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Insect pollinators in corn and soybean agricultural fields

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Insect pollinators in corn and soybean agricultural fields

by

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ABSTRACT

Iowa’s landscape is dominated by row crop agriculture with the majority of acres being in corn and soybean production, and as a result is spatially uniform and functionally homogenized. In landscapes dominated by agriculture, such as those found in Iowa, the availability of mass flowering crop species show strong positive effects on the density of generalist, native pollinators. While soybean, a self-pollinated plant, and corn, a wind pollinated plant, do not require physical pollination for fruit production, they can be a source of nectar and/or pollen for insect pollinators. The first objective is to develop methodology to accurately describe the in-field abundance and diversity of insect pollinators associated cornfields in Iowa. The second objective is to define the community of insect pollinators using Iowa row crops as a potential resource. Over 2012 and 2013, 3,617 insect pollinators representing 51 species were captured using bee bowls in cornfields. Traps deployed at the height of the tassels describe a more abundant and species rich community of pollinators than traps at ear height (2x as many individuals) or ground height (4x as many individuals). Blue bowls captured more bees than white (2.75x as many individuals) or yellow bowls (3.5x as many individuals); and yellow bowls captured more flies than white (2x as many individuals) or blue (2.3x as many individuals). Over the two field seasons 3,087 individual insect pollinators were collected using bee bowls in soybean fields. These individuals represented more than 43 species (or morphospecies) of insect pollinators. Summed across both years and crop types, 6,704 individual insect pollinators were captured representing more than 56 species or morpho-species. A common group of 34 species use both crops.

CHAPTER ONE: GENERAL INTRODUCTION AND LITERATURE REVIEW

Thesis Organization

The scope of this research encompasses sampling methods development and community identification for pollinator communities in corn and soybean row crop agriculture. This thesis is organized into four chapters: Chapter one will provide background information and a review of the relevant literature; chapter two will focus on sampling methodology and community identification of insect pollinators visiting Iowa cornfields; chapter three will examine the similarity of the pollinator communities found in Iowa corn and soybean fields; and chapter four will offer a brief summary of the conclusions presented in this thesis and acknowledgements.

Introduction and Literature Review

Flower visiting insects that feed on nectar and pollen may be considered insect pollinators as they have the potential to transfer pollen from the male parts of the flower to the female parts of the flower. This transfer of male genetic material is an essential step in the reproduction of flowering plants across the world. Many crop species depend on insect mediated pollination for fruit production, seed production, or to achieve economically viable yields (Kevan *et al* 1983, Klein *et al* 2007). Global crop production is at an all time high. To feed a growing population, yields will need to continue to increase. Suggesting that more land will be put into production with an accompanying increase in agricultural inputs such as pesticides, fertilizers, and herbicides. The maintenance of ecosystem services to agriculture will only increase in importance as more land is put into production. The millennium ecosystem assessment (MEA, 2005) grouped ecosystem services into four broad categories: *provisioning*, such as the production of food and water; *regulating*, such as the control of climate and disease; *supporting*, such as nutrient cycles and crop pollination; and *cultural*, such as spiritual and recreational benefits. Of these provisioning and supporting services are the most relevant to agriculture.

An estimated 35% of world crops rely on pollination (Klein *et al* 2007). 70% of all fruit and vegetable crops show an increase in size, quantity, quality, or stability of harvest when pollinated by bees or other animals (Ricketts *et al.* 2008; Nichols and Altieri 2012). The European honey bee (*Apis mellifera*) provides the majority of pollination services to US agriculture. The value of the services provided by this insect species is estimated to be worth $14.6 billion to US crop production annually (Morse and Calderone 2000). In addition to the honey bee, there are more than 4,000 species of native bees in North America. Most of these species are solitary and ground nesting bees, however there are both social species and stem/cavity nesting species (Michner 2000). It has been documented for a variety of crops that honey bees may not be the most effective pollinator. Native bees have been shown to be more effective pollinators of watermelon, blueberry, squashes, tomato, and several other crops than the honey bee (Kremen *et al.* 2002; Kremen *et al.* 2002; Winfree *et al.* 2007). Pollination services from native pollinators have been valued at $3.1 billion per year in the United States (Losey and Vaughan 2006). Despite their efficacy as pollinators, the role of native bees has only been studied sufficiently for a limited number of crops and regions.

Globally both native and managed pollinator populations are declining. This decline has been linked to decreasing natural habitat and an increase in agricultural and may have a profound impact on agriculture (Potts *et al* 2012). An essential step in maintaining pollination services is to understand the pollinator community found in agroecosystems for each crop-producing region (Klein *et al.* 2011) as native pollinator diversity and abundance are strongly affected by the diversity of the surrounding landscape at a scale of 1.5 km (Ricketts *et al.* 2008).

Iowa's landscape is dominated by row-crop agriculture with the majority of acres being in corn and soybean production. Iowa's landscape is spatially uniform functionally homogenized due to intense row crop production (Brown and Schulte 2011). Industrial agricultural systems, like those found in Iowa, may be unfavorable for insect pollinators due to disturbances associated with management practices, particularly the non-target effects of pesticides. There is a growing body of research demonstrating that pollinators are exposed to pesticides through a variety of mechanisms (Stoner and Eitzer 2012; Krupke *et al.* 2012). Non-target effects, such as sub-lethal exposure to pesticides, have been shown to negatively effects honey bee health by increasing *Nosema* growth, and have been suggested as a causative agent in colony collapse disorder (Pettis *et al.* 2012). Colony collapse disorder and declines in pollinator populations world wide have prompted growers and researchers to place special emphasis on understanding and conserving the bee community to maintain pollination as a viable ecosystem service.

In landscapes dominated by agriculture, such as those found in Iowa, the availability of mass flowering crop species show strong positive effects on the density of generalist, native pollinators such as *Bombus* species (Westphal et al. 2003). While soybean a self-pollinated plant and corn a wind pollinated plant and do not require physical pollination for fruit production, they can be a source of nectar and/or pollen for bees. Additionally anthophilious flower-visitors may exploit soybeans for resources. Flower flies (Syrphidae) are commonly found consuming nectar from a variety of flowering plant species; the larval stages are commonly found in surveys of aphidophigous predators in Iowa (Triplehorn and Johnson 2005, Schmidt et al 2008).

There is some evidence that bees will use soybean flowers as a source of pollen and nectar. For example, *Megachile rotundata* has been used as a cross pollinating agent in the creation of hybrid soybean lines (Ortiz-Perez *et al.* 2008). While soybean does not require insects for pollination (McGregor 1976), it may still benefit from visitation by insect pollinators. Soybeans may experience a yield boost of up to 18% when exposed to honey bees and native pollinators (Milfont *et al.* 2013). Recently Gill (2012) described an abundant and diverse community of pollinating insects some of which forage the flowers for soybean pollen in central Iowa. However, to what extent this community is unique to Iowa is unknown.

While it has been demonstrated that a robust community of pollinators have been found visiting soybeans in Iowa, there are few studies that have examined the pollinator community found within cornfields. Gardiner *et al*. (2010) examined the implication of three different bio-fuel crops on beneficial arthropods in an agricultural landscape. To assess the pollinator community, bee bowls were placed on the ground for 48-hour intervals in cornfields. They reported 213 individuals representing 42 species. Another study examining the effects of bio-fuel crops on arthropod communities used sweep-netting to describe the pollinator community and found greater biomass of pollinators in more diverse plantings (Robertson *et al*. 2011), supporting the findings of Gardiner *et al.* (2010). However, it is possible that these studies under-represented the abundance and diversity of pollinators within cornfields as it is known that height and position of the pan-traps (bee bowls) have an effect on capture across vertical strata (Tuell and Isaacs 2008). Passive methods of sampling, such as yellow sticky traps and colored bee bowls can describe pollinators in agroecosystems (Droege 2011). However, sampling methods often need to be modified for optimal use within a specific crop, especially if a unique guild of insects is targeted.

Objectives and Hypotheses

Chapter two

Evaluate collection methods that could potentially be use to describe the diversity and abundance of pollinators within Iowa cornfields and characterize the community using Iowa cornfields.

- I hypothesize that the pollinator community will vary in abundance and diversity with trapping method used; with bee bowls describing more species than yellow sticky cards.
- I hypothesize that the pollinator community will vary in abundance and diversity by trap height; with traps placed at the height of the tassels describing more species than traps placed at the height of the ear or on the ground.

Chapter three

Examine the similarity of the communities of insect pollinators found in Iowa corn and soybean fields.

- There are three general possibilities when considering how similar these groups of pollinators may be: 1) the two groups are distinctly different sharing no similar species, 2) the two groups' share a few common species, but some are found in only one of the crops and not the other, or 3) all species are common between the two crops.

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CHAPTER TWO. INSECT POLLINATORS IN IOWA CORNFIELDS: COMMUNITY IDENTIFICATION AND TRAPPING METHODS ANALYSIS

A paper submitted to PloS One

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Abstract

Availability of mass flowering crop species in landscapes dominated by agriculture can have a strong positive impact on the density of generalist, native pollinators. Row-crop production in Iowa accounts for 75% of the arable acres, with corn, *Zea mays,* representing the majority of hectares planted. To date, there has been no description of the insect pollinator community found within cornfields in Iowa. We report a field study to determine the optimal sampling methodology to characterize the community of insect pollinators within cornfields. During 2012 and 2013, 3,616 insect pollinators representing 51 species were captured using bee bowls, and 945 individuals representing 10 species were captured using sticky cards. We examined the effects of trap type, height, and bowl color on the described community. Bee bowls captured a more abundant and species rich community than sticky cards with all species captured on sticky cards also present in bee bowl samples. Traps deployed at the height of the tassels describe a more abundant and species rich community of pollinators than traps at ear height (2x as many individuals) or ground height (4x as many individuals). Blue bowls captured more bees than white (2.75x as many individuals) or yellow bowls (3.5x as many individuals); and yellow bowls captured more flies than white (2x as many individuals) or blue (2.3x as many individuals). To provide the most complete description of the community of insect pollinators using cornfields as

a resource, we suggest sampling-using bee bowls at the height of the tassels using all three bee bowl colors.

Introduction

Fragmented landscapes devoted to annual crop production generally lower insect biodiversity, including pollinators, (Potts et al. 2010) than natural landscapes do. However, flowering crops can have a strong impact on the density of generalist pollinators, such as bumblebees (*Bombus* spp.) (Westphal et al. 2003). Iowa's landscape is dominated by agriculture, with 75% of arable acres planted in row crop production, primarily corn (*Zea mays)* and soybean (*Glycine max)* (IDALS 2012). Both corn and soybean may be considered mass flowering crop species. While neither requires insects for pollination (McGregor 1976), both may provide resources for pollinators that forage within them.

Recently Gill (2012) described a robust community of at least 50 species of insect pollinators visiting Iowa soybean fields. This community was composed of mostly of solitary, ground nesting bees. Social bees, such as bumblebees and the honey bee (*Apis mellifera)* were rarely detected, represented only 0.005% of individuals collected. The most abundant species described by Gill (2012) included *Agapostemon virescens*, *Lasioglossum* (*Dialictus)* spp., *Melissodes bimaculata* and *Toxomerous marginatus*. The most commonly collected species were also found carrying soybean pollen. This suggests that soybean flowers are a source of nectar and/or pollen for several native social and solitary bees. Additionally anthophilious flies exploit these crops for resources, especially syrphid adults that consume nectar from a variety of flowering species (Triplehorn and Johnson 2005).

Corn is wind pollinated and does not require insect mediated pollination to set seed however like soybean, it may be a resource for pollinators. Recently Gardiner et al. (2010) examined the implication of three different bio-fuel crops on beneficial arthropods in an agricultural landscape. To assess the pollinator community, bee bowls were placed on the ground of cornfields for intervals of 48 h during a growing season. They reported 213 individuals representing 42 species. Gardiner (2010) is the first study to examine the potential community of bee pollinators that may use cornfields in Michigan as a resource. However, it is possible that the method under-represented the abundance and diversity of pollinators within cornfields as the height and position of the bee bowls have an effect on capture (Tuell and Isaacs 2008). Since bee bowls were left on the ground they may not have captured insects visiting the tassels or the silks.

To date, there has been no description of the community of insect pollinators that visit cornfields in Iowa. Such baseline data can inform conservation and management decisions, and be used to assess what species may be at risk from agronomic practices. Describing the community of insect pollinators using cornfields as a resource requires the establishment of a sampling method that will allow for comparisons with future studies. Passive methods of sampling, such as sticky traps and bee bowls have been used to describe pollinators in agro-ecosystems (Droege 2011); however, sampling methods often need to be modified for optimal use within a specific crop, especially if a unique guild of insects is targeted (LeBuhn et al. 2007). We conducted a field study to determine the optimal sampling method to characterize the community of pollinators within Iowa cornfields.

Materials and Methods

Sampling sites. During 2012 and 2013, insect pollinators were sampled at three Iowa State University research farms. All farms were located in central Iowa, at least 2 km from each other (Table 1). We began sampling one week prior to the occurrence of tassels (VT) and continued to milk stage (R3; Abendroth et al. 2011). In 2012 sampling occurred from July 3rd-August 9th and in 2013 from July 16th-August 23rd. Growth stage was estimated at each sampling date, taking special note when tassels emerged and when pollen shed was complete. Pollen shed was estimated by shaking tassels of five random plants and visibly looking for pollen.

Collection methods. Unbaited Pherocon® AM yellow sticky cards (YSC, Trécé Incorporated) and bee bowls (BB) adapted from Droege (2011) were used to sample pollinators. Bee bowls (3.25oz. SOLO® brand white plastic soufflé cups, Food Service Direct, Hampton, VA, USA) were painted fluorescent yellow and fluorescent blue (East Coast Guerra Paint and Pigment, New York, NY, USA) or left white and filled halfway with a soapy water solution. We choose YSC as they are recommended for sampling insect pests in cornfields and are commercially available (Hein and Tollefson 1985). Bee bowls were selected because they are considered effective for sampling pollinators in a variety of ecosystems. In addition, BB have been used in corn (Gardiner et al. 2010) and soybean (Gill 2012) to describe pollinator communities.

Telescoping poles were constructed so that BB and YSC could be set at multiple heights next to a mature corn plant (Fig. 1). Each trap consisted of two 1.52 m sections of schedule 40 PVC. One section was 3.8 cm in diameter, the other 5.1 cm in diameter, allowing the smaller section to fit within the larger one. When combined, these two sections reached a maximum height of 2.74 m. Bee bowls were attached to the pole by connecting three galvanized steel pipe-hangers to a shelf bracket (Fig. 2), so that one of each color-white, yellow, and blue-were present at each height. We refer to a set of three BB (one of each color) as a ‘bowl unit’ hereafter. Bowl units were attached at ‘ground height’, ‘ear height’, and ‘tassel height’. The bowl unit at ground height and ear height were fixed at 0.308 m and 1.22 m, respectively. The bowl unit at tassel height was never enclosed by the canopy and was adjusted as the corn plant grew from a starting height of 1.5 m to a maximum of 2.74 m. The same pole was used to deploy YSC, with a single trap attached at each of the three heights.

Two parallel transects were established at each sampling farm; one located 5 m into the field from the nearest edge and a second located 20 m farther in field from the first transect. Each transect started 15 m into the field and consisted of 5 traps 5m apart (Fig. 3). At each farm, 90 BB (3/height/trap) were deployed for 24 h once a week during this period. After BB were collected, 30 YSC per farm (1/height/trap) were deployed and left in the field for 5 d.

Specimen processing and identification. Insects captured using BB were processed according to the methods outlined by Droege (2011), and specimens identified using the Discover Life key (URL:http://www.discoverlife.org/mp/20q?search=Apoidea). Specimens were identified to species with the exception of bees in the genus *Lasioglossum*, which were grouped by sub-genera. Pollinating flies (Syrphidae, Tachinidae, Dolichopodidae, or Bombyliidae) were grouped by morpho-species within each family. Specimens from YSC were identified to the lowest taxonomic unit possible based on condition.

Pollen analysis. To determine if bees captured in BB were foraging in the field, we examined captured bees for corn pollen. We examined a subset of bees based on whether they were carrying visible amounts of pollen during the period when corn pollen was being shed in a given field. Pollen was removed from the bee, rinsed in ethanol, and then slide mounted using glycerin jelly for identification with a light microscope. Pollen grains removed from bees were compared to light micrographs obtained from the USDA pollen library (http://pollen.usda.gov/) and to reference slides containing corn pollen obtained from plants at each study farm.

Data analysis. Abundance of species and morpho-species were recorded for each sample. To meet the assumptions of multivariate normality a log transformation of abundance data was performed. Abundance data were characterized by a high number of zero values; therefore 0.5 was added to each cell such that data could be log transformed. A three-way multivariate analysis of variance (MANOVA) was conducted to test the hypothesis that the abundance of bees captured in bowls varied by the following factors: bowl color, trap height, and farm. The statistical model also contained the interactions of height*bowl color and height*farm as multivariate fixed effects. Significant effects in the MANOVA were examined using separate analysis of variance (ANOVA) tests to understand the effect size separately for both bees and flies using the post-hoc Tukey Honest Significant Differences (Tukey HSD) test.

To determine if we had fully captured the pollinators visiting cornfields, we constructed species accumulation curves using the vegan package in R (Community Ecology Package V2.0-8, 2013) with data from the bee bowls. The species included all insects considered pollinators or at least . We reported these curves by trap height and bowl color.

Results

During the course of this study a total of 3,616 insects were captured using BB and 945 were captured using YSC (Table 2). When these data were combined, the pollinator community found in Iowa cornfields contained 51 taxonomic units (species and morpho-species). Bees accounted for 60% and flies accounted for 40% of total abundance summed across trapping types. There were at least 36 species of bee, 9 species of syrphid fly, and 6 morpho-species from other fly families. The bee community was composed of mostly solitary, ground nesting, bees.

Yellow sticky cards captured 30 bees representing 5 species across all dates, heights, and farms. We observed more flies on YSC than in bee bowls, capturing 915 individuals across all dates, heights, and farms. No significant differences in bee species richness or abundance were detected among the YCS placed at different heights. Bee bowls were a more effective tool at describing the community of insect pollinators in Iowa cornfields (Table 2), as more individuals and more species of insect pollinators were collected using BB (2,717 individual bees representing ~36 taxonomic units and 899 individual flies representing ~15 taxonomic units) compared to YSC. Therefore, the following analysis will focus on data obtained from BB samples.

Bee bowls captured a total of 2,717 individual bees (representing ~36 taxonomic units) and 899 individual flies (representing ~15 taxonomic units) across all farms and dates. In total 3,240 bee bowls were deployed of which 1,105 bowls contained at least one individual, resulting in an overall success rate of 34%. Bees dominated the bee bowl catch, accounting for 75% of individuals captured. The most abundant species did not differ among years. The most abundant bee species captured were *Lasioglossum (Dialictus)* (28%), *Melissodes bimaculata* (20%), and *Agpostemon virescens* (11%). The most abundant flies were *Toxomerus marginatus* (15%) and flies belonging to Dolichopodidae (4%).

Summary of bee bowl sampling method. We observed significant main effects for bowl color, height, and farm within the three-way MANOVA as well as significant effects for the interactions of height*bowl*color and height*farm (Table 3). Analysis of variance fit statistics were examined for the significant multivariate main effects on log bee abundance and log fly abundance separately. Bee abundance was significantly affected by height, color, farm, and the interaction of height*color. The interaction of height*farm was not significant. For fly abundance only the main effects were significant; the interactions of height*color and height*farm were not significant (Table 4).

Bowl units at tassel height captured significantly more bees on average than bowl units at ear (2x as many) and ground height (4x as many; Table 5). Significant differences in bee abundace were detected, with blue bowls capturing more than yellow (3.5x as many) or white (2.75x as many). There was no significant difference between yellow or white bowls. There were significant differences in fly abundace for levels of height and bowl color as well. Significant differences among levels of height were detected, with bowl units at ear height capturing more than bowl units at ground height (1.75x as many) and capturing more than bowl units at tassel height (1.5x as many). There were no detectable differences between bowl units at tassel height and bowl units at ground height. Flies were not equally attracted to each bowl color. Fly abundance varied across the three levels of bowl color with yellow bowls capturing more on average than white (2x as many) or blue bowls (2.3x as many). There were no detectable differences between blue or white bowls.

Not only did the sampling methodology affect the abundance of insect pollinators captured, it also affected the species richness of the captured community. Species richness was not equally distributed across all sample heights. Bowl units at tassel height captured a total of 44 species, bowl units at ear height captured 37 species, and bowl units at ground height captured 24 species. We observed limited overlap among the species accumulation curves developed from the three heights (Fig. 4). Each curve approached an asymptote, suggesting that increasing the sample effort will not increase the likelihood of capturing novel taxa. In addition the curves suggest that the richness at each height are significantly different from one another, as the confidence intervals eventually did not overlap as each curve approached an asymptote. The asymptote was lowest and more quickly reached by traps placed at the ground height. These curves suggest that traps placed at the height of the tassels collected the most species for the same amount of sampling effort.

The pollinators captured at tassel height represent 87% of all species captured in BB. The following speices were captured only at ear height: *Bombus auricomus, B. fraternus,* a Chrysididae species, *Eristalis transversa,* and a *Platycheirus* species. *Calliopsis andreniformis* and *Melanostoma mellinum* were only captured at ground height. We captured a total of eight *C. andreniformis*, while single specimens represented the remaining species that were found only at ear or ground height.

When species accumulation curves were examined by bowl color we observe a similar pattern. There is limited overlap among the curves generated by bowl color (Fig. 5). Each is approaching an asymptote suggesting that increased sampling with bowls of that color is not likely to increase the likelihood of capturing novel taxa. The asymptote was lowest and most quickly reached for white bowls. The curves suggest that blue and yellow bowls collected the most species for the same amount of sampling effort.

Blue bowls captured 82% of all pollinator taxa in this experiment. Eight species were only found in blue bowls: *Dieunomia heteropoda*, *Nomada* sp., *Xenoglossa strenua*, *anthophora bomboidies, Nomia universitatis, Melissodes nivea,* and Bombyliidae. Yellow bowls captured 74% of all pollinator taxa with six novel taxa: *Bombus auricomus, B. griseocollis, B. fraternus,* *Melanostoma mellinum,* and *Eristalis transversa.* White bowls captured only 60% of the pollinator taxa with only one novel species, *Bombus impatiens.*

Pollen Analysis. Of 1,782 female bees collected during pollen shed, 162 were carrying visible amounts of pollen. Of the bees with visible amounts of pollen, we identified 80 bees carrying corn pollen. These 80 bees represented five species. The most frequently captured *Lasioglossum (Dialictus)*, *Melissodes bimaculata*, and *Agpostemon virescens* were identified as carrying corn pollen. In addition we identified two more Apidae species carrying corn pollen: *Apis mellifera* and *Melissodes communis*.

Discussion

We observed that sampling methodology affects the community of pollinators described in Iowa cornfields. Trap type had a significant effect on the community of insect pollinators collected with BB collecting a more abundant and diverse community of pollinators than YSC. Trap height also significantly affected the described community. Traps deployed at the height of the tassels describe a more abundant and species rich community of pollinators than traps at ear or ground height. Bee bowls at tassel height did not capture all species observed in corn. Therefore, to capture all of the species we observed, traps would have to be placed at all heights. Blue bowls captured more bees than white or yellow bowls; and yellow bowls captured more flies than white or blue. To provide the most efficient description of the community of insect pollinators using cornfields as a resource, we suggest sampling with BB at the height of the tassels using all three colors. Sampling using YSC is not recommended as YSC do not efficiently describe the community of insect pollinators visiting cornfields.

A criticism of using bee bowls is that the trap is designed to be attractive to bees. It is possible that these traps are recruiting bees to the field and therefore may not represent their use of corn as a forage or nesting site. However, several species that we captured were observed carrying corn pollen. This suggests that the BB are not just an attractive trap, but are collecting individuals that are actively foraging in these fields.

Despite the low abundance of *A. mellifera* captured over the two years, this species will forage on corn (Keller et al. 2005, Krupke et al. 2012). One explanation for why we observed so few *A. mellifera* may be that BB are an ineffective tool for capturing this species when they are foraging. In 2013 we made visual observations of cornfields as a possible complementary sampling method. We did not observe any *A. mellifera* during a total of 18 hours of observation. How often *A. mellifera* and other pollinators forage in cornfields may be function of the surrounding landscape and the availability of more preferred forage. A more detailed study that accounts for the effect of the surrounding landscape may be required to better understand the extent to which corn is used as forage for insect pollinators.

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Table 1. Iowa cornfields surveyed for pollinators

Year	County	Coordinates
2012	Boone	42°00'05.69"N 93°47'19.72"W
	Story	42°00'08.54"N 93°39'32.57"W
	Story	41°58'54.94"N 93°38'38.41"W
2013	Boone	42°00'05.69"N 93°47'19.72"W
	Story	42°06'23.65"N 93°35'23.79"W
	Story	42°00'08.54"N 93°39'32.57"W

Table 2. Species abundance captured for 2012(2013) by sampling method

Taxa		Sampling Method	
	HYMENOPTERA	**Bee Bowls**	**Sticky Cards**
Andrenidae			
	Andrena wilkella (Kirby)	2 (2)	0 (0)
	Calliopsis andreniformis (Smith)	1 (7)	0 (0)
Apidae			
	Anthophora bomboidies	0 (1)	0 (0)
	Apis mellifera L.	5 (12)	2 (2)
	Bombus auricomus	0 (1)	0 (0)
	Bombus bimaculatus (Cresson)	0 (1)	0 (0)
	Bombus fraternus	0 (1)	0 (0)
	Bombus griseocollis	0 (1)	0 (0)
	Bombus impatiens	2 (2)	0 (0)
	Ceratina Spp.	0 (0)	1 (0)
	Melissodes agilis	14 (25)	0 (0)
	Melissodes bimaculata (Lepeletier)	272 (474)	0 (0)
	Melissodes communis	22 (14)	0 (0)
	Melissodes druriella (Kirby)	0 (10)	0 (0)
	Melissodes nivea	0 (1)	0 (0)
	Melissodes trinodus (Robertson)	13 (35)	0 (0)
	Nomada Spp.	0 (0)	0 (0)
	Svastra atripes	0 (1)	0 (0)
	Svastra obliqua	0 (6)	0 (0)
Chrysididae			
	Chrysididae spp.	0 (1)	0 (0)
Colletidae			
	Hylaeus affinis (Smith)	2 (4)	2 (2)
Halictidae			
	Agapostemon texanus	28 (68)	0 (0)
	Agapostemon virescens (F.)	124 (290)	0 (0)
	Augochlora pura (Say)	3 (29)	0 (0)
	Augochlorella aurata (Smith)	46 (32)	0 (0)
	Augochloropsis metallica (F.)	0 (7)	0 (0)
	Dieunomia heteropoda	2 (6)	0 (0)
	Dieunomia triangulifera	1 (0)	0 (0)
	Halictus confusus (Smith)	22 (33)	0 (0)
	Halictus ligatus (Say)	6 (28)	0 (0)
	Halictus parallelus	4 (0)	0 (0)
	Halictus rebicondus (Christ)	6 (11)	0 (0)
	Halictus tripartitus (Cockerell)	1 (2)	0 (0)
	Lasioglossum (Dialictus) spp.	268 (762)	17 (4)
	Nomia universitatis	0 (2)	0 (0)
	Xenoglossa strenua	0 (2)	0 (0)
Megachilidae			

	Megachile relativa	0 (2)	0 (0)
	Megachilie rotundata (F.)	0 (1)	0 (0)
	DIPTERA		
Bombyliidae		0 (1)	0 (0)
Calliphoridae		11 (22)	5 (1)
Dolichopodidae		77 (53)	169 (43)
Tachinidae			
	Tachinidae morphospecies 1	19 (2)	0 (0)
	Tachinidae morphospecies 2	5 (55)	0 (0)
	Tachinidae morphospecies 3	1 (44)	0 (0)
	Tachinidae Undet.	0 (0)	17 (225)
Syrphidae			
	Eristalis transversa	0 (3)	0 (0)
	Eristalis spp. 1	2 (5)	0 (0)
	*Helophilu*s spp.	0 (2)	0 (0)
	Melanostoma mellinum (L.)	0 (1)	0 (0)
	Platycheirus spp.	0 (2)	0 (0)
	Sphaerophoria spp.	1 (18)	0 (0)
	Syrphus spp 1	2 (4)	0 (0)
	Toxomerous geminatus Say	5 (18)	19 (0)
	Toxomerous marginatus Say	32 (514)	16 (0)
	Syrphidae Undet.	0 (0)	1 (419)
TOTALS			
Hymenoptera		**845 (1872)**	**22 (8)**
Diptera		**155 (744)**	**227 (688)**
GRAND TOTAL		**1000 (2616)**	**249 (696)**

Table 3: MANOVA fit statistics height, color, and farm on bee and fly abundances in bee bowls deployed in Iowa cornfields

Effect	Df	Wilks λ	ApproxF	NumDf	DenDf	Pr>F
Height[a]	2	0.552	53.203	4	616	0.0001
Color[b]	2	0.571	49.680	4	616	0.0001
Farm[c]	2	0.740	24.967	4	616	0.0001
Height*Color	4	0.942	2.297	8	616	0.019
Height*Farm	4	0.944	2.254	8	616	0.022
Residuals	309					

[a] Traps were set at ground (0.308m), ear (1.22m), and a variable tassel height (1.5m-2.74m).

[b] One bowl colored yellow, white, and blue were present at each trapping height.

[c] Three farms were sampled in each year. Farms were all located in central Iowa with each at least 2km from one another.

Table 4: ANOVA fit statistics for the effects of height, color, and farm separately for bee and fly abundance from bee bowl deployed in Iowan cornfields

Log Bee Abundance

Effect	Df	Mean Sq.	F-Value	Pr>F
Height[a]	2	17.415	105.0606	0.0001
Color[b]	2	9.4544	57.0366	0.0001
Farm[c]	2	8.0816	48.7544	0.0001
Height*Color	4	0.6012	3.6268	0.0067
Height*Farm	4	0.3895	2.3496	0.0543
Residuals	309	0.1658		

Log Fly Abundance

Effect	Df	Mean Sq.	F-Value	Pr>F
Height[a]	2	1.765	9.6192	0.0001
Color[b]	2	3.799	20.7038	0.0001
Farm[c]	2	4.072	22.1898	0.0001
Height*Color	4	0.067	0.3667	0.8323
Height*Farm	4	0.310	1.6869	0.1528
Residuals	309	0.1835		

[a] Traps were set at three different heights: ground (0.308m), ear (1.22m), and a variable tassel height (1.5m-2.74m).

[b] One bowl of each color, yellow, white, and blue, were present at each trapping height.

[c] Three farms were sampled in each year. Farms were all located in central Iowa with each at least 2km from one another.

Table 5. Tukey Honest significant differences for varying levels of height and color for bee and fly abundance from bee bowls deployed in Iowan cornfields

Log bee abundance by height

Contrast	Diff	lwr	upr	p adj
Tassel-Ground	0.79	0.66	0.92	0.0001
Ear-Ground	0.53	0.40	0.66	0.0001
Tassel-Ear	0.26	0.13	0.39	0.0001

Log bee abundance by bowl color

Contrast	Diff	lwr	upr	p adj
Blue-White	0.56	0.43	0.69	0.0001
Blue-Yellow	0.44	0.31	0.57	0.0001
Yellow-White	0.12	0.00	0.25	0.0680

Log fly abundance by height

Contrast	Diff	lwr	upr	p adj
Ear-Ground	0.25	0.12	0.39	0.0001
Ear-Tassel	0.16	0.2	0.29	0.0190
Tassel-Ground	0.10	-0.04	0.23	0.2280

Log fly abundance by bowl color

Contrast	Diff	lwr	upr	p adj
Yellow-Blue	0.36	0.23	0.50	0.0001
Yellow-White	0.29	0.15	0.42	0.0001
White-Blue	0.08	-0.06	0.21	0.3874

Figure Captions

Figure 1. Bee bowl stand used to sample insect pollinators in cornfields, raised to maximum height of 2.74 m. Image was taken in early June prior to sampling to illustrate how traps function; traps were obscured by the corn plants once sampling began.

Figure 2. A ‘bowl-unit’ at ear height contained one bowl of each color (yellow, white, and blue) made from three hangers attached to a wall shelf bracket.

Figure 3. Diagram depicting the location within a cornfield where bees were sampled; circles represent location of traps.

Figure 4. Species accumulation curves generated from samples collected from bee bowls in 2012 and 2013. Curves represent the accumulation of both bee and fly species. The black curve corresponds to traps at tassel height; the blue curve corresponds to traps at ear height; and the red curve corresponds to traps at ground height. The dashed lines about the curves represent the 95% confidence interval.

Figure 5. Species accumulation curves generated from samples collected from bee bowls in 2012 and 2013. Curves represent the accumulation of both bee and fly species. The black curve corresponds to samples collected from blue bowls; the medium grey curve corresponds to samples collected from yellow bowls and the light grey curve corresponds to samples collected from white bowls. The dashed lines about each curve represents the 95% confidence interval.

Figure 1.

Figure 2.

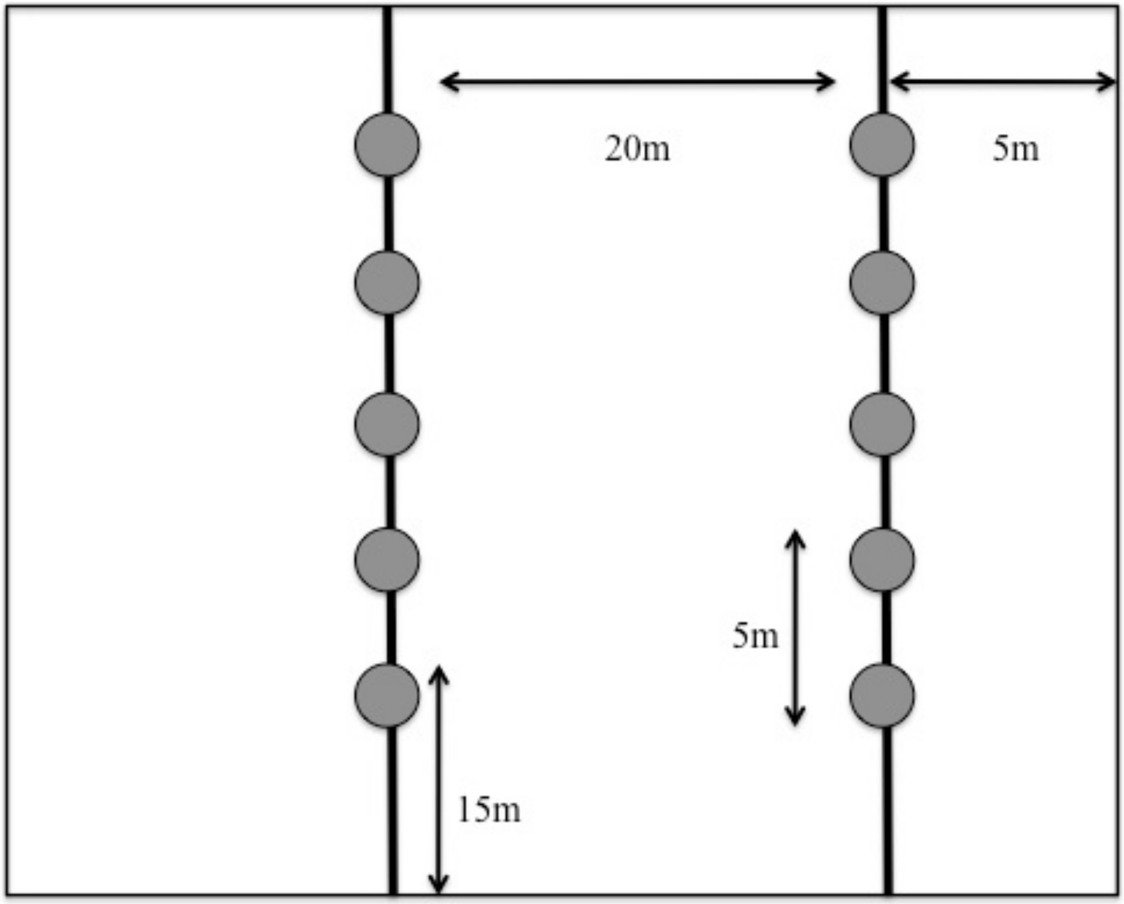

Figure 3.

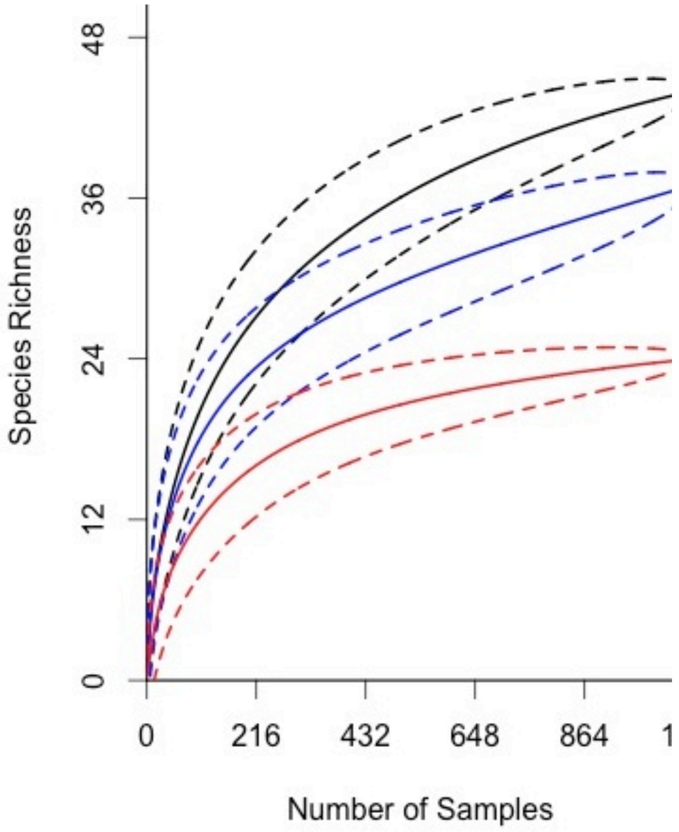

Figure 4.

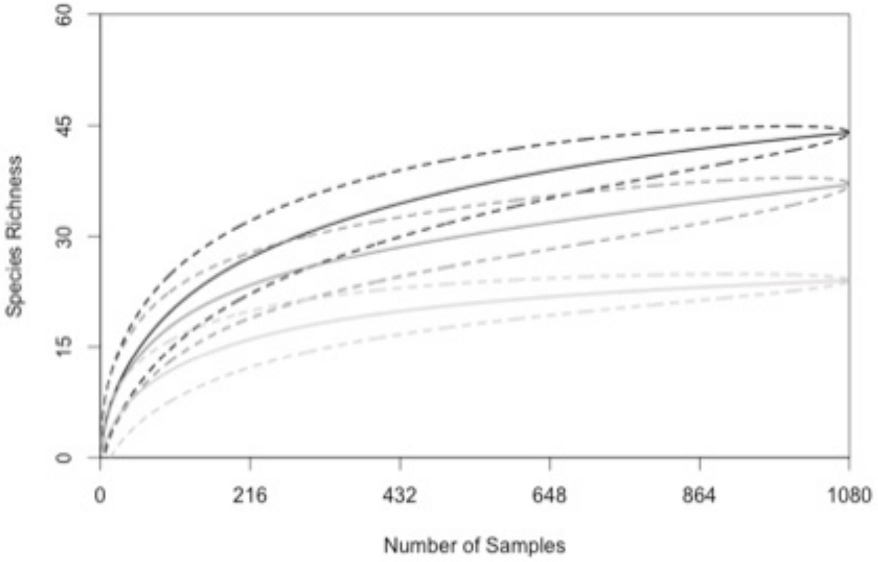

Figure 5.

CHAPTER THREE. DEFINING THE INSECT POLLINATORY COMMUNITY FOUND IN IOWA ROW CROP AGRICULTURAL FIELDS

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Abstract

Defining the pollinator community utilizing soybean (*Glycine max*) and cornfields (*Zea mays*) can provide baseline data for surrogate species selection for laboratory and field studies, inform conservation decisions, and outline what species may be at risk due to agronomic practices. We explored the similarity between two groups of pollinators collected during 2012 and 2013 in soybean and cornfields using multivariate methods of analysis. These fields were located within central Iowa (Story County), at least 2 km from each other. There are three general possibilities when considering how similar these groups of pollinators may be: 1) the two groups may be distinctly different sharing no similar species, 2) the two groups share a few common species, but some are found in only one of the crop types and not the other, or 3) all species are common between the two crops. Summed across both corn and soybean, 6,704 individual insect pollinators were captured representing more than 56 species or morpho-species; 34 species were collected in both crop fields; 17 were collected only in corn; and five in soybean fields. Based on non-metric multi-dimensional scaling, we infer that the samples collected from each crop significantly overlap in ordination space, indicating a shared community of pollinators comprised of mostly solitary, ground nesting bees. This suggests that there is a common group of insect pollinators using both crops as a resource in central Iowa. A defined community can

inform conservation/management decisions aimed at protecting these organisms in an agricultural landscape.

Introduction

Many crop species depend on or benefit from insect mediated pollination to achieve economically viable yields (Kevan et al. 1983, Klein et al. 2007). Globally, with an estimated 35% of crop production a result of insect pollination (Klein et al. 2007). The majority of crop pollination services are provided by the European honey bee (*Apis mellifera*) valued annually to be worth $14.6 billion to US crop production alone (Morse and Calderone 2000). In addition to the honey bee there are over 4,000 species of unmanaged, native pollinators that occur in North America (Michner 2000). These native, mostly solitary, bees are capable of providing pollination services to a wide variety of crop species. The estimated annual contribution of this group to US agriculture is valued at $3.1 billion (Losey and Vaughan 2006). Despite the critical role Pollinators play in the US economy,the descriptions of pollinator communities in flowering crops are available for only a limited number of plant species (Kremen 2008).

Pollinators are strongly affected by the diversity of the surrounding landscape at a scale of 1.5 km (Ricketts et al. 2008, Bennet and Isaacs 2014). The landscape must have sufficient nesting resources as well as floral resources to maintain a community of unmanaged pollinators. Agricultural intensification that removes nesting habitat and reduces the availability and diversity of floral resources can negatively affect pollinator diversity and abundance, which can have a profound impact on agriculture (Kremen 2002). However, landscapes dominated by annual agriculture can have periods of time when floral resources are very abundant. In such landscapes, the availability of mass flowering crop species can have strong, positive effects on the density of *Bombus* species (Westphal et al. 2003).

Despite being a self-pollinated plant, there is evidence that bees use soybean flowers as a source of pollen and nectar. A diverse community of pollinating insects have been found in central Iowa soybean fields, with a subset observed with soybean pollen (Gill 2014, Gill and O'Neal *in review*). *Megachile rotundata* has been used as a cross pollinating agent in the creation of hybrid soybean lines (Ortiz-Perez et al. 2008). A small-scale field study conducted in Brazil suggests that soybeans experience an increase in yield when exposed to honey bees and unmanaged pollinators (Milfont et al. 2013). Few studies have examined the pollinator community found within cornfields. Although corn is a wind-pollinated plant that offers no nectar reward, the honey bee (*Apis mellifera*) will forage for its' pollen (Keller et al. 2005). Additionally cornfields have been shown to support a diverse community of mostly native, solitary, ground nesting bees in central Iowa and in Michigan (Gardiner et al. 2010, Wheelock 2014, Wheelock and O'Neal *in review*).

Iowa's landscape is spatially uniform and functionally homogenized due to intense row crop agriculture (Brown and Schulte, 2011), with 75% of arable acres planted in either corn or soybean (IDALS 2012). While soybean has been breed to be self-pollinated and corn is a wind pollinated, both managed and unmanaged bees may use these crops as a resource. Additionally, anthophilious flower-visitors may exploit soybeans for resources. Flower flies (Syrphidae) larval stages prey on insect pests (Triplehorn and Johnson 2005) and are commonly found in surveys of aphidophagous predators in Iowa soybean fields (Schmidt et al 2008). The extent to which both hymenopteran and dipteran flower-visiting species may use both of these crops as a resource is unclear.

Defining the pollinator community utilizing soybean and cornfields can provide baseline data for surrogate species selection for laboratory and field studies, inform conservation decisions, and outline what species may be at risk due to common agronomic practices. Here we explore the similarity between two groups of pollinators collected over 2012 and 2013 in central Iowa corn and soybean fields. There are three general possibilities when considering how similar these groups of pollinators may be: 1) the two groups are distinctly different sharing no similar species, 2) the two groups' share a few common species, but some are found in only one of the crops and not the other, or 3) all species are common between the two crops. Using multivariate methods of analysis, we determined which of these scenarios best describes the pollinator community within these two crops.

Materials and Methods

Field sites

During the 2012 and 2013 field seasons, insect pollinators were sampled at corn and soybean fields located within Iowa State University research farms, located in central Iowa, at least 2 km from one another (Table 1). Soybean fields were conventionally managed and had been planted with corn in the previous year. Four fields were sampled in 2012 during 6 weeks (June 27th-August 3rd) while two fields were sampled in 2013 during 7 weeks (July 9th-August 23rd). This sampling period occurred during the reproductive stages (R1-R6) of soybean growth, encompassing the growth stages in which flowers are present. We used a modified pan trap (bee bowl) to sample pollinators at each farm following methodology developed by Gill and O'Neal (in review). Within each site, two transects (50 m in length) were arranged in an 'X' formation and 15 bee bowls were placed at 3.3 m intervals along each transect (30 bee bowls/farm/date, 10 of each white, yellow, and blue). Bee bowls were filled with a soapy water solution and deployed for 24 h, once a week during the sampling period. A total of 1140 samples were collected during the two years.

Cornfields were conventionally managed and all were planted to soybeans in the previous year. Traps were deployed for 6 weeks in 2012 and 2013, starting one week prior to the occurrence of tassels (VT) and continuing to milk stage (R3; Abendroth et al. 2011). In 2012, sampling occurred from July 3rd-August 9th and in 2013 from July 16th-August 23rd. Sampling was conducted using bee bowls on a telescoping pole. Each trap consisted of two 1.52 m sections of schedule 40 PVC. One section was 3.8 cm in diameter, the other 5.1 cm in diameter, allowing the smaller section to fit within the larger one. When combined, these two sections reached a maximum height of 2.74 m. Bee bowls were attached to the pole by connecting three galvanized steel pipe-hangers to a shelf bracket, so that one bowl of each color-white, yellow, and blue-were present at each height. We refer to a set of three bee bowls (one of each color) as a ‘bowl unit’ hereafter. Bowl units were attached at ‘ground height’, ‘ear height’, and ‘tassel height’. The bowl unit at ground height and ear height were fixed at 0.308 m and 1.22 m, respectively. The bowl unit at tassel height was never enclosed by the canopy and was adjusted as the corn plant grew from a starting height of 1.5 m to a maximum of 2.74 m.

Two parallel transects were established at each farm; one located 5 m into the field from the nearest edge and a second located 20 m farther in field from the first transect. Each transect started 15 m into the field and consisted of 5 traps 5m apart (Fig. 3). At each farm, 90 BB (3/height/trap) were deployed for 24 h once a week during this period. Bee bowls were filled with a soapy water solution and deployed for 24 hours at each sampling date. A total of 3240 samples were collected during the two years.

Bee identification

Samples from both corn and soybean fields, were brought back to the lab and processed according to the methods outlined by Droege (2011) and specimens identified using the Discover Life key (URL:http://www.discoverlife.org/mp/20q?search=Apoidea). Specimens were identified to species with the exception of bees in the genus *Lasioglossum*. Bees in this genus were grouped by sub-genera. Pollinating flies (Syrphidae, Tachinidae, Dolichopodidae, Bombyliidae) were grouped by morphospecies within each family.

Data Analysis

We constructed species accumulation curves using the vegan package in R (Community Ecology Package V2.0-8, 2013) with data collected for each crop. The species included all insects considered pollinators. Curves were reported by crop type.

Non-metric multidimensional scaling (nmds) was used to explore the similarity of the two groups of insect pollinators. Non-metric multidimensional scaling is an ordination method for community data sets that employs ecologically meaningful ways of measuring community dissimilarity. This method preserves the rank order relationship and attempts to map these ranks non-linearly onto ordination space. It is suggested over other forms of ordination as it can readily handle non-linear species responses effectively (Oksanen 2013). This analysis was performed using the metaMDS function in the vegan package in R (Community Ecology Package V2.0-8, 2013) with the data collected for each group. We used nmds analysis of Jaccard similarity matrices with auto-transformation in R. Starting with five axes 20 iterations from random starts were performed in this analysis. After 20 iterations the axes were reduced by one from five to just a single axis. As the number of dimensions increases there is a concurrent reduction in error. To prevent over fitting the ordination model a scree plot was constructed. Where the “elbow” of the plot occurs is the suggested number of dimensions for the ordination, for these data sets two dimensions were selected.

Results

Pollinator community in Soybean

Over the two field seasons 3,087 individual insect pollinators were collected using bee bowls in soybean fields. These individuals represented more than 43 species (or morphospecies) of insect pollinators (Table 2). The most abundant species captured were *Lasioglossum (Dialictus)* species*, Agapostemon virescens, Melissodes agilis, Melissodes bimaculata,* and *Toxomerous marginatus*. In soybean fields, bees were more commonly captured than flower visiting flies; ground nesting bees were more abundant than stem nesting bees; and solitary bees were more abundant than social bees.

The species accumulation curve generated in R suggests that the species richness observed using bee bowls in soybean fields would not likely increase with the addition of more sampling units as the curve approached an asymptote (Fig. 2). Both the accumulation and final estimate of species richness are consistent with what Gill (2014) observed previously in soybean fields of central Iowa..

Pollinator community in Corn

Bee bowls captured a total of 3,617 individual insect pollinators representing more than 50 species across all sites and dates (Table 2). Bees dominated the observed community, accounting for 75% of individuals captured. During the two years the most abundant species did not differ. The most abundant bee species captured were *L. (Dialictus)* species, *M. bimaculata, A. virescens, T. marginatus* and flies belonging to Dolichopodidae. In this community bees were more commonly captured than flower visiting flies; ground nesting bees were more abundant than stem nesting bees; and solitary bees were more abundant than social bees.

The species accumulation curve generated in R suggests that the species richness observes using bee bowls in cornfields would not likely increase with the addition of more sampling units as the curve approached an asymptote (Fig. 3). This is consistent with what has been previously observed in corn (Wheelock 2014, O'Neal and Wheelock in review).

Community Similarity

The final nmds solution had a stress, or measure of error, of 0.012 with a non-metric fit of R^2=0.978 and a linear fit R^2=0.966. Based on the nmds plot constructed from these two communities, pollinators found in soybeans are a subset of a larger community that was found in cornfields (Fig 4). There is more variation on a per sample basis in bowls collected from soybean fields, as this hull is much larger than the hull for corn.

The hulls produced by the nmds analysis indicated a significant overlap, comprised of 34 species that were collected from both corn and soybean fields. These shared species were mostly solitary ground nesting bees. The four most abundant species: *L. (Dialictus)* species*, A. virescens*, *M. bimaculata,* and *T. marginatus* account for 65% of the total abundance of insect pollinators collected from these two crops. There were 5 species that were unique to the soybean community: *Ceratina calcarata, Eucera* spp., *Epeolus* spp., *Peponapis pruniosa,* and *Colletes brevicornis*. There were a total of 17 species that were only captured in corn: *Antophora* *bomboidies*, *Bombus auticomus*, *Bombus bimaculatus*, *Bombus fraternus*, *Bombus impatiens*, *Svastra atripes*, Chrysididae, *Augochlora pura*, *Dieunomia triangulifera*, *Halictus parallelus*, *Nomia universitatus*, *Xenoglossa strenua*, *Megachile relativa*, Bombyliidae, *Eristalis transversa*, *Helophilus* spp., and *Platycherius* spp. None of these 22 species that were unique to each crop were particularly abundant in either community. For example, *A. pura* was the most frequently captured of these species representing only .008% of the total corn community. Generally the 22 species that were not shared were represented by just a few individuals and in many cases just one or two. These 22 species would explain the portions of the corn/soybean hulls that do not overlap as Jaccard measures similarity in terms of presence/absence.

Discussion

Globally both native and managed populations of insect pollinators are declining. There is a growing body of research demonstrating that pollinators are exposed to pesticides through a variety of mechanisms (Krupke et al. 2012). Non-target effects such as sub-lethal exposure to pesticides have been shown to negatively effect honey bee health by increasing *Nosema* growth (Pettis et al. 2012). Declines in pollinator populations worldwide have prompted growers and researchers to place special emphasis on understanding and conserving the bee community to maintain pollination as a viable ecosystem service. An essential step in maintaining pollination services is to understand the pollinator community found in agroecosystems for each crop-producing region. The objective of this study was to examine the insect pollinator community found visiting Iowa corn and soybean fields.

The results of the nmds analysis suggest that there is a common group of insect pollinators using both crops as a resource in central Iowa. As the hulls are overlapping in the nmds plot we infer that the samples collected from each crop are not distinctly different in terms of community composition since there is no separation between the corn samples and the soybean samples. Samples that have a very different species composition would be plotted far apart and samples that have a similar species composition would be plotted close together in nmds. If there were two different communities using these crops we would expect to see separation among the samples in the nmds plot, with no overlap in the hulls. Overall, 35 species were commonly collected across both crop types including the four of the six most abundant species collected overall.

A defined community can inform conservation and management decisions based around protecting these organisms in an agricultural landscape by reducing their exposure to risk from agronomic practices. The current standard species for non-target risk assessment is *A. mellifera,* however it was rarely detected in this study. Species for non-target risk assessment should be selected from the most abundant species described in this community. A better understanding of the system as a whole may be required to buffer against continued pollinator decline. The majority of the species that make up this community are solitary and ground nesting. Further studies should examine where these species are nesting and how far into the field they forage as such measurements will help guide conservation efforts.

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Table 1. Iowa farms surveyed for pollinators in 2012 and 2013.

Year	County	Coordinates	Crop
2012	Boone	42°00'05.69"N 93°47'19.72"W	Corn
	Story	42°00'08.54"N 93°39'32.57"W	Corn
	Story	41°58'54.94"N 93°38'38.41"W	Corn
	Hardin	41°24'13.43"N 93°18'09.27"W	Soybean
	Boone	42°00'05.69"N 93°47'19.72"W	Soybean
	Story	42°06'23.65"N 93°35'23.79"W	Soybean
	Story	41°58'54.94"N 93°38'38.41"W	Soybean
2013	Boone	42°00'05.69"N 93°47'19.72"W	Corn
	Story	42°06'23.65"N 93°35'23.79"W	Corn
	Story	42°00'08.54"N 93°39'32.57"W	Corn
	Boone	42°00'05.69"N 93°47'19.72"W	Soybean
	Story	41°58'54.94"N 93°38'38.41"W	Soybean

Table 2. Abundance of pollinator by crop type for 2012 (2013).

Taxa	Corn	Soybean
HYMENOPTERA		
Andrenidae		
Andrena wilkella (Kirby)	2 (2)	0 (5)
Calliopsis andreniformis (Smith)	1 (7)	30 (3)
Apidae		
Anthophora bomboidies	0 (1)	0 (0)
Apis meliffera L.	5 (12)	10 (3)
Bombus auricomus	0 (1)	0 (0)
Bombus bimaculatus (Cresson)	0 (1)	0 (0)
Bombus fraternus	0 (1)	0 (0)
Bombus griseocollis	0 (1)	1 (0)
Bombus impatiens	2 (2)	0 (0)
Ceratina calcarata	0 (0)	1 (0)
Eucera dibutata	0 (0)	0 (5)
Epeolus spp.	0 (0)	2 (1)
Melissodes agilis	14 (25)	344 (20)
Melissodes bimaculata (Lepeletier)	272 (474)	181 (112)
Melissodes communis	22 (14)	18 (14)
Melissodes druriella (Kirby)	0 (10)	0 (10)
Melissodes nivea	0 (1)	0 (8)
Melissodes trinodus (Robertson)	13 (35)	11 (29)
Peponapis pruniosa	0 (0)	6 (1)
Svastra atripes	0 (1)	0 (0)
Svastra obliqua	0 (6)	0 (2)
Chrysididae		
Chrysididae spp.	0 (1)	0 (0)
Colletidae		
Collettes brevicornis	0 (0)	1 (0)
Hylaeus affinis (Smith)	2 (4)	2 (1)
Halictidae		
Agapostemon texanus	28 (68)	66 (122)
Agapostemon virescens (F.)	124 (290)	416 (173)
Augochlora pura (Say)	3 (29)	0 (0)
Augochlorella aurata (Smith)	46 (32)	99 (14)
Augochloropsis metallica (F.)	0 (7)	0 (1)
Dieunomia heteropoda	2 (6)	8 (2)
Dieunomia triangulifera	1 (0)	0 (0)
Halictus confuses (Smith)	22 (33)	26 (10)
Halictus ligatus (Say)	6 (28)	35 (19)
Halictus parallelus	4 (0)	0 (0)
Halictus rebicondus (Christ)	6 (11)	8 (7)
Halictus tripartitus (Cockerell)	1 (2)	6 (0)
Lasioglossum (*Dialictus*) spp.	268 (762)	345 (428)
Nomia universitatis	0 (2)	0 (0)

Table 2. Continued.

Taxa	Corn	Soybean
Xenoglossa strenua	0 (2)	0 (0)
Megachilidae		
Megachile relativa	0 (2)	0 (0)
Megachilie rotundata (F.)	0 (1)	1 (0)
DIPTERA		
Bombyliidae	0 (1)	0 (0)
Calliphoridae	11 (22)	0 (13)
Dolichopodidae	77 (53)	0 (5)
Tachinidae		
Tachinidae morphospecies 1	19 (2)	68 (4)
Tachinidae morphospecies 2	5 (55)	6 (51)
Tachinidae morphospecies 3	1 (44)	11 (58)
Syrphidae		
Eristalis transversa	0 (3)	0 (0)
Eristalis spp. 1	2 (5)	0 (6)
Helophilus spp.	0 (2)	0 (0)
Melanostoma mellinum (L.)	0 (1)	0 (1)
Platycheirus spp.	0 (2)	0 (0)
Sphaerophoria spp.	1 (18)	0 (3)
Syrphus spp 1	2 (4)	0 (1)
Toxomerous geminatus Say	5 (18)	1 (18)
Toxomerous marginatus Say	32 (514)	43 (191)
Total Hymenoptera	**844 (1,874)**	**1,617 (990)**
Total Diptera	**155 (744)**	**129 (351)**
GRAND TOTAL	**999 (2,618)**	**1,746 (1,341)**

Figure Captions

Figure 1. A Scree plot constructed that plots the stress, a measure of error, against the number of dimensions included in the nmds analysis. Where the elbow occurs is the suggested number of dimensions to include in the final analysis. These data suggest that two dimensions best fits this analysis.

Figure 2. Species accumulation curves generated from samples collected from bee bowls in soybean fields in 2012 and 2013. The dashed lines about the curves represent the 95% confidence interval.

Figure 3. Species accumulation curves generated from samples collected from bee bowls in cornfields in 2012 and 2013. The dashed lines about the curves represent the 95% confidence interval.

Figure 4. Non-metric, multi-dimensional scaling plot examining the similarity of the community found in corn and soybean fields in central Iowa. Black circles represent bee bowl samples (all individuals collected per bowl) and red plus signs represent the weighted species scores. The blue hull encompasses all samples collected from soybean fields and the black hull encompasses all samples collected from cornfields.

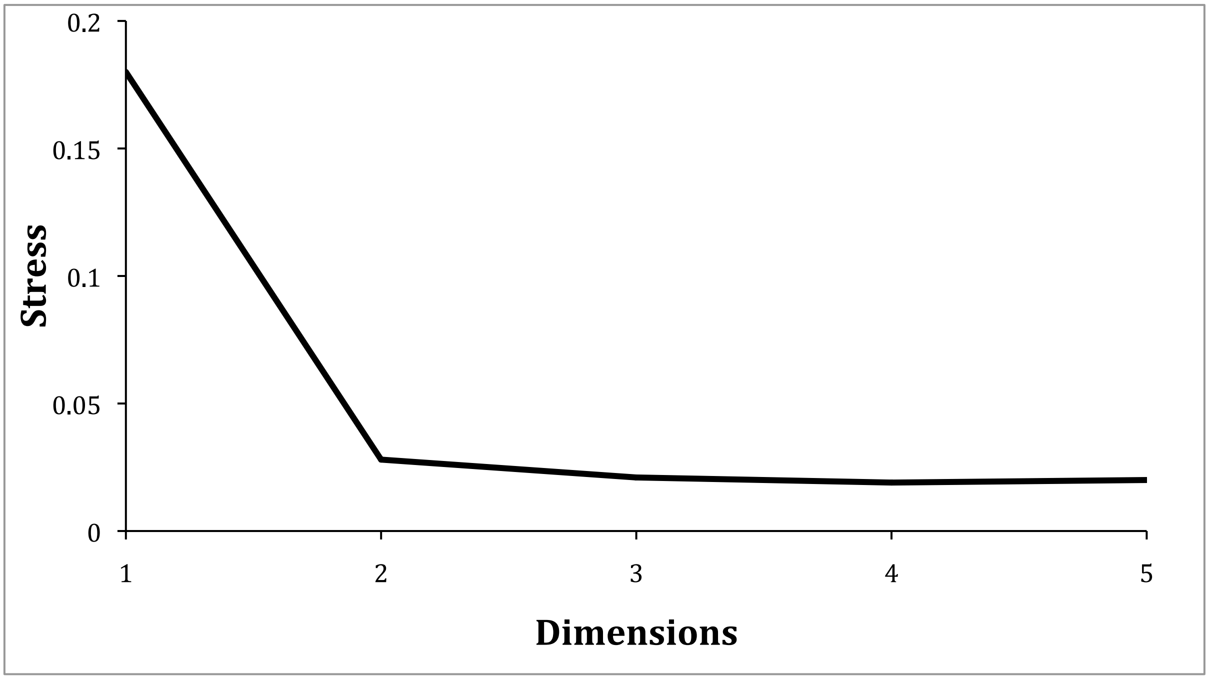

Figure 1.

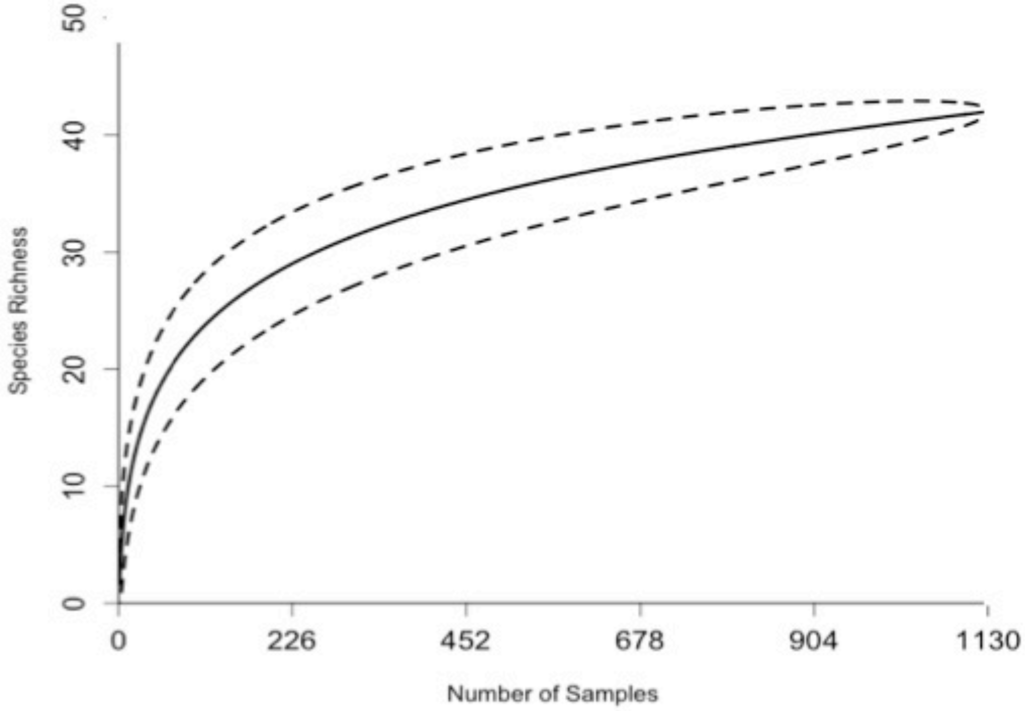

Figure 2.

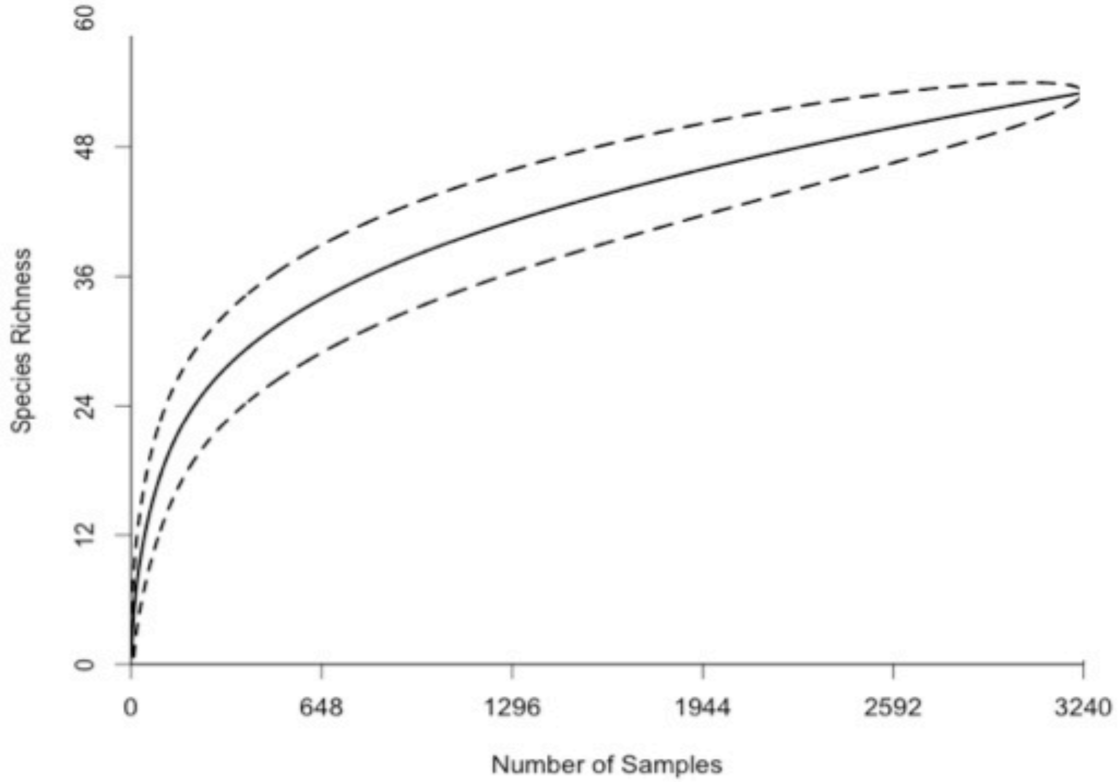

Figure 3

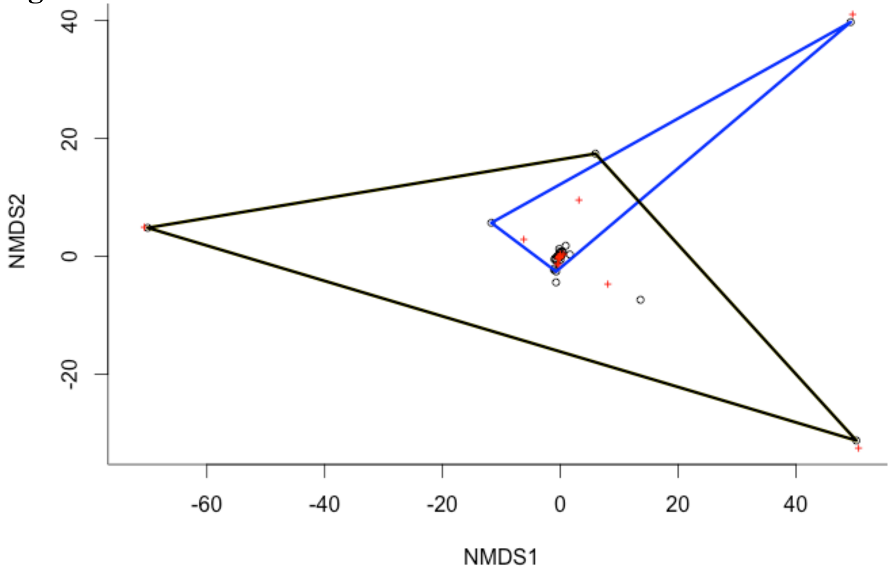

Figure 4.

CHAPTER FOUR. GENERAL CONCLUSIONS & ACKNOWLEDGEMENTS

The goal of this research was to understand how insect pollinators interacted with row crop agriculture, specifically corn and soybean crops. To do so I conducted two field research experiments with the objectives to 1) Evaluate collection methods for characterizing the pollinators using Iowa cornfields and 2) Examine the similarity between the communities of insect pollinators found in Iowa corn and soybean fields.

Chapter Two

We observed that sampling methodology affects the community of pollinators described in Iowa cornfields. Trap type, trap height, and trap color all had a significant effect on the community of insect pollinators collected. Bee bowls (BB) collected a more abundant and diverse community of pollinators than yellow sticky cards (YSC) therefore sampling using YSC is not recommended, as YSC do not efficiently describe the community of insect pollinators visiting cornfields. Trap height also significantly affected the described community. Traps deployed at the height of the tassels describe a more abundant and species rich community of pollinators than traps at ear or ground height, however BB at tassel height did not capture all species observed in corn. Trap color affected the described community with blue bowls captured more bees than white or yellow bowls; and yellow bowls captured more flies than white or blue. Therefore to provide the most efficient description of the community of insect pollinators using cornfields as a resource, we suggest sampling with BB at the height of the tassels using all three colors.

Chapter Three

My results suggest that there is a common group of insect pollinators using both crops as a resource in central Iowa. 6,704 individual insect pollinators were captured representing more than 56 species/morphospecies. 34 species were collected from both crop fields. This community is composed primarily of solitary, ground nesting, bees. Social bees and flower visiting flies were not frequently captured.

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