Native Bee Diversity in Conventional and Organic Hedgerows in Eastern
Ontario

by

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Abstract

Agricultural intensification has resulted in reduced biodiversity on farmland. A consequence of this decline is the potential loss of ecosystem services. The effects of intensification on native bees in agricultural habitats are not well understood. The objective of this study was to compare bee diversity in hedgerows on conventional and organic farms in order to assess how different management techniques affect bee populations. Bee diversity data was also analyzed in relation to other field variables, floral diversity and landscape structure. Bees were sampled by pan trapping and netting in hedgerows adjacent to soybean fields on 9 pairs of organic and conventional farms in Eastern Ontario, Canada during the summer of 2009. Bee diversity did not differ between farm types at the local scale; however bumble bee abundance was higher on organic farms in intensively managed landscapes. The amount of semi-natural habitat emerges as the most important factor for bee populations.

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Introduction

Biodiversity loss is one of the most important problems facing the world today (Loreau *et al.* 2001, Vitousek *et al.* 1997). Biodiversity can be seen as important for its intrinsic value and for its value in terms of the ecosystems services that it provides. One such ecosystem service is pollination, provided by invertebrate and vertebrate pollinators, the most important of which are bees (Committee on the Status of Pollinators in North America 2007, Goulson 2003, Michener 2007.).

Importance of wild bees - agriculture

The obvious benefits of the honey bee are the production of honey and wax. The act of pollination is far more important in comparison, yet it is often underestimated. The honey bee is the most important pollinator for agriculture in North America (Kevan 1999, Westerkamp 1991). In fact, the honey bee is not native to North America at all. The species was imported from Europe to pollinate agricultural crops. Wild bees are not given the credit they deserve in terms of crop pollination, which is usually completely attributed to the honey bee (Buchmann & Nabhan 1996). However, with the occurrence of Colony Collapse Disorder, which has caused huge declines in honey bee populations, it has proven risky to rely on a sole species of pollinator for all crop pollination (Stokstad 2007). Thirty-five per cent of the world's crops are dependent on animal pollination (Klein *et al.* 2007). A pollinator shortage should therefore be of serious concern. While it is obvious that wild bees would be better pollinators of natural vegetation in North America, it is less well-known that wild bees are more appropriate agents for pollination of certain cultivated crops. Some native species are now being managed for crop pollination, for example, bumble bees (*Bombus* spp) are well-suited for pollinating

tomatoes in greenhouses, and the alfalfa leafcutter bee (*Megachile rotundata*) is efficient at pollinating alfalfa crops (Michener 2007, Free 1993). If honey bees are to decline further then wild bees will be needed to fill in the pollination gaps (Winfrey *et al.* 2007, Yachi & Loreau 1999).

Importance of wild bees – natural vegetation

In temperate climates wild bees are responsible for pollinating many kinds of shrubs and herbaceous plants. Bees are directly responsible for maintaining aspects of ecosystems on which other wildlife depend. Honey bees are very generalist when it comes to pollination. They are therefore less likely to visit the same species of flowers consecutively, which means that they are less likely to perform pollination. Wild bees are much more specialized and are thus better suited to wild flower pollination. (Buchmann & Nabhan 1996). If plants lose their pollinators this could have dramatic effects on the entire ecosystem (Kearns & Inouye 1997). The loss of specialized pollinators would no doubt cause a change in species assemblages in the plant community due to specialized relationships between plant and pollinator. Biesmeijer (2006) tested this assumption and found that, in Britain and in the Netherlands, insect-pollinated plants were decreasing, wind-pollinated plants were increasing and self-pollinated plants remained the same. However it is not clear whether the declining plants are causing the decline of the pollinators or vice-versa (Biesmeijer *et al.* 2006, Kearns & Inouye 1997, Potts *et al.* 2010). If bee abundance or diversity declines then there could be negative impacts on the entire ecosystem.

Bees as bioindicators

In order to assess the health of an ecosystem it necessary to have some sort of indicator that provides evidence as to whether or not ecosystem processes are functioning normally. Bees can act as bioindicators in ecosystems. Bees are especially susceptible to extinction due to their single locus sex determination (Zayed *et al.* 2005). Reduced genetic variability can eventually result in an extinction vortex (Packer & Owen 2001). A reduction in genetic variation within pollinator populations will make them less likely to be able to adapt to environmental changes. Bee guilds can also act as bioindicators by the way different guilds are affected by environmental disturbances (Williams et al, 2010). Kevan (1999) argues that pollinators, including wild bees, should be seen as bioindicators because of their diversity and their role as pollinators of agricultural crops and natural vegetation.

Life History

What are bees?

Bees (family: Apoidea) are part of the Order Hymenoptera, which also includes wasps, ants and sawflies. Bees differ from wasps in that wasps are predatory animals whereas bees have evolved to become herbivores. Although wasps will feed on flower nectar, they will not eat and collect pollen like bees (Michener 2007). Bees can be readily distinguished from wasps by the presence of branched hairs (Packer *et al.* 2007).

Wild bees nest in soil, wood, pith, snail shells, and other natural cavities or will construct nests attached to structures. Bumble bees will nest on the ground or in abandoned rodent nests. Nests are made of burrows and cells where each individual larva grows along with

its food supply. Parasitic bees do not make nests of their own. True parasitic bees are either social parasites or cleptoparasites. Social parasites enter a colony and replace the queen, forcing the worker bees to raise the offspring of the parasite queen (i.e. *Bombus* (*Psithyrus*)). The majority of parasitic bees are cleptoparasites, that is, they lay their eggs in the nest of a host species but do not remain in the nest to raise their young (Michener 2007).

Most wild bees are solitary, where one female will construct her own nest and provide food for her own young. Wild bees can also be social and live in colonies, which consist of two or more adult females living in a nest. Bumble bees (*Bombus* spp) are an example of primitive eusocial bees, where the queen works alone to form the colony but is still able to perform other duties such as foraging and nest construction. Social bees tend to be generalists (polylectic) since they are active all season. Solitary bees, however, have short flight seasons and are therefore more likely to be specialists (oligolectic) on flowers that happen to be blooming at the same time. Pollinators are mostly made up of female bees that are collecting pollen as a protein source for themselves or for their larvae.

Nectar is the main source of carbohydrates for bees and is eaten by adults. It is mixed in with pollen to feed to larvae. The act of pollination occurs when the bees end up losing excess pollen on the stigmata of another flower. Male bees (and female parasitic bees) take nectar from flowers but don't have the necessary structure to carry pollen and are therefore much less efficient at pollinating (Michener 2007).

The foraging distance of different bee species is important in order to determine the appropriate scale at which they respond to the landscape (Kremen & Ostfeld 2005). This has implications for pollinator conservation and management, as well as crop pollination

and plant conservation (Lennartsson 2002, Osborne *et al.* 1999). A study by Osborne *et al.* (1999) found that, after attaching radar transponders to bumblebees, they travelled a range of 70-631 m from their nest when foraging. Greenleaf *et al.* (2007) found that bee body size is predictive of bee foraging distance, in a non-linear sense. Larger bees are able to forage greater distances than smaller bees (Greenleaf *et al.* 2007). The majority of bees will be affected by a landscape scale of less than 1 km (Gathmann & Tschamntke 2002, Steffan-Dewenter *et al.* 2002).

Patterns and determinants of bee diversity

It is estimated that there are as many as 19,700 species of bees worldwide (Ascher *et al.* 2008; Pickering, 2011). Grasslands, forest margins and disturbed areas provide the most floral opportunities and are considered high quality habitat for wild bees, unlike uninterrupted forest, which is usually wind-pollinated in temperate climate (Michener 2007). One of the problems with assessing wild bee abundance and diversity is the lack of baseline data: museum collections can act as presence/absence data for bee species; however there is no way to compare past and present abundance. This enforces the need to conduct ecological studies on wild bees and the factors affecting their populations (Michener 2007).

Bees in decline

There is much information on the status of honey bees due to our dependence on them for crop pollination; however the population status of wild bees is not as clear (Allen-Wardell *et al.* 1998). There is a growing consensus, however, that bees are in decline (Biesmeijer *et al.* 2006, Committee on the Status of Pollinators in North America 2007,

Kluser & Peduzzi 2007, Watanabe 1994). There have been several studies that point towards the decline of wild bees. A study by Biesmeijer et al (2006) found an overall reduction of bee species richness of about 30% from pre-1908 to post-1980 in England and the Netherlands. Of the wild bees, bumble bee declines are the most well known. Colla and Packer (2008) re-surveyed 43 sites in 2004-2006 that were originally sampled for bumblebees in 1971-1973. The researchers found that the majority of the bumble bee species declined in abundance over the time period while a few of the species' abundances increased. Of special note is the species *Bombus affinis*, which was found to have declined considerably over its entire native range (Colla & Packer 2008). The first bumble bee (*Bombus franklini*) was added to the IUCN's red list in 2008 (Kevan 2008).

Possible causes of bee decline – the effects of agricultural practices

Biodiversity is faced with many threats, including pollution, invasive species and climate change, however the most significant threat is natural habitat loss through human-induced landscape modification (Vitousek *et al.* 1997). The conversion of natural areas to agricultural land is a major form of habitat loss. In fact, it is predicted that 10^9 hectares of natural land will be converted to agriculture by the year 2050 (Tilman *et al.* 2001).

Pollinator abundance and richness has been lost due to agricultural intensification and habitat loss (Potts *et al.* 2010; Williams et al, 2010). Although wild bees do benefit from some degree of disturbance, which promotes the growth of herbaceous plants and wildflowers, too much human-caused disturbance can have negative impacts (Williams et al, 2010). Destruction of floral resources, of nesting habitat and the creation of large fields of monoculture as well as the application of pesticides all affect wild bees in adverse ways (Michener 2007; Williams et al, 2010). Habitat destruction is detrimental

to bee populations through the loss of floral resources, nesting resources, and mating and resting sites, especially since some oligolectic bees require specific flowers (Kearns & Inouye 1997, Kevan 1999).

Agricultural intensification

Agriculture is an example of human-caused landscape modification on a large scale. Agriculture has potential to act as a semi-natural habitat for some wildlife, however, agricultural intensification over the past 50 years has resulted in loss of biodiversity on farmland, and further intensification continues to threaten biodiversity (Feber *et al.* 1997, Tilman *et al.* 2001). Conventional agriculture consisting of large parcels of land devoted to monoculture, especially crops consisting of wind-pollinated plants such as wheat and corn, constricts bee populations to remnant semi-natural habitats such as field margins and roadsides. This also isolates bee populations from one another, which can reduce genetic diversity. The destruction of natural vegetation removes food resources from bee populations when crops are not in bloom or when the crop is not insect-pollinated (Kevan 1999). In Europe the majority of natural habitat has been lost and biodiversity is now supported by agricultural land and intensification has led to declines in biodiversity (Kevan 1999). This scenario can also be applied to agricultural areas in North America. The protection of wild bees is important and areas should be set aside in agricultural landscapes for their resource use (Corbet 1995). In the past pollination was viewed as a ‘free’ service by farmers. With evidence of a decline it can no longer be viewed as such.

Pesticide use and tillage

Pesticides are often considered to be responsible for bee decline in agricultural landscapes (Brittain *et al.* 2010b, Gels *et al.* 2002, Johansen 1977, Kevan 1975, Kevan 1999, Kevan *et al.* 1997, Thomson *et al.* 1985). Kevan (1975) found that blueberry crop failures in New Brunswick were due to the effects of Fenitrothion, an organophosphorus insecticide that was sprayed to control spruce budworm. This insecticide is known to be toxic to bees and its application resulted in lower bee abundance in fields adjacent to where the insecticide was sprayed. However, in contrast to studies conducted in a laboratory setting, it can be difficult to pin-point pesticides as the main culprit when so many other factors are at play in the field. In addition to the toxicity effects, pesticides (mostly herbicides) can have negative impacts in that they can select against floral resources that wild bees depend upon (Johansen 1977).

Tillage is an important factor when considering ground-nesting bees. Many species of bees prefer to construct nests in the ground where the soil surface is exposed (Michener 2007, Packer *et al.* 2007). This makes areas alongside of crop fields as well as in between crop rows an attractive place for bees to nest. Two studies on the effects of tillage on bee abundance produced conflicting results. A study by Shuler *et al.* (2005) showed that the squash bee (*Peponapis pruinosa* Say), a ground-nester, had an abundance that was 3 times higher in no-till fields compared with tilled fields. There was no significant effect of tillage on abundances of bumblebees (*Bombus sp*) or honey bees (*Apis mellifera*). Neither of these bees excavate their nests in bare substrate. The authors did not find any effects of pesticides, and this is likely due to the large variation in chemicals that were used by the participating farmers (Shuler *et al.* 2005). In contrast,

another study in the same area found no effect of tillage on abundance of *P. pruinosa*. The authors did find, however, that *P. pruinosa* shows a preference for nesting in the ground within crops, both at tillage and no-till sites, therefore it is conceivable that the nests would be negatively affected by farming practices. The results from this study may be due to the fact the researchers focused on pumpkin crops that are grown later in the season after the larvae have emerged from their underground nests, unlike Shuler et al who studied a variety of *Cucurbita spp.* (Julier & Roulston 2009).

Possible solutions to bee decline in agricultural landscapes

Organic farming, landscape context and conservation

Intensive agricultural practices have been blamed for biodiversity declines on farmland (Krebs *et al.* 1999). Organic farming is an alternative that benefits wildlife in agricultural areas due to lack of chemical inputs and subsequent increase in habitat heterogeneity (Hole *et al.* 2005). In the same sense, organic farming may benefit wild bee diversity in agricultural landscapes. Many studies have been conducted that look at the benefits of organic farming to overall arthropod biodiversity and also to specific arthropod groups, including pollinators, and more specifically, bees. The following table summarizes some of the major contributions to this research.

Author(s)	Study goal	Study subject	Location	Results
(Feber <i>et al.</i> 1997)	To determine the effects of farming system (organic vs. conventional) on butterfly abundances	Butterflies	Europe	Organic: Total butterfly abundance was higher on organic farms than on conventional farms.
(Weibull <i>et al.</i> 2000)	How is butterfly abundance and diversity affected by farming system and landscape heterogeneity?	Butterflies	Europe	No difference: the researchers found that butterfly abundance and diversity was more dependent on landscape heterogeneity than on farming system.
(Kleijn <i>et al.</i> 2001)	Does agri-environmental schemes in Europe increase biodiversity?	Plants, birds, bees and hoverflies	Europe	Organic: There was no change in diversity between farm management types for plants and birds. There was an increase in diversity for bees and hoverflies on farms with agri-environmental management.

(Kremen <i>et al.</i> 2002)	Does farming system and/or proximity to natural habitat affect pollination services by wild bees?	Bees	North America	Organic, if near natural habitat: This condition showed sufficient pollination by wild bees. All other conditions (conventional, or organic fields far from natural habitat) were insufficient.
(Weibull <i>et al.</i> 2003)	How does farming system and landscape heterogeneity affect the diversity of different groups?	Plants, butterflies, carabids, rove beetles and spiders	Europe	No difference: Species richness did not differ between farm management systems, although carabid diversity was higher on conventional farms. Landscape heterogeneity was correlated with an increase in species richness.
(Kremen <i>et al.</i> 2004)	How does crop pollination vary between organic and conventional farms along a gradient of isolation from natural habitat	Bees	North America	No difference: Crop pollination was completely dependent on amount of natural habitat in the landscape.
(Wickramasinghe <i>et al.</i> 2004)	Do nocturnal insects differ in abundance and diversity between farming systems?	Nocturnal insects, mostly Lepidoptera	Europe	Organic: Insect abundance, species diversity and moth diversity was higher on organic farms.

(Belfrage <i>et al.</i> 2005)	The effects of farm size and organic farming on diversity	Birds, butterflies, bumblebees and plants	Europe	Organic: Bumblebee abundance was greater on the small farms. The largest difference was between small organic and large conventional. There were also differences between small and large organic farms. The authors conclude that it is also important to consider farm size as well as farming system.
(Bengtsson <i>et al.</i> 2005)	Does organic farming affect species richness and abundance: a meta-analysis	Birds, predatory insects, caribidae, non-predatory insects, soil organism and plants.	Europe	Organic: Overall species richness was usually higher on organic compared with conventional. Abundance of different organisms tended to be higher, but this was variable. The effects of organic farming will be much more pronounced in intensively managed landscapes with less natural habitat for refuge.
(Hole <i>et al.</i> 2005)	Does organic farming benefit biodiversity: a literature review	Mammals, birds, invertebrates.	Various	Organic: but the results are variable and further research is needed

(Rundlof & Smith 2006)	An assessment of butterfly abundance and diversity in pairs of organic and conventional farms in homogeneous and heterogeneous landscapes	Butterflies	Europe	Organic: but only in homogeneous landscapes
(Clough <i>et al.</i> 2007)	Alpha and beta diversity of arthropods in organic and conventional fields	Bees, and others	Europe	Organic: Bee diversity was higher in organic fields. Landscape effects also apply.
(Holzschuh <i>et al.</i> 2007)	The effects of farming systems, landscape composition and regional context on bee diversity	Bees	Europe	Organic: Bee diversity was higher in organic farms, but also correlated with flower cover and diversity. The effect of farming system was more pronounced in a homogeneous landscape.
(Williams & Kremen 2007)	How does resource distribution in the landscape affect bee survival in semi-natural areas as well as on conventional and organic farms?	Bees	North America	Organic: Bees on conventional farms were most adversely affected by a lack of floral resources in the landscape; bees on organic farms were better able to cope.

(Holzschuh <i>et al.</i> 2008)	To determine the effects of higher proportions of organic fields in the landscape on bee diversity and abundance.	Bees	Europe	Organic: Landscapes with a higher proportion of organic fields in the landscape supported a higher diversity and abundance of wild bees.
(Winfree <i>et al.</i> 2008)	How does land use intensity (organic vs conventional and habitat area) at two scales affect flower visitation rates by bees?	Bees	North America	No difference: Neither farm type nor amount of natural habitat affected bee visitation rates. The authors attributed this to heterogeneity in the landscape: the effects of organic farms or amount of natural habitat will be more pronounced in homogeneous landscapes that are devoid of small habitat islands.
(Boutin <i>et al.</i> 2009)	How does abundance family richness of beneficial and phytophagous insects differ between farming systems?	Beneficial and phytophagous insects	North America	Arthropod richness and composition were more affected by plant diversity and landscape factors than by farm type. Insect abundance was marginally higher on organic farms.

(Brittain <i>et al.</i> 2010a)	A study looking at differences in abundance and diversity of bees with farm system and proportion of uncultivated land as factors.	Mostly bees	Europe	No difference: The authors found that there was no difference in abundance, diversity, or guilds between C and O. They attribute this to the lack of difference of floral resources between farming systems in their study.
(Hodgson <i>et al.</i> 2010)	Optimizing crop yields and wildlife conservation in agricultural landscapes	Butterflies	Europe	Organic: Organic farms supported higher diversity than did conventional farms, but not as much as reserves. Landscape plays a role.

A meta-analysis and a literature review both found positive, but variable, effects of farm type on biodiversity (Bengtsson *et al.* 2005, Hole *et al.* 2005). Other studies have found that incorporating landscape scale effects can alter the effects of organic farming on biodiversity (Brittain *et al.* 2010a, Clough *et al.* 2007, Holzschuh *et al.* 2007, Holzschuh *et al.* 2008, Kremen *et al.* 2004, Kremen *et al.* 2002, Weibull *et al.* 2000, Weibull *et al.* 2003, Williams & Kremen 2007, Winfree *et al.* 2008). Therefore, farming system can affect biodiversity at the local scale, however, this approach is not realistic since bees, and other highly mobile organisms, are also subject to landscape scale effects. From the above it can be concluded that when the landscape scale is taken into account organic farms will have much more of an effect in homogeneous landscapes of intensive farming since in these situations the organic fields will serve as areas of resources due to the higher diversity of herbaceous plants (Tscharntke *et al.* 2005). In landscapes with high heterogeneity, there will be less of a difference between organic and conventional farms in terms of bee abundance and diversity since there are already sufficient resources in the landscape. Similarly, the amount of natural habitat or the distance to natural habitat will have an effect on bee abundance and diversity and will thus alter the benefits of organic farms in the landscape (Ricketts *et al.* 2008). In addition, in some systems there is not a large difference between organic and conventional fields in characteristics such as field size or weed diversity (Winfree *et al.* 2008).

Research objectives

Very few bee diversity studies have been conducted in Ontario, Canada. The purpose of this study is to determine whether bee abundance or diversity differs between conventional and organic farm types in the field cropping regimes of Eastern Ontario. If

not, then other factors, including floral community composition, tillage, and pesticide use are taken into account. It is hypothesized that ground-nesting bees will be negatively affected by tillage practices. The amount of semi-natural habitat was also incorporated in order to test for interactions between factors at the local and landscape scale. It is predicted that there will be a higher abundance and diversity of bees on organic farms in homogeneous landscapes of intensive agriculture.

Methods

Sites selection

Eighteen sampling sites were established in the area around Ottawa, Ontario, Canada (Figure 1). In order to limit as many variables as possible all sampling was done along hedgerows which border soybean fields. A paired design was used to compare conventional and organic farms, therefore the 18 sampling sites consisted of 9 organic-conventional pairs. Contact information for organic soybean growers in the Ottawa area was provided by Homestead Organics (www.homesteadorganics.com). Additional soybean farmer contacts were provided through interaction with local farmers. All organic sites were certified, which requires at least 3 years of organic management (Canadian General Standards Board, 2008). Every attempt was made to pair organic and conventional sites using the following criteria: geographic location, hedgerow vegetation type (i.e. treed vs. grassy), hedgerow orientation and crop type on the opposite side of the hedgerow from sampling location. Paired sites were between 2 and 6 km apart. All sites were separated by at least 1 km, so that the landscape around each site was independent. Since it is important that pan traps be exposed to as much sunlight as possible, every attempt was made to sample on the south-side of hedgerows with east-west orientation. Since it was not possible that all sites could meet these criteria, effort was made to ensure that each pair of hedgerows had similar orientation. Again, this was not possible in all cases. In order to guarantee that each pair of sites was as similar as possible it was ensured that the crop type on the opposite side of the soybean field matched: either they were both a crop (soybean, corn, wheat etc) or they were either hay or field. In addition, the field management in the field on the opposite side of the hedgerow matched the

treatment; i.e. organic sites were adjacent to organic fields, and conventional sites were adjacent to conventional fields.

Bee sampling

Pan Traps

Bees were sampled approximately every 14 days beginning May 6th, 2009 and ending on September 10th, 2009 for a total of 9 sampling runs (see Appendix 1 for exact dates).

Each sampling day was chosen based on the predicted weather: sampling only took place on days that were at least mostly sunny and without precipitation or strong wind. Bees were collected by pan traps using the standardized protocol developed by CANPOLIN (www.uoguelph.ca/canpolin). All traps on all 18 sites were set up by 9 AM on the chosen sampling day and were retrieved beginning at 5 PM the same day. The pan traps consisted of plastic bowls that were painted fluorescent yellow or blue, or were left as white. At each site 30 pan traps were placed 3 m apart along the hedgerow at the edge of the soybean field, forming a 87 m long transect. All three colours of pan traps were used at each site so that there was an equal proportion of each. The three colours of pan traps were placed in a random order at each site over the season. This was done by randomly choosing the colour of the first pan trap in the transect and then by randomly choosing the second colour out of the remaining two. This order of colours was used for the remainder of the transect. Each pan trap was filled $\frac{3}{4}$ full of a solution of water and unscented dish soap (Blue Dawn). Pan traps were set up in an area along the length of the hedgerow where the vegetation was the least dense so that the traps were exposed to the most amount of sunlight possible. Tall vegetation was removed from around the pan traps as the season progressed in order to ensure that the traps were visible from at least 3 m

away. At the end of the day the samples from each trap were collected in individual Ziploc bags and were brought back to the lab where they were transferred to vials of 70% ethanol. Bees remained in the ethanol until they were removed and pinned for identification.

Bumble bee netting

Bumble bees (*Bombus* spp) were sampled at the same paired field sites. Specimens were collected opportunistically using an insect net over the course of the hedgerow. Each site was actively sampled for 30 minutes, not including the time it took to process each specimen. Sites were sampled approximately every 14 days for the months of July and August 2009, 4 separate times over the course of 2 months (see Appendix 2 for exact dates). Sampling was conducted between 9 AM and 5 PM. Pairs of sites were always sampled consecutively, the order of sampling reversed at each sampling period. All sites were sampled within one week within each sampling period. Sampling did not take place on days that were not sunny or when there was strong wind. Bumble bee specimens were terminated using a cyanide killing tube and were stored in the freezer until they were pinned for identification.

Bee identification

Each bee was first sorted to genus using Packer et al (2007). Specimens were then identified to species using Lavery and Harder (1988) for *Bombus* spp, Rehan and Richards (2007) for *Ceratina* and McGinley (1986) for the sub-genus *Lasioglossum*. Specimens from all other genera were identified using Mitchell (1960, 1962). Following initial species identifications, the genera *Agapostemon*, *Auglochlorella*, *Augochlorella*, *Ceratina*, *Halictus* and sub-genus *Lasioglossum* were compared to specimens in the

Canadian National Collection. Specimens from the sub-genus *Evylaeus* were verified by Dr. Laurence Packer. Specimens from the sub-genus *Dialictus* were verified by Dr. Jason Gibbs and specimens from the genus *Bombus* were verified by Sheila Colla. All other specimens were verified by Dr. Cory Sheffield.

Field management information

Each farmer that participated in the study was interviewed at the end of the 2009 field season in order to obtain information regarding their field management techniques. Information was collected on tillage practices as well as fertilizer, herbicide, and insecticide use.

Floral resources

Floral resources were assessed at each field site through monthly vegetation surveys. A total of four surveys were completed. During each survey each blooming floral species occurring along the length of the pan trap transect was identified and given an abundance rank based on a 3-point scale, where 1 indicates a rare species and a rank of 3 indicates a species that is abundant.

Landscape factors

Air photographs corresponding with each site for the year 2008 were obtained from the Carleton University library (DRAPE, 2008). ArcMap 10.0 was used to digitize the photos within a 1 km radius around the mid-point of each pan trap transect. This radius was chosen because most wild bee collections are made up of solitary wild bees, and they will be influenced by a smaller landscape scale (Gathmann & Tschardtke 2002, Steffan-Dewenter *et al.* 2002). The following land-use classes were created: ploughed field, hay

field, pasture, verge, hedgerow (treed, grassy or mixed), riparian zone, forest, and other semi-natural. It was assumed that the proportion of ploughed fields to hay fields remained constant between 2008 and 2009. Hay fields, pasture, verge, grassy and mixed hedgerows, riparian zones and other non-forested and semi-natural areas were considered to be habitat for bees. We call this 'semi-natural habitat'. The area of each polygon classified as semi-natural habitat was calculated in ArcMap. As a result, the entire area of semi-natural habitat was determined for each site.

Data analysis

Bee abundance

Bee abundance was calculated as the total number of bees captured in pan traps over the 9 sampling runs. Likewise, bumble bee abundance was calculated as the total number of specimens captured over the 4 sampling periods in July and August. In order to visualize the relative abundances of each species rank abundance plots were created for each site using Biodiversity Pro (McAleece 1997).

Species diversity

Species richness is the simplest and most common method for measuring species diversity (Magurran 2004). In this study, I calculated species richness as the total number of species encountered over the course of the sampling season. Species richness is often used as a diversity measure because of its simplicity, however the number of species encountered while sampling will increase as sample size increases. It is therefore difficult to compare species richness values among sites if abundance values differ. Species richness can only truly be compared among sites when the community has been

sampled sufficiently to represent all species present. Rarefaction curves can be used to assess sampling completeness: if the curve reaches an asymptote then all of the species within the community have been encountered and the absolute number of species is known (Gotelli & Colwell 2001). Rarefaction curves were created using Biodiversity Pro to determine if sites were sampled sufficiently to assess the entire bee community (McAleece 1997). Invertebrate communities are almost never sampled completely. In order to compare species diversity among sites then the true species richness of the community must be estimated. Magurran (2004) recommends using a non-parametric estimator of the absolute number of species in an assemblage: Chao 1.

$$S_{\text{Chao 1}} = S_{\text{obs}} + F_1^2 / 2F_2$$

Where,

S_{obs} = the number of species in the sample

F_1 = the number of observed species represented by a single individual (singletons)

F_2 = the number of observed species represented by two individuals (doubletons)

If sites were not sampled sufficiently then expected species richness (S^*) was calculated using Chao 1.

It is also useful to measure species diversity using indices that incorporate both species richness and abundance. Shannon diversity (H') was measured because it can be used in general linear models and because of its common usage in the literature.

$$H' = -\sum p_i \ln p_i$$

Where, p_i is the proportion of individuals found in the i th species. H' is biased when the true species richness is not known, however this is the majority of cases. H' is still useful when comparing results with other studies.

Evenness (J') was also calculated. It is a measure of how similar different species are in an assemblage in terms of their abundances.

$$J' = H'/H'_{\max} = H'/\ln S$$

Where, S = observed species richness.

High evenness is equated with high diversity (Magurran 2004).

Guild analysis

The impacts of environmental disturbances are sometimes masked when analyzing large communities of organisms with different ecological traits and life histories (Williams *et al.* 2010). Consequently, some trends may only become apparent when analyzing ecological guilds separately. Here, the overall bee community was separated by species-specific nesting preferences: cavity-nesting (above-ground) bees and ground-nesting (below-ground) bees. Cleptoparasitic bees were grouped according to their hosts' guild. For example, ground-nesting bees may be more affected by tillage in agricultural fields compared to other bee guilds, which may not be apparent when the entire dataset is used in the analysis. Bees were separated into guilds using Packer *et al.*, 2007 and the advice of C. Sheffield.

Pesticide index

For this study, pesticides are defined as insecticides and fungicides. Although some of the herbicides applied at the study sites were considered toxic to bees, these effects were considered to be mild therefore herbicides were excluded from the analysis. Insecticides and fungicides used on soybeans were either applied as a seed treatment (systemic

fungicide/insecticide) or as a foliar spray (insecticide). Participating farmers provided information on what kinds of pesticides were used and the corresponding rates. Bee toxicity information was provided by P. Mineau. A pesticide index was created for each site using the following formula:

Pesticide index = application rate/bee toxicity

For example, the pesticide index for a site that used a foliar spray insecticide:

Foliar insecticidal spray: Cyhalothrin-lambda

Application rate: 83 ml/ha

Pesticide concentration: 120 g/L

LD50: 0.0932 µg/bee

Pesticide index = application rate/bee toxicity

120 g/L = 0.12 g/ml

$0.12 \text{ g/ml} * 83 \text{ ml/ha} = 9.96 \text{ g/ha}$

$9.96 \text{ g/ha} = 9,960,000 \text{ µg/ha} / 0.0932 \text{ µg/bee}$

Final pesticide index = 106,849,496 bee LD50's/ha

See Appendix 11 for pesticide information and corresponding bee toxicity values. Since the values for pesticide index cannot be normally distributed as a continuous variable (all organic sites will have a pesticide index value of 0), the index values were converted to a categorical variable. This categorical variable represents the intensity of the pesticide application. The effects of pesticide use on bee abundance and diversity was further analyzed by assessing if site-specific bee abundance or observed species richness differed before and after the application of a foliar spray. This was compared to the corresponding abundance and species richness values found in the organic pair. In addition, the abundance and species richness of bees were compared before and after the soybean

bloom in order to determine if bees are affected by systemic insecticides through nectar uptake from soybean flowers.

Floral composition

Data obtained during the field season on floral diversity and rank abundance was reduced to one value using a non-metric multidimensional scaling ordination (NMS) using PC-ORD (McCune & Mefford 1999). Mantel tests were also conducted in order to determine if floral abundance was correlated with bee abundance.

Assessing differences in diversity using General Linear Models (GLMs)

Abundance (N), expected species richness (S^*), Shannon diversity (H'), and evenness (J') were measured for each site, for both the pan trap data and the bumble bee data. Above-ground and below-ground abundance and expected species richness was also calculated. The following predictor variables were used in the analysis for each site: farm type (C or O), pesticide category (1, 2, 3, or 4), tillage (Y or N), floral NMS score, and amount of semi-natural habitat within a 1 km buffer.

Each response variable was tested in a general linear model (GLM) with farm type as a predictor variable and pair as a randomized block. If there was no significant effect of farm type then it was removed from the model and replaced by the other predictor variables: tillage, pesticide category, floral NMS score and amount of semi-natural habitat. Non-significant predictors were eliminated from the model using backward selection: the predictor with the lowest F-ratio was removed from the model. This process continued until the most parsimonious, significant model was obtained. If a significant model was not obtained then all of the predictors were left in. A Bonferroni

correction was applied to measures of guild abundance and expected species richness to avoid Type 1 errors.

$$\alpha^* = \alpha / \text{number of tests}$$

Where, α = significance level (0.05). The new significance level for these tests is therefore $\alpha^* = 0.025$.

Predictor variables were tested for collinearity through correlation tests and by calculating variance inflation factors.

Finally, abundance and expected species richness response variables for the pan trap and *Bombus* dataset were tested for an interaction between farm type and semi-natural habitat.

Cluster analysis

Cluster analysis is a useful way of looking for differences in species composition among sites (Krebs 1999, Magurran 2004). Single-linkage clustering dendrograms were created using the Jaccard measure of similarity in order to compare community similarity between organic and conventional sites for the pan trap dataset and the *Bombus* dataset using PAST (Hammer *et al.* 2001).

DCA ordination

Ordination is another useful method for visualizing patterns in data, and in ecology it is used to describe patterns in species composition (McCune & Mefford 1999). Detrended Correspondence Analysis (DCA) was used to determine how the different predictor

variables (farm type, tillage, pesticide category, floral composition and semi-natural habitat) affect individual bee species in both the pan trap and *Bombus* datasets.

Results

Bee abundance

Pan traps

A total of 4860 traps were placed in 18 sites over 9 sampling runs in the summer of 2009. The contents of 240 of these traps were lost due to tipped pan traps in the field or leaked Ziploc sample bags. This represents an overall trap loss of 5%. This was not taken into account in the statistical analysis. It should be noted that one third of the transect at site O3 was destroyed during sampling run 2 (May 21st). This site was repeated on May 25th and the data from this date were used instead.

A total of 3472 bees were collected, with 1558 from conventional sites and 1914 from organic sites. This collection represents 149 species from 24 genera. *Apis mellifera* specimens were not included in the analysis since they are not native to North America. Three species that contributed the most to the total abundance were *Ceratina calcarata* (392 individuals), *Andrena nasonii* (278 individuals) and *Lasioglossum (Dialictus) versatum* (258 individuals). A full list of species can be found in the Appendix 3. Rank abundance plots were created for each site to provide a visualization of the community abundance and evenness at each site. Each site is characterized by a few species that were very abundant and many species that were rare, although some communities are more even than others (see Appendix 7). Abundance values for each site are found in Table 1. Abundance values for each nesting guild at each site are found in Table 2.

Bombus

A total of 280 bumble bees were collected, with 103 from conventional sites and 177 from organic sites. This collection represents 13 species from this genus. The most dominant species was *Bombus impatiens* (123 individuals). A full list of species can be found in Appendix 4. Rank abundance plots and a full species list can be found in the Appendix 8. Abundance values for each site are found in Table 3.

Species diversity

None of the rarefaction curves reached an asymptote for any of the sites, in either the pan trap or *Bombus* datasets. It is therefore evident that none of the communities were sampled sufficiently enough to encounter all species in the assemblages (Figure 2 & Figure 3). Site-specific rarefaction curves are found in Appendix 5 for the pan trap dataset, and in Appendix 6 for the *Bombus* dataset. Since sites were not sampled thoroughly enough to represent the entire community, raw species richness values should not be used to compare diversity between sites. Expected species richness should be used as a diversity measure instead (Magurran 2004). Diversity indices H' and J' were calculated for each site and presented in Table 1 for the pan trap dataset, Table 2 for each guild and in Table 3 for the *Bombus* dataset.

Predictor variables: pesticide category, tillage, and semi-natural habitat

The values for all predictor variables can be found in Table 4. Tillage, floral composition, and the amount of natural habitat did not differ between farm types (Table 5). Predictors were not correlated and variance inflation factors never exceeded a value of 10 (Table 6). Pesticide use, of course, did differ between farm types since it is not

used on organic fields. The amount of semi-natural habitat within a 1 km buffer of the midpoint of the sampling transect ranged from $3.89 * 10^6 \text{ m}^2$ to $2.20 * 10^7 \text{ m}^2$ (Figure 4).

Floral data

Mantel tests were conducted for all sites pooled together (Appendix 9). It was found that highest floral abundance, no matter what the month, was correlated with the highest bee abundance, no matter what the month ($p < 0.001$). Highest floral abundance, no matter what the month, was also correlated with total bee abundance ($p < 0.001$). When broken down into individual months, it was found that floral abundance was not correlated with bee abundance. An NMS ordination was used to reduce a matrix of the highest abundance of each floral species at each sampling site, no matter what month the vegetation survey was conducted. Results from the NMS analysis are presented in the Appendix 10. Axis 1 of the ordination explains 62.5% of the variation; therefore the scores from this axis can be used in a GLM to represent floral composition. In order to determine what Axis 1 means in terms of floral abundance and diversity, the abundance values for each floral species were correlated with Axis 1 of the NMS ordination. I considered any R^2 value above 0.2 to be correlated. A list of the floral species that are most highly correlated with axis 1 are found in Table 7. It can therefore be assumed that this floral community is most associated with axis 1. Flowers with positive correlations have a higher abundance associated with positive values of axis 1. Flowers with a negative correlation have a higher abundance associated with negative values of axis 1.

Assessing abundance and diversity change across treatments for the overall bee community.

There was no significant difference in abundance or expected species richness between farm types. Similarly, Shannon diversity and evenness values did not differ between farm types (Table 8). However, in all cases except for evenness, pair is a significant factor in the model. This means that the pairs are significantly different in terms of abundance, expected species richness and Shannon diversity. There was no significant difference in abundance or expected species richness of either the above-ground or the below-ground bees between farm types (Table 8). There was no significant difference in any measure of bumble bee abundance or diversity between farm types (Table 8).

General Linear Models

The results of the GLMs are found in Table 9. Above-ground bee abundance was significantly predicted by pair, pesticide category and floral NMS scores ($F(12,5)=34.5855$, $p=0.0005$, $R^2=0.95$), however, only pair and floral NMS scores are significant, after a Bonferroni correction. The relationship between above-ground bee abundance and floral score is negative (Figure 5). This means there is higher above-ground bee abundance associated with flowers with negative correlations.

All other models did not produce significant results.

Interaction models

The results of the interaction models between farm type and amount of semi-natural habitat are presented in Table 10. Including pair, farm type, semi-natural habitat and the

interaction between farm type and semi-natural habitat reveals a significant relationship with bumble bee abundance ($F(11,6)=4.158$, $p=0.046$, $R^2=0.67$). Only the interaction term is significant ($p=0.03$). Bumble bee abundance is higher on organic farms when there is less semi-natural habitat at the landscape scale (Figure 6).

Cluster analysis

Jaccard single-linkage cluster dendrograms are presented for pan trap data (Figure 7) and for *Bombus* data (Figure 8). Communities do not seem to cluster by farm type or by site pair.

DCA ordination

Axis 1 of the DCA explained 21% of the variance of the pan trap bee species composition (Figure 9). Axis 1 is most highly correlated with the amount of semi-natural habitat ($R^2=0.397$). This suggests that the amount of semi-natural habitat is the most important variable when it comes to bee species composition (Figure 9), however this is not a very strong relationship.

Axis 1 of the DCA explained 22% of the variance of the bumble bee species composition (Figure 10). Axis 1 is most highly correlated with the amount of semi-natural habitat ($R^2=0.306$). This also suggests that the amount of semi-natural habitat is the most important variable when it comes to bumble bee communities (Figure 10). Again, this relationship is not particularly strong.

Effects of site-specific pesticide use on bee abundance and species richness

Bee abundance was not negatively affected by the application of foliar insecticide (Figures 11-13). Bee abundance did experience a decline at site C9 following a foliar spray application, however this was accompanied by an even larger decline at the organic pair, O9, over the same time period (Figure 14). Insecticide spray did not seem to affect species richness. Sites C1 (Figure 15) and C9 (Figure 18) both experienced a decline in species richness, however so did the organic pairs. Sites C4 (Figure 16) and C8 (Figure 17) actually experience an increase in species richness following the insecticide application.

Systemic insecticides were applied to fields C3 and C7. Site C3 experienced an increase in both abundance (Figure 19) and species richness (Figure 21) following the soybean flower bloom. Site C7 experienced a decrease in abundance and species richness following the soybean bloom, however this decrease also occurred in the organic pair (Figures 20 and 22).

Discussion

I found that overall bee abundance and diversity did not differ between hedgerows adjacent to organic and conventional soybean farms (Table 8). Habitat suitability may be reduced in agricultural landscapes and organic agriculture is often viewed as a method to counter biodiversity declines, however, results from the literature are mixed: many studies determined that organic farms benefit biodiversity in agricultural landscapes (Belfrage *et al.* 2005, Feber *et al.* 1997, Kleijn *et al.* 2001, Wickramasinghe *et al.* 2004), while others support the finding of this study that local farm management has no effect on biodiversity (Weibull *et al.* 2000, Weibull *et al.* 2003, Winfree *et al.* 2008). More recent studies suggest that the effect of farm management on biodiversity will depend on the nature of the surrounding landscape. Organic farming is often regarded as beneficial for biodiversity; however this benefit is more apparent in landscapes devoid of surrounding natural and semi-natural habitat (Bengtsson *et al.* 2005, Boutin *et al.* 2009, Clough *et al.* 2007, Holzschuh *et al.* 2007, Holzschuh *et al.* 2008, Kremen *et al.* 2004, Kremen *et al.* 2002, Rundlof & Smith 2006). This agrees with my finding that bumble bee abundance was related to the amount of semi-natural habitat at the landscape scale.

I may not have found a difference in biodiversity between farm types simply because the difference between conventional and organic farms in Eastern Ontario is not large enough in terms of floral composition, tillage, extent of pesticide use and amount of natural habitat (Table 5).

Landscape effects

I found that bumble bees were affected by the amount of semi-natural habitat in the landscape. Bee body size is correlated with foraging range (Greenleaf *et al.* 2007), so it is perhaps not surprising that bumble bees responded to a landscape scale, while other bees did not. I also found a significant interaction between farm-type and semi-natural habitat, with semi-natural habitat having had a much stronger effect on bees captured in organic hedgerows than those captured in conventional hedgerows. This led to the highest bumble bee abundance being found in organic hedgerow with low cover of semi-natural habitat (Table 10, Figure 6). This is in agreement with much of the literature. Organic farming has the biggest impact in intensively managed, homogeneous landscapes (Carvalho *et al.* 2010, Gabriel *et al.* 2010, Holzschuh *et al.* 2007, Rundlof *et al.* 2010, Rundlof & Smith 2006). Because of this the effect of farm type may not be evident unless landscape factors are included in the study (Gabriel *et al.* 2010). Since most bumble bees nest above-ground, they require nesting resources that are less likely to be available in intensively managed areas (Williams *et al.* 2010, Osborne *et al.* 2008)). Bumble bee abundance is higher on organic sites in more intensive agricultural landscapes due to increased floral and nesting resources found on the organic sites compared to the surrounding landscape. Bumble bee abundance decreases on organic sites when the amount of semi-natural habitat increases at the landscape scale because there are simply more resources available (Gabriel *et al.* 2010). In fact, if there are a large number of organic fields or semi-natural habitat in the landscape the abundance of bees from these fields could overflow into adjacent conventional fields thus making it more difficult to detect an effect of farm type (Rundlof *et al.* 2010). Similarly, Batary *et*

al (2010) found that the abundance and species richness of bees did not differ between farm types and this may be due to a low-intensity landscape. Complex landscapes still contain enough diversity for species to spill over in poor quality sites, masking the effect of organic agriculture at the local scale (Batary *et al.* 2010). When incorporating the landscape scale most studies calculate the amount of semi-natural habitat in the landscape, but few take into account the agricultural management of the fields in the landscape (Rundlof *et al.* 2010). Calculating the amount of organic farming in the landscape allows one to determine if organic farming is the factor that's affecting biodiversity, instead of semi-natural habitat. Gabriel *et al* (2010) found that organic farming benefits wildlife at both the farm and landscape levels but there is variation between groups. There was higher floral diversity in organic fields, which may contribute to higher bee densities in organic fields due to increased resources. In this study I did not take into account the amount of organic fields within the landscape, therefore, there may be an effect of agricultural management within the landscape that explains variation of bee abundance and diversity that is absent from this study.

Pesticides

This study did not find any effects of pesticide use on bee abundance, expected species richness, Shannon diversity, or evenness (Table 9; Figures 12-23).

Some point to pesticides as a possible cause of bee decline (Kearns *et al.* 1998), however it is difficult to determine if pesticides have a lasting negative effect in the field since there are many other factors at play. Many studies have found no effect of pesticides on wild bees in the field (Kremen *et al.* 2004, Shuler *et al.* 2005, Winfree *et al.* 2009),

however that does not mean that pesticides do not have an impact since the effects of various insecticides on wild bees are not well understood (Tuell & Isaacs 2010). Kovacs *et al* (2011) measured bee abundance and species richness on fields using fertilizer and insecticide. They found a negative impact of pesticide application on small bee species richness. This is logical since small bees will have a smaller foraging range and will be more likely to be affected by local farm management practices (Johansen 1977, Kovacs-Hostyanszki *et al.* 2011). I did not find any effect of pesticide use, even though the categorical pesticide measure used in this study was detailed (Table 9, Figures 12-23). It should be noted that pesticide intensity at the field sites was low; with only one spray application on 4 out of 9 conventional sites. In addition, 3 out of 9 sites used a seed treatment, yet it is not known how often wild bees are taking up nectar from soybean flowers (Davis & Shuel, 1988). Furthermore, I may have detected a negative effect of pesticide application had I quantified the extent of pesticide use at the landscape scale (Brittain *et al.*, 2010a). I also may have found a negative effect of pesticide use had I taken bee life histories (body size, sociality, lecty) into account. Bee populations can be variable from year to year therefore one season of data may not be sufficient in order to see a trend (Tuell & Isaacs 2010). Finally, I may have detected a negative effect of pesticide use had I included information on herbicide use in the calculated pesticide index.

Tillage

Tillage did not affect abundance, expected species richness, Shannon diversity or evenness of the pan trap dataset or the bumble bee dataset (Table 9). It was hypothesized that tillage would have an effect on abundance or diversity of ground-nesting bees,

however, this was not the case. Julier & Roulston (2009) found no effect of tillage on bee abundance, unlike Schuler *et al* (2005), who found that tillage negatively affected the abundance of a species of ground-nesting bee. It is likely that I did not find an effect of tillage because only 3 out of 18 sites practiced no-till. It is often thought that organic farmers till their fields to a much greater extent, thus disturbing ground-nesting bees. In this study, however, only 3 out of 18 farmers practiced no-till, and one of these three farmers was organic. Kim *et al* (2006) showed that some species of ground-nesting bees prefer soft tilled soils for nesting. It is also possible that tillage may not have been deep enough to reach bee nests (Kim *et al.* 2006). Also, there may have been a greater effect in the spring when more bees are in the larval stage (Michener 2007).

Floral diversity

Bee abundance and diversity can be enhanced by an increase in floral resources in organic fields (Gabriel *et al.* 2010, Grundel *et al.* 2010, Holzschuh *et al.* 2007). In this study, however, floral community composition did not differ between farm types and this is a possible explanation as to why there was no difference in bee abundance or diversity between farm types (Table 5). Above-ground bees were negatively correlated with floral NMS score (Table 9, Figure 5). This suggests that above-ground bee abundance was associated with higher abundances of asters, goldenrods, and clover, among others. This could indicate that this community provides more attractive floral resources thus attracting higher above-ground bee abundance; however it is not clear why this wouldn't extend to ground-nesting bees. Alternatively, this flower community could be indicative of better quality nesting resources used exclusively by above-ground bees. It is difficult to make this conclusion since nesting resources were not assessed in the field. We

should be very cautious when linking bee and flower abundance: pan traps tend to increase in attractiveness when there is less competition with real flowers (Stephen & Rao 2007). This may have been why I did not find a strong relationship between bee abundance or diversity and floral community composition (Kovacs-Hostyanszki *et al.* 2011). Consequently, it would be useful to compare the results from the *Bombus* dataset to that of my pan traps since netting does not provide the same kind of bias. Floral community composition did not affect bumble bee abundance or diversity, however, and this is likely because bumble bees are reacting to floral resources at the landscape scale whereas floral composition for this study was measured at the local scale.

Bee community composition

Shifts in community composition from habitat loss and other environmental disturbances may be masked when only overall abundance or species richness is measured (Bommarco *et al.* 2010, Williams *et al.* 2010). For example, there may be an increase in generalists but this would not be evident from an overall species richness measure. An increase in generalists could lead to lost plant-pollinator relationships, and ultimately plant and pollinator extinction (Biesmeijer *et al.* 2006). Community composition was measured by producing dendrograms (Figures 7 & 8) and by producing DCA ordination plots (Figure 9, 10, & 11).

The dendrogram for the pan trap dataset showed that the bee communities at each site did not cluster by farm type, nor did they cluster by pair (Figure 7). Similarly, the dendrogram produced for the *Bombus* dataset did not cluster by farm type or pair (Figure 8). This suggests that farm type did not have an effect on bee community composition and that conventional management in this region is not having a detrimental effect on bee

community composition. Alternatively, bee community composition may be reacting at a larger scale than the field scale at which it was measured. The results of the dendrograms are not surprising since floral composition, tillage and amount of semi-natural habitat did not differ between farm types (Table 5). Since bee community composition did not cluster by pairs this suggests something in the local environment is affecting bee abundance and diversity. A clustering by pair was expected in view of the strong effect of 'pair' in most of my models. The availability of nesting substrate was not taken into account in this study and it could be that these resources present at a very small scale are important (Grundel *et al.* 2010, Potts *et al.* 2005). It would have been useful to measure the availability of nesting substrate for nesting sites for both ground and cavity-nesting bees to see if they were actually nesting at the sampling sites.

DCA ordination plots show that the pan trap community is correlated with the amount of semi-natural habitat ($R^2=0.397$), however axis 1 only explains 21% of the variation. This plot suggests that out of all of the predictors, the quantity of semi-natural habitat is most important. Similarly, the amount of semi-natural habitat was the most important factor in the DCA ordination when the *Bombus* dataset is considered ($R^2=0.306$), where axis 1 explains 22% of the variation. I would have expected a stronger effect of natural habitat on the bumble bee community since they are known to respond most strongly to the landscape scale, and they mostly nest above-ground, however it is known that even different bumble bee species vary in their foraging ranges and nesting habits (Darvill *et al.*, 2004).

Conclusions, recommendations and future research

The results of this research suggest that organic farms benefit bumble bee abundance when located in landscapes with low amounts of semi-natural habitat. At the local scale farm type, and the associated agricultural practices within the bounds of the Eastern Ontario cropping system, do not affect bee abundance or diversity. The results from this study contribute to a list of studies on organic farming that are already producing mixed results and this suggests that it is necessary to take a landscape scale approach when studying the effects of farm management on biodiversity in agriculture.

In future studies I would recommend that nesting guild, bee size and other species traits be taken into account since this likely influences reaction to disturbance. Different taxa respond to their environment at different spatial scales. One would expect that taxa with limited mobility, such as plants or earthworms, would be more influenced by farm management at the local scale. Other organisms that have greater mobility, such as birds, will react to larger spatial scales and the local farm scale becomes less important (Rundlof *et al.* 2010). This concept can also be applied to bees. Bee body size is highly correlated with foraging range, in a non-linear fashion (Greenleaf *et al.* 2007). The 149 species in my pan trap dataset have varying levels of mobility. For example, species from the subgenus *Dialictus* are small and therefore likely only forage within a few hundred metres of their nesting sites. On the other hand, bumble bees are much larger and are therefore able to forage greater distances from their nest, up to 1 km. My overall results indicate that there is no effect of farm type on overall bee abundance, expected species richness, Shannon diversity or evenness. Consequently, there may have been an effect of farm type had I split up my bees into ‘small’ and ‘large’ categories and used

two different spatial scales for each. I hypothesize that small bees would be affected by the local scale and that larger bees would be affected by the landscape scale. Within farm biodiversity is therefore a product of farm management (local scale) and the management of the surrounding farms and landscape (Gabriel *et al.* 2010).

Other species traits could also be important. For example, generalists could be more adaptable compared to specialists in terms of changing floral resources and habitat loss (Taki & Kevan 2007). Smaller bees could be more susceptible to pesticide use due to their increase surface area (Johansen *et al.* 1983). Likewise females and social bees may be more susceptible to chemical use (Ackerman & Montalvo 1985, Smith *et al.* 2007). Agricultural landscapes can provide important habitat for organisms. The landscape scale should be taken into account in future studies in order to assess the true value of agricultural landscapes for biodiversity.

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Tables

Table 1. Pan trap data: Diversity measures for each site, where N = abundance, S = observed species richness, S* = expected species richness (Chao 1), H' = Shannon-Weiner index, and J' = species evenness.

	N	S	S*	H'	J
Conventional sites					
C1	66	25	49.5	2.718	0.8443
C2	104	37	68.5	3.066	0.8491
C3	158	50	64.25	3.498	0.8942
C4	224	56	134.4	3.471	0.8624
C5	305	59	115.33	3.292	0.8074
C7	216	55	125.08	3.247	0.8103
C8	191	53	66.57	3.475	0.8752
C9	189	36	50.06	2.681	0.748
C10	105	37	56.13	3.021	0.8365
Organic sites					
O1	67	30	60.08	2.867	0.8428
O2	170	29	40.25	2.542	0.755
O3	173	44	116	3.021	0.7984
O4	474	67	83.96	3.53	0.8394
O5	337	53	108.13	3.08	0.7757
O7	240	53	110.6	3.368	0.8484
O8	125	39	66	3.183	0.8687
O9	205	38	47.75	2.873	0.7898
O10	123	29	48.6	2.65	0.7871

Table 2. Pan trap data: Distribution of guild abundance and observed guild species richness for each site.

Site	Above-ground N	Above-ground S	Above-ground S*	Below-ground N	Below-ground S	Below-ground S*
Conventional sites						
C1	16	6	10.5	50	19	39.17
C2	48	12	30	56	25	43.75
C3	40	8	10.25	118	42	54
C4	75	14	38.5	149	42	97.13
C5	104	16	31	201	43	76.33
C7	64	12	48	152	43	76.33
C8	24	8	11	167	45	56.12
C9	22	10	14.17	167	26	33.5
C10	23	10	12	82	27	42.17
Organic sites						
O1	11	6	14	56	24	46.5
O2	55	11	32	115	18	18.75
O3	67	13	25.25	106	31	103.25
O4	103	15	18.75	371	52	63.25
O5	91	13	18	246	40	82.67
O7	63	12	33	177	41	69.9
O8	26	10	10.75	99	29	66.5
O9	29	8	14	176	30	34.5
O10	15	8	20.5	108	21	31.13

Table 3. *Bombus* data: Diversity measures for each site, where N = abundance, S = observed species richness, H' = Shannon-Weiner index, and J' = species evenness.

	N	S	S*	H'	J'
Conventional sites					
C1	6	2	2	0.4506	0.7846
C2	23	4	4	1.008	0.6848
C3	9	4	7	1.003	0.6814
C4	10	7	15.5	1.834	0.8945
C5	8	5	6.5	1.494	0.8911
C7	20	3	3	0.7306	0.6921
C8	2	2	3	0.6931	1
C9	26	6	6	1.433	0.6983
C10	0	0	NA	NA	NA
Organic sites					
O1	13	5	5.5	1.413	0.8214
O2	57	8	11	1.484	0.5511
O3	12	7	7.75	1.864	0.9211
O4	2	2	3	0.6931	1
O5	41	7	7.5	1.427	0.5953
O7	32	8	16	1.493	0.556
O8	9	7	10.33	1.889	0.9448
O9	6	4	7	1.242	0.866
O10	5	4	5.5	1.332	0.9473

Table 4. Values for predictor variables for each site: Farm type (C = 1, O = 2), Floral NMS (NMS score from axis 1), Tillage (untilled = 1, tilled = 2), Pesticide category (no pesticide = 1, fungicidal seed treatment = 2, insecticidal/fungicidal seed treatment = 3, insecticidal foliar spray = 4), and the amount of semi-natural habitat within a 1 km buffer.

Site	Farm type	Floral NMS	Tillage	Pesticide category	Semi-natural habitat (ha)
C1	1	1.1315	2	3	95.0
C2	1	0.3597	1	1	39.0
C3	1	1.0091	2	4	116.0
C4	1	-0.7741	2	3	122.5
C5	1	-0.9497	2	2	107.0
C7	1	1.536	2	4	105.0
C8	1	0.0084	2	3	142.6
C9	1	0.1202	1	3	145.6
C10	1	-0.4494	2	1	191.7
O1	2	0.4129	2	1	136.9
O2	2	0.1574	1	1	89.2
O3	2	0.365	2	1	122.0
O4	2	0.0031	2	1	102.8
O5	2	-0.5079	2	1	39.3
O7	2	-0.1726	2	1	106.6
O8	2	1.2113	2	1	130.6
O9	2	0.2586	2	1	220.0
O10	2	-0.8539	2	1	184.9

Table 5. Results of statistical tests examining whether floral composition, the amount of semi-natural habitat and tillage differ between conventional and organic farms.

Test	Predictor	Response	p-value
ANOVA	Farm type	Floral NMS value	0.727
ANOVA	Farm type	Semi-natural habitat	0.740
X ²	Farm type	Tillage	>0.05

Table 6. Results of statistical tests examining whether predictor variables are correlated.

Test	Predictor	Response	p-value
Correlation	Floral NMS value	Semi-natural habitat	0.5808
ANOVA	Floral NMS value	Tillage	0.8940
ANOVA	Floral NMS value	Pesticide category	0.0777
ANOVA	Semi-natural habitat	Tillage	0.2167
ANOVA	Semi-natural habitat	Pesticide category	0.9881
X ²	Tillage	Pesticide category	>0.05

Table 7. Floral species that are most highly correlated with axis 1 of the NMS ordination.

Floral species	Common Name	R	R ²
Negative correlation			
<i>Aster vimineus</i>	small white aster	-0.79	0.63
<i>Erigeron philadelphicus</i>	common fleabane	-0.73	0.53
<i>Solidago rugosa</i>	rough-stemmed goldenrod	-0.71	0.51
<i>Galium concinnum</i>	shining bedstraw	-0.66	0.43
<i>Ranunculus acris</i>	tall buttercup	-0.61	0.37
<i>Aster novae-angliae</i>	new england aster	-0.57	0.32
<i>Asclepias syriaca</i>	common milkweed	-0.57	0.32
<i>Galium mollugo</i>	wild madder	-0.55	0.30
<i>Ranunculus repens</i>	buttercup	-0.53	0.28
<i>Trifolium pratense</i>	red clover	-0.53	0.28
<i>Vicia americana</i>	purple vetch	-0.48	0.23
<i>Solidago canadensis</i>	Canada goldenrod	-0.48	0.23
Positive correlation			
<i>Solanum dulcamara</i>	bittersweet nightshade	0.73	0.53
<i>Echinocystis lobata</i>	wild cucumber	0.51	0.26
<i>Verbana hastata</i>	blue vervain	0.47	0.22
<i>Typha latifolia</i>	cattail	0.47	0.22
<i>Lonicera morrowi</i>	morrow's honeysuckle	0.47	0.22
<i>Impatiens capensis</i>	spotted touch-me-not	0.47	0.22

Table 8. GLM results outlining the effects of pair and farm type on diversity measures for the pan trap data, above-ground and below-ground bees and bumble bees, where N = abundance, S* = expected species richness, H' = Shannon diversity and J' = evenness.

Group	Response	Pair		Farm type	
		F (9,8)	p	F	p
Pan trap	N	4.657	0.021	1.892	0.206
	S*	4.248	0.028	0.336	0.577
	H'	4.005	0.033	2.538	0.149
	J'	1.750	0.222	2.218	0.174
Above-ground	N	18.873	0.0001	1.277	0.291
	S*	3.048	0.067	0.309	0.593
Below-ground	N	2.773	0.085	1.663	0.233
	S*	3.150	0.062	0.0008	0.977
<i>Bombus</i>	N	2.025	0.168	1.979	0.197
	S*	0.238	0.969	1.004	0.349
	H'	0.175	0.987	1.691	0.234
	J'	2.023	0.184	0.019	0.892

Table 9. GLM results outlining the effects of pair, pesticide category, tillage, floral composition, and amount of semi-natural habitat on diversity measures for the pan trap data, above-ground and below-ground bees and bumble bees, where N = abundance, S* = expected species richness, H' = Shannon diversity and J' = evenness. Items in bold are statistically significant.

Group	Response	Pair	Pesticide category	Tillage	Floral composition	Semi-natural habitat	R ²	F	p
Pan trap	N	0.022					0.60	F _(8,9) =4.23	0.022
	S*	0.017					0.62	F _(8,9) =4.58	0.017
	H'	0.042					0.53	F _(8,9) =3.42	0.04
	J'	0.816	0.822	0.445	0.646	0.548533	0.65	F _(14,3) =0.51	0.827
Above-ground	N	0.0003	0.038		0.015		0.95	F _(12,5) =34.58	0.0005
	S*	0.047					0.52	F _(8,9) =3.30	0.047
Below-ground	N	0.299	0.387	0.828	0.780	0.427	0.31	F _(14,3) =1.56	0.402
	S*	0.038					0.54	F _(14,3) =3.54	0.038
<i>Bombus</i>	N	0.615	0.358	0.370	0.355	0.545	0.30	F _(14,3) =1.52	0.408
	S*	0.110	0.046		0.057	0.040	0.70	F _(13,3) =3.94	0.142
	H'	0.252	0.092	0.134		0.042	0.42	F _(13,3) =1.87	0.332
	J'	0.462	0.389	0.938	0.225	0.719	0.49	F _(14,2) =2.08	0.371

Table 10. GLM results outlining the effects of pair, farm type, semi-natural habitat, and the interaction between farm type and semi-natural habitat on pan trap and bumble bee abundance (N) and expected species richness (S*). Items in bold are statistically significant.

Response	Pair		Farm Type		Semi-natural habitat		Farm Type * Semi-natural habitat	
	F	p-value	F	p-value	F	p-value	F	p-value
Pan trap N	3.099	0.092	0.439	0.543	0.046	0.835	0.263	0.625
Pan trap S*	2.728	0.118	0.246	0.635	0.020	0.890	0.177	0.688
<i>Bombus</i> N	2.868	0.108	0.916	0.492	0.388	0.555	7.613	0.032
<i>Bombus</i> S*	0.211	0.973	1.000	0.500	0.481	0.518	0.319	0.596

Figures

Figure 1. Map of sampling sites. Organic sites are represented by green markers and conventional sites are represented by blue markers. Organic and conventional sites are organized into pairs (#1-10, #6 was dropped before the start of the field season).

Figure 2. Rarefaction curves calculated the cumulative abundance and species richness pan trap data for each site.

Figure 3. Rarefaction curves calculated the cumulative abundance and species richness *Bombus* data for each site.

Figure 4. Site C2 has the least amount of semi-natural habitat within the 1 km buffer (39.0 ha) while site O9 has the most (220.0 ha). Semi-natural habitat is blue, forest is green and ploughed fields are brown. The midpoint of the sampling transect is represented by the red dot.

Figure 5. Above-ground bee abundance decreases as NMS scores representing floral composition increase. There seems to be a slightly higher abundance of bees associated with the floral community that is represented by negative NMS scores.

Figure 6. Bumble bee abundance is higher on organic farms than on conventional farms when there is less semi-natural habitat at the landscape level.

Figure 7. Jaccard single-linkage cluster dendrograms showing dissimilarity between pan trap communities. Communities do not cluster by farm type or by pair.

Figure 8. Jaccard single-linkage cluster dendrograms showing dissimilarity between bumble bee communities. Communities do not cluster by farm type or by pair.

Figure 9. Detrended Correspondence Analysis for pan trap data. The blue crosses represent individual species while triangles represent conventional (red) and organic (green) sites. Axis 1 explains 21% of the variance. Semi-natural habitat and axis 1 have a correlation with an $R^2 = 0.397$.

Figure 11. Bee abundance at sties C1 and O1 before and after insecticide spray (last week of July).

Figure 12. Bee abundance at sites C4 and O4 before and after insecticide spray (last week of July)

Figure 13. Bee abundance at sites C8 and O8 before and after insecticide spray (last week of July)

Figure 14. Bee abundance at sites C9 and O9 before and after insecticide spray (August 3rd)

Figure 15. Bee species richness at sites C1 and O1 before and after insecticide spray

Figure 16. Bee species richness at sites C4 and O4 before and after insecticide spray

Figure 17. Bee species richness at sites C8 and O8 before and after insecticide spray

Figure 18. Bee species richness at sites C9 and O9 before and after insecticide spray

Figure 19. Effect of systemic insecticide on bee abundance at site C3.

Figure 20. Effect of systemic insecticide on bee abundance at site C7.

Figure 21. Effect of systemic insecticide on bee species richness at site C3.

Figure 22. Effect of systemic insecticide on bee species richness at site C7.

Appendices

Appendix 1. Fields sites, farm type and sampling dates for pan traps

Site	Management	Town	R1	R2	R3	R4	R5	R6	R7	R8	R9
O1	Organic	Inkerman	May 6	May 21	June 2	June 16	July 9	July 21	August 5	August 19	September 10
C1	Conventional	Inkerman	May 6	May 21	June 2	June 16	July 9	July 21	August 5	August 19	September 10
O2	Organic	Inkerman	May 6	May 21	June 2	June 16	July 9	July 21	August 5	August 19	September 10
C2	Conventional	Inkerman	May 6	May 21	June 2	June 16	July 9	July 21	August 5	August 19	September 10
O3	Organic	Inkerman	May 6	May 25	June 2	June 16	July 9	July 21	August 5	August 19	September 10
C3	Conventional	Inkerman	May 6	May 25	June 2	June 16	July 9	July 21	August 5	August 19	September 10
O4	Organic	Williamsburg	May 6	May 21	June 2	June 16	July 9	July 21	August 5	August 19	September 10
C4	Conventional	Williamsburg	May 6	May 21	June 2	June 16	July 9	July 21	August 5	August 19	September 10

O5	Organic	Williamsburg	May 6	May 21	June 2	June 16	July 9	July 21	August 5	August 19	September 10
C5	Conventional	Williamsburg	May 6	May 21	June 2	June 16	July 9	July 21	August 5	August 19	September 10
O7	Organic	Kars	May 6	May 21	June 2	June 16	July 9	July 21	August 5	August 19	September 10
C7	Conventional	Kars	May 6	May 21	June 2	June 16	July 9	July 21	August 5	August 19	September 10
O8	Organic	Kinburn	May 6	May 21	June 2	June 16	July 9	July 21	August 5	August 19	September 10
C8	Conventional	Kinburn	May 6	May 21	June 2	June 16	July 9	July 21	August 5	August 19	September 10
O9	Organic	Dunrobin	May 6	May 21	June 2	June 16	July 9	July 21	August 5	August 19	September 10
C9	Conventional	Dunrobin	May 6	May 21	June 2	June 16	July 9	July 21	August 5	August 19	September 10
O10	Organic	Woodlawn	May 6	May 21	June 2	June 16	July 9	July 21	August 5	August 19	September 10
C10	Conventional	Woodlawn	May 6	May 21	June 2	June 16	July 9	July 21	August 5	August 19	September 10

Appendix 2. Fields sites, farm type and sampling dates for bumble bees

Site	Management	Town	B1	B2	B3	B4
O1	Organic	Inkerman	July 15	July 29	August 10	August 28
C1	Conventional	Inkerman	July 15	July 29	August 10	August 28
O2	Organic	Inkerman	July 15	July 30	August 13	August 24
C2	Conventional	Inkerman	July 15	July 30	August 13	August 24
O3	Organic	Inkerman	July 15	July 31	August 13	August 28
C3	Conventional	Inkerman	July 15	July 31	August 13	August 28
O4	Organic	Williamsburg	July 14	July 30	August 10	August 25
C4	Conventional	Williamsburg	July 14	July 30	August 10	August 25
O5	Organic	Williamsburg	July 14	July 30	August 10	August 25
C5	Conventional	Williamsburg	July 14	July 30	August 10	August 25
O7	Organic	Kars	July 15	July 28	August 13	August 24
C7	Conventional	Kars	July 15	July 28	August 13	August 24
O8	Organic	Kinburn	July 16	July 28	August 12	August 31
C8	Conventional	Kinburn	July 16	July 28	August 12	August 31
O9	Organic	Dunrobin	July 16	July 31	August 12	August 27
C9	Conventional	Dunrobin	July 16	July 31	August 12	August 27
O10	Organic	Woodlawn	July 16	July 31	August 12	August 27
C10	Conventional	Woodlawn	July 16	July 31	August 12	August 27

<i>Andrena melanothroa</i>	0	0	0	1	0	0	0	0	0	1
<i>Andrena nasonii</i>	5	2	7	0	0	0	0	0	0	14
<i>Andrena pruni</i>	1	0	0	0	0	0	0	0	0	1
<i>Andrena robertsonii</i>	0	0	3	0	0	0	0	0	0	3
<i>Andrena thaspiae</i>	0	1	0	0	0	0	0	0	0	1
<i>Andrena wheeleri</i>	1	0	2	0	0	0	0	0	0	3
<i>Andrena wilkella</i>	0	0	0	4	1	0	0	0	0	5
<i>Andrena w-scripta</i>	1	1	4	0	0	0	0	0	0	6
<i>Augochlorella aurata</i>	0	0	2	0	0	0	3	2	0	7
<i>Bombus fervidus</i>	0	0	0	0	0	0	1	0	0	1
<i>Bombus impatiens</i>	0	0	0	0	0	1	1	0	0	2
<i>Bombus vagans vagans</i>	0	0	0	1	0	0	0	0	0	1
<i>Ceratina calcarata</i>	0	0	0	1	4	1	1	3	11	21
<i>Ceratina dupla</i>	0	0	2	1	1	0	0	2	3	9
<i>Ceratina strenua</i>	0	0	0	0	0	0	0	1	0	1
<i>Halictus confusus</i>	0	0	0	0	0	0	2	0	1	3
<i>Halictus ligatus</i>	0	0	0	0	0	0	1	3	0	4
<i>Halictus rubicundus</i>	0	0	0	0	0	0	1	0	0	1
<i>Hoplitis producta</i>	0	0	0	0	2	0	0	1	0	3
<i>Hylaeus affinis</i>	0	0	0	1	0	0	0	1	0	2
<i>Hylaeus mesillae</i>	0	0	0	1	0	0	0	1	0	2
<i>Lasioglossum admirandum</i>	0	0	1	2	0	0	0	1	0	4
<i>Lasioglossum coriaceum</i>	0	1	0	0	0	0	0	0	0	1
<i>Lasioglossum cressonii</i>	0	0	0	0	2	0	0	0	0	2
<i>Lasioglossum divergens</i>	0	0	0	1	1	0	0	0	0	2
<i>Lasioglossum ephialtum</i>	0	0	0	0	0	0	1	0	0	1
<i>Lasioglossum leucozonium</i>	0	0	0	0	0	0	1	3	0	4
<i>Lasioglossum lineatulum</i>	0	0	0	0	0	0	2	0	1	3
<i>Lasioglossum novascotiae</i>	0	0	1	0	1	1	1	1	0	5
<i>Lasioglossum oenotherae</i>	0	0	0	0	0	0	0	1	0	1
<i>Lasioglossum perpunctatum</i>	0	0	1	0	0	0	1	0	1	3
<i>Lasioglossum versans</i>	0	0	0	0	0	0	1	1	0	2
<i>Lasioglossum zonulum</i>	0	0	0	0	0	0	3	2	0	5
<i>Melissodes desponsa</i>	0	0	0	0	0	0	1	0	0	1
<i>Nomada ceanothi</i>	0	0	3	0	0	0	0	0	0	3
<i>Nomada cressonii</i>	0	0	2	0	0	0	0	0	0	2

<i>Nomada hydrophylli</i>	0	0	3	0	0	0	0	0	0	3
<i>Nomada lehighensis</i>	0	0	2	0	0	0	0	0	0	2
<i>Nomada lepida</i>	0	0	1	0	0	0	0	0	0	1
<i>Nomada pseudops</i>	0	0	1	0	0	0	0	0	0	1
<i>Nomada pygmaea</i>	0	0	1	0	0	0	0	0	0	1
<i>Nomada vicina</i>	0	0	0	0	0	0	0	1	0	1
<i>Pseudopanurgus nebrascensis</i>	0	0	0	0	0	0	0	1	0	1
<i>Sphecodes cressonii</i>	0	0	0	0	0	0	1	0	1	2
<i>Sphecodes stygius</i>	0	0	0	0	1	0	0	0	0	1
C4	21	24	61	30	26	11	16	22	13	224
<i>Agapostemon virescens</i>	0	0	0	1	1	2	0	0	1	5
<i>Andrena commoda</i>	0	2	2	0	0	0	0	0	0	4
<i>Andrena cressonii</i>	0	2	0	0	0	0	0	0	0	2
<i>Andrena frigida</i>	1	0	0	0	0	0	0	0	0	1
<i>Andrena hippotes</i>	1	0	0	0	0	0	0	0	0	1
<i>Andrena imitatrix/morrisonella</i>	1	0	0	0	0	0	0	0	0	1
<i>Andrena melanothroa</i>	0	0	0	1	0	0	0	0	0	1
<i>Andrena mendica</i>	1	0	0	0	0	0	0	0	0	1
<i>Andrena nasonii</i>	9	5	3	0	0	0	0	0	0	17
<i>Andrena robertsonii</i>	0	0	1	0	0	0	0	0	0	1
<i>Andrena wheeleri</i>	0	1	0	0	0	0	0	0	0	1
<i>Andrena wilkella</i>	0	0	1	0	0	0	0	0	0	1
<i>Augochlorella aurata</i>	1	0	2	1	2	0	6	2	0	14
<i>Bombus rufocinctus</i>	0	0	0	0	0	0	1	0	2	3
<i>Ceratina calcarata</i>	0	1	1	5	6	0	0	1	1	15
<i>Ceratina dupla</i>	0	0	1	1	0	0	0	0	0	2
<i>Halictus confusus</i>	0	1	1	0	0	0	0	0	0	2
<i>Halictus ligatus</i>	0	1	0	0	0	0	1	2	1	5
<i>Halictus rubicundus</i>	1	0	0	0	0	0	0	0	0	1
<i>Heriades leavitti</i>	0	0	0	0	0	0	0	0	1	1
<i>Hoplitis pilosifrons</i>	0	0	0	1	0	0	0	0	0	1
<i>Hoplitis producta</i>	0	0	0	2	3	0	0	0	0	5
<i>Hylaeus affinis</i>	0	0	0	0	0	0	0	1	0	1
<i>Hylaeus mesillae</i>	0	0	0	0	1	0	0	0	0	1
<i>Hylaeus saniculae</i>	0	0	0	1	0	0	0	0	0	1
<i>Lasioglossum admirandum</i>	0	4	5	2	0	1	0	0	0	12
<i>Lasioglossum albipenne</i>	0	1	1	0	0	0	0	0	0	2
<i>Lasioglossum coriaceum</i>	0	0	0	0	0	0	1	0	0	1

<i>Andrena wilkella</i>	0	0	1	0	0	0	0	0	0	1
<i>Anthophora terminalis</i>	0	0	0	0	1	0	0	0	0	1
<i>Augochlorella aurata</i>	0	7	5	1	0	0	0	0	0	13
<i>Bombus impatiens</i>	0	1	0	0	0	0	0	0	1	2
<i>Bombus rufocinctus</i>	0	0	0	0	1	0	0	0	0	1
<i>Ceratina calcarata</i>	1	4	11	18	10	0	0	0	8	52
<i>Ceratina dupla</i>	0	4	2	3	2	0	0	0	1	12
<i>Ceratina strenua</i>	0	0	2	0	0	1	0	0	1	4
<i>Halictus confusus</i>	0	0	0	1	0	1	0	0	1	3
<i>Halictus ligatus</i>	0	3	0	0	0	0	1	0	0	4
<i>Halictus rubicundus</i>	0	1	0	0	0	0	0	0	0	1
<i>Hoplitis producta</i>	0	0	0	4	0	1	0	0	0	5
<i>Hoplitis spoliata</i>	0	0	0	0	1	0	0	0	0	1
<i>Hylaeus affinis</i>	0	0	0	2	2	0	0	0	0	4
<i>Hylaeus annulatus</i>	0	0	0	1	0	0	0	0	0	1
<i>Hylaeus mesillae</i>	0	0	0	1	2	0	0	0	0	3
<i>Hylaeus modestus</i>	0	0	0	0	1	0	2	3	1	7
<i>Hylaeus saniculae</i>	0	0	0	0	1	0	0	0	0	1
<i>Hylaeus sp 1</i>	0	0	0	0	0	2	1	0	0	3
<i>Lasioglossum admirandum</i>	0	2	3	2	0	2	0	0	0	9
<i>Lasioglossum anomalum</i>	0	0	1	0	0	0	0	0	0	1
<i>Lasioglossum atwoodi</i>	0	2	0	0	0	0	0	0	0	2
<i>Lasioglossum coriaceum</i>	0	6	0	0	1	0	1	0	0	8
<i>Lasioglossum cressonii</i>	0	1	0	0	0	0	0	0	0	1
<i>Lasioglossum divergens</i>	1	0	0	1	1	0	0	0	0	3
<i>Lasioglossum ephialtum</i>	0	0	1	4	0	1	1	0	0	7
<i>Lasioglossum heterognathum</i>	0	1	0	1	0	0	0	0	0	2
<i>Lasioglossum imitatum</i>	1	0	0	0	0	1	1	0	0	3
<i>Lasioglossum laevissimum</i>	3	1	1	0	2	1	0	1	0	9
<i>Lasioglossum leucomomum</i>	0	0	0	0	0	1	0	0	0	1
<i>Lasioglossum leucozonium</i>	0	1	0	0	1	0	0	0	0	2
<i>Lasioglossum mitchelli</i>	2	11	2	0	1	3	2	0	0	21
<i>Lasioglossum novascotiae</i>	0	0	0	1	1	1	0	0	0	3
<i>Lasioglossum perpunctatum</i>	0	0	1	2	0	4	1	0	0	8

<i>Hylaeus mesillae</i>	0	0	0	0	2	1	0	0	0	3
<i>Hylaeus modestus</i>	0	0	0	0	1	0	0	0	0	1
<i>Hylaeus sp 1</i>	0	0	0	0	0	0	0	1	0	1
<i>Lasioglossum admirandum</i>	0	4	2	3	0	3	0	0	0	12
<i>Lasioglossum albipenne</i>	0	0	0	1	0	0	0	0	0	1
<i>Lasioglossum atwoodi</i>	0	2	0	0	0	0	0	0	0	2
<i>Lasioglossum coriaceum</i>	1	0	0	0	1	0	0	0	0	2
<i>Lasioglossum divergens</i>	0	1	1	0	3	0	0	1	0	6
<i>Lasioglossum ephialtum</i>	0	3	0	1	1	3	0	0	0	8
<i>Lasioglossum foxii</i>	2	3	2	0	0	0	0	0	0	7
<i>Lasioglossum heterognathum</i>	0	1	0	0	0	0	0	0	0	1
<i>Lasioglossum imitatum</i>	1	0	1	0	0	0	0	0	0	2
<i>Lasioglossum leucozonium</i>	0	0	0	3	0	1	0	0	1	5
<i>Lasioglossum mitchelli</i>	0	3	0	0	3	3	0	0	0	9
<i>Lasioglossum novascotiae</i>	0	2	1	3	1	2	0	0	0	9
<i>Lasioglossum perpunctatum</i>	0	4	0	0	4	1	0	0	0	9
<i>Lasioglossum versans</i>	1	0	0	0	0	0	0	0	0	1
<i>Lasioglossum versatum</i>	0	11	1	2	0	11	1	0	0	26
<i>Lasioglossum weemsi</i>	0	1	0	0	0	0	0	0	0	1
<i>Lasioglossum zephyrum</i>	0	0	0	0	0	1	0	0	0	1
<i>Lasioglossum zonulum</i>	1	1	0	0	0	0	1	0	0	3
<i>Megachile inermis</i>	0	0	0	0	0	0	1	0	0	1
<i>Melissodes bidentis</i>	0	0	0	0	0	0	1	0	0	1
<i>Melissodes desponsa</i>	0	0	0	0	0	0	2	2	0	4
<i>Melissodes druriella</i>	0	0	0	0	0	0	1	0	0	1
<i>Nomada cressonii</i>	0	0	1	0	0	0	0	0	0	1
<i>Nomada lepida</i>	1	0	0	0	0	0	0	0	0	1
<i>Nomada maculata</i>	1	0	0	0	0	0	0	0	0	1
<i>Osmia atriventris</i>	0	1	0	0	0	0	0	0	0	1
<i>Peponapis pruinosa</i>	0	0	0	0	0	0	1	0	1	2
<i>Sphecodes cressonii</i>	0	1	0	0	0	0	0	0	0	1
<i>Sphecodes stygius</i>	0	0	0	1	0	0	0	0	0	1
<i>Stelis lateralis</i>	0	0	0	1	0	0	0	0	0	1
C8	2	26	86	32	14	7	9	10	5	191
<i>Andrena canadensis</i>	0	0	0	0	0	0	0	1	0	1
<i>Andrena commoda</i>	0	4	19	0	0	0	0	0	0	23

<i>Andrena cressonii</i>	0	0	1	0	0	0	0	0	0	1
<i>Andrena erigeniae</i>	0	2	0	0	0	0	0	0	0	2
<i>Andrena hippotes</i>	0	1	0	0	0	0	0	0	0	1
<i>Andrena imitatrix/morrisonella</i>	0	0	1	0	0	0	0	0	0	1
<i>Andrena nasonii</i>	0	3	7	1	0	0	0	0	0	11
<i>Andrena persimulata</i>	0	1	1	0	0	0	0	0	0	2
<i>Andrena robertsonii</i>	0	0	0	2	0	0	0	0	0	2
<i>Andrena tridens</i>	1	0	0	0	0	0	0	0	0	1
<i>Andrena wilkella</i>	0	0	0	1	1	0	0	0	0	2
<i>Andrena w-scripta</i>	0	0	4	0	0	0	0	0	0	4
<i>Anthophora terminalis</i>	0	0	0	0	0	0	0	0	1	1
<i>Augochlorella aurata</i>	0	0	10	4	2	0	1	2	0	19
<i>Bombus borealis</i>	0	0	0	0	0	0	1	0	0	1
<i>Bombus rufocinctus</i>	0	0	0	0	0	0	0	0	1	1
<i>Ceratina calcarata</i>	0	0	2	1	2	0	0	2	0	7
<i>Ceratina dupla</i>	0	0	0	2	0	0	0	1	1	4
<i>Halictus confusus</i>	0	1	0	1	0	0	0	0	0	2
<i>Halictus ligatus</i>	0	0	0	1	0	0	0	1	0	2
<i>Hylaeus affinis</i>	0	0	0	0	2	1	0	0	0	3
<i>Hylaeus annulatus</i>	0	0	1	2	0	0	0	0	0	3
<i>Lasioglossum admirandum</i>	0	0	2	2	0	0	0	0	0	4
<i>Lasioglossum albipenne</i>	0	0	0	2	0	0	0	0	0	2
<i>Lasioglossum coriaceum</i>	0	0	8	1	0	0	0	0	0	9
<i>Lasioglossum cressonii</i>	0	0	1	0	0	0	0	0	0	1
<i>Lasioglossum divergens</i>	0	3	3	2	1	4	1	0	0	14
<i>Lasioglossum dreisbachi</i>	0	0	0	1	1	0	0	0	0	2
<i>Lasioglossum ellisiae</i>	0	1	1	3	0	0	0	0	0	5
<i>Lasioglossum ephialtum</i>	0	0	0	0	1	0	1	0	0	2
<i>Lasioglossum foxii</i>	0	0	1	0	0	0	0	0	0	1
<i>Lasioglossum imitatum</i>	0	0	0	0	0	1	0	0	0	1
<i>Lasioglossum leucomum</i>	0	1	0	0	2	0	0	0	0	3
<i>Lasioglossum leucozonium</i>	0	0	1	0	0	0	0	0	0	1
<i>Lasioglossum lineatulum</i>	0	0	0	0	0	0	1	0	0	1
<i>Lasioglossum mitchelli</i>	0	2	0	0	0	0	1	0	1	4
<i>Lasioglossum novascotiae</i>	0	0	7	0	0	0	0	0	0	7

<i>Lasioglossum oceanicum</i>	0	2	0	0	0	0	0	1	0	3
<i>Lasioglossum perpunctatum</i>	0	0	1	0	0	0	0	0	0	1
<i>Lasioglossum versans</i>	0	0	4	0	0	0	0	0	0	4
<i>Lasioglossum versatum</i>	0	0	7	0	1	1	1	0	0	10
<i>Lasioglossum zonulum</i>	0	1	0	0	0	0	1	0	0	2
<i>Megachile relativa</i>	0	0	0	0	0	0	1	0	0	1
<i>Melissodes desponsa</i>	0	0	0	0	0	0	0	2	0	2
<i>Nomada cressonii</i>	0	0	1	0	0	0	0	0	0	1
<i>Nomada lehighensis</i>	0	0	1	0	0	0	0	0	0	1
<i>Nomada lepida</i>	0	0	0	1	0	0	0	0	0	1
<i>Nomada sayi</i>	1	0	0	0	0	0	0	0	0	1
<i>Osmia pumila</i>	0	0	0	1	0	0	0	0	0	1
<i>Osmia simillima</i>	0	3	1	0	0	0	0	0	0	4
<i>Sphecodes cressonii</i>	0	1	0	1	0	0	0	0	0	2
<i>Sphecodes ranunculi</i>	0	0	1	1	0	0	0	0	0	2
<i>Sphecodes stygius</i>	0	0	0	2	1	0	0	0	1	4
C9	7	13	18	75	40	22	10	2	2	189
<i>Andrena carlini</i>	1	0	0	0	0	0	0	0	0	1
<i>Andrena nasonii</i>	0	0	3	0	0	0	0	0	0	3
<i>Augochlorella aurata</i>	0	1	2	4	7	0	0	0	0	14
<i>Bombus fervidus</i>	0	1	1	0	0	0	0	0	0	2
<i>Bombus griseocollis</i>	0	0	0	0	1	1	0	0	0	2
<i>Bombus impatiens</i>	0	0	3	0	0	2	0	0	0	5
<i>Bombus rufocinctus</i>	0	0	0	1	0	0	0	0	0	1
<i>Bombus ternarius</i>	1	0	1	0	0	0	0	0	0	2
<i>Bombus vagans vagans</i>	1	0	0	0	0	0	0	0	0	1
<i>Ceratina calcarata</i>	1	1	1	3	0	0	0	1	0	7
<i>Halictus confusus</i>	0	1	0	0	2	0	0	0	0	3
<i>Halictus rubicundus</i>	0	0	0	1	0	0	0	0	0	1
<i>Hoplitis producta</i>	0	0	0	0	1	0	0	0	0	1
<i>Hylaeus modestus</i>	0	0	0	0	1	0	0	0	0	1
<i>Hylaeus sp 1</i>	0	0	0	0	2	0	0	0	0	2
<i>Lasioglossum acuminatum</i>	0	0	0	0	1	0	0	0	0	1
<i>Lasioglossum admirandum</i>	0	3	4	29	3	3	3	0	0	45
<i>Lasioglossum albipenne</i>	0	0	0	4	1	0	0	0	0	5
<i>Lasioglossum atwoodi</i>	0	0	0	1	1	0	0	0	0	2
<i>Lasioglossum coriaceum</i>	0	0	0	2	0	0	0	0	1	3

<i>Lasioglossum divergens</i>	0	0	0	1	2	1	0	0	0	4
<i>Lasioglossum ephialtum</i>	0	0	0	0	0	1	1	0	0	2
<i>Lasioglossum leucozonium</i>	0	0	0	2	0	0	0	0	0	2
<i>Lasioglossum novascotiae</i>	0	0	2	12	2	1	0	0	0	17
<i>Lasioglossum perpunctatum</i>	0	0	0	5	1	1	0	0	0	7
<i>Lasioglossum quebecense</i>	1	0	0	0	0	0	0	0	0	1
<i>Lasioglossum sagax</i>	0	0	0	1	0	0	0	0	0	1
<i>Lasioglossum versans</i>	0	0	0	0	1	0	0	0	0	1
<i>Lasioglossum versatum</i>	1	3	1	6	13	12	4	1	0	41
<i>Lasioglossum viridatum</i>	0	0	0	2	0	0	0	0	0	2
<i>Megachile rotundata</i>	0	0	0	0	0	0	1	0	0	1
<i>Melissodes druriella</i>	0	0	0	0	0	0	0	0	1	1
<i>Nomada lehighensis</i>	1	0	0	0	0	0	0	0	0	1
<i>Osmia simillima</i>	0	3	0	0	0	0	1	0	0	4
<i>Sphecodes stygius</i>	0	0	0	1	0	0	0	0	0	1
<i>Stelis foederalis</i>	0	0	0	0	1	0	0	0	0	1
C10	39	7	25	9	2	2	9	12	0	105
<i>Andrena carlini</i>	2	0	0	0	0	0	0	0	0	2
<i>Andrena commoda</i>	0	0	2	0	0	0	0	0	0	2
<i>Andrena cressonii</i>	0	1	0	0	0	0	0	0	0	1
<i>Andrena mendica</i>	1	0	0	0	0	0	0	0	0	1
<i>Andrena nasonii</i>	20	2	8	0	0	0	0	0	0	30
<i>Andrena nubecula</i>	0	0	0	0	0	0	0	1	0	1
<i>Andrena vicina</i>	3	0	0	0	0	0	0	0	0	3
<i>Andrena wheeleri</i>	0	0	1	0	0	0	0	0	0	1
<i>Augochlora pura</i>	0	1	0	0	0	0	0	0	0	1
<i>Augochlorella aurata</i>	0	0	1	0	0	0	4	0	0	5
<i>Bombus impatiens</i>	0	0	1	0	0	0	0	0	0	1
<i>Ceratina calcarata</i>	1	0	0	1	1	0	0	1	0	4
<i>Ceratina dupla</i>	0	1	0	0	0	0	0	0	0	1
<i>Halictus confusus</i>	0	0	0	0	0	0	3	2	0	5
<i>Halictus ligatus</i>	0	0	1	0	0	0	1	1	0	3
<i>Hylaeus affinis</i>	0	0	0	0	0	0	1	4	0	5
<i>Hylaeus annulatus</i>	0	0	1	1	0	0	0	0	0	2
<i>Hylaeus mesillae</i>	0	0	0	1	0	0	0	2	0	3
<i>Hylaeus modestus</i>	0	0	0	0	0	0	0	1	0	1
<i>Lasioglossum admirandum</i>	0	0	1	0	0	0	0	0	0	1

<i>Lasioglossum albipenne</i>	0	0	0	1	0	0	0	0	0	1
<i>Lasioglossum ephialtum</i>	0	0	1	1	0	0	0	0	0	2
<i>Lasioglossum laevissimum</i>	2	0	0	1	0	1	0	0	0	4
<i>Lasioglossum leucocomum</i>	1	0	0	1	0	0	0	0	0	2
<i>Lasioglossum leucozonium</i>	0	0	1	0	0	0	0	0	0	1
<i>Lasioglossum perpunctatum</i>	0	0	2	0	0	0	0	0	0	2
<i>Lasioglossum versans</i>	1	0	0	0	0	0	0	0	0	1
<i>Lasioglossum versatum</i>	0	0	1	1	0	1	0	0	0	3
<i>Nomada cuneata</i>	1	0	0	0	0	0	0	0	0	1
<i>Nomada lehighensis</i>	3	0	2	0	0	0	0	0	0	5
<i>Nomada lepida</i>	1	0	0	0	0	0	0	0	0	1
<i>Nomada perplexa</i>	1	0	0	0	0	0	0	0	0	1
<i>Nomada sayi</i>	1	0	0	0	0	0	0	0	0	1
<i>Osmia atriventris</i>	1	0	0	0	0	0	0	0	0	1
<i>Osmia pumila</i>	0	1	0	1	0	0	0	0	0	2
<i>Osmia simillima</i>	0	1	2	0	0	0	0	0	0	3
<i>Sphecodes cressonii</i>	0	0	0	0	1	0	0	0	0	1
O1	36	8	12	5	1	3	1	1	0	67
<i>Andrena carlini</i>	1	0	0	0	0	0	0	0	0	1
<i>Andrena erigeniae</i>	1	0	0	0	0	0	0	0	0	1
<i>Andrena melanochoa</i>	0	0	0	1	0	0	0	0	0	1
<i>Andrena nasonii</i>	16	2	1	0	0	0	0	0	0	19
<i>Andrena thaspia</i>	0	0	1	0	0	0	0	0	0	1
<i>Andrena tridens</i>	1	0	0	0	0	0	0	0	0	1
<i>Andrena wheeleri</i>	1	0	0	0	0	0	0	0	0	1
<i>Andrena w-scripta</i>	1	0	1	0	0	0	0	0	0	2
<i>Augochlorella aurata</i>	0	1	0	0	0	0	0	0	0	1
<i>Bombus fervidus</i>	0	1	0	0	0	0	0	0	0	1
<i>Bombus impatiens</i>	0	0	0	0	1	0	0	0	0	1
<i>Ceratina calcarata</i>	0	1	1	0	0	0	0	0	0	2
<i>Ceratina dupla</i>	0	1	4	0	0	0	0	0	0	5
<i>Ceratina strenua</i>	0	0	1	0	0	0	0	0	0	1
<i>Halictus rubicundus</i>	0	0	0	0	0	0	1	0	0	1
<i>Hylaeus modestus</i>	0	0	0	0	0	1	0	0	0	1
<i>Lasioglossum mitchelli</i>	1	1	0	0	0	0	0	0	0	2
<i>Lasioglossum novascotiae</i>	0	0	0	1	0	0	0	1	0	2
<i>Lasioglossum</i>	0	0	0	0	0	1	0	0	0	1

<i>perpunctatum</i>										
<i>Lasioglossum planatum</i>	0	0	0	0	0	1	0	0	0	1
<i>Lasioglossum taylorae</i>	1	0	0	0	0	0	0	0	0	1
<i>Lasioglossum versans</i>	3	0	2	1	0	0	0	0	0	6
<i>Lasioglossum versatum</i>	1	0	0	0	0	0	0	0	0	1
<i>Lasioglossum zephyrum</i>	1	0	0	0	0	0	0	0	0	1
<i>Lasioglossum zonulum</i>	0	1	0	2	0	0	0	0	0	3
<i>Nomada lepida</i>	2	0	0	0	0	0	0	0	0	2
<i>Nomada maculata</i>	2	0	0	0	0	0	0	0	0	2
<i>Nomada perplexa</i>	1	0	0	0	0	0	0	0	0	1
<i>Nomada sayi</i>	3	0	0	0	0	0	0	0	0	3
<i>Osmia atriventris</i>	0	0	1	0	0	0	0	0	0	1
O2	0	24	5	69	24	20	16	10	2	170
<i>Andrena commoda</i>	0	0	0	4	0	0	0	0	0	4
<i>Andrena nasonii</i>	0	1	1	1	0	0	0	0	0	3
<i>Andrena wilkella</i>	0	0	0	0	3	0	0	0	0	3
<i>Augochlorella aurata</i>	0	0	0	2	0	0	0	1	0	3
<i>Bombus bimaculatus</i>	0	0	0	1	0	0	0	0	0	1
<i>Bombus fervidus</i>	0	1	0	0	0	0	0	0	0	1
<i>Bombus impatiens</i>	0	0	1	0	0	0	0	2	0	3
<i>Bombus vagans vagans</i>	0	0	0	0	1	0	0	0	0	1
<i>Ceratina calcarata</i>	0	4	3	8	0	0	0	0	1	16
<i>Ceratina dupla</i>	0	0	0	1	0	0	0	0	0	1
<i>Halictus confusus</i>	0	8	0	0	0	1	0	0	0	9
<i>Halictus ligatus</i>	0	0	0	0	1	0	0	1	0	2
<i>Hoplitis producta</i>	0	0	0	6	10	9	1	0	0	26
<i>Hylaeus affinis</i>	0	0	0	1	0	0	1	1	0	3
<i>Hylaeus mesillae</i>	0	0	0	0	3	0	0	0	0	3
<i>Hylaeus modestus</i>	0	0	0	0	1	0	0	0	0	1
<i>Hylaeus sp 1</i>	0	0	0	0	1	0	0	0	0	1
<i>Lasioglossum admirandum</i>	0	4	0	2	0	1	4	0	0	11
<i>Lasioglossum albipenne</i>	0	1	0	5	0	0	1	0	0	7
<i>Lasioglossum ephialtum</i>	0	1	0	1	0	0	0	1	0	3
<i>Lasioglossum leucozonium</i>	0	0	0	3	0	0	0	0	0	3
<i>Lasioglossum mitchelli</i>	0	0	0	0	0	0	1	0	0	1
<i>Lasioglossum novascotiae</i>	0	0	0	1	0	2	1	0	0	4
<i>Lasioglossum perpunctatum</i>	0	0	0	0	0	1	1	0	0	2
<i>Lasioglossum versans</i>	0	0	0	1	0	0	0	0	0	1

<i>Lasioglossum zonulum</i>	0	4	0	32	3	6	4	3	1	53
<i>Melissodes bidentis</i>	0	0	0	0	0	0	1	0	0	1
<i>Melissodes illata</i>	0	0	0	0	0	0	1	1	0	2
<i>Osmia pumila</i>	0	0	0	0	1	0	0	0	0	1
O3	7	43	21	64	7	11	6	11	3	173
<i>Andrena commoda</i>	0	0	0	1	0	0	0	0	0	1
<i>Andrena erigeniae</i>	1	0	0	0	0	0	0	0	0	1
<i>Andrena imitatrix</i>	1	0	0	0	0	0	0	0	0	1
<i>Andrena melanochoa</i>	0	1	0	0	0	0	0	0	0	1
<i>Andrena nasonii</i>	0	7	1	0	0	0	0	0	0	8
<i>Andrena persimulata</i>	0	0	1	0	0	0	0	0	0	1
<i>Andrena robertsonii</i>	2	1	4	1	0	0	0	0	0	8
<i>Andrena wheeleri</i>	2	11	1	0	0	0	0	0	0	14
<i>Andrena wilkella</i>	0	0	0	0	0	1	0	0	0	1
<i>Augochlorella aurata</i>	0	2	2	3	0	0	0	0	0	7
<i>Bombus borealis</i>	0	0	0	0	0	0	2	0	0	2
<i>Bombus impatiens</i>	0	0	1	0	0	0	0	0	0	1
<i>Bombus terricola</i>	0	0	0	0	0	1	0	0	0	1
<i>Ceratina calcarata</i>	0	5	1	28	1	0	0	4	1	40
<i>Ceratina dupla</i>	0	3	2	4	0	0	0	0	0	9
<i>Ceratina strenua</i>	0	1	0	1	0	0	0	0	1	3
<i>Halictus confusus</i>	0	0	0	0	0	1	0	0	0	1
<i>Halictus ligatus</i>	0	1	0	2	0	0	0	0	0	3
<i>Hoplitis producta</i>	0	0	0	0	0	2	0	0	0	2
<i>Hoplitis spoliata</i>	0	0	0	1	0	0	0	0	0	1
<i>Hylaeus affinis</i>	0	0	0	1	0	0	0	0	0	1
<i>Hylaeus modestus</i>	0	0	0	1	0	0	0	0	0	1
<i>Hylaeus sp 1</i>	0	0	0	0	0	1	0	0	0	1
<i>Hylaeus sp 2</i>	0	0	0	1	0	0	0	0	0	1
<i>Lasioglossum admirandum</i>	0	1	1	1	1	1	1	0	0	6
<i>Lasioglossum atwoodi</i>	0	2	1	0	0	0	0	0	0	3
<i>Lasioglossum divergens</i>	0	0	0	0	0	1	0	0	0	1
<i>Lasioglossum leucozonium</i>	0	0	0	3	0	0	0	0	0	3
<i>Lasioglossum mitchelli</i>	0	2	1	1	1	0	0	0	0	5
<i>Lasioglossum novascotiae</i>	0	0	0	1	0	0	0	0	0	1
<i>Lasioglossum oceanicum</i>	0	1	0	0	0	0	0	0	0	1
<i>Lasioglossum perpunctatum</i>	0	0	0	0	1	0	0	0	0	1

<i>Lasioglossum planatum</i>	0	0	0	1	0	0	0	0	0	1
<i>Lasioglossum versans</i>	1	0	1	0	1	0	0	0	0	3
<i>Lasioglossum versatum</i>	0	0	1	0	0	1	0	1	0	3
<i>Lasioglossum zonulum</i>	0	1	1	10	2	2	2	4	0	22
<i>Megachile relativa</i>	0	0	0	0	0	0	1	0	0	1
<i>Melissodes bidentis</i>	0	0	0	0	0	0	0	2	0	2
<i>Melissodes desponsa</i>	0	0	0	0	0	0	0	0	1	1
<i>Nomada pseudops</i>	0	0	1	0	0	0	0	0	0	1
<i>Osmia atriventris</i>	0	1	0	0	0	0	0	0	0	1
<i>Osmia pumila</i>	0	2	0	2	0	0	0	0	0	4
<i>Osmia simillima</i>	0	1	1	0	0	0	0	0	0	2
<i>Sphecodes stygius</i>	0	0	0	1	0	0	0	0	0	1
O4	18	14 2	29	89	24	38	52	18	64	474
<i>Agapostemon texanus</i>	0	2	0	0	0	0	0	0	0	2
<i>Agapostemon virescens</i>	0	0	0	5	1	0	0	0	1	7
<i>Andrena commoda</i>	0	8	2	1	0	0	0	0	0	11
<i>Andrena distans</i>	1	0	0	0	0	0	0	0	0	1
<i>Andrena fragilis</i>	0	5	0	0	0	0	0	0	0	5
<i>Andrena mariae</i>	1	0	0	0	0	0	0	0	0	1
<i>Andrena melanochroa</i>	0	0	1	1	0	0	0	0	0	2
<i>Andrena nasonii</i>	2	12	2	7	0	0	0	0	0	23
<i>Andrena persimulata</i>	0	1	0	0	0	0	0	0	0	1
<i>Andrena robertsonii</i>	0	4	0	5	0	0	0	0	0	9
<i>Andrena wheeleri</i>	0	3	1	0	0	0	0	0	0	4
<i>Andrena wilkella</i>	0	0	1	1	0	0	0	0	0	2
<i>Andrena w-scripta</i>	0	1	0	0	0	0	0	0	0	1
<i>Augochlorella aurata</i>	0	2	0	2	0	1	0	3	1	9
<i>Bombus fervidus</i>	0	1	0	0	0	0	0	0	0	1
<i>Bombus rufocinctus</i>	0	0	0	0	0	0	0	0	1	1
<i>Bombus vagans vagans</i>	0	0	0	0	0	0	0	0	1	1
<i>Ceratina calcarata</i>	0	14	0	10	3	1	0	0	21	49
<i>Ceratina dupla</i>	1	7	0	3	1	0	0	0	3	15
<i>Ceratina strenua</i>	0	0	0	0	0	0	0	0	2	2
<i>Coelioxys rufitarsis</i>	0	0	0	0	0	0	2	0	0	2
<i>Halictus confusus</i>	0	3	2	1	0	0	1	0	2	9
<i>Halictus ligatus</i>	0	0	0	0	0	1	2	1	3	7
<i>Halictus rubicundus</i>	0	2	0	0	0	0	0	0	0	2
<i>Hoplitis pilosifrons</i>	0	0	0	1	1	0	0	0	0	2
<i>Hoplitis producta</i>	0	0	0	5	4	7	1	0	0	17
<i>Hylaeus mesillae</i>	0	0	0	2	0	0	0	0	1	3

<i>Osmia atriventris</i>	0	2	0	0	0	0	0	0	0	2
<i>Osmia pumila</i>	0	1	0	3	0	0	0	0	0	4
<i>Osmia simillima</i>	0	3	0	0	0	0	0	0	0	3
<i>Pseudopanurgus nebrascensis</i>	0	0	0	0	0	0	0	0	1	1
<i>Sphecodes coronus</i>	0	0	0	0	0	1	0	1	0	2
<i>Sphecodes cressonii</i>	0	0	0	0	0	0	4	0	1	5
<i>Sphecodes stygius</i>	0	0	0	0	0	0	2	0	0	2
O5	23	12 8	75	62	19	10	5	3	12	337
<i>Agapostemon texanus</i>	0	1	1	0	0	0	0	0	1	3
<i>Agapostemon virescens</i>	0	0	4	14	0	2	1	0	2	23
<i>Andrena carlini</i>	3	0	0	0	0	0	0	0	0	3
<i>Andrena commoda</i>	0	2	6	1	0	0	0	0	0	9
<i>Andrena cressonii</i>	1	0	0	0	0	0	0	0	0	1
<i>Andrena distans</i>	0	0	0	1	0	0	0	0	0	1
<i>Andrena erythronii</i>	1	0	0	0	0	0	0	0	0	1
<i>Andrena fragilis</i>	0	0	1	0	0	0	0	0	0	1
<i>Andrena imitatrix</i>	0	1	0	0	0	0	0	0	0	1
<i>Andrena nasonii</i>	9	40	20	1	0	0	0	0	0	70
<i>Andrena wheeleri</i>	0	8	3	0	0	0	0	0	0	11
<i>Andrena wilkella</i>	0	0	0	3	2	0	0	0	0	5
<i>Anthophora terminalis</i>	0	0	0	0	0	0	0	0	1	1
<i>Augochlorella aurata</i>	0	3	0	1	0	0	0	0	0	4
<i>Bombus fervidus</i>	0	1	0	0	0	0	0	0	0	1
<i>Bombus impatiens</i>	0	1	0	0	0	2	0	1	0	4
<i>Bombus rufocinctus</i>	0	1	0	1	0	0	0	0	2	4
<i>Bombus vagans vagans</i>	0	0	0	0	2	0	0	0	2	4
<i>Ceratina calcarata</i>	1	17	10	14	7	2	0	2	1	54
<i>Ceratina dupla</i>	1	5	1	1	0	0	0	0	0	8
<i>Halictus confusus</i>	0	1	2	0	0	0	0	0	0	3
<i>Halictus ligatus</i>	0	0	0	2	0	0	0	0	0	2
<i>Heriades variolosa</i>	0	0	0	0	0	0	0	0	1	1
<i>Hoplitis pilosifrons</i>	0	0	0	1	0	0	0	0	0	1
<i>Hoplitis producta</i>	0	0	0	1	2	0	0	0	0	3
<i>Hylaeus affinis</i>	0	0	1	0	0	0	0	0	0	1
<i>Hylaeus sp 1</i>	0	0	0	1	0	1	0	0	0	2
<i>Lasioglossum admirandum</i>	0	6	2	1	0	0	0	0	0	9
<i>Lasioglossum albipenne</i>	0	3	1	3	0	0	0	0	0	7
<i>Lasioglossum atwoodi</i>	0	0	0	1	0	0	0	0	0	1
<i>Lasioglossum</i>	1	0	2	0	0	0	0	0	0	3

<i>coriaceum</i>										
<i>Lasioglossum cressonii</i>	1	0	2	0	0	0	0	0	0	3
<i>Lasioglossum divergens</i>	0	1	0	0	0	0	0	0	0	1
<i>Lasioglossum ephialtum</i>	0	0	0	0	1	0	0	0	0	1
<i>Lasioglossum imitatum</i>	0	0	2	0	0	0	0	0	0	2
<i>Lasioglossum leucozonium</i>	0	0	0	5	0	1	1	0	0	7
<i>Lasioglossum mitchelli</i>	2	7	2	0	0	0	0	0	0	11
<i>Lasioglossum novascotiae</i>	0	0	1	0	0	0	0	0	0	1
<i>Lasioglossum oceanicum</i>	0	13	8	3	0	0	1	0	1	26
<i>Lasioglossum paradmirandum</i>	0	0	0	1	0	0	0	0	0	1
<i>Lasioglossum perpunctatum</i>	0	1	0	0	3	0	0	0	0	4
<i>Lasioglossum versans</i>	0	2	0	0	0	0	0	0	0	2
<i>Lasioglossum versatum</i>	1	1	2	0	0	0	0	0	0	4
<i>Lasioglossum viridatum</i>	0	0	0	0	0	1	0	0	0	1
<i>Lasioglossum zonulum</i>	0	0	1	5	1	1	2	0	1	11
<i>Nomada australis</i>	0	0	1	0	0	0	0	0	0	1
<i>Nomada lehighensis</i>	1	0	0	0	0	0	0	0	0	1
<i>Nomada pseudops</i>	0	0	1	0	0	0	0	0	0	1
<i>Osmia atriventris</i>	1	3	0	0	0	0	0	0	0	4
<i>Osmia pumila</i>	0	4	0	0	0	0	0	0	0	4
<i>Osmia simillima</i>	0	5	0	1	1	0	0	0	0	7
<i>Sphecodes cressonii</i>	0	0	1	0	0	0	0	0	0	1
<i>Sphecodes ranunculi</i>	0	1	0	0	0	0	0	0	0	1
O7	12	43	48	42	36	43	5	7	4	240
<i>Agapostemon texanus</i>	0	1	2	3	3	0	0	0	0	9
<i>Agapostemon virescens</i>	0	0	0	3	1	4	0	0	0	8
<i>Andrena algida</i>	1	0	0	0	0	0	0	0	0	1
<i>Andrena commoda</i>	0	1	0	0	0	0	0	0	0	1
<i>Andrena distans</i>	1	0	0	0	0	0	0	0	0	1
<i>Andrena erigeniae</i>	1	0	0	0	0	0	0	0	0	1
<i>Andrena erythrogaster</i>	1	0	0	0	0	0	0	0	0	1
<i>Andrena hippotes</i>	0	1	0	0	0	0	0	0	0	1
<i>Andrena nasonii</i>	2	4	8	1	0	0	0	0	0	15
<i>Andrena persimulata</i>	0	1	0	0	0	0	0	0	0	1
<i>Andrena wheeleri</i>	0	1	0	0	0	0	0	0	0	1
<i>Andrena wilkella</i>	0	0	0	0	2	0	0	0	0	2
<i>Augochlorella aurata</i>	0	1	1	0	3	1	0	0	0	6

<i>Bombus citrinus</i>	0	0	0	0	1	0	0	0	0	1
<i>Bombus rufocinctus</i>	0	1	1	0	0	0	0	0	0	2
<i>Ceratina calcarata</i>	0	15	5	8	1	3	0	1	0	33
<i>Ceratina dupla</i>	1	2	4	6	0	0	0	0	0	13
<i>Ceratina strenua</i>	0	0	1	2	0	0	0	0	0	3
<i>Halictus confusus</i>	0	1	0	1	0	1	0	0	0	3
<i>Halictus ligatus</i>	0	0	1	0	1	10	3	2	3	20
<i>Hoplitis pilosifrons</i>	0	1	0	0	0	0	0	0	0	1
<i>Hoplitis producta</i>	0	0	0	0	1	0	0	0	0	1
<i>Hylaeus affinis</i>	0	0	0	1	2	0	0	0	0	3
<i>Hylaeus modestus</i>	0	0	0	0	0	1	0	0	0	1
<i>Hylaeus sp 1</i>	0	0	0	0	0	1	0	0	0	1
<i>Lasioglossum admirandum</i>	0	2	5	2	1	2	0	0	0	12
<i>Lasioglossum albipenne</i>	0	0	0	1	0	0	0	0	0	1
<i>Lasioglossum atwoodi</i>	0	1	0	0	0	4	0	0	0	5
<i>Lasioglossum coriaceum</i>	0	1	0	2	1	0	0	0	0	4
<i>Lasioglossum divergens</i>	0	0	0	0	2	0	0	0	0	2
<i>Lasioglossum ellisiae</i>	0	0	0	0	1	0	0	0	0	1
<i>Lasioglossum ephialtum</i>	0	0	2	1	0	0	0	0	0	3
<i>Lasioglossum foxii</i>	0	0	1	0	0	0	0	0	0	1
<i>Lasioglossum leucocomum</i>	0	0	1	2	0	0	0	0	0	3
<i>Lasioglossum leucozonium</i>	0	0	1	2	4	7	0	2	0	16
<i>Lasioglossum mitchelli</i>	0	0	5	1	0	1	0	0	0	7
<i>Lasioglossum novascotiae</i>	0	0	2	0	0	0	0	0	0	2
<i>Lasioglossum oceanicum</i>	1	0	1	0	0	1	1	0	0	4
<i>Lasioglossum perpunctatum</i>	0	0	4	2	2	0	0	0	0	8
<i>Lasioglossum versatum</i>	1	1	0	0	6	5	1	0	1	15
<i>Lasioglossum viridatum</i>	0	0	0	0	1	0	0	0	0	1
<i>Lasioglossum weemsi</i>	1	0	1	1	0	0	0	0	0	3
<i>Lasioglossum zonulum</i>	0	0	0	3	1	2	0	0	0	6
<i>Megachile brevis</i>	0	0	0	0	0	0	0	1	0	1
<i>Megachile latimanus</i>	0	0	0	0	1	0	0	0	0	1
<i>Melissodes illata</i>	0	0	0	0	1	0	0	1	0	2
<i>Nomada lehighensis</i>	0	0	1	0	0	0	0	0	0	1
<i>Nomada lepida</i>	0	1	0	0	0	0	0	0	0	1
<i>Nomada sayi</i>	2	1	0	0	0	0	0	0	0	3

<i>Osmia atriventris</i>	0	1	0	0	0	0	0	0	0	1
<i>Osmia simillima</i>	0	4	0	0	0	0	0	0	0	4
<i>Sphecodes cressonii</i>	0	1	0	0	0	0	0	0	0	1
<i>Sphecodes ranunculi</i>	0	0	1	0	0	0	0	0	0	1
O8	7	17	6	57	14	12	6	1	5	125
<i>Andrena carlini</i>	2	0	0	0	0	0	0	0	0	2
<i>Andrena commoda</i>	0	0	0	1	0	0	0	0	0	1
<i>Andrena erigeniae</i>	0	4	0	0	0	0	0	0	0	4
<i>Andrena fragilis</i>	0	1	0	0	0	0	0	0	0	1
<i>Andrena mendica</i>	1	0	0	0	0	0	0	0	0	1
<i>Andrena nasonii</i>	0	1	2	1	0	0	0	0	0	4
<i>Andrena thaspia</i>	1	0	0	0	0	0	0	0	0	1
<i>Andrena wheeleri</i>	0	0	1	0	0	0	0	0	0	1
<i>Andrena wilkella</i>	0	0	0	1	0	1	1	0	0	3
<i>Augochlorella aurata</i>	0	0	0	1	0	0	0	0	0	1
<i>Bombus borealis</i>	0	0	0	0	0	0	1	0	0	1
<i>Bombus citrinus</i>	0	0	0	0	1	0	1	0	0	2
<i>Bombus fervidus</i>	0	0	0	0	1	1	0	0	0	2
<i>Bombus impatiens</i>	0	0	1	0	0	0	0	0	0	1
<i>Bombus rufocinctus</i>	0	0	0	0	0	0	1	0	0	1
<i>Bombus ternarius</i>	0	1	0	0	0	0	0	0	0	1
<i>Ceratina calcarata</i>	0	2	0	5	1	0	0	0	0	8
<i>Ceratina dupla</i>	0	0	0	0	0	0	0	0	1	1
<i>Chelostoma ranunculi</i>	0	0	0	0	1	1	0	0	0	2
<i>Halictus confusus</i>	0	0	0	3	1	1	1	1	0	7
<i>Halictus ligatus</i>	0	0	0	1	0	0	0	0	1	2
<i>Hoplitis producta</i>	0	0	0	0	3	0	0	0	0	3
<i>Hylaeus annulatus</i>	0	0	0	0	1	0	0	0	0	1
<i>Hylaeus mesillae</i>	0	0	0	2	1	0	0	0	0	3
<i>Lasioglossum admirandum</i>	1	1	0	11	0	2	0	0	0	15
<i>Lasioglossum atwoodi</i>	0	0	0	1	1	3	0	0	0	5
<i>Lasioglossum divergens</i>	0	0	0	1	0	0	0	0	0	1
<i>Lasioglossum ephialtum</i>	0	0	0	1	0	0	0	0	0	1
<i>Lasioglossum leucozonium</i>	0	0	0	1	0	0	0	0	0	1
<i>Lasioglossum mitchelli</i>	2	1	0	0	0	0	0	0	1	4
<i>Lasioglossum novascotiae</i>	0	0	2	18	0	0	1	0	0	21
<i>Lasioglossum oceanicum</i>	0	0	0	1	0	0	0	0	0	1
<i>Lasioglossum</i>	0	0	0	4	0	0	0	0	0	4

<i>perpunctatum</i>										
<i>Lasioglossum versatum</i>	0	4	0	0	1	2	0	0	0	7
<i>Lasioglossum viridatum</i>	0	0	0	0	0	1	0	0	1	2
<i>Lasioglossum weemsi</i>	0	1	0	0	0	0	0	0	0	1
<i>Lasioglossum zonulum</i>	0	0	0	3	1	0	0	0	0	4
<i>Megachile rotundata</i>	0	0	0	0	0	0	0	0	1	1
<i>Osmia simillima</i>	0	1	0	1	1	0	0	0	0	3
O9	14	21	11	27	58	55	7	8	4	205
<i>Andrena carlini</i>	2	0	3	0	0	0	0	0	0	5
<i>Andrena commoda</i>	0	0	1	0	0	0	0	0	0	1
<i>Andrena hippotes</i>	2	0	0	0	0	0	0	0	0	2
<i>Andrena imitatrix/morrisonella</i>	1	0	0	0	0	0	0	0	0	1
<i>Andrena nasonii</i>	2	1	0	0	0	0	0	0	0	3
<i>Andrena robertsonii</i>	0	0	0	2	0	0	0	0	0	2
<i>Andrena wilkella</i>	0	0	0	1	4	1	0	0	0	6
<i>Augochlorella aurata</i>	0	0	2	1	2	0	0	0	0	5
<i>Bombus fervidus</i>	0	2	1	0	0	2	0	0	0	5
<i>Bombus impatiens</i>	0	0	0	0	0	0	1	0	0	1
<i>Bombus perplexus</i>	1	0	0	0	0	0	0	0	0	1
<i>Calliopsis adreniformis</i>	0	0	0	0	0	1	0	0	0	1
<i>Ceratina calcarata</i>	0	4	0	3	4	0	0	0	1	12
<i>Ceratina dupla</i>	0	1	0	0	0	0	0	0	0	1
<i>Chelostoma ranunculi</i>	0	0	0	0	1	0	0	0	0	1
<i>Halictus confusus</i>	0	2	1	0	4	4	1	1	0	13
<i>Halictus ligatus</i>	0	0	0	2	1	2	1	0	1	7
<i>Halictus rubicundus</i>	0	0	0	0	1	0	0	0	0	1
<i>Hoplitis pilosifrons</i>	0	0	0	1	0	0	0	0	0	1
<i>Hylaeus modestus</i>	0	0	0	0	2	0	1	0	0	3
<i>Lasioglossum admirandum</i>	2	9	0	10	1	6	0	0	0	28
<i>Lasioglossum albipenne</i>	0	0	0	3	0	1	0	0	0	4
<i>Lasioglossum atwoodi</i>	1	0	0	0	0	1	0	0	0	2
<i>Lasioglossum coriaceum</i>	0	0	0	0	1	0	0	0	1	2
<i>Lasioglossum ellisiae</i>	0	0	1	1	0	0	0	0	0	2
<i>Lasioglossum ephialtum</i>	0	0	1	0	1	1	1	0	0	4
<i>Lasioglossum laevissimum</i>	1	0	0	0	0	0	0	0	0	1
<i>Lasioglossum leucomum</i>	0	0	0	0	3	1	0	0	0	4
<i>Lasioglossum</i>	0	0	0	0	2	2	0	0	0	4

<i>lineatulum</i>										
<i>Lasioglossum mitchelli</i>	0	0	0	0	1	1	1	0	1	4
<i>Lasioglossum perpunctatum</i>	1	0	0	2	4	5	0	0	0	12
<i>Lasioglossum pilosum</i>	0	0	0	1	0	1	0	0	0	2
<i>Lasioglossum versatum</i>	1	2	0	0	26	24	0	1	0	54
<i>Lasioglossum viridatum</i>	0	0	0	0	0	1	1	0	0	2
<i>Megachile latimanus</i>	0	0	0	0	0	1	0	0	0	1
<i>Megachile rotundata</i>	0	0	0	0	0	0	0	5	0	5
<i>Melissodes illata</i>	0	0	0	0	0	0	0	1	0	1
<i>Nomada pseudops</i>	0	0	1	0	0	0	0	0	0	1
O10	14	16	21	23	8	19	5	10	7	123
<i>Agapostemon texanus</i>	0	0	0	0	1	0	0	0	0	1
<i>Andrena carlini</i>	1	3	1	0	0	0	0	0	0	5
<i>Andrena commoda</i>	0	1	0	1	0	0	0	0	0	2
<i>Andrena nasonii</i>	8	2	14	4	0	0	0	0	0	28
<i>Andrena vicina</i>	0	1	0	0	0	0	0	0	0	1
<i>Augochlorella aurata</i>	0	1	1	1	0	0	1	0	1	5
<i>Bombus citrinus</i>	0	0	0	0	2	1	0	0	0	3
<i>Bombus fervidus</i>	0	1	0	1	1	0	2	0	0	5
<i>Bombus impatiens</i>	0	1	0	0	0	0	0	0	0	1
<i>Bombus rufocinctus</i>	0	0	0	0	0	0	1	0	0	1
<i>Ceratina calcarata</i>	0	1	0	1	0	0	0	0	0	2
<i>Ceratina dupla</i>	0	0	0	1	0	0	0	0	0	1
<i>Halictus rubicundus</i>	1	1	0	0	0	0	0	0	0	2
<i>Hoplitis pilosifrons</i>	0	0	0	1	0	0	0	0	0	1
<i>Hoplitis producta</i>	0	0	0	1	0	0	0	0	0	1
<i>Hylaeus annulatus</i>	0	0	0	1	0	0	0	0	0	1
<i>Hylaeus modestus</i>	0	0	0	1	0	0	0	0	0	1
<i>Lasioglossum admirandum</i>	0	2	0	3	0	3	0	1	0	9
<i>Lasioglossum albipenne</i>	0	0	0	2	2	0	0	0	0	4
<i>Lasioglossum atwoodi</i>	0	0	0	0	0	1	0	0	0	1
<i>Lasioglossum coriaceum</i>	0	0	0	1	0	0	0	1	0	2
<i>Lasioglossum laevissimum</i>	0	0	0	0	0	1	0	0	0	1
<i>Lasioglossum leucomum</i>	1	0	0	0	0	1	0	0	0	2
<i>Lasioglossum mitchelli</i>	1	0	0	0	0	0	0	0	0	1
<i>Lasioglossum oceanicum</i>	0	0	1	3	1	0	1	3	4	13

<i>Lasioglossum pectorale</i>	0	0	0	0	0	0	0	1	0	1
<i>Lasioglossum perpunctatum</i>	1	0	0	0	0	1	0	1	0	3
<i>Lasioglossum versatum</i>	1	1	4	1	1	11	0	3	2	24
<i>Lasioglossum weemsi</i>	0	1	0	0	0	0	0	0	0	1
Grand Total	24 4	72 2	54 5	72 9	37 0	32 2	20 6	16 6	16 8	3472

Appendix 4. Cumulative *Bombus* species list for all sites

	Run				Grand Total
	1	2	3	4	
C1	1	0	2	3	6
<i>Bombus.impatiens</i>	1	0	1	3	5
<i>Bombus.rufocinctus</i>	0	0	1	0	1
C2	1	1	3	18	23
<i>Bombus.borealis</i>	0	0	0	2	2
<i>Bombus.impatiens</i>	0	1	3	11	15
<i>Bombus.rufocinctus</i>	1	0	0	3	4
<i>Bombus.vagans</i> <i>vagans</i>	0	0	0	2	2
C3	2	0	0	7	9
<i>Bombus.bimaculatus</i>	1	0	0	0	1
<i>Bombus.impatiens</i>	1	0	0	5	6
<i>Bombus.rufocinctus</i>	0	0	0	1	1
<i>Bombus.vagans</i> <i>vagans</i>	0	0	0	1	1
C4	2	0	8	0	9
<i>Bombus.bimaculatus</i>	1	0	0	0	1
<i>Bombus.grisecollis</i>	0	0	1	0	1
<i>Bombus.impatiens</i>	0	0	1	0	1
<i>Bombus.rufocinctus</i>	0	0	2	0	2
<i>Bombus.terricola</i>	0	0	1	0	1
<i>Bombus.vagans</i> <i>vagans</i>	1	0	2	0	3
C5	4	2	1	1	8
<i>Bombus.bimaculatus</i>	1	0	0	0	1
<i>Bombus.borealis</i>	0	1	0	0	1
<i>Bombus.fernaldae</i>	1	0	0	0	1
<i>Bombus.impatiens</i>	0	1	0	1	2
<i>Bombus.vagans</i> <i>vagans</i>	2	0	1	0	3
C7	1	8	1	10	20
<i>Bombus.bimaculatus</i>	0	3	0	0	3
<i>Bombus.impatiens</i>	1	5	0	9	15
<i>Bombus.vagans</i> <i>vagans</i>	0	0	1	1	2
C8	2	0	0	0	2
<i>Bombus.citrinus</i>	1	0	0	0	1

<i>Bombus.impatiens</i>	1	0	0	0	1
C9	1				
	1	0	1	14	26
<i>Bombus.borealis</i>	0	0	1	1	2
<i>Bombus.citrinus</i>	1	0	0	12	13
<i>Bombus.grisecollis</i>	2	0	0	0	2
<i>Bombus.impatiens</i>	4	0	0	1	5
<i>Bombus.pensylvanicu</i> <i>s</i>	1	0	0	0	1
<i>Bombus.rufocinctus</i>	3	0	0	0	3
C10	0	0	0	0	0
O1	4	2	4	3	13
<i>Bombus.bimaculatus</i>	0	1	0	0	1
<i>Bombus.impatiens</i>	2	0	1	2	5
<i>Bombus.perplexus</i>	1	0	1	0	2
<i>Bombus.rufocinctus</i>	1	0	0	0	1
<i>Bombus.vagans</i> <i>vagans</i>	0	1	2	1	4
O2	5	16	25	11	57
<i>Bombus.bimaculatus</i>	1	5	2	0	8
<i>Bombus.borealis</i>	2	1	2	0	5
<i>Bombus.citrinus</i>	0	1	0	0	1
<i>Bombus.fervidus</i>	0	0	1	0	1
<i>Bombus.impatiens</i>	0	6	15	9	30
<i>Bombus.perplexus</i>	0	1	0	0	1
<i>Bombus.rufocinctus</i>	0	0	3	1	4
<i>Bombus.vagans</i> <i>vagans</i>	2	2	2	1	7
O3	2	1	5	4	12
<i>Bombus.borealis</i>	0	0	0	1	1
<i>Bombus.citrinus</i>	0	0	0	2	2
<i>Bombus.impatiens</i>	0	1	1	1	3
<i>Bombus.perplexus</i>	1	0	0	0	1
<i>Bombus.rufocinctus</i>	0	0	2	0	2
<i>Bombus.ternarius</i>	1	0	0	0	1
<i>Bombus.vagans</i> <i>vagans</i>	0	0	2	0	2
O4	1	0	0	1	2
<i>Bombus.bimaculatus</i>	1	0	0	0	1
<i>Bombus.impatiens</i>	0	0	0	1	1
O5	9	17	12	3	41
<i>Bombus.borealis</i>	0	0	1	0	1

<i>Bombus.impatiens</i>	2	4	3	3	12
<i>Bombus.perplexus</i>	1	0	0	0	1
<i>Bombus.rufocinctus</i>	0	1	2	0	3
<i>Bombus.ternarius</i>	1	0	2	0	3
<i>Bombus.terricola</i>	0	0	2	0	2
<i>Bombus.vagans</i>					
<i>vagans</i>	5	12	2	0	19
O7	2	8	16	6	32
<i>Bombus.bimaculatus</i>	1	0	0	0	1
<i>Bombus.citrinus</i>	0	0	2	0	2
<i>Bombus.fervidus</i>	1	0	0	0	1
<i>Bombus.grisecollis</i>	0	1	0	0	1
<i>Bombusimpatiens</i>	0	3	10	4	17
<i>Bombus.perplexus</i>	0	1	0	0	1
<i>Bombus.rufocinctus</i>	0	1	3	0	4
<i>Bombus.vagans</i>					
<i>vagans</i>	0	2	1	2	5
O8	0	4	4	1	9
<i>Bombus.bimaculatus</i>	0	1	0	0	1
<i>Bombus.borealis</i>	0	1	0	0	1
<i>Bombus.citrinus</i>	0	1	0	0	1
<i>Bombusimpatiens</i>	0	0	1	1	2
<i>Bombus.rufocinctus</i>	0	0	2	0	2
<i>Bombus.ternarius</i>	0	0	1	0	1
<i>Bombus.vagans</i>					
<i>vagans</i>	0	1	0	0	1
O9	0	2	0	4	6
<i>Bombus.borealis</i>	0	1	0	0	1
<i>Bombus.grisecollis</i>	0	0	0	1	1
<i>Bombusimpatiens</i>	0	1	0	2	3
<i>Bombus.rufocinctus</i>	0	0	0	1	1
O10	0	2	1	2	5
<i>Bombus.citrinus</i>	0	1	0	0	1
<i>Bombus.fervidus</i>	0	1	0	1	2
<i>Bombus.rufocinctus</i>	0	0	1	0	1
<i>Bombus.ternarius</i>	0	0	0	1	1
	4				
Grand Total	7	63	82	88	280

Appendix 5. Pan trap rarefaction curves for each conventional/organic pair

Figure 5a. Rarefaction curve for sites C1 and O1.

Figure 5b. Rarefaction curve for sites C2 and O2.

Figure 5c. Rarefaction curve for sites C3 and O3

Figure 5d. Rarefaction curve for sites C4 and O4.

Figure 5e. Rarefaction curve for sites C5 and O5.

Figure 5f. Rarefaction curves for sites C7 and O7.

Figure 5g. Rarefaction curves for sites C8 and O8.

Figure 5h. Rarefaction curves for sites C9 and O9.

Figure 5i. Rarefaction curves for sites C10 and O10.

Appendix 6. *Bombus* rarefaction curves for each conventional/organic pair

Figure 6a. Rarefaction curves for sites C1 and O1.

Figure 6b. Rarefaction curves for sites C2 and O2.

Figure 6c. Rarefaction curves for sites C3 and O3.

Figure 6d. Rarefaction curves for sites C4 and O4.

Figure 6e. Rarefaction curves for sites C5 and O5.

Figure 6f. Rarefaction curves for sites C7 and O7.

Figure 6g. Rarefaction curves for sites C8 and O8.

Figure 6h. Rarefaction curves for sites C9 and O9.

Figure 6i. Rarefaction curves for sites C10 and O10.

Appendix 7. Pan trap rank-abundance plots for each conventional/organic pair

Figure 7a. Rank abundance plots for sites C1 and O1.

Figure 7b. Rank abundance plots for sites C2 and O2

Figure 7c. Rank abundance plots for sites C3 and O3

Figure 7d. Rank abundance plots for sites C4 and O4.

Figure 7e. Rank abundance plots for sites C5 and O5.

Figure 7f. Rank abundance plots for sites C7 and O7.

Figure 7g. Rank abundance plots for sites C8 and O8

Figure 7h. Rank abundance plots for sites C9 and O9

Figure 7i. Rank abundance plots for sites C10 and O10.

Appendix 8. *Bombus* Rank-abundance plots for each conventional/organic pair

Figure 8a. Rank abundance plots for sites C1 and O1.

Figure 8b. Rank abundance plots for sites C2 and O2.

Figure 8c. Rank abundance plots for sites C3 and O3.

Figure 8d. Rank abundance plots for sites C4 and O4.

Figure 8e. Rank abundance plots for sites C5 and O5.

Figure 8f. Rank abundance plots for sites C7 and O7.

Figure 8g. Rank abundance plots for sites C8 and O8.

Figure 8h. Rank abundance plots for sites C9 and O9.

Figure 8i. Rank abundance plots for sites C10 and O10.

Appendix 9. Mantel tests between bee abundance and floral abundance for each month with farm types pooled together, as well as with bee and floral abundance analyzed separately between farm types. Statistically significant items are in bold.

Table 9a. Mantel test results, farm types pooled together

Floral matrix	Bee matrix	p-value
Maximum floral abundance value, no matter what month	Maximum bee abundance value, no matter what month	<0.001
Maximum floral abundance value, no matter what month	Total bee abundance	<0.001
Mean floral abundance	Mean bee abundance	0.112
May abundance	May abundance	0.323
June abundance	June abundance	0.132
July abundance	July abundance	0.263
August abundance	August abundance	0.359

Table 9b. Mantel test results, farm types analyzed separately

Floral matrix - abundance	Bee matrix - abundance	p-value
Mean abundance - conventional	Mean abundance - conventional	0.234
Mean abundance -organic	Mean abundance -organic	0.464
Conventional sites		
May	May	0.258
June	June	0.435
July	July	0.506
August	August	0.299
Organic sites		
May	May	0.228
June	June	0.333
July	July	0.07
August	August	0.043

Appendix 10. NMS ordination axis fit and site scores for the floral abundance matrix.

Table 10a. NMS model fit

Axis	R ² Increment	R ² Cumulative
1	0.625	0.625
2	0.142	0.767
3	0.114	0.881

Table 10b. NMS axes scores for floral composition

Site	Fit	Axis 1	Axis 2	Axis 3
C1	11.7020	1.1315	-0.7801	-0.4568
C2	11.3310	0.3597	-0.3855	0.3583
C3	11.0363	1.0091	0.6103	-0.2376
C4	12.5170	-0.7741	0.5953	-0.0739
C5	12.2781	-0.9497	0.1481	-0.8921
C7	10.2668	1.5360	0.9824	0.8739
C8	10.6841	0.0084	0.9711	0.3737
C9	11.0821	0.1202	-0.1262	1.0684
C10	10.4562	-0.4494	0.3999	1.0190
O1	11.1633	0.4129	0.5916	0.2348
O2	10.7034	0.1574	-0.9643	0.0002
O3	12.1018	0.3650	-0.9229	-0.2468
O4	12.2783	0.0031	0.9673	-0.2468
O5	11.1519	-0.5079	0.6179	0.9233
O7	11.1053	-0.1726	0.3698	0.7844
O8	10.3222	1.2113	-0.5471	0.3398
O9	10.3965	0.2586	-1.0469	0.5991
O10	10.3197	-0.8539	-0.1300	1.0684

Appendix 11. Pesticide application rates, bee toxicity levels and calculated indices.

Table 11a. Seed treatment application rates (seeds/ha), bee toxicity levels (LD50) and pesticide indices (bee/ha).

	seeds/ha	µg/seed	app rate	LD50	bee/ha
CRUISERMAXX					
Thiamethoxam	1110000	76	84360000	0.004999995	16872016872
Metalaxyl-M	1110000	5.7	6327000	70.71044922	89477.58174
Fludioxonil	1110000	3.8	4218000	101	41762.37624
TOTAL					16872148112
APRON MAXX					
Fludioxonil	1110000	3.8	4218000	101	41762.37624
Metalaxyl-M	1110000	5.7	6327000	70.71044922	89477.58174
TOTAL					131239.958
50% APRON MAXX					
Fludioxonil	555000	3.8	2109000	101	20881.18812
Metalaxyl-M	555000	5.7	3163500	70.71044922	44738.79087
TOTAL					65619.97899

Table 11b. Foliar spray application rate (ml/ha), bee toxicity levels (LD50) and pesticide index (bee/ha).

	ml/ha	g/L	g/ml	g/ha	µg/ha	LD50	bee/ha
MATADOR							
Cyhalothrin-lambda	83	120	0.12	9.96	9960000	0.093215227	106849496

Table 11c. Site-specific pesticide use, calculated pesticide indices and associated categories.

Site	Pesticide	Type	Application	Pesticide index	Category
C1	Matador	Insecticide	Foliar spray	106849495.59	3
C2					1
C3	CruiserMaxx	Insecticide + fungicide	Seed treatment	16872148111.97	4
C4	Matador	Insecticide	Foliar spray	106849495.59	3
C5	ApronMaxx	Fungicide	Seed treatment	131239.95	2
C7	CruiserMaxx	Insecticide + fungicide	Seed treatment	16872148111.97	4
C8	Matador + ApronMaxx	Insecticide + fungicide	Foliar spray + 50% seed treatment	106915116.60	3
C9	Matador + ApronMaxx	Insecticide + fungicide	Foliar spray + seed treatment	106980735.54	3
C10					1

Appendix 12. DCA axis fit for pan trap and bumble bee communities.

Table 12a. Axis fit for pan trap data

Axis	R ² Increment	R ² Cumulative
1	.208	.208
2	.006	.215
3	.103	.317

Table 12b. Axis fit for *Bombus* data

Axis	R ² Increment	R ² Cumulative
1	0.222	0.222
2	0.046	0.267
3	-0.002	0.266