Effects of Aphid (Homoptera) Abundance and Surrounding Vegetation on the Encounter Rate of Coccinellidae (Coleoptera), Chrysopidae (Neuroptera), and Nabidae (Hemiptera) in Alfalfa[1]

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Abstract Predaceous insect encounter rate was measured in 21 southeast Nebraska alfalfa fields through weekly sweep net sampling during 2002–03. The most frequently encountered predaceous insect families were Coccinellidae (Coleoptera), Nabidae (Hemiptera), and Chrysopidae (Neuroptera). The study used multiple regression analysis to examine the effect of aphid abundance and the surrounding vegetative patch composition on predaceous insect abundance. In 2002, *Hippodamia parenthesis* Say was encountered more frequently in fields with lower aphid abundances, and *Hippodamia convergens* Guerin-Meneville, *Coccinella septempunctata* L., and *Nabis americoferus* Carayon were encountered more frequently in fields with higher aphid abundances. In 2003, *Coleomegilla maculata* DeGeer was encountered more frequently in fields with higher aphid abundance. The remaining two species of coccinellids and *Chryoperla* spp. did not exhibit significant correlations with aphid abundance in either year. It was determined that in 2002, *H. parenthesis* was encountered more frequently in alfalfa surrounded by a higher percentage of unfarmed land, and *C. maculata*, *C. septempunctata*, *N. americoferus*, and *Chrysoperla* spp. were encountered more frequently in alfalfa surrounded by a higher percentage of farmed land. In 2003, *N. americoferus* was again encountered more frequently in alfalfa fields surrounded by a higher percentage of farmed land. The remaining three coccinellid species collected did not exhibit significant relationships between vegetative patch composition and encounter rate in either year.

Key words alfalfa, Aphididae, Coccinellidae, Nabidae, Chrysopidae, patch composition, Shannon Evenness Index, conservation biological control

Damage caused by Aphididae (Homoptera) can significantly reduce the quantity and quality of alfalfa, *Medicago sativa* L. (Danielson et al. 1993). When aphid infestations reach levels of economic significance, the producer typically applies a pesticide to the field (Danielson et al. 1993). Current integrated pest management trends

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aim to reduce the amount of pesticides applied to reduce both expense and environmental perturbation.

Previous work has shown that conservation biological control techniques have the potential to be used to manipulate predaceous insect populations and possibly control aphid infestations (Honěk and Hodek 1996, Ferro and McNeil 1998, Landis et al. 2000). Studies have shown the vegetative landscape structure can influence coccinellid abundance in agricultural landscapes (Colunga-Garcia et al. 1997, Elliott et al. 1998, 2002a, b). Successful application of conservation biological control techniques is dependent upon an understanding of how aphid abundance and the surrounding vegetative patch composition may affect predatory insect abundance within the field. This study investigated the relationship between aphid abundance and vegetative patch composition and predator abundance using patch analysis, a tool of landscape ecology.

Methods and Materials

During 2002 and 2003, 21 alfalfa fields in Butler and Seward counties, NE, USA, were sampled weekly from the second week of May through the first week of August. Only fields containing ≥75% pure alfalfa stands were sampled. This was measured at the beginning of each field season by visually examining 4 approx. 40 × 40 m randomly selected plots within each alfalfa field. If any of these plots contained <75% pure alfalfa the entire field was examined to determine if the entire field fell below this threshold. This analysis was done to reduce the effects of within-field vegetative diversity by ensuring that the fields being sampled were primarily pure alfalfa.

Sampling was conducted during late morning and afternoon when the alfalfa was not wet from either morning dew or rain and the air temperature was ≥15.5°C. Alfalfa fields that were recently harvested or <15 cm in height were not sampled, because at canopy heights <15 cm the insect population is greatly reduced and was assumed to be negligible for the purposes of this study. Pesticides were not applied to the study fields during the sampling periods. These collection guidelines were similar to those of Kieckhefer et al. (1992) and Wright and DeVries (2000).

Sampling was conducted using a 38-cm diam sweep net with a canvas bag, and sweeping was performed as close to the ground as possible given the height of the alfalfa. Four subsamples of 50 sweeps were taken along randomly chosen transects in a randomly chosen direction for a total of 200 sweeps per weekly sampling event per field. Sweep net sampling was chosen based on Fenton and Howell (1957) and Pruess et al. (1977) who observed that sweep net sampling provided reliable estimates of both total and relative abundance of predatory insects in alfalfa. Schotzko and O'Keeffe (1989) found that sweep net sampling could be used to obtain estimates of the relative abundance of Coccinellidae (Coleoptera), Nabidae (Hemiptera), and Chrysopidae (Neuroptera) in a variety of leguminous crops including alfalfa. Samples were frozen, sorted, and the number and species of adult coccinellids and adult and larval nabids were recorded. The number of adult and larval chrysopids and larval coccinellids was recorded, but they were not identified beyond genus due to taxonomic difficulties and lack of appropriate taxonomic keys. Members of the coccinellid genus *Cycloneda* were not identified to species because of taxonomic difficulties with the group.

Aphid abundance was measured by counting all the aphids in one quarter of each 50 sweep subsample. The counts were converted into an aphid index that ranged from 0-4 with 0 assigned to a subsample containing no aphids, 1 assigned for 1-10 aphids, 2 for 11-100 aphids, 3 for 101-400 aphids, and 4 for subsamples containing >400 aphids. The mean of the four subsamples was used as the sample aphid index, and the sample aphid index was used in the analysis.

Vegetative landcover characteristics surrounding each field were mapped, using aerial photographs, within a radius of approx. 1.61 km from the centroid of each alfalfa field. The data from these maps were used to create digital maps using Digital Orthophoto Quarter Quadrangles (DOQQ) and ArcView GIS 3.0 (ESRI 2001). Similar to Jonsen and Fahrig (1997) and Elliott et al. (1998, 2002a, b), the landscape was classified into the vegetative categories: other alfalfa (alfalfa other than the sampled field), Conservation Reserve Program (CRP) and meadow, pasture, cropland [means for 2002–03 (annual means were not significantly different at alpha = 0.05), corn (51% of the total cropland), soybean (47%), wheat (<1%), oats (<1%), rye (<1%), and grain sorghum (<1%)], and the sampled alfalfa field. These landcover vegetation types were designated on the digital maps inside an oval, the outer edge of which was 500 m (±5 m) from the centroid of each sampled alfalfa field. The 500 m distance was based on the desire to examine only the influence of the immediate surrounding vegetation, evidence from previous studies, and the insects known biology and ecology. Cartwright et al. (1977) found that approx. 75% of the time released predaceous coccinellids remained in the field into which they were released long enough to produce a second generation. Other studies found that, if given ample food, coccinellid species remained close to their overwintering sites during the growing season (Duelli et al. 1990, Elliott et al. 1998). Results from these studies indicate that whereas it is known that most coccinellid species are good dispersers (Honěk and Hodek 1996), they likely prefer not to do so if adequate resources are available. The digital maps were used to determine the area of each vegetative landcover category surrounding the sampled field and to perform patch analysis of the surrounding landscape.

Patch structure maps were developed by laying a grid of 40 × 40 m squares over the digital landscape maps at a standardized scale equal to 9500:1. The 40 × 40 m squares of landscape were small enough to detect diversity, but large enough to be manageable for the methods of analysis. A grid square was assigned a specific vegetative category if that category was greater than 50% of the square. If the square was composed of equal parts of more than one landcover, the designation was assigned randomly between the competing categories. Patch analysis used the four-neighbor rule; two adjacent grid squares were considered part of the same patch only if they were designated the same vegetative category and touched on a flat side. Squares composed of the same vegetative category touching only at their corners were not considered part of the same patch (see Cardille and Turner 2002). Patch structure maps were used to calculate the Shannon Evenness Index (SHEI):

$$\mathrm{SHEI} = \frac{\sum[p_i(\ln(p_i))]}{\ln(S)}$$

where S was equal to the number of landcover vegetation categories, p_i was the proportion of the *i*th cover type, and ln was the natural logarithm function. The SHEI was a measure of evenness in composition of vegetative patch structure. The index ranged from 0.0-1.0, a value approaching 0.0 indicated a landscape dominated by one vegetative category. A value approaching 1.0 indicated a landscape that was evenly composed of different vegetative categories. The SHEI can be interpreted as an implicit measure of landscape spatial heterogeneity.

The SHEI was calculated using three vegetative categories, pasture, CRP/meadow, and farmed land. The category, farmed land, included all cropland and all other alfalfa excluding the field being sampled. It was determined that alfalfa and field crops could be combined for two reasons. First, the area of other alfalfa was very small (mean = 3.42%, 0.0% in 7/21 fields). Second, there were no significant correlations between predator encounter rate and other alfalfa [significant correlations (α = 0.05) were found with the other three landcover categories]. Using the landcover categories, SHEI values, aphid abundance index, and predatory insect encounter rates, exploratory data analysis was performed that determined potential relationships between aphid abundance, vegetative patch composition, and the abundance of predatory insects. Raw insect counts were converted to an insect encounter rate (insects per 100 sweeps), and the arcsine square root transformation was applied to the landcover category percentages and SHEI values. The insect encounter rates were plotted against the aphid abundance index and the transformed landcover variables. From this set of plots, hypotheses were developed regarding the potential relationships between aphid abundance, surrounding vegetative patch composition, and predatory insect encounter rates in alfalfa.

Regression models fit using Number Cruncher Statistical System (NCSS) (NCSS 2004) were used to describe the relationships between the predator encounter rates and the aphid abundance and landscape categories that were identified through exploratory data analysis. Linear and quadratic models were considered, and plots were constructed to verify that the order of the polynomial used in the model was appropriate. Regression analysis was performed using four vegetative landcover categories (farmed (cropland + other alfalfa), pasture, CRP/meadow, and unfarmed (pasture + CRP/meadow). The regression analysis revealed that the significant relationships (α = 0.05) that existed between the encounter rates and aphid abundance and landscape categories could best be described as linear. Plots of the data, along with the fitted curves, were constructed using NCSS (NCSS 2004).

Results

Coccinellid species collected during the study included: *Hippodamia parenthesis* Say, *Coleomegilla maculata* DeGeer, *Hippodamia convergens* Guerin-Meneville, *Coccinella septempunctata* L., *Cycloneda* spp. and *Harmonia axyridis* (Pallas). *Nabis americoferus* Carayon was the only species of Nabidae collected in significant numbers. *Chrysoperla* spp. and coccinellid larvae were collected, but they were not identified to species. Four aphid species were collected, *Acyrthosiphon pisum* (Harris), *Acyrthosiphon kondoi* Shinji, *Therioaphis maculata* (Buckton) and *Aphis craccivora* Koch

The most frequently encountered adult coccinellid during 2002 was *C. maculata* with an encounter rate of 5.67 beetles per 100 sweeps (28.1% of total Coccinellidae). The remaining species in decreasing abundance were *H. convergens* (5.61 per 100 sweeps, 27.8%), *H. parenthesis* (4.26 per 100 sweeps, 21.1%), *C. septempunctata* (4.02 per 100 sweeps, 20.0%), *Cycloneda* spp. (0.329 per 100 sweeps, 1.6%) and *H. axyridis* (0.287 per 100 sweeps, 1.4%). The collection rate for the coccinellid larvae was 8.70 larvae per 100 sweeps. *Nabis americoferus* was the most abundant non-coccinellid predatory insect in the study with a collection rate of 14.5 per 100 sweeps.

Chrysoperla spp. was collected at a rate of 2.96 lacewings per 100 sweeps. The aphid abundance index ranged from 0.64-2.31 in 2002.

The most frequently encountered adult coccinellid during 2003 was *H. convergens* with the encounter rate of 7.36 beetles per 100 sweeps (51.4% of total Coccinellidae). The remaining species in decreasing abundance were *C. septempunctata* (3.78 per 100 sweeps, 22.4%), *C. maculata* (2.22 per 100 sweeps, 15.4%), *H. parenthesis* (0.98 per 100 sweeps, 6.8%), *Cycloneda* spp. (0.32 per 100 sweeps, 2.5%) and *H. axyridis* (0.29 per 100 sweeps, 1.5%). Due to the small number of *H. axyridis* and *Cycloneda* spp. collected in both years, the two were combined into a category called, "other coccinellids". The collection rate of coccinellid larvae was 0.96 larvae per 100 sweeps in 2003. *Nabis americoferus* was the most abundant non-coccinellid predatory insect in 2003 with a collection rate of 10.09 per 100 sweeps. *Chrysoperla* spp. was collected at a rate of 1.23 lacewings per 100 sweeps. The aphid abundance index ranged from 1.08-2.17 in 2003.

Landscape analysis revealed considerable variation in the landcover vegetative composition among the 21 sampled fields. Some fields were surrounded predominantly by farmed land (maximum = 96.0%), some by unfarmed land (maximum = 97.4%), and others were embedded in a heterogeneous landscape. This variation enabled an examination of the effects of varying landscape vegetative composition on the abundance of predatory insects. The SHEI revealed that the fields varied in the amount of evenness (heterogeneity) they displayed within their surrounding vegetative patch composition; SHEI values were distributed in a range from 0.154-0.995.

In 2002, a significant negative relationship was found between aphid abundance and the encounter rate of *H. parenthesis* (slope = –3.4197 (SE = 0.7913), $P = 0.0004$, $r = -0.7041$). Significant positive relationships were found between aphid abundance and *H. convergens* (slope = 3.5601 (0.8767), $P = 0.0007$, $r = 0.6817$), *C. septempunctata* (slope = 3.3264 (0.8483), $P = 0.0009$, $r = 0.6688$), *N. americoferus* (slope = 6.9356 (1.7217), $P = 0.0007$, $r = 0.6787$) and coccinellid larvae (slope = 8.4588 (1.6750), $P = 0.0001$, $r = 0.7570$). In 2003, a significant positive relationship was found between aphid abundance and *C. maculata* (slope = 3.8466 (1.1148), $P = 0.0027$, $r = 0.6207$) and the group "other coccinellids" (slope = 0.4821 (0.2149), $P = 0.0370$, $r = 0.4577$).

During 2002, *H. parenthesis* was collected with greater frequency in fields surrounded by a higher percentage of unfarmed land (slope = 3.6806 (1.1515), $P = 0.0048$, $r = 0.5913$). The encounter rate of *H. parenthesis* exhibited a positive relationship with increased pasture (slope = 5.6169 (1.9748), $P = 0.0104$, $r = 0.5465$) and CRP/meadow (slope = 4.6998 (1.5086), $P = 0.0057$, $r = 0.5815$). The species exhibited a negative relationship between encounter rate and farmed land (slope = –3.6789 (1.1514), $P = 0.0048$, $r = -0.5912$). Analysis of the SHEI with the *H. parenthesis* encounter rate revealed a positive correlation with increased landscape heterogeneity (slope = 3.6220 (1.1912), $P = 0.0067$, $r = 0.5721$). No significant relationships were detected between the encounter rate of *H. parenthesis* and any landscape categories during 2003.

Analysis of *C. maculata* revealed that during 2002, the species was more frequently encountered in fields surrounded by a higher percentage of farmed land (slope = 4.3724 (1.9990), $P = 0.0414$, $r = 0.4485$). The species was less frequently encountered in fields surrounded by a higher percentage of pasture (slope = –7.6471 (3.2513), $P = 0.0296$, $r = -0.4749$) and unfarmed land (slope = –4.3753 (1.9994), $P = 0.413$, $r = -0.4487$). Analysis of the SHEI indicated a negative correlation between

C. maculata encounter rate and increased landscape heterogeneity (slope = −4.4123 (2.0379), *P* = 0.0433, r = −0.4449). No significant relationships were found between *C. maculata* encounter rate and any landscape categories during 2003.

Analysis of *C. septempunctata* revealed only a significant negative relationship with increased SHEI (slope = −3.2125 (1.2918), *P* = 0.0224, r = −0.4955) during 2002. No significant relationships were found between *C. septempunctata* encounter rate and any landscape categories during 2003. *Hippodamia convergens,* "other coccinellids" and coccinellid larvae displayed no significant relationships between their encounter rates and any landscape categories in either year.

Chrysoperla spp. exhibited a negative relationship between increased SHEI and encounter rate (slope = −2.0839 (0.7183), *P* = 0.0092, r = −0.5541) during 2002. No significant relationships were found between *Chrysoperla* spp. encounter rate and any landscape categories during 2003.

In 2002, *N. americoferus* exhibited a positive relationship between encounter rate and farmed land (slope = 6.4598 (2.6124), *P* = 0.0230, r = 0.4934). The species was encountered less frequently in fields surrounded by a greater percentage of unfarmed land (slope = −6.4571 (2.6317), *P* = 0.0231, r = −0.4931). The species also exhibited negative relationships between encounter rate and increased pasture (slope = −12.5960 (4.0327), *P* = 0.0056, r = −0.5825) and CRP/meadow (slope = −7.7337 (3.4745), *P* = 0.0383, r = −0.4548). The encounter rate of *N. americoferus* decreased with increased SHEI (slope = −8.6823 (2.3173), *P* = 0.0014, r = −0.6518).

In 2003, *N. americoferus* exhibited a positive relationship between farmed land and encounter rate (slope = 3.9837 (1.8769), *P* = 0.0472, r = 0.4378). The species exhibited a negative relationship between encounter rate and unfarmed land (slope = −3.9829 (1.8776), *P* = 0.0473, r = −0.4376). The species also exhibited negative relationships between encounter rate and increased pasture (slope = −7.8950 (2.9343), *P* = 0.0145, r = −0.5253) and CRP/meadow (slope = −4.8156 (2.4764), *P* = 0.0668, r = −0.4074). The encounter rate of *N. americoferus* decreased with increased SHEI (slope = −5.7493 (1.6647), *P* = 0.0027, r = −0.6210).

Discussion

The six species of Coccinellidae that were collected were not unexpected as *H. parenthesis, C. maculata, H. convergens*, and *Cycloneda* spp. are considered native to Nebraska (Gordon 1985). *Coccinella septempunctata* is a species that was introduced into the United States from Eurasia (Angalet et al. 1979, Obryki and Kring 1998). *Harmonia axyridis* is an exotic species that has been collected in Nebraska during only the past 10-15 yrs (Chapin and Brou 1991, Wright and DeVries 2000). The occurrence of *N. americoferus* and *Chrysoperla* spp. also was anticipated, as they are known to be common predators in Nebraska alfalfa (Danielson et al. 1993).

It is well documented that there is a relationship between prey and predator abundance. The relationships detected in this study are similar to those found in other studies examining aphid and predator relationships in alfalfa (Neuenschwander et al. 1975, Evans and Youssef 1992, Elliot et al. 2002a, 2002b). The significant positive relationships seen in 2002 between the aphid index and the encounter rates of *H. convergens*, *C. septempunctata*, *N. americoferus* and coccinellid larvae were expected. The lack of significant relationships among these groups in 2003 could be the result of extreme drought conditions in the study area severely damaging alfalfa. The negative relationship found between *H. parenthesis* and aphid abundance in 2002 was not expected. Little is known about the biology of this species. It is possible that the primary prey of *H. parenthesis* is not aphids, but rather larval instars of other species. If so, further examination of *H. parenthesis* could reveal that the species could be a useful biological control agent of other economically significant pests.

The lack of a relationship between aphid abundance and *C. maculata* in 2002 is likely the result of their habit of feeding on pollen (Smith 1971, Andow and Risch 1985, Groden et al. 1990). Elliott et al. (2002a) found a negative relationship between the abundance of *C. maculata* and aphid abundance. The authors attributed this finding to pollenivory. In this study the abundance of *C. maculata* in alfalfa decreased greatly in late June and early July when the corn pollinated and their abundance did not recover to prepollination levels in either year. The presence of a significant relationship between aphid abundance and *C. maculata* encounter rate during 2003 could be the result of the extreme drought. Much of the corn in the study area did not reach the tassel stage due to the severe drought conditions and, therefore, pollen availability was likely limited. The significant relationship between "other coccinellids" and aphid abundance in 2003 should be considered with caution given the very low abundance of the group, but could also be the result of the drought and potential reduction of their typical prey.

Hippodamia parenthesis was encountered more frequently during 2002 in fields surrounded by unfarmed land. This may indicate a preference for the grass-dominated more native-like habitats of meadows, CRP acres, and some pastures. Palmer (1914) stated that *H. parenthesis* was mainly taken from grasses and sedges not from annual crops. Balduf (1926) reported this species occurring most often in mixed grass and alfalfa or clover fields in Illinois. The relationship between increased heterogeneity and *H. parenthesis* may demonstrate a preference for alfalfa fields surrounded by unfarmed land. When alfalfa is harvested, all surviving adult coccinellids presumably must move into another habitat because the alfalfa habitat is temporarily destroyed. Little is known about the biology of *H. parenthesis*, it is a relatively small coccinellid and smaller coccinellids generally have less ability to disperse, making them more dependent upon immediately adjacent landscape (Honěk and Hodek 1996). If an alfalfa field is adjacent to unfarmed, grassland-like habitat, it is reasonable to conclude that *H. parenthesis* may be more abundant within that field.

That *C. maculata* exhibited greater encounter rates in alfalfa fields surrounded by mostly farmed land during 2002 was not unexpected. As discussed earlier, *C. maculata* is known to be pollenivorous and has been shown to congregate in annual crops (especially corn) during pollination (Smith 1971, Andow and Risch 1985, Groden et al. 1990). This behavior could be a reason why *C. maculata* was encountered more frequently in fields surrounded by a higher percentage of farmed land. The findings of this study differ from those of other studies of this species. Elliott et al. (2002a) working in eastern South Dakota found a positive relationship between *C. maculata* abundance and wooded land and pasture/grassland. Elliott et al. (2002a) argued that this relationship may exist because wooded land provides overwintering habitat for the species. The lack of this relationship in our study could result from a difference in landscape structure. In our study area all wooded pasture was initially separated into its own category, wooded pasture. The initial data analysis revealed no significant difference between pasture and wooded pasture and predator abundance and the two categories were grouped into one. The wooded areas in our study area were not densely wooded and, therefore, may not be suitable overwintering habitat for *C. maculata*, possibly explaining the lack of a significant relationship.

Hippodamia convergens displayed no significant correlations between any vegetative categories or SHEI and encounter rate in either year. These results were not surprising given the generalist behavior, habitat requirements, and good dispersal ability of the species. *Hippodamia convergens* is a native species that occurs in many habitats in many parts of North America (Obrycki and Kring 1998). Members of the species are large and generally considered to be strong flyers (Honěk and Hodek 1996), and they likely are not dependent upon immediately adjacent habitats following alfalfa harvest. The species was likely able to disperse longer distances than *H. parenthesis* and was not as specialized to specific habitats like *C. maculata*.

Coccinella septempunctata has been introduced as a biological control agent in a number of different crops across the United States (Obryki and Kring 1998). This fact may be reflected in the negative correlation between its encounter rate and increased SHEI in 2002. In this study, an increase in SHEI indicated an increase in landscape heterogeneity and thus a decrease in the dominance of farmed land in a landscape. Presumably, a species introduced for biological control in annual crops would prefer alfalfa surrounded by a higher percentage of farmed land to unfarmed land.

The group "other coccinellids" revealed no significant correlations between any vegetative categories and encounter rate in either year. The group exhibited very low encounter rates and, therefore, statistical power probably was lacking.

The fact that coccinellid larvae distribution showed no relationships between any vegetative landscape categories or SHEI in either year may indicate that adults were not selecting oviposition sites based on the surrounding vegetative patch structure. Oviposition sites were likely selected on some other within field factor such as the general health and condition of the alfalfa as indicators of predator abundance. Predator abundance is critical for larval development because generally larvae cannot disperse from the field in which they were oviposited.

Chrysoperla spp. exhibited a negative relationship between increased SHEI and encounter rate in 2002. The presence of this negative relationship could indicate a preference for alfalfa fields surrounded by a greater percentage of farmed land. This preference was not unexpected, as adults *Chrysoperla* spp. are known to oviposit on a wide variety of plants and their larvae are voracious predators known to readily prey on a wide variety of arthropods (Canard et al. 1984).

The analysis of *N. americoferus* indicated higher encounter rates in alfalfa fields surrounded by a higher percentage of farmed land. Analysis also revealed a negative correlation between increased SHEI and encounter rate. These relationships, exhibited in both years, indicated that *N. americoferus* was more abundant in alfalfa fields located within a landscape dominated by farmed land. Given the generalist nature and habitat preference of this species, these correlations were not unexpected. The literature indicated that nabids are widespread in almost all agricultural systems and often are the most abundant arthropod predator (Carroll and Hoyt 1984, Guppy 1986, Elliott et al. 1998).

This study presented the results from 2 years from an ecoregion that exhibits very high interannual climatic variability. Only *N. americoferus* exhibited significant relationships during both years. There are numerous factors that could influence encounter rates of predatory insect in alfalfa. However, it should be noted that 2003 was one of the driest years on record in many parts of eastern NE (HPRCC 2004). Alfalfa and all crops throughout the region were severely damaged and, thus, they were a considerably less suitable habitat for predatory insects and their prey (HPRCC 2004, Kriz pers. obs.). This may have been reflected in the fact that there were nearly 2.5× fewer coccinellids, 2.7× fewer nabids, 5.4× fewer chrysopids and 10× fewer coccinellid larvae collected during 2003.

The study effectively demonstrated that whereas many elements influence predator abundance in alfalfa, the surrounding vegetative patch composition appears to be a potentially significant influence on some species. An understanding of these relationships will lead to more successful applications of conservation biological control, which could lead to a reduction in the amount of pesticides applied to agricultural lands. The data from this study support the postulation that conservation biological control should be targeted at specific species in specific habitats to achieve higher rates of successful control.

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