Diversity, distribution and phenology of *Lygus* species (Hemiptera: Miridae) in relation to vegetable greenhouses in the lower Fraser Valley, British Columbia, and southwestern Ontario

D. R. GILLESPIE

AGRICULTURE AND AGRI-FOOD CANADA, PACIFIC AGRI-FOOD RESEARCH CENTRE, AGASSIZ, BC V0M 1A0

R. G. FOOTTIT

AGRICULTURE AND AGRI-FOOD CANADA, EASTERN CEREAL AND OILSEEDS RESEARCH CENTRE, OTTAWA, ON, K1A 0C6

J. L. SHIPP

AGRICULTURE AND AGRI-FOOD CANADA, GREENHOUSE AND PROCESSING CROPS RESEARCH CENTRE, HARROW, ON, N0R 1G0

M. D. SCHWARTZ

AGRICULTURE AND AGRI-FOOD CANADA, EASTERN CEREAL AND OILSEEDS RESEARCH CENTRE, OTTAWA, ON, K1A 0C6

D. M. J. QUIRING

AGRICULTURE AND AGRI-FOOD CANADA, PACIFIC AGRI-FOOD RESEARCH CENTRE, AGASSIZ, BC V0M 1A0

KAIHONG WANG

AGRICULTURE AND AGRI-FOOD CANADA, GREENHOUSE AND PROCESSING CROPS RESEARCH CENTRE, HARROW, ON, N0R 1G0

ABSTRACT

Lygus spp. were collected from near and inside vegetable greenhouses during three years in the lower Fraser Valley, British Columbia (BC) and in Leamington, Ontario (ON). In BC, the dominant species was *Lygus shulli*, followed in abundance by *L. elisus* and *L. hesperus*; *L. lineolaris* was not collected in the lower Fraser Valley. In ON, only *L. lineolaris* was collected. In BC, *L. shulli* was generally distributed throughout the region, whereas *L. hesperus* was captured in sweep net samples only in coastal areas. *Lygus hesperus* appeared to be univoltine in BC. All other species in ON and BC were apparently bivoltine. In ON, numbers of adults collected outside of greenhouses correlated with numbers collected inside greenhouses whereas this was not the case in BC. Differences in flight behaviour, abundance and greenhouse construction may account for this latter difference. Our results highlight the need for different approaches to IPM of pest *Lygus* species in the ON and BC greenhouse industries.

INTRODUCTION

Lygus bugs, *Lygus* spp. are important pests of crops throughout Canada (Philip 1997, Schwartz and Foottit 1998, Braun *et al.* 2001). They are known to attack greenhouse vegetable crops in both British Columbia (BC) and Ontario (ON) (Howard *et al.* 1994, Broadbent and Murphy 1997, Gillespie and Foottit 1997, Gillespie *et al*. 2000). All species that are pests seem to be associated with either alfalfa or weedy habitats and to invade from those habitats into crops (Khattat and Stewart 1980, Fye 1982, Schwartz and Foottit 1992a, Gerber and Wise 1995, Broadbent *et al.* 2002,)

In light of the recent taxonomic revision of the Nearctic *Lygus* (Schwartz and Foottit 1998) knowledge of the pest species distribution and occurrence with respect to greenhouse crops needs to be updated so that pest managers are making up-to-date recommendations. Surveys of canola have reported shifts in the complex of *Lygus* spp. (Butts and Lamb 1991, Schwartz and Foottit 1992b, Cárcamo *et al.* 2002).

The timing of adult flights and occurrence of immatures is important for making pest management decisions for crops where *Lygus* spp. are pests (Butts and Lamb 1991, Varis 1995). Yellow sticky traps are a useful tool for gathering this information (Luczynski *et al.* 1997), and are more practical than sweep net samples for evaluation of numbers in greenhouses.

The objectives of this study were to survey the *Lygus* complex associated with weedy habitats near greenhouse crops in two key greenhouse production regions, the Lower Fraser Valley, BC and southwestern ON, and to determine the phenology of the key species.

MATERIALS AND METHODS

BC 1996 Collections. In 1996, 60 collections of *Lygus* spp. adults were made at approximately two wk intervals at 22 localities throughout the lower Fraser Valley and immediate surroundings between 7 May and 19 September to determine the diversity of *Lygus* spp. in weedy habitats around greenhouses. Sampling was conducted with a standard insect sweep net; each sample consisted of 100 sweeps made in a 180° arc. Some localities were sampled at least three times, which provided a measure of changes in numbers over time.

In greenhouses, adult *Lygus* spp. were monitored using yellow sticky traps (30 x 60 cm, Phero Tech Inc, Richmond, BC) placed in each of six commercial greenhouses in the lower Fraser Valley starting on 23 April. Additional yellow sticky traps were placed on 60 cm tall posts in eight, low-growing, weedy, locations. Traps were oriented in an east-west direction. Three of these were within 10 m of greenhouses which had traps placed inside, two were adjacent to greenhouses without traps, and three were in locations approximately 1 km from greenhouses, in Agassiz, Chilliwack and Abbotsford, BC. Traps were replaced every two weeks, from 7 May to 20 September and the *Lygus* adults on the traps identified to species and counted.

BC 1997 Collections. In 1997, 25 sweep net collections were made between 2 April and 26 September, as in 1996. These collections were made in weedy habitats, generally within 100 m of greenhouses. On 29 June and 20 August, additional collections were made on east-west and north-south routes through the valley, from Ladner on the coast to Rosedale, near the head of the valley, and from Aldergrove, BC, on the Canada/US border to Mission, BC, on the north side of the Fraser River. We made 18 collections on 29 June and 23 on 20 August. The purpose of these samples was to provide data on species distribution within the Fraser Valley.

As in 1996, yellow sticky traps (30 x 60 cm) were placed on 60 cm posts at 10 locations in weedy fields and near greenhouses. The traps were changed every two weeks,

and the *Lygus* spp. collected were counted and identified. No collections were made in greenhouses.

BC 1998 Collections. In 1998, 103 sweep collections were made in weedy vegetation at 25 locations through the Fraser Valley, from 2 April to 26 September. These locations were at sites either within 100 m of greenhouse, or isolated from greenhouses by approximately 1 km. Ten of these locations were visited every two weeks from 2 April to 26 September. It was not possible to collect at every site in every interval because of rain. *Lygus* spp. adults and 4th and 5th instar nymphs were removed from the samples. The nymphs were reared in the laboratory to the adult stage on snap-beans and cauliflower pieces. The number of nymphs of each species was determined for each two week interval.

Yellow sticky traps (30 x 60 cm) were placed in nine locations within 10 m of commercial greenhouses. Traps were replaced every two weeks and the *Lygus* spp. on them were counted and identified. Inside each of these greenhouses, 10 small, yellow sticky traps (12.7 x 7.6 cm, Phero Tech Inc, Richmond, BC) were suspended on the trellis wire, 10 to 50 cm above the crop and approximately 10 m apart. These also were changed every two weeks, and the collected *Lygus* spp. counted and identified. Crops in the greenhouses (numbers of greenhouses) were tomato (1), cucumber (2) and pepper (6).

Ontario Field Survey. Surveys were conducted in three fields located at Pyramid Farm, Andrew Prytocki Farm and Chris Tiessen Farm in the Leamington area, Essex County, ON at two week intervals from 4 June to 9 September, 1997 and from 5 May through 6 October 1998. The sampling sites were < 10 m from greenhouses and in dense weed cover. On each sample date, 100 sweeps were taken at each site. *Lygus* spp. adults and nymphs were counted and identified.

Ontario Greenhouse Survey. Monitoring was conducted on greenhouse sweet pepper at one greenhouse in the Leamington area from May through October in 1997 using five small yellow sticky traps (12.7 x 7.6 cm, Phero Tech Inc, Richmond, BC) that were placed over five rows of pepper plants (total of 0.5 ha area). Traps were approximately 30 cm above the crop and traps were approximately 10 m apart. At the same time, *Lygus* spp. populations were surveyed by visual inspection of five rows of plants (212 plants/row) with four sampling units per row and five plants per unit. For each plant, the growing tip and flowers of two stems were checked for *Lygus* nymphs and adults. In 1998, monitoring was conducted from May through October, with 10 traps placed over 10 pepper rows and visual inspections of 10 rows of plants with two sampling units per row and five plants per sample unit.

Specimens and Records. Specimens of the dominant plants present in the sampled habitats were collected and identified. All *Lygus* spp. adult material was pinned and identified and voucher specimens were placed in the Canadian National Collection of Insects (Agriculture and Agri-Food Canada, Ottawa) (CNC). Historical records of *Lygus* spp. in the lower Fraser Valley were extracted from a database of records in Canada compiled by Schwartz and Foottit (1998). These records were compared with those documented during this study to determine any changes in distribution.

Data Analysis. Data were grouped by week to allow comparison between years. For each species locality data was pooled across all years for trap and sweep collections. The relationships between counts of insects outside and inside greenhouses were tested with Pearson correlation (CORR procedure) using SYSTAT 7.0 (SPSS 1997).

RESULTS

Extant Lygus. In southwestern ON, only *Lygus lineolaris* (Palisot de Beauvois) was collected over both years of sampling. Sampled weed hosts were ragweed, *Ambrosia artemisiifolia* L., smartweed, *Polygonum persicaria* L., green foxtail, *Setaria viridis* (L.) Beauv., red clover, *Trifolium pratense* L. and pigweed , *Amaranthus retroflexus* L.

In BC, *Lygus shulli* Knight, *Lygus elisus* Van Duzee and *Lygus hesperus* Knight were collected over the three year survey. Depending on location, the sampled habitats contained grasses, mainly *Festuca* and *Bromus* spp, red clover, *Trifolium pratense L.,* Dutch white clover *T. repens* L. shepherd's purse, *Capsella bursa-pastoris* (L.) Medic, chamomile, *Matricaria maritime* L., stinking mayweed, *Matricaria chamomilla* L., dandelion, *Taraxacum officianale* Weber, and various unidentified mustards (Brassicaceae). Based on the total numbers collected in sweep samples and on traps over the three years, *L. shulli* represents about 79% of the Lygus, *L. elisus* about 15% and *L. hesperus* about 6%. Individual species, however, varied in abundance at specific locations and in particular years. *Lygus lineolaris* was not collected in the Fraser Valley in 1996, 1997 or 1998.

Historical Records. Records in Schwartz and Foottit (1998) and in the North America *Lygus* database provide a historical record of the diversity of *Lygus* spp. in the lower Fraser Valley. The specimens representing the records for the Fraser Valley were validated by M.D. Schwartz, and were housed in the Spencer Entomological Collection (SMDV) at the University of British Columbia and in the CNC. *Lygus shulli* is represented by 65 specimens, collected from 1922 to 1996 and housed in both collections. *Lygus hesperus* is represented by 31 specimens collected from 1923 to 1996, all at the SMDV. *Lygus elisus* is represented by 23 specimens collected between 1923 and 1996, present in the CNC and the SMDV. *Lygus lineolaris* is represented by 27 specimens collected between 1923 and 1965 in the lower Fraser Valley, all of which are housed in the SMDV.

Distribution. In general, *L. shulli* was widely distributed in the lower Fraser Valley, and occurred in most samples and at all locations (Fig. 1). *Lygus elisus* was also widely distributed, although this species was collected in fewer locations than *L. shulli*. In contrast, *L. hesperus* was collected primarily in the locations close to the coast, with a small number of individuals occurring in scattered locations through the remainder of the region. Because *L. lineolaris* was the only species noted around greenhouses in the Ontario collections and was collected at all locations, its local distribution was not mapped.

Ontario phenology. In 1997, a few adult *L. lineolaris* were collected outdoors in June, the first nymphs were noted in early July, and the peak of the first generation appeared in early August (Fig. 2). A second generation followed in early September, indicated by an increase in nymphs in collections (Fig. 2). Collections were not continued to the end of this second generation in 1997. In 1998, a few adults were collected at the beginning of May. The first generation peaked in the middle of July and a second generation peaked around the end of September.

In greenhouses in 1997, the first *L. lineolaris* were sampled in mid June (Fig. 2). The numbers increased to about 1.8 adults per trap. A pesticide was applied by the greenhouse grower after the early June collection to reduce the numbers of nymphs on the plants. In 1998, *Lygus* adults were first seen in early May, along with nymphs. The population of *Lygus* adults increased to 3 adults/trap by the end of June. By 22 September, a second generation peaked at 3.9 adults/trap.

BC phenology. Adults of *L. shulli* were collected in sweep samples starting in May in 1996 (Fig 3A) and adults of both *L. shulli* and *L. elisus* were collected in April in 1998 (Figs. 4A, B). In 1998, nymphs of the first generation of both *L. shulli* and *L. elisus* appeared in sweep collections when the numbers of adults were low, in early June. The first generation of nymphs of *L. shulli* completed development by mid July, and nymphs of the second generation appeared in the field in late July. The first generation nymphs of *L. elisus* completed development in early July, and nymphs of the second generation appeared in late July. More adults than nymphs of *L. elisus* were caught. There was no

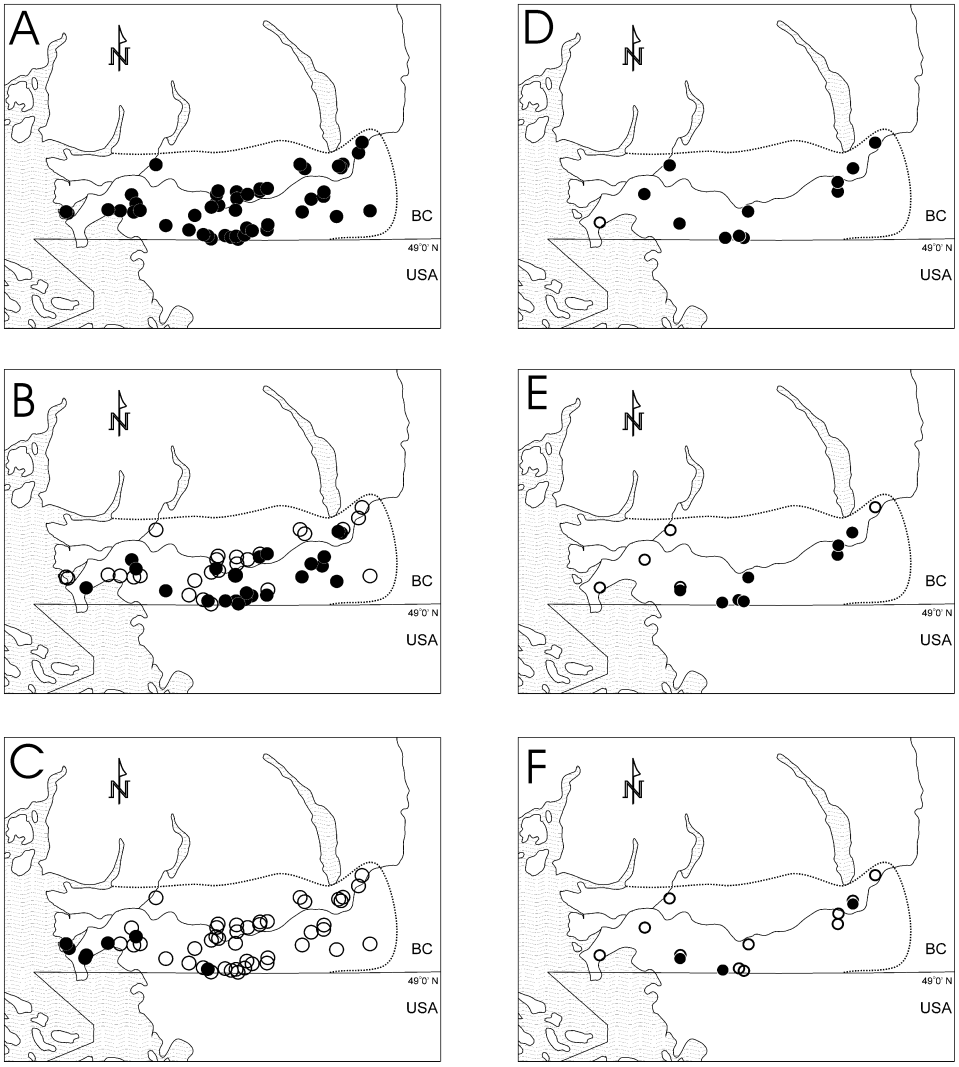

Figure 1. Distribution of *Lygus* spp. in the lower Fraser Valley, British Columbia, based on sampling in 1996, 1997 and 1998. A-C Sweep samples: A. *Lygus shulli*; B. *L. elisus*; C. *L. hesperus*. D-F yellow sticky trap captures: D. *L. shulli*; E. *L. elisus*; F. *L. hesperus*. Open circles designate locations where the relevant species was not captured, and closed circles are locations where that species was captured. The right border of the maps is at 121º 50' West. The dashed line indicates the approximate boundary of the lower Fraser Valley.

evidence of a third generation of either *L. shulli* or *L. elisus*. Adults of *L. hesperus* were collected in sweep samples only in late June and early July (Figs. 3A, 4C), and nymphs were collected only in July and August (Fig. 4C).

Sticky trap collections outside of greenhouses showed that a flight of *L. shulli* occurred in May in both 1996 and 1998 (Figs. 3, 5). These were probably adults dispersing from overwintering sites. Numbers of *L. shulli* adults on traps declined in June, increased in July

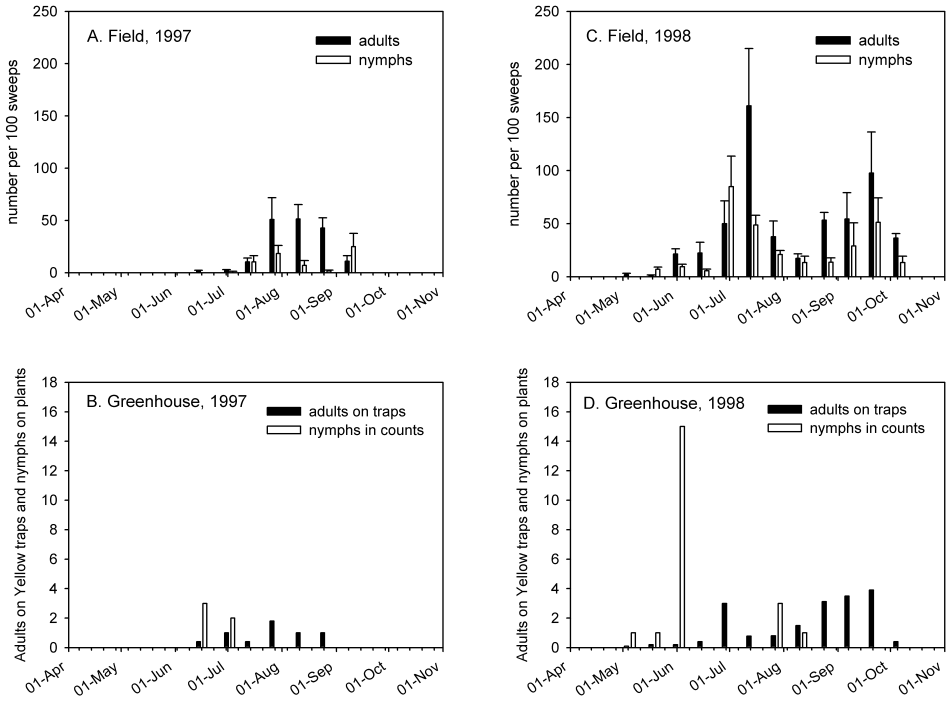

Figure 2. Numbers of *Lygus lineolaris* in sweep net samples near greenhouses, in counts on pepper plants, and on yellow sticky traps in pepper greenhouses in southwestern Ontario in 1997 and 1998. A, C: Mean number (±SE) of adults and nymphs in 100 sweeps in 1997 and 1998 respectively. B, D: numbers of adults per sticky trap and numbers of nymphs in surveys of 100 plants in 1997 and 1998, respectively.

and August, and decreased again in September. On traps outside of greenhouses, *L. elisus* also showed an early flight of overwintering adults in May (Figs. 3B, 5A). Like *L. shulli*, adults declined on traps in June and July. Adults then increased in numbers on traps in August and September, but this increase occurred somewhat later than *L. shulli*, perhaps indicating a longer developmental period. *Lygus hesperus* was never captured on traps outside of greenhouses in May (Figs. 3, 5). Adults of *L. hesperus* were noted on traps only in early August in 1996 and in August and September, 1998. The abundance of adults in sweep collections coincided with the results from traps outside of greenhouses.

Adults were relatively rare on yellow sticky traps inside greenhouses (Figs. 3C, 5B). The most abundant species was *L. shulli*, followed by *L. elisus*. Only one specimen of *L. hesperus* was captured on a yellow sticky trap inside a greenhouse. In general, captures of adults on traps inside greenhouses coincided with times when adults were captured on traps outside of greenhouses. *Lygus shulli* appeared in early May in 1996 and in mid June in 1998 in greenhouses, but *L. elisus* was not seen until mid August in 1996 and in mid June in 1998 (Figs. 3, 5). *Lygus hesperus* was not collected on traps in greenhouses in 1996, and only in late September in 1998 (Figs. 3, 5)

Correlation of field and greenhouse samples. Numbers of adults caught in sweeps outside of greenhouses in ON correlated with numbers of adults on traps in greenhouse in 1997 but not in 1998 (Pearson Correlation Coefficient (PCC) = 0.628, Bartlett's χ^2 = 10.76, $P < 0.0001$ and PCC = 0.303, Bartlett's χ^2 = 2.33, P = 0.073, respectively). No correlation was found between numbers of *Lygus* spp. adults in field sweeps and numbers of *Lygus* spp. on traps in greenhouses in 1996 or 1998 (PCC = 0.152, Bartlett's χ^2 = 0.195,

P = 0.659, and PCC = -0.074, Bartlett's $\chi^2 = 0.352$, P = 0.553, respectively). Similarly, no correlations were found between the numbers of *L. shulli* on traps in field sites and in nearby greenhouses in 1996 or 1998 (PCC = 0.553, Bartlett's $\chi^2 = 1.729$, P = 0.189, and PCC = 0, Bartlett's $\chi^2 = 0.000$, P = 0.998, respectively).

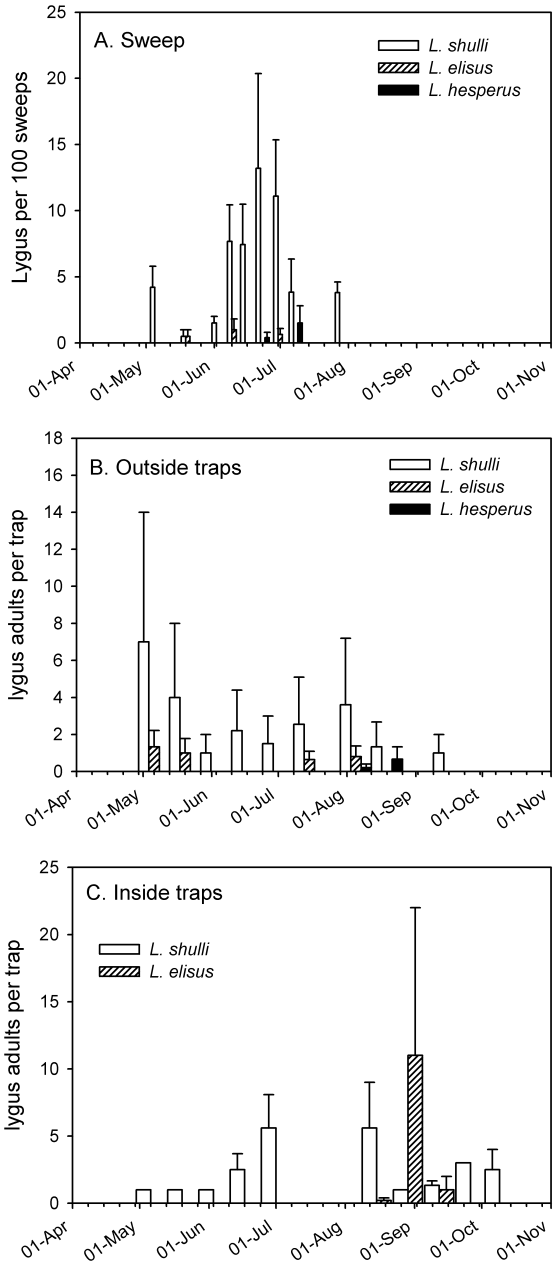

Figure 3. Mean captures (±SE) of *L. shulli*, *L. elisus* and *L. hesperus* in the lower Fraser Valley, BC in 1996. A. Average captures in 100 sweeps. B. average captures on yellow traps outside of greenhouses. C. Average captures on yellow traps inside greenhouses

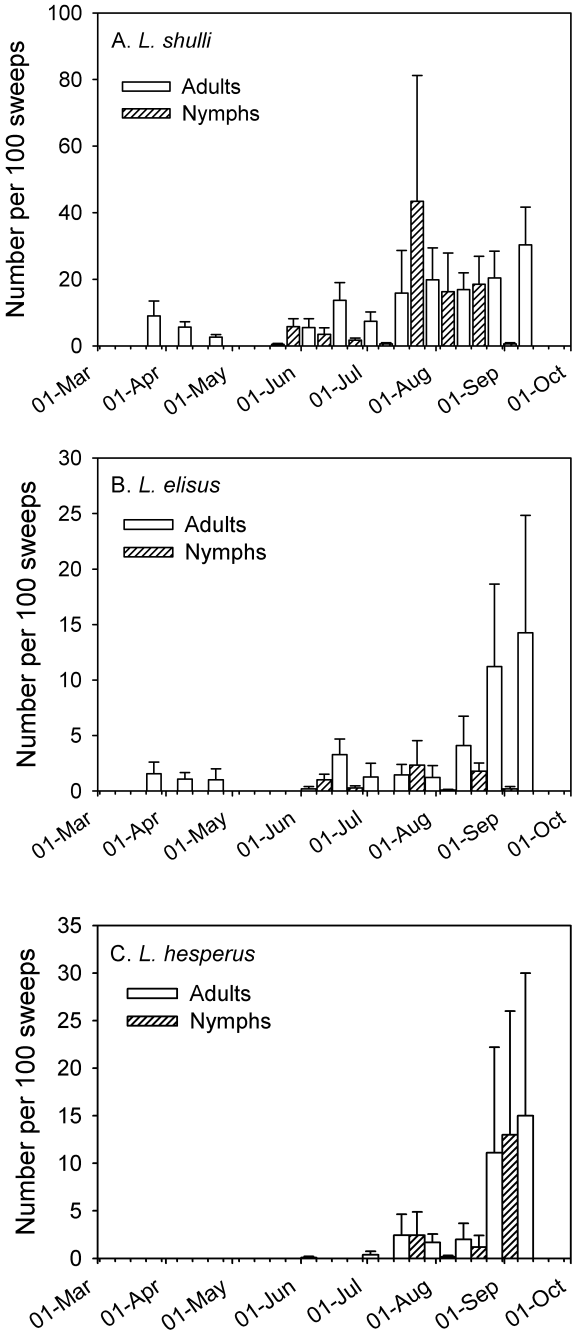

Figure 4. Mean captures (±SE) of adult and immature *L. shulli*, *L. elisus* and *L. hesperus* in sweep net samples in the Lower Fraser Valley, BC in 1998: A. *L. shulli*; B. *L. elisus*; C. *L. hesperus*.

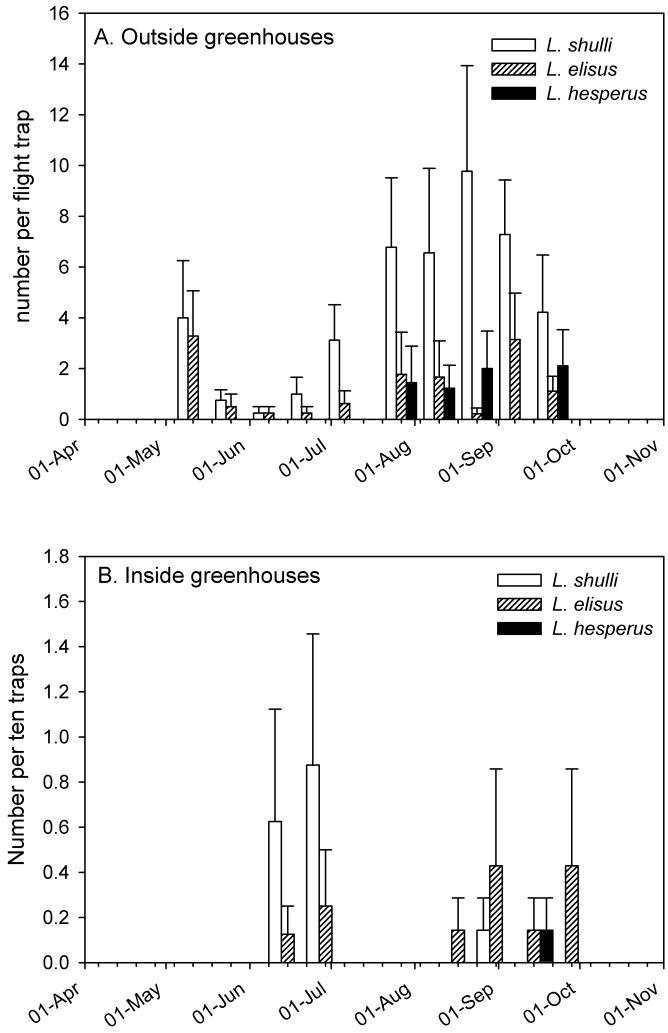

Figure 5. Mean captures (±SE) of *L. shulli, L. elisus* and *L. hesperus* on yellow sticky traps in the lower Fraser Valley, BC in 1998. A. Captures outside of greenhouses. B. Captures inside greenhouses.

DISCUSSION

The historical collection records for the Fraser Valley show that *L. lineolaris* was once one of four *Lygus* spp. in the region. This species was not collected in the current study, strongly suggesting it has either been extirpated or reduced dramatically in numbers in the lower Fraser Valley. Day (1996) noted dramatic decreases in abundance of *L. lineolaris* in alfalfa fields in eastern North America following the establishment of the exotic bivoltine parasitoid, *Peristenus digoneutis* Loan (Hymenoptera: Braconidae). Impacts of a parasitoid would not appear to be involved in BC, since a) parasitism in 1998 samples averaged only 5% by a univoltine *Peristenus* sp. attacking only the first generation (Gillespie, unpublished data), and b) *L. lineolaris* has been collected routinely in the interior and

eastern regions of British Columbia in the last decade based on collections records at the CNC.

In Ontario, numbers of *L. lineolaris* on traps in greenhouses were correlated with numbers caught in sweeps in nearby fields in one year but not in another. The correlation in 1997 may have actually been due to a pesticide application against *L. lineolaris* nymphs that were present in the greenhouse in 1997. The consequence of this was adults emerging in the greenhouse were not present and the relationship between sticky trap catches in greenhouse and field was not affected by these adults. In BC, numbers of *Lygus* spp. on traps inside of greenhouses were not related to numbers of *Lygus* spp. in sweep collections or on traps outside of greenhouses. The difference between the BC and ON results may be a consequence of either differences in species' plant location and flight behaviour, or differences in the physical structure of the greenhouses.

Little is known about host plant location and flight behaviour in *Lygus* spp. Cleveland (1982) reported that *L. lineolaris* moves from spring weed hosts into cotton fields when the latter were at the most susceptible stage. Stewart and Gaylor (1994) showed that females with chorionated eggs were more likely to fly than females without eggs, supporting observations that young reproductive females were most likely to invade crops. Rancourt *et al.* (2000) showed that flight in *L. lineolaris* was predominantly 1 m from the ground. It is possible that the species in BC differ in their host location and flight behaviour from *L. lineolaris* to the extent that they are less likely to invade greenhouses.

The flight behaviour of *L. shulli* and *L. elisus* has not been studied. Increases in the numbers of adults of both species in sweep samples preceded the increase in numbers on traps (Fig. 4A) by 2-4 weeks, suggesting that newly matured adults do not immediately move from their development locations. Adults of both *L. shulli* and *L. elisus* continued to increase in sweep samples until the last collections in late September. However, adults of both species on traps declined through September. This suggests that the sweep sample locations were also overwintering habitats, or at least very close to overwintering habitats, and that adults did not disperse from this habitat.

The greenhouse industries in the lower Fraser Valley of BC and southerwestern Ontario typically use different greenhouse structures. The Ontario industry favours double polyethylene greenhouses that have side-wall vents, that is, vents that open at or near to the ground surface. In contrast, the BC industry favours glass greenhouses that that have vents only on the roof, 4 m or more above ground level. If flight at approximately 1 m above ground level is typical of *Lygus* spp., then in Ontario, invasions of *L. lineolaris* into greenhouses through ground-level vents would be driven by field populations. In BC, invasions through roof vents or doorways would be random events and therefore unpredictable. Finally, there is a difference in the numbers of *Lygus* spp. adults in sweep samples in the field in BC and Ontario. In Ontario, captures exceeding 150 adults per 100 sweeps occurred, whereas in BC captures are typically one-tenth of that number. Thus, the differences in correlation between field and greenhouse numbers could be due to differences in field populations in the two regions making greenhouse invasion in BC less likely than in Ontario.

Cárcamo *et al.* (2002) reported wide-scale changes in *Lygus* spp. diversity on the prairies that were important for pest management. The differences in distribution of *Lygus* spp. within the Fraser Valley, an area about 150 km on an east-west axis and 50 km on a north-south axis, are also significant for pest management. Differences in abundance among the three species may cause differences in significance in certain parts of the valley. Differences among the species in behaviour, phenology or pesticide tolerances could mean that growers would have to adopt different IPM strategies for the different species. For example, *L. elisus* favours annual weedy Brassicaceae, whereas *L. shulli* prefers common Asteraceae (Schwartz and Foottit 1998).

Nymphs of *L. hesperus* did not appear in 1998 until early August, two weeks after the first adults had appeared in sweep samples and in traps outside of greenhouses. Based on this result, *L. hesperus* appears to be univoltine in the lower Fraser Valley, and does not occur in the field until after *L. shulli* and *L. elisus* have completed their first generation.

Lygus hesperus is a key pest of many crops in western North America (Kamm 1987, Ruberson and Williams 2000, Udayagiri *et al.* 2000), but in Canada, this species seems to occur primarily along the western, coastal part of the Fraser Valley, and appears to be univoltine. Thus, *L. hesperus* does not seem to be a major pest of agriculture in the Fraser Valley. Distribution maps in Schwartz and Foottit (1998) suggest that the northern limit for *L. hesperus* is in the southern BC area. This species may be univoltine in, or may migrate annually into the northern part of its range. Either explanation would account for the observed distribution.

We have shown regional differences in species distribution and phenology of *Lygus* spp. near and in vegetable greenhouses between BC and ON. These differences will result in growers taking different approaches to management of *Lygus* spp. in greenhouses.

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