

DIVERSITY, PHENOLOGY, AND HOST ASSOCIATIONS OF
WILD BEES (HYMENOPTERA: ANTHOPHILA) IN
THUNDER BAY, ONTARIO

by

Amber Fredenburg



FACULTY OF NATURAL RESOURCES MANAGEMENT
LAKEHEAD UNIVERSITY
THUNDER BAY, ONTARIO

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A graduate thesis submitted in partial fulfillment
of the requirements for the degree of Master of Science in Forestry

Supervisor: Dr. Don Henne

Committee: Dr. Brian McLaren and Dr. Janice Hughes

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Supervisor Dr. Don Henne

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A CAUTION TO THE READER

This M.Sc. Forestry thesis has been through a semi-formal process of review and comment by my supervisor, Dr. Don Henne, and members of my supervisory committee, Dr. Brian McLaren and Dr. Janice Hughes. It is made available for loan by the Faculty of Natural Resources Management for the purpose of advancing the practice of professional and scientific forestry.

The reader should be aware that the opinions and conclusions expressed in this document are those of the student and do not necessarily reflect the opinions of the thesis supervisor, supervisory committee, the Faculty of Natural Resources Management or Lakehead University

ABSTRACT

Fredenburg, A.N. 2020. Diversity, phenology, and host associations of wild bees (Hymenoptera: Anthophila) in Thunder Bay, Ontario. Master of Science Thesis, Faculty of Natural Resources Management, Lakehead University, Thunder Bay, ON. 83 pp.

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Although extremely important to the functioning of productive ecosystems, wild bee communities are at risk due habitat loss and agricultural intensification. Wild bee species surveys provide valuable information on the health of wild bee communities, especially in agricultural areas where these bee species are vulnerable; however, many regions are under studied. For example, northwestern Ontario lacks a comprehensive wild bee survey, and many of the species that inhabit this area are unknown. The aim of this study was to inventory wild bee species, the flowers they visit, and their periods of activity in Thunder Bay in northwestern Ontario to fill in gaps in our knowledge of wild bee species that occur in this region, while also investigating the diversity of wild bee communities at three representative flower-rich sites in the area. I collected 64 wild bee species throughout this survey. Twenty-two of these species had not previously been documented in northwestern Ontario, and one (*Nomada alpha*) is a newly documented species to Canada. Additionally, this study found that at an agricultural site wild bee diversity was the lowest, and wild bee community composition was the most uneven compared to two other sites, supporting evidence that agricultural land use may negatively affect wild bee diversity in this region of Canada.

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INTRODUCTION

Pollinators have an essential role in the functioning of terrestrial ecosystems and perform an important ecosystem service for both wild (Ollerton 2017) and agricultural communities (Klein et al. 2007; Sheffield et al. 2013). Animals pollinate an average of 87.5% of all angiosperm species (Ollerton et al. 2011). Additionally, the estimated value of insect pollination is approximately \$240 billion (CAD) annually (Gallai et al. 2009), and nearly 70% of leading global crops increase in harvest size and quality when pollinators are present (Ricketts et al. 2008). Honey bees (*Apis mellifera* L.) are widely used for the pollination of crops, but wild bees recently gained attention as important pollinators for agriculture (Aizen et al. 2009; Garibaldi et al. 2013; Koh et al. 2016). However, in the last two decades many wild bee species have exhibited alarming declines due to habitat destruction (Potts et al. 2010; Goulson et al. 2015; Vogel 2017; Bartomeus et al. 2018).

Changes in land use from natural to agricultural land is one of the leading causes of global biodiversity loss (Newbold et al. 2015). Agriculture endangers wild bee communities through many factors, but the foremost threat agriculture presents to these communities is fragmentation and loss of habitat (Ricketts et al. 2008; Le Féon et al. 2010). The intensification of agricultural land worldwide is linked to declines in wild bee species (Hines and Hendrix 2005; Goulson et al. 2006). These declines are likely because monocultures reduce floral diversity, thus reducing wild bee diversity (Nicholls and Altieri 2013). In addition to reducing wild bee diversity, agriculture also reduces abundance (Kremen et al. 2002) and community evenness (Hall et al. 2019), as well as changes the types of bees that inhabit an area (Harrison et al. 2017; Grab et al. 2019).

A global decline of bees is a cause for concern because if pollinators decline there will likely be an effect on pollination services, with subsequent economic ramifications (Winfree et al. 2009). Historical records of bee species are invaluable in showing changes in species abundance, richness, and range, suggesting these changes are due to habitat loss (Biesmeijer et al. 2006, Cameron et al. 2011; Bartomeus et al. 2013), and agricultural land use (Burkle et al. 2013). Data on wild bee communities, especially in regions with agricultural landscapes, will further our understanding of the conservation status of wild bees and the reasons for their declines (Mathiasson and Rehan 2019; Wagner 2020).

Canada is home to approximately 850 bee species (Grixt et al. 2006; CESCC 2015; Sheffield et al. 2017; Ascher and Pickering 2020), and this number could increase substantially with additional surveys (Packer et al. 2007). Despite the importance of pollinators, wild bee surveys are geographically biased in many historically understudied regions, including parts of Canada (Bartomeus et al. 2018). Large-scale bee surveys (Bartomeus et al. 2018) and local bee surveys (Mathiasson and Rehan 2019) to determine conservation status often have conflicting results. These conflicting results suggest that increased surveying efforts and inclusion of under sampled areas will advance knowledge of wild bee species distributions (Jamieson et al. 2019) and aid in the understanding of local bee ecology (Macphail et al. 2018).

Northwestern Ontario is an understudied secondary region of northern Ontario, northwest of Lake Superior; it has a range of wild bee habitats but lacks a comprehensive wild bee survey. The city of Thunder Bay, on the northwest coast of

Lake Superior has areas of abundant naturally occurring flowers (henceforth referred to as wildflowers) as well as approximately 20,000 hectares of agricultural land (OMAFRA 2016a) within the dense boreal forest of northwestern Ontario. The range of habitats with abundant flora, including agricultural habitats, makes Thunder Bay an appropriate area to investigate wild bee diversity. Three sites were chosen as representative habitats that occur in Thunder Bay to investigate the diversity of the local wild bee communities: an agricultural area with a range of flowering crop plants that grow in the area, a tree plantation with young conifers and wildflowers, and an open meadow with abundant wildflower growth between two dense forest patches. Wild bee surveys in this area could uncover undocumented wild bee species in northwestern Ontario, fill gaps in knowledge of wild bee species ranges, and serve as a starting point for future wild bee inventories in this region. The Ontario government recognizes the importance of wild bees, but more information on local bee ecology including bee species, the flowers they visit, their active flight season, and their diversity are necessary to conserve them (OMAFRA 2016b).

The objectives of this study are to 1) create a comprehensive list of wild bee species, when they are seasonally active, and the flowers they visit in Thunder Bay, Ontario to fill in gaps of knowledge on the wild bee communities that inhabit Thunder Bay, Ontario, and 2) investigate the diversity of wild bee communities in Thunder Bay, Ontario in three representative wildflower-rich habitats of the area: an agricultural site, a tree plantation, and a meadow. I hypothesize that agriculture negatively affects wild bee diversity (evenness and richness). I predict that the agricultural site will be less even and less rich in wild bee diversity than the other two sites.

LITERATURE REVIEW

THE COMPOSITION OF WILD BEE COMMUNITIES

North America is home to approximately 4000 species of bees (Hymenoptera: Anthophila), representing six of seven families found globally (Wilson and Messinger Carril 2016). The range of wild bee species, floral preference, and phenology shape the composition of bee communities. Wild bee communities are also made up of species with varying levels of sociality (Wilson and Messinger Carril 2016). Bumble bees (*Bombus* spp.), honey bees (*Apis mellifera*), and some sweat bees live in social colonies, but the majority of bee species in North America are mostly solitary (Linsley 1958). These bee communities are represented by a few common species in high abundance, and many rare species in low abundance (Winfrey et al. 2018). An individual species' range may be very local or it can extend across North America, and each bee species has its own distinct nesting and floral preferences that determine its range (Potts et al. 2010).

The species that make up wild bee communities vary from highly specialized (called oligoleges or specialists), which visit only a few floral species, to generalists (or polyleges) that visit a wide range of floral species (Wilson and Messinger Carril 2016). However, both specialists and generalists (Sedivy et al. 2011) can exhibit preferences, and these preferences for certain host plants determine whether a bee species will occur in an area (Müller and Kuhlmann 2008; Minckley et al. 2013). Generalists occur in high abundance across habitat types and usually occur in higher proportions than specialists because they can utilize many floral resources (Waser et al. 1996). Conversely, xeric areas like deserts have higher proportions of specialist bee species due to the bee

specialist's capacity to respond to changes in resource availability brought on by drought (Minckley et al. 2013).

Phenology, or the occurrence of plants and animals at different times of the year, also shapes the composition of wild bee communities. Bees emerge at different times of the spring, summer and fall coinciding with flower bloom (Fye 1972). Temperature regulates phenology, making it sensitive to climate change (Bartomeus et al. 2011). Therefore, the mutualistic relationship between host plants and pollinators is vulnerable to climate change resulting in phenological mismatchings (Miller-Rushing et al. 2010).

The linked relationship between bees and their host plants (Cappellari et al. 2013) is evident by the changes in bee species community composition that occur as a result of changes in plant community composition (Biesmeijer et al. 2006). Generalist bees typically exhibit lower frequency of species declines than specialists (Williams et al. 2010) however, they are not exempt from declining (Scheper et al. 2014). Cascading declines and major changes in community compositions in both plant and bee species may occur if a generalist pollinator declines (Pauw 2007). Habitat destruction changes plant and bee communities, causing these communities to become more uneven, resulting in dominant species becoming more dominant and rare species becoming rarer (Winfrey et al. 2018).

THE EFFECT OF LAND USE AND AGRICULTURE ON WILD BEES

Anthropogenic change has brought substantial loss of biodiversity (Cardinale et al. 2012). Land use — the change of natural environments to managed environments — is one of the main causes of biodiversity loss (Newbold et al. 2015). For wild bees,

studies show loss in diversity is due to habitat loss (Hines and Hendrix 2005; Goulson et al. 2006; Winfree et al. 2009). Many other human disturbances such as tillage, logging, fire, and grazing lead to habitat loss. These disturbances may all have negative effects on wild bee richness and abundance, but more studies on these specific types of disturbances are necessary to fully understand their impacts (Winfree et al. 2009).

Land use changes reduce wild bee taxonomic, functional, and phylogenetic diversity (Grab et al. 2019), reduces wild bee abundance (Kremen et al. 2002), and changes bee community composition (Potts et al. 2010, Harrison et al. 2017). Nonetheless, many land-use practices such as agriculture are necessary for humanity, and as the human population grows so does agricultural land use (Newbold et al. 2015). Ontario has the highest number of farms in Canada and these farms yielded approximately \$12 billion (CAD) in 2010 (OMAFRA 2016a). Therefore, agriculture is important in this region of Canada and it is necessary to study the impacts of agricultural land use on wild bee communities to conserve wild bees and their pollination services (Foley et al. 2005; Klein et al. 2007).

Destruction of habitat shifts the range of many flowering species and restructures bee communities (Nemésio et al. 2016). The wild bee species that inhabit agricultural landscapes differ from the species that inhabit forest landscapes in life-history traits such as sociality and phenology (Harrison et al. 2017). Additionally, bees move freely between habitats to exploit the best food and nesting resources and will leave habitats with small floral areas and limited plant species (Sheffield et al. 2013). Therefore, habitats dominated by few floral species, like agroecosystems, tend to have lower bee

diversity than other types of ecosystems (Kremen et al. 2002; Klein et al. 2007; Le Féon et al. 2010).

The harmful effects of agricultural land use on wild bee populations due to loss of habitat are apparent. In Europe, 67% of floral species on which bumble bees depend are experiencing range shrinkage due to agricultural intensification within the last 50 years (Carvell et al. 2006). The loss of floral-rich grasslands in these areas of intensification are linked to declines in many wild bee species (Goulson et al. 2006). Similarly, prairie habitats in the U.S. Midwest that provide abundant bee forage shrank significantly due to agricultural intensification in the last 150 years (Hines and Hendrix 2005). The decline of wild bees in Europe and the loss of bee habitat in North America due to agricultural land use are cause for concern.

BEES OF CANADA AND THEIR CONSERVATION STATUS

The Canadian Endangered Species Conservation Council list 34 bee species in Canada as imperiled or critically imperiled (CESCC 2015). Surveys of historical collections have indicated that many bee species are experiencing widespread loss, particularly species in the genera *Andrena*, *Bombus*, *Halictus*, *Lasioglossum*, *Megachile* and *Nomada* (Bartomeus et al. 2013; Mathiasson and Rehan 2019). It is likely that more species are also experiencing declines and range changes, but due to a lack of baseline data, they have not been documented (Bartomeus et al. 2018). Range shifts are usually discussed in terms of range contractions as in the case of the rusty patch bumble bee (*B. affinis* Cresson) (Federal Register 2016). Conversely, range expansions can lead to

problems of resource competition and must also be considered as a part of wild bee conservation (Gibbs and Sheffield 2009; Ratti and Colla 2010).

Northwestern Ontario is an important area for bee surveys. Many plant taxa in this region are at the northern extent of their range (Klemet-N'Guessan et al. 2019), potentially causing a parallel phenomenon in bees. Southern Ontario wild bee diversity studies are comprehensive (Colla et al. 2009; Richards et al. 2011), but the bee surveys done in northwestern Ontario are taxonomically biased and only sample specific genera as opposed to all wild bee species (Knerer and Atwood 1962, 1964; Lavery and Harder 1988; Romankova 2003a, 2003b, 2007; Onuferko 2017). Wild bee surveys in northwestern Ontario could provide valuable information on bee species in their northern range and continued surveying of this area could identify changes in these bee species ranges.

MATERIALS AND METHODS

STUDY SITE DESCRIPTIONS

To capture Thunder Bay's wild bee diversity, study sites were selected by including habitats that are representative of flower-rich areas in the region. Additionally, study sites were chosen that had abundant wildflower blooms, were near each other and were in close proximity to the city to allow for higher frequency sampling. The first site is at the Lakehead University Agricultural Research Station (LUARS) (48°18'18.4" N, 89°23'15.7" W), which contains a range of flowering crop plants and mowed grass areas and fallow areas surrounding crop plots. The second site, Hogarth Plantation (48°21'19.4" N, 89°23'34.4" W), a woodlot owned by Lakehead University Faculty of Natural Resources Management, has tall grass, abundant wildflower bloom and young pine trees. The third site is on the Lakehead University campus near the campus's Hangar facility (48°25'08.8" N, 89°16'00.8" W) where an unmowed naturally occurring wildflower meadow exists between two tree lines.

Lakehead University Agricultural Research Station (LUARS)

LUARS is a 16-hectare agricultural crop field located approximately 10 kilometers southwest of Thunder Bay, Ontario. Other agricultural fields and a waste management facility are in proximity to the station, with forests approximately one kilometer to the south and west (Fig. 1). The site consists of crop plots and mowed grass in between the crop plots (Fig. 2), but there also is a small shrubby patch along one side of the field (Fig. 3). The research station grows a range of different crops which include cultivated rapeseed (*Brassica napus* L.), mustard (*B. juncea* (L.) Czern.), lentils (*Lens culinaris* Medik.), alfalfa (*Medicago sativa* L.), and flax (*Linum usitatissimum* L.).



Figure 1. Overhead view of LUARS and surrounding area from Google Earth.



Figure 2. Northeast view of LUARS from entrance.



Figure 3. South view of LUARS of the shrubby patch next to the fields.

Hogarth Plantation

Hogarth Plantation is a 44-hectare tree plantation (woodlot) used for forestry research and education by the Faculty of Natural Resources Management at Lakehead University. The plantation is located approximately 9 kilometer west of Thunder Bay, Ontario. Residential areas and forest surround the woodlot (Fig. 4). The area used for this study burned in 2007 and currently has tall grass, wildflowers, and young conifer trees (Fig. 5 and Fig. 6).

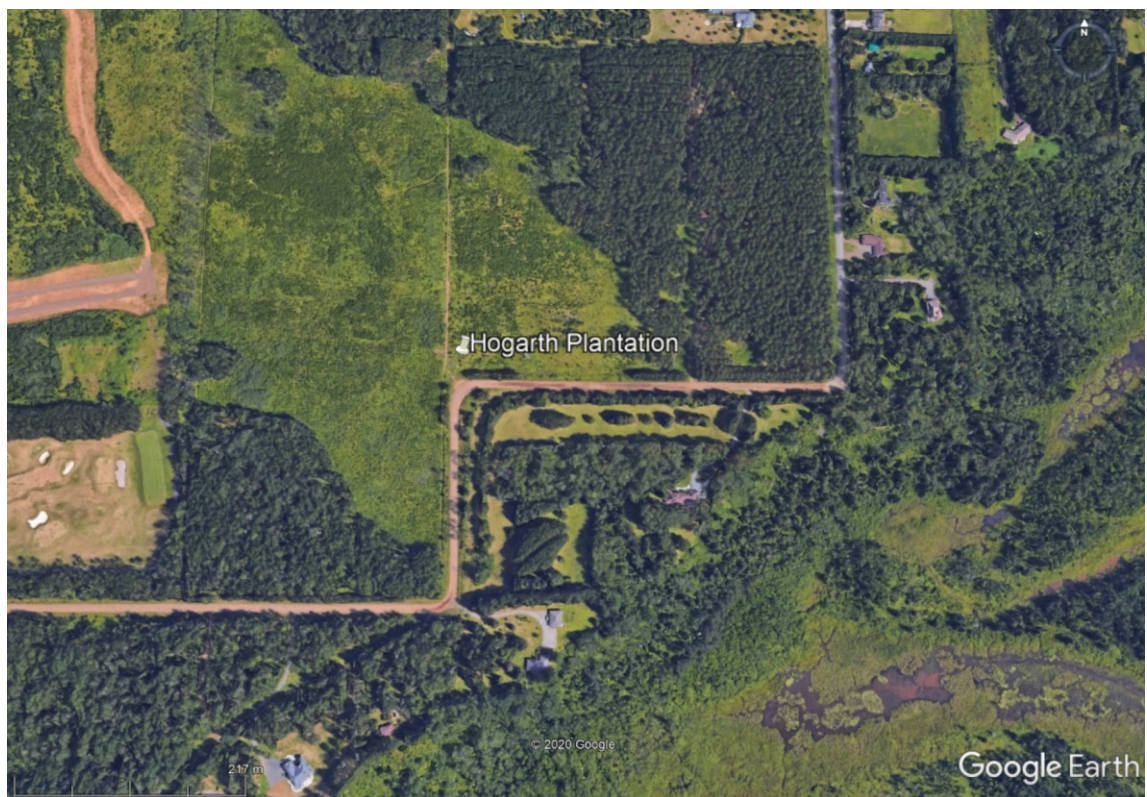


Figure 4. Overhead view of Hogarth woodlot and surrounding area from Google Earth.



Figure 5. North view of Hogarth woodlot.



Figure 6. East view of Hogarth woodlot.

Lakehead University Hangar (LU Hangar)

LU Hangar is an unmowed meadow located at between two forest patches on the campus of Lakehead University (Fig. 7) with sloping terrain adjacent to the McIntyre River. Between the two forest patches is wildflower growth (Fig. 8 and Fig. 9).

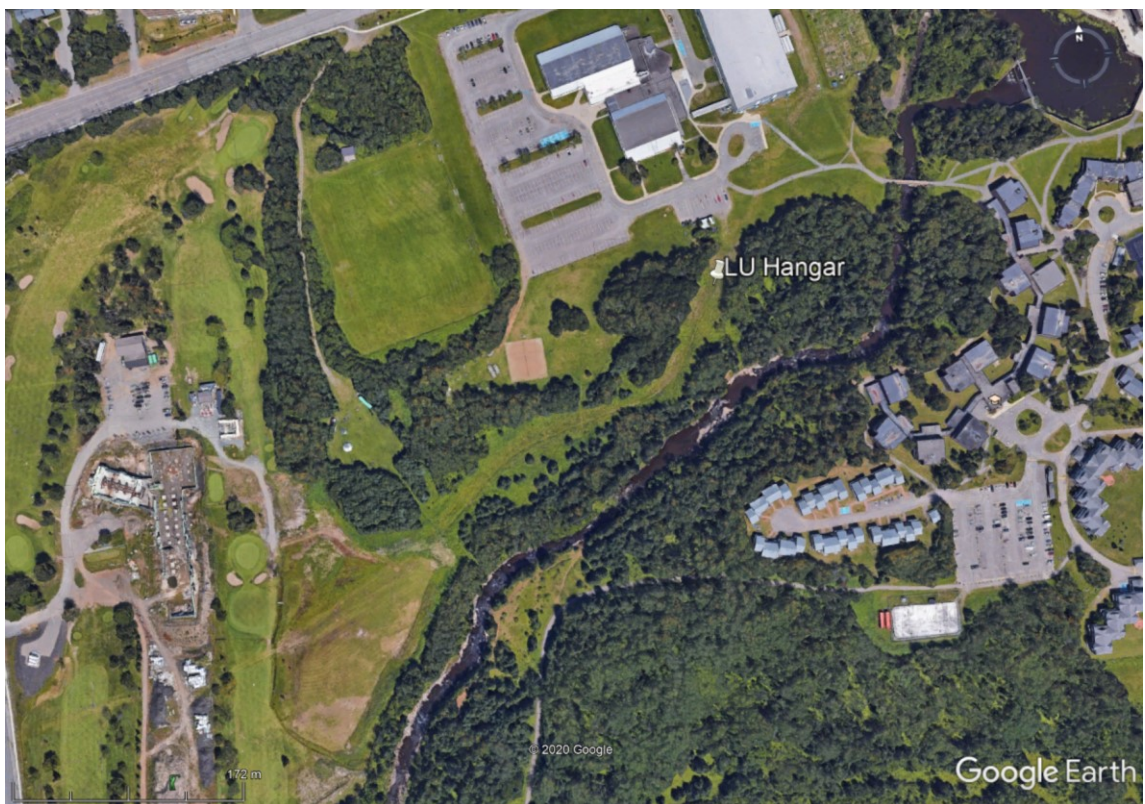


Figure 7. Overhead view of LU Hangar and surrounding area from Google Earth.



Figure 8. Northeast view of LU Hangar.



Figure 9. Southwest view of LU Hangar.

SAMPLING

I sampled sites between 09:00 and 16:00 for two hours once or twice a week (depending on weather conditions) between 10 June 2019 and 19 September 2019. The onset of sampling was determined by local wildflower phenology at the sites. Sampling began when flowering areas had enough bloom for bee bowling to begin (i.e., large enough areas where majority of bee bowls would not be left in an area without flowers if placed at the appropriate distance apart). I sampled Hogarth Plantation and LU Hangar for 14 days and LUARS for 19 days. Sampling methods included both bee bowling (described below) and collecting with an insect net. The net had a 91.5 cm handle, a 30.5 cm net ring diameter, and a standard white aerial net bag (BioQuip products, Rancho Dominguez, California, USA). I included both sampling methods to help eliminate inherent biases in each method (Cane et al. 2000; Grundel et al. 2011), however these methods should still be viewed considering their biases (Portman et al. 2020).

I collected bees with a net by surveying the sites in their entirety over two hours by walking at a continuous steady pace through the site. When I observed a bee, I swung the net horizontally over the top a flower. I then transferred the captured bee into a kill jar (BioQuip products, Rancho Dominguez, California, USA) containing ethyl acetate in the lid compartment. Positively identified individuals of bee duplicate species that were observed on the same flower species on the same day were written down and released from the net. I recorded the bees, and flowers that I observed them on, put the bees into a jar to freeze overnight, and mounted them into the bee collection box the following day.

Bee bowling is another common method for bee sampling (Droege et al. 2010). To make bee bowls, I painted the inside of plastic bowls (3.25 oz Solo™ party bowls, Highland Park, Illinois, U.S.A) (Leong and Thorp 1999) one of three colours, (fluorescent blue, glow-in-the-dark white, and fluorescent yellow acrylic Americana Neons by DecoArt™), with a sponge brush until the colour was uniform throughout. I left one group of bowls unpainted as a partially translucent white. I then drew four straight lines from one end to the other (through the middle) on the bottom of the cups with a permanent (Sharpie™) marker at equal distances. These lines, known as nectar guides, resemble the natural pattern on flowers that guide bees to the center to retrieve nectar (Wilson et al. 2016).

I chose 20 bowls, five of each colour in random order and placed them approximately 3-5 m apart in a transect on the ground (Droege et al. 2010) in an area with significant flower bloom. If large areas of continuous bloom exceeded approximately 60 meters in length additional bowls of random colours in a random order were added to the original 20 until the area was covered. This was done, for example, when the large area of alfalfa at LUARS was in bloom. I filled the bowls with soapy water made by adding a few drops of Palmolive™ extra strength original scent dish soap to a 3.78-liter jug of water to trap the bees when they flew into the bowls. I then left the bowls unattended for the duration of the survey. At the end of the survey, I collected the bowls, removed trapped bees with forceps, and stored the bees in containers labeled with the bowl colour that they were found in. I put the bees in the freezer overnight and mounted them into the bee collection box the following day. Other bee surveys that employ both net sampling and bee bowling suggest leaving bowls out

for the duration of the survey which was done in this study (Cane et al. 2000; Grundel et al 2011). However, the duration of surveys in this study were shorter than other published studies and may present limitations. The short survey duration was continued to allow consistent two-hour sample times on all days of the survey, as well as keep sample times between net sampling and bee bowling the same.

Additionally, Japanese beetle traps were already set up at LUARS and LU Hangar and these traps were checked for bee species the same day these sites were sampled and provided additional observations.

Bee identification and taxonomy of each individual's species and sex was carried out by Dr. Jason Gibbs (University of Manitoba, Department of Entomology) and followed published taxonomic studies (Stephen 1954; Mitchell 1960, 1962; LaBerge 1961, 1973, 1986, 1989; Shinn 1967; Snelling 1970; Baker 1975; Donovan 1977; Bouseman and LaBerge 1979; McGinley 1986; Laverty and Harder 1988; Gibbs 2011; Rehan and Sheffield 2011; Sheffield et al. 2011; Gibbs et al. 2013, 2017; Sheffield and Perron 2014; Williams et al. 2014). I identified plant species using the PictureThis app (PictureThis 2019) as a beginning reference point. I then used the dichotomous key in Newcomb's Wildflower Guide (Newcomb and Morrison 1989) to key out the floral species, and then searched the flower species in the USDA Plants Database (USDA 2019) to confirm the identification and to verify that the name from the key was the current accepted name. The USDA Plants Database was used because it includes information on floral species such as if the species is native or exotic by state and all synonyms of past floral names throughout the U.S. and Canada.

I searched observations for each bee species on DiscoverLife (<http://www.discoverlife.org>), Global Biodiversity Information Facility (<http://gbif.org>), and Integrated Digitized Biocollections (<http://idigbio.org>) for geographic range. The northern-most observation to the east and west, and the southern-most observation to the east and west described a general geographic range. The citations of the observations within the databases were checked to avoid erroneous records. A search of NatureServe Explorer (<https://explorer.natureserve.org/>) determined conservation status rank.

DATA ANALYSIS

I calculated a Sorensen's Similarity Index, which is a measure of the similarity of species found among sites (here, three site comparisons were made) but does not compare abundance, using the formula:

$$C_s = 2N_{ab}/(N_a + N_b)$$

where N_{ab} is the number of shared species at the other sites, and N_a and N_b are the number of species in each group A and B (Magurran 1988).

I also calculated Shannon and Simpson Diversity Indices to analyze wild bee diversity (Magurran et al. 2013). I calculated both the Shannon Index (more sensitive to richness) and the Simpson Index (more sensitive to evenness) (Colwell 2009), to fully represent bee diversity as a measure of both richness and evenness (Kearns and Oliveras 2009). Larger values for these indices indicated more diverse communities. The Shannon diversity formula is:

$$H = - \sum_{i=1}^S p_i \ln p_i$$

and the Simpson diversity formula is:

$$D = 1 - \sum_{i=1}^s p_i^2$$

where S is the number of species, p_i is a proportion (n/N), where n is the number of individuals of one species found, and N is the total number of individuals (Shannon and Weaver 1949; Simpson 1949).

I also created rarefaction curves using R (R Core Team 2020), which standardized the sample and estimated minimum sample size (Gotelli and Colwell 2001), to compare wild bee diversity between sites. R packages ‘vegan’ (Oksanen et al. 2008) and ‘iNEXT’ (Hsieh et al. 2016) plotted rarefaction curves and extrapolated the results to a greater sampling effort (Hsieh et al. 2016). The rarefaction formula is

$$S_{est} = S_{obs} + \frac{a^2}{2b}$$

where S_{obs} is the total number of species observed, S_{est} is the estimated number of species in assemblage in the sample, a is species represented by only one individual, and b is species represented by two individuals (Sanders 1968).

I also used the ‘iNEXT’ package in R to extrapolate the number of species using Hill numbers based on Shannon and Simpson Indices (Hsieh et al. 2016). Hill numbers, or effective number of species, uses diversity indices to estimate richness in an even population (Hill 1973). The Hill number formula is:

$${}^qD = \left(\sum_{i=1}^s p_i^q \right)^{\frac{1}{1-q}}$$

where D is the effective number of common species, q is the order of diversity (0 =richness, 1 =Shannon, 2 =Simpson), S is richness, and p_i is proportional abundance of species i .

For the bee bowl data, I combined the abundance of wild bee species among the bowl colours at each site. I calculated a chi-square goodness of fit test for each genus found in the bee bowls to compare the richness and abundance between bowl colours. The null hypothesis was that wild bees would have no preference among bee bowl colours and would be rejected if the p-value is less than 0.05.

RESULTS

BEE SPECIES LIST

A total of 792 individuals belonging to 64 species, 18 genera, and five families of bees were collected in this study using combined bee bowling and net collecting methods. The most speciose genus was *Lasioglossum* (14 species), followed by *Bombus* (10 species), *Andrena* (8 species) and *Megachile* (8 species). A total of 368 individuals belonging to 38 species were collected at LUARS across 19 days of sampling, 268 individuals belonging to 42 species were collected at LU Hangar across 14 days, and 156 individuals belonging to 40 species were collected at Hogarth. An average of approximately 19 individuals were collected each day at both LUARS and LU Hangar, and an average of 11 individuals per day were collected at Hogarth. The following species list contains the bee species, the flowers on which each species was found on, and which sites the species were found at during this survey. Additionally, the list contains range information and conservation status. This list format follows a previously published bee species list (Grundel et al. 2011).

Key to list: **Genus (Subgenus) species** Author; ♂ males collected; ♀ females collected; Q queens collected (*Bombus* spp. only); northern range; southern range; new observation in NW Ontario? (yes/no); native or exotic; conservation status rank; additional note; flower species associated with bee specimens (number of individuals observed on that flower); sites the species found at.

None indicated that the specimen was not found on any flower and was found either in the bee bowls, bare ground or in a Japanese beetle trap deployed at two of the

sites. The number of individuals collected on each flower may not add up to the total individuals in that species due to observations in bee bowls, bare ground, or beetle trap.

Andrenidae

1. *Andrena (Cnemidandrena) canadensis* Dalla Torre; ♂ 1; ♀ 9; Saskatchewan to Nova Scotia; Florida to Mississippi; no; native; no status rank; goldenrod specialist (Wolf and Ascher 2008); *Solidago canadensis* (7), *Solidago juncea* (3); Hogarth, LU Hangar
2. *Andrena (Holandrena) cressonii* Robertson; ♂ 0; ♀ 1; British Columbia to Nova Scotia; California to Florida; yes; native; secure; *Taraxacum officinale* (1); LUARS
3. *Andrena (Melandrena) dunningi* Cockerell; ♂ 0; ♀ 3; Manitoba to Nova Scotia; Missouri to Georgia; yes; native; secure; *Capsella bursa-pastoris* (1), *Taraxacum officinale* (2); LUARS
4. *Andrena (Trachandrena) hippotes* Robertson; ♂ 2; ♀ 0; British Columbia to Nova Scotia; California to Georgia; no; native; secure; none; LUARS
5. *Andrena (Melandrena) nivalis* Smith; ♂ 0; ♀ 4; Yukon to Newfoundland; California to North Carolina; no; native; secure; *Brassica napus* (4); LUARS
6. *Andrena (Melandrena) regularis* Malloch; ♂ 0; ♀ 3; British Columbia to Nova Scotia; Colorado to Georgia; no; native; secure; none; Hogarth
7. *Andrena (Taeniandrena) wilkella* Kirby; ♂ 2; ♀ 13; Manitoba to Nova Scotia; Arizona to North Carolina; no; exotic; no status rank; prefers Fabaceae (Wood and Roberts 2017); *Lens culinaris* (1), *Lotus corniculatus* (1), *Lupinus*

polyphyllus (1), *Symphytum officinale* (1), *Taraxacum officinale* (3),

Tragopogon pratensis (2), *Vicia cracca* (6); Hogarth, LU Hangar, LUARS

8. ***Andrena (Thysandrena) w-scripta*** Viereck; ♂ 6; ♀ 1; Yukon to Newfoundland; California to Louisiana; no; native; secure; *Lotus corniculatus* (1), *Medicago sativa* (2), *Trifolium pratense* (1), *Vicia cracca* (3); Hogarth, LU Hangar, LUARS
9. ***Calliopsis (Calliopsis) andreniformis*** Smith; ♂ 2; ♀ 0; Manitoba to Nova Scotia; Arizona to Georgia; no; native; secure; none; LU Hangar
10. ***Protandrena aestivalis*** (Provancher); ♂ 0; ♀ 21; Saskatchewan to New Brunswick; Colorado to Texas; yes; native; secure; late season Asteraceae specialist (Sheffield et al. 2014); *Cirsium arvense* (1), *Eurybia macrophylla* (7), *Solidago canadensis* (10), *Solidago juncea* (2), *Solidago puberula* (1); Hogarth, LU Hangar

Apidae

11. ***Anthophora (Clisodon) terminalis*** Cresson; ♂ 0; ♀ 2; Alaska to Prince Edward Island; California to North Carolina; no; native; secure; *Medicago sativa* (1); LUARS
12. ***Bombus (Subterraneobombus) borealis*** Kirby; ♂ 21; W 21; Q 5; Alaska to Newfoundland and Labrador; New Mexico to Louisiana; no; native; apparently secure; *Brassica napus* (1), *Cirsium arvense* (1), *Lotus corniculatus* (1), *Medicago sativa* (4), *Solidago canadensis* (3), *Symphytum officinale* (3), *Taraxacum officinale* (1), *Trifolium pratense* (17), *Vicia cracca* (12); Hogarth, LU Hangar, LUARS

13. ***Bombus (Psithyrus) fernaldae*** (Franklin); ♂ 1; W 2; Q 0; Alaska to Newfoundland and Labrador; California to North Carolina; no; native; secure; nest parasite; *Cirsium arvense* (2), *Medicago sativa* (1); LU Hangar, LUARS
14. ***Bombus (Cullumanobombus) griseocollis*** (De Geer); ♂ 7; W 6; Q 2; British Columbia to New Brunswick; California to Florida; no; native; secure; *Cirsium arvense* (1), *Galega officinalis* (1), *Helianthus tuberosus* (1), *Lotus corniculatus* (3), *Medicago sativa* (6), *Onobrychis viciifolia* (1), *Taraxacum officinale* (1), *Vicia cracca* (1); Hogarth, LUARS
15. ***Bombus (Pyrobombus) impatiens*** Cresson; ♂ 7; W 22; Q 1; British Columbia to Nova Scotia; California to Florida; no; native; secure; *Brassica napus* (5), *Cirsium arvense* (1), *Euphrasia pectinate* (1), *Eurybia macrophylla* (3), *Lotus corniculatus* (1), *Medicago sativa* (4), *Solidago canadensis* (13), *Trifolium pratense* (2); Hogarth, LU Hangar, LUARS
16. ***Bombus (Pyrobombus) perplexus*** Cresson; ♂ 2; W 0; Q 0; Alaska to Nova Scotia; New Mexico to Georgia; native; no; secure; *Helianthus tuberosus* (1), *Vicia cracca* (1); Hogarth
17. ***Bombus (Cullumanobombus) rufocinctus*** Cresson; ♂ 34; W 73; Q 15; Alaska to Newfoundland and Labrador; no; native; apparently secure; *Brassica napus* (17), *Capsella bursa-pastoris* (2), *Cirsium arvense* (12), *Cirsium vulgare* (1), *Eurybia macrophylla* (5), *Galega officinalis* (1), *Lens culinaris* (4), *Leucanthemum vulgare* (1), *Lotus corniculatus* (14), *Onobrychis viciifolia* (2), *Potentilla recta* (1), *Solidago canadensis* (16), *Solidago juncea* (3), *Solidago puberula* (1), *Sonchus arvensis* (2), *Symphytum officinale* (1), *Trifolium*

hybridum (1), *Trifolium pratense* (4), *Trifolium repens* (6), *Vicia cracca* (6);

Hogarth, LU Hangar, LUARS

18. ***Bombus (Pyrobombus) sandersoni*** Franklin; ♂ 0; W 4; Q 2; British Columbia to Newfoundland and Labrador; Utah to North Carolina; no; native; apparently secure; *Brassica napus* (2), *Lotus corniculatus* (1), *Solidago canadensis* (1),

Vicia cracca (2); Hogarth, LU Hangar, LUARS

19. ***Bombus (Pyrobombus) ternarius*** Say; ♂ 20; W 85; Q 5; Yukon to Newfoundland and Labrador; New Mexico to Georgia; no; native; secure; *Apocynum androsaemifolium* (9), *Brassica juncea* (1), *Brassica napus* (13), *Cirsium arvense* (4), *Euphrasia pectinate* (2), *Eurybia macrophylla* (3), *Galega officinalis* (2), *Lens culinaris* (2), *Leucanthemum vulgare* (1), *Linum usitatissimum* (1), *Lotus corniculatus* (11), *Lupinus polyphyllus* (2), *Medicago sativa* (7), *Onobrychis viciifolia* (1), *Persicaria laphifolia* (2), *Rudbeckia hirta* (1), *Solidago canadensis* (14), *Solidago juncea* (4), *Solidago puberula* (2), *Sonchus arvensis* (1), *Taraxacum officinale* (4), *Trifolium hybridum* (1), *Trifolium pratense* (2), *Trifolium repens* (10), *Vicia cracca* (6); Hogarth, LU Hangar, LUARS

20. ***Bombus (Bombus) terricola*** Kirby; ♂ 2; W 21; Q 0; Alaska to Newfoundland and Labrador; California to Florida; no; native; vulnerable; *Brassica juncea* (1), *Brassica napus* (11), *Lotus corniculatus* (5), *Medicago sativa* (1), *Solidago canadensis* (2), *Trifolium hybridum* (1), *Vicia cracca* (2); Hogarth, LU Hangar, LUARS

21. ***Bombus (Pyrobombus) vagans*** Smith; ♂ 34; W 17; Q 12; Alaska to Newfoundland and Labrador; New Mexico to Florida; no; native; apparently secure; *Apocynum androsaemifolium* (2), *Capsella bursa-pastoris* (1), *Chamaenerion angustifolium* (1), *Cirsium arvense* (9), *Cirsium vulgare* (1), *Dasiphora fruticosa* (1), *Eurybia macrophylla* (3), *Galega officinalis* (1), *Helianthus tuberosus* (4), *Leucanthemum vulgare* (1), *Lotus corniculatus* (2), *Lupinus polyphyllus* (1), *Melilotus alba* (1), *Onobrychis viciifolia* (1), *Rudbeckia hirta* (1), *Solidago canadensis* (7), *Solidago juncea* (2), *Solidago puberula* (1), *Symphytum officinale* (2), *Taraxacum officinale* (1), *Trifolium pratense* (7), *Vicia cracca* (10); Hogarth, LU Hangar, LUARS
22. ***Ceratina (Zadontomerus) mikmaqi*** Rehan and Sheffield; ♂ 3; ♀ 5; North Dakota to Maine; Missouri to North Carolina; yes; native; secure; *Cirsium arvense* (1), *Solidago canadensis* (1), *Solidago juncea* (1); Hogarth, LU Hangar, LUARS
23. ***Melissodes (Eumelissodes) druriellus*** (Kirby); ♂ 9; ♀ 12; North Dakota to Nova Scotia; Colorado to Alabama; yes; native; no status rank; Asteraceae specialist (Wolf and Ascher 2008); *Cirsium arvense* (1), *Eurybia macrophylla* (5), *Rudbeckia hirta* (2), *Solidago canadensis* (9), *Solidago juncea* (2), *Solidago puberula* (1); Hogarth, LU Hangar, LUARS
24. ***Melissodes (Eumelissodes) illatus*** Lovell and Cockerell; ♂ 0; ♀ 3; Manitoba to Nova Scotia; Arizona to North Carolina; no; native; secure; Asteraceae specialist (Wolf and Ascher 2008); *Solidago canadensis* (1), *Solidago juncea* (2); Hogarth

25. *Nomada alpha* Cockerell; ♂ 1; ♀ 1; Canada: None; United States: Colorado; yes; native; no status rank; none; Hogarth
- First confirmed observation in Canada. Recently documented from the Upper Peninsula in neighboring Michigan (Gibbs et al. 2017).
26. *Nomada cressonii* Robertson; ♂ 0; ♀ 1; Idaho to Nova Scotia; California to North Carolina; yes; native; no status rank; none; Hogarth
27. *Nomada pygmaea* Cresson; ♂ 0; ♀ 1; Michigan to Nova Scotia; Tennessee to Georgia; yes; native; no status rank; *Taraxacum officinale* (1); LUARS
28. *Triepeolus subalpinus* Cockerell; ♂ 1; ♀ 0; Alberta to Saskatchewan; California to Colorado; yes; native; no status rank; *Solidago juncea* (1); LU Hangar

Colletidae

29. *Colletes kincaidii* Cockerell; ♂ 2; ♀ 1; British Columbia to Prince Edward Island; California to Illinois; no; native; secure; *Brassica napus* (2); LUARS
30. *Hylaeus (Hylaeus) annulatus* (Linnaeus); ♂ 0; ♀ 2; Alaska to Newfoundland and Labrador; California to North Carolina; no; native; secure; *Lotus corniculatus* (1); Hogarth, LU Hangar
31. *Hylaeus (Hylaeus) mesillae* (Cockerell); ♂ 0; ♀ 2; British Columbia to Nova Scotia; California to Georgia; no; native; secure; *Solidago canadensis* (1); LUARS
32. *Hylaeus (Prosopis) modestus* Say; ♂ 0; ♀ 4; Alaska to Newfoundland and Labrador; California to Florida; no; native; secure; *Solidago puberula* (1); Hogarth

33. *Hylaeus (Hylaeus) verticalis* (Cresson); ♂ 1; ♀ 2; British Columbia to Nova Scotia; California to Maryland; no; native; secure; *Apocynum androsaemifolium* (2), *Eurybia macrophylla* (1); Hogarth, LU Hangar

Halictidae

34. *Halictus (Seladonia) confusus* Smith; ♂ 2; ♀ 7; Alaska to Nova Scotia; California to Florida; no; native; secure; *Brassica napus* (1), *Capsella bursa-pastoris* (1), *Solidago canadensis* (1), *Sonchus arvensis* (2); LU Hangar, LUARS
35. *Halictus (Protohalictus) rubicundus* (Christ); ♂ 3; ♀ 1; Alaska to Newfoundland and Labrador; California to Florida; no; native; secure; *Brassica napus* (1), *Cirsium arvense* (1), *Symphotrichum puniceum* (1), *Vicia cracca* (1); LU Hangar, LUARS
36. *Lasioglossum (Dialictus) admirandum* (Sandhouse); ♂ 0; ♀ 1; North Dakota to New Hampshire; Texas to Florida; yes; native; secure; *Capsella bursa-pastoris* (1); LUARS
37. *Lasioglossum (Dialictus) albipenne* (Robertson); ♂ 2; ♀ 16; Washington to Nova Scotia; Oregon to Virginia; yes; native; secure; *Capsella bursa-pastoris* (1), *Leucanthemum vulgare* (1), *Medicago sativa* (1); LU Hangar, LUARS
38. *Lasioglossum (Evyllaesus) cinctipes* (Provancher); ♂ 2; ♀ 2; North Dakota to Nova Scotia; Texas to Florida; no; native; secure; *Eurybia macrophylla* (1), *Solidago canadensis* (2), *Solidago juncea* (1); Hogarth, LU Hangar
39. *Lasioglossum (Sphecodogastra) comagenense* (Knerer and Atwood); ♂ 0; ♀ 1; Alaska to New York; Washington to Maryland; no; native; secure; *Capsella bursa-pastoris* (2); LUARS

40. *Lasioglossum (Dialictus) cressonii* (Robertson); ♂ 1; ♀ 1; British Columbia to Nova Scotia; Utah to Georgia; no; native; secure; *Solidago canadensis* (2); LU Hangar
41. *Lasioglossum (Hemihalictus) inconditum* (Cockerell); ♂ 1; ♀ 0; Alaska to Newfoundland and Labrador; Colorado to West Virginia; no; native; secure; *Eurybia macrophylla* (1); Hogarth
42. *Lasioglossum (Dialictus) laevissimum* (Smith); ♂ 1; ♀ 20; North Dakota to Newfoundland and Labrador; New Mexico to North Carolina; no; native; secure; *Brassica napus* (3), *Eurybia macrophylla* (1), *Lotus corniculatus* (1), *Lupinus polyphyllus* (1), *Potentilla recta* (1), *Sonchus arvensis* (3); Hogarth, LU Hangar, LUARS
43. *Lasioglossum (Dialictus) leucomus* (Lovell); ♂ 2; ♀ 1; North Dakota to Maine; Nebraska to North Carolina; yes; native; secure; *Sonchus arvensis* (2); LU Hangar, LUARS
44. *Lasioglossum (Leuchalictus) leucozonium* (Schrank); ♂ 21; ♀ 6; British Columbia to Prince Edward Island; Utah to North Carolina; yes; exotic; no status rank; *Cirsium arvense* (3), *Euphrasia pectinata* (1), *Helianthus tuberosus* (3), *Lupinus polyphullus* (1), *Medicago sativa* (1), *Oxalis corniculata* (1), *Solidago canadensis* (2), *Sonchus arvensis* (3), *Trifolium pratense* (1); Hogarth, LU Hangar, LUARS
45. *Lasioglossum (Lasioglossum) paraforbesii* McGinley; ♂ 2; ♀ 4; Alberta to Ontario; New Mexico to Kansas; yes; native; no status rank; *Helianthus tuberosus* (1), *Solidago canadensis* (1); Hogarth, LU Hangar, LUARS

46. *Lasioglossum (Dialictus) planatum* (Lovell); ♂ 7; ♀ 29; Alberta to New Brunswick; Michigan to Virginia; no; native; secure; *Brassica juncea* (1), *Brassica napus* (2), *Capsela bursa-pastoris* (1), *Eurybia macrophylla* (1), *Linum usitatissimum* (2), *Medicago sativa* (1), *Solidago canadensis* (4), *Sonchus arvensis* (2), *Taraxacum officinale* (1); LU Hangar, LUARS
47. *Lasioglossum (Sphecodogastra) quebecense* (Crawford); ♂ 0; ♀ 1; Alberta to Nova Scotia; North Dakota to North Carolina; yes; native; secure; *Solidago canadensis* (1); LU Hangar
48. *Lasioglossum (Leuchalictus) zonulum* (Smith); ♂ 1; ♀ 25; Washington to Nova Scotia; California to Pennsylvania; no; exotic; no status rank; *Euphrasia pectinata* (1), *Solidago canadensis* (1), *Sonchus arvensis* (2), *Symphytum officinale* (1), *Taraxacum officinale* (1); LU Hangar, LUARS
49. *Sphecodes atlantis* Mitchell; ♂ 0; ♀ 1; Wisconsin to Maine; Texas to Florida; yes; native; no status rank; none; Hogarth
50. *Sphecodes confertus* Say; ♂ 0; ♀ 1; Michigan to Maine; Kansas to South Carolina; yes; native; no status rank; none; Hogarth
51. *Sphecodes coronus* Mitchell; ♂ 1; ♀ 2; Minnesota to Maine; Illinois to Georgia; yes; native; no status rank; *Solidago canadensis* (3); LU Hangar
52. *Sphecodes dichrous* Smith; ♂ 2; ♀ 1; Oregon to Nova Scotia; Texas to Florida; yes; native; no status rank; *Solidago canadensis* (1), *Solidago juncea* (2); LU Hangar

Megachilidae

53. *Coelioxys (Boreocoelioxys) rufitarsis* Smith; ♂ 1; ♀ 2; British Columbia to Nova Scotia; Virginia to California; no; native; no status rank; *Lotus corniculatus* (2); Hogarth
54. *Hoplitis (Alcidamea) pilosifrons* Cresson; ♂ 0; ♀ 9; Alberta to Nova Scotia; California to Florida; yes; native; secure; *Leucanthemum vulgare* (1), *Lotus corniculatus* (1), *Vicia cracca* (1); Hogarth, LU Hangar, LUARS
55. *Hoplitis (Alcidamea) producta* (Cresson); ♂ 0; ♀ 4; British Columbia to Nova Scotia; California to South Carolina; yes; native; secure; *Lotus corniculatus* (1); Hogarth, LU Hangar
56. *Megachile (Xanthosarus) frigida* Smith; ♂ 6; ♀ 1; Alaska to Newfoundland and Labrador; California to Florida: no; native; secure; *Lotus corniculatus* (3), *Medicago sativa* (1), *Vicia cracca* (1); LU Hangar, LUARS
57. *Megachile (Xanthosarus) gemula* Cresson; ♂ 0; ♀ 9; Alaska to Nova Scotia; California to Florida; no; native; secure; *Apocynum androsaemifolium* (2), *Lotus corniculatus* (4), *Lupinus polyphyllus* (1), *Vicia cracca* (2); Hogarth, LU Hangar
58. *Megachile (Megachile) inermis* Provancher; ♂ 9; ♀ 13; Alaska to Nova Scotia; California to North Carolina; no; native; secure; *Anaphalis margaritacea* (1), *Brassica napus* (1), *Cirsium arvense* (2), *Cirsium vulgare* (1), *Helianthus tuberosus* (1), *Lotus corniculatus* (1), *Solidago canadensis* (3), *Vicia cracca* (4); Hogarth, LU Hangar, LUARS
59. *Megachile (Xanthosarus) latimanus* Say; ♂ 1; ♀ 11; Northwest Territories to Nova Scotia; California to North Carolina; no; native; secure; *Brassica napus*

(5), *Helianthus tuberosus* (1), *Hieracium canadense* (1), *Lotus corniculatus* (1),
Medicago sativa (1), *Solidago canadensis* (1); Hogarth, LU Hangar, LUARS

60. *Megachile (Xanthosarus) melanophaea* Smith; ♂ 2; ♀ 2; Alaska to
 Newfoundland and Labrador; California to Louisiana; no; native; secure; *Lotus*
corniculatus (1), *Onobrychis viciifolia* (1), *Vicia cracca* (2); Hogarth, LU
 Hangar, LUARS
61. *Megachile (Sayapis) pugnata* Say; ♂ 1; ♀ 0; British Columbia to Nova Scotia;
 California to North Carolina; no; native; secure; Asteraceae specialist (Wolf and
 Ascher 2008); *Solidago canadensis* (1); LU Hangar
62. *Megachile (Megachile) relativa* Cresson; ♂ 1; ♀ 6; Alaska to Newfoundland
 and Labrador; California to Georgia; no; native; secure; *Chamaenerion*
angustifolium (1), *Cirsium arvense* (1), *Lotus corniculatus* (1), *Rudbeckia hirta*
 (1), *Solidago canadensis* (1), *Solidago puberula* (1), *Sonchus arvensis* (1);
 Hogarth, LU Hangar, LUARS
63. *Megachile (Eutricharaea) rotundata* (Fabricius); ♂ 0; ♀ 2; Alaska to
 Newfoundland and Labrador; California to Florida; yes; exotic; secure; *Lotus*
corniculatus (1), *Vicia cracca* (1); Hogarth, LU Hangar
64. *Osmia (Nothosmia) distincta* Cresson; ♂ 0; ♀ 2; North Dakota to Quebec;
 Illinois to Florida; yes; native; secure; *Lupinus polyphyllus* (2); Hogarth

Table 1. Bee species phenology based on abundance in Thunder Bay, Ontario. Species were considered with relative abundance if it had four or more total observations. Light grey = < 10% of individuals in a species, dark grey = 10%-50%, black = > 50%. Species with less than four total individuals were coloured light grey on the weeks it was found.

Family	Species	June			July					August				September					
		2	3	4	1	2	3	4	5	1	2	3	4	1	2	3			
Halictidae	<i>Halictus confusus</i>		Dark			Dark			Dark		Dark	Dark			Dark		Dark		
	<i>Halictus rubicundus</i>							Black	Dark						Dark				
	<i>Lasioglossum admirandum</i>		Light																
	<i>Lasioglossum albipenne</i>		Black			Dark						Dark							
	<i>Lasioglossum cinctipes</i>											Dark	Dark			Dark		Dark	
	<i>Lasioglossum comagenense</i>		Light																
	<i>Lasioglossum cressonii</i>												Light					Light	
	<i>Lasioglossum inconditum</i>																	Light	
	<i>Lasioglossum laevissimum</i>		Light	Light			Dark	Dark	Light							Dark			Dark
	<i>Lasioglossum leucomus</i>																	Light	Light
	<i>Lasioglossum leucozonium</i>	Light		Light								Dark	Dark	Light	Dark			Light	
	<i>Lasioglossum paraforbesii</i>		Black				Dark						Dark	Light					
	<i>Lasioglossum planatum</i>		Light				Dark	Dark	Light	Dark			Light	Light					Light
	<i>Lasioglossum quebecense</i>																		Light
	<i>Lasioglossum zonulum</i>		Dark	Dark			Dark			Light				Light				Light	Light
	<i>Sphecodes atlantis</i>																		Light
	<i>Sphecodes confertus</i>		Light																
	<i>Sphecodes coronus</i>																		Light
	<i>Sphecodes dichrous</i>																		Light
	Megachilidae	<i>Coelioxys rufitarsis</i>																	Light
<i>Hoplitis pilosifrons</i>						Dark	Dark		Dark			Dark							Dark
<i>Hoplitis producta</i>			Light																Dark
<i>Megachile frigida</i>						Black	Dark												
<i>Megachile gemula</i>							Dark	Black	Dark										
<i>Megachile inermis</i>								Light	Dark	Dark	Dark	Dark	Dark	Dark	Dark	Dark	Dark	Dark	Light
<i>Megachile latimanus</i>							Dark	Dark	Dark	Dark	Dark	Dark	Dark	Dark	Dark	Dark	Dark	Dark	Dark
<i>Megachile melanophaea</i>							Dark	Dark	Dark	Dark	Dark	Dark	Dark	Dark	Dark	Dark	Dark	Dark	Dark
<i>Megachile pugnata</i>																			Light
<i>Megachile relativa</i>																			Dark
<i>Megachile rotundata</i>																			Light
<i>Osmia distincta</i>				Light															

The phenology table presented (Table 1) is modeled after a published bee phenology paper (Heithaus 1979). The median number of total observations was four, so

I calculated relative abundance for species with four or more total observations and notated it on the phenology table with different shades of grey and black. Species that had weeks where more than 50% of individuals were found (black) all had under 20 total observations. Species with more abundant observations, like species in the genus *Bombus*, had consistently high abundance throughout the sampling weeks.

DIVERSITY

More than half of the 792 bees collected were from the family Apidae (58.2%), followed by the families Halictidae, Megachilidae, Andrenidae, and Colletidae (Fig. 10). The most frequently observed genera were *Bombus*, which accounted for 53.3% of all observations, and *Lasioglossum*, which accounted for 18.7% of all observations (Fig. 11). The Shannon Diversity Index for all bees collected was 3.28 and the Simpson's Diversity Index was 0.94 (Table 2).

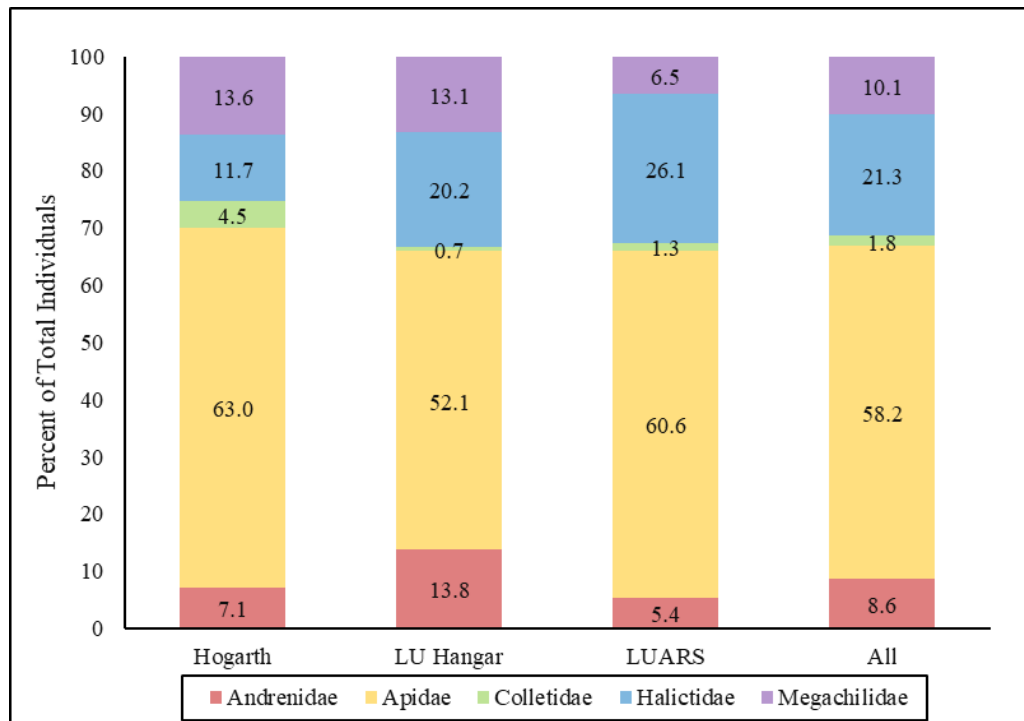


Figure 10. Percent of individuals collected in each bee family from all study sites, and total for all sites combined.

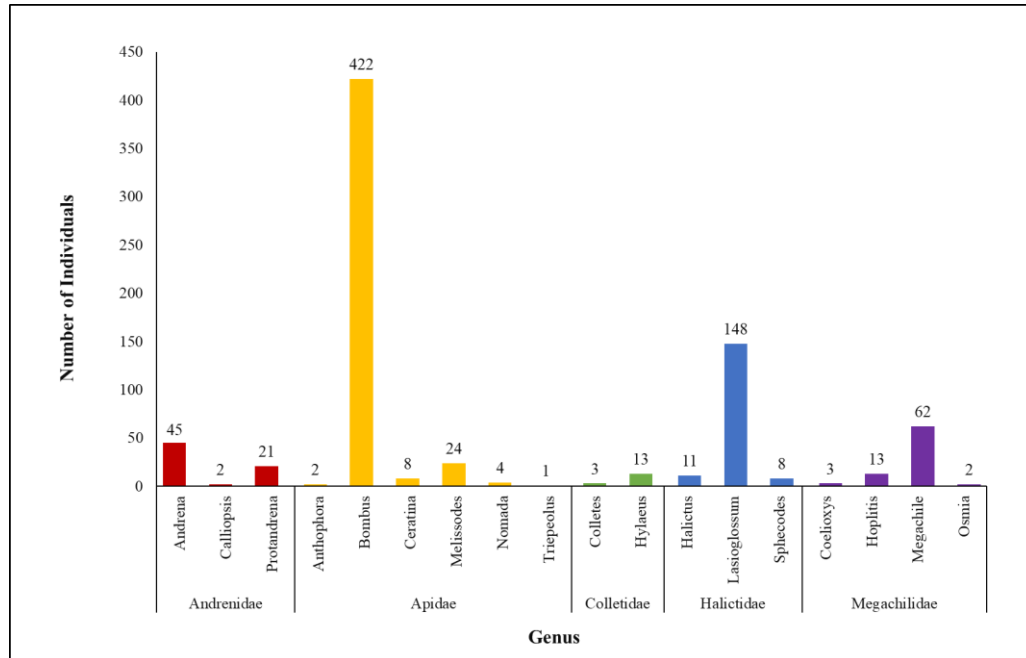


Figure 11. Number of individuals collected within each bee genus and organized by family.

Table 2. Number of bee individuals, species, unique species, genera, and singletons observed at each site and in total, observed and estimated richness and Hill numbers based on the Shannon Diversity Index and Simpson's Diversity Index.

	Hogarth	LU Hangar	LUARS	Total
Individuals	154	267	371	792
Species (Observed Richness)	39	43	38	64
Unique Species	11	7	10	-
Genera	13	13	12	18
Singletons	15	12	6	10
Shannon Index	2.96	3.12	2.81	3.28
Simpson Index	0.92	0.94	0.90	0.94
Estimated Richness	51	52	40	69
Observed Hill Numbers (Shannon)	19	23	17	-
Observed Hill Numbers (Simpson's)	11	15	10	-
Estimated Hill Numbers (Shannon)	24	26	18	-
Estimated Hill Numbers (Simpson's)	12	16	11	-

The richness, or observed number of bee species, at LU Hangar was the highest with 43 species, followed by Hogarth with 39 species, and LUARS with 38 species (Table 2). Each of the sites also had its own subset of unique species that were not found at the other sites. Singletons, or species represented by only one individual were found 10 times across the total collection. Each site also had their own number of singletons represented by one individual at that site. Hogarth had 15, LU Hangar had 12 and LUARS had 6.

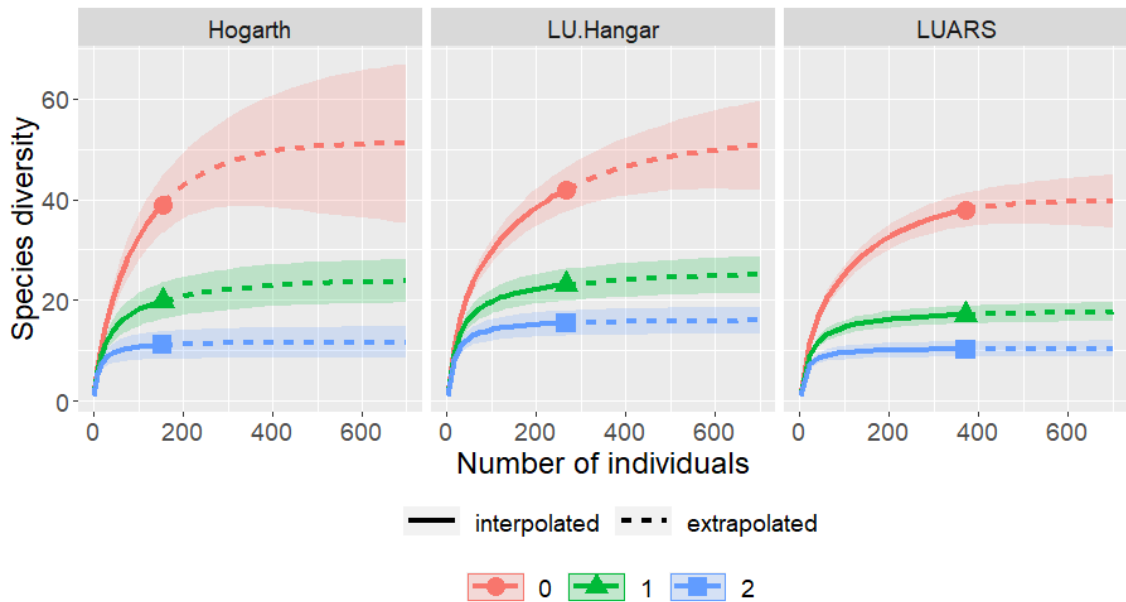


Figure 12. Rarefaction interpolation and extrapolations using R. 0= richness, 1=Hill numbers based on Shannon Index, 2= Hill numbers based on Simpson's index. Shaded area represents the 95% confidence intervals.

Both the LU Hangar and Hogarth sites had similar estimated bee richness, while the LUARS site had a lower estimated richness than LU Hangar and Hogarth by 12 and 11 species, respectively (Table 2, Fig. 12). LU Hangar had the highest estimated richness with 52 bee species and the highest diversity indices of 3.12 for the Shannon Index and 0.94 for the Simpson Index (Table 2). Hogarth had an estimated richness of

51 bee species, a Shannon index of 2.96, and a Simpson Index of 0.92. LUARS had the lowest estimated richness at 40 species, with diversity indices of 2.81 for the Shannon Index and 0.90 for the Simpson Index. Based on these indices, LU Hangar had the highest bee diversity, followed by Hogarth, and finally LUARS. The Sorenson's Similarity Index for LU Hangar and Hogarth was 0.61, for LU Hangar and LUARS was 0.60, and for Hogarth and LUARS was 0.67.

COMPOSITION

The composition by family for all sites was similar, but the bee communities at Hogarth and LUARS were more dominated by Apidae than the community at the LU Hangar was (Fig. 10). While *Bombus* and *Lasioglossum* were the most abundant bee genera at all three sites, the various genera at LU Hangar were more evenly distributed than they were at Hogarth or LUARS (Table 3). LUARS had the most uneven distribution of genera, with 83.3% of all observations belonging *Bombus* and *Lasioglossum*.

Table 3. Percent of individuals collected by genus at each site.

	Hogarth		LU Hangar		LUARS
<i>Bombus</i>	53.9	<i>Bombus</i>	45.3	<i>Bombus</i>	58.8
<i>Lasioglossum</i>	10.4	<i>Lasioglossum</i>	15.4	<i>Lasioglossum</i>	24.5
<i>Megachile</i>	9.1	<i>Megachile</i>	11.2	<i>Andrena</i>	5.4
<i>Melissodes</i>	6.5	<i>Protandrena</i>	7.1	<i>Megachile</i>	4.3
<i>Andrena</i>	5.8	<i>Andrena</i>	6.0	<i>Halictus</i>	1.6
<i>Hylaeus</i>	4.5	<i>Melissodes</i>	4.5	<i>Hoplitis</i>	1.6
<i>Coelioxys</i>	1.9	<i>Halictus</i>	2.6	<i>Colletes</i>	0.8
<i>Nomada</i>	1.9	<i>Sphecodes</i>	2.2	<i>Anthophora</i>	0.5
<i>Hoplitis</i>	1.3	<i>Ceratina</i>	1.9	<i>Ceratina</i>	0.5
<i>Osmia</i>	1.3	<i>Hoplitis</i>	1.9	<i>Hylaeus</i>	0.5
<i>Protandrena</i>	1.3	<i>Hylaeus</i>	0.7	<i>Melissodes</i>	0.5
<i>Sphecodes</i>	1.3	<i>Calliopsis</i>	0.7	<i>Nomada</i>	0.3
<i>Ceratina</i>	0.6	<i>Triepeolus</i>	0.4		

Bombus was the most abundant genus at each site, with the species *B. rufocinctus*, *B. ternarius*, and *B. vagans*, common at all sites (Table 4.). *Lasioglossum*, was another common genus. The abundant *Lasioglossum* species varied across sites. When examining only the ten most commonly observed species, the species at Hogarth and LUARS were similarly abundant. However, LU Hangar and Hogarth had seven species in common, whereas LU Hangar and LUARS had five species in common; LUARS and Hogarth had four species in common.

Table 4. Ten most abundant bee species by percent of total individuals collected at each site.

	Hogarth		LU Hangar		LUARS
<i>Bombus vagans</i>	20.1	<i>Bombus rufocinctus</i>	16.4	<i>Bombus rufocinctus</i>	20.2
<i>Bombus ternarius</i>	17.5	<i>Bombus vagans</i>	8.6	<i>Bombus ternarius</i>	18.1
<i>Lasioglossum leucozonium</i>	7.8	<i>Bombus borealis</i>	7.9	<i>Lasioglossum planatum</i>	8.6
<i>Bombus borealis</i>	5.2	<i>Protandrena aestivalis</i>	7.1	<i>Bombus terricola</i>	5.4
<i>Melissodes druriellus</i>	4.6	<i>Bombus ternarius</i>	6.0	<i>Bombus borealis</i>	4.9
<i>Bombus impatiens</i>	3.9	<i>Megachile inermis</i>	6.0	<i>Lasioglossum albipenne</i>	4.9
<i>Bombus rufocinctus</i>	2.6	<i>Bombus impatiens</i>	4.5	<i>Lasioglossum laevissimum</i>	4.3
<i>Hylaeus modestus</i>	2.6	<i>Melissodes druriellus</i>	4.5	<i>Lasioglossum zonulum</i>	4.3
<i>Megachile relativa</i>	2.6	<i>Lasioglossum leucozonium</i>	4.1	<i>Bombus griseocollis</i>	3.5
<i>Andrena regularis</i>	1.9	<i>Lasioglossum zonulum</i>	3.8	<i>Bombus impatiens</i>	3.2

Bees were observed on 21 floral species at LUARS, 19 at Hogarth, and 17 at LU Hangar. Of the floral species present at each site, 19% were native species at LUARS, 41% were native species at LU Hangar, and 53% were native species at Hogarth. Hogarth had the most abundant bee observations on *Solidago canadensis* L. (Canada goldenrod), and *Vicia cracca* L. (bird vetch) with both plant species accounting for 15% of total bee observations. LU Hangar had the most abundant observations on Canada goldenrod with 32% of total bee observations, and the second most abundant observations on bird vetch with 14%. LUARS had the most abundant bee observations

on *Brassica napus* L. (cultivated rapeseed) with 22%, and the second most abundant bee observations on *Lotus corniculatus* L. (bird's-foot trefoil) with 15%. Overall, 27 wild bee species visited Canada goldenrod, 22 species visited bird's-foot trefoil, 17 species visited bird vetch, and 14 species visited cultivated rapeseed. Canada goldenrod also had the highest percentage of overall bee observations with 14% of all observations on this species.

BEE BOWLS

The bee bowling method collected a total of 114 individuals (Appendix II), about half of which were in the genus *Lasioglossum*. The chi-square goodness of fit test resulted in a rejection of the null hypothesis that there was no preference for bee bowl colour for total individuals collected in the bowls at a p-value of 7.36×10^{-14} and for the genera *Bombus* (1.89×10^{-4}), *Hylaeus* (0.035), *Lasioglossum* (1.92×10^{-11}), and *Megachile* (0.026).

DISCUSSION

Most of the wild bee species found in this study were widespread, or northeastern species. Many of these species have had few observations from more northern locations, suggesting that Thunder Bay could represent a northern range limit for many of the species found there. However, this region and many other regions of northern Canada are under sampled, so these species with potential range edges found in this study may exist further north but have not yet been documented. Additionally, the survey conducted in this study was small and geographically limited, so the species list is likely not a full list of the species in this area, and therefore the evidence found through the comparison of the sites in this study should be considered tentatively.

A total of 64 wild bee species were collected in this study. This number of species found is comparable to other surveys using the same sample and geographic size (Tonietto et al. 2011; Milam et al. 2018; Rothwell and Ginsberg 2019). There were 22 species collected that were previously undocumented in northwestern Ontario based on the database search used in this study. However, most species were documented to the east and west. The lack of observations in northwestern Ontario suggests that this region is under sampled because relatively common, widespread species did not have previously recorded observations from this area. As bee species worldwide are experiencing declines, it is increasingly important to survey areas where bees may be vulnerable (Mathiasson and Rehan 2019). The loss of diversity in wild bees is a cause for concern as this loss may lead to the decline of the critical ecosystem services they provide (Cardinale et al. 2012), but these losses cannot be understood if all regions are not sampled.

This study reported one new wild bee species, *Nomada alpha*, for the first time in Canada. Species in the genus *Nomada* are difficult to identify, so while this may be the first documented individual of this species, there may be individuals in Canada that have not been correctly identified. Of the species collected, only *Bombus terricola*, is a species of special concern with a “vulnerable” conservation status rank based on the NatureServe Explorer database. This species has experienced a severe range contraction within the last century. While this species was the only one with a ‘species of concern’ conservation status rank, *B. vagans* is also experiencing range contractions and is possibly being displaced by the expanding range of *B. impatiens* (Jacobson et al. 2018). *B. impatiens* is an important species for crop pollination, but its range expansion into western North America is concerning as local bee species can be outcompeted by nonresident bee species (Ratti and Colla 2010).

The most speciose bee genera found in the study sites were *Bombus* and *Lasioglossum*. East of Manitoba, *Andrena* and *Lasioglossum* are the most speciose genera in Canada (Packer et al. 2007). *Andrena* species are more sensitive to land use change (Grab et al. 2019) and this could be why this genus had fewer species found in this study. However, many *Andrena* species are active in spring (Wilson and Messinger Carril 2016) and since this study started in mid-June, there is a possibility these species were missed. *Lasioglossum* are commonly found across North America and can persist in disturbed or degraded habitats, making them one of the most dominant genera in many regions (Le Féon 2010). Species in the family Halictidae, in which *Lasioglossum* belongs, are also frequently caught in high abundance in bee bowl traps (Toler et al. 2005) which could account for their high abundance in this study. *Bombus*, the second

most speciose genus in this study, are most abundant in the northern hemisphere and, like *Lasioglossum*, are dominant across North America (Williams et al. 2014).

Generalist species like *Bombus* and *Lasioglossum* thrive in disturbed areas like open farmland and roadsides (Le Féon et al. 2010), but these types of sites are associated with uneven bee communities due to the loss of landscape features such as trees and scrubs (Hall et al. 2019). *Bombus* and *Lasioglossum* accounted for the majority of species at all sites in this study but comprised the largest percentage of total bee species at the agricultural site compared to the other sites. The agricultural site had the most uneven wild bee community composition of the three sites, with majority of observations comprised of two genera and a large portion of observations comprised of two bumble bee species. Likewise, the woodlot site also had an uneven bee community composition with two bumble bee species making up the majority of observations. Bumble bees also made up a large portion of the observations at the meadow site, but the species at this site were in moderate abundance compared to the other sites which had two highly abundant species while the rest were in very low abundance.

While natural communities tend to have species at varying levels of abundance, disturbed habitats lead to functional homogenization where rare species become rarer and dominant species become more dominant (Clavel et al. 2010). These homogenized, or highly uneven, communities decrease the production of essential ecosystem services like pollination (Winfrey et al. 2018). The uneven wild bee community found at the agricultural site in this study supports existing literature that agriculture negatively impacts the evenness of wild bee communities (Sheffield et al. 2013; Beduschi et al.

2018; Hall et al. 2019). However, the uneven wild bee community found at the woodlot site, suggests agriculture may not be the only land use actively that can negatively affect wild bee community composition.

Not only did the agricultural site have the most uneven wild bee community composition, it also had the lowest diversity indices, observed richness, and estimated richness, making this site the least bee diverse. These result supports evidence that agriculture also negatively impacts wild bee richness (Ricketts et al. 2008; Burkle et al. 2013). Species in the genera *Bombus* and *Lasioglossum* have similar life-history traits like long foraging duration, sociality, and a broad diet (Hall et al. 2019). These genera were highly abundant in this study and were especially dominant at the agricultural site. In contrast, solitary cavity nesters like bees in the genera *Megachile* and *Hylaeus* were found in much lower abundance at the agricultural site than the other sites. The high abundance of species with the same functional traits at the agricultural site supports findings that agricultural landscapes simplify phylogenetic diversity (Grab et al. 2019) and diversity of life-history traits (Harrison et al. 2017). Many bees can utilize agricultural landscapes, but agroecosystems often cannot cater to many functional groups of bees because of a lack of diverse landscape features, thereby reducing bee diversity (Hall et al. 2019). This is likely why diversity indices and estimated richness at the agricultural site were much lower than the other sites.

The common usage of certain flowers in this survey, such as cultivated rapeseed, bird's-foot trefoil, Canada goldenrod, and bird vetch suggests that these are important floral species for wild bee communities in northwestern Ontario. Bird vetch

and bird's-foot trefoil, while found to be commonly visited by wild bees, are invasive weed species that are native to Europe that occur in disturbed habitats (Gleason and Cronquist 1963; Aarssen et al. 1986). While the sites used in this study represented flower-rich areas in Thunder Bay, the occurrence of invasive weed species suggests that they were likely disturbed habitats. However, of the total floral species found at each site, the agricultural site had more than half the number of native species than the other sites.

Studies have shown that wild bees tend to prefer native species over exotic, introduced species (Morandin and Kremen 2013), and this could explain why wild bees visited Canada goldenrod, which is native to Canada, most often. However, weed species can provide valuable forage for wild bee species as well, especially in agricultural landscapes where floral diversity may be low (Nicholls and Altieri 2013). Additionally, wild bee richness and abundance is driven by floral abundance and cover (Potts et al. 2009), and unfortunately floral abundance was not explicitly measured in this study. Future studies in this area should measure floral abundance to further understand what drives wild bee diversity in the region.

Cultivated rapeseed, which is another non-native introduced species to Canada (USDA 2019), supported a wide range of bee species. The high wild bee diversity found on this flower in this study supports evidence that wild bees are important to the pollination of cultivated rapeseed (Morandin and Winston 2005; Jauker et al. 2012) and that cultivated rapeseed can provide ample food resources for wild bees (Holzshuh et al. 2013). While this floral species can provide resources for wild bees, it also increases

competition with grassland plants and can decrease the number of wild bees in natural ecosystems near mass-flowering cultivated rapeseed (Holzschuh et al. 2011). Crops also make for poor wild bee habitat because monocultures lack floral diversity and turnover, leaving large areas devoid of floral resources for long periods of time and making them unable to support diverse wild bee communities (Hagen and Kraemer 2010; Watson et al. 2011; Holzschuh et al. 2013).

The approximate time frame of expected activity for each species observed suggests that the wild bees in the Thunder Bay area are most active in July and August. However, species with limited observations, such as species with fewer than four individuals collected, may not be accurately represented (Table 1). The active flight season observed in this study could be used in future surveys in this region to understand when bee species that inhabit Thunder Bay are active. Additionally, the results found in this study using the bee bowling method can provide useful information for future surveys in the region. The abundant wild bee species collected in the bee bowls showed a strong preference for the yellow and/or blue bowls over the glow-in-the-dark (white) bowl and the unpainted bowls. This result supports the findings from other studies that the use of multiple bowl colors, especially blue and yellow, catches a wide variety of bee species (Leong and Thorp 1999; Toler et al. 2005; Grundel et al. 2011), and these should continue to be used in future bee surveys.

Not unexpectedly, this study was subject to limitations. First, only three study sites were used so inferences drawn from the data found are tentative. Additionally, these sites were disturbed habitats that potentially may not be representative of the

overall habitat characteristics in northwestern Ontario. However, in Thunder Bay, these areas were representative of where wildflowers grew in abundance. Future surveys should include more sites and replications to draw accurate conclusions about the wild bee communities in the region. Second, the study was initiated later in the season, so there is a potential that surveying efforts missed a few species, particularly early spring species in the genus *Andrena*. The sites used in this study were open habitats, so they lacked understory forbs and arboreal shrubs that are associated with these species of bees (Packer et al. 2007). When these types of spring floral species finish blooming, sites are left with little wildflower abundance, where the open sites can be sampled throughout the summer (Hall et al. 2019). Future surveys in the area should start earlier and include different kinds of habitats that have early spring floral species to avoid missing any potential species.

Third, the bee bowls were left out for a shorter period than other studies suggest are optimal, potentially leading to fewer individuals collected in the bowls. The reason for this choice was to follow the methods of published studies to leave bee bowls out for the length of the survey to keep the sample times for both sampling methods the same. However, the surveys done in this study were shorter than other surveys that used this method. Leaving the bee bowls out for longer intervals when surveying this area in the future could address this limitation. Future studies could also test bee bowl survey duration to determine the optimal length the bowls should be left out in this area to capture the majority of expected species. Finally, this study had a small sample size of collected individuals. Rarefaction curves extrapolated richness to a greater sample size for this reason. Additional surveys with increased sample size could identify even more

species in the area and should be done in the future. However, it is important to be aware that high volume sampling in one area, multiple times a week can be potentially destructive to bee communities (Gezon et al. 2015) and larger future surveys should take this into account.

Despite the limitations, the findings of this study reveal further studies are critically needed in this region and sets a starting point for future studies in northwestern Ontario for wild bee species, the flowers they visit and their local flight season. This study also supported evidence that agriculture negatively impacts wild bee diversity through decreasing richness and evenness.

CONCLUSIONS

Bees are vital components of terrestrial ecosystems (Ollerton 2017) and maintaining bee diversity is essential for pollination services (Grab et al. 2019). As bees decline due to habitat destruction and agricultural intensification, it is important to continue to survey wild bee communities across regions to further understand wild bee ranges and wild bee diversity (MacPhail et al. 2018). While more attention is being given to wild bees, there is still a need for more data on local bee communities and the flowers they visit to better target local conservation efforts and plant the proper flowers to promote wild bee communities. The information presented in this survey fills in gaps of knowledge about the wild bee species that inhabit northwestern Ontario in Thunder Bay and sheds light on the critical need for baseline studies of wild bees in this region. Many species collected in this survey previously did not have observations in northwestern Ontario, and the first observation was made in Canada for the species *Nomada alpha*. Northwestern Ontario is a valuable survey area because many species found had few observations north of Thunder Bay. Additional wild bee surveys in this region would therefore be helpful in tracking changes in many bee species' ranges and continued sampling of northwestern Ontario could likely uncover more wild bee species.

Wild bee diversity and composition reflect the quality of a habitat. The combination of low wild bee diversity and an uneven wild bee community found at the agricultural site supported my hypothesis that wild bee diversity is negatively affected by agriculture. While general habitat loss is the main driver for wild bee decline (Winfrey et al. 2009), agricultural land use destroys wild bee habitat (Carvell et al. 2006;

Goulson et al. 2006) and homogenizes wild bee communities (Clavel et al. 2010). Therefore, agriculture may be a large contributor to the loss of wild bee diversity. If a diverse community of wild bees are not supported by the resources within agricultural landscapes, there may be a loss of diversity and ecosystem function (Hall et al. 2019).

While the floral species that grew at each site suggests the habitats in this study may have all been disturbed, the agricultural site had the lowest wild bee diversity and the most uneven wild bee community composition. Planting attractive species like Canada goldenrod could potentially be beneficial to the wild bee species in this area of northwestern Ontario, especially in agricultural landscapes. Future directions for research include investigating if native floral species can increase wild bee diversity in agroecosystems in northwestern Ontario.

Only a handful of species have documented evidence of their declines in North America, but it is unlikely that these are the only species experiencing them (Bartomeus et al. 2018). Further surveying wild bee communities is necessary to truly understand the conservation status of wild bee species (MacPhail et al. 2018). The Ontario government recognizes the importance of pollinators with the Pollinator Health Action Plan (OMAFRA 2016b) and implementing this plan is a step towards improving wild bee populations. More data on local bee species diversity are imperative to concentrate conservation efforts and to understand how to counter the negative effects of agriculture. The decline of wild bees is evident, and the task of conserving their populations is daunting, but with continued monitoring and improvement of habitat, vulnerable and declining wild bee populations could thrive.

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APPENDICES

APPENDIX I

LIST OF BEE-VISITED FLOWERS AND THE BEE SPECIES COLLECTED ON THEM (n-number of individuals)

Plant family/ Flower species/ Bee Species	n	Plant family/ Flower species/ Bee Species	n
Apocynaceae		<i>Melissodes druriellus</i>	5
<i>Apocynum androsaemifolium</i>		<i>Protandrena aestivalis</i>	7
<i>Bombus ternarius</i>	9	<i>Helianthus tuberosus</i>	
<i>Bombus vagans</i>	2	<i>Bombus griseocollis</i>	1
<i>Hylaeus verticalis</i>	2	<i>Bombus perplexus</i>	1
<i>Megachile gemula</i>	2	<i>Bombus vagans</i>	4
Asteraceae		<i>Lasioglossum leucozonium</i>	3
<i>Anaphalis margaritacea</i>		<i>Lasioglossum paraforbesii</i>	1
<i>Megachile inermis</i>	1	<i>Megachile inermis</i>	1
<i>Cirsium arvense</i>		<i>Megachile latimanus</i>	1
<i>Bombus borealis</i>	1	<i>Hieracium canadense</i>	
<i>Bombus fernaldae</i>	2	<i>Megachile latimanus</i>	1
<i>Bombus griseocollis</i>	1	<i>Leucanthemum vulgare</i>	
<i>Bombus impatiens</i>	1	<i>Bombus rufocinctus</i>	1
<i>Bombus rufocinctus</i>	12	<i>Bombus ternarius</i>	1
<i>Bombus ternarius</i>	4	<i>Bombus vagans</i>	1
<i>Bombus vagans</i>	9	<i>Hoplitis pilosifrons</i>	1
<i>Ceratina mikmaqi</i>	1	<i>Lasioglossum albipenne</i>	1
<i>Halictus rubicundus</i>	1	<i>Rudbeckia hirta</i>	
<i>Lasioglossum leucozonium</i>	3	<i>Bombus ternarius</i>	1
<i>Megachile inermis</i>	2	<i>Bombus vagans</i>	1
<i>Megachile relativa</i>	1	<i>Megachile inermis</i>	1
<i>Melissodes druriellus</i>	1	<i>Megachile relativa</i>	1
<i>Protandrena aestivalis</i>	1	<i>Solidago canadensis</i>	
<i>Cirsium vulgare</i>		<i>Andrena canadensis</i>	7
<i>Bombus rufocinctus</i>	1	<i>Bombus borealis</i>	3
<i>Bombus vagans</i>	1	<i>Bombus impatiens</i>	13
<i>Megachile inermis</i>	1	<i>Bombus rufocinctus</i>	16
<i>Eurybia macrophylla</i>		<i>Bombus sandersoni</i>	1
<i>Bombus impatiens</i>	3	<i>Bombus ternarius</i>	14
<i>Bombus rufocinctus</i>	5	<i>Bombus terricola</i>	2
<i>Bombus ternarius</i>	3	<i>Bombus vagans</i>	7
<i>Bombus vagans</i>	3	<i>Ceratina mikmaqi</i>	1
<i>Hylaeus verticalis</i>	1	<i>Halictus confuses</i>	1
<i>Lasioglossum cinctipes</i>	1	<i>Hylaeus mesillae</i>	1
<i>Lasioglossum inconditum</i>	1	<i>Lasioglossum cinctipes</i>	2
<i>Lasioglossum laevisimum</i>	1	<i>Lasioglossum cressonii</i>	2
<i>Lasioglossum planatum</i>	1	<i>Lasioglossum leucozonium</i>	2

Plant family/ Flower species/ Bee Species	n	Plant family/ Flower species/ Bee Species	n
<i>Lasioglossum paraforbesii</i>	1	<i>Bombus borealis</i>	1
<i>Lasioglossum planatum</i>	4	<i>Bombus griseocollis</i>	1
<i>Lasioglossum quebecense</i>	1	<i>Bombus ternarius</i>	4
<i>Lasioglossum zonulum</i>	1	<i>Bombus vagans</i>	1
<i>Megachile inermis</i>	3	<i>Lasioglossum planatum</i>	1
<i>Megachile latimanus</i>	1	<i>Lasioglossum zonulum</i>	1
<i>Megachile pugnata</i>	1	<i>Nomada pygmaea</i>	1
<i>Megachile relativa</i>	1	<i>Tragopogon pratensis</i>	
<i>Melissodes druriellus</i>	9	<i>Andrena wilkella</i>	2
<i>Melissodes illatus</i>	1	<i>Lasioglossum leucozonium</i>	1
<i>Protandrena aestivalis</i>	10		
<i>Sphecodes coronus</i>	3	Boraginaceae	
<i>Sphecodes dichrous</i>	1	<i>Symphytum officinale</i>	
<i>Solidago juncea</i>		<i>Andrena wilkella</i>	1
<i>Andrena canadensis</i>	3	<i>Bombus rufocinctus</i>	1
<i>Bombus rufocinctus</i>	3	<i>Bombus vagans</i>	2
<i>Bombus ternarius</i>	4	<i>Lasioglossum zonulum</i>	1
<i>Bombus vagans</i>	2		
<i>Ceratina mikmaqi</i>	1	Brassicaceae	
<i>Lasioglossum cinctipes</i>	1	<i>Brassica juncea</i>	
<i>Melissodes druriellus</i>	2	<i>Bombus ternarius</i>	1
<i>Melissodes illatus</i>	2	<i>Bombus terricola</i>	1
<i>Protandrena aestivalis</i>	2	<i>Lasioglossum planatum</i>	1
<i>Sphecodes dichrous</i>	2	<i>Brassica napus</i>	
<i>Triepeolus subalpinus</i>	1	<i>Andrena nivalis</i>	4
<i>Solidago puberula</i>		<i>Bombus borealis</i>	1
<i>Bombus rufocinctus</i>	1	<i>Bombus impatiens</i>	5
<i>Bombus ternarius</i>	2	<i>Bombus rufocinctus</i>	17
<i>Bombus vagans</i>	1	<i>Bombus sandersoni</i>	2
<i>Hylaeus modestus</i>	1	<i>Bombus ternarius</i>	13
<i>Megachile relativa</i>	1	<i>Bombus terricola</i>	11
<i>Melissodes druriellus</i>	1	<i>Colletes kincaidii</i>	2
<i>Protandrena aestivalis</i>	1	<i>Halictus confuses</i>	1
<i>Sonchus arvensis</i>		<i>Halictus rubicundus</i>	1
<i>Bombus rufocinctus</i>	2	<i>Lasioglossum laevissimum</i>	3
<i>Bombus ternarius</i>	1	<i>Lasioglossum planatum</i>	2
<i>Halictus confuses</i>	1	<i>Megachile inermis</i>	1
<i>Lasioglossum laevissimum</i>	1	<i>Megachile latimanus</i>	5
<i>Lasioglossum leucocomus</i>	2	<i>Capsella bursa-pastoris</i>	
<i>Lasioglossum leucozonium</i>	3	<i>Andrena dunningi</i>	1
<i>Lasioglossum planatum</i>	2	<i>Bombus rufocinctus</i>	1
<i>Lasioglossum zonulum</i>	1	<i>Bombus vagans</i>	1
<i>Megachile relativa</i>	1	<i>Halictus confuses</i>	1
<i>Symphytotrichum puniceum</i>		<i>Lasioglossum admirandum</i>	1
<i>Halictus rubicundus</i>	1	<i>Lasioglossum albipenne</i>	1
<i>Taraxacum officinale</i>		<i>Lasioglossum comagenense</i>	1
<i>Andrena cressonii</i>	1	<i>Lasioglossum planatum</i>	1
<i>Andrena dunningi</i>	2		
<i>Andrena wilkella</i>	3	Fabaceae	
<i>Bombus borealis</i>	1	<i>Galega officinalis</i>	
		<i>Bombus griseocollis</i>	1
		<i>Bombus rufocinctus</i>	1
		<i>Bombus ternarius</i>	2

Plant family/ Flower species/ Bee Species	n	Plant family/ Flower species/ Bee Species	n
<i>Bombus vagans</i>	1	<i>Melilotus alba</i>	
<i>Lens culinaris</i>		<i>Bombus vagans</i>	1
<i>Andrena wilkella</i>	1	<i>Onobrychis vicifolia</i>	
<i>Bombus rufocinctus</i>	3	<i>Bombus griseocollis</i>	1
<i>Bombus ternarius</i>	2	<i>Bombus rufocinctus</i>	2
<i>Lotus corniculatus</i>		<i>Bombus ternarius</i>	1
<i>Andrena wilkella</i>	1	<i>Bombus vagans</i>	1
<i>Andrena w-scripta</i>	1	<i>Megachile melanophaea</i>	1
<i>Bombus borealis</i>	1	<i>Trifolium hybridum</i>	
<i>Bombus griseocollis</i>	3	<i>Bombus rufocinctus</i>	1
<i>Bombus impatiens</i>	1	<i>Bombus ternarius</i>	1
<i>Bombus rufocinctus</i>	14	<i>Bombus terricola</i>	1
<i>Bombus sandersoni</i>	1	<i>Trifolium pretense</i>	
<i>Bombus ternarius</i>	11	<i>Andrena w-scripta</i>	1
<i>Bombus terricola</i>	5	<i>Bombus borealis</i>	17
<i>Bombus vagans</i>	2	<i>Bombus impatiens</i>	2
<i>Coelioxys rufitarsis</i>	2	<i>Bombus rufocinctus</i>	4
<i>Hoplitis pilosifrons</i>	1	<i>Bombus ternarius</i>	2
<i>Hoplitis producta</i>	1	<i>Bombus vagans</i>	7
<i>Hylaeus annulatus</i>	1	<i>Lasioglossum leucozonium</i>	1
<i>Lasioglossum laevissimum</i>	1	<i>Trifolium repens</i>	
<i>Megachile frigida</i>	3	<i>Bombus rufocinctus</i>	6
<i>Megachile gemula</i>	4	<i>Bombus ternarius</i>	10
<i>Megachile inermis</i>	1	<i>Vicia cracca</i>	
<i>Megachile latimanus</i>	1	<i>Andrena wilkella</i>	6
<i>Megachile melanophaea</i>	1	<i>Andrena w-scripta</i>	3
<i>Megachile relativa</i>	1	<i>Bombus borealis</i>	12
<i>Megachile rotundata</i>	1	<i>Bombus griseocollis</i>	1
<i>Lupinus polyphyllus</i>		<i>Bombus perplexus</i>	1
<i>Andrena wilkella</i>	1	<i>Bombus rufocinctus</i>	6
<i>Bombus ternarius</i>	2	<i>Bombus sandersoni</i>	2
<i>Bombus vagans</i>	1	<i>Bombus ternarius</i>	6
<i>Lasioglossum laevissimum</i>	1	<i>Bombus terricola</i>	2
<i>Lasioglossum leucozonium</i>	1	<i>Bombus vagans</i>	10
<i>Megachile gemula</i>	1	<i>Halictus rubicundus</i>	1
<i>Osmia distincta</i>	1	<i>Hoplitis pilosifrons</i>	1
<i>Medicago sativa</i>		<i>Megachile frigida</i>	1
<i>Andrena w-scripta</i>	2	<i>Megachile gemula</i>	1
<i>Anthophora terminalis</i>	1	<i>Megachile inermis</i>	4
<i>Bombus borealis</i>	4	<i>Megachile melanophaea</i>	2
<i>Bombus fernaldae</i>	1	<i>Megachile rotundata</i>	1
<i>Bombus griseocollis</i>	6	Linaceae	
<i>Bombus impatiens</i>	4	<i>Linum usitatissimum</i>	
<i>Bombus ternarius</i>	7	<i>Bombus ternarius</i>	1
<i>Bombus terricola</i>	1	<i>Lasioglossum planatum</i>	2
<i>Lasioglossum albipenne</i>	1	Onagraceae	
<i>Lasioglossum leucozonium</i>	1	<i>Chamaenerion angustifolium</i> spp. <i>angustifolium</i>	
<i>Lasioglossum planatum</i>	1	<i>Bombus vagans</i>	1
<i>Megachile frigida</i>	1	<i>Megachile relativa</i>	1
<i>Megachile latimanus</i>	1		

Plant family/ Flower species/ Bee Species	n
Oxalidaceae	
<i>Oxalis corniculata</i>	
<i>Lasioglossum leucozonium</i>	1
Polygonaceae	
<i>Persicaria lapathifolia</i>	
<i>Bombus ternarius</i>	2
Rosaceae	
<i>Dasiphora fruticosa</i>	
<i>Bombus vagans</i>	1
<i>Potentilla recta</i>	
<i>Bombus rufocinctus</i>	1
<i>Lasioglossum laevissimum</i>	1
Scrophulariaceae	
<i>Euphrasia pectinate</i>	
<i>Bombus impatiens</i>	1
<i>Bombus ternarius</i>	2
<i>Lasioglossum leucozonium</i>	1
<i>Lasioglossum zonulum</i>	1

APPENDIX II

LIST OF BEE BOWL COLOURS AND THE BEE SPECIES FOUND IN THEM
(n= number of individuals)

Bee Bowl Colour/ Bee Species	n	Bee Bowl Colour/ Bee Species	n
Blue bowl		<i>Lasioglossum leucozonium</i>	3
<i>Bombus borealis</i>	3	<i>Lasioglossum planatum</i>	11
<i>Bombus rufocinctus</i>	3	<i>Lasioglossum zonulum</i>	4
<i>Bombus ternarius</i>	1	<i>Megachile inermis</i>	1
<i>Ceratina mikmaqi</i>	2	<i>Megachile latimanus</i>	1
<i>Halictus confusus</i>	2	<i>Sphecodes atlantis</i>	1
<i>Hoplitis pilosifrons</i>	2	<i>Sphecodes confertus</i>	1
<i>Hylaeus mesillae</i>	1		
<i>Lasioglossum albipenne</i>	1		
<i>Lasioglossum laevissimum</i>	5		
<i>Lasioglossum leucozonium</i>	7		
<i>Lasioglossum paraforbesii</i>	1		
<i>Lasioglossum planatum</i>	8		
<i>Lasioglossum zonulum</i>	12		
<i>Megachile frigida</i>	1		
<i>Megachile inermis</i>	5		
<i>Melissodes druriellus</i>	1		
Clear bowl			
<i>Coelioxys rufitarsis</i>	1		
<i>Hoplitis pilosifrons</i>	2		
<i>Lasioglossum planatum</i>	1		
<i>Megachile frigida</i>	1		
Glow bowl			
<i>Calliopsis andreniformis</i>	2		
<i>Halictus confusus</i>	2		
<i>Hoplitis pilosifrons</i>	1		
<i>Hoplitis producta</i>	2		
<i>Lasioglossum leucomus</i>	1		
<i>Lasioglossum planatum</i>	1		
Yellow bowl			
<i>Bombus rufocinctus</i>	9		
<i>Bombus ternarius</i>	2		
<i>Ceratina mikmaqi</i>	3		
<i>Hoplitis pilosifrons</i>	1		
<i>Hoplitis producta</i>	1		
<i>Hylaeus annulatus</i>	1		
<i>Hylaeus modestus</i>	3		
<i>Lasioglossum laevissimum</i>	6		

APPENDIX III

LIST OF FLORAL SPECIES AT EACH SITE
(n= number of individuals found on that flower species)

Site/Floral Species	n	Site/Floral Species	n
Hogarth		LUARS	
<i>Apocynum androsaemifolium</i>	13	<i>Brassica juncea</i>	3
<i>Chamaenerion angustifolium</i>	2	<i>Brassica napus</i>	52
<i>Cirsium arvense</i>	3	<i>Capsella bursa-pastoris</i>	8
<i>Eurybia macrophylla</i>	8	<i>Cirsium arvense</i>	8
<i>Helianthus tuberosus</i>	12	<i>Cirsium vulgare</i>	1
<i>Hieracium canadense</i>	1	<i>Dasiphora fruticosa</i>	1
<i>Leucanthemum vulgare</i>	1	<i>Eurybia macrophylla</i>	1
<i>Lotus corniculatus</i>	10	<i>Galega officinalis</i>	5
<i>Lupinus polyphyllus</i>	8	<i>Lens culinaris</i>	5
<i>Oxalis corniculata</i>	1	<i>Leucanthemum vulgare</i>	3
<i>Persicaria lapathifolia</i>	2	<i>Linium usitatissimum</i>	3
<i>Rudbeckia hirta</i>	3	<i>Lotus corniculatus</i>	35
<i>Solidago canadensis</i>	20	<i>Medicago sativa</i>	29
<i>Solidago juncea</i>	11	<i>Onobrychis viciifolia</i>	5
<i>Solidago puberula</i>	8	<i>Solidago canadensis</i>	10
<i>Sonchus arvensis</i>	2	<i>Sonchus arvensis</i>	12
<i>Tragopogon pratensis</i>	2	<i>Taraxacum officinale</i>	14
<i>Trifolium pratense</i>	5	<i>Trifolium hybridum</i>	3
<i>Vicia cracca</i>	20	<i>Trifolium pratense</i>	14
LU Hangar		<i>Trifolium repens</i>	13
<i>Anaphalis margaritacea</i>	1	<i>Vicia cracca</i>	10
<i>Cirsium arvense</i>	24		
<i>Cirsium vulgare</i>	2		
<i>Euphrasia nemorosa</i>	5		
<i>Eurybia macrophylla</i>	19		
<i>Leucanthemum vulgare</i>	1		
<i>Lotus corniculatus</i>	9		
<i>Melilotus alba</i>	1		
<i>Potentilla recta</i>	2		
<i>Rudbeckia hirta</i>	2		
<i>Solidago canadensis</i>	65		
<i>Solidago juncea</i>	13		
<i>Symphotrichum puniceum</i>	1		
<i>Symphytum officinale</i>	8		
<i>Trifolium hybridum</i>	1		
<i>Trifolium pratense</i>	11		
<i>Vicca cracca</i>	28		