Native bee diversity of Pierce Cedar Creek Institute

Sarah Arnosky

Mentor: Dr. Ann Fraser, PhD
Pierce Cedar Creek Institute

Acknowledgements

First, I would like to thank Dr. Ann Fraser for providing me with the opportunity to work on this project with her and for helping me with nearly every step along the way. I would also like to thank Pierce Cedar Creek Institute, Hastings, MI for hosting my study, especially Matt Dykstra for providing me with resources and guidance of the property. Additionally, I would like to recognize Elliot Wolfson, Leah Blazek, and Ryan Carrigan for assisting me in the collection and pinning of the specimens throughout the study.

Abstract

The role of native bees as pollinators is essential to ecosystem and economic integrity. Without native bees, two-thirds of all angiosperms would cease to exist and over one-third of the world food supply would be gone. Recently, there has been suspicion to plausible declines in native bee populations; however, due to their unmanaged status in the environment, native bee populations have historically not been monitored. In order to gain insight into current native bee populations and diversity, our study acted as an initial dataset for a long-term monitoring dataset at Pierce Cedar Creek Institute, Hastings, Barry Co., MI. This relatively rural and heavily agricultural area, hosted a myriad of habitats. To ensure a thorough survey of native bee diversity we sampled multiple habitats categorized as "Open Field," "Mixed," and "Woody" and used two different sampling techniques, bee bowls and aerial netting. Our collection took place from May to August, 2008 and yielded a total of 987 specimens representing 34 genera and a variety of life histories. The Open Field habitats yielded the largest number of genera and individuals, followed by the Mixed habitats, while the Woody habitats yielded the fewest number of genera and individuals. Overall, the most commonly occurring genera were *Lasioglossum, Augochlorella,* and *Halictus*, respectively, whereas the most abundant genera were *Lasioglossum, Augochlorella*, and *Ceratina*.

Table of Contents

List of Tables and Figures

Introduction

Of all animal pollinators, bees are one of the most, if not the most, economically and environmentally important (Kremen 2004). Economically, thirty-five percent of the global food supply depends on animal pollination (Winfree 2007); environmentally, sixty-six percent of angiosperms require animal pollination for sexual reproduction (Greenleaf and Kremen 2006). Bees are well-known to the general public and thought to be easily recognized. However, many people mistake hornets and hover flies for bees and are unaware of bees' importance. Familiarity usually extends only to honeybees and bumbles bees when in fact there are more than 17,000 species of bees worldwide (Michener 2007). The vast diversity of bees contributing to pollination increases chances of plant fertilization and also increases crop yield. Over the past twenty years there has been plausible rationale to suspect declines in native bee populations (Allen-Wardell 1998) but this suspicion has not been confirmed. This suspicion stems from a recent decline in production of animal pollination-dependent crops and from studies that show decline has occurred in a number of bee species (Kremen and Ricketts 2000). Additionally, urban sprawl has led to habitat destruction, improper use of pesticide, and habitat fragmentation, all of which are factors that destroy bee nesting and foraging sites and could contribute to a bee population decline. These factors are mostly attributed to human ignorance. Yet, through increased efforts in native bee research there is hope to overcome the barrier of unfamiliarity surrounding bees and gain insight on bee population status.

The United States alone is home to over 4,000 species of native bees (Mitchell 1960). This sizeable diversity spans a wide variety of environmental niches, allowing

bees to exist in several different habitat types. Common groups of native bees in the United States include mason bees (family Megachilidae), leafcutter bees (family Megachilidae), sweat bees (family Halictidae), andrenid bees (family Andrenidae), and bumble bees (family Apidae) (Issacs 2007). Visually, these groups are distinguished by differences in wing venation, size, location of pollen collection, and other microscopic characteristics.

Additionally, native bees can be distinguished by their nesting, social, and foraging behaviors. Nesting sites include hollow plant stems, wood, underground burrows, and sand pits (Xerces). With regard to sociality, native bees can be described as solitary and eusocial. The majority of native bees are solitary, meaning the females make individual nests and care for their own larvae (Michener 2007). Unlike solitary bees, eusocial bees have a social caste system in which there is a division of labor for reproduction, foraging, and defense (Michener 2007). Not all bees fit the extremes of solitary or eusocial; many fall along the spectrum and blend habits of both lifestyles. For example, nest-sharing bees are solitary in reproduction but live in large aggregations in common nesting sites. Furthermore, bees described as solitary and communal share a common entrance tunnel to a common nesting site with other bees (Michener 2007).

When considering the foraging behaviors of bees, they are either parasitic or non-parasitic. Most native bees are non-parasitic. While foraging, non-parasitic bees collect nectar and pollen to provision developing larvae and in process, transfer pollen. On the other hand, parasitic bees do not forage or pollinate at all. Instead, they invade other non-parasitic bees' nests, steal stored food, and kill larvae. Parasites are divided into two groups: social parasites and cleptoparasites (Michener 2007). Social parasites will enter a

nest and replace a queen and take over the nest by forcing workers to raise offspring of the parasite. Moreover, cleptoparasites will enter the nest of a host, lay eggs in a cell, depart the nest, and leave the parasitic larva to feed on the food meant for the host larva.

The role of bees as pollinators in the environment is essential to sustaining ecosystem integrity. Without the pollination of bees, the quantity and quality of fruit production of these plants would significantly decrease. Plants that are not properly pollinated will not gather enough pollen at the flower's stigmas, causing the seeds to not fully develop, resulting in a smaller, lopsided fruit (Shepherd 2006). Without proper fertilization, the plant species could not produce seeds for new generations and the species would eventually die out. This would not only affect the life of that plant but also that of all organisms that depend on the plant as well. In many cases, frugivores and herbivores require the consumption of certain plants in order to live and reproduce. In some ecosystems, animal-pollinated angiosperms act as keystone species in which the entire food web is dependent on for existence. For example, if figs or dipterocarps, two keystone species, lose their pollinators, the plants would die and the entire biotic communities that depend on them would be dramatically altered (Allen-Wardell 1998). Furthermore, humans rely on many pollinated crops for not only nutrients but also as a source of economic income. Crops that are most dependent on bee pollination include almonds, blueberries, watermelon, tomatoes and apples (Klein 2006). Insufficient pollination of these crops causes fruit deformation leading to unmarketable crops (Issacs 2007). Furthermore, without bee pollination, fields do not produce adequate amounts of crops to make a sufficient profit for the grower. Without pollination from bees, the growers lose money and the consumers pay more for less-available products.

The most common managed pollinator is the European honeybee, *Apis mellifera*. This exotic bee was introduced to North America in 1622 for its wax and honey production (Isaacs 2007). Today, the service honeybees offer to crops is worth an estimated $14.8 billion annually in the United States (Winfree 2007). Throughout the last one-hundred years, fluctuations in honeybee populations have been common. However, the condition known as Colony Collapse Disorder (CCD) has recently swept through honey bee populations all over the world, resulting in an abrupt disappearance of worker bees from honey bee colonies. As a result, honeybee stocks have declined 59% in the United States in the past 58 years (Winfree 2007). Even more immediate, some farmers reported 80-100% honeybee colony loss in 2007 alone (Oldroyd 2007). Despite extensive discussion on causation of this disorder, no final conclusions have been made. A variety of factors have been suggested as the cause of CCD: including bacterial and fungal diseases, parasitic mites such as *Varroa detructor* (Allen-Wardall 1997) and *Acarapis woodi* (Oldroyd 2007). Other studies conjecture symptomless viruses, pesticide contamination of pollen and nectar poisons the honeybees, or immunosupressed genetics in combination with stresses of diseases and non-optimal brood nest temperature cause CCD (Oldroyd 2007). Regardless of causation, this drastic decline threatens growers whose heavy reliance on honeybee pollination is imperative to their success.

With an apparent continuous decline in honeybee populations, researchers have begun to seek out alternative sources of pollination, such as native bees. In fact, studies have shown that it may be advantageous to use native bees instead of honey bees for several reasons. Native bees pollinate in cooler and wetter conditions than honeybees, prolonging the pollination season (Shephard 2006). Secondly, native bees are able to

collect nectar and pollen simultaneously and pollinate flowers such that the stigma and anther contact is ensured (Kraemer 2005). Additionally, honey bees are unable to perform buzz pollination, an efficient sonication mechanism used by many native bees on non-nectar plants (Greenleaf and Kremen 2006). Furthermore, native bees have been shown to deposit up to 197 pollen grains per visit, while honeybees deposit an average of 21 pollen grains per visit. This increase in pollen deposits by native bees is strongly related to increased fruit production (Kremen 2004). In fact, recent studies have shown that native bees alone have the ability to provide sufficient pollination without the assistance of honeybees, particularly on organic farms where there is an increased habitat and crop diversity (Winfree 2007; Kremen 2002). Therefore, agricultural risk is decreased by diversifying the pollinators that are active on the farms instead of relying solely on the honeybee.

While general details of bee habits are known, there are many unanswered questions regarding the population status and life history of many native bee species. Unlike honeybees, which are predominately kept in culture, native bees have been inadequately documented and monitored because of their unmanaged existence in nature. Like the honeybee, there are a variety of threats facing the native bee population. These threats include loss of nesting and floral resources, pesticide poisoning, and competition of floral sources with honey bees (Kremen 2000). While widespread declines in the native bee population are plausible, none of the proposed hypotheses on native bee status can be strongly supported at the present time because there is inadequate historical census data. However, European studies have suggested a decline in bumble bee populations in central England (Williams 1986, as cited by Williams 1989), east Germany (Peters 1972

as cited by Williams 1989), and in Belgium and France (Rasmont 1988, as cited by Williams 1989). These studies mostly attribute altered land use resulting in food-plant reductions and changed climatic niches to the decline of these bumblebee species.

The effects of habitat area and context on native bee populations vary across studies. Many studies cite that decreasing habitat size and increasing habitat isolation negatively affect native bee populations. For example, Kremen and Williams, et al. (2002), showed that both native bee diversity and abundance were significantly related to the proportional area of surrounding habitat: the greater the proportion of natural habitat, the more diversity and abundance that existed. When habitat fragmentation occurs, habitat and food plant specialists, such as some native bees, are expected to go extinct first (Steffan-Dewenter 2001). Furthermore, agricultural intensity, especially the creation of monocrop fields, jeopardizes wild bee community by taking away suitable and diverse floral and nesting sites (Klein 2007). Without access to proper resources for survival, native bee populations cease to exist in many disturbed areas.

Due to the substantial variation of composition in bee communities over time and space, the initialization and creation of a long-term data set is crucial in order to effectively evaluate the status of the native bee population. For example, Hererra (1988) found that only one-third of the bee species visiting a particular flower species returned every year in a five-year study Additionally, sites located less than 5 km apart have been shown to share <40% of native bee species, on average, when measured in the same year (Williams 2001). Another study, followed up and revisited a geographic location in Illinois 75 years later to compare present native bee species. They discovered no evidence of a marked decline in the species composition. In fact, 82% of the species

originally collected were recollected 75 years later (Marlin 2001). Temporal and spatial variation in population diversity can be easily misinterpreted as major declines unless we look at the bigger picture over time. Furthermore, scientists have realized different methods were being used to assess bee populations, making it difficult to compare results from studies over time and space (Williams 2001). Thus, to get an accurate assessment of native bee populations, we must incorporate long-term data sets in numerous localities and implement standardized sample procedures.

In order to create organized and compatible data sets from different regions of the world, standardized collecting protocols are necessary. By standardizing the protocols, bias and imprecise techniques can be avoided as much as possible. With the help of government, private and non-profit organizations, efforts to promote and coordinate studies of native bees have emerged. For example, a *Bee Inventory Plot* was drafted by a group of researchers in 2002 with the goal of "enticing many investigators already living worldwide to contribute to a single set of data" in order to generate information on geographic patterns of bee diversity (LeBuhn 2002). The researchers designed a protocol that was simple, time-efficient, thorough, and cost-effective. Thus, data sets from researchers of different regions could be combined to produce a comprehensive data set of bee populations over time allowing researchers to effectively compare and contrast native bee populations in different areas and across time and to discern factors affecting their existence.

The importance of gathering continuous data sets of native bee populations across the United States and globally is increasingly acknowledged. Efforts are underway to help study native bees including, studies investigating topics such as pollination

efficiency, the role of native bees in crop production , and the effect of habitat area on bee populations are becoming more prevalent (Kremen 2004; Winfree 2007; Steffan-Dewnter 2002). Researcher Sam Droege conducted a two-day survey at the Carolina Sandhills National Wildlife Refuge in South Carolina in spring of 2006. During this short period he collected 56 bee species, 20 of which had never been recorded in South Carolina (Cassel, radio). Furthermore, a bee survey in 2000 in the Pinnacles National Monument of California collected 410 bee species. This collection represents more than 10% of all the known native bees in the United States (Cassel, radio). These studies reveal there is much more on the status of native bees to be explored and surveyed across the United States.

To enhance our knowledge of native bee populations, we undertook a study of native bee diversity in west Michigan. Ranging from hardwood forests, to prairie grasslands, to sandy shores, Michigan provides a variety of environments to support many different flora and fauna. This unique landscape provides an environment allowing Michigan to produce over 200 commercial commodities, second only to California. Michigan agriculture generates $60.1 billion for the state economy and employs nearly one million residents (MAS 2006-07). Because Michigan habitats support many crops, it is not surprising that Michigan is home to over 300 native bee species (Mitchell 1960). The mutualistic dependence between native bees and plants is central to their biological success. Michigan is the United States' number one producer of blueberries and tart cherries, and the third largest producer of United States' apples, behind Washington and New York; all three products are heavily dependent on bee pollination (MAS 2006-07).

Southwest Michigan is a particularly rich area for the production of fruits and vegetables. In 2006, the top three counties in Michigan for apple production were located in southwest Michigan (Kent, Berrien, Ottawa/Van Buren) and the top four counties in Michigan for blueberry production were located in southwest Michigan (Van Buren; Ottawa; Allegan; Berrien) (MAS 2006-07). Because these abundant crops heavily depend on bee pollination, we suspected southwest Michigan to be present with native bees and an excellent region for our study.

The purpose of the study was to collect baseline data for a long-term monitoring program of native bee diversity in southwest Michigan. We chose to conduct our study at the Pierce Cedar Creek Institute (PCCI), located in Hastings, Barry County, Michigan. PCCI is set on 661 acres and contains forests, wetland, mixed vegetation and several large open fields that contain a diversity of flowering plant species. Despite the increasing urban sprawl throughout the United States, the area surrounding PCCI has remained relatively rural. This low-impact, heterogeneous environment may conserve bee nesting habitat and therefore support a good diversity of bee species.

To collect baseline data, we performed our survey in various habitats at various times throughout the warmer months of the year when bees are active. The habitats were forested hard-woods, wetlands, sandy sediment, and wildflower fields. Additionally, we sampled bee diversity using bee bowls and aerial netting in order to collect the most diversity possible. In addition to a general survey of bee diversity we addressed questions surrounding factors that could potentially influence native bee populations: (1) How does bee diversity differ within habitat types? (2) How does bee diversity change seasonally over time within habitats? (3) How does mowing affect bee diversity? (4) Are the two

collecting methods (bee bowl and aerial netting) equally effective? We catalogued bee diversity according to species, parasitic versus non-parasitic habit, sociality, and nesting habit (e.g. ground or wood). We expected an increase in native bee diversity in a more heterogeneous floral habitat. We expected an increase in diversity in the later summer months because of the consistently warmer temperatures and increased floral abundance. Lastly, we anticipated that a human disturbance, specifically mowing, would decrease the native bee diversity due to the destruction of its nectar and pollen sources. Additionally, we conducted preliminary pollination observations to gain insight into levels of floral specialization by visiting bees and to develop appropriate sampling procedure for future studies.

Methods

Study System

This study was conducted at Pierce Cedar Creek Institute (PCCI) in Hastings, Barry Co., Michigan. PCCI is set on more than 660 acres of wetlands, forests, marshes, streams, lakes, and prairies. The rural environment in which this blend of diverse habitats is located is relatively undisturbed by human impact. We sampled bee diversity along ten 70-meter transects on various habitats. Of the ten transects, five were classified as "Open Field," two were described as "Mixed," and three were described as "Woody" (Figure 1). The Open Fields were dominated by wildflowers and prairie grasses. Open Fields containing Transects 1 and 2 were covered with wildflowers including white beardtongue (*Penstemon digitalis*), golden rod (*Solidago speciosa*), red clover (*Trifolium pretense*), Queen Anne's lace (*Daucus carota)*, and oxeye daisy (*Leucanthemum*

vulgare). Open Fields containing Transects 4 and 7 were covered with red clover (*Trifolium pretense*), Queen Anne's lace, oxeye daisy*,* and daisy fleabane (*Erigeron annuus).* The Open Field containing Transect 3 was covered with butterfly milkweed (*Asclepias tuberosa*), Queen Anne's lace, and white beardtongue early in the summer season, but was comprised of mostly tall prairie grasses reaching heights of 3 m by mid-summer. The Mixed habitats, Transects 5 and 6, were marshy and sandy habitats respectively. The Woody habitats were dominated by older hardwoods such as black cherry (*Prunus serotina*), black walnut (*Juglans nigra*), black oak (*Quercus kelloggii*), and grey dogwood (*Cornus racemosa*) and herbaceous understory of scattered grasses. Samples were collected in May-August 2008 on approximately a monthly basis. Due to time constraint and manpower, only data from Transects 1-5 were collected for the month of May.

We used two methods to sample bees: bee bowls and aerial netting. Each method may be biased in terms of species it yields (Stephan and Rao 2007); therefore, by performing both we could more accurately collect a representative sample of native bees. Weather conditions of humidity, temperature, and wind speed ranges were measured at the PCCI Weather Station and noted during all days of sampling.
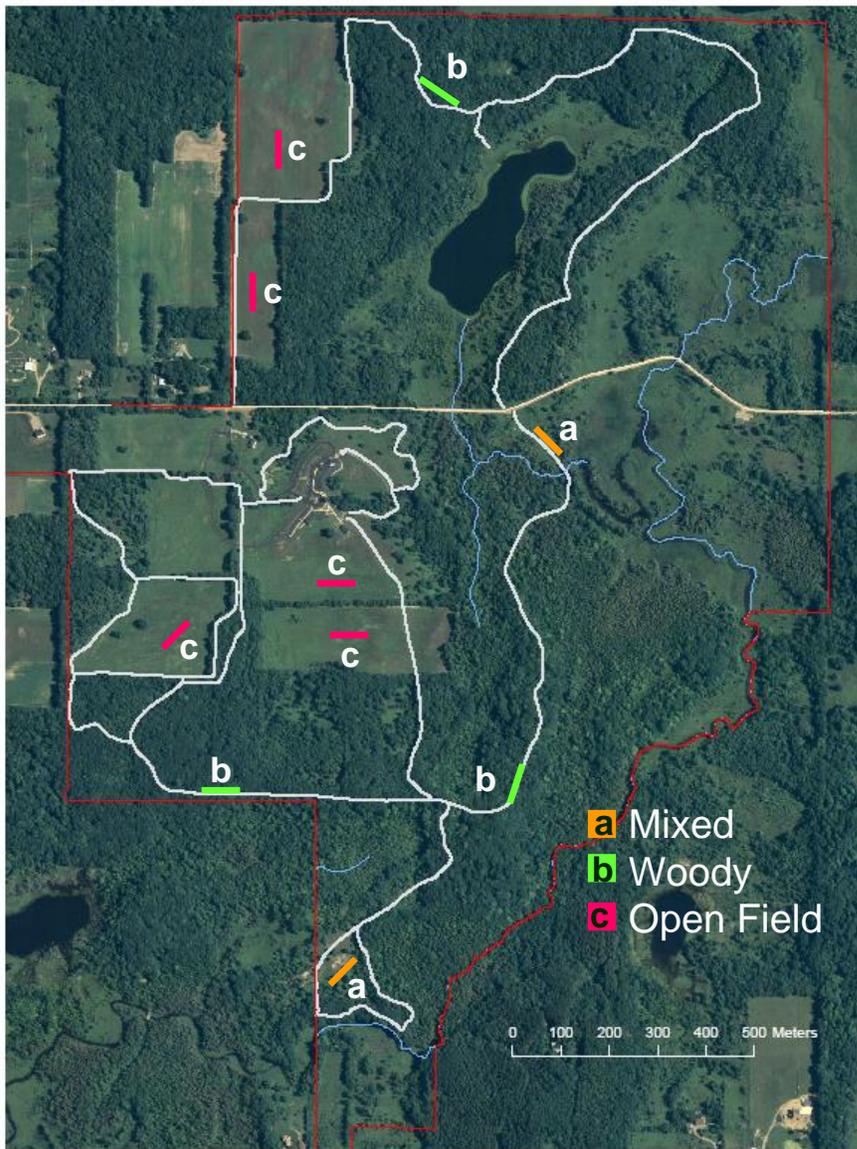
Figure 1. Locations of transects on Pierce Cedar Creek Institute property.

Bee Bowls

Bee bowls consisted of 96 ml plastic portion cups (Gordon Food Services, Grand Rapids, MI) that were filled two-thirds full of soapy water containing Dawn® ultra concentrated dishwashing soap with original scent. We used three colors of bee bowls: opaque white bowls were left unpainted, whereas the inner surface of the translucent bowls were painted with fluorescent blue or fluorescent yellow paint made using a silica flat base color and mixing in fluorescent yellow or fluorescent blue pigment (Guerra

Paint Co., New York City, NY). These bee bowls acted as visual attractants to the bees (Droege 2007) and trapped bees landing in the liquid. We placed the bee bowls every five meters in an alternating pattern along each transect. The five meter distance has been shown to be an effective distance apart to avoid competition between the bowls (Carboni and LeBuhn 2007). We set up the bee bowls before 0900 h on a given day and picked them up after 1500 h on the same day. This time period ensured coverage of peak bee activity hours. We combined the contents of all 15 bowls of a transect to form a single sample. Preference for particular bowl color was not examined.

Contents of bowls were strained in the field and then preserved in 70% ethanol until bees could be pinned. To remove pollen that may obscure hairs and other identification features, bees were washed by initially straining the 70% ethanol and rinsing the bees while in a glass jar capped with a plastic screen. We dried the bees in the glass jar by using a funnel attached to a hair dryer that was set on high and cool settings. This caused the hairs of the bees to fluff and separate which allowed for easier identification. Finally, the bees were pinned through the thorax or glued onto a pin and labeled with site, transect, date, and collector information.

Aerial Netting

We performed aerial netting along each transect on a monthly basis from June-August 2008. We spent a total of approximately 30 min on each transect, walking the length twice and collecting bees found within one meter distance from the longitudinal axis of the transect using an aerial net. All aerial netting took place between 1100 h and 1400 h on a day within two days of the bee bowl collection of the same transect.

Representatives, but not all individuals of each type of bee encountered were collected. Bees were captured into killing jar containing ethyl acetate and preserved until they were rinsed, dried, pinned, and labeled in a same manner to bees captured in bee bowls.

Bee Identification and Cataloguing

We used an interactive identification key to bees of the Eastern United States (www.DiscoverLife.org) to identify each specimen to genus. To evaluate differences and changes in bee diversity at PCCI, we noted many elements regarding location collected and life histories. We recorded the date, location, habitat type, and genus. Additionally, we documented the nesting habitat, sociality, and parasitic habits of the bees for comparison.

Furthermore, the occurrence and abundance of number of individuals of bee genera were catalogued for each sample date and transect. Occurrence was determined by genera that were collected at the greatest number of transects while abundance was based on the total number of individuals of a particular genera found throughout the course of the study in all habitats.

Flower Visitation Observation

In order to gain insight into the pollination habits of the native bees, we observed bee visitation to four floral species: red clover, Queen Anne's lace, orange day lily (*Hemerocallis fulva)*, and oxeye daisy. We chose these flowers based on their distinctive colors and varied floral shape. For each pollination observation, we spent ten minutes at a particular flower or cluster of flowers and noted any bee that landed on it. Bees were

identified by sight to genus where possible and categorized as large (>8mm) or small bees (<8mm). We followed this same procedure at four different locations for the same floral species. These locations were not necessarily along an established transect. Pollination observation took place between 1100 h and 1400 h in a single day during the time period between 31 July to 11 August. We examined visitation data qualitatively to determine whether different bees preferentially visited particular flower types.

Results

Our survey yielded 987 native bee specimens representing 6 families and 34 genera (Table I). The "Open Field" habitats yielded 31 of the 34 genera. The "Mixed" habitats together yielded 18 of the 34 genera. The "Woody" habitats yielded 10 of the 34 genera.

The most commonly occurring genera for the entire data set were *Lasioglossum, Halictus,* and *Augochlorella*, occurring at 94.3%, 45.7%, 45.7% of all sampling transects respectively. Thirteen genera were collected at less than 3% of the transects. The most abundant genera were *Lasioglossum, Augochlorella,* and *Ceratina*, at 39.4%, 16.9%, 15.5% of all individuals collected, respectively. Nine genera (26.5%) were represented by a single individual.

Comparison of sampling methods

Of the 34 genera found throughout the course of the study 33 genera (97.1%) were collected using bee bowls and 9 genera (26.5%) were collected using aerial netting. Eight of the 34 bee genera (23.5%) were collected by both bee bowls and aerial netting.

Xylocopa was the only genus collected solely by aerial netting. Bee bowls captured over 19 times as many individuals as aerial netting (total abundance: bee bowls = 939, aerial netting = 48). However, when corrected for amount of sampling time, bee bowls only captured 1.4 times as many individuals as aerial netting.

Diversity and life history

The preferred nesting sites of the collected bees involved excavated or preexisting holes or openings in the ground, solid wood, or hollow stems. (Table I). The social organization of the collected bees spanned the spectrum from eusocial (e.g. *Apis, Augochlorella, Nomia*) to solitary (e.g. *Andrena, Ceratina, Osmia*) and those that show characteristics of both (e.g. *Agapostemon, Xylocopa*) . Moreover, some genera include both solitary and eusocial species.

Table I. Summary of all genera found in study and life histories. N represents non-parasitic. P represents parasitic. Abundance and occurrence is based on all ten transects.

Family	Genus	Nest Site	Sociality	Parasite	Abundance	Occurance
Andrenidae	*Andrena*	ground/sand	solitary	N	44	6
	Perdita	ground	solitary	N	3	1
	Pseudopanurgus	ground	solitary	N	1	1
Apidae	*Apis*	hive	eusocial	N	9	4
	Bombus	burrows, plant litter	eusocial	N/P	27	7
	Ceratina	stem	solitary	N	153	8
	Eucera	ground	solitary	N	2	1
	Melissodes	ground	solitary	N	9	4
	Nomada	N/A	N/A	P	14	8
	Triepeolus	N/A	N/A	P	25	6
	Xenoglossa	ground	solitary	N	4	1
	Xylocopa	wood	solitary+communal	N	1	1
Colletidae	*Caupolicana*	ground	solitary	N	1	1
	Colletes	ground	solitary	N	3	2
	Hylaeus	stem	solitary	N	12	7
Halictidae	*Agapostemon*	ground	solitary+communal	N	23	6
	Augochlora	wood	solitary	N	3	1
	Augochlorella	ground	eusocial	N	167	8
	Dieunomia	ground/wood	eusocial	N	4	4
	Duforea	ground/wood	solitary	N	1	1
	Halictus	ground	eusocial/solitary	N	52	7
	Lasioglossum	ground/wood	eusocial/solitary	N/P	389	10
	Nomia	ground/wood	eusocial	N	2	3
	Sphecodes	N/A	eusocial	P	7	3
Megachilidae	*Chelostoma*	cavities+stems	solitary	N	4	2
	Heriades	cavities+stems	solitary	N	1	1
	Hoplitis	cavities+stems	solitary	N	3	2
	Lithurgus	wood	solitary	N	1	1
	Osmia	cavities+stems	solitary	N	14	5
	Stelis	N/A	N/A	P	2	1
	Trachusa	ground	solitary	N	1	1
Melittidae	*Hesperapis*	ground	solitary	N	1	1
	Melitta	ground	solitary	N	4	3

The majority of the bee genera collected were free living species that provisioned resources for their young, but at least some species of six genera were parasitic on other bee species (Table I). Among the genera that contained parasitic species some are social parasites while others were cleptoparasitic. Additionally, hosts of the parasitic bees were noted (Table II). All of the hosts of the parasitic bees were also collected during this study.

Table II. Found parasitic genera, their hosts, and type of parasitism. S represents social parasites. C represents cleptoparasites.

Parasite	Host	Type
Bombus	*Bombus*	S
Lasioglossum	*Lasioglossum*	S
Nomada	*Andrena/Agapostemon/Nomia*	C
Sphecodes	*Halictus*	S/C
Stelis	*Megachile*	C
Triepeolus	*Melissodes*	C

Habitat Differences

We calculated the mean number of genera found along each transect for each particular habitat type. Qualitatively, the Open Field habitat yielded both the greatest mean number of genera for the study, the Woody habitat yielded the fewest mean number of genera, and the Mixed habitat was intermediate (Figure 2).
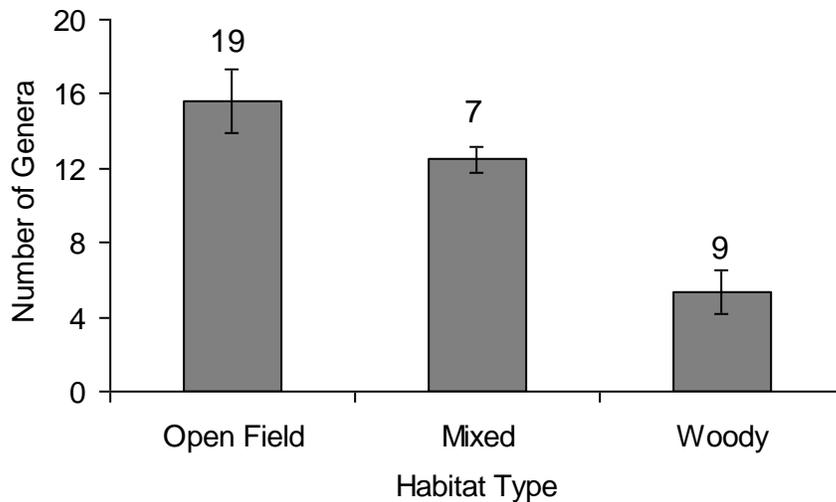

Figure 2. Mean number of genera for each habitat type. Error bars represent standard deviations. Numbers above bars indicate total number of samples.

We counted the total number of genera and individuals collected during each sample month to assess seasonal changes in diversity and abundance. During the months

of May and July, we collected the most genera. However, the collection in May was only half the sample size of collected in July. Meanwhile, we collected the second least number of genera during June, and the least number of genera during August (Figure 3).

During the month of May we collected nearly twice as many individuals than during any other month. July had the second highest number of individuals, followed by August, then June (Figure 4).
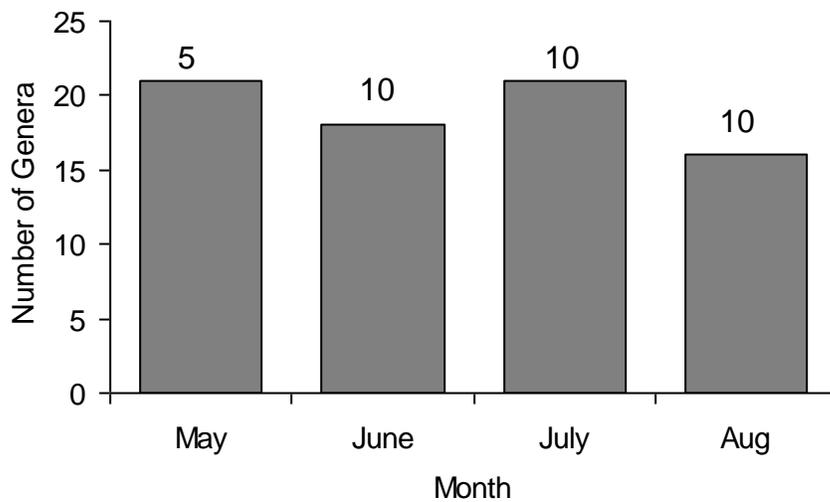

Figure 3. Total number of bee genera found on sampled transects per month. Numbers above bars indicate number of samples.
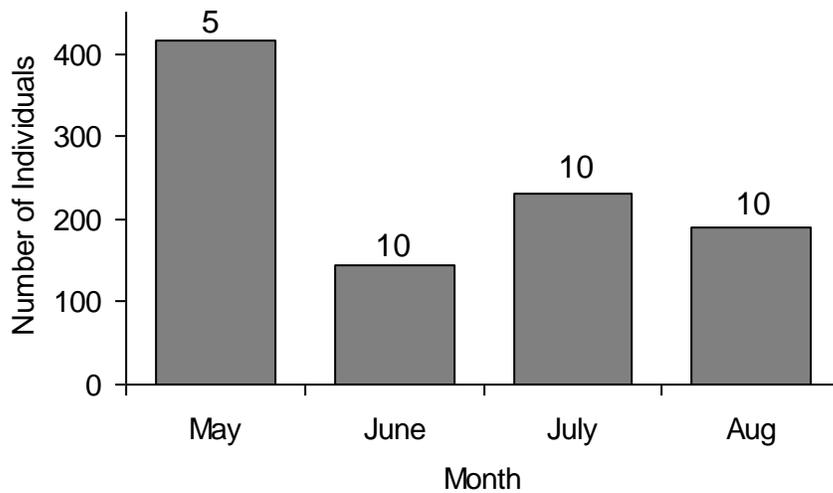
Figure 4. Total number of individuals found during each summer month. Numbers above bars indicate number of samples.

Variation Within Transects

We also evaluated variation in bee diversity within each transect over time. Specifically, we counted the total genera collected at each transect during each month and compared it to genera counts of transects located in habitats of the same category. Among the Open Field habitats, the total number of genera decreased from May to June within all transects sampled (Figure 5). For the remaining months, no general trend for diversity levels exist.
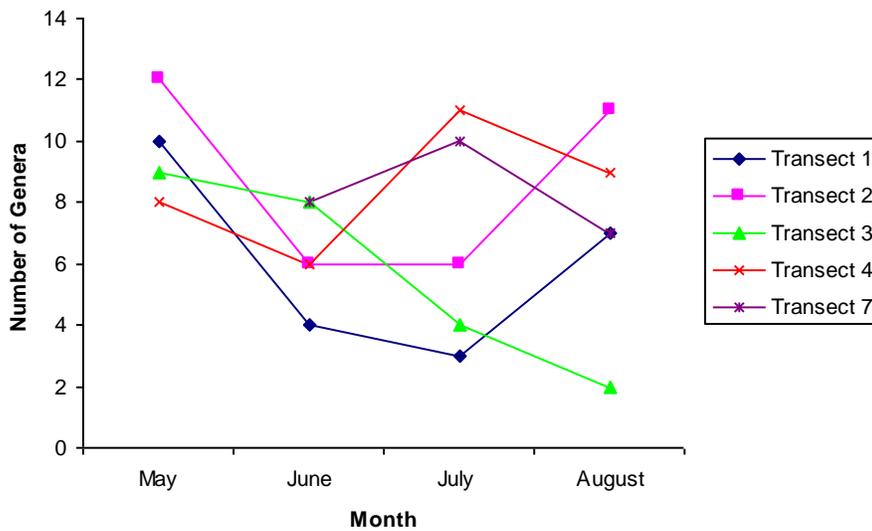
Figure 5. Number of genera collected at each Open Field transect from monthly surveys conducted May to August.

Among the Mixed habitats, the marshy area (Transect 5) showed steady decrease in total genera from May to July, but then increased in August. The sandy sediment (Transect 6) increased total genera from June to July, but then decreased from July to August (Figure 6).
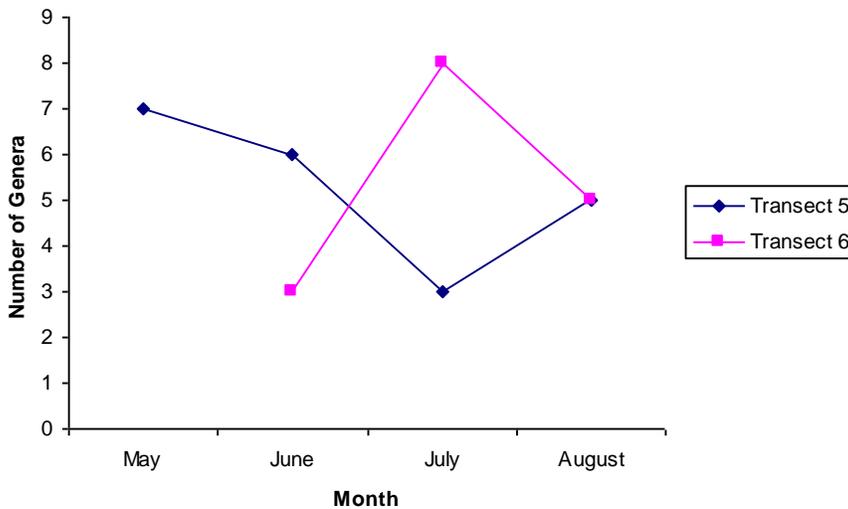

Figure 6. Number of bee genera collected at each Mixed transect from monthly surveys conducted May to August.

21

Among the Woody habitats, total genera counts remained relatively constant from June to July for all three transects. However, from July to August, Transects 9 and 10 had the same number of genera while Transect 8 increased 400% (Figure 7).
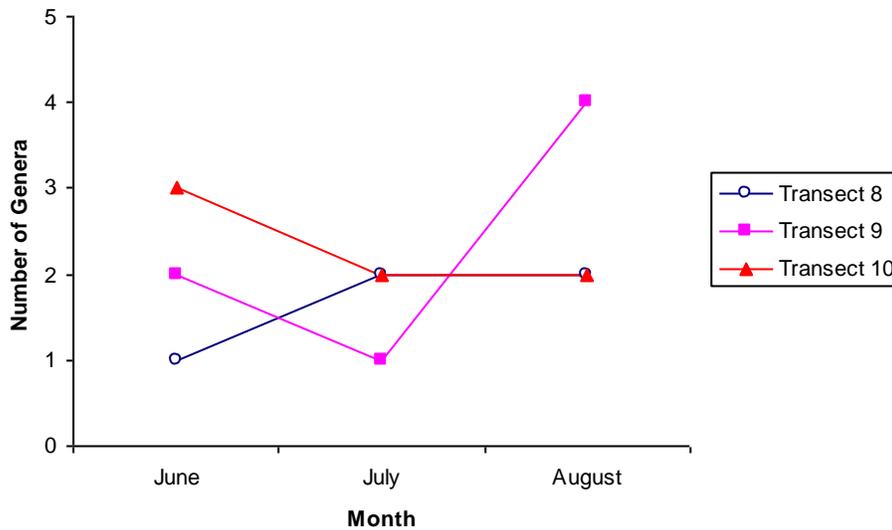

Figure 7. Number of genera collected at each Woody transect during monthly surveys conducted June to August.

Mowing Effects

There were two adjacent fields with similar vegetation that each contained bee transects, Transect 4 and Transect 7. Both fields were sampled July 10, 2008 and yielded similar numbers of genera and individuals. On July 20, the field containing transect 7 was mowed to a height of approximately 7 cm from its previous 1 m height. On July 30, one week after the mowing, we conducted a sample again in both fields. In post-mowing sampling, the newly mowed field (Transect 7) yielded twice as many genera and 6-fold greater number of individuals as the unmoved control field (Transect 4) (Table III).

Table III. Effect of mowing wildflower vegetation on total genera and individual counts. Transect 7 was mowed while Transect 4 on the adjacent field was not.

	Un-mowed transect		Mowed transect	
	Genera	Individuals	Genera	Individuals
Pre-mowing	8	30	6	22
Post-mowing	3	12	6	75

Discussion

Comparison of sampling methods

We found that bee bowls yielded many more individuals, more genera, and more occurrences of most genera than did aerial netting. However, neither method captured all genera and each method was biased in the genera of native bees it collected most effectively. Particularly, larger bees, such as *Bombus* and *Xylocopa*, were much more prevalent in the captures via aerial netting than bee bowls. Therefore, where possible, we recommend using both sampling techniques for optimal results.

One explanation for the more abundant collection of bees using the bee bowls is due to the longer time period for which they sampled. The bee bowls collected bees for at least six hours, while the aerial netting only took place for a half an hour per transect. This time bias favors the longer sampling duration of the bee bowls over the aerial netting.

As vegetation grew taller, the bee bowls became more hidden in the grasses, particularly in the Open Field sites. This was one disadvantage to the use of the bee bowls compared to the aerial netting. It was difficult for us to find the bee bowls and the end transect points in the tall grasses, thus we hypothesize the lack of visibility of the bowls caused a decline in total bee collection during the months of June, July, and August. We anticipate an increase in bee collection during the month of September once some of the vegetation has died, allowing the bee bowls to be more visible. To help

address the visibility problem in future studies, we hope to utilize mowed pathways that often run through fields at PCCI. By placing the bee bowls along these pathways, the bowls are still immersed within a habitat but are also exposed in plain sight.

Native Bee Diversity and Abundance

Our survey yielded 987 specimens representing 34 bee genera collected from various habitats in a temperate climate over the course of four months. MacKenzie and Eickwort (1996) performed a one month study in a single habitat type in New York and collected 68 specimens, representing 19 species (Williams 2001). A study performed at the E.S. George Reserve in Michigan yielded 2996 specimens representing 145 species over the course of 12 months (Williams 2001). Thirdly, a study outside of Chicago, IL the most diversity of these studies by collecting 5241 specimens representing 168 species over the course of 12 months (Williams 2001). Because we did not identify our specimens down to species and sampling efforts are not mentioned, it is difficult to accurately compare our study to these other temperate climate studies. However, when taking spatial and temporal differences into account, we anticipate that our findings would give similar results with regard to number of specimens and species. As the standard protocol we used for this study becomes more utilized, it will be easier to compare our data with other findings.

Parasitic Genera

The hosts of the collected parasitic genera were all collected at some point throughout this study. This is consistent with findings that suggest that the rate of

parasitism does not depend on habitat area but only on the local and regional abundance of hosts (Steffan-Dewenter 2003). In future studies we would like to see how parasitism affects the community structure of the hosts. Questions to investigate would include: Do parasitic bees contribute to the potentially overall decline in native bee populations? Do parasitic bees help advance the evolution of non-parasitic bees such that non-parasitic bees could survive against more threatening predators?

Mowing Effects

In contrast to our hypothesis, the disturbance of mowing actually increased the number of genera and individuals collected. There are a number of factors that could cause these results. First, the mowing took away the taller grasses that could be hiding the bowls, causing the bowls to be more visible than in the control. Additionally, because the mowing chopped off all nearby flowers, the bee bowls did not have to compete with other colorful bee attractants. Thirdly, it is also possible that the mowing created a new, functional habitat for some bees. Specifically, ground-nesting bees, such as *Bombus*, actually benefit from new nesting sites created in disturbed areas (Klein 2007).

Flower Visitation Observation

We encountered a number of challenges with the flower visit observation component of our study. Due to time constraint and manpower, we were unable to make recurrent observations to build up a useful dataset to analyze. In the future we hope to make more frequent flower visit observations in order to create a more thorough dataset, as done by Stephen and Rao (2007) in their study.

Additionally, due to the difficulty of onsite bee identification, it was challenging to identify the bees to genus in the short period of time they were on the flower. In order to collect the data we would ultimately like from the flower visitation, we recommend changing our method to pollen grain analysis. Pollen grain analysis would involve the collection of pollen from the scopa of the bee and then identifying the species of plant associated with those pollen grains (Kremen 2002). This would allow us to identify trends between genera of bees and the flowers they most frequently pollinate.

Significance of Survey

Overall, this study acted as a thorough initial sample of the native bee populations found at Pierce Cedar Creek Institute. We are pleased with our results and hope to use what we learned from this study and continue it in the future. Additionally, it is our hope that other studies similar to this one will continue to take place throughout the world in quest of creating the large dataset to accurately and thoroughly monitor and protect the invaluable native bee populations.

Literature Cited

Batra, SWT. 1995. Bees and pollination in our changing environment. *Apidologie* 26(1995): 361-370.

Carboni M, and G LeBuhn. Effect of Distance Among Bowls of Numbers of Bees Captured [Internet]. Discover Life. 2008 Oct [cited 2007]. Available from *http://www.discoverlife.org*.

Droege, S. Impact of Color and Size of Bowl Trap on Numbers of Bees Captured [Internet]. Discover Life. 2008 Oct [cited 2007]. Available from *http://www.discoverlife.org*.

Greenleaf, S S and C Kremen. 2006. Wild bee species increase tomato production and respond differently to surrounding land use in Northern California. *Biolog. Conserv.* 133(2006):81-87.

Isaacs, R and J Tuell. 2007. Conserving Native Bees on Farmland. *Michigan State Extension Bulletin* E- 2985.

Klein A-M, ad I Steffan-Dewenter, et al. 2006. Importance of pollinators in changing landscapes for world crops. *Proc. R. Soc. B.* 274(2007): 303-313.

Kraemer M E and Favi F D. 2005. Flower Phenology and Pollen Choice of *Osmia lignaria* (Hymenoptera: Megachilidae) in Central Virginia. *Environ. Entomol.* 34(6): 1593-1605.

Kremen, C et al. 2004. The area requirements of an ecosystem service: crop pollination by native bee communities in California. *Ecol. Letters* 7(2004): 1109-1119.

Kremen, C, N M Williams, and R W Thorp. 2002. Crop pollination from native bees at risk from agricultural intensification. *Proc. National Academy of Sciences* 99(26): 16812-16816.

Kremen, C and T Ricketts. 2000. Global Perspectives on Pollination Disruptions. *Conserv. Biol.* 14(5): 1226-1228.

Marlin, J C and W E LaBerge. 2001. The Native Bee Fauna of Carlinville, Illinois, Revisited After 75 Years: a Case for Persistence. *Conserv. Ecol.* 5(1): 9.

Meffe, G K. 1998. The Potential Consequences of Pollinator Declines on the Conservation of Biodiversity and Stability of Food Crop Yields. *Conserv. Biol.* 12(1): 8-16.

Michigan Agricultural Statistics. 2006-2007. pp. 1-90. USDA, NASS Michigan Field Office. Lansing, MI.

Michener, C D. 2007. *Bees of the World*, second ed. The Johns Hopkins University Press, MD, pp. 1-116.

Mitchell, T B. 1960. *Bees of the Eastern United States, Vol. I and II*. The North Carolina Agricultural Experiment Station & National Science Foundation. pp. 1-45.

Oldroyd, B P. 2007. What's Killing American Honey Bees? *PLoS Biol* 5(6): e168 doi:10.1371/journal.pbio.0050168

Packer, L. 2007. Bee Genera of Eastern Canada. Canadian Journal of Arthropod Identification.

Peters, G. 1972. Ursachen für den Rückgang der seltenen heimishchen Hummelarten (Hym., Bombus et Psithyrus). Entomologische Berichte 1972: 85-90.

Rasmont, P.1988. Monographie écologique et zoogéographique des bourdons de France et de Belgique (Hymenoptera, Apidae, Bombinae). 309+lxi pp. Ph.D. thesis, Faculté des Sciences agronomiques de l'Etat, Gembloux.

Steffan-Dewenter, I. 2001. Importance of Habitat Area and Landscape Context for Species Richness of Bees and Wasps in Fragmented Orchard Meadows. *Conserv. Biol.* 17(4): 1036-1044.

Stephen, W P and S Rao. 2007. Sampling Native Bees in Proximity to a Highly Competitive Food Resource (Hymenoptera: Apiformes). *J. Kansas Entomological Society* 80(4): 369-376.

Ullah, S and S P Faulkner. 2006. Denitrification potential of different land-use types in an agricultural watershed, lower Mississippi valley. *Ecological Engineering* 28(2): 131-140.

Winfree, R et al. 2007. Native bees provide insurance against ongoing honey bee losses. *Ecol. Letters* 10(2007): 1105-1113.

Williams, P.H. Environment Change and the Distributions of the British Bumble Bees (*Bombus* Latr.) *Bee World* 67:50-61.

Williams, N. M., R. L. Minkley, and F. A. Silveira. 2001. Variation in Native Bee Faunas and its Implications for Detecting Community Changes. *Conserv. Biol.* 5(1):7.

Shepherd, M et al. 2003. *The Conservation Handbook*. The Xerces Society., OR, pp. 6-23.