Urban Alliance

The Native Bee Fauna and its Floral Relations in The City of Calgary, Alberta

Term of Project: January 2020 – December 2021

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Background

Importance of pollinators and bees. Pollinating insects are essential for the reproduction of flowering food crops and wild-growing plants worldwide. In fact, it is estimated that one third of the world's crops depend on animal pollination, mainly provided by bees (Klein et al., 2007). Most wild flowering plants depend on or benefit from animal pollination as well (Ollerton et al., 2011), with parallel declines in plant species observed following pollinating insect declines (Biesmeijer et al., 2006). Harder to fully quantify are the radiating benefits that insect-pollinated wild plants have on other components of an ecosystem, such as providing wildlife food and cover, or stabilising banks and reducing erosion—ultimately highlighting the embedded importance of pollinators within a habitat. However, pollinating insect declines are well documented, with habitat loss and the associated loss of food and nesting resources considered a primary threat (Cameron et al., 2011; Goulson et al., 2015; Grixti et al., 2009).

Floral associations of pollinators and bees. The presence of diverse and abundant flowering plants is an important habitat feature for supporting pollinators. Many pollinating insects prefer specific types of flowering plants, so the types of flowering plants present in a habitat can influence the types of pollinators that it can support (Narango et al., 2017; Nichols et al., 2019; Purvis et al., 2021; Warzecha et al., 2018). Regionally specific observations of plant-pollinator interactions can help to determine the preferences of different pollinators in different ecosystems (Isaacs et al., 2009). For example, Narango et al. (2017) found high variation between flowering plant species in their contribution to supporting Lepidoptera larvae diversity and abundance, and these larvae are critical forage for insectivorous birds and their young. For restoration practitioners, information regarding pollinator diversity and floral interactions is necessary to optimize decision making for conservation and enhancement through revegetation initiatives. For example, research into plant-pollinator relationships has provided plant mixing recommendations for cover crops (Hicks et al. 2016) and urban meadows (Mallinger et al. 2019). For The City of Calgary, this work will further inform the *City of Calgary Seed Mixes* and *City of Calgary Plant Lists* (https://www.calgary.ca/csps/parks/construction/park-development-guidelines.html). These documents intend to improve restoration performance, and research into plant-pollinator relationships can assist in prioritizing species for restoration work.

Pollinator diversity in Calgary. In an effort to conserve urban biodiversity, The City of Calgary signed the Durban Commitment and committed to a ten year strategic plan, Our BiodiverCity initiative and Biodiversity Policy (https://www.calgary.ca/csps/parks/planning-and-operations/biodiversity.html). In urban environments, remnant semi-natural areas like parks, riparian zones, or roadsides often provide important pockets of pollinator habitat (Baldock et al. 2015; Theodorou et al. 2016; Samuelson et al. 2018). In other transformed landscapes in Alberta, such as croplands, remnant habitats adjacent to water (riparian areas) have been identified as reservoirs for native bee diversity (Vickruck et al., 2019), especially if these areas have undergone revegetation (Purvis et al., 2020). As roadside management has been found as one way to promote biodiversity (Hopwood, 2008; Phillips et al. 2020), The City of Calgary has explored roadside naturalization and management to meet these goals. In 2017, The City developed the first Bee Boulevard at Canyon Meadows followed by a second Bee Boulevard in Coventry

Hills (https://www.calgary.ca/csps/parks/planning-and-operations/bee-boulevard.html). In combination with The City's educational efforts around pollinators, this work led to The City of Calgary becoming a Bee City in 2019. The "Bee-A-Pollineighbour" campaign continues to educate citizens and promote urban naturalization and boulevard plantings to support pollinators (https://www.calgary.ca/csps/parks/planning-and-operations/bee-a-polli-neighbour.html).

Project objectives and deliverables

We sought to continue developing our knowledge of native bee species' occurrence, and the floral relations of the diverse fauna found within Calgary. Building on the foundation of our pilot project (2017-2019) examining native bee diversity in habitats adjacent to wetlands in The City of Calgary, we conducted a survey of the native bees in The City of Calgary, and documented the associations between common flowering plants and native bees. We then estimated the richness (i.e., "*how many species?*") and abundance (i.e., "*how many visitors?*") of native bee visitors to native plant species occurring in wetlands and adjacent habitats. Our survey enabled us to rank the contribution of each of these plant species to native bee communities. This information is a key consideration for decision-makers working to increase ecosystem complexity, resilience, and productivity in similar sites throughout The City, as it allows them to make restoration decisions that will support richer and larger communities of wild bees. To allow engagement beyond the scope of our work, we also launched a citizen science project, the Calgary Pollinator Count (https://ucalgary.ca/sustainability/our-sustainable-campus/bee-campus/bee-citizen-scientist), to engage the wider Calgary community in understanding and documenting native bee and insect biodiversity in The City of Calgary.

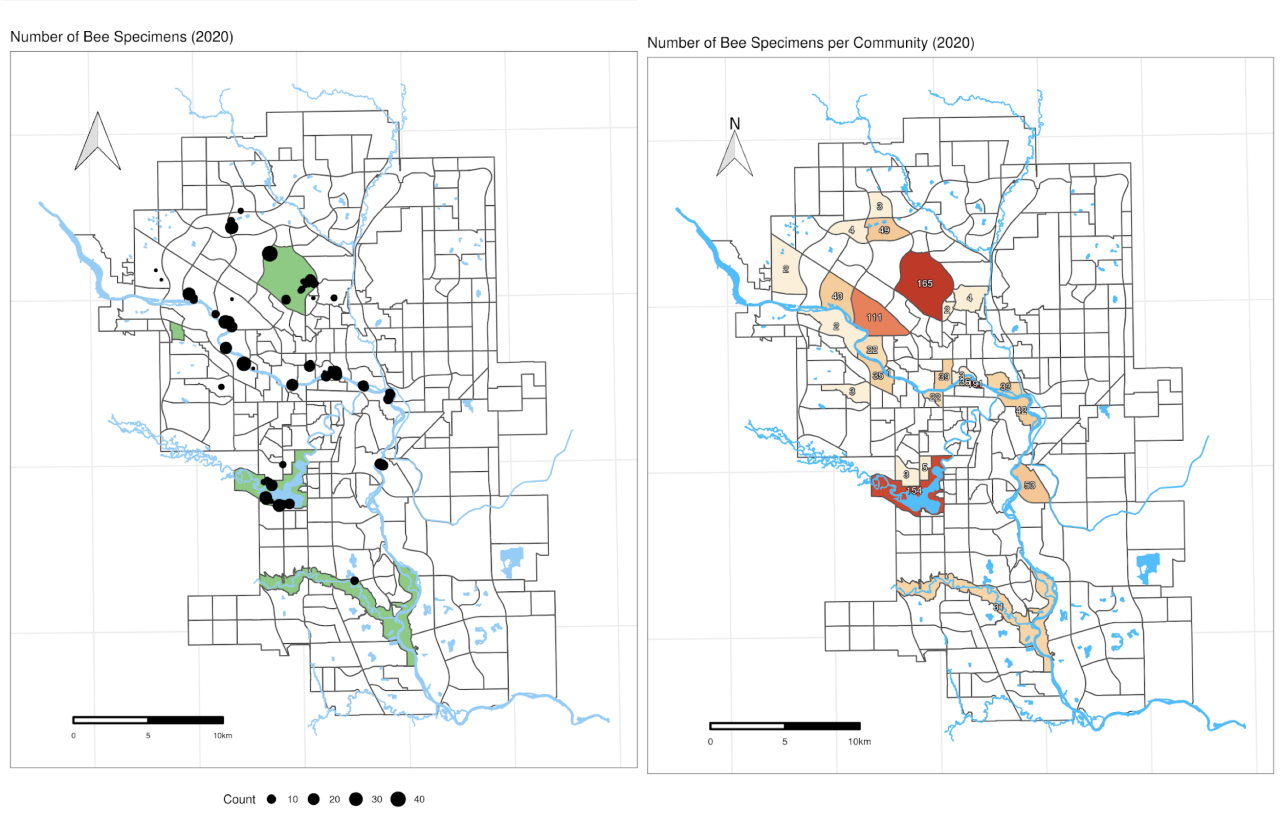
Objective 1: Native Bee and Pollinator Diversity

Objective: Collect and identify native bees to document pollinator diversity in The City of Calgary.

Methods. Native bee diversity was documented using physical sampling with nets (Canyon Meadows Bee Survey (2017, 2018); this project (2020 and 2021)), and pan traps and blue vanes (backyard survey 2019). A total of 2288 insect specimens were pinned and catalogued by students and a research technician. All bee specimens were then identified by L.R. Best. Non-bee pollinators were identified to order or lower where possible by students and a research technician.

Results.

Figure 1. Number of bee specimens collected by locality (left) and community (right).



Bee biodiversity. Bees collected were identified to five families, 19 genera, and 82 species.

Figure 2. Number of bee species, genera, and families collected and identified.

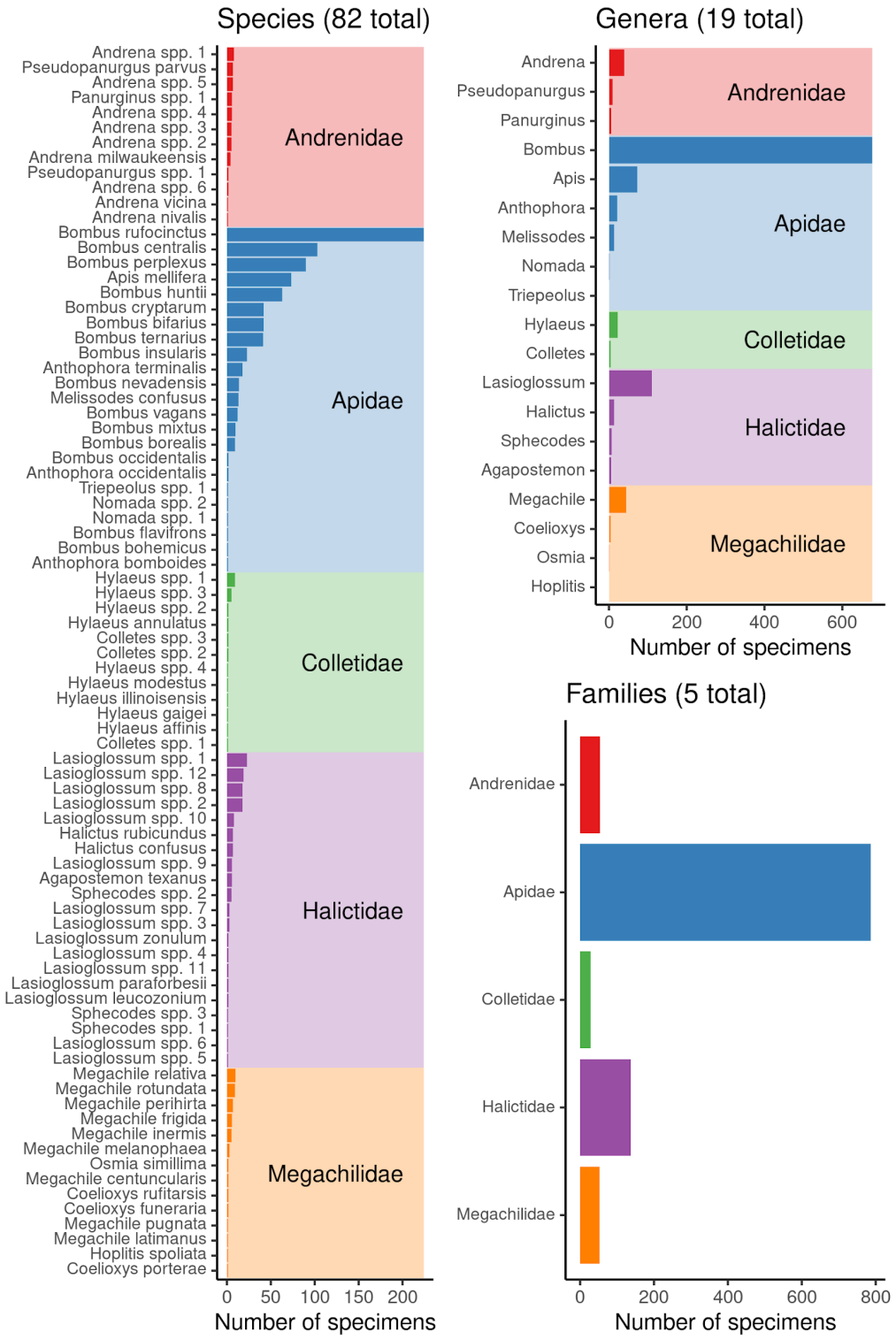


Table 1. Checklist of bee species recorded from The City of Calgary. 199 species and morphospecies compiled from this project, 2017-2018 Canyon Meadows survey, 2019 backyard survey, Zoology 435 insect survey, published records (see Appendix C), and L.R.Best private holdings.

Family

Subfamily

Tribe

Colletidae

Colletinae

Colletini

Colletes aberrans Cockerell, 1897

Colletes brevicornis Robertson, 1897

Colletes kincaidii Cockerell, 1898

Colletes phaceliae Cockerell, 1906

Colletes wickhami Timberlake, 1943

Colletes - 2 morphospecies

Hylaeinae

Hylaeus (Prosopis) affinis (Smith, 1853)

Hylaeus (Hylaeus) annulatus (Linnaeus, 1758)

Hylaeus (Prosopis) illinoisensis (Robertson, 1896)

Hylaeus (Prosopis) modestus Say, 1837

Hylaeus (Hylaeus) verticalis (Cresson, 1869)

Hylaeus gaigei (Cockerell, 1916)

Hylaeus - 3 morphospecies

Andrenidae

Andreninae

Andrenini

Andrena (Andrena) birtwelli Cockerell, 1901

Andrena (Andrena) clarkella (Kirby, 1802)

Andrena (Andrena) frigida Smith, 1853

Andrena (Andrena) milwaukeensis Graenicher, 1903

Andrena (Andrena) thaspii Graenicher, 1903

Andrena (Cnemidandrena) apacheorum Cockerell, 1897

Andrena (Cnemidandrena) canadensis Dalla Torre, 1896

Andrena (Cnemidandrena) costillensis Viereck and Cockerell, 1914

Andrena (Cnemidandrena) chromotricha Cockerell, 1899

Andrena (Cnemidandrena) columbiana Viereck, 1917

Andrena (Cnemidandrena) hirticincta Provancher, 1888

Andrena (Cnemidandrena) peckhami Cockerell, 1902

Andrena (Cnemidandrena) surda Cockerell, 1910

Andrena (Euandrena) algida Smith, 1853

Andrena (Melandrena) carlini Cockerell, 1901

Andrena (Melandrena) lupinorum Cockerell, 1906

Andrena (Melandrena) nivalis Smith, 1853

Andrena (Melandrena) transnigra Viereck, 1904

Andrena (Melandrena) vicina Smith, 1853

Andrena (Parandrena) welleslayana Robertson, 1897

Andrena (Thysandrena) w-scripta Viereck, 1904

Andrena (Trachandrena) amphibola (Viereck, 1904)

Andrena (Trachandrena) cyanophila Cockerell, 1906

Andrena (Trachandrena) mariae Robertson, 1891

Andrena (Trachandrena) miranda Smith, 1879

Andrena (Trachandrena) salisifloris Cockerell, 1897

Andrena (Trachandrena) sigmundi Cockerell, 1902

Andrena (Trachandrena) striatifrons Cockerell, 1897

Andrena - 12 morphospecies

Panurginae

Panurgini

Pseudopanurgus parvus (Robertson, 1892)

Pseudopanurgus renimaculatus (Cockerell, 1896)

Pseudopanurgus - 3 morphospecies

Perditini

Perdita (Cockerellia) albipennis Cresson, 1868

Perdita (Perdita) swenki Crawford, 1915

Perdita (Perdita) bruneri Cockerell, 1897

Halictidae

Rophitinae

Dufourea marginata (Cresson, 1878)

Dufourea maura (Cresson, 1878)

Halictinae

Halictini

Agapostemon (Agapostemon) texanus Cresson, 1872

Agapostemon (Agapostemon) virescens (Fabricius, 1775)

Halictus (Odontalictus) ligatus Say, 1837

Halictus (Protohalictus) rubicundus (Christ, 1791)

Halictus (Seladonia) confusus Smith, 1853

Lasioglossum (Dialictus) albipenne (Robertson, 1890)

Lasioglossum (Dialictus) cressonii (Robertson, 1890)

Lasioglossum (Dialictus) laevissimum (Smith, 1853)

Lasioglossum (Dialictus) nigroviride (Graenicher, 1910)

Lasioglossum (Dialictus) pavoninum (Ellis, 1913)

Lasioglossum (Dialictus) ruidosense (Cockerell, 1897)

Lasioglossum (Dialictus) sagax (Sandhouse, 1924)

Lasioglossum (Dialictus) semicaeruleum (Cockerell, 1895)

Lasioglossum (Dialictus) succinipenne (Ellis, 1913)

Lasioglossum (Dialictus) tenax (Sandhouse, 1924)

Lasioglossum (Dialictus) versans (Lovell, 1905)

Lasioglossum (Dialictus) – 13 morphospecies

Lasioglossum (Evylaeus) – 1 morphospecies

Lasioglossum (Hemihalictus) – 5 morphospecies

Lasioglossum (Lasioglossum) colatum (Vachal, 1904)

Lasioglossum (Lasioglossum) mellipes (Crawford, 1907)

Lasioglossum (Lasioglossum) paraforbesii McGinley, 1986

Lasioglossum (Leuchalictus) leucozonium (Schrank, 1781)

Lasioglossum (Lasioglossum) zonulum (Smith, 1848)

Lasioglossum (Sphecodogastra) aberrans (Crawford, 1903)

Lasioglossum (Sphecodogastra) – 3 morphospecies

Sphecodes – 6 morphospecies

Melittidae

Melittinae

Macropis (Macropis) nuda (Provancher, 1882)

Megachilidae

Megachilinae

Osmiini

Heriades (Neotrypetes) carinata Cresson, 1864

Hoplitis (Alcidamea) albifrons (Kirby, 1837)

Hoplitis (Alcidamea) pilosifrons (Cresson, 1864)

Hoplitis (Alcidamea) spoliata (Provancher, 1888)

Osmia (Helicosmia) texana Cresson, 1872

Osmia (Melanosmia) simillima Smith, 1853

Osmia (Osmia) lignaria Say, 1837

Osmia – 7 morphospecies

Anthidiini

Anthidium (Anthidium) tenuiflorae Cockerell, 1907

Anthidium (Anthidium) clypeodentatum Swenk, 1914

Anthidium (Anthidium) manicatum Linnaeus, 1758

Dianthidium (Dianthidium) pudicum (Cresson, 1879)

Stelis (Stelis) montana Cresson, 1864

Megachilini

Coelioxys (Schizocoelioxys) funeraria Smith, 1854

Coelioxys (Boreocoelioxys) porterae Cockerell, 1900

Coelioxys (Boreocoelioxys) rufitarsis Smith, 1854

Coelioxys (Coelioxys) sodalis Cresson, 1878

Megachile (Addendella) addenda Cresson, 1878

Megachile (Eutricharaea) rotundata (Fabricius, 1787)

Megachile (Megachile) centuncularis (Linnaeus, 1758)

Megachile (Megachile) inermis Provancher, 1888

Megachile (Megachile) lapponica Thomson, 1872

Megachile (Megachile) montivaga Cresson, 1878

Megachile (Megachile) relativa Cresson, 1878

Megachile (Xanthosarus) circumcincta (Kirby, 1802)

Megachile (Xanthosarus) frigida Smith, 1853

Megachile (Xanthosarus) melanophaea Smith, 1853

Megachile (Xanthosarus) perihirta Cockerell, 1898

Megachile (Sayapis) pugnata Say, 1837

Apidae

Nomadinae

Nomadini

Nomada – 12 morphospecies

Epeolini

Epeolus – 2 morphospecies

Triepeolus – 3 morphospecies

Apinae

Emphorini

Diadasia (Coquillettapis) australis (Cresson, 1878)

Diadasia (Coquillettapis) diminuta (Cresson, 1878)

Eucerini

Melissodes (Eumelissodes) agilis Cresson, 1878

Melissodes (Eumelissodes) confusus Cresson, 1878

Melissodes (Eumelissodes) illatus Lovell and Cockerell, 1906

Melissodes (Heliomelissodes) rivalis Cresson, 1872

Anthophorini

Anthophora (Melea) bomboides Kirby, 1838

Anthophora (Melea) occidentalis Cresson, 1869

Anthophora (Clisodon) terminalis Cresson, 1869

Melectini

Xeromelecta (Melectomorpha) californica (Cresson, 1878)

Apini

Apis (Apis) mellifera Linnaeus, 1758

Bombini

Bombus (Bombias) nevadensis Cresson, 1874

Bombus (Bombus) cryptarum Fabricius, 1775

Bombus (Bombus) occidentalis Greene, 1858

Bombus (Bombus) terricola Kirby, 1837

Bombus (Cullumanobombus) griseocollis (De Geer, 1773)

Bombus (Cullumanobombus) rufocinctus Cresson, 1863

Bombus (Pyrobombus) centralis Cresson, 1864

Bombus (Pyrobombus) flavifrons Cresson, 1863

Bombus (Pyrobombus) huntii Greene, 1860

Bombus (Pyrobombus) melanopygus Nylander, 1848

Bombus (Pyrobombus) mixtus Cresson, 1878

Bombus (Pyrobombus) perplexus Cresson, 1863

Bombus (Pyrobombus) ternarius Say, 1837

Bombus (Pyrobombus) vagans Smith, 1854

Bombus (Pyrobombus) vancouverensis ssp. nearcticus Cresson, 1878 [previously *Bombus (Pyrobombus) bifarius* Cresson, 1878]

Bombus (Psithyrus) insularis (Smith, 1861)

Bombus (Psithyrus) bohemicus (Seidl, 1838)

Bombus (Subterraneobombus) borealis Kirby, 1837

Bombus (Thoracobombus) fervidus (Fabricius, 1798)

Objective 2: Native Plant-Pollinator Associations

Objective: Catalogue insects found on native plants commonly used in restoration projects and hardy non-native plants found in disturbed habitats.

Methods: Native bees and other pollinators were caught on flowering plants using nets (2020-2021) and curated observations of pollinators on plants were compiled from available observations on the iNaturalist platform submitted through August 2021.

Physical opportunistic sampling.

Site selection: In spring 2020, we identified City of Calgary parks with natural or restored wetlands using Calgary Open Data (https://data.calgary.ca/) and assessed these parks for the presence of target plants using plant observation records available on iNaturalist (https://inaturalist.ca/). We ranked parks based on the number of target plants previously identified. We then used this ranked list to apply for the initial scientific permit (**Permit No 236834**). Our initial sampling focused on target sites along the Bow River and as we identified floral targets throughout the summer, we added additional sites to the permit. We surveyed a total of 25 parks (Appendix A) across The City of Calgary in 2020 (Figure 1). In 2021, insects were opportunistically sampled in seven of these parks (Appendix A), as well as at seven Calgary roadside sites: 16th Ave - 36-38 St, 16 Ave NW, Sarcee Trail SW, Country Hills Blvd NW, Bow Bottom Trail SE, Metis Trail NE, and Macleod Trail & 162 Ave SE.

Plant selection and identification: In consultation with J. Cross in 2020, we chose 20 plant targets from a list of native plants used in restoration projects, compiled in the *City of Calgary Plant Lists* document. We chose plants that met the following requirements: native; common; clear features for identification in the field; and easy to grow and maintain in a variety of city habitats. During the study, we added additional plants that met the criteria, particularly common native plants, to the target list. To maximize the number and diversity of bees surveyed, we reduced sampling effort for uncommon plants with few visitors. In 2021, 11 common non-native plant targets were also added to sampling efforts based on observations of plants that appeared to host a large number of pollinators and discussion with City of Calgary Parks Ecologists.

Prior to field work, we used iNaturalist to estimate flowering time and identify potential sampling localities. We used the iNaturalist/National Geographic app Seek to assist in initial plant identifications in the field, and by uploading photographs to iNaturalist most plant identifications were confirmed. Following field work, J. Cross was consulted to confirm and update the identification of plants sampled.

Bee collection: Using rarefaction analyses on available Alberta bee and plant association datasets, we set a collection goal of 50 total specimens from each target plant species. We also sought to collect specimens from each plant target from at least three different parks. Based on the rarefaction analyses, in 2021 sampling efforts for fireweed (*Chamaenerion angustifolium*), goldenrods (*Solidago* sp), and roses (*Rosa* sp.) were increased to 100 total specimens for each plant.

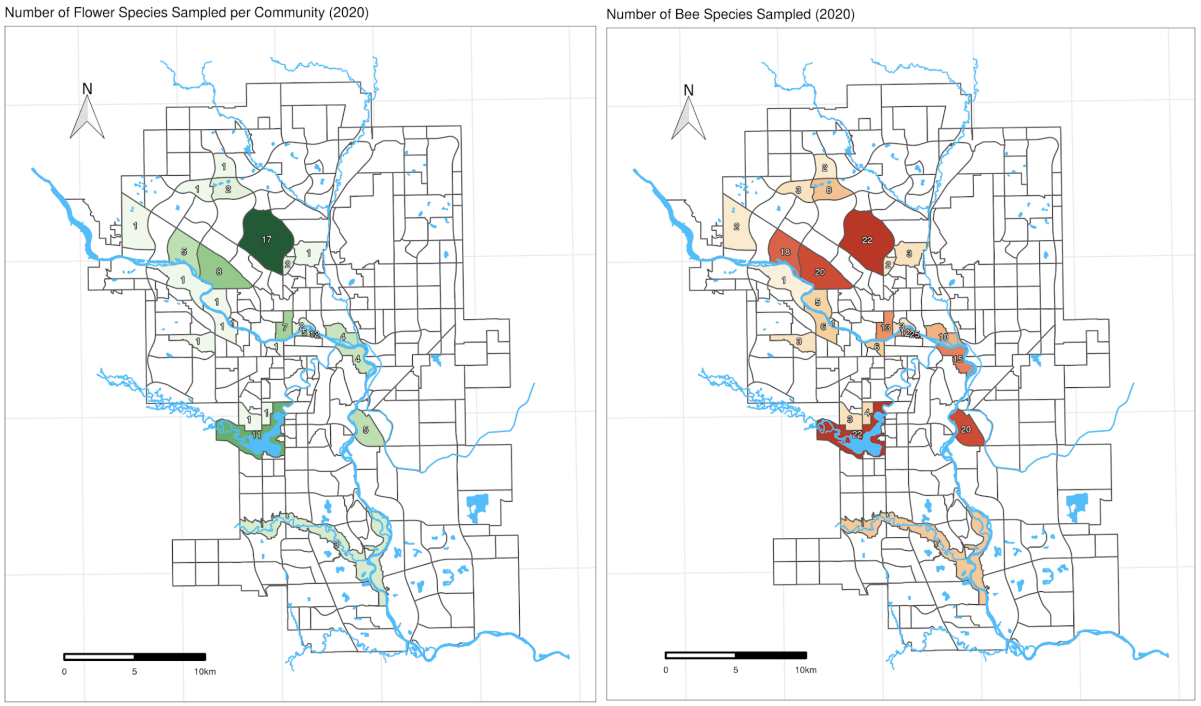
We used a hand-netting sampling protocol to collect insects associated with each plant target. Target plants were first photographed and metadata was uploaded to a private iNaturalist project. We then observed the target plant and used a net to collect insect visitors. Plants were observed and insects collected for up to 20 minutes. Once 20 individual bees or 50 total specimens from the same target plant species were collected, we stopped collection to prevent oversampling. In some cases we sampled from one individual plant in the 20 minute observation period, while in other situations we sampled from several of the same plant species. For all plant targets we tried to survey as many different plants in different parks as possible.

Data analysis: We used descriptive statistics to summarize insect and flower associations. We then estimated bee species richness of common flower species using the Chao1 estimator (Chiu et al. 2014) through the *vegan* package (Oksanen et al. 2020) in R version 4.0.4. This analysis estimates how many species were missed by our sampling efforts, and accounts for the problem of small samples tending to have fewer species simply because of their size.

iNaturalist observation curation. A citizen scientist-aimed pilot project named 'Calgary Pollinators' was launched on iNaturalist on June 11, 2021. This project asks citizen observers to upload photograph observations of insects interacting with the flower parts of a plant, including wild, cultivated, and native plant species. Observation data was pulled from 2008 to August 26, 2021 to analyze the floral associations of insect species. We used floral-association matrices to describe plant-pollinator associations.

Results: One faculty member and 12 undergraduate students enrolled in Zoology 435 collected 1840 insect specimens between May 16 – September 14, 2020, and a student research technician collected 430 insect specimens between May 31 - August 18, 2021. Student research technicians could not be hired in summer 2020 due to COVID-19.

Figure 3. Number of floral species (left) and bee species (right) collected in each community.



Plants surveyed. 49 total plants were surveyed, of which 31 were target native plants and 18 were non-native plants. Non-target plants included five additional species of native plants and two non-native plants sampled by students (see Table 2).

Table 2. 43 targeted native and non-native plants. Native plant species are bolded.

Floral species	Common name	Flowering time	No. specimens
***Salix* sp.**	**Willow**	April/May	112
Prunus virginiana	**Chokecherry**	May/June	31
Fragaria virgiana	**Virginia strawberry**	May/June	6
Amelanchier alnifolia	**Saskatoon**	May/June	3
Ribes aureum	**Golden currant**	May/June	2
Dasiphora fruticosa	**Shrubby cinquefoil**	June/July	139
Rosa sp.	**Rose**	June/July	107
Linum lewisii	**Lewis flax**	June/July	31
Gaillardia aristata	**Common gaillardia**	June/July	28
Apocynum androsaemifolium	**Spreading dogbane**	June/July	20
Anemonastrum canadense	**Canada/Meadow anemone**	June/July	10
Rosa woodsii	**Woods' rose**	June/July	5
Dalea purpurea	**Purple prairie clover**	July	36
Glycyrrhiza lepidota	**Wild licorice**	July	13
Oenothera suffrutescens	**Scarlet beeblossom**	July	7
***Solidago* sp.**	**Goldenrod**	July/August	493
Chamaenerion angustifolium	**Fireweed**	July/August	180
***Aster* sp.**	**Aster**	July/August	136
Monarda fistulosa	**Wild bergamot**	July/August	90
Symphoricarpos occidentalis	**Western snowberry**	July/August	58
Heterotheca villosa	**Hairy goldenaster**	July/August	49
Achillea millefolium	**Common yarrow**	July/August	40
Hedysarum alpinum	**Alpine vetch**	July/August	26
Geranium viscossimum	**Sticky geranium**	July/August	21
Astragalus canadensis	**Milkvetch**	July/August	15
***Erigeron* sp.**	**Fleabane**	July/August	14
Hedysarum boreale	**Boreal vetch**	July/August	9
Erigeron philadelphicus	**Philadelphia fleabane**	July/August	2
Ratibida columnifera	**Upright prairie coneflower**	July/August	2
Symphyotrichum laeve	**Smooth blue aster**	August	104
Helianthus petiolaris	**Prairie sunflower**	August	13
Grindelia squarrosa	**Gumplant**	August	2
Sisymbrium loeselii	False london-rocket	June-August	49
Euphorbia virgata	Leafy spurge	June-August	3
Vicia cracca	Tufted vetch	June-August	1
Trifolium sp.	Trifolium clover	June-September	11
Tripleurospermum inodorum	Scentless mayweed	June-September	10
Melilotus officinalis	Yellow sweet clover	June-September	10
Medicago sativa	Alfalfa	June-September	5
Melilotus albus	White sweet clover	June-October	14
Astragalus cicer	Chickpea milkvetch	July/August	14
Cirsium arvense	Creeping thistle	July-September	70
Arctium sp.	Burdock	July-September	6

Five plants on the original target list were either not found in the parks surveyed or were at very low abundance and removed from the target list:

Astragalus crassicarpus (Ground Plum)
Cirsium undulatum (Wavy leaf thistle)
Lysimachia ciliata (Fringed Loosestrife)
Oenothera biennis (Evening Primrose)
Penstemon nitidus (Wax-leaf Beardtongue)

More than 50 specimens (sampling goal) were collected from nine target native plants:

Aster sp. (Aster)
Chamaenerion angustifolium (Fireweed)
Dasiphora fruticosa (Shrubby cinquefoil)
Monarda fistulosa (Wild Bergamot)
Rosa sp. (Rose)
Salix sp. (Willow)
Solidago sp. (Goldenrod)
Symphoricarpos occidentalis (Western Snowberry)
Symphyotrichum laeve (Smooth Blue Aster)

Figure 4. Number of bee specimens and number of bee species collected from target plants.

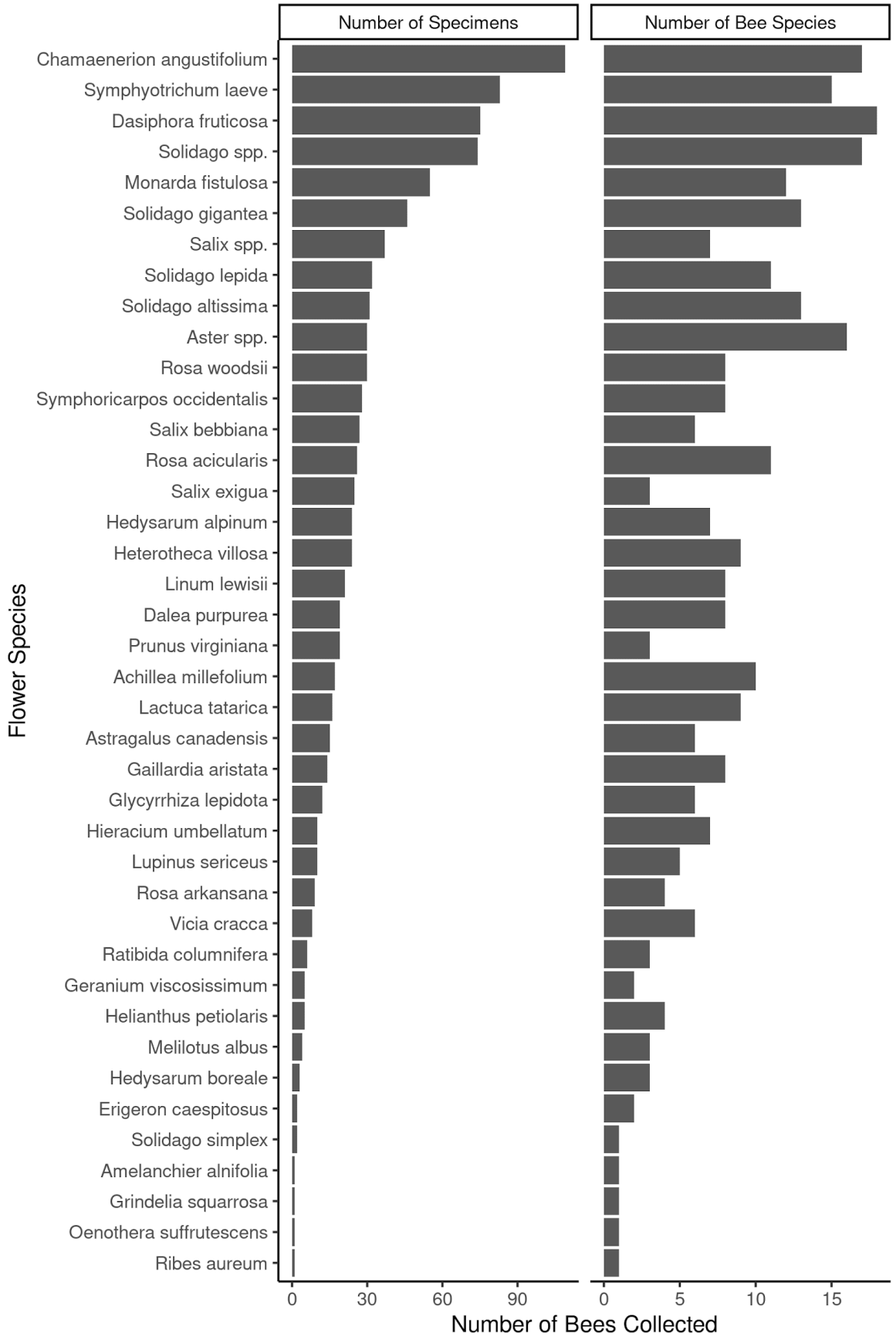
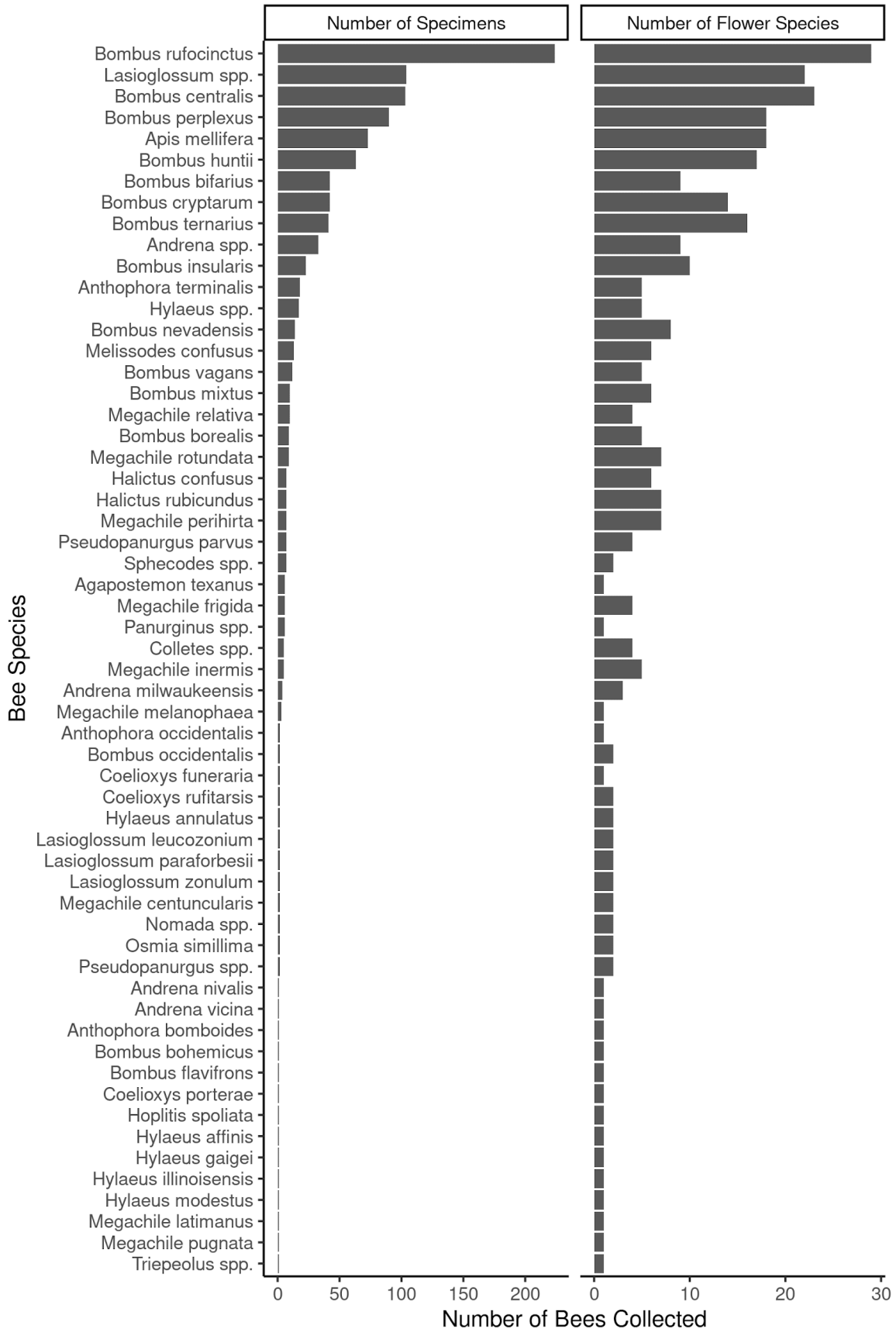


Figure 5. Number of floral associates for each bee species.



Sampling Effort. We used rarefaction analyses to model estimated bee species richness for each of the target plants of 2021. Estimated species richness of bee visitors to each of these plant species ranged from 8 to 26 (Fig. 6) A total of 89 unique bee species and morphospecies were identified (Tab. 2). We met or exceeded our pollinator specimen number target (50) for 12 target plant species.

Figure 6. Coverage-based rarefaction analyses for all bee specimens collected on twelve highest-sampled plants in 2021. N = number of specimens; S.obs = number of observed species; S.chao1 = estimated species richness (i.e. "*how many species would we find if we caught a very large number of bees?*").

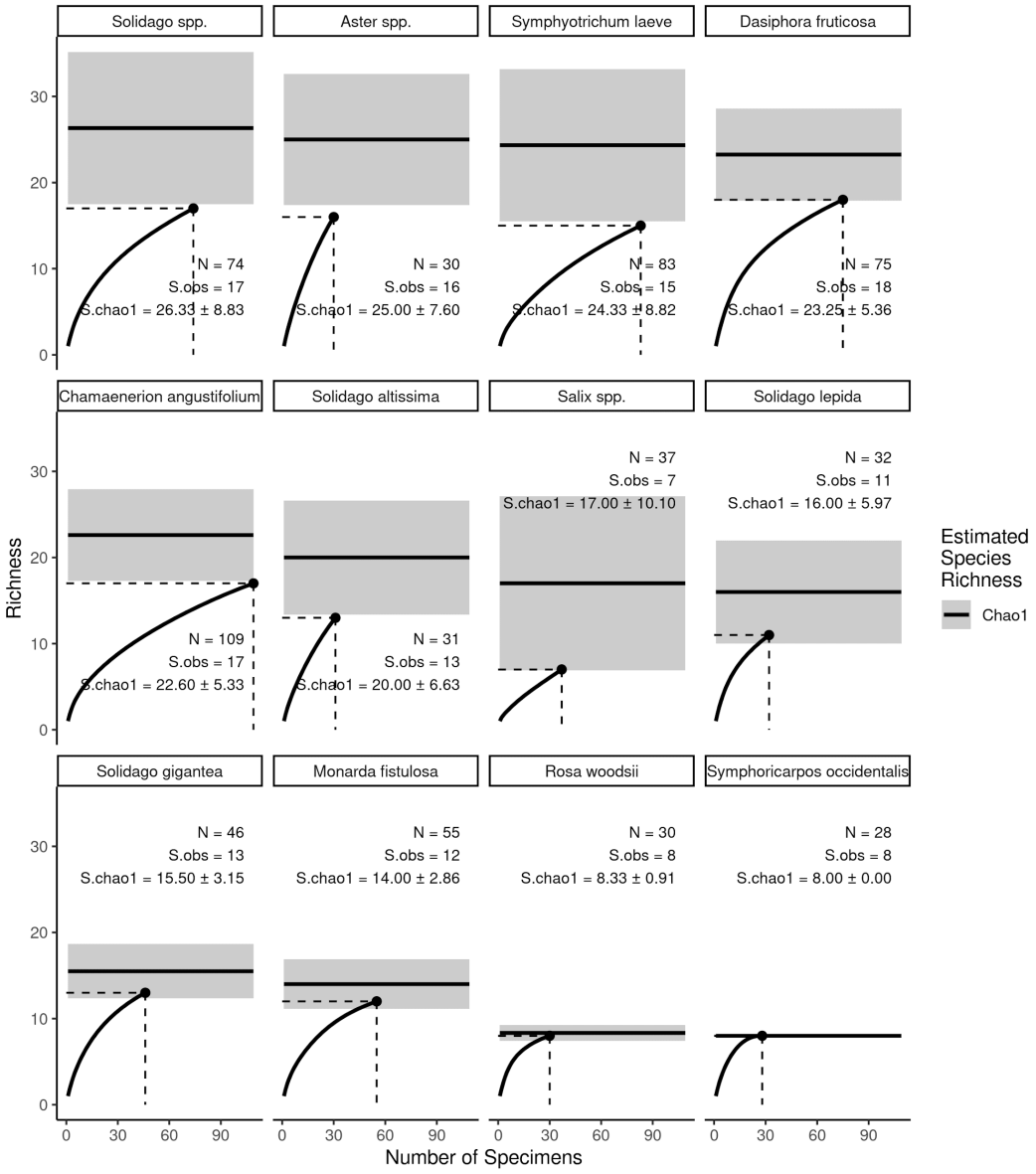
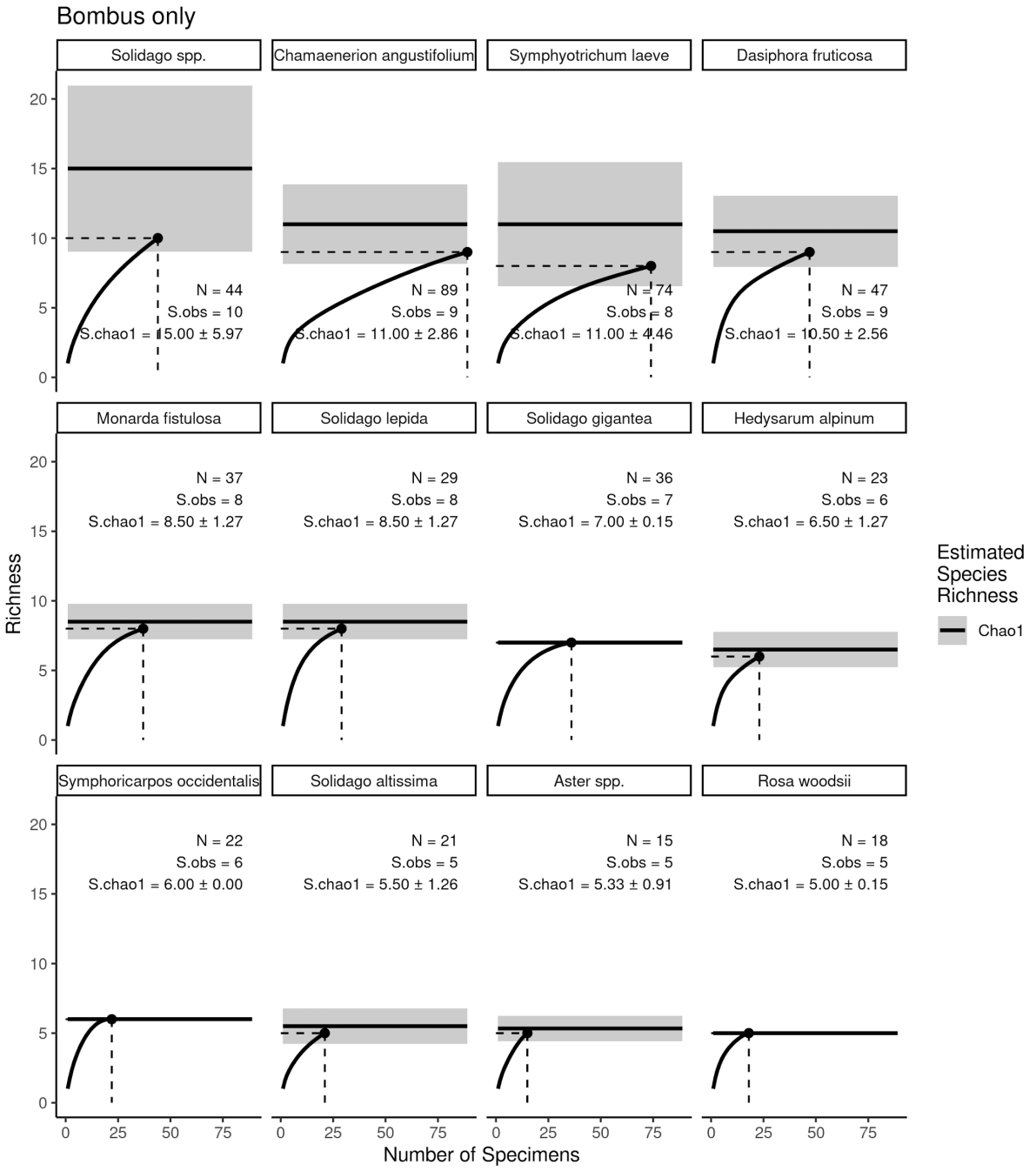


Figure 7. Coverage-based rarefaction analyses for bumble bee (*Bombus*) specimens collected on the twelve highest-sampled plants in 2021. N = number of specimens; S.obs = number of observed species; S.chao1 = estimated species richness.



Pollinator-plant associations.

Table 3. Presence/Absence table of the plant-insect pollinator relationships found for native plants within The City of Calgary (1866 pollinator observations). Coloured boxes indicate presence, while white boxes indicate that the group was not observed. The number of observations is provided within each coloured box. Plants observed in transect and quadrat surveys (2021) and physical collecting (2020) were identified using iNaturalist and the *Vascular Flora of Alberta: An Illustrated Guide*.

Native Plants	Flies	Solitary Bees	Bumble Bees	Butterflies	True Bugs	Beetles	Wasps	Ants	Honeybees	# Insect Group Associations
Dasiphora fruticosa (Shrubby Cinquefoil)	35	29	50	2	3	3	1	1	3	9
Gaillardia aristata (Common Gaillardia)	13	14	11	5	8	4		8	1	8
Rosa sp. (Roses)	22	43	66	2	1	66		1	11	8
Geranium viscosissimum (Sticky Geranium)	7	3	10	1	11		1		5	7
Solidago sp. (Goldenrod)	39	49	165		7	16	16		7	7
Symphoricarpos occidentalis (Western Snowberry)	7	10	28		1		4	8	1	7
Apocynum androsaemifolium (Spreading Dogbane)	3	13	20	6		1	7		4	7
Achillea millefolium (Common Yarrow)	18	6	5			4	1		7	6
Chamaenerion angustifolium (Fireweed)	11	84	122	2		4			12	6
Symphoricarpos sp. (Snowberry)	1	1	3	3		1	6			6
Cirsium sp. (Thistle)	1	4	13	12		7			4	6
Helianthus sp. (Sunflowers)	4	1	3	6	2				3	6
Linum lewisii (Lewis Flax)	18	13	9	2					5	5
Monarda fistulosa (Wild Bergamot)	3	22	54	2			1			5
Symphyotrichum laeve (Smooth Blue Aster)	8	7	75	4					3	5
Salix sp. (Willows)	21	78	16	5					6	5
Anemonastrum canadense (Meadow Anemone)	6	1		1	1	2				5
Elaeagnus commutata (Silverberry / Wolfwillow)	1	1	1	1					1	5
Thermopsis rhombifolia (Buffalo Bean)	1	1	13	2	1					5
Vicia sp. (Vetch)		3	17	23			1		2	5
Potentilla (Cinquefoils)	2	3		1		1	1			5
Cornus sericea (Red Osier Dogwood)	1	2				3		1	1	5
Astragalus canadensis (Canadian Milkvetch)		1	15		1			8		4
Ratibida columnifera (Upright Prairie Coneflower)	5	42	2				4			4
Campanula rotundifolia (Harebell)	2	1	6	1						4
Rudbeckia (Coneflowers & Black-eyed Susans)	4	1	14				1			4
Fragaria virginiana (Virginia Strawberry)	1	1		1	1					4
Dalea purpurea (Purple Prairie Clover)	6	5	17							3
Hedysarum boreale (Boreal Sweet-Vetch)		1	2						1	3
Helianthus petiolaris (Prairie Sunflower)	2	2	3							3
Heterotheca villosa (Hairy Goldenaster)	16	15	9							3
Oenothera suffrutescens (Scarlet Beeblossom)	2	1	1							3
Asclepias speciosa (Showy Milkweed)			2					13	23	3
Potentilla gracilis (Slender Cinquefoil)	5	5			2					3
Allium schoenoprasum (Chives)		2		1					3	3
Helianthus annuus (Common Sunflower)	1		3		1					3
Symphoricarpos occidentalis (Western Stoneseed)			1		1	1				3
Fragaria sp.(Strawberries)	2					1			1	3
Pulsatilla nuttalliana (Prairie Pasqueflower)	3				1				10	3
Glycyrrhiza lepidota (Wild Licorice)		4	8							2
Hedysarum alpinum (Alpine Sweet-Vetch)		1	23							2
Hieracium umbellatum (Canada Hawkweed)		2	9							2
Prunus virginiana (Choke Cherry)	6	20								2
Ribes aureum (Golden Currant)	1	1								2
Erigeron philadelphicus (Philadelphia Fleabane)	1	1								2
Amelanchier alnifolia (Saskatoon)	1	3								2
Rosa arkansana (Prairie rose)			5			2				2
Symphyotrichum sp. (Blue asters)	2		1							2
Erigeron sp. (Fleabanes)	2			1						2
Arctostaphylos uva-ursi (Bearberry)			1						1	2
Oxytropis campestris (Yellow Oxytropis)			1		1					2
Sherpherdia canadensis (Canadian Buffalo-Berry)						1		1		2
Heracleum maximum (Common Cowparsnip)	2					2				2
Anticlea elegans (Mountain Deathcamas)					1	1				2
Aster alpinus (Alpine Aster)	3				2					2
Achillea millefolium (Common Yarrow)		3		1						2
Lupinus sericeus (Silky Lupine)	1		10			2				1
Senecio eremophilus (Cut-Leaved Ragwort)	1									1
Grindelia squarrosa (Curlycup Gumweed)		1								1
Potentilla norvegica (Rough cinquefoil)								1		1
Agoseris glauca (Pale Agoseris)			1							1
Symphyotrichum sp. (American Asters)	3									1
Erigeron specisus (Aspen Fleabane)	1									1
Packera paupercula (Balsam Ragwort)	1									1
Gutierrezia sarothrae (Broom Snakeweed)	2									1
Oenothera stricta (Common Evening-Primrose)	1									1
Lonicera dioica (Glaucous Honeysuckle)	1									1
Liatris ligulistylis (Rocky Mountain Blazing Star)	1									1
Helianthus pauciflorus (Stiff Sunflower)	1									1
Zizia aptera (Heart-Leaf Golden Alexander)		1								1
Shepherdia argentea (Silver Buffaloberry)									1	1
# Plant Associations per Insect Group	**51**	**44**	**40**	**23**	**18**	**19**	**12**	**9**	**24**	
# Insect Observations	353	502	815	85	46	122	44	42	116	

Citizen Engagement

Calgary Pollinator Count. In summer 2021, we launched the Calgary Pollinator Count through partnership with the University of Calgary Office of Sustainability (https://ucalgary.ca/sustainability/our-sustainable-campus/bee-campus/bee-citizen-scientist). There were two ways for participants to get involved:

1) Plant counts: This activity involves creating a 50 x 50 cm quadrat and placing the quadrat over a flowering plant of interest. The plant could be a listed target plant or any plant the observer sees insects visiting in their backyard, garden, or a park. Before the count, participants are asked to answer questions on the weather and plant observed. Participants then spend either five or ten minutes counting all of the insects that touch a flower in their quadrat, with the option of identifying different major types of insects. Datasheets can then be entered into an online form. To assist participants in insect identification, we also created an insect identification quiz. Preliminary results of these counts are provided in Appendix B.
2) iNaturalist: We created the iNaturalist Calgary Pollinators Project to organize and annotate photographs of insects on plants taken within The City of Calgary. As of August 25, 2021 the project included over 3000 individual observations of insects visiting flowers by 365 observers. Over 240 insect species were photographed on over 200 identifiable plant species. The results from these data are summarized in Table 3 (Objective 2).

Summary & Future Work

Native bee diversity and at-risk pollinators. Over 199 species and morphospecies of bees have been observed in The City of Calgary. We collected and observed three species of conservation concern - *Bombus bohemicus* (3 specimens; SARA listed - Endangered), *Bombus occidentalis* (3 specimens; 8 research-grade iNaturalist observations; COSEWIC advised - Threatened), and *Bombus terricola* (3 research-grade iNaturalist observations; SARA listed - Special Concern) - and now have plant-pollinator association information for these species.

Bombus bohemicus was found associated with *Solidago* sp. (Goldenrod).

Bombus occidentalis was found associated with *Aster* sp. (Asters), *Monarda fistulosa* (Wild Bergamot), *Dasiphora fruticosa* (Shrubby cinquefoil), *Solidago* sp. (Goldenrods), *Crocus* sp. (Crocuses), *Telekia* sp. (Yellow oxeye), *Rosa* sp. (Roses), *Rudbeckia* sp. (Black-eyed susans), *Prunus* sp. (Plums and cherries), and *Hylotelephium* sp. (Live-forevers).

Bombus terricola was found associated with *Malus* sp. (Apples), *Lupinus* sp. (Lupines), *Cirsium arvense* (Creeping thistle), and *Dasiphora fruticosa* (Shrubby cinquefoil).

Native plant recommendations. We recommend targeted plantings of native plants to support pollinator biodiversity in Calgary. Based on our work, we found the following 15 plants to support the greatest diversity of pollinators:

Spring - *Salix* sp. (Willow)

Early summer - *Rosa* sp. (Rose); *Dasiphora fruticosa* (Shrubby cinquefoil); *Linum lewisii* (Lewis flax)

Summer - *Chamaenerion angustifolium* (Fireweed); *Monarda fistulosa* (Wild Bergamot); *Symphoricarpos occidentalis* (Western Snowberry); *Ratibida columnifera* (Upright prairie coneflower); *Asclepias speciosa* (Showy milkweed); *Geranium viscosissimum* (Sticky geranium); *Dalea purpurea* (Purple prairie clover); *Apocynum androsaemifolium* (Spreading dogbane)

Late summer - *Solidago* sp. (Goldenrod); *Aster* sp./*Symphyotrichum laeve* (Asters); *Astragalus canadensis* (Canadian milkvetch); *Campanula alaskana* (Alaska Bellflower)

Non-native plants in The City of Calgary. Eleven genera and species of non-native plants were found to support a large number of pollinators, and a few species were identified as

supporting at-risk pollinators. This suggests that leaving flowering weeds may help support pollinator populations. However, timing of mowing and/or removing these plants will still be important to prevent spread of these invasive species. Regulation of noxious weeds that are required to be removed and destroyed by law should also be kept in mind. There were three noxious weeds surveyed in our study that supported a large number of pollinators, including *Euphorbia virgata* (leafy spurge), *Tanacetum vulgare* (tansy), and *Cirsium arvense* (creeping thistle); see https://www.alberta.ca/provincially-regulated-weeds.aspx.

Top non-native plant associations - *Tanacetum vulgare* (Tansy), *Sisymbrium loeselii* (False london-rocket), *Melilotus albus* (White sweet clover), *Melilotus officinalis* (Yellow sweet clover), *Medicago sativa* (Alfalfa), and non-native members of *Trifolium* sp. (Trifolium clovers), *Taraxacum* sp. (Dandelions), *Cirsium* sp. (Thistles), *Vicia* sp. (Vetches), and *Astragalus* sp. (Milkvetches).

Future Research. Our future research efforts will focus on continuing to uncover plant-pollinator relationships for native and hardy non-natives, with the addition of common cultivars. We aim to use this information to inform current and future planting designs and guides for city managers and ecologists, community gardeners, and landscape designers, such as the *City of Calgary Plant Lists* and *City of Calgary Seed Mixes*. We are currently working on developing photographic techniques and identification guides for surveying pollinating insects, particularly bumble bees, instead of physical sampling. For example, we have developed ***Bumble Bees of Calgary*** as an open-educational resource to introduce bumble bee biology, conservation, and diversity with a series of different types of identification guides and tools (https://prism.ucalgary.ca/handle/1880/113505). When physical collection is required, our analyses suggest that 50 insects is an appropriate target for most plants, with a target of 100 necessary for only the plants that support higher numbers of pollinators. In addition, future work focusing on early spring and late fall pollinators will likely add to known diversity.

This proposed research parallels studies of the relations of native bees to wetland plant communities by the Ecologics Lab at the University of Calgary, the Pollinator Health Lab at Oregon State University, and ongoing research between L.R. Best and the Kootenay Native Plant Society (Nelson, BC). We aim to build more connections with these groups to compile and share information to contribute more broadly to our understanding of bees in NW North America.

Engaging Calgarians. We will continue to expand opportunities for students at the University of Calgary and other institutions and schools to survey biodiversity through course-based research experience, independent studies, and internships (e.g., see ZOOL 435 Insect Survey Report - https://prism.ucalgary.ca/handle/1880/113404?show=full). We will also be expanding and developing the Calgary Pollinator Count citizen-science initiative to increase public participation in both the discovery and conservation of native pollinators.

References

About Pollinators. (n.d.). Pollinator.Org. Retrieved August 1, 2021, from https://www.pollinator.org/pollinators

Baldock, K. C. R., Goddard, M. A., Hicks, D. M., Kunin, W. E., Mitschunas, N., Osgathorpe, L. M., Potts, S. G., Robertson, K. M., Scott, A. V., Stone, G. N., Vaughan, I. P., & Memmott, J. (2015). Where is the UK's pollinator biodiversity? The importance of urban areas for flower-visiting insects. *Proceedings of the Royal Society B: Biological Sciences*, *282*(1803), 20142849. https://doi.org/10.1098/rspb.2014.2849

Biesmeijer, J. C., Roberts, S. P. M., Reemer, M., Ohlemüller, R., Edwards, M., Peeters, T., Schaffers, A. P., Potts, S. G., Kleukers, R., Thomas, C. D., Settele, J., & Kunin, W. E. (2006). Parallel declines in pollinators and insect-pollinated plants in Britain and the Netherlands. *Science*, *313*(5785), 351–354. https://doi.org/10.1126/science.1127863

Cameron, S. A., Lozier, J. D., Strange, J. P., Koch, J. B., Cordes, N., Solter, L. F., & Griswold, T. L. (2011). Patterns of widespread decline in North American bumble bees. *Proceedings of the National Academy of Sciences*, *108*(2), 662–667. https://doi.org/10.1073/pnas.1014743108

Chiu, C.-H., Wang, Y.-T., Walther, B. A., & Chao, A. (2014). An improved nonparametric lower bound of species richness via a modified good-turing frequency formula: An improved nonparametric lower bound of species richness. *Biometrics*, *70*(3), 671–682. https://doi.org/10.1111/biom.12200

City of Calgary, Parks, Urban Conservation. 2018. *City of Calgary Seed Mixes: Recommendations and guidelines for seed mixes, handling procedures, timing and methodologies for The City of Calgary to inform revegetation work.* http://www.calgary.ca/CSPS/Parks/Pages/Construction/Park-development-guidelines.aspx

City of Calgary, Parks, Urban Conservation. 2019. *City of Calgary Plant Lists: Recommendations based on habitat type and desired outcome to inform revegetation work.* http://www.calgary.ca/CSPS/Parks/Pages/Construction/Park-development-guidelines.aspx

Goulson, D., Nicholls, E., Botías, C., & Rotheray, E. L. (2015). Bee declines driven by combined stress from parasites, pesticides, and lack of flowers. *Science*, *347*(6229), 1255957. https://doi.org/10.1126/science.1255957

Grixti, J. C., Wong, L. T., Cameron, S. A., & Favret, C. (2009). Decline of bumble bees (*Bombus*) in the North American midwest. *Biological Conservation*, *142*(1), 75–84. https://doi.org/10.1016/j.biocon.2008.09.027

Hicks, D. M., Ouvrard, P., Baldock, K. C. R., Baude, M., Goddard, M. A., Kunin, W. E., Mitschunas, N., Memmott, J., Morse, H., Nikolitsi, M., Osgathorpe, L. M., Potts, S. G., Robertson, K. M., Scott, A. V., Sinclair, F., Westbury, D. B., & Stone, G. N. (2016). Food for pollinators: Quantifying the nectar and pollen resources of urban flower meadows. *PLOS ONE*, *11*(6), e0158117. https://doi.org/10.1371/journal.pone.0158117

Hopwood, J. L. (2008). The contribution of roadside grassland restorations to native bee conservation. *Biological Conservation*, *141*(10), 2632–2640. https://doi.org/10.1016/j.biocon.2008.07.026

iNaturalist. (n.d.). iNaturalist. Retrieved May 10, 2021, from https://www.inaturalist.org/

Isaacs, R., Tuell, J., Fiedler, A., Gardiner, M., & Landis, D. (2009). Maximizing arthropod-mediated ecosystem services in agricultural landscapes: The role of native plants. *Frontiers in Ecology and the Environment*, *7*(4), 196–203. https://doi.org/10.1890/080035

Klein, A.-M., Vaissière, B. E., Cane, J. H., Steffan-Dewenter, I., Cunningham, S. A., Kremen, C., & Tscharntke, T. (2007). Importance of pollinators in changing landscapes for world crops. *Proceedings of the Royal Society B: Biological Sciences*, *274*(1608), 303–313. https://doi.org/10.1098/rspb.2006.3721

Kershaw, L., & Allen, L. (2020). *Vascular flora of Alberta: An illustrated guide*.

Mallinger, R. E., Franco, J. G., Prischmann-Voldseth, D. A., & Prasifka, J. R. (2019). Annual cover crops for managed and wild bees: Optimal plant mixtures depend on pollinator enhancement goals. *Agriculture, Ecosystems & Environment*, *273*, 107–116. https://doi.org/10.1016/j.agee.2018.12.006

Narango, D. L., Tallamy, D. W., & Marra, P. P. (2017). Native plants improve breeding and foraging habitat for an insectivorous bird. *Biological Conservation*, *213*, 42–50. https://doi.org/10.1016/j.biocon.2017.06.029

Nichols, R. N., Goulson, D., & Holland, J. M. (2019). The best wildflowers for wild bees. *Journal of Insect Conservation*, *23*(5–6), 819–830. https://doi.org/10.1007/s10841-019-00180-8

Oksanen, J., Blanchet, F. G., Friendly, M., Kindt, R., Legendre, P., McGlinn, D., Minchin, P. R., O'Hara, R. B., Simpson, G. L., Solymos, P., Stevens, M. H. H., Szoecs, E., & Wagner, H. (2020). *Vegan: Community ecology package* (2.5-7) [Computer software]. https://CRAN.R-project.org/package=vegan

Ollerton, J., Winfree, R., & Tarrant, S. (2011). How many flowering plants are pollinated by animals? *Oikos*, *120*(3), 321–326. https://doi.org/10.1111/j.1600-0706.2010.18644.x

Our Mission & Programs. (n.d.). *Bee City Canada*. Retrieved September 16, 2021, from https://beecitycanada.org/about-us/mission/

Phillips, B. B., Bullock, J. M., Osborne, J. L., & Gaston, K. J. (2020). Ecosystem service provision by road verges. *Journal of Applied Ecology*, *57*(3), 488–501. https://doi.org/10.1111/1365-2664.13556

Protecting pollinators. (n.d.). Edmonton & Area Land Trust. Retrieved August 1, 2021, from https://www.ealt.ca/protecting-pollinators

Purvis, E. E. N. (2021). *Restoration for wild bee community recovery in the prairie pothole region*. https://doi.org/10.11575/PRISM/38844

Purvis, E. E. N., Meehan, M. L., & Lindo, Z. (2020). Agricultural field margins provide food and nesting resources to bumble bees (*Bombus* spp., Hymenoptera: Apidae) in Southwestern Ontario, Canada. *Insect Conservation and Diversity*, *13*(3), 219–228. https://doi.org/10.1111/icad.12381

Samuelson, A. E., Gill, R. J., Brown, M. J. F., & Leadbeater, E. (n.d.). Lower bumblebee colony reproductive success in agricultural compared with urban environments. *Proceedings of the Royal Society B: Biological Sciences*, *285*(1881), 20180807. https://doi.org/10.1098/rspb.2018.0807

Theodorou, P., Radzevičiūtė, R., Settele, J., Schweiger, O., Murray, T. E., & Paxton, R. J. (2016). Pollination services enhanced with urbanization despite increasing pollinator parasitism. *Proceedings of the Royal Society B: Biological Sciences*, *283*(1833), 20160561. https://doi.org/10.1098/rspb.2016.0561

Thomas, S. (2020, January 24). *City of Calgary declared Bee City, promotes pollinators*. Calgary. https://calgary.ctvnews.ca/city-of-calgary-declared-bee-city-promotes-pollinators-1.4782405

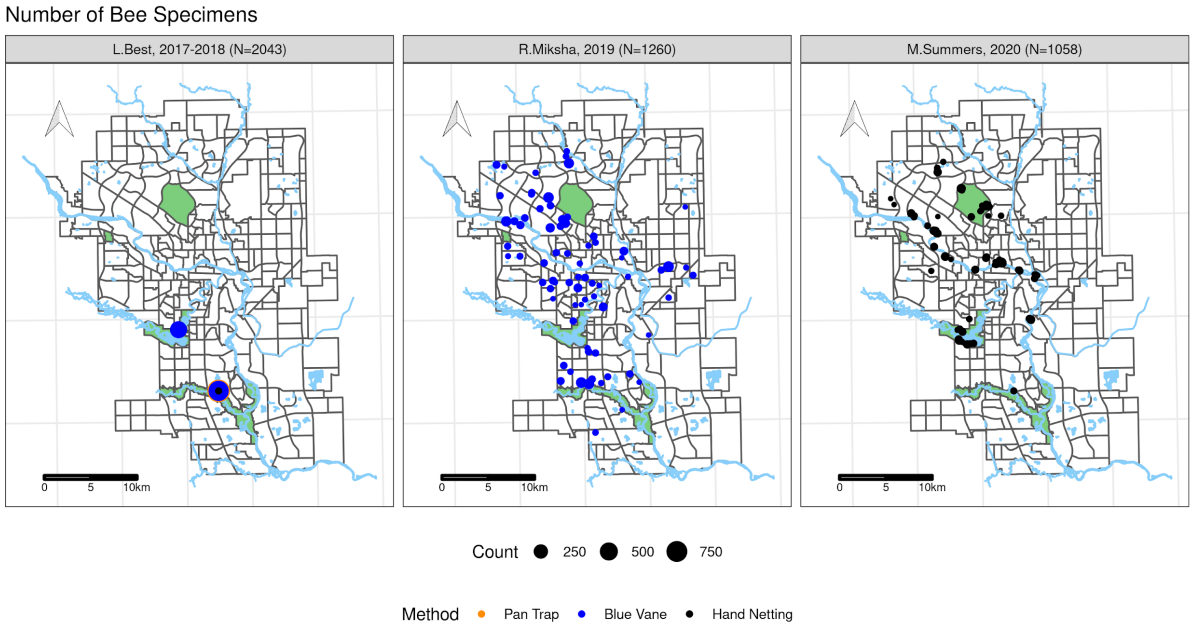
Vickruck, J. L., Best, L. R., Gavin, M. P., Devries, J. H., & Galpern, P. (2019). Pothole wetlands provide reservoir habitat for native bees in prairie croplands. *Biological Conservation*, *232*, 43–50. https://doi.org/10.1016/j.biocon.2019.01.015

Warzecha, D., Diekötter, T., Wolters, V., & Jauker, F. (2018). Attractiveness of wildflower mixtures for wild bees and hoverflies depends on some key plant species. *Insect Conservation and Diversity*, *11*(1), 32–41. https://doi.org/10.1111/icad.12264

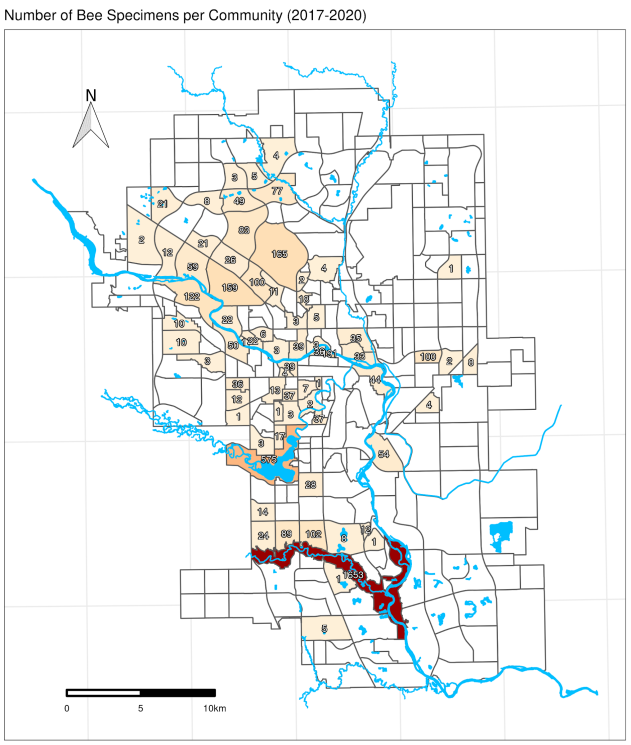
Appendices

Appendix A. Sampling localities and effort across The City of Calgary.

Bee sampling conducted for three projects (2017-2020).



Number of bee specimens collected and identified by community (2017-2020). Further research into bee biodiversity in northeast and southeast communities is particularly needed.



Number of total insect specimens collected and number of flower species for each sampling locality in 2020 through 2021. City of Calgary Parks in bold.

Site	No. specimens	No. floral species
12 Mile Coulee	3	1
Beaverdam Flats	492	6
Bow River Pathway	44	1
Bowmont Park	319	16
Canyon Meadows Bee Boulevard	112	6
Citadel	11	1
Dale Hodges Park	56	5
Edworthy Park	41	2
Hamptons	60	2
Hillhurst	69	6
Inglewood Bird Sanctuary	4	1
Montgomery	37	1
Murdoch Park	22	1
North Glenmore Park	55	3
Nose Creek Park	86	8
Nose Hill Park	460	28
Pearce Estate Park	248	6
Prince's Island Park	356	14
Roads Site 3 - Sarcee Trail SW - South	46	5
Roads Site 5 - Sarcee Trail SW - North	58	2
Roads Site 6 - 16th Ave Montgomery	6	2
Sandstone	4	1
South Glenmore Park	163	7
St Patrick's Island Park	32	2
Strathcona Park	9	1
Sunnyside	7	3
Symons Valley	4	1
Weaselhead Park	12	1

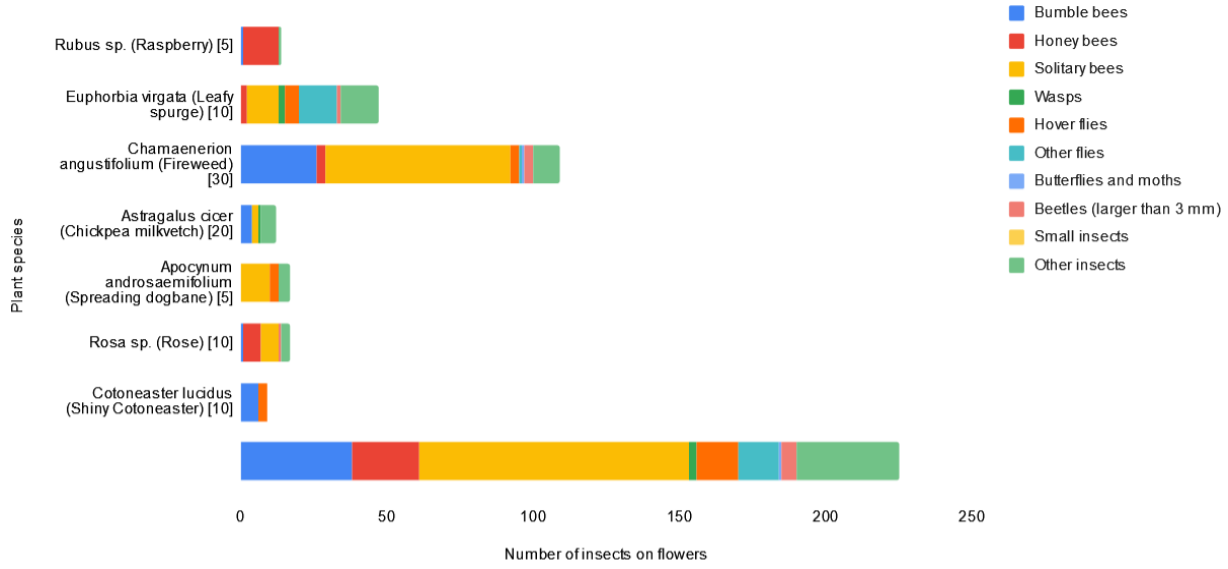
Appendix B. Results from Calgary Pollinator Counts.

Ten entries were received, surveying seven different plant species with a total of 225 insects observed on flowers.

Number of insects per minute of observation.

				Insects on flowers per minute										
Plant species	Common name	Number of entries	Total time observed (min)	Total insects	Bumble bees	Honey bees	Solitary bees	Wasps	Hover flies	Other flies	Butterflies and moths	Beetles	Small insects	Other insects
Rubus sp.	Raspberry	1	5	2.8	0.2	2.4	0	0	0	0	0	0	0	0.2
Euphorbia virgata	Leafy spurge	1	10	4.7	0	0.2	1.1	0.2	0.5	1.3	0	0.1	0	1.3
Chamaenerion angustifolium	Fireweed	3	30	3.6	0.9	0.1	2.1	0	0.1	0	0	0.1	0	0.3
Astragalus cicer	Chickpea milkvetch	2	20	0.6	0.2	0	0.1	0.1	0	0	0	0	0	0.3
Apocynum androsaemifolium	Spreading dogbane	1	5	3.4	0	0	2	0	0.6	0	0	0	0	0.8
Rosa sp.	Rose	1	10	1.7	0.1	0.6	0.6	0	0	0	0	0.1	0	0.3
Cotoneaster lucidus	Shiny cotoneaster	1	10	0.9	0.6	0	0	0	0.3	0	0	0	0	0

Number of insects per plant species. Total number of minutes the plant was survey for indicated in square brackets



Appendix C. References for historical Calgary bee records.

Bouseman, J.K., and W.E. LaBerge. 1978. A revision of the genus Andrena of the western hemisphere. Part IX. Subgenus Melandrena. *Transactions of the American Entomological Society*. *104*: 275-389.

Cockerell, T.D.A. 1909. Two new bees. *The Canadian Entomologist*. *41(1)*:35-37.

Cockerell, T.D.A. 1910. The bee fauna of Calgary, Alberta. *The Canadian Entomologist*. *42(1)*: 25.

Cockerell, T.D.A. 1912a. Two Bees new to Canada. *Canadian Entomologist*. *44(1)*: 293.

Cockerell, T.D.A. 1912b. Canadian Bees in the British Museum. *Canadian Entomologist*. *44(12)*: 354-358.

Cockerell, T.D.A. 1937. The Bees of Alberta II. *The Canadian Entomologist*. *69*: 33-35.

Cockerell, T.D.A. 1930. Descriptions and Records of Bees. CXXIII. *Annals and Magazines of Natural History: Series 10. 5:28*, 405-411.

Criddle, N. 1925. The Entomological Record, 1924. *Annual Report of the Entomological Society of Ontario*. 55: 89-106.

Donovan, B.J. 1977. A revision of North American bees of the subgenus *Cnemidandrena* (Hymenoptera: Andrenidae). *University of California Publications in Entomology*. *81*:1-107.

Fletcher, J., and A. Gibson. 1907. The Entomological Record, 1906. *Annual Report of the Entomological Society of Ontario*. *37*: 113-133.

Franklin, H.J. 1913. The Bombidae of the New World Part I. *Transactions of the American Entomological Society*. *38(3-4)*:177-482.

GBIF.org (16 March 2020) GBIF Occurrence Download https://doi.org/10.15468/dl.a37fve
GBIF.org (16 March 2020) GBIF Occurrence Download https://doi.org/10.15468/dl.hv1m1i
GBIF.org (16 March 2020) GBIF Occurrence Download https://doi.org/10.15468/dl.nzfii6
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GBIF.org (16 March 2020) GBIF Occurrence Download https://doi.org/10.15468/dl.8olj2y

Gibbs, J. 2010: Revision of the metallic species of *Lasioglossum (Dialictus)* in Canada (Hymenoptera, Halictidae, Halictini). *Zootaxa*. *2591*: 1–382.

LaBerge, W.E. 1956b. A revision of the bees of the genus *Melissodes* in North and Central America. Part II (Hymenoptera, Apidae). *The University of Kansas Science Bulletin*. *38*: 533-578.

LaBerge, W.E. 1961. A revision of the bees of the genus *Melissodes* in North and Central

America. Part III (Hymenoptera, Apidae). *The University of Kansas Science Bulletin*. 42: 283-663.

LaBerge, W.E., and D.W. Ribble. 1972. A revision of the bees of the genus *Andrena* of the western hemisphere. Part V. *Gonandrena, Geissandrena, Parandrena, Pelicandrena*. *Transactions of the American Entomological Society*. *98*: 271-358.

LaBerge, W.E. 1973. A revision of the bees of the genus *Andrena* of the western hemisphere.Part VI. Subgenus Trachandrena. *Transactions of the American Entomological Society*. 99: 235-371.

LaBerge, W.E. 1977. A revision of the bees of the genus *Andrena* of the western hemisphere. Part VIII. *Subgenera Thysandrena, Dasyandrena, Psammandrena, Rhacandrena, Euandrena, Oxyandrena*. *Transactions of the American Entomological Society*. 103: 1-143.

LaBerge, W.E. 1980. A revision of the bees of the genus *Andrena* of the western hemisphere. Part X. Subgenus *Andrena*. *Transactions of the American Entomological Society*. *106*: 395-525.

LaBerge, W.E., and D.W. Ribble. 1975. A revision of the bees of the genus *Andrena* of the western hemisphere. Part VII. Subgenus *Euandrena*. *Transactions of the American Entomological Society*. *101*: 371-446.

McGinley, R.J. 1986. Studies of Halictinae (Apoidea: Halictidae), I: Revision of New World *Lasioglossum* Curtis. *Smithsonian Contributions in Zoology*. *429*: 1-294.

Mitchell, T.B. 1933. A revision of the genus *Megachile* in the Nearctic Region. Part I. Classification and descriptions of new species (Hymenoptera: Megachilidae). *Transactions of the American Entomological Society*. *59(4)*: 295-361.

Mitchell, T.B. 1935. A revision of the genus *Megachile* in the Nearctic Region. Part III. Taxonomy of subgenera *Anthemois* and *Delomegachile* (Hymenoptera: Megachilidae). *Transactions of the American Entomological Society*. *61(3)*: 155-205.

Mitchell, T.B. 1936a. A revision of the genus *Megachile* in the Nearctic Region. Part IV. Taxonomy of subgenera *Xanthosarus, Phaenosarus, Megachiloides* and *Derotropis* (Hymenoptera: Megachilidae). *Transactions of the American Entomological Society*. 62(2): 117-166.

Mitchell, T.B. 1936b. A Revision of the genus *Megachile* in the Nearctic Region. Part V. Taxonomy of subgenus *Xeromegachile* (Hymenoptera: Megachilidae). *Transactions of the American Entomological Society*. 62(4): 323-382.

Mitchell, T.B. 1937. A revision of the genus *Megachile* in the Nearctic Region. Part VII. Taxonomy of the subgenus *Sayapis* (Hymenoptera: Megachilidae). *Transactions of the American Entomological Society*. *63(2)*: 175-206.

Sandhouse, G.A. 1925. Canadian bees of the genus *Osmia*. *Canadian Entomologist*. 57(3): 33-41, 60-65.

Schwarz, H.F. 1927b. Additional North American bees of the genus *Anthidium*. *American Museum Novitates*. No. 253: 1-17.

Schwarz, H.F. 1928. Anthidiinae mostly collected in Canada (Hymenop.). *Canadian Entomologist*. 60: 212-217.

White, J.R. 1952. A Revision of the genus *Osmia*, subgenus *Acanthosmioides* (Hymenoptera, Megachilidae). *University of Kansas Science Bulletin*. 35(1): 219-307.

Viereck, H.L. 1924b. Prodromus of *Andrena*, A genus of bees. *Canadian Entomologist*. 56(4):19-24, 28-32, 76-81, 237-244.