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A Survey of the Solitary Native Bees of the Leach Botanical Garden, and their Floral Associations

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by

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Abstract

Solitary native bees are known to be diverse, but are not well studied in Oregon. In order to identify the bee genera present in the Leach Botanical Garden, and their floral usage, a survey was conducted over 2020 and 2021. Biweekly sampling was used to collect bees on flowers, in order to obtain floral usage data. Bees were identified to genus with published taxonomic keys. In total, 19 genera of bees were found. Bee abundance fit a normal distribution, and peaked in July. *Ceratina* and *Lasioglossum* were a significant proportion of the population, and were present in the garden from April to September. Megachilidae, especially *Osmia*, was relatively abundant in April and May. Halictidae was a significant part of the summer and fall bee population. The vast majority of bee genera surveyed were found to be generalists, utilizing many flowers across multiple plant families. Asteraceae was by far the most utilized plant family, with *Solidago* and *Symphyotrichum* being highly visited genera. Overall, Leach was found to contain a highly diverse bee population, utilizing a wide array of flowering plants. Asteraceae was found to be a good choice of flower to attract high numbers of bees to a garden space, however early season bees must also be considered in choosing plants.

Introduction

When people think of bees, what most likely comes to mind is the European honey bee, or the bumble bee. These taxa, however, represent a small fraction of the estimated 16,000 known bee species worldwide (Michener 2007). Most bee species native to North America do not form the communal nests typical of honey or bumble bees, instead the females each construct their own nests to lay their eggs in. Many species build their nests in the ground, whereas others construct them in the stems of plants or woody material. Bees spend most of their lives in their nests, developing through the egg, larvae, pupae, and adult stages. Most bees spend the winter in their nests, and emerge as an adult at the appropriate time to mate and, for the females, construct nests for their eggs; solitary bees typically live only a few weeks once they emerge. The time frame over which bees emerge as adults is termed the bee season, and generally lasts from February to September in Portland, Oregon. Females collect pollen from flowers to store in their nests as food for their offspring. Both of the sexes utilize nectar from flowers as food for themselves. Bees can be classified as generalists or specialists based on their usage of flowering plants. Generalists utilize a variety of flowering plants for resources, whereas specialists utilize floral resources from only a single family, genus, or even species of plant. Bees are typically more specialized for pollen collection then nectar usage (Michener 2007).

Bees are critical to the pollination of flowering plants, and solitary native bees contribute to the pollination of both native and domesticated plant species. Native bees have been shown to increase fruit yield (Garibaldi 2013), and may be more important that honeybees in pollinating some crop species (Winfree 2007). The contribution of native bees has been estimated to be at least $3 billion per year (Losey 2006). Native bees do not inhabit land used for agriculture, and instead travel to cropland from surrounding natural areas (Kreman 2004, Öckinger 2006). Given that native bees require habitat with flower resources and nesting areas, understanding the flowers that bees use is important to manage populations to maximize agricultural output. Native bees are important pollinators for many of the food producing plants grown in urban gardens (Kremen 2002), and also act as pollinators for both the native and non-native ornamental plants in garden spaces (Frankie 2009). In addition to the importance of native bees to agriculture, native bees are important pollinators of the approximately 87 percent of wild flowering plants that utilize animal pollination (Ollerton 2011), many of which have long evolutionary histories with pollinators. Determining the bee populations of an area is therefore important for conservation and management of natural environments.

Non-domesticated bees are highly diverse in the Western United States, with some estimates of many hundreds of species in particularly diverse regions (Michener 2007), and significant diversity has been found in urban areas (Fortel 2014, Choate 2018). Despite this known diversity, the study of native bees of the Pacific Northwest has been significantly neglected. The Oregon Bee Atlas project has been running a citizen science checklist survey of bees in Oregon (OSU Extension Service 2022), and a few studies have systematically surveyed bee populations (Roof 2018, Galbraith April 2019, Galbraith December 2019, Mitchell 2021). However, only three studies were found that examined bee populations in urban areas (Tyler 2018, Diamond 2020), including an ongoing long term survey of the native bee diversity of Portland by the Susan Masta lab at Portland State University. In order to expand on this research, and systematically survey the native bees of Portland, a study was developed to cover the Leach Botanical Garden, one of the sites studied previously (Tyler 2018, Diamond 2020). The Leach Botanical Garden is a small public garden in South-East Portland. The garden consists of publicly accessible trails through a mix of wooded and exposed areas planted with varied plants. Additionally, there is a non-publicly accessible restored natural area, also consisting of a mix of woodland and exposed slope, planted with native flowering plants. Prior research has focused most survey work on locations in other parts of the city, notably on the western half, and so the data from this study serves as a complement to these studies (Rudolph 2020). During 2019 and 2020, the garden underwent significant renovations, including the removal and replanting of most of the flowering plants in the garden. I surveyed the gardens in

2020 during these renovations, and in 2021, the year following the completion of renovations. Collection was focused on solitary native bees, as they are much less studied than honey bees or bumble bees. Bumble bees can be identified visually in the field (Koch 2012), and so there is less of a need to collect specimens. There is also an ongoing citizen science survey of bumble bees run by the Xerces society, documenting their distribution (Bumble Bee Watch 2022).

Methods

The general survey method for this study was designed to collect information consistently across the bee season, focusing on the interaction of bees with the flowers they utilize. The survey procedures of the Susan Masta lab's survey of the bees of Portland, and LeBuhn et. al. (2003), were used to develop the survey method. Specimens were primarily captured with collection vials on flowers the bees landed on. Netting was also used to capture bees observed to land on flowers, especially fast-moving taxa. Although common in many surveys, pan traps were not used, in order to allow documentation of the floral resources the bees were using.

During the 2020 bee season, collection was opportunistic due to major renovations the gardens were undergoing. Only a few small areas of flowering plants were present, and overall presence of native bees was low. Bees were mostly caught in a single space, a planted rocky garden approximately 20 square meters in area. In April of 2021, the garden renovations were completed. From the opening of the gardens on the 17th of April, to the end of the bee season in September, the garden was surveyed biweekly. Collection days were chosen on days with warm, sunny weather, in order to survey when bees are known to be flying and on flowers. The two primary survey areas in the garden were an "ornamental" garden consisting of paved walkways with flowers planted in mulched beds, and a "native" garden, consisting of an exposed hillside planted with a variety of plants. Both areas were surrounded by tall evergreen trees, but received direct sunlight for the duration of each survey. Bees were collected for four hours each day, beginning between 11am and 12pm, with the time divided evenly between areas of flowering plants. The time intervals were between 20 to 30 minutes. An initial walk of the garden was used to determine which plants were flowering, and had native bees present on or around them. The flowers selected by this initial walk were divided into roughly equal areas and each was surveyed. During this time, flowers were visually scanned for bees which were then captured. When more bees were present than could be captured at a time, specimens were collected as quickly as possible, with the next target for capture being the next bee observed to land on a flower, without considering previous captured specimens. Due to a need to stay on paved trails in public areas, and avoid trampling plants in non-public areas, some plants could not be sampled. A complete record of plants flowering in the garden was not kept, with data limited to only flowering plants on which bees were captured. Capture information was recorded, and flowers were photographed for later identification.

Specimens were euthanized by freezing, and pinned in a standard method for museum collections. In particular, a pin was placed through the right side of the scutum, or glued to the right side of the specimen for small bees, and the specimen was positioned to allow easy access to morphological features. Bees were identified to the genus level with a taxonomic key provided by the Oregon Bee Atlas project, developed by the Canadian Pollinator Initiative. The specific key could not be found publicly available, but Packer et. al. (Packer 2007) provides a representative key. Identifications were confirmed by descriptions in *The Bees in Your Backyard* (Carril 2015). Identifications were made based on morphological features. Bees were identified to the genus level, as species identification requires substantially more time, and for some genera there are no published species level taxonomic keys. Limited species identification was completed, and the results have been included, however these remain preliminary findings. All specimens were added to the invertebrate zoology museum collection at Portland State University as voucher specimens. Data processing and analysis was performed using the “tidyverse” meta-package of the R programming language.

Results

Over the 2020 bee season, 57 bees in 7 genera were captured. The most common bee genera in the data was, *Ceratina* followed by *Osmia* (**Table 1**). Specimens were collected on April 26, May 17, and July 15. In the 2021 season, 518 specimens were captured across 19 genera (**Table 2**). The six most numerous genera in the data were *Ceratina, Lasioglossum, Melissodes, Halictus, Agapostemon,* and *Osmia.* Genera of moderate abundance in this survey included *Nomada, Panurginus, Protosmia,* and *Andrena*. Rare genera captured include *Sphecodes, Atoposmia, Triepeolus, Anthidium,* and *Anthidiellum.* The total bee abundance across the season approximately follows a normal distribution, with a peak in abundance during the July 22 collection date (**Figure 1**). There is a slight trend of increasing diversity of bee genera as the bee season progresses (**Figure 2**).

Table 1: Specimens captured in each bee genera, and the plant genera they were captured on. Data from the 2020 bee season.

Genus	Specimen Count	Plant Genus	Specimen Count
Ceratina	27	*Solidago*	3
		Penstemon	2
		Rudbeckia	2
		Allium	1
		Claytonia	1
Osmia	13	*Penstemon*	6
		Iris	1
		Phlox	1
Andrena	6	*Oxalis*	1
		Penstemon	1
Lasioglossum	5	*Dichelostemma*	1
Nomada	3		
Hylaeus	2		
Halictus	1	*Solidago*	1

Table 2: Bees captured in each bee genera, and the top three plant genera (family when genus unknown) they were captured on. Bees not captured on a flower are included in the total specimen number for each genus, but not shown as a plant category. Data from the 2021 bee season.

Genus	Specimen Count	Plant Genus	Specimen Count
Ceratina	168	*Solidago*	46
		Convolvulus	21
		Veronica	18
Lasioglossum	132	*Solidago*	60
		Gilia	16
		Symphyotrichum	14
Melissodes	53	*Solidago*	26
		Symphyotrichum	8
		Gilia	6
Halictus	36	*Symphyotrichum*	15
		Helenium	7
		Geranium	6
Agapostemon	33	*Helenium*	11
		Symphyotrichum	9
		Geranium	4
Osmia	30	*Penstemon*	10
		Hyacinthoides	4
		Myosotis	2
Hylaeus	11	*Solidago*	3
		Apiaceae	3
		Veronica	3
Megachile	9	*Symphyotrichum*	5
		Deutzia	1
		Geranium	1
Heriades	8	*Solidago*	8
Nomada	8	*Myosotis*	3
		Camassia	2
		Deutzia	1
Hoplitis	6	*Anagallis*	1
		Convolvulus	1
		Fragaria	1
Panurginus	5	*Veronica*	3
		Solidago	1
		Ranunculaceae	1
Protosmia	5	*Hyacinthoides*	4
		Ajuga	1
Andrena	4	*Veronica*	2
		Camassia	1
		Deutzia	1
Sphecodes	3	*Solidago*	1
		Veronica	1
Atoposmia	2	*Gilia*	1
		Myosotis	1
Triepeolus	2	*Mentha*	1
		Symphyotrichum	1
Anthidiellum	1	*Solidago*	1
Anthidium	2	*Betonica*	2

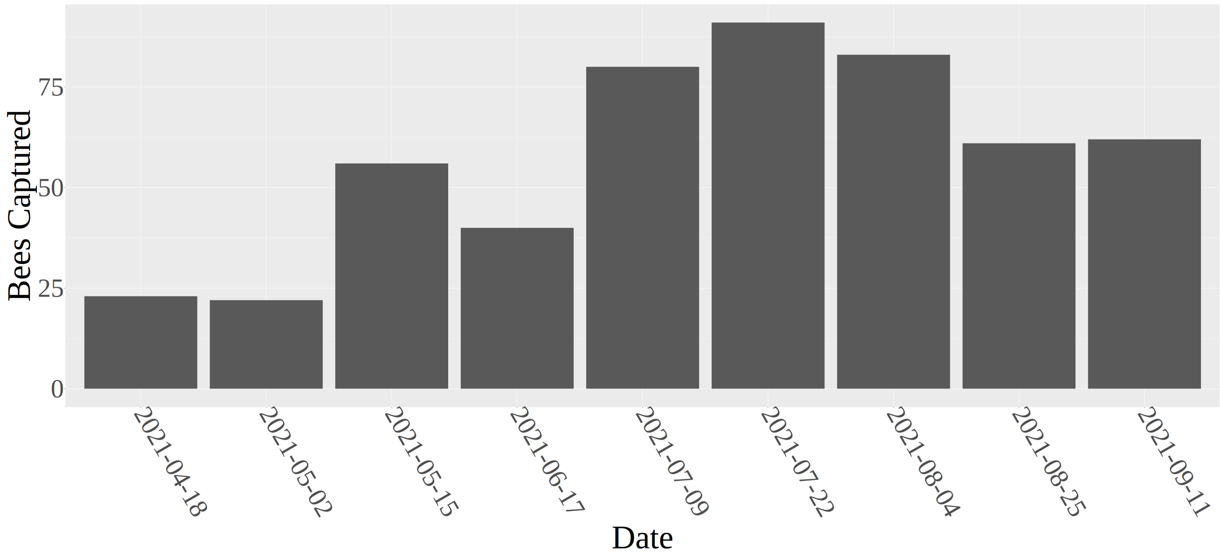

Figure 1: Number of bees captured on each collection date over the 2021 bee season.

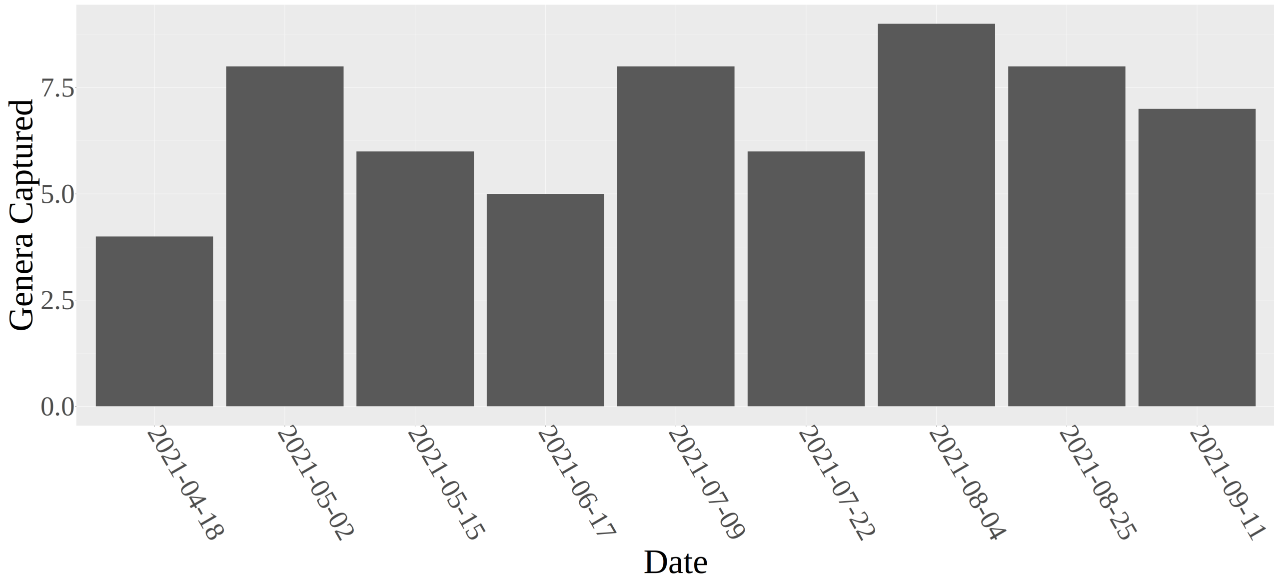

Figure 2: The number of bee genera captured in the garden over the bee season.

Bee Seasonality

Of the most abundant bee genera in 2021, *Ceratina* was present the entire bee season, and made up a large proportion of the bee population at each date. Most of these were a single species, *Ceratina acantha*. *Lasioglossum* was also present throughout the season, in low numbers in spring, and with a peak in abundance in July. The most abundant taxa in April and May were *Ceratina*, and *Osmia*. Bees of relatively moderate abundance included *Protosmia*, and *Nomada*. Rarely caught bees included *Atoposmia*, *Megachile*, and *Melissodes*. A small number of *Andrena* were captured in late May, as was a single *Agapostemon*. In June and July, the population of bees was dominated by

Lasioglossum, *Ceratina*, and *Melissodes*. *Hylaeus* was present in moderate to low numbers from June to August. *Panurginus* and *Hoplitis* were present in June and July, and *Heriades* were captured on July 9. Rare bees in June and July included *Anthidiellum* and *Atoposmia*. In August and September, the bee population was predominantly a more even mix of *Lasioglossum*, *Ceratina, Agapostemon*, *Melissodes*, and *Halictus*. Less frequently caught taxa included *Megachile, Sphecodes*, *Triepeolus*, and *Anthidium* (**Figure 3**).

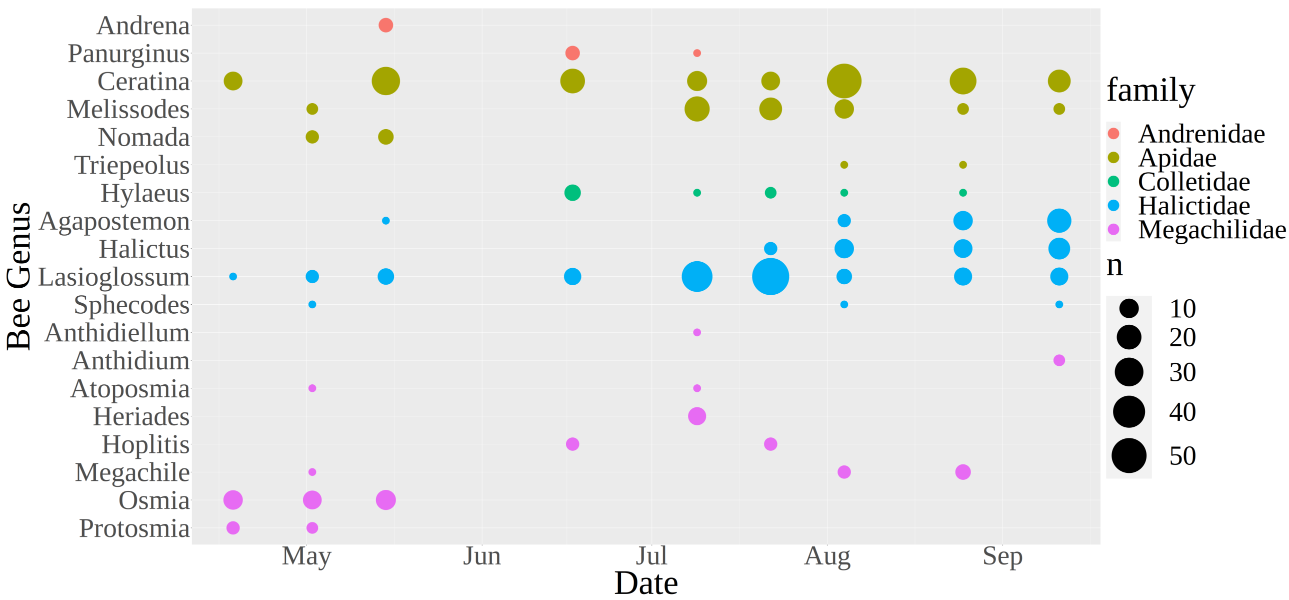

Figure 3: The seasonality of each bee genera over the 2021 bee season. Note that the smallest points visible represent a single bee.

<u>Floral Usage</u>

Almost all bee genera captured were present on a variety of flowers, including plants in different families (**Figure 4**). In April and May, bees were captured on *Hyacinthoides*, *Penstemon*, *Myosotis*, *Veronica*, and *Camassia* in relatively higher numbers (**Figure 5a**). In June, bees were commonly captured on *Veronica* and Rosaceae. In July, the most common plants on which bees were captured consisted of Asteraceae, *Gilia*, and *Geranium* (**Figure 5b**). In the months of August and September, the plants on which bees were captured were dominated by Asteraceae, especially *Solidago*, and *Symphyotrichum*. *Helenium*, *Convolvulus* and *Geranium* were also visited at a relatively higher frequency in these months (**Figure 5c**).

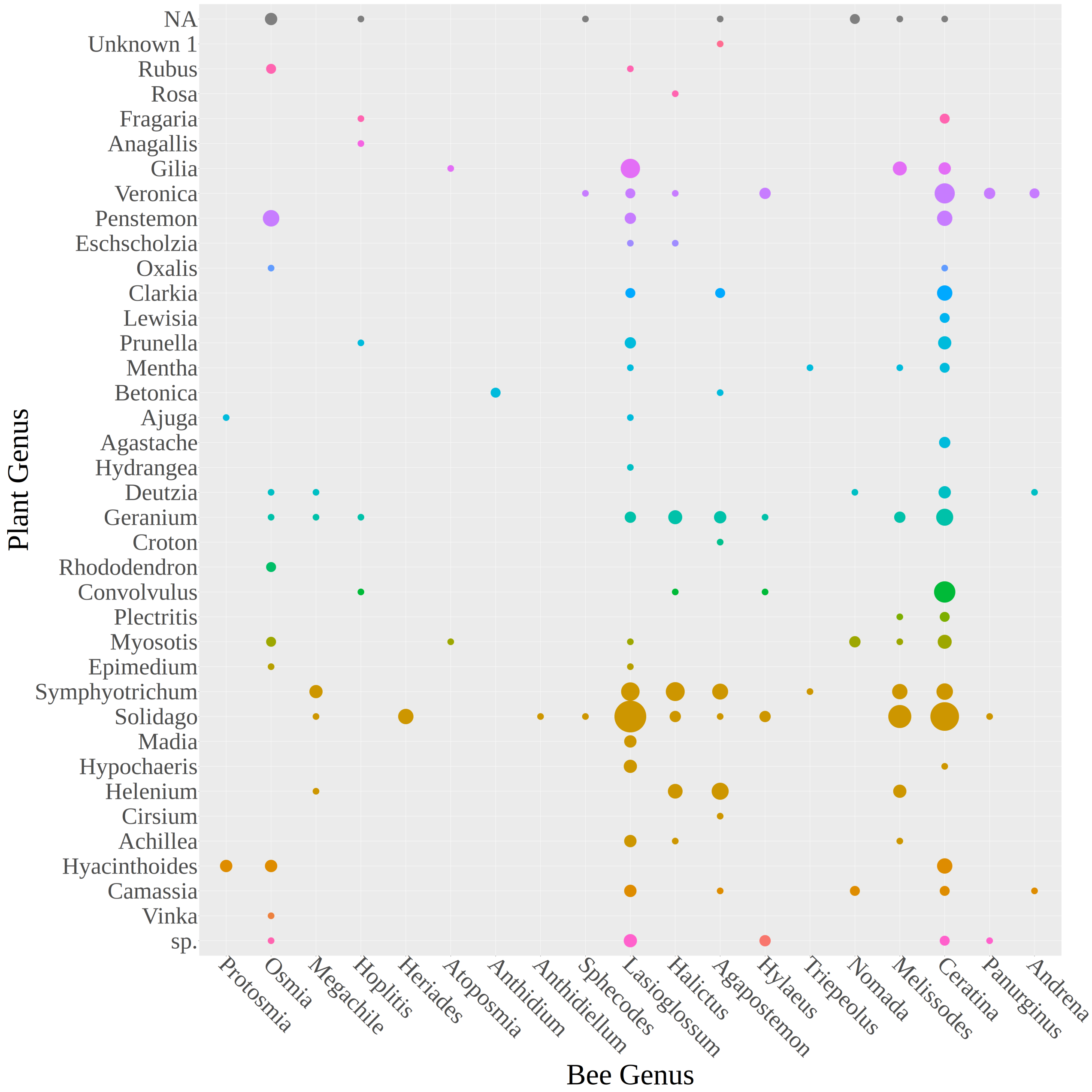

Figure 4: The plant usage of each genera. Coloration indicates plant family. NA represents specimens collected without flower association.

From July to the end of the bee season, *Solidago* and *Symphyotrichum* were blooming in high numbers, in roughly a five to ten meter diameter oval patch of densely growing flowers. A high number of bees were observed in the vicinity of this flower patch. It was also observed that fewer flowering plants were present in the garden in the early season, compared to July and August. The most commonly used flowers were in the family Asteraceae, followed by Plantaginaceae and Geraniaceae (**Figure 6**).

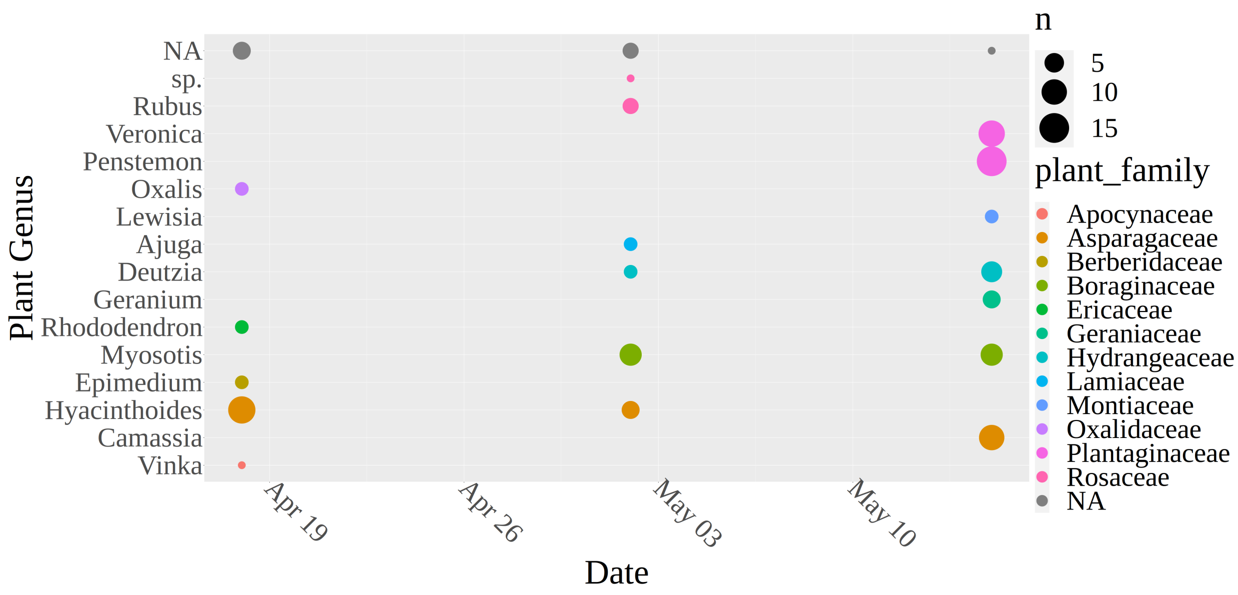

Figure 5a: Flowers on which bees were collected over the "spring" dates.

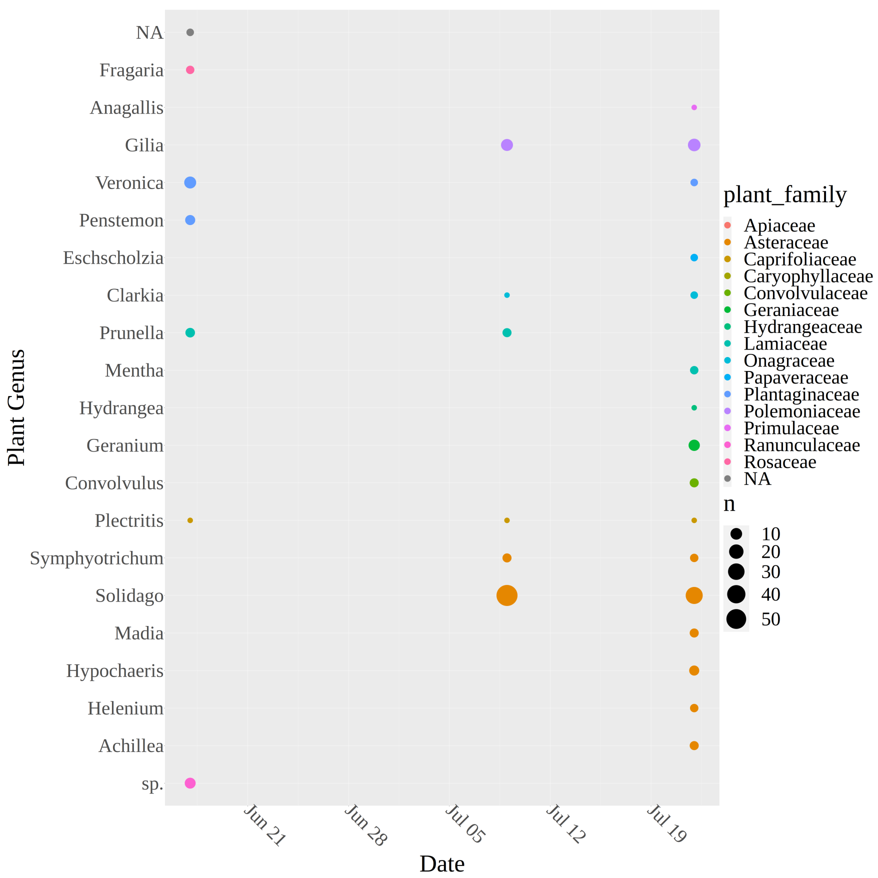

Figure 5b: Plants on which bees were captured over the "summer" collection dates.

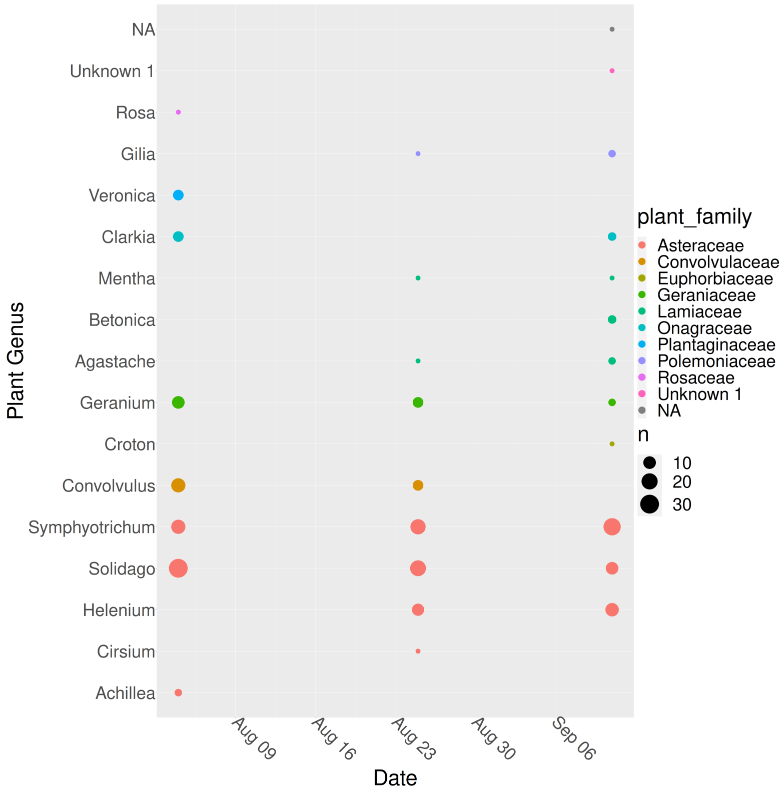

Figure 5c: Flowers on which bees were collected over the "fall" collection dates.

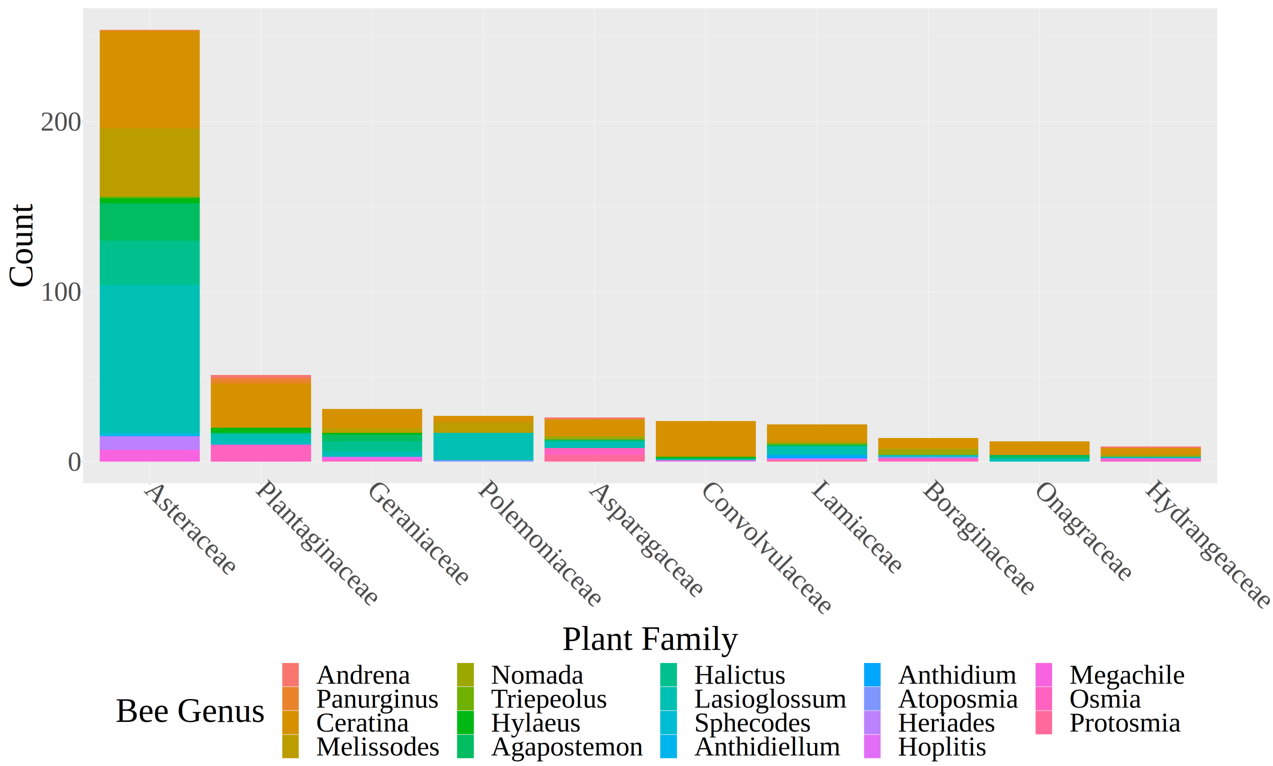

Figure 6: The ten most visited plant families in the 2021 bee season.

Analyzing the floral usage by genera reveals that *Ceratina* utilized a broad range of flowering plants across the entire season. *Lasioglossum* demonstrated similar patterns across most of the bee season, except for late August and September. On these two collection dates, *Lasioglossum* was overwhelmingly captured on *Solidago* and *Symphyotrichum*, with only a single specimen captured on *Mentha*. *Melissodes* male specimens were captured on a range of flowering plants, however the females were almost exclusively captured on Asteraceae. *Agapostemon* was also predominantly captured on Asteraceae, especially on *Symphyotrichum* and *Helenium*. Males of *Osmia* were captured on a range of flowering plants, whereas females were mostly captured on *Penstemon*, with single specimens captured on four other plant genera. *Halictus* was predominantly captured on Asteraceae and *Geranium*.

Three kleptoparasitic genera of bees were captured: *Nomada*, *Sphecodes*, and *Triepeolus*. For all three, at least some of the specimens were captured on a flower. *Nomada* was captured in May on *Myosotis, Camassia*, and *Deutzia*. *Triepeolus* was captured in August on *Symphyotrichum* and *Mentha*. *Sphecodes* was captured in May, July, and September, on *Solidago* and *Veronica*.

Discussion

High levels of bee diversity were present in the garden throughout the season. *Ceratina* and *Lasioglossum* were constants, but the rest of the bee population changed as the season progressed, with a slight increase in number of genera captured, and a more even distribution of bee numbers in each genera. Several taxa were rarely collected in this survey, including two kleptoparasitic genera. The low frequency of kleptoparasitic genera was expected, as parasites are almost always less abundant that their hosts. Bees in the garden utilized a diverse array of flowers, although Asteraceae made up a significant fraction of visitations during the latter half of the season. Flower usage also displays a shift as the season progresses.

The observed pattern of increasing bee abundance from April to July could be explained by several factors. There are generally fewer bees flying in the early spring, as most bees are not able to remain active in the colder weather of these months. Bee species have evolved to emerge at times when the weather is favorable, and there are suitable floral resources. Given that this pattern of abundance is generally observed in bee populations, this is likely an important factor. Another possible reason for the low number of bees early in the season was the renovations of the garden. During the part of the renovations that occurred in 2021, virtually all of the flowering plants in the garden were removed, and replanted in the week before the gardens opened on April 17. The lack of flowers in the garden prior to the first collection date may have delayed bees finding the garden's floral resources. The high abundance of bees in July and August, and the high usage levels of *Symphyotrichum* and *Solidago* are likely related. These genera were blooming in high numbers in a dense patch of flowers, which represents a high-quality floral resource for bees.

The data from the 2020 bee season generally reflects the results of the 2021 bee season, in the presence of relatively high numbers of *Ceratina* and *Osmia*. The low number of specimens from 2020, collected over dates restricted to the first half of the bee season, limits meaningful analysis of the first year of data. The latter consideration may explain the relatively lower numbers of *Lasioglossum* from 2020, as the second half of the season in 2021 was when the majority of *Lasioglossum* were captured. The results do add to the list of plant genera on which bees were observed.

<u>Bee Seasonality</u>

The data from this survey demonstrates that *Ceratina* and *Lasioglossum* make up a large part of the bee populations of Leach, and are present throughout the season. When looking for bees on the flowering plants of Leach, these are the bees that are most likely be found. Preliminary identification of the bees to species suggests that the vast majority of *Ceratina* collected are *Ceratina acantha*, a common and widespread species in the Pacific Northwest (Daly 1973). *Ceratina* is known to emerge multiple times in a season, as separate broods (multi-voltine), or as multiple flights of the same adults (Daly 1966, Rehan 2010). The emergence data from Leach is generally consistent with two emergence times, once in May and again in August (**Figure 2**). *Lasioglossum* is known to be highly diverse, and is often extremely difficult to identify to species. This is especially true for the subgenus Dialictus, whose diversity is largely undescribed in the western US (Gibbs 2010, 2011, 2017). A significant majority of the specimens collected at Leach were Dialictus, and while identifying them to species will likely take significant work, what can be concluded is that there is a high diversity of halictid bee species in Leach. At the genera level, the diversity of the Halictideae family was highest in August and September, increasing from the early spring to the summer.

In contrast to Halictadae, Megachilidae was most abundant, in terms of numbers and genera diversity, in April and May, with another peak in late July. The population was dominated by *Osmia*, and *Protosmia* in the spring. *Megachile* was the most prevalent of this family in August. Many of the Megachilidae are cavity nesting, and will utilize human constructed nesting blocks.

Their presence over bee season emphasizes the importance of providing this resource, or other suitable nesting habitat, throughout the year. Megachilidae are one of the long-tongued bees (Michener 2007), and can utilize deeper flowers. Their presence throughout the year suggests that such plants can be utilized throughout the season. This is also true of Apidae, another of the long-tongued bees. One of the Megachilidae taxa captured rarely was *Anthidium manicatum*, the wool-carder bee, one bee of each sex. This species was introduced from Europe, and has recently, and rapidly, spread to the western United States. The presence of *A. manicatum* is important to note, as it is known to be highly aggressive and territorial with floral resources (Graham 2018). The presence of this species, observed to be common in Portland by the Masta lab, in the garden indicates a potential negative pressure on late season native bee populations. A single specimen of *Anthidiellum* was also captured in July. This specimen may be *notatum*, which is known to be native to Oregon (Schwarz 1926), and has been collected in spring and late summer. This genus is rare in prior surveys (Turrell 1976, Reese 2018). Like *Anthidium*, *Anthidiellum* is territorial with floral resources (Turell 1976), and the presence of these genera indicate the potential for inter-species competition for flower resources in the garden. It also indicates that Leach provides floral resources for this rare genus.

The low number of *Andrena* collected in this survey is noteworthy, especially considering prior studies of this site found relatively high numbers of *Andrena* in spring (Tyler 2018, Diamond 2020). There are two factors which may have contributed to this. The survey methods were designed to maximize bee-flower association, and so netting was relatively infrequent. It is known that there is a bias against *Andrena* when netting is not performed, especially the males of the species, and the lack of netting may have reduced the capture number. Additionally, the renovations of the garden resulted in significant disturbance of ground soil. *Andrena*, like most bees, nests in the ground (Michener 2007), and so the low number of *Andrena* may have been caused by the destruction or absence of nesting sites in the garden. Prior research (Diamond 2020) found *Andrena* in the garden utilized flowers in the Rosaceae family. The lack of *Andrena* collected in this survey could be explained by the lack of Rosaceae in the survey data. Whether there were few Rosaceae in the garden, or Rosaceae were not significantly surveyed, this may explain the absence of *Andrena* in the data.

Hylaeus was the only representative of Colletidae found in the garden, and was present in July and August. A single specimen of *Agapostemon* was captured in May. *Agapostemon* is known to emerge twice in a season, once in the spring, and again, in a much larger peak in abundance in the late summer (Roberts 1973). The collection results are consistent with this research, and indicate that both waves of *Agapostemon* can be found in the garden utilizing floral resources.

The emergence patterns of the kleptoparasitic genera match the emergence times of their host bees, as would be expected. *Nomada* was present in May, when its host genera, *Andrena*, is flying. *Sphecodes*, which generally parasitizes Halictinae, is present across the season, as is *Triepeolus*, which parasitizes Eucerini (Michener 2007).

The absence of a bee taxa on a specific date in the survey data does not necessarily confirm the taxa was not present at that time. It is possible that such bees were flying on a given collection day, but not in the garden due to a lack of desirable floral resources. Also possible is that bees were present in the garden, but not on any flowers, or were utilizing flowers when focus was on another area.

Floral Usage

A general division can be made between the floral usage patterns prior to, and following, the July 9th collection date. On and after July 9th, bees were primarily captured on blooming plants in Asteraceae. There were also shifts in floral usage of plants in the other families, though not as large as with Asteraceae. The flower usage data from this study suggest that Asteraceae is the most utilized plant family in the garden. As mentioned previously, the relatively high density of Asteraceae in the garden may have played a role in the higher bee abundance during the latter half of the season. Asteraceae may be especially attractive to bees present in Leach, or bees may have simply been attracted to the high density of flowers present in the patches of Asteraceae. That most genera collected in this survey were captured on a wide range of plant families suggests the latter. Asteraceae generally produce numerous small flowers, providing a large amount of floral resources for bees per plant, and would be an explanation for a preference for Asteraceae, if that is indeed the cause of high utilization. Regardless, such plant arrangements are clearly an effective way to attract high numbers of bees to a garden space in the summer months.

The most abundant genera utilized many of the flowers that were surveyed on each date. Based on this, it can be said that most of the bee genera captured in large numbers are generalists. One exception to this is *Melissodes*. This genus is known to specialize on Asteraceae for pollen (Parker 1981), and the results from this study are consistent with this. Interestingly, males of this genus were found on several plant families. As male bees do not collect pollen, they are less likely to be specialized on flower taxa.

Two bees captured in May were identified as *Melissodes*, but are almost certainly *Eucera* given their spring collection date. The data indicates Eucerini may be present in the garden across most of the season in two genera, albeit rarely in the early season. Both of the female specimens were captured on *Veronica*, potentially indicating a different floral usage pattern that *Melissodes.* In May, *Agapostemon* was found to utilize *Camassia*, although the low number of individuals captured limits what can be determined about its floral usage. In the late summer, this genus utilizes flowers from several plant families, with the majority of specimens caught on *Symphyotrichum* and *Helenium*. It is likely that the *Agapostemon* population in the spring is also a generalist species, and may utilize other flowers in the garden.

In April, May, and June, female *Osmia* were predominantly captured on *Penstemon*, with males present on a broader range of flowers. *Ceratina* was captured on diverse flower genera, with *Penstemon, Veronica, Prunella*, and *Myosotis* being flowers with relatively high capture numbers. On all dates later than July, Asteraceae dominated the flowers that bees were using, however *Geranium* and *Gilia* were also plants with high bee capture numbers. Few, if any, Asteraceae were blooming in the garden prior to July. Whether Asteraceae would be highly utilized by bees in the garden in spring is not known, however the results of this study suggest that Asteraceae blooming early in the season would be popular with bees.

The *Ceratina* at Leach were found to be floral generalists, consistent with what is known about this taxon. *Lasioglossum* is a species rich group, and therefore could consist of generalists, or consist of some mix of generalist and more flower specialized species. Answering this question will require identification of the species of Dialictus, which is unlikely in the near future given the difficulty of working with this group (Gibbs 2017).

Examining floral usage patterns is more difficult for rarely caught genera. However, few bees in urban areas are expected to be specialists, given the significant changes in floral resources due to urbanization. None of the taxa collected at Leach were found to be specialists, matching this expectation. Given the focus on bee-flower interactions, and relative lack of netting, the study was biased against kleptoparasitic bee genera, which do not spend large amounts of time on flowers, instead searching for and parasitizing the nests of other bees. Nonetheless, three kleptoparasitic taxa were captured on flowers. None of these bees utilize pollen from flowers, instead drinking nectar for themselves. Kleptoparasitic bees are flower generalists, and this data provides an insight into some of the floral resources these bees are using.

The focus of the collection methods on flowers was also expected to bias the study against collecting males of the species, and in general fewer males were captured than females in a given genus. The exceptions to this were *Agapostemon* and *Osmia*, in which roughly equal numbers of male and female bees were captured. The *Lasioglossum* captured contained a relatively high proportion of males to females (56 to 76). The high number of male *Lasioglossum* in the collection may potentially provide the ability to associate males and females of the same species together in future molecular study, as the sexes are dimorphic in this genus.

Sampling locations were determined based on a preliminary examination of the garden. Flowers with large number of bumble bees and honey bees, but no apparent native bees, were not sampled on that date. This may have eliminated some flowers from consideration which native bees utilized, but in low numbers compared to excluded bees. Additionally, not every flower in the garden could be examined, due to a requirement to stay on paved pathways in public areas, and lack of accessibility in non-public areas due to dense vegetation. The vast majority of flowers in the garden were examined at least initially, but some rare flowering species may have been missed. The associations recorded between bees and flowers are not able to confirm how the floral resources were being used by bees. Further research would be necessary to determine whether genera captured in this study were utilizing pollen from all of the flowers they were captured on, or solely nectar. What can be determined from the data, is that bees were most likely utilizing some resource from the flower they were captured on.

Conclusion

I found large numbers of bees were attracted to the Asteraceae that was planted in relatively dense clusters. Therefore, if the Leach Botanical Garden wants to increase the population of bees that utilize their garden, planting more Asteraceae in dense patches would be an effective way to do so. However, given that the bees present in Leach were generalists, planting more dense patches of the other plants highly utilized by bees is also recommended. In doing so, it is also important to consider the early season bees, and the flowers they utilize, as many of the Asteraceae did not bloom until late in the summer. Several good options for plants that bloom earlier in the year include *Penstemon*, *Myosotis*, *Camassia*, and *Hyacinthoides*. Later in the season, flowers from *Geranium*, *Gilia*, or *Clarkia* are also options to plant that will be utilized by bees.

I found a high diversity of bee taxa at the Leach Botanical Garden, including many of the species-rich *Lasioglossum* genus, as well as moderate and low abundance taxa like the Megachilidae. Spring saw high diversity of Megachilidae, and high numbers of *Osmia*. In late summer, Halictidae had the highest genera diversity. Many low and moderately abundant bee genera, like *Hylaeus* and *Panurginus*, were also found utilizing garden flowers. This high diversity of bees likely pollinates a broad range of native, ornamental, and agricultural flowering plants in the surrounding developed areas. Increasing the number of flowering plants in the garden that bees were found to use will help to support these bee populations into the future. Further work on identifying the species present would allow us to better understand the bee diversity at Leach and in the Portland region, as well as their seasonality and floral usage patterns. It will be important to continue to provide habitat and resources at Leach into the future, to protect the diverse bee populations found in the garden, and in southeast Portland.

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