A Survey of the Foliar and Soil Arthropod Communities in Sunflower (*Helianthus annuus*) Fields of Central and Eastern South Dakota

Author(s): Michael M. Bredeson and Jonathan G. Lundgren

Source: Journal of the Kansas Entomological Society, 88(3):305-315.
Published By: Kansas Entomological Society
DOI: http://dx.doi.org/10.2317/0022-8567-88.3.305
URL: http://www.bioone.org/doi/full/10.2317/0022-8567-88.3.305

JOURNAL OF THE KANSAS ENTOMOLOGICAL SOCIETY
88(3), 2015, pp. 305–315

A Survey of the Foliar and Soil Arthropod Communities in Sunflower (*Helianthus annuus*) Fields of Central and Eastern South Dakota

MICHAEL M. BREDESON[1] AND JONATHAN G. LUNDGREN[2,3]

ABSTRACT: The long coevolutionary history between sunflowers (*Helianthus annuus,* Asterales: Asteraceae) and arthropods in the northern Great Plains has resulted in a commonly grown oilseed crop that harbors a large diversity of insects. A bioinventory of foliar and subterranean arthropods was performed in 22 sunflower fields over a period of three site years in central and eastern South Dakota. Overall, 467 morphospecies were collected. From foliage, 15 arthropod orders were observed. Those containing the greatest species diversity were Hymenoptera, Coleoptera, Hemiptera, Diptera and Araneae with 80; 53; 53; 40 and 30 morphospecies each, respectively. Subterranean arthropods from 19 orders were collected. The five orders containing the highest number of morphospecies were Coleoptera, Hymenoptera, Hemiptera, Araneae and Diptera containing 77; 17; 14; 11 and nine morphospecies respectively. Although bioinventories can be expensive and time consuming, information gathered from them has many uses, including efforts to assess the implications of pesticide use, wildlife conservation, land use- and climate-change on community structure in sunflowers.

KEY WORDS: Insect community, Bioinventory, Predators, Pollinators, Herbivores, Detritivores

Farmland represents the largest biome on planet Earth, comprising 40% of its terrestrial surface (FAO, 2007). As such, management decisions made within farmland have important implications for biodiversity (Butler *et al*., 2007; Polasky *et al*., 2011). Inventories of biological communities (bioinventories) provide an important dataset critical to informing researchers and producers on how current management practices support biodiversity and its services (Goldstein, 2004; Fattorini *et al*., 2012). In recent years climate change (Andrew *et al*., 2013), habitat loss (Marini *et al*., 2012), and agriculture intensification (Tscharntke *et al*., 2012) have altered biological communities. For example, the conversion of prairie grasslands to large-scale row-crop acreage reduces the overall insect diversity and abundance that the habitat once hosted (Schmid *et al*., in press). Similarly, in established row-crop acreage, management decisions such as applying an insecticide can alter not only herbivore communities but also beneficial predator, detritivore and pollinator communities (Wolfenbarger *et al*., 2008). Comprehensive bioinventories within cropland can provide an important benchmark for examining how cultural activities affect biodiversity (Hooper *et al*., 2012) and crop production (Hoehn *et al*., 2008). Although scientists have been conducting research in agroecosystems for generations, there are few bioinventories of arthropod communities within major cropping systems and regions to form a baseline for further assessments (Fattorini, 2013; Lundgren *et al*., 2015).

Cultivated sunflowers, *Helianthus annuus* (Asterales: Asteraceae), are an important crop grown in South Dakota, occupying nearly 250,000 ha in 2014 (NASS, 2015). There is a long coevolutionary history between insects and the

[1] Department of Biology and Microbiology, South Dakota State University, Brookings, South Dakota 57006, USA
[2] USDA-ARS, North Central Agricultural Research Laboratory, Brookings, South Dakota 57006, USA; e-mail: jonathan.lundgren@ars.usda.gov; jgl.entomology@gmail.com
[3] Corresponding author.

Accepted 22 April 2015; Revised 31 August 2015

≈50 native *Helianthus* spp. in North America, resulting in a diverse and abundant arthropod community within cultivated sunflowers (Charlet *et al.*, 1992). The large plants provide numerous microclimates, pollen (Nicolson and Human, 2013), floral (Jadhav *et al.*, 2011) and extra-floral nectar (Moscardini *et al.*, 2014) that attract an assortment of species from numerous functional guilds. Previous research on sunflower insect communities has taken place over parts of North America (Cockerell, 1916; Walker, 1936; Lynch and Garner, 1980; Hilgendorf and Goeden, 1981; Charlet *et al.*, 1987; Rogers, 1988; Royer and Walgenbach, 1991; Charlet *et al.*, 1992), but the arthropod assemblages within South Dakota sunflower fields remain poorly described. Royer and Walgenbach (1991) described the predatory insects found on the foliage and ground surface in sunflowers grown in far eastern South Dakota. Their study, however, did not include herbivores found on the foliage or in the soil, or the predators dwelling in the soil of sunflower fields. To our knowledge, the soil dwelling arthropod community within sunflower fields has not been described for any location. In the present study, both the foliar and soil predatory and herbivorous arthropod communities found in sunflower fields over a period of three site years in eastern South Dakota are described. This bioinventory will provide the basis for experiments that explore the effects of neonicotinoid seed treatments (among other cultural practices) on target and non-target organisms.

Materials and Methods

Plot Design

Insect communities were described in 22 sunflower fields over three site-years. In 2013, six fields (30.5 × 30.5 m each) of cultivated sunflowers (Pioneer®, variety: 63M80) were planted on June 14 at the Eastern South Dakota Soil and Water Research Farm (USDA-ARS) in Brookings County, SD (44.3064°, 96.7881°, latitude, longitude). In different areas on the same farm, eight fields (24.5 × 36.5 m) were planted on May 23, 2014 with Mycogen® variety 8H288CLDM. The same variety was planted in eight fields (24.5 × 36.5 m) at Dakota Lakes Research Farm (Dakota Lakes) in Hughes, County, SD (44.3680°, 100.3364°) on June 6, 2014. All fields had been no-tilled for at least 5 y, and followed a crop of teff (*Eragrostis tef*) at Dakota Lakes, and soybeans (*Glycine max*) in Brookings. Planting rate was 76,600 seeds/ha at all locations, with 51 cm row spacing at Dakota Lakes and 76 cm row spacing in Brookings. Weeds were managed in Brookings with a mixture of glyphosate (2.34 L/ha in 2013 and 1.61 L/ha in 2014, Roundup WeatherMAX®, Monsanto Company, St. Louis, MO) and sulfentrazone (0.44 L/ha, Spartan®, FMC Corporation, Philadelphia, PA) on the day that the fields were planted. Fields at Dakota Lakes were sprayed shortly after planting with a mixture of glyphosate (1.17 L/ha) and pendimethalin (2.92 L/ha, Prowl® H2O, BASF Corporation, Research Triangle Park, NC). Half of the fields at each site received a thiamethoxam seed dressing (0.25 mg active ingredient/seed; Cruiser®, Syngenta, Greensborough, NC); comparisons between the treated and untreated sunflowers will be the subject of additional research (Bredeson and Lundgren, in press). All fields were surrounded by margins (12.2 m wide in Brookings, and 6.1 m wide at Dakota Lakes) that were planted to sorghum × sudangrass (Sorghum × drummondii var. MS9000, Millborn Seeds Inc, Brookings, SD) in Brookings, 2013, and to soybeans (93M11, Pioneer

Hybrid International, Johnston, IA) without insecticidal treatments at both Brookings and Dakota Lakes in 2014.

Foliar Arthropod Community

Foliar arthropod communities were assessed using whole plant counts multiple times in each field over the seasons. In 2013, between the V-6 and R-7 sunflower stages (Schneiter *el al.*, 2003), the foliar arthropod communities within sunflower fields were assessed eight times at the Brookings location. In 2014, foliar insect communities were assessed 10 times at the Brookings site and six times at Dakota Lakes between V-2 and R-6 sunflower stages. All arthropods found on the foliage were collected from randomly selected sunflower plants from each field. The number of plants sampled per field varied over the season depending on the resources needed to evaluate the community. In Brookings (2013), 10 plants from each field per date were examined. In Brookings (2014), 20 plants per field were examined on the first two sampling dates, 15 plants on the second and third sampling dates and 10 plants per field on remaining dates. In 2014 at Dakota Lakes, 15 plants per field were examined on the first collection date and 10 plants were examined per field on remaining dates. Field collected arthropods were stored in 70% ethanol (70: 30, ethanol: water) and later sorted and counted.

Soil Arthropod Community

Soil cores were used to describe the soil community in South Dakota sunflowers. In 2013, soil arthropod communities were assessed on six dates between planting and the R-6 plant stage in Brookings. In 2014, soil communities were assessed eight times at Brookings and six times at Dakota Lakes between the V-2 and R-6 stages. In 2013, four soil cores (diameter: 11 cm, depth: 10 cm) were collected using a golf-hole cup cutter from within sunflower rows at randomly selected locations in each field on every sampling date (n = 144). In 2014, three soil cores were taken in each plot on every sampling date (n = 336). On each collection date, the cores that were taken within individual plots were pooled and subjected to a Berlese funnel extraction for 7 d. The arthropods were stored in 70% ethanol until they were sorted and counted.

Community Composition

To characterize the arthropod communities and assess insect diversity, each specimen was identified to as low a taxonomic level as possible, hereafter referred to as morphospecies. To further characterize the arthropod communities, individual morphospecies' biologies were considered and grouped into four functional guilds: predators, herbivores, pollinators and detritivores.

Results

Foliar Arthropod Community

A total of 2040 individual sunflower plants were subjected to whole plant counts throughout the course of this study. In sum, 19,193 arthropods representing 310 different morphospecies from 15 orders (class Arthropoda: Araneae, Coleoptera, Collembola, Diptera, Ephemeroptera, Hemiptera, Hymenoptera, Lepidoptera, Neuroptera, Odonata, Opiliones, Orthoptera, Psocoptera, and Thysanoptera, class Gastropoda: Pulmonata) were collected from sunflower foliage. The five orders containing the largest number of morphospecies were Hymenoptera, Coleoptera, Hemiptera, Diptera and Araneae with 80; 53; 53; 40 and 30 morphospecies in each order respectively. The mean (±SEM) number of morphospecies collected per field from each of those five orders was 15.18 ± 1.53; 12.18 ± 0.95; 17.27 ± 0.81; 8.91 ± 0.75 and 11.23 ± 0.66 (Table 1A contains average arthropods per field per plant in each of these orders). Orders representing the greatest arthropod abundance were Hemiptera, Neuroptera, Diptera, Thysanoptera, Hymenoptera, Coleoptera, Orthoptera, Araneae and Lepidoptera containing 7529; 2631; 2628; 2278; 1563; 1042; 807; 305 and 259 specimens each, respectively (refer to Table 1A for these orders found per plant). When grouped into the functional guilds predators, herbivores and pollinators, 6374; 9918 and 295 individuals within 140; 126 and 16 morphospecies and eight, eight and one orders were collected, respectively. According to Knodel *et al.* (2010), there are 20 species of herbivorous arthropods of sunflowers in the northern Great Plains that are of economic importance. Twelve of these were collected by whole plant counts representing 1216 individuals and 6.32% of the total foliar herbivore population. Important sunflower pests collected often (>0.01 per plant) are highlighted in Table 1A. The mean (±SEM) Shannon Diversity Index per field was 2.75 ± 0.08, with an evenness of 0.63 ± 0.02. The most commonly captured morphospecies' (>0.01 individuals per plant) per field per sunflower plant are represented in Table 1A.

Soil Arthropod Community

In total, 25,530 specimens (excluding nematodes and earthworms) in 157 morphospecies from 19 orders (Acarina, Araneae, Coleoptera, Collembola, Diplura, Diptera, Ephemeroptera, Hemiptera, Hymenoptera, Isopoda, Julida, Lepidoptera, Lithobiomorpha, Neuroptera, Orthoptera, Protura, Pseudoscorpiones, Psocoptera and Thysanoptera) were extracted from the soil cores (n = 480 total cores). The five orders containing the highest numbers of morphospecies were Coleoptera, Hymenoptera, Hemiptera, Araneae and Diptera containing 77; 17; 14; 11 and 9 morphospecies respectively. Within these five orders, the mean (±SEM) number of morphospecies collected per field were 12.41 ± 1.16; 2.5 ± 0.31; 1.27 ± 0.38; 2.41 ± 0.30 and 2.14 ± 0.28 (Table 1B contains average arthropods per m^2 soil in each of these orders). Orders representing the greatest arthropod abundance were Acarina, Collembola, Coleoptera, Diplura, Hymenoptera, Thysanoptera and Araneae with 15,370; 8198; 604; 351; 326; 190 and 165 individuals respectively. Individuals per m^2 soil from these orders are represented in Table 1B. For predators, 935 individuals from seven orders and 75 morphospecies, and 345 herbivores from five orders and 35 different morphospecies were collected from the soil cores. Known detritivores comprised the majority of subterranean arthropods. Six orders, including Acarina, Collembola, Isopoda, Julida, Protura, and Psocoptera contained a total of 23,600 individuals, averaging 5868.51 ± 621.75 individuals per m^2. Mean (±SEM) soil arthropod diversity per field was 0.98 ± 0.05 and evenness was 0.29 ± 0.01. Morphospecies most commonly captured from the soil samples (10 or more individuals in total) are represented as individuals per field per m^2 in the top 10 cm of soil in Table 1B.

Arthropods in Both Soil and Foliage

The arthropod communities from foliar and soil collected specimens were distinct. Of the 467 morphospecies collected, only 16, representing 3.43% of total morphospecies were collected from both environments. However, the 16 morphospecies found in both environments represented 16,935 individuals, 37.12% of all specimens collected during the survey. This was largely driven by the presence of Collembola, aphids and thrips in both areas of the habitat, representing 8205; 3390 and 2468 total collected specimens respectively. When calculated at a per ha basis, total Collembola, aphid and thrips populations from both the soil and foliage were 17,587,908 ± 4,533,990; 19,339 ± 7470 and 460,990 ± 86,968, respectively.

Discussion

Arthropods collected from the sunflower fields of eastern South Dakota were abundant and diverse. Previous studies assessing the arthropod communities in sunflowers have yielded similar results, but this is the first comprehensive community description in South Dakota sunflowers. For example, a literature review conducted by Hilgendorf and Goeden (1981) of all phytophagous insects reported on sunflowers in North America north of Mexico reported 159 species in six different insect orders. The most commonly observed orders in their database were Hemiptera, Coleoptera, Lepidoptera and Diptera with 46; 40; 37 and 21 species respectively. This is similar to the species richness of herbivores collected in eastern South Dakota. However, a survey of arthropods (both predatory and herbivorous) in sunflower fields across the southern United States generated a list of 213 species representing 10 different orders (Rogers, 1988) whereas in the current study, 310 morphospecies from 15 orders were collected. That survey, however, was non-exhaustive (as described by the authors), and was meant to be used as a guide for future work in the area of arthropod community characterization, rather than a complete inventory of sunflower insects. This may explain the difference in community structure found in the two studies. Differences in collection methods and farm management practices may also partially explain the differences in communities between the current study and the published literature. Manual whole plant counts are relatively time- and labor-intensive compared to use of sweep nets or vacuum sampling, but may provide a more comprehensive assessment of species diversity and density in fields. The focal farms in the current study were managed to promote biodiversity through the use of no-till, residue management, diverse crop rotations, and cover crops. These sustainable farm management practices likely contributed to the insect abundance and diversity seen in the current study compared to more conventionally managed fields. Bioinventories of fields under varying management practices could help farmers appreciate biodiversity and the services that it provides on their farms.

In natural ecosystems, herbivorous arthropods play an important role in regulating plant dominance within a community (Brown *et al.*, 1988; Carson and Root, 2000). This is in direct contrast to most farms, where a focal crop dominates the plant community. Large, densely-planted monocultures provide opportunities for pest outbreaks (Döring *et al.*, 2012; Reddy, 2015). Therefore, it was surprising that only 6.32% of insect specimens found on foliage were economic pests (Knodel *et al.*, 2010). Natural enemies may have been partially responsible for this. Crop residue management and limited insecticide usage may have promoted beneficial insects (Landis *et al.*, 2000; Altieri, 2012). The current study illustrates the tremendous abundance of soil macrofauna beneath the soil surface. The vast majority of arthropods collected were Acarina and Collembola, both important in agroecosystems for decomposing organic matter and spreading microbial diversity (Hodge, 2000;

Table 1A. Herbivorous, predatory and pollinating arthropods collected in 2013 and 2014 whole plant counts. The mean ± SEM number of each taxonomic group collected per plant per field in a total of 2040 plants over three site years. A total of 19,193 arthropods were collected. Groups infrequently collected (<0.01 per plant) are presented as a footnote. Highlighted morphospecies represent common sunflower pests of concern. A total of 22 fields were sampled.

Order	Family	Morphospecies	Abundance per plant (mean ± SEM)
Araneae	**All Araneae**	**All Araneae**	**0.17 ± 0.01**
	Dictynidae	Undetermined sp.	0.01 ± 0.00
	Salticidae	Undetermined sp.	0.01 ± 0.00
	Tetragnathidae	*Tetragnatha* sp.	0.05 ± 0.01
	Thomisidae	*Megaphesa* sp.	0.04 ± 0.01
Coleoptera	**All Coleoptera**	**All Coleoptera**	**0.69 ± 0.09**
	Cantharidae	*Chauliognathus pennsylvanicus*	0.04 ± 0.02
	Chrysomelidae	*Diabrotica barberi*	0.05 ± 0.02
	Coccinellidae	*Coccinella septempunctata*	0.04 ± 0.01
		Hippodamia convergens	0.15 ± 0.04
	Curculionidae	*Smicronyx fulvus*	0.13 ± 0.03
		Smicronyx sordidus	0.04 ± 0.01
	Mordellidae	*Mordellistena* sp. 1	0.03 ± 0.01
		Mordellistena sp. 2	0.02 ± 0.01
	Nitidulidae	Undetermined sp.	0.03 ± 0.01
Diptera	**All Diptera**	**All Diptera**	**1.29 ± 0.22**
	Cecidomyiidae	*Contarina schulzi*	0.02 ± 0.00
	Chironomidae	Undetermined sp.	0.01 ± 0.01
	Chloropidae	Undetermined sp. 1	1.00 ± 0.24
		Undetermined sp. 2	0.01 ± 0.00
	Dolichopodidae	*Condylostylus* sp.	0.01 ± 0.01
	Syrphidae	Undetermined sp.	0.01 ± 0.00
	Tephritidae	*Gymnocarena diffusa*	0.03 ± 0.01
		Neotephritis finalis	0.03 ± 0.01
Hemiptera	**All Hemiptera**	**All Hemiptera**	**4.72 ± 0.63**
	Aleyrodidae	*Plagiognathus* sp.	0.88 ± 0.11
	Anthocoridae	*Orius insidiosus* adults	0.96 ± 0.18
		Orius insidiosus nymphs	0.06 ± 0.01
	Aphididae	*Aphis nasturtii*	1.67 ± 0.48
	Cicadellidae	*Empoasca* sp.	0.03 ± 0.01
		Idiocerus sp.	0.03 ± 0.01
	Myridae	*Lygus lineolaris* adults	0.09 ± 0.02
		Lygus lineolaris nymphs	0.35 ± 0.06
	Nabidae	*Nabis americoferus*	0.02 ± 0.00
	Rhyparochromidae	*Ligyrocoris diffusus*	0.03 ± 0.01
	Tingidae	*Corythucha marmorata*	0.02 ± 0.01
		Undetermined sp.	0.01 ± 0.00
	Undetermined immature species	Undetermined sp. immature 1	0.05 ± 0.02
	Undetermined immature leaf hopper	Undetermined sp. immature leaf hopper 1	0.02 ± 0.02
Hymenoptera	**All Hymenoptera**	**All Hymenoptera**	**0.90 ± 0.14**
	All Formicidae	**All Formicidae**	**0.40 ± 0.12**
	Formicidae	*Lasius neoniger*	0.36 ± 0.11
		Solenopsis molesta	0.04 ± 0.02
	All Parasitoids	**All Parasitoid Hymenoptera**	**0.28 ± 0.04**
		Parasitoid 1	0.10 ± 0.02
		Parasitoid 2	0.02 ± 0.01
		Parasitoid 3	0.03 ± 0.02

Table 1A. Continued.

Order	Family	Morphospecies	Abundance per plant (mean ± SEM)
		Parasitoid 4	0.01 ± 0.01
		Parasitoid 29	0.01 ± 0.00
	All Pollinators	**All Pollinator Hymenoptera**	**0.20 ± 0.01**
	Andrenidae	Undetermined sp.	0.04 ± 0.01
	Apidae	*Apis mellifera*	0.01 ± 0.00
		Bombus pensylvanicus	0.01 ± 0.00
		Mellisodes sp.	0.02 ± 0.00
		Mellisodes trinodis	0.02 ± 0.00
		Xylocopa sp.	0.02 ± 0.00
	Halictidae	Undetermined sp. 1	0.02 ± 0.00
		Undetermined sp. 2	0.03 ± 0.00
Lepidoptera	**All Lepidoptera**	**All Lepidoptera**	**0.16 ± 0.02**
	All Lepidoptera Adults	**All Lepidoptera Adults**	**0.03 ± 0.01**
	All Lepidoptera Larvae	**All Lepidoptera Larvae**	**0.13 ± 0.02**
	Pyralidae	*Homoeosoma electellum*	0.03 ± 0.01
	Tortricidae	*Cochylis hospes*	0.01 ± 0.00
	Undetermined Family	Undetermined sp. 1	0.02 ± 0.01
	Undetermined Family	Undetermined sp. 2	0.01 ± 0.00
Neuroptera	Chrysopidae	*Chrysoperla* sp. adults	0.08 ± 0.01
		Chrysoperla sp. larvae	0.03 ± 0.01
		Chrysoperla sp. eggs	1.34 ± 0.17
Opiliones	Phalangiidae	Undetermined sp.	0.04 ± 0.01
Orthoptera	**All Orthoptera: Caelifera**	**All Orthoptera: Caelifera**	**0.35 ± 0.10**
Gastropoda	Undetermined Family	Undetermined sp.	0.01 ± 0.00
Thysanoptera	Thripidae	Undetermined sp.	1.36 ± 0.24
Community Characteristics		**Shannon Diversity Index**	2.75 ± 0.08
		H Max	4.35 ± 0.04
		Evenness	0.02 ± 0.00

Footnote: Specimens represented by fewer than nine specimens collected included (*n* = number of morphospecies): Araneae (*n* = 26), Coleoptera: Anthicidae (*n* = 1), Coleoptera: Bruchidae (*n* = 1), Coleoptera: Carabidae (*n* = 3), Coleoptera: Cerambycidae (*n* = 1), Coleoptera: Chrysomelidae (*n* = 8), Coleoptera: Coccinellidae (*n* = 11), Coleoptera: Curculionidae (*n* = 6), Coleoptera: Elateridae (*n* = 2), Coleoptera: Lampyridae (*n* = 4), Coleoptera: Meloidae (*n* = 3), Coleoptera: Melyridae (*n* = 1), Coleoptera: Nitidulidae (*n* = 2), Coleoptera: Staphylinidae (*n* = 1), Collembola (*n* = 1), Diptera (*n* = 32), Ephemeroptera (*n* = 1), Hemiptera: adults (*n* = 26), larvae (*n* = 14), Hymenoptera: Ants (*n* = 3), Hymenoptera: Parasitoids (*n* = 53), Hymenoptera: Pollinators (*n* = 8), Hymenoptera: Sawfly (*n* = 1), Lepidoptera: adults (*n* = 7), larvae (*n* = 29), Neuroptera (*n* = 1), Odonata (*n* = 1), Orthoptera (*n* = 2), and Thysanoptera (*n* = 1).

Zangerl *et al.*, 2013). Predatory arthropods were also very abundant within the soil. Soil predators may protect sunflowers from root feeding herbivores and prevent pests from reaching economic thresholds (Lundgren and Fergen, 2011; Navarro-Campos *et al.*, 2012). The nature of relationships between subterranean arthropods, plants, and other organisms requires further research, and identifying the organisms that live in the soil is an important first step.

Describing the biological composition of the arthropod community within a specific production system provides useful knowledge for future investigations on a wide range of topics (Goldstein, 2004; Apfelbaum and Haney, 2012). Agronomists and land managers planning crop rotations to improve arthropod diversification and attraction of natural enemies may utilize this data (Jones and Gillett, 2005). Researchers

Table 1B. Herbivorous and Predatory arthropods collected in 2013 and 2014 soil cores. The mean number of each taxonomic group collected per meter square in the top 10 cm of soil over three site years. A total of 25,530 arthropods were collected. Groups that were infrequently collected (9 or fewer specimens) are presented as a footnote. A total of 22 fields were sampled.

Order	Family	Morphospecies	Abundance per m^2 soil (*mean* ± SEM)
Acarina	**All Acarina**	**All Acarina**	**3950.24 ± 593.48**
Araneae	**All Araneae**	**All Araneae**	**38.99 ± 12.76**
	Clubionidae	Undetermined sp.	10.00 ± 3.41
	Gnaphosidae	Undetermined sp.	4.64 ± 1.50
	Linyphiidae	*Islondiana* sp.	3.77 ± 3.25
		Undetermined sp. 1	11.16 ± 6.28
		Undetermined sp. 2	2.39 ± 1.17
	Theridiidae	Undetermined sp.	3.70 ± 2.44
Coleoptera	**All Coleoptera Adults**	**All Coleoptera Adults**	**77.37 ± 11.31**
	Undetermined Family	Undetermined sp.	5.72 ± 1.96
	Anthicidae	*Leptoremus* sp.	3.78 ± 0.99
	Carabidae	*Elaphropus* sp.	4.73 ± 1.57
		Ogonum decorum	2.41 ± 1.41
		Polyderis sp.	2.47 ± 1.27
	Staphylinidae	*Aleocharinae* sp.	5.29 ± 2.05
		Lobrathium sp.	10.67 ± 2.33
		Philonthus sp.	2.77 ± 1.01
		Stenistoderus rubripennis	4.13 ± 2.06
	All Coleoptera Larvae	**All Coleoptera Larvae**	**73.58 ± 12.36**
		Undetermined beetle larva 1	5.08 ± 1.20
		Undetermined beetle larva 2	37.49 ± 7.55
		Undetermined beetle larva 3	10.95 ± 2.72
		Undetermined beetle larva 4	3.48 ± 2.44
		Undetermined beetle larva 5	3.40 ± 1.83
		Undetermined beetle larva 6	4.78 ± 1.85
Collembola	**All Collembola**	**All Collembola**	**1852.29 ± 429.62**
Diplura	**All Diplura**	**All Diplura**	**84.87 ± 10.76**
Diptera	**All Diptera**	**All Diptera**	**13.42 ± 2.04**
Hemiptera	**All Hemiptera**	**All Hemiptera**	**5.25 ± 1.84**
	Rhyparochromidae	*Ligyrocoris diffusus*	3.06 ± 1.12
Hymenoptera	**All Hymenoptera**	**All Hymenoptera**	**80.09 ± 23.71**
	All Formicidae	**All Formicidae**	**73.35 ± 23.74**
	Formicidae	*Amblyopone pallipes*	8.48 ± 3.65
		Formica sp.	34.23 ± 20.65
		Ponera sp.	6.02 ± 2.16
		Solenopsis molesta	24.63 ± 15.81
	All Parasitoids	**All Parasitoids**	**6.74 ± 2.68**
	Undetermined Family	Undetermined sp.	2.90 ± 2.32
Lithobiomorpha	Undetermined Family	Undetermined sp.	7.03 ± 1.77
Julida	Undetermined Family	Undetermined sp.	4.49 ± 1.45
Orthoptera	Gryllidae	Undetermined sp. nymphs	7.83 ± 6.34
Thysanoptera	Thripidae	Undetermined sp.	44.26 ± 8.59

Table 1B. Continued.

Order	Family	Morphospecies	Abundance per m^2 soil (mean ± SEM)
Community Characteristics		**Shannon Diversity Index**	0.98 ± 0.05
		H Max	3.40 ± 0.05
		Evenness	0.29 ± 0.01

Footnote: Specimens represented by fewer than nine specimens collected included (*n* = number of morphospecies): Araneae (*n* = 5), Coleoptera: Anthicidae (*n* = 2), Colepotera: Carabidae (*n* = 28), Coleoptera: Chrysomelidae (*n* = 2), Coleoptera: Coccinellidae (*n* = 1), Coleoptera: Cryptophagidae (*n* = 1), Coleoptera: Cucujidae (*n* = 1), Coleoptera: Dermestidae (*n* = 3), Coleoptera: Dytiscidae (*n* = 1), Coleoptera: Elateridae (*n* = 2), Coleoptera: Erotylidae (*n* = 1), Coleoptera: Leiodidae (*n* = 3), Coleoptera: Mordelidae (*n* = 2), Coleoptera: Nitidulidae (*n* = 2), Coleoptera: Scarabaeidae (*n* = 2), Coleoptera: Staphylinidae (*n* = 5), Coleoptera larvae (*n* = 6), Diptera (*n* = 9), Ephemeroptera (*n* = 1), Hemiptera: Aphididae (*n* = 1), Hemiptera adults (excluding aphids) (*n* = 12), Hymenoptera parasitoids (*n* = 12), Isopoda (*n* = 1), Lepidoptera adults (*n* = 8), larvae (*n* = 2), Neuroptera: Chrysopidae larvae (*n* = 1), Orthoptera (*n* = 1), Protura (*n* = 1), Pseudoscorpionida (*n* = 1), Psocoptera (*n* = 1), and Unidentified larvae (*n* = 8).

performing insecticidal risk assessments could examine shifts in community composition after novel pest management techniques are implemented (Lundgren *et al.*, 2013). Perhaps most importantly, changes to global climate and biodiversity (Bellard *et al.*, 2012) elevate the importance of knowledge on biological community structure. Exhaustive bioinventories of specific land use areas are no simple task, requiring considerable time, energy and resources to accomplish, and funding for such studies is difficult to obtain (Gardner *et al.*, 2008). However, these bioinventories provide a metric of the overall health of managed habitats and are vital to future researchers studying changes in the environment or optimization of land management schemes.

Acknowledgements

Janet Fergen, Megan Wentzel, Mallory Wentzel, Ryan Schmid, Ryan Bell, Cally Strobel, Nicole Berg, Marissa Layman, Jacob Pecenka, Claire Bestul, Nathan Koens, Kae Januschka, Kristine Nemec, Mireia Solá and Greta Schen were critical to the collecting and sorting of field specimens. Mark Longfellow, Chrissy Mogren, David Rider, Stephen Gaimari, Beth Choate, Al Newton, Louis Hesler and Kelton Welch were very helpful in assisting with insect identification.

Literature Cited

Altieri, M. A. 2012. Insect pest management in the agroecosystems of the future. Atti Accademia Nazionale Italiana di Entomologia 60:137–144.

Andrew, N. R., S. J. Hill, M. Binns, M. H. Bahar, E. V. Ridley, M. P. Jung, C. Fyfe, M. Yates, and M. Khusro. 2013. Assessing insect responses to climate change: What are we testing for? Where should we be heading? PeerJ 1:e11.

Apfelbaum, S., and A. Haney. 2012. Develop a good monitoring program. *In* Restoring Ecological Health to Your Land, pp. 91–107. Island Press/Center for Resource Economics; Washington DC; xvii+80.

Bellard, C., C. Bertelsmeier, P. Leadley, W. Thuiller, and F. Courchamp. 2012. Impacts of climate change on the future of biodiversity. Ecology Letters 15:365–377.

Bredeson, M., and J. Lundgren. 2015. Thiamethoxam seed treatments have no impact on pest numbers or yield in cultivated sunflowers. Journal of Economic Entomology, in press.

Brown, V., M. Jepsen, and C. Gibson. 1988. Insect herbivory: effects on early old field succession demonstrated by chemical exclusion methods. Oikos 52:293–302.

Butler, S., J. Vickery, and K. Norris. 2007. Farmland biodiversity and the footprint of agriculture. Science 315:381–384.

Carson, W. P., and R. B. Root. 2000. Herbivory and plant species coexistence: community regulation by an outbreaking phytophagous insect. Ecological Monographs 70:73–99.

Charlet, L. D., V. H. Beregovoy, and G. J. Brewer. 1992. Insect fauna of the heads and stems of native sunflowers (Asterales: Asteraceae) in eastern North Dakota. Environmental Entomology 21:493–500.

Charlet, L. D., D. D. Kopp, and C. Y. Oseto. 1987. Sunflowers: Their history and associated insect community in the Northern Great Plains. Bulletin of the ESA 33:69–75.

Cockerell, T. D. A. 1916. Sunflower insects in California and South Africa. The Canadian Entomologist 48:76–79.

Döring, T. F., M. Pautasso, M. R. Finckh, and M. Wolfe. 2012. Pest and disease management in organic farming: implications and inspirations for plant breeding. *In* T. Lammerts van Bueren and J. R. Myers (eds.). Organic Crop Breeding, pp. 39–59. John Wiley & Sons, Hoboken, NJ.

FAO. 2007. Paying farmers for environmental services, State of Food and Agriculture. Vol. 38. Food and Agriculture Organization of the United Nations, Rome, Italy. 222 pp.

Fattorini, S. 2013. Regional insect inventories require long time, extensive spatial sampling and good will. PLoS ONE 8:e62118.

Fattorini, S., E. Maurizi, and A. D. Giulio. 2012. Tackling the taxonomic impediment: a global assessment for ant-nest beetle diversity (Coleoptera: Carabidae: Paussini). Biological Journal of the Linnean Society 105: 330–339.

Gardner, T. A., J. Barlow, I. S. Araujo, T. C. Ávila-Pires, A. B. Bonaldo, J. E. Costa, M. C. Esposito, L. V. Ferreira, J. Hawes, M. I. M. Hernandez, M. S. Hoogmoed, R. N. Leite, N. F. Lo-Man-Hung, J. R. Malcolm, M. B. Martins, L. A. M. Mestre, R. Miranda-Santos, W. L. Overal, L. Parry, S. L. Peters, M. A. Ribeiro-Junior, M. N. F. Da Silva, C. Da Silva Motta, and C. A. Peres. 2008. The cost-effectiveness of biodiversity surveys in tropical forests. Ecology Letters 11:139–150.

Goldstein, P. Z. 2004. Systematic collection data in North American invertebrate conservation and monitoring programmes. Journal of Applied Ecology 41:175–180.

Hilgendorf, J. H., and R. D. Goeden. 1981. Phytophagous insects reported from cultivated and weedy varieties of the sunflower, *Helianthus annuus* L., in North America. Bulletin of the Entomological Society of America 27:102–109.

Hodge, A. 2000. Microbial ecology of the arbuscular mycorrhiza. FEMS Microbiology Ecology 32:91–96.

Hoehn, P., T. Tscharntke, J. M. Tylianakis, and I. Steffan-Dewenter. 2008. Functional group diversity of bee pollinators increases crop yield. Proceedings of the Royal Society B: Biological Sciences 275:2283–2291.

Hooper, D. U., E. C. Adair, B. J. Cardinale, J. E. K. Byrnes, B. A. Hungate, K. L. Matulich, A. Gonzalez, J. E. Duffy, L. Gamfeldt, and M. I. O'Connor. 2012. A global synthesis reveals biodiversity loss as a major driver of ecosystem change. Nature 486:105–108.

Jadhav, J. A., K. Sreedevi, and P. R. Prasad. 2011. Insect pollinator diversity and abundance in sunflower ecosystem. Current Biotica 5:344–350.

Jones, G. A., and J. L. Gillett. 2005. Intercropping with sunflowers to attract beneficial insects in organic agriculture. Florida Entomologist 88:91–96.

Knodel, J. J., L. D. Charlet, and J. Gavloski. 2010. Integrated pest management of sunflower insect pests in the Northern Great Plains. North Dakota State University Extension Service Bulletin: E1457.

Landis, D. A., S. D. Wratten, and G. M. Gurr. 2000. Habitat management to conserve natural enemies of arthropod pests in agriculture. Annual Review of Entomology 45:175–201.

Lundgren, J. G., and J. K. Fergen. 2011. Enhancing predation of a subterranean insect pest: A conservation benefit of winter vegetation in agroecosystems. Applied Soil Ecology 51:9–16.

Lundgren, J. G., L. S. Hesler, S. A. Clay, and S. W. Fausti. 2013. Insect communities in soybeans of eastern South Dakota: The effects of vegetation management and pesticides on soybean aphids, bean leaf beetles, and their natural enemies. Crop Protection 43:104–118.

Lundgren, J. G., T. McDonald, T. A. Rand, and S. W. Fausti. 2015. Spatial and numerical relationships of arthropod communities associated with key pests of maize. Journal of Applied Entomology 136:446–456.

Lynch, R., and J. Garner. 1980. Insects associated with sunflower in south Georgia. Journal of the Georgia Entomological Society 15:182–189.

Marini, L., H. H. Bruun, R. K. Heikkinen, A. Helm, O. Honnay, J. Krauss, I. Kühn, R. Lindborg, M. Pärtel, and R. Bommarco. 2012. Traits related to species persistence and dispersal explain changes in plant communities subjected to habitat loss. Diversity and Distributions 18:898–908.

Moscardini, V., P. Gontijo, J. P. Michaud, and G. Carvalho. 2014. Sublethal effects of chlorantraniliprole and thiamethoxam seed treatments when *Lysiphlebus testaceipes* feed on sunflower extrafloral nectar. BioControl 59:503–511.

[NASS] National Agricultural Statistics Service. 2015. Web-based document. www.nass.usda.gov. Accessed August, 31, 2015

Navarro-Campos, C., A. Pekas, M. L. Moraza, A. Aguilar, and F. Garcia-Marí. 2012. Soil-dwelling predatory mites in citrus: Their potential as natural enemies of thrips with special reference to *Pezothrips kellyanus* (Thysanoptera: Thripidae). Biological Control 63:201–209.

Nicolson, S., and H. Human. 2013. Chemical composition of the 'low quality' pollen of sunflower (*Helianthus annuus,* Asteraceae). Apidologie 44:144–152.

Polasky, S., E. Nelson, D. Pennington, and K. Johnson. 2011. The impact of land-use change on ecosystem services, biodiversity and returns to landowners: A case study in the state of Minnesota. Environmental and Resource Economics 48:219–242.

Reddy, P. P. 2015. Impacts on Crop Protection. *In* Climate Resilient Agriculture for Ensuring Food Security, pp. 107–113. Springer India; New Delhi, India; 373 pp.

Rogers, C. 1988. Insects from native and cultivated sunflowers (*Helianthus*) in southern latitudes of the United States. Journal of Agricultural Entomology 5:267–287.

Royer, T. A., and D. D. Walgenbach. 1991. Predacious arthropods of cultivated sunflower in eastern South Dakota. Journal of the Kansas Entomological Society 64:112–116.

Schmid, R., J. Lundgren, M. Layman, and V. Brozel. 2015. Reductions in local biodiversity curtail gut microbial communities within a beneficial insect. Annals of the Entomological Society of America, in press.

Schneiter, A., J. Miller, and D. Berglund. 2003. Stages of Sunflower Development. North Dakota State University Extension Service. Bulletin: A-1145.

Tscharntke, T., Y. Clough, T. C. Wanger, L. Jackson, I. Motzke, I. Perfecto, J. Vandermeer, and A. Whitbread. 2012. Global food security, biodiversity conservation and the future of agricultural intensification. Biological Conservation 151:53–59.

Walker, F. H., and Jr. 1936. Observations on sunflower insects in Kansas. Journal of the Kansas Entomological Society 9:16–25.

Wolfenbarger, L. L., S. E. Naranjo, J. G. Lundgren, R. J. Bitzer, and L. S. Watrud. 2008. Bt crop effects on functional guilds of non-target arthropods: A meta-analysis. PLoS ONE 3:e2118.

Zangerl, A. R., S. Miresmailli, P. Nabity, A. Lawrance, A. Yanahan, C. A. Mitchell, K. J. Anderson-Teixeira, M. B. David, M. R. Berenbaum, and E. H. DeLucia. 2013. Role of arthropod communities in bioenergy crop litter decomposition. Insect Science 20:671–678.