THE BEES OF ELOISE BUTLER WILDFLOWER GARDEN AND BIRD SANCTUARY

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SUMMARY FOR GENERAL PUBLIC

Bees play an important role in the Garden as pollinators of many of the plants. In 2023 and 2024, two scientists from the University of Minnesota Department of Entomology studied the bees of Eloise Butler. They collected bees visiting flowers in the Garden. They captured 2,030 bees representing at least 116 species from 138 plant species. When combined with the previous bee survey which took place from 2013 to 2014 and found 103 bee species, the number of bee species recorded in the Garden is now at a total of at least 145 species. The high bee diversity found in the Garden is likely due to the floral diversity of the Garden. Among the bees observed were several rare bees. The rusty-patched bumble bee, a bumble bee is listed as critically at risk of extinction by the U.S. Fish and Wildlife Service, was recorded in the Garden in both 2023 and 2024. In addition, we recorded rare, specialist bees including *Andrena ziziae*, which is a specialist on *Zizia*, *Andrena geranii*, which specialiszes on *Hydrophyllum*, *Andrena rudbeckia*, which specializes on *Rudbeckia*, and *Paranthidium jugatorium*, which specializes on plants in the family Asteraceae. The plants that supported the greatest abundance and diversity of bees were *Prunus americana, Ceanothus americanus, Monarda fistulosa, Filipendula ulmaria, Zizia aurea, Solidago flexicaulis, Cirsium discolor,* and *Cornus racemosa*. The bee population can be maintained and encouraged by encouraging populations of bee-friendly plants as well as nesting habitat.

INTRODUCTION

Bee population decline is a concern not just because of loss of intrinsically valuable biodiversity but also because bees are important pollinators of both agricultural crops that supply us with some our most nutritious food sources, aiding food production globally (Klein et al. 2007; Garibaldi et al. 2013; Eilers et al. 2011), and wild plants (Ollerton et al. 2011) that help maintain healthy soil and clean water as well as provide food and shelter for countless bird, mammals and other insects. Florally diverse gardens that have a focus on native plants may provide important refuges for bees in urban areas by providing both foraging and nesting resources (Tommasi et al. 2004, McFrederick & LeBuhn 2006).

The Eloise Butler Wildflower Garden and Bird Sanctuary (the Garden) is a historic, native-plant botanical garden located within Theodore Wirth Regional Park, less than four kilometers from downtown Minneapolis, Minnesota. The Garden was established in 1907 as a botanical preserve for native plants. and Eloise Butler, a local botany teacher helped to found the Garden and became its first curator in 1911. Butler wanted to create a botanical garden that contained all of the flora of Minnesota in one location while maintaining a wild feeling through

naturalistic planting styles and garden design. She introduced several hundred plant species to build the native plant collection she envisioned. This highly unique botanical garden has been curated with these original goals in mind into the present day with the addition of many plant species, mostly native. About half of the plant species currently present are indigenous and half have been introduced. Today, the Garden covers about 18 acres, including areas of wetland, hardwood forests, oak savanna, and meadow, and host over 640 plant species. In this study, we surveyed wild bees in the Garden to assess species abundance and diversity, patterns of floral host use, and the potential value of the Garden as a pollinator refuge.

Bees rely on flowers as their sole food source. In general, bees are less choosey about which flowers they visit for nectar than the ones they visit to gather pollen. Floral preference most often refers to pollen collecting preferences. The breadth of floral preferences for pollen collection varies from monolectic bees foraging on one flower species such as *Hesperapis oraria* which only collects nectar and pollen from *Balduina angustifolia* (Asterceae) (Cane & Snelling 1996) to oligolectic bees foraging on a limited range of flowers often in the same genus such as *Melissodes agilis* which visits flowers belonging to the tribes Astereae and Heliantheae (Robertson 1926), to polylectic bees foraging on a wide rage of plant genera such as *Bombus* spp. (Milliron 1971).

Bees form nests in various materials. Globally, roughly 55% of bees form their nest by tunneling in the ground, 30% of bees form their nests in stems or tunnels in wood, 1% nest in pre-existing cavities or undisturbed vegetative debris, and 14% of bees are parasitic, usurping nests of other bees (based on estimates from Cane & Neff 2011). Within these broad categories there are preferences for varying soil types. Some ground-nesting bees prefer sand, and many prefer sandy-loam (Stephen et al. 1969; Černá et al. 2013; Cane et al. 2007; Wuellner 1999; Davis et al. 2010; Michener 1979). Little is known about preferences of many stem-nesting bees. Some stem-nesting bees are associated with certain plants but the preference seems to be based primarily on stem size and availability, as many species will nest in artificial nests (or man-made) constructed from holes drilled into wood. Some species of stem and ground nesters collect materials to use in their nest construction. These materials include leaves (showing preferences for certain plants), mud, resin, and pebbles (O'Toole & Raw 1991). Pre-existing cavities used by bees are often formed by other animals, most commonly rodent (Michener 2000). Bees that nest in undisturbed vegetative debris prefer undisturbed areas where vegetative debris has accumulated (Michener 2000). Parasitic bees are present in all the previous categories of nesting habitats but are dependent on their hosts to form nests (Michener 2000).

This bee survey took place in 2023 and 2024. The results are supplemented with findings from the bumble bee surveys at the Garden took place in 2024. In addition, we collected a similar set of data in 2013-2014, so we are also able to make some comparisons of bee diversity in the Garden across 10 years. While the two data points of the current and previous survey from 10 years ago are not sufficient to detect trends in bee populations, there may be other changes that the comparison can reveal. Since the Garden is home to many rare, native plants, the bee survey provides a unique opportunity to gather information on bee visitation to a wide array of native wildflowers.

METHODS

Bee diversity was sampled using sweep netting. Sweep netting took place once approximately every two weeks between May and September on days when the temperature was above 60º F and there was no precipitation. Locations for sweep netting were chosen by finding areas of blooming flowers with evidence of bee visitation. All bees flying with an area of approximately 25m x 25m were collected for five minutes. An attempt was made to collect bees from all flowering patches that were attractive to bees on all sampling dates. Most sweep net sampling took place between 10:00 AM and 5:00 PM. Most of the bumble bees were identified, marked and released. All other bees were collected and curated, forming the bee collection. Supplementary bumble bee abundance information was shared from the Minnesota Bumble Bee Survey. In 2024, bumble bees were captured, marked and released on survey dates from late June to early September. A minimum of 200 bees were caught across three survey dates using a volunteer work force.

Bees were identified to species or morphospecies by ZMP using a combination of published revisions and comparisons to previously identified specimens in the University of Minnesota Insect Collection (Baker 1975; Bouseman and LaBerge 1978; Coelho 2004; Gibbs 2010, 2011; Gibbs et al. 2013; LaBerge 1971, 1989; LaBerge and Bouseman 1970; Laverty and Harder 1988; Mitchell 1960; Roberts 1972, 1973; Sheffield et al. 2011; Williams et al. 2014). Specimens are deposited in the collection of the Cariveau Native Bee Lab and the University of Minnesota Insect Collection.

RESULTS AND DISCUSSION

2,030 bees representing at least 116 species were collected from 2023 to 2024 from 138 plant species. These bee species represent six families and twenty-five genera. The collection is summarized in Appendix 1, along with 2013-2014 collections. The total number of bee species across both the 2013-2014 and 2023-2024 collections is 145. This represents 29% of the total number of bee species currently documented in Minnesota (Portman et al. 2023). Given the relatively small size of the Garden, this number of bee species is more than double the number of species that have been documented in less florally diverse parks (Wolfin et al. 2023).

There are *at least* 116 species, rather than *exactly*, because not all bees collected could be confidently identified to species. The *Hylaeus affinis/modestus* group, in particular, was very common and includes four species (*H. affinis*, *H. modestus*, *H. illinoisensis*, and an undescribed species currently called *Hylaeus* sp. A) which cannot be separated based on current taxonomic knowledge. Since the 2013-2014 surveys, advances in taxonomy mean that *H. affinis* can now be confidently identified but cryptic species remain in the *H. modestus* group. In addition, research has revealed that *H. mesillae* is a cryptic species complex (Portman et al. 2023), and we have begun referring to what was previously called "*Hylaeus mesillae*" as the "*Hylaeus mesillae* group".

Some new taxonomic research has created a mismatch between the species concepts used in the 2013-2014 study and the present study. Taxonomic research on *Augochloropsis metallica* revealed that it was a cryptic species complex and in Minnesota it was split into two species: *Augochloropsis metallica* and *Augochloropsis viridula*. Ongoing taxonomic research has also revealed that *Augochlorella aurata* is a cryptic species complex, and specimens of *Augochlorella*

confusa found in 2023-2024 would have previously been identified as *Augochlorella aurata* in 2013-2014.

Other problematic groups include the *Nomada* bidentate group (containing an unknown number of species, the *Lasioglossum viridatum* group (containing at least 20 species which are usually, but not always separable. If the taxonomy of these groups is fully resolved, the total number of species will increase. Many of the incongruencies between the taxonomy of the 2013-2014 collection and the recent collections can be rectified through reexamination of the 2013-2014 specimens.

Bumble Bees

712 bumble bees representing ten species were collected from 2023 to 2024. A species accumulation curve for all pooled bumble bee data (Fig. 1) indicates that sampling effort was sufficient to capture all bumble bee species present in the area. The mean estimate for total species richness levels off at ten species at around 12 survey events. Thus, additional bumble bee collections would be unlikely to find new species.

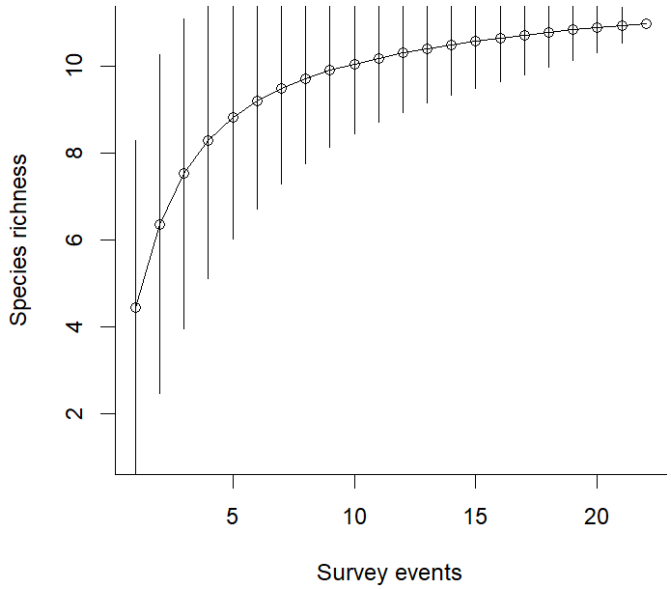

Figure 1. Species accumulation curve for bumble bees collected from 2023 to 2024. The curve quickly reaches an asymptote at 10 species, indicating that all species present were found. The curve was generated in R software using the BiodiversityR package, with individual-based data sampled 100 times without replacement.

Other Bees

To examine the sampling effort for bees other than bumble bees, we included records from 1,325 bees representing 109 species or species groups that were collected in 2023 and 2024. The species accumulation curve for the 2023-2034 collection (Fig. 2 A.) does not level off,

indicating that sampling was not sufficient to capture all bee species present. However, when combined with the 2013-2014 collections, the species accumulation curve is closer to an asymptote (Fig. 2. B.). However, additional collecting would likely reveal additional species.

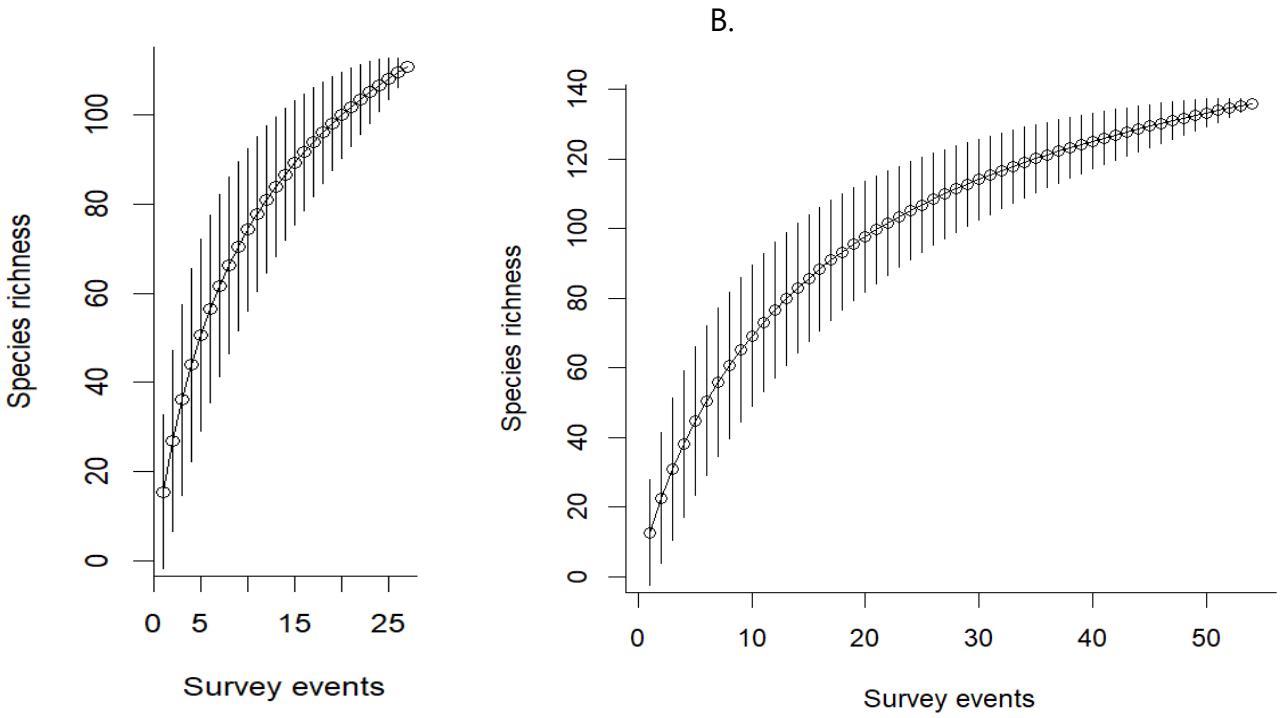

Figure 2. Species accumulation curves for bees other than bumble bees. A. Bees collected over 27 survey dates in 2023 and 2024. B. Bees collected over 54 survey dates in 2013-2014 and 2023-2024. Curves were generated in R software using the BiodiversityR package, with individual-based data sampled 100 times without replacement.

Species of Particular Note

About one quarter of the species in this collection are represented by only one specimen; an additional 13% are represented by two. This high proportion of rare species is typical of wild bee communities and is the reason why multiple years of collecting are usually needed to more accurately characterize bee species richness. Rare species in this study are not necessarily rare in general, even within the same geographical area, as bee populations are known to fluctuate dramatically from year to year (Williams et al. 2001). Comparing the two different collection periods, there are many species that were caught in only one of the collection periods (28 in 2013-2014, 41 in 2023-2024). Several rare or otherwise noteworthy bee species were found in the course of this project and will be highlighted here.

Bombus affinis, the rusty-patched bumble bee, has been a major target of conservation efforts since it was shown to be in steep decline compared to historical levels (Evans et al. 2008; Colla & Packer 2008).It has been listed as endangered in Canada since 2010, and the U.S. since 2017. Five *B. affinis* workers and two males were found in the Eloise Butler Wildflower Garden. They were foraging on *Veronicastrum virginicum, Solidago speciosa, Eupatorium purpureum, Doellingeria umbellata,* and *Thalictrum* sp. *B. affinis* was first recorded in the Garden in 2014. The continued documentation of this bee here and in other locations is encouraging, although numbers remain low compared to historic levels, with only a very slight increase since the 2013-2014 collections (*B. affinis* comprised 0.3% of the bumble bee indicduals in 2013-2014 and 1% in the 2023-2024 collections).

The common eastern bumble bee showed a dramatic increase in abundance from the 2013-2014 collection to the 2023-2024 collection. *Bombus impatiens* became more dominant, comprising 34% of bumble bee individuals in the 2013-2014 collection and 65% of bumble bee individuals in the 2023-2024 collection. While bumble bee species richness remained consistent from the 2013-2014 collections to the 2023-2024 collections, the changes in relative abundances, particularly the increase in the dominance of *B. impatiens* indicates that there could a loss of bumble bee diversity.

Macropis nuda is a seldom-seen oil-collecting bee that was found in the Garden in 2014, but not in the 2023-2024 collection. Due to the rarity of this bee, it is possible that it was still present but was not detected. The females of *Macropis* specialize on loosestrife (*Lysimachia* spp.; not to be confused with purple loosestrife, *Lythrum salicaria*), which produce oil instead of nectar. The bees use this oil as food for their larvae and in nest cell linings, making them entirely dependent upon *Lysimachia* flowers for survival (Cane et al. 1983). To protect these bees, the *Lysimachia ciliata* plants in the Garden should be monitored and not allowed to dwindle.

There were 15 other species of bees documented in the Garden in 2023-2024 that specialize their pollen collection on various plant hosts (Appendix 3). On particular note are *Andrena ziziae*, which specialists on Zizia, *Andrena geranii*, which specialiszes on *Hydrophyllum*, *Andrena rudbeckia*, which specializes on *Rudbeckia*, and *Paranthidium jugatorium*, which specializes on plants in the family Asteraceae. Providing suitable host plants can support populations of these bees. There are other pollen specialists often found in Minnesota that were absent from our collections. Two of note are *Perdita perpallida,* which specialized on *Dalea* spp., and *Colletes andrewsi,* which specializes on *Heuchera* spp. While these plants were present in the Garden, larger stands of these flowers could prove attractive to these bee species, although there may be other needs for them that the Garden may not supply such as preferred nesting habitat.

Four bee species not native to North America were documented in the 2013-2014 and 2023-204 collections. *Apis mellifera,* the western honey bee, was being managed within the Garden in 2013-2014. Without managed colonies in Garden, *A. mellifera w*as still present. Three other species, (*Anthidium manicatum, Anthidium oblongatum,* and *Megachile rotundata*) were present in the 2013-2014 as single individuals, and were not present in collections from 2023-2024.

Patterns of floral use

Examining bees collected by sweeping flowers in both 2013-2014 and 2023-2024, the ten plant species or genera that supported the greatest abundance of bees were *Prunus americana, Filipendula ulmaria, Ceanothus americanus, Monarda fistulosa, Zizia aurea, Cirsium discolor, Amorpha canescens, Solidago flexicaulis, Campanula rapunculoides*, and *Cornus racemosa*. (Appendix 2). The ten plant species or genera that supported the greatest diversity of bee species were *Prunus americana, Ceanothus americanus, Monarda fistulosa, Filipendula ulmaria, Zizia aurea, Solidago flexicaulis, Geranium maculatum, Cirsium discolor, Cornus* racemosa, and *Doellingeria umbellata*. Of particular note are species which supported both high abundance and diversity of bees: *Prunus americana, Ceanothus americanus, Monarda fistulosa, Filipendula ulmaria, Zizia aurea, Solidago flexicaulis, Cirsium discolor,* and *Cornus racemosa*.

GARDEN MANAGEMENT RECOMMENDATIONS

Bee abundance and diversity is best supported by floral diversity, a continuing series of blooming flowers from April through September, and the availability of undisturbed ground and woody material. The Garden currently appears to have sufficient floral diversity to support bees, but there are times when floral abundance could be improved. In the Midwest, there is a natural occurring lull in floral availability after early spring ephemerals bloom and before mid-summer flowers become abundant. *Cornus, Zizea*, *Geranium maculatum,* and *Ceanothus americanus* were some of the flowering plants in the Garden that helped to fill this gap. Their populations should be encouraged. *Prunus americana, Ceanothus americanus, Monarda fistulosa, Filipendula ulmaria, Zizia aurea, Solidago flexicaulis, Cirsium discolor,* and *Cornus racemosa*.were plant species that supported both an abundance and diversity of bee species. Their populations should also be encouraged.

The Garden is home to a diverse and abundant population of stem and tunnel nesting bees. Populations of these bees can be encouraged by provided nesting materials for them in the Garden. Stem nesting bees use stems of many different sizes. If plants are being cut back, consider leaving standing stems of about 12 inches for use by stem nesting bees. Dead standing trees and downed wood are excellent sources of homes for tunnel nesting bees and should be left in situ when not contradicting other management needs.

Ground nesting bees often prefer bare patches of soil and some have specific soil preferences. Many prefer sandy loam and some prefer sand. Regular fires or mowing through the prairie area will encourage more openness in plant density and would provide more opportunities for ground nesting bees to access the ground. While heavy mulching of trails is effective in discouraging weeds, it also limits access to bare ground. If several trail sections could be left un-mulched, it would provide more access to bare ground for ground nesting bees.

Bees that nest in pre-existing cavities, such as bumble bees, benefit from a healthy population of small rodents in the garden. It should be noted that of all the bees present in the garden, the bumble bees have the widest foraging range and so are more affected by what is happening outside of the Garden fences. The bumble bee population in the Garden would benefit from pollinator friendly management of the land surrounding the park.

CONCLUSIONS

The Eloise Butler Wildflower Garden continues to support bee diversity through providing both diverse floral resources and nesting habitat. The diversity of bees present in the

collections from the Garden outsizes expectations based on the size of the Garden, particularly when compared to other parks that do not manage their gardens to provide a wide variety of native blooming plants. Continued monitoring in the future is likely to reveal additional bee species. Additionally, while we can make some comparisons on changes in the bee community over the last ten years between this and the last survey, the minimum number of surveys to detect changes in populations is three. Ideally, bee surveys would be conducted at regular intervals, every five or ten years. We are continuing to work on identification of problematic species, particularly those in the genus *Nomada.* When we are able to obtain more identifications, we will share an updated species list.

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APPENDICES

Appendix 1. Summary of bee species collected from 2013-2014, 2023-2024, and totals. The associated plant for a given bee species is the plant that bee was most frequently collected on, if any. Bees not collected on one plant species, genus, or tribe at least 30% of the time are marked "various". Bees that were collected five or fewer times have been left blank.

Species	Abundance 2013-2014	Abundance 2023-2024	Associated Plant(s)
Andrenidae			
Andrena aliciae Robertson	6		*Helianthus*
Andrena alleghaniensis Viereck		1	
Andrena brevipalpis Cockerell		2	
Andrena carlini Cockerell	20	35	various
Andrena chromotricha Cockerell	7	22	Asteraceae
Andrena crataegi Robertson	2	54	*Ceanothus americanus*
Andrena cressonii Robertson		11	*Zizia aurea*
Andrena distans Provancher	2	3	*Geranium maculatum*
Andrena dunningi Cockerell	4	10	various
Andrena forbesii Robertson		2	
Andrena fragilis Smith	1		
Andrena geranii Robertson	2	1	
Andrena helianthi Robertson	6	1	*Coreopsis, Helianthus*
Andrena hippotes Robertson	1	8	*Prunus americana*
Andrena hirticincta Provancher	6	1	*Solidago, Symphoritrichum*
Andrena imitatrix Cresson		3	
Andrena integra Smith	1		
Andrena mandibularis Robertson		2	
Andrena milwaukeensis Graenicher	1	1	
Andrena miserabilis Cresson		35	*Prunus americana*
Andrena nasonii Robertson	1	12	various
Andrena nivalis Smith		2	
Andrena nubecula Smith	1	7	*Solidago* spp.
Andrena peckhami Cockerell	8		various
Andrena perplexa Smith		1	
Andrena robertsonii Dalla Torre		1	
Andrena rudbeckiae Robertson		2	
Andrena rugosa Robertson	2	8	various
Andrena spiraeana Robertson		9	various
Andrena vicina Smith	11	77	various
Andrena virginiana Mitchell	3		
Andrena wheeleri Graenicher		6	*Zizia aurea*
Andrena wilkella (Kirby)	9	6	various
Andrena wilmattae Cockerell		4	

Andrena ziziae Robertson	6	7	*Zizia aurea*
Andrena sp.		9	
Protandrena andrenoides (Smith)	5	18	Asteraceae
Protandreana labrosus (Robertson)	8		various
Protandrena rudbeckiae (Robertson)	1	1	
Apidae			
Anthophora terminalis Cresson	4	22	various
Apis mellifera Linnaeus	na	55	various
Bombus affinis Cresson	2	7	various
Bombus auricomus (Robertson)	165	87	various
Bombus bimaculatus Cresson	95	19	various
Bombus citrinus (Smith)	30	12	various
Bombus fervidus (Fabricius)	15	2	various
Bombus griseocollis (De Geer)	98	80	various
Bombus impatiens Cresson	233	463	various
Bombus pensylvanicus (De Geer)	13	1	various
Bombus rufocinctus Cresson	3	21	various
Bombus vagans Smith	34	16	various
Calliopsis andreniformis Smith	15		*Amorpha canescens*
Ceratina calcarata Robertson	35	65	various
Ceratina dupla Say	6	3	various
Ceratina mikmaqi Rehan and Sheffield	22	89	various
Holcopasites calliopsidis (Linsley)	1		
Melissodes agilis Cresson	1	1	
Melissodes desponsus Smith	21	10	*Cirsium*
Melissodes druriellus (Kirby)	3	7	various
Melissodes subillatus LaBerge	2	1	various
Melissodes trinodis Robertson	17	34	various
Nomada cressonii Robertson	1		
Nomada denticulata Robertson		1	
Nomada lehighensis Cockerell	1		
Nomada luteoloides Robertson	1	4	
Nomada maculata Cresson		20	various
Nomada sp. (bidentate)	12	45	various
Nomada sp. (illinoensis/sayi group)	3		
Svastra obliqua (Say)	1		
Collectidae			
Hylaeus affinis (Smith)		5	
Hylaeus fedorica (Cockerell)		4	
Hylaeus mesillae (Cockerell)	1		
Hylaeus modestus Say		18	various
Hylaeus verticalis (Cresson)		1	
Hylaeus sp. (affinis group)	50		various
Hylaeus sp. (annulatus/affinis group)	1		

Hylaeus sp. (mesillae group)		7	various
Hylaeus sp. (modestus group)		50	various
Halictidae			
Agapostemon sericeus (Förster)		35	various
Agapostemon virescens (Fabricius)	8		various
Augochlora pura (Say)	16	46	various
Augochlorella aurata (Smith)	33	19	various
Augochlorella confusa (Robertson) (formerly considered the same as *A. aurata*)		15	various
Augochloropsis viridula (Smith)		11	various
Augochloropsis metallica or *viridula*	8		various
Dufourea monardae (Viereck)	21	2	*Monarda fistulosa*
Halictus confusus Smith	3	2	
Halictus ligatus Say	10	20	various
Halictus rubicundus (Christ)	5	12	various
Lasioglossum abanci or *planatum*	2	1	
Lasioglossum anomalum (Robertson)	7	6	various
Lasioglossum birkmanni (Crawford)		2	
Lasioglossum cattellae (Ellis)	15	29	*Prunus americana*
Lasioglossum cinctipes (Provancher)		15	*Prunus americana*
Lasioglossum coeruleum (Robertson)	1	5	*Solidago flexicaulis*
Lasioglossum coriaceum (Smith)	3	3	various
Lasioglossum cressonii (Robertson)	6	2	various
Lasioglossum ellisiae (Sandhouse)		1	
Lasioglossum foxii (Robertson)	2	23	*Prunus americana*
Lasioglossum heterognathus (Mitchell)	23	91	*Filipendula ulmaria*
Lasioglossum hitchensi Gibbs	2	3	
Lasioglossum illinoense (Robertson)	2	1	
Lasioglossum imitatum (Walker)	3	2	
Lasioglossum laevissimum (Smith)	1	2	
Lasioglossum lineatulum (Crawford)	5	5	various
Lasioglossum macoupinense (Robertson)	23	22	various
Lasioglossum nigroviride (Graenicher)	2	11	various
Lasioglossum oblongum (Lovell)		1	
Lasioglossum obscurum (Robertson)		1	
Lasioglossum paradmirandum (Knerer & Atwood)	4	1	
Lasioglossum pectorale (Smith)		1	
Lasioglossum subviridatum (Cockerell)	1	10	various
Lasioglossum truncatum (Robertson)		6	various
Lasioglossum versans (Lovell)	4	10	various
Lasioglossum viridatum (Lovell)	1		
Lasioglossum weemsi (Mitchell)	1		
Lasioglossum zephyrum (Smith)	10	5	various
Lasioglossum sp.	1	1	
Lasioglossum sp. (atwoodi?)	1		

Lasioglossum sp. (viridatum group)	2		
Sphecodes davisii Robertson		1	
Sphecodes galerus Lovell and Cockerell		2	
Sphecodes sp.	2		
Megachilidae			
Anthidium manicatum (Linnaeus)	1		
Anthidium oblongatum (Illiger)	1		
Heriades carinatus Cresson	18	46	*Monarda fistulosa*
Heriades sp.		1	
Hoplitis pilosifrons (Cresson)		3	
Megachile campanulae (Robertson)	12	12	*Campanula*
Megachile frigida Smith	6	3	various
Megachile gemula Cresson	6	2	various
Megachile inermis Provancher	4		
Megachile latimanus Say	10		various
Megachile mendica Cresson		1	
Megachile pugnata Say	2	4	various
Megachile relativa Cresson	5		
Megachile rotundata (Fabricius)	1		
Megachile texana Cresson	2	1	
Osmia atriventris Cresson	1	2	*Penstemon digitalis*
Osmia lignaria Say	1	3	*Erythronium albidum*
Osmia pumila Cresson	5	7	various
Paranthidium jugatorium (Say)		2	
Stelis coarctatus Crawford		5	
Mellitidae			
Macropis nuda (Provancher)	2		*Lysimachia ciliata*
Total individuals	**1,305**	**2,030**	
Total species per study	**103**	**116**	
Total species recorded	**145**		

Appendix 2. Summary of bee abundance and species richness by plant species. Indiv=the abundance of all bees collected from a plant species. Spp=the number of bee species collected from a plant species.

Plant Family	Plant name	Indiv.	Spp.
Aceraceae	*Acer spicatum*	10	5
Anacardiaceae	*Rhus glabra*	10	8
Apiaceae	*Zizia aurea*	47	17
Apocynaceae	*Amsonia tabernaemontana*	1	1
	Apocynum cannabinum	5	4
Asclepiadaceae	*Asclepias exaltata*	4	3
	Asclepias syriaca	1	1
Asteraceae	*Achillea millefolium*	3	2
	Ageratina altissima	11	8
	Cichorium intybus	20	11
	Cirsium discolor	46	14
	Coreopsis palmata	14	5
	Coreopsis tripteris	8	4
	Doellingeria umbellata	21	13
	Echinacea angustifolia	4	3
	Echinacea purpurea	6	4
	Erigeron strigosus	13	7
	Eurybia macrophylla	4	4
	Eutrochium maculatum	8	6
	Eutrochium purpureum	1	1
	Eutrochium purpureum	11	8
	Helenium autumnale	19	7
	Helianthus	20	8
	Helianthus hirsutus	13	7
	Helianthus maximiliani	5	2
	Helianthus pauciflorus	5	4
	Helianthus tuberosus	11	5
	Heliopsis helianthoides	10	7
	Liatris pycnostachya	13	6
	Prenanthes alba	2	2
	Ratibida pinnata	11	4
	Rudbeckia hirta	13	9
	Rudbeckia laciniata	2	2
	Rudbeckia triloba	12	8
	Silphium integrifolium	11	6
	Silphium laciniatum	4	3
	Silphium perfoliatum	7	3
	Silphium terebinthinaceum	23	9
	Solidago canadensis complex	23	12
	Solidago flexicaulis	41	16

	Solidago rigida	22	11
	Solidago speciosa	14	10
	Symphyotrichum boreale	11	6
	Symphyotrichum cordifolium	17	4
	Symphyotrichum ericoides	8	7
	Symphyotrichum firmum	11	4
	Symphyotrichum laeve	8	7
	Symphyotrichum lanceolatum	1	1
	Symphyotrichum lateriflorum	13	8
	Symphyotrichum novae-angliae	9	7
	Symphyotrichum sericeum	1	1
	Symphyotrichum urophyllum	5	5
	Taraxacum officinale	7	5
Balsaminaceae	*Impatiens capensis*	5	3
Berberidaceae	*Jeffersonia diphylla*	1	1
Boraginaceae	*Mertensia virginica*	9	6
	Myosotis scorpioides	2	2
Brassicaceae	*Cardamine concatenata*	3	1
	Cardamine concatenate	10	5
	Cardamine diphylla	11	7
Campanulaceae	*Campanula rapunculoides*	37	12
	Campanula rotundifolia	14	9
	Campanulastrum americanum	11	2
	Lobelia siphilitica	18	5
Caprifoliaceae	*Diervilla lonicera*	8	7
	Sambucus racemosa	2	1
	Triosteum perfoliatum	6	5
	Viburnum opulus	1	1
Caryophyllaceae	*Saponaria officinalis*	3	3
Clusiaceae	*Hypericum pyramidatum*	10	7
Cornaceae	*Cornus racemosa*	34	13
Ericaceae	*Vaccinium angustifolium*	2	1
Euphorbiaceae	*Euphorbia esula*	2	2
Fabaceae	*Amorpha canescens*	41	12
	Apios americana	1	1
	Baptisia australis	19	8
	Dalea candida	1	1
	Desmodium canadense	1	1
	Lathyrus venosus	1	1
	Strophostyles helvola	1	1
	Trifolium pratense	3	2
Gentianaceae	*Gentiana andrewsii*	13	6
	Gentiana flavida	1	1
	Gentiana flavida	2	2

Geraniaceae	*Geranium maculatum*	21	15
Grossulariaceae	*Ribes americanum*	1	1
	Ribes missouriense	2	2
Hydrophyllaceae	*Hydrophyllum virginianum*	6	4
Iridaceae	*Iris versicolor*	5	3
Lamiaceae	*Agastache foeniculum*	15	9
	Monarda fistulosa	98	20
	Physostegia virginiana	8	5
Liliaceae	*Asparagus officinalis*	6	2
	Erythronium albidum	29	9
	Erythronium americanum	3	2
	Lilium michiganense	1	1
	Maianthemum racemosum	21	6
	Polygonatum biflorum	2	2
	Trillium flexipes	1	1
	Uvularia grandiflora	21	8
Malvaceae	*Napaea dioica*	9	2
Melanthiaceae	*Trillium erectum*	4	4
	Trillium grandiflorum	7	3
Onagraceae	*Chamerion angustifolium*	12	6
	Circaea canadensis	5	3
	Epilobium ciliatum	2	2
	Gaura biennis	6	3
	Oenothera pilosella	16	7
Orchidaceae	*Cypripedium reginae*	1	1
Papaveraceae	*Sanguinaria canadensis*	17	8
	Stylophorum diphyllum	4	3
Poaceae	*Dactylis glomerata*	1	1
Primulaceae	*Dodecatheon meadia*	7	7
	Lysimachia ciliata	11	4
	Lysimachia quadriflora	1	1
	Lysimachia quadrifolia	12	6
	Lysimachia vulgaris	1	1
Ranunculaceae	*Actaea racemosa*	1	1
	Actaea rubra	1	1
	Anemone americana or acutiloba	1	1
	Anemone virginiana	3	2
	Caltha palustris	12	7
	Clematis virginiana	10	6
	Enemion biternatum	18	12
	Hepatica nobilis	3	3
	Ranunculus acris	9	7
	Ranunculus hispidus	1	1

	Thalictrum dasycarpum	7	3
Rhamnaceae	*Ceanothus americanus*	98	30
Rosaceae	*Filipendula ulmaria*	104	17
	Potentilla recta	13	6
	Prunus americana	262	35
	Prunus virginiana	7	5
	Rosa arkansana	18	10
	Rosa setigera	9	4
	Rubus allegheniensis	3	3
	Rubus occidentalis	23	10
	Spiraea alba	13	7
Rubiaceae	*Cephalanthus occidentalis*	10	5
Ruscaceae	*Maianthemum racemosum*	4	2
Rutaceae	*Zanthoxylum americanum*	24	7
Salicaceae	*Salix discolor*	2	1
	Salix humilis	11	8
Saxifragaceae	*Heuchera americana*	3	1
	Heuchera richardsonii	4	1
	Micranthes pensylvanica	6	6
	Tiarella cordifolia	1	1
Scrophulariaceae	*Chelone glabra*	12	7
	Chelone obliqua	7	4
	Penstemon digitalis	24	9
	Penstemon gracilis	3	2
	Scrophularia marilandica	1	1
	Veronicastrum virginicum	16	10
Staphyleaceae	*Staphylea trifolia*	4	2
Thymelaeaceae	*Direa palustris*	2	2
Verbenaceae	*Verbena hastata*	10	5
Violaceae	*Viola sororia*	3	2

Appendix 3. Specialist bees and their plant hosts from 2023-2024 collection. Host genera were gathered from Fowler (2020).

Plant host family	Bee species	Plant host genera
Apiaceae	*Andrena ziziae*	*Zizia*
Asteraceae	*Andrena chromotricha*	*Grindelia , Helianthus Solidago Symphyotrichum*
	Andrena helianthi	*Helianthus*
	Andrena hirticincta	*Euthamia, Grindelia , Solidago, Symphyotrichum*
	Andrena nubecula	*Euthamia , Solidago, Symphyotrichum*
	Andrena rudbeckiae	*Ratibida , Rudbeckia*
	Megachile pugnata	*Cirsium, Coreopsis, Erigeron, Grindelia , Helianthus, Rudbeckia*
	Melissodes agilis	*Cirsium, Grindelia , Helianthus, Rudbeckia, Ratibida , Simsia , Solidago, Verbesina*
	Melissodes desponsus	*Cirsium*
	Melissodes druriellus	*Eurybia, Euthamia , Helianthus, Rudbeckia, Solidago, Symphyotrichum , Verbesina, Vernonia*
	Melissodes subillatus	*Coreopsis, Cirsium, Rudbeckia, Symphyotrichum , Vernonia*
	Melissodes trinodis	*Coreopsis, Grindelia , Helianthus, Heliopsis , Ratibida , Rudbeckia, Solidago, Symphyotrichum , Verbesina*
	Paranthidium jugatorium	*Erigeron, Grindelia , Haplopappus ,Helianthus Heterotheca , Rudbeckia, Silphium, Verbesina ,Viguiera*
Boraginaceae	*Andrena geranii*	*Hydrophyllum*
Geraniaceae	*Andrena distans*	*Geranium*