3	1	27	5	0.07±0.05	7	1

NOTE: Number consumed includes partially as well as completely consumed individual prey.

*Arachnida.

[†]Insecta.

TABLE 3. Consumption of first instar *Pieris rapae* on potted cabbage plants by groups of predators.

Species	No. of predators/plant*	No. of *Pieris rapae* consumed (mean ± SE)
Pardosa milvina[†]	10	0.90±0.38
Phalangium opilio[†]	4	5.60±0.72
Lygus lineolaris[‡]	6	0.00
Nabis americoferus[‡]	6	6.11±0.81
Orius insidiosus[‡]	10	0.90±0.31
Stenolophus comma[‡]	6	0.00
Coleomegilla maculata[†]	6	5.70±1.07
Hippodamia variegata[‡]	6	5.60±0.65

NOTE: Ten *P. rapae* were placed on each plant initially. For *N. americoferus*, $n = 9$ plants; for all others, $n = 10$ plants.

*Some predators died during the course of the experiment, as follows: *P. opilio*, 1/40; *L. lineolaris*, 9/60; *N. americoferus*, 5/54; *C. maculata*, 1/60.

[†]Arachnida.

[‡]Insecta.

high densities of predators in the cages. Although a few predators died during the experiments, there was no evidence of cannibalism, except for one *Phalangium opilio* that was found partially consumed.

Discussion

Predators Occurring in Cabbage Fields. Our intensive trapping and sampling revealed a diverse array of arthropod predators occurring in cabbage fields. This information will serve as a foundation for future studies of the ecological roles of naturally occurring arthropod predators found in cabbages in New York State and their effects on cabbage pests. Only a few predator species, however, appeared to occur in numbers high enough to have the potential to significantly affect populations of cabbage pests, whereas the vast majority of species appear to be relatively rare.

In many cases, the numbers of the most abundant and active predators varied substantially according to plot, year, or date. Such variation could present problems for growers seeking to increase reliance on predators to help reduce *Pieris rapae* and other pests in their fields. More extensive monitoring across many sites, over several years, and throughout the cabbage growing season would help delineate the range of such variation and provide clues to the factors causing it. Outbreaks of *Pieris rapae* can occur in the cabbage fields at almost any time during the periods we sampled (Shelton *et al.* 1983*b*; AM Shelton, unpublished data).

Predators Occurring on Cabbage Plants in the Field. Many of the species that appear, from pitfall-trapping, to be abundant in the ground fauna seem to be rare or absent on plants, as shown by the results of sticky-trapping and plant-sampling. Because larval *Pieris rapae* rarely leave suitable host plants before dispersing to pupate (Harcourt 1961; Jones 1977), ground dwelling predators that do not forage on cabbage plants would likely have little direct effect on populations of larval *Pieris rapae* in the crop. Centipedes, *Trochosa ruricola* (Arachnida), most of the Carabidae, and many of the Staphylinidae, as well as the species of Formicidae collected in our study seem to fall into this category. Relatively common species that occurred both on the ground and on

plants included *Stenolophus comma*, *Meioneta unimaculata*, *Tennesseellum formicum*, *Phalangium opilio*, *Philonthus* spp., and *A. cervinus*. *Lygus lineolaris* and species of the Syrphidae and Coccinellidae were found primarily or solely on plants.

For many of the species that occur both on plants and on the soil surface, pitfall-trapping may be a more effective monitoring tool than either sticky-trapping or plant-sampling. The larger numbers of predatory arthropods collected by pitfall-trapping could indicate that these predators tend to be more active or abundant on the ground than on plants. Alternatively, they could simply be more susceptible to collection by pitfall traps than by the other two methods. Because of the differences in the sampling methods used for foliar and ground-dwelling fauna, it is not possible to make precise inferences about the relative numbers and activity of the different species occurring on plants and on the ground. The results confirm the importance of using multiple sampling methods to study arthropod predator faunas in crops.

Predator Foraging on Cabbage Plants. The occurrence of a species on plants does not necessarily indicate that it searches for prey there. For example, ground-foraging predators may climb plants before taking flight to disperse (*e.g.*, Dennis and Sotherton 1994) and spiders often ascend plants or other objects for ballooning (Comstock 1940). Dispersing ground dwellers may also alight on plants haphazardly before finding their way to the soil surface. The laboratory feeding trials with potted plants were intended to identify those species that actively seek food on cabbage plants. *Stenolophus comma* was relatively abundant in pitfall and sticky traps, occurred in low numbers in the plant samples, and fed readily on *Pieris rapae* in the small arenas; however, no feeding was observed when *Stenolophus comma* were offered *Pieris rapae* on cabbage plants. *Stenolophus comma* fly readily and are attracted to lights in large numbers on warm humid summer nights (Kirk 1975; Wyman *et al.* 1976; Pausch 1979). We suspect that the beetles we found in the sticky traps on cabbage leaves and in plant samples may have been dispersing rather than foraging.

All but two of the species tested for predation on potted plants consumed some of the larvae presented. Despite the high densities of predators used, in every case, many of the *Pieris rapae* escaped predation for the duration of the experiment. Observation of the predators' movements on the plants revealed that many had difficulty gaining sufficient foothold to search all parts of the plants. It appears that areas on the undersides of the leaf far from the leaf veins and leaf edges may be essentially inaccessible to these predators, probably leaving *Pieris rapae* that feed in these areas safe from them. Shah (1982) and Grevstad and Klepetka (1992), working with coccinellids, and Eigenbrode *et al.* (1996), working with coccinellids, anthocorids, and chrysopids, made similar observations on these predators' difficulties in foraging on crucifers with thick cuticular waxes. Experiments should be conducted with syrphid larvae and hunting linyphiids as well, to determine if the cuticular wax and other aspects of cabbage morphology similarly restrict foraging of these types of predators. We were unable to obtain sufficient numbers of either to conduct laboratory predation assays in small arenas or on potted plants.

Linyphiidae and Syrphidae. Linyphiidae were the most abundant predatory arthropods in the plant samples. The only linyphiid tested in the feeding assays, *Meioneta unimaculata*, formed sheet webs and did not feed on *Pieris rapae* eggs or first instars. Although the linyphiids are generally known as sheet-web weavers (Nyffeler *et al.* 1994), the large number of linyphiids—including *Meioneta unimaculata*—collected in our pitfall traps indicates that these spiders not only reside in webs awaiting prey, but also spend time wandering about. Others have noted that male linyphiids often

predominate in pitfall-trap catches (*e.g.*, Thornhill 1983), suggesting that mate searching, rather than foraging, may be the primary activity of many of the individuals captured in pitfall traps. We did not enumerate the spiders we captured by sex, but did note substantial numbers of females in the catch (MA Schmaedick, unpublished data). Further investigation could help determine if this movement by males and females is solely for dispersal or mate finding or whether it also includes foraging. Spiders that actively hunt for their prey would be expected to be much more likely to encounter and prey upon the slow moving larval *Pieris rapae* than those that rely on webs.

Syrphid larvae were also relatively abundant in the plant samples, and adults of this taxon were the most numerous in the 1996 sticky-trap samples. Syrphids were not tested in our laboratory experiments, but researchers working on brussels sprouts, *Brassica oleracea* var. *gemmifera* D.C., in England (Dempster 1967) and cabbage in New Zealand (Ashby 1974) have found syrphids to be important predators of *Pieris rapae* in these countries. If sufficient numbers of local syrphid species can be obtained, perhaps through rearing, then laboratory experiments to evaluate their foraging ability on cabbage could help to elucidate their role in cabbages in New York State.

***Lygus lineolaris* in Cabbage: Friend or Foe?** *Lygus lineolaris* occurred primarily on plants in the cabbage field and were observed to climb readily on the potted plants in the laboratory trial; however, they did not consume any of the larval *Pieris rapae* from the plants, although 43% of *Lygus lineolaris* fed on larval *Pieris rapae* in small arenas. Although *Lygus lineolaris* is regarded primarily as a plant feeder and a pest in many crops, it is not considered a pest of cabbages in New York State. There is at least one published observation of apparent *Lygus lineolaris* predation on larval *Pieris rapae* on collards, *Brassica oleracea* var. *acephala* (Culliney *et al.* 1986), and Parker (1970) reported that an unspecified *Lygus* sp. fed on *Pieris rapae* eggs and larvae in plantings of mixed *Brassica* spp. Cleveland (1987) described predation by *Lygus lineolaris* on *Heliothis virescens* (F.) (Lepidoptera: Noctuidae) eggs and larvae on caged cotton plants in a greenhouse. Numerous reports of predation by *Lygus* spp. were reviewed by Wheeler (1976), who concluded that *Lygus* spp. may, in certain situations, be more beneficial through their roles as predators than they are harmful as plant feeders. The behaviour of *Lygus lineolaris* under our experimental conditions may differ from that under field conditions.

Other Predators. Our sampling and trapping procedures neglected two taxa in particular that may have roles in reducing *Pieris rapae* populations: predatory mites and wasps. Mites were not monitored in our plots but were occasionally seen in pitfall traps or on plants and have been observed to prey on *Pieris rapae* eggs or larvae in other studies (Richards 1940; Parker 1970; Yamamoto 1981; Jones *et al.* 1987). Although a few vespids were caught on the sticky traps, the trapping and sampling methods we used were not designed to measure levels of vespid abundance or activity. Both *Polistes* spp. (Insecta), and *Vespula* spp. (Insecta) have been observed to prey on larval *Pieris rapae* (Richards 1940; Sutherland 1966; Parker 1970; Hasui 1977; Jones and Ives 1979; Gould and Jeanne 1984); both were frequently seen foraging in our plots.

Conclusions. Although important questions remain, this study has succeeded in documenting some of the diversity of predatory arthropods found in cabbages in New York State and in identifying a set of species that are likely to be effective predators of *Pieris rapae* in New York State cabbage fields. These species were relatively abundant, occurred on cabbage plants in the field, fed readily on eggs and larvae of *Pieris rapae*, and foraged for prey on cabbage plants. Conversely, we have also shown that many of the arthropod predators found in cabbage fields lack one or more of these attributes and are

therefore unlikely to play a significant or direct role in *Pieris rapae* dynamics in the crop. Based on our study, species that merit further investigation as potential *Pieris rapae* predators include *Pardosa milvina*, *Phalangium opilio*, *Coleomegilla maculata*, and *Hippodamia variegata*. All four species occurred on cabbage foliage in the field and, in the laboratory, fed readily on *Pieris rapae* eggs and first instars, both in small arenas and on plants. Although *N. americoferus* and *O. insidiosus* preyed on *Pieris rapae* in the laboratory, they will have little effect in the area of New York State unless their numbers in cabbage fields can be increased. In contrast, *A. cervinus*, while often abundant, showed a low propensity to feed on *Pieris rapae* and, thus, it appears unlikely that it would have a substantial effect in the field. Several species of Syrphidae and Linyphiidae were relatively abundant on plants in the field but remain to be tested for their foraging ability and propensity to feed on *Pieris rapae*. Vespid wasps and mites, important predators on *Pieris rapae* in other areas, were not evaluated in this study, athough both were present in the fields. For *Lygus lineolaris*, additional studies are required to clarify the conditions under which it is predaceous and whether its potential role as a predator in cabbage will outweigh its role as a pest.

Our results provide valuable information on the diversity and relative abundance and activity of predatory arthropods in cabbage fields and show which of the many predatory arthropods occurring there are most likely to be effective predators of *Pieris rapae*. Future efforts should focus on further elucidating the roles of these species in *Pieris rapae* population dynamics and on developing ways to maximize their impact on the cabbage crop.

Acknowledgements

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