



Bee Abundance and Diversity Baseline in West Kootenay Camas Meadows

COL-F21-W-3304

Prepared for: Fish and Wildlife Compensation Program

Prepared by: Valerie Huff, Iraleigh Anderson, Lincoln R. Best, Emily Purvis and Samuel Robinson

Prepared with financial support of the Fish and Wildlife Compensation Program, on behalf of its program partners BC Hydro, the Province of BC, Fisheries and Oceans Canada, First Nations and Public Stakeholders.

Date: 31-Mar-2021

Executive Summary

Improving conservation and understanding of culturally important plants and animals has been identified as a high priority action in the Fish and Wildlife Compensation Program (FWCP) Columbia Region Wetland & Riparian Action Plan (FWCP 2019b; COLWRA.CXP.RI.05.01: Culturally important resources.). The FWCP Upland and Dryland Action Plan (FWCP 2019a) supports inventory and monitoring for pollinators to elucidate community structure and act as an indicator of ecosystem function (COLUPD.SOI.ME.33.01: Invertebrate monitoring for pollinators).

This project provides a baseline understanding of West Kootenay camas meadows to inform future conservation, restoration, and enhancement activities. The Kootenay Native Plant Society is working with the Sinixt peoples to renew people-plant relationships in their traditional territory. Documenting plant-pollinator diversity in the remaining meadows is a critical first step in understanding what diversity remains and helps us understand how best to conserve and restore West Kootenay camas meadows.

Nine camas meadow sites were selected at low elevations along approximately 60 km of the Kootenay and Columbia river systems. The sites represent a diversity of habitat types including bedrock seepage meadows, rocky shorelines, and open floodplains. General site attributes and plant community structure were recorded at each site. Native bee species were sampled at six of the sites, and the abundance of floral resources was sampled at five of the sites. Floral phenology was recorded during multiple visits at seven of the sites.

A total of 106 flowering plant species were observed in the six sites, including 75 native species and 31 exotic species. No plant species at risk were detected during the surveys. We observed 84 bee species or morphospecies using six camas meadow sites. The genus *Bombus* (bumble bees) were the most abundant taxa, representing nearly 45% of all bee specimens sampled. *Eucera* (spring long-horned bees), *Agapostemon* (metallic-green sweat bees), *Lasioglossum* (sweat bees), and *Osmia* (mason bees) followed in abundance.

Two of the bumble bee species observed are considered to be at risk; *Bombus occidentalis* (Greene, 1858) is blue-listed provincially and assessed as Threatened by COSEWIC, and *Bombus flavidus* (Eversmann, 1852) is blue-listed provincially, and may be declining in other parts of Canada.

The observed diversity of flowering plant and bee species associated with camas meadows highlights the ecological value of this habitat type, in addition to the known cultural significance. Future directions will include collecting data on assessment of bee nesting resources and plant-pollinator interactions to better elucidate pollinator habitat status and community relationships in the West Kootenay region.

Table of Contents

Executive Summary.....	i
1 Introduction.....	1
2 Goals and Objectives.....	2
3 Study Area.....	2
3.1 Site Sampling Overview.....	3
4 Methods.....	5
4.1 Site Description	5
4.2 Floral Resources.....	5
4.3 Bee Sampling.....	6
4.4 Bee Identification.....	6
4.5 Data Analysis.....	6
5 Results and Outcomes.....	6
5.1 Floral Resources.....	6
5.2 Plant Communities.....	9
5.3 Bees.....	10
6 Discussion.....	13
6.1 Bee and flowering plant relationships in camas meadows	13
6.2 Bee species at risk supported in camas meadows	14
7 Conclusions.....	15
7.1 Future Directions	15
8 Recommendations.....	15
9 Acknowledgements.....	17
10 References	18
Appendix A Extended General BBCH Plant Phenology Scale.....	22
Appendix B Checklist of Plants by Site	24
Appendix C Checklist of Bees and their Status Rankings.....	29

List of Figures

Figure 1. Study area maps indicating locations of 9 survey sites sampled along the Kootenay and Columbia rivers in 2020.	4
Figure 2. Flowering phenology of early blooming plants (plants with peak bloom before June 10) across all sampling sites, grouped by peak bloom time. Bars indicate the time span from budding to the last flowers observed, while dots indicate the closest point to full flowering (50% of flowers open). Plants that were only observed once during the season are indicated by a single dot....	7
Figure 3. Flowering phenology of later blooming plants (plants with peak bloom after June 10) across all sampling sites, grouped by peak bloom time. Bars indicate the time span from budding to the last flowers observed, while dots indicate the closest point to full flowering (50% of flowers open). Plants that were only observed once during the season are indicated by a single dot....	8
Figure 4. Relative number of flowering stems of the 28 most abundant plants at 5 sites. Species in bold are non-native.....	9
Figure 5. Non-metric multidimensional scaling (NMDS) plots of flowering plant communities at each site, with first and second rotational axes (NMDS1 and NMDS2) displayed on the x- and y-axis.	10
Figure 6. Species, genus, and family-level abundance of bees split into five major families.....	11
Figure 7. Rarefaction curves for each collection site, along with estimated total species richness. N indicates the total number of specimens, S.obs indicates the number of observed species, and S.chao1 indicates estimated total richness using the Chao1 estimator (Chiu et al. 2014).	12
Figure 8. Rarefaction curves for each collection site, along with estimated <i>Bombus</i> species richness. N indicates the total number of specimens, S.obs indicates the number of observed species, and S.chao1 indicates estimated total richness using the Chao1 estimator (Chiu et al. 2014)	12

List of Tables

Table 1. Summary of survey methods used at each study site in 2020.....	3
Table 2. Portion of the BBCH phenology scale used to describe the growth stage of forbs that were flowering during the bee sampling period. See Appendix D for complete scale.	5

1 Introduction

Pollination is a critical ecosystem service and native bees are our most important pollinators. Pollination sustains native ecosystem health and function, yet little is known about the identity, status, habitat use, and pollinator-plant relationships in West Kootenay (WK) ecosystems. Baseline data on native bee distribution and abundance in the WK is limited (but see Westcott and Irvine 2010, Best 2018). Even less is known about the pollinator diversity and abundance in the meadows of common camas (*Camassia quamash* (Pursh) Greene [Asparagaceae]), though wet meadows are known to harbour diverse pollination networks (Moroñ et al. 2008), and, in one survey of Garry oak meadows in southwestern British Columbia (BC), camas was the most frequently visited plant species by the largest diversity of bees (Parachnowitsch and Elle 2005). In our previous work in WK camas meadows, we have observed and photographed many invertebrate visitors on camas (Huff and Johansson 2012). Lynn Westcott, a bee specialist familiar with local flora and bee fauna has suggested that up to 60 different bee species may rely on camas meadows for their livelihood (L. Westcott, pers. comm. Sept. 30, 2013). It is possible that at least two CDC listed bumble bee species (*Bombus occidentalis*, *B. suckleyi*) use camas meadows throughout the season. Only bumble bees have been assessed by the BC Conservation Data Centre; the number of bee species in BC is not yet known, and we are losing high quality habitat faster than we can survey for BC bee diversity.

Camas, known as itqwa/black camas in the Interior Salish language, is a perennial herb with grass-like leaves, light blue to deep purplish-blue flowers, and an edible bulb. It is native to the Pacific Northwest from California, through Oregon, Washington, Utah, Idaho, Wyoming, Montana to southern BC and Alberta. In BC, it occurs along the Pacific Coast, largely restricted to southeastern Vancouver Island and the Southern Gulf Islands, as well as in the Canadian Columbia Basin from Trail to Nakusp (Huff and Johansson 2012; Beckwith 2004). In every place where camas occurs across western North America it has played a dominant role in shaping First Nations/Native American economies and identity for millennia (Thoms 2008; Beckwith 2004; Hunn 1981). The bulbs are a significant resource, a "root food" that was—and still is for many Native Americans—a staple component of the traditional diet. Camas was cultivated primarily by women, who maintained bulb quality and quantity (Beckwith 2004), by creating and maintaining extensive meadows that, when in bloom, were described as blue lakes by Lewis and Clark (Stevens et al. 2001). Widely celebrated in story, legend, and ceremony, it has been called a cultural keystone species (Garibaldi and Turner 2004).

The formerly cultivated camas wet meadow habitats are also ecologically significant, supporting a diversity of other plant, animal, and fungal species/beings. In the Columbia Basin, these communities occur along the Columbia and Kootenay rivers in floodplain meadows, in the upper riparian zone, and in moist seeps in bedrock meadows from Marsden Face, located outside of Nelson, south to the US border. Small populations are known from the Slocan Valley, Pass Creek, and Robson. Historically, camas occurred up the Arrow Lakes as far as Nakusp and Edgewood in locations now underwater after the construction of the Hugh Keenleyside Dam. Ongoing habitat loss, agricultural conversion, forest in-growth, and invasive species have contributed to the decline of these ecologically and culturally significant places and, it is suspected, that changing precipitation patterns with the climate crisis could further imperil the remnant camas populations. In the BC Interior, it is estimated that camas occupies less than 1% of the original, pre-settler extent (B. Beckwith, KNPS Restoration Ethnoecologist, pers.

comm., October 15, 2019). The loss of camas meadows is likely accompanied by a corresponding loss of invertebrate pollinator species abundance and richness.

This project was undertaken to provide a baseline understanding of West Kootenay camas meadows to inform future conservation, restoration, and enhancement activities. The Kootenay Native Plant Society is working with the Sinixt peoples to renew people-plant relationships in their traditional territory. Documenting plant-pollinator diversity in the remaining meadows is a critical first step in understanding what diversity remains and help us understand how best to conserve and restore West Kootenay camas meadows.

2 Goals and Objectives

Improving conservation and understanding of culturally important plants and animals has been identified as a high priority action in the Fish and Wildlife Compensation Program (FWCP) Columbia Region Wetland & Riparian Action Plan (FWCP 2019b):

COLWRA.CXP.RI.05.01 Culturally important resources. Work with appropriate Indigenous groups and organizations to conduct research and inventory to improve the understanding of culturally important plants and animals. Conservation and increased understanding of culturally important species.

Camas has been identified by our indigenous colleagues from the Colville Confederated Tribes as their highest priority for eco-cultural restoration. Through the mapping of camas meadow vegetation and habitat attributes in the study area, this project will establish a baseline from which to measure progress toward the recovery of these culturally significant ecosystems.

The FWCP Upland and Dryland Action Plan (FWCP 2019a) supports inventory and monitoring for pollinators to elucidate community structure and act as an indicator of ecosystem function:

COLUPD.SOI.ME.33.01 Invertebrate monitoring for pollinators. Support inventory/monitoring of upland terrestrial invertebrate groups to increase knowledge of community structure and act as an indicator of productivity and ecosystem health/function in areas related to FWCP compensation activities.

Pollinator biodiversity data for the West Kootenay is sorely lacking (Jennifer Heron pers. comm., October 21, 2019). The collection and identification of native bees in West Kootenay camas meadow will significantly increase our understanding of bee distribution in an important eco-cultural landscape.

3 Study Area

Nine camas meadow study sites (Table 1) were selected at low elevations along approximately 60 km of the Kootenay/Columbia river system (See Study Area Map - Figure 1). The sites represent a diversity of habitat types including bedrock seepage meadows, rocky shorelines, and open floodplains, which do not fit well within current provincial ecological land classification systems (e.g., MacKillop and Ehman 2016; MacKenzie and Moran 2004; etc.) A common characteristic of each site is that the diversity of flowering

plants is high relative to adjacent habitat. Each site represents a small patch of unique habitat within a varied landscape dominated by managed forests, reservoirs, urban development, industrial infrastructure, and transportation corridors. Most sites fall within the Interior Cedar Hemlock - Very Dry Warm (ICHxw) Biogeoclimatic Subzone, though the Beaver Creek Provincial Park site is transitional to the Cedar Hemlock - Very Dry Warm - Warm Phase (ICHxwa) in the south, and the Upper Marsden Conservancy site is transitional with the Interior Cedar Hemlock - Dry Warm Subzone (ICHdw1) in the North (MacKillop and Ehman 2016). The climate includes very hot, very dry summers and mild dry winters (MacKillop and Ehman 2016). The ICHxw subzone contains forests and brushlands with a diverse assemblage of tree and shrub species and a disproportionately large number of wildlife and plant species at risk (MacKillop and Ehman 2016).

3.1 Site Sampling Overview

Our initial plan was to conduct bee and floral resource sampling at six camas meadows from Beaver Creek Provincial Park in the south to the Marsden Conservancy in the north. We were unable to access Beaver Creek Provincial Park during the study as all provincial parks were closed due to COVID-19. We will include Beaver Creek in 2021 research. At Crescent Valley, we determined that blue-vane trapping was untenable due to the public prominence of the site. At Upper Marsden, access intensive floral abundance surveys were not conducted due to the fragile nature of the substrate (thin soil over bedrock seepage). Early flooding prevented access to Oxbow Island for floral abundance sampling. We added blue-vane traps to an adjacent mainland area where we carried out floral phenology surveys but not floral abundance. Two of the traps at this Oxbow Mainland site were either vandalized or carried away by floodwaters. We also did a floral survey of a meadow being encroached by forest in-growth near kp'it'l'els but did not do any bee sampling there. This sub-site was sampled in anticipation of developing restoration thinning prescriptions in areas where lodgepole pines are encroaching on significant camas populations. All survey methods were used at Mount Sentinel, but the blue vane traps were disturbed by bears. Likewise, all survey methods were used at the kp'it'l'els shoreline, but one set of blue-vane traps were damaged by floodwaters.

Table 1. Summary of survey methods used at each study site in 2020.

Site	Blue Vane Traps	Floral Abundance	Floral Phenology	Site Data
Beaver Creek Provincial Park				
Crescent Valley		x	x	x
kp'it'l'els (shoreline)	x	x	x	x
kp'it'l'els (forest)		x	x	x
Mount Sentinel	x	x	x	x
Oxbow Island	x			x
Oxbow Mainland	x		x	x
Upper Marsden	x		x	x
Lower Marsden	x	x	x	x

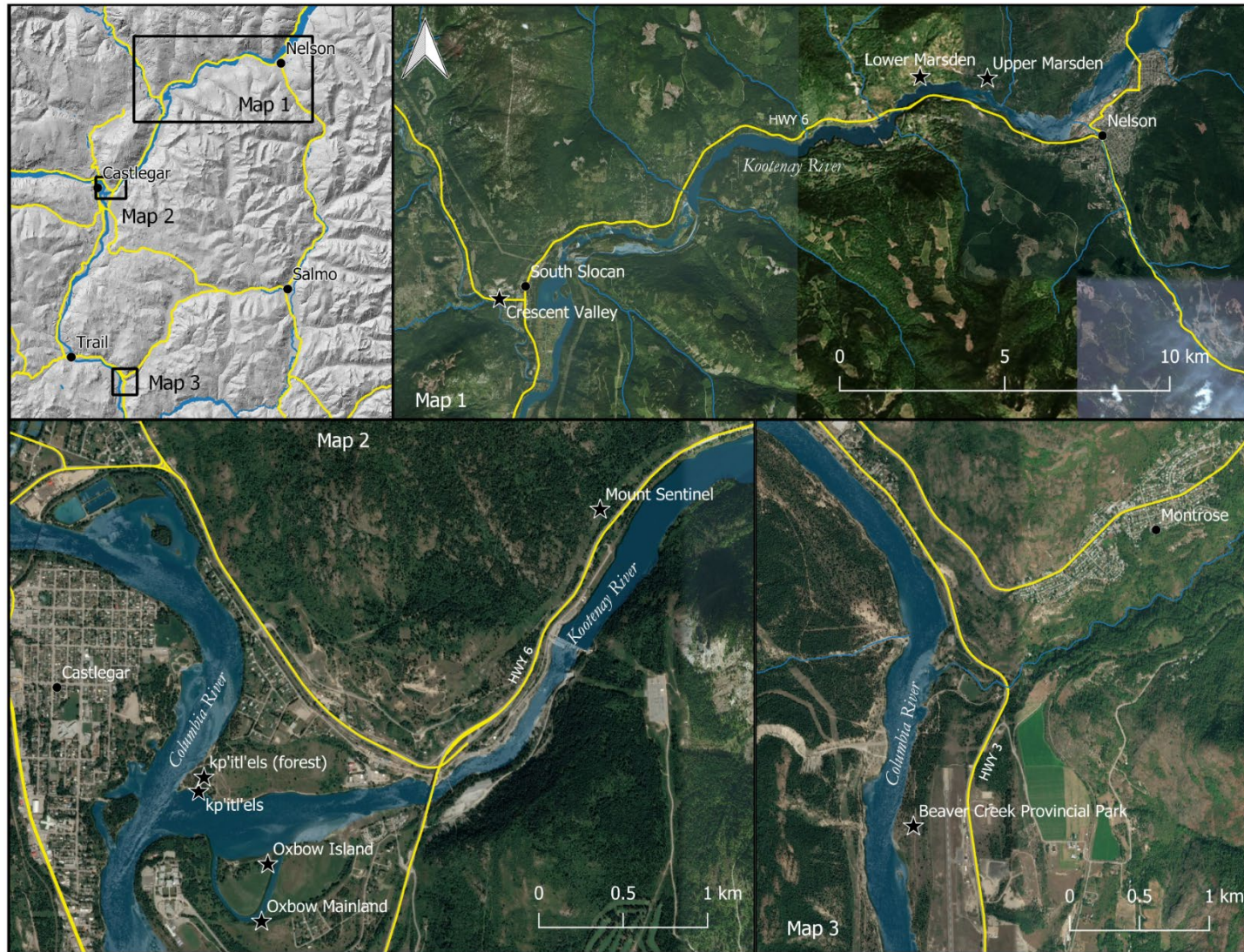


Figure 1. Study area maps indicating locations of 9 survey sites sampled along the Kootenay and Columbia rivers in 2020.

4 Methods

4.1 Site Description

Site attributes and plant community structure were recorded at each site as per provincial standards (BC Ministry of Forests and Range and BC Ministry of Environment 2010).

4.2 Floral Resources

Sampling of floral resources was conducted from May 2 to July 14, 2021. At each site, plants were identified to species. Where field identification was not possible, a collection was made and identified after the survey. To characterize pollen and nectar resources available to bees over the sampling period, we identified all forb species that were flowering in each meadow at least twice during the bee sampling period. Each flowering forb was assigned a number on the extended BBCH scale (Hess et. al. 1997) to describe the flowering stage of each species across the plot (Table 2). A visual assessment was made to assign a number on the scale for the population encountered in the meadow. This will allow for future comparisons of flowering phenology among sites across time.

Table 2. Portion of the BBCH phenology scale used to describe the growth stage of forbs that were flowering during the bee sampling period. See Appendix D for complete scale.

Code	Description
	<i>Principal growth stage 5: Inflorescence emergence (main shoot)</i>
51	Inflorescence or flower buds visible
55	First individual flowers visible (still closed)
59	First flower petals visible (in petalled forms)
	<i>Principal growth stage 6: Flowering (main shoot)</i>
60	First flowers open (sporadically)
61	Beginning of flowering: 10% of flowers open
63	30% of flowers open
65	Full flowering: 50% of flowers open, first petals may be fallen
67	Flowering finishing: majority of petals fallen or dry
69	End of flowering: fruit set visible

An additional survey was carried out at five sites (Table 1) to measure the relative abundance of available floral resources available. Quadrats (1 m²) were randomly established along random 30 meter transects within representative habitat at each site. The density of flowering stems was recorded for each species in each quadrat.

4.3 Bee Sampling

Native bee species were sampled using Blue Vane (BV) traps. The sampling period was from May 2 to July 14, 2020. Sampling duration was typically 14-18 days, with the exception of some sampling sites which experienced substantial flooding and traps could not be recovered safely until flooding subsided (max duration 72 days). Three BV traps were set at each of six camas sites. Food grade propylene glycol was used as a preservative in the traps. At each site, the contents of the three BV traps were pooled to produce a single sample. The contents of a sample were transferred to jars containing 95% ethanol. Thirteen BV trap samples were collected which produced 1517 insect specimens, including 1440 bee specimens.

4.4 Bee Identification

Bee specimens were identified to species-level (48 species) or morphospecies (36 types) depending on the availability of modern taxonomic revisions, keys for identification, reference specimens, and the condition of specimens. Morphospecies were identified to genus and/or subgenus, then differentiated using morphological characters and assigned a sequential morphospecies number. Appendix C contains a checklist of bee species and their status rankings. The following resources were used in this study to identify the bee specimens: Ascher and Pickering 2013, Bouseman et al. 1978, DeSilva 2012, Gibbs 2010, Hurd and Michener 1955, LaBerge 1969, LaBerge 1986, McGinley 1986, Roberts 1973a, Roberts 1973b, Sheffield et al. 2011, and Stephen 1954. Species occurrence data for the bee specimens collected will be served to the Global Biodiversity Information Facility (GBIF) via the Canadensys Integrated Publishing Toolkit (IPT).

4.5 Data Analysis

Total bee species richness and *Bombus* species richness at each site were estimated using the Chao1 estimator (Chiu et al. 2014) through the *vegan* package (Oksanen et al. 2020) in R version 4.0.4 (R Core Team 2021). Flowering plant communities were decomposed using Non-Metric Multidimensional Scaling (NMDS, Kruskal 1964) with the *vegan* package, and were displayed using *ggplot2* (Oksanen et al. 2020; Wickham 2016). All analysis was done in R version 4.0.4 (R Core Team 2021).

5 Results and Outcomes

5.1 Floral Resources

A total of 106 plant species were observed flowering in the six sites, including 75 native species and 31 exotic species (Appendix 2). No plant species at risk were detected during the surveys. It is important to note that only forb species that were in flower during the sampling period were documented, so these numbers represent only a small portion of the plant diversity at these sites.

Mount Sentinel had the highest species richness (49 species), followed by Upper Marsden (43 species), and Lower Marsden (40 species). The fewest species (19) were detected on the Oxbow Mainland. The most widespread species were common camas (*Camassia quamash*), saskatoon (*Amelanchier alnifolia*),

spotted knapweed (*Centaurea stoebe*), mouse-ear chickweed (*Cerastium fontanum*), tall cinquefoil (*Drymocallis arguta*), tall Oregon-grape (*Mahonia aquifolium*), and sheep sorrel (*Rumex acetosella*).

Different species hit peak flowering at different times through the sampling window (Figures 2 and 3). The sampling began in early May, when camas was at peak bloom, along with saskatoon, upland larkspur (*Delphinium nuttalianum*), and one-flowered broomrape (*Orobanche uniflora*) (Figure 2). Different floral resources became available as the season progressed. At the end of the flowering season, several species were just beginning to bloom, including tiger lily (*Lilium columbianum*), hare's foot clover (*Trifolium arvense*), and yellow penstemon (*Penstemon confertus*).

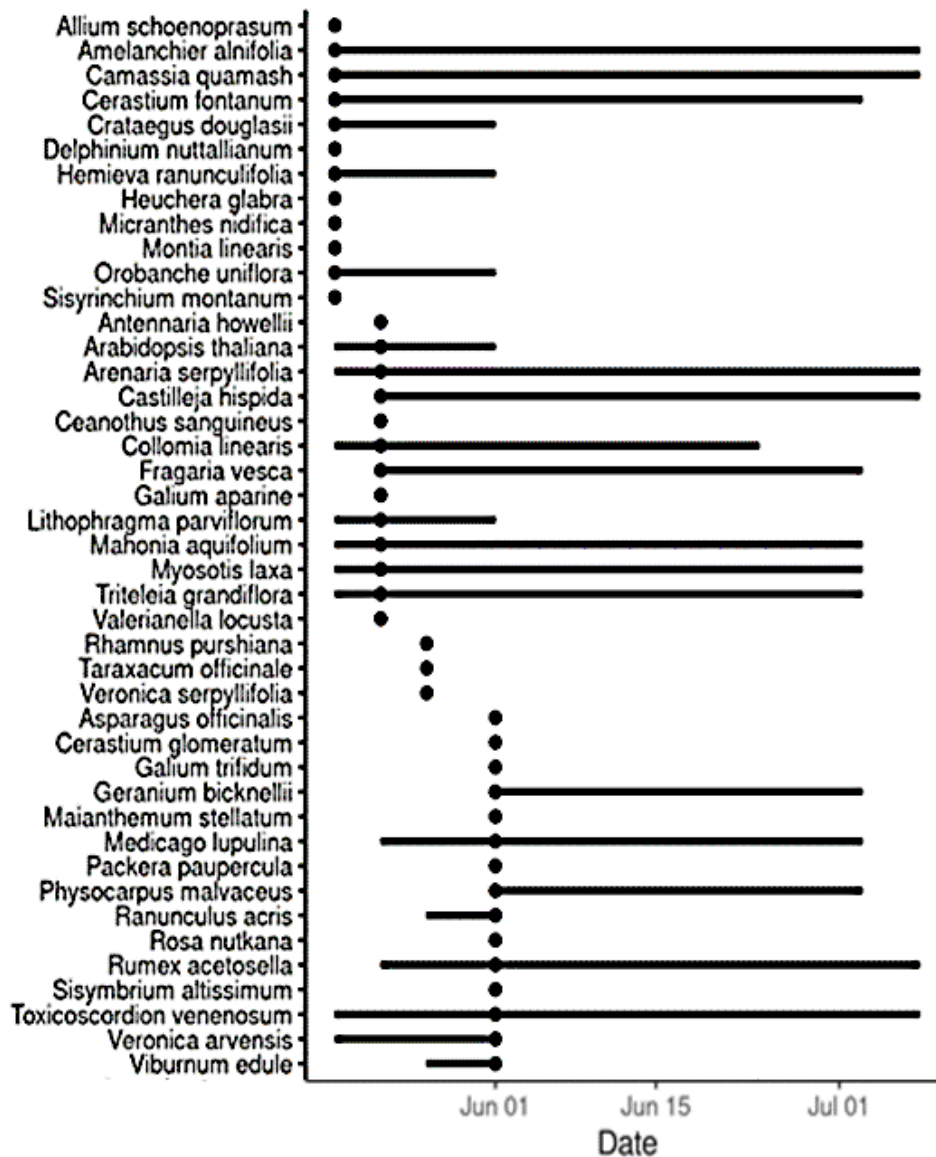


Figure 2. Flowering phenology of early blooming plants (plants with peak bloom before June 10) across all sampling sites, grouped by peak bloom time. Bars indicate the time span from budding to the last flowers observed, while dots indicate the closest point to full flowering (50% of flowers open). Plants that were only observed once during the season are indicated by a single dot.

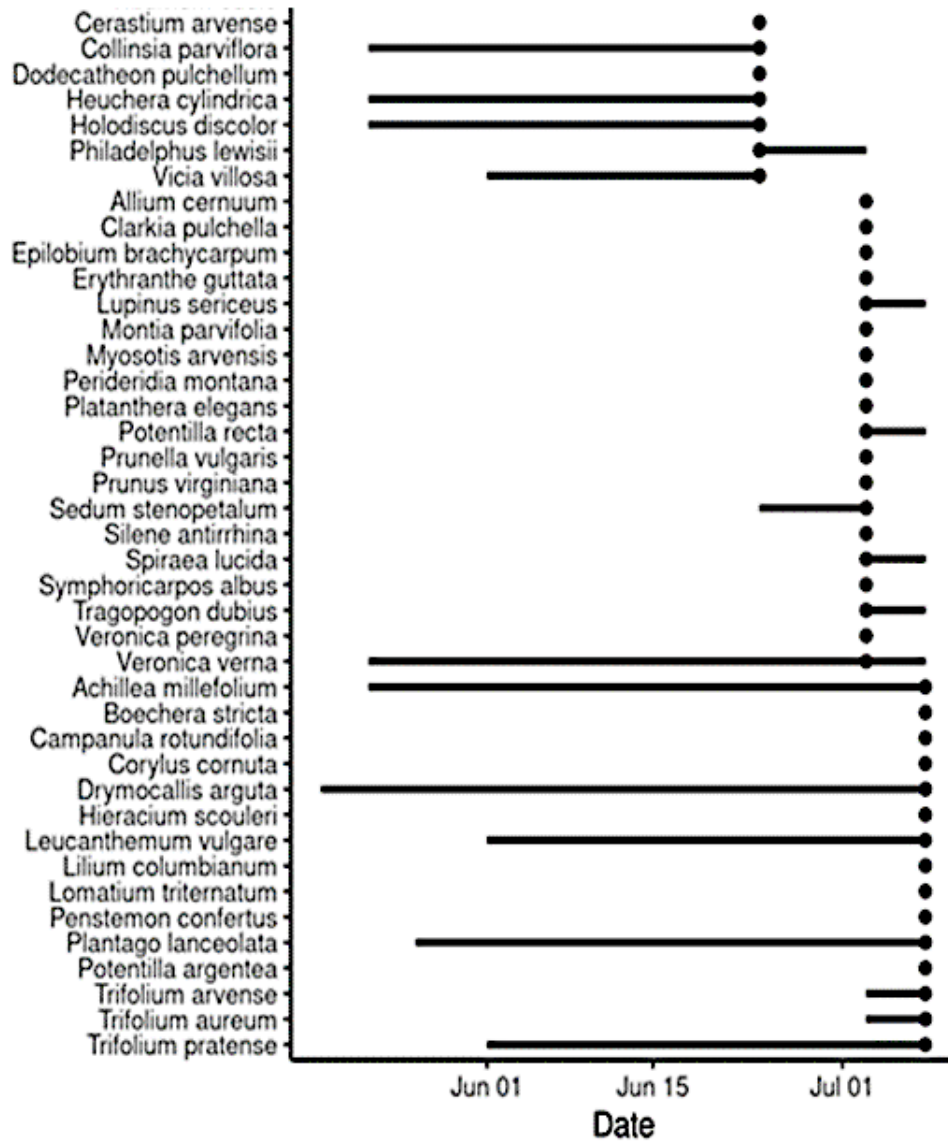


Figure 3. Flowering phenology of later blooming plants (plants with peak bloom after June 10) across all sampling sites, grouped by peak bloom time. Bars indicate the time span from budding to the last flowers observed, while dots indicate the closest point to full flowering (50% of flowers open). Plants that were only observed once during the season are indicated by a single dot.

The relative abundance of floral resources across sites is shown in Figure 4. Yarrow (*Achillea millefolium*), saskatoon, camas, and snowberry (*Symphoricarpos albus*) were frequent natives on most sites. At all sites, non-native plants were a significant portion of the floral resources available to bees during the flowering period (Figure 2), including spotted knapweed and sulphur cinquefoil (*Potentilla recta*) at Crescent Valley and Lower Marsden, hare's-foot clover at Lower Marsden, and hairy vetch (*Vicia villosa*) at kp'it'el's and Mount Sentinel.

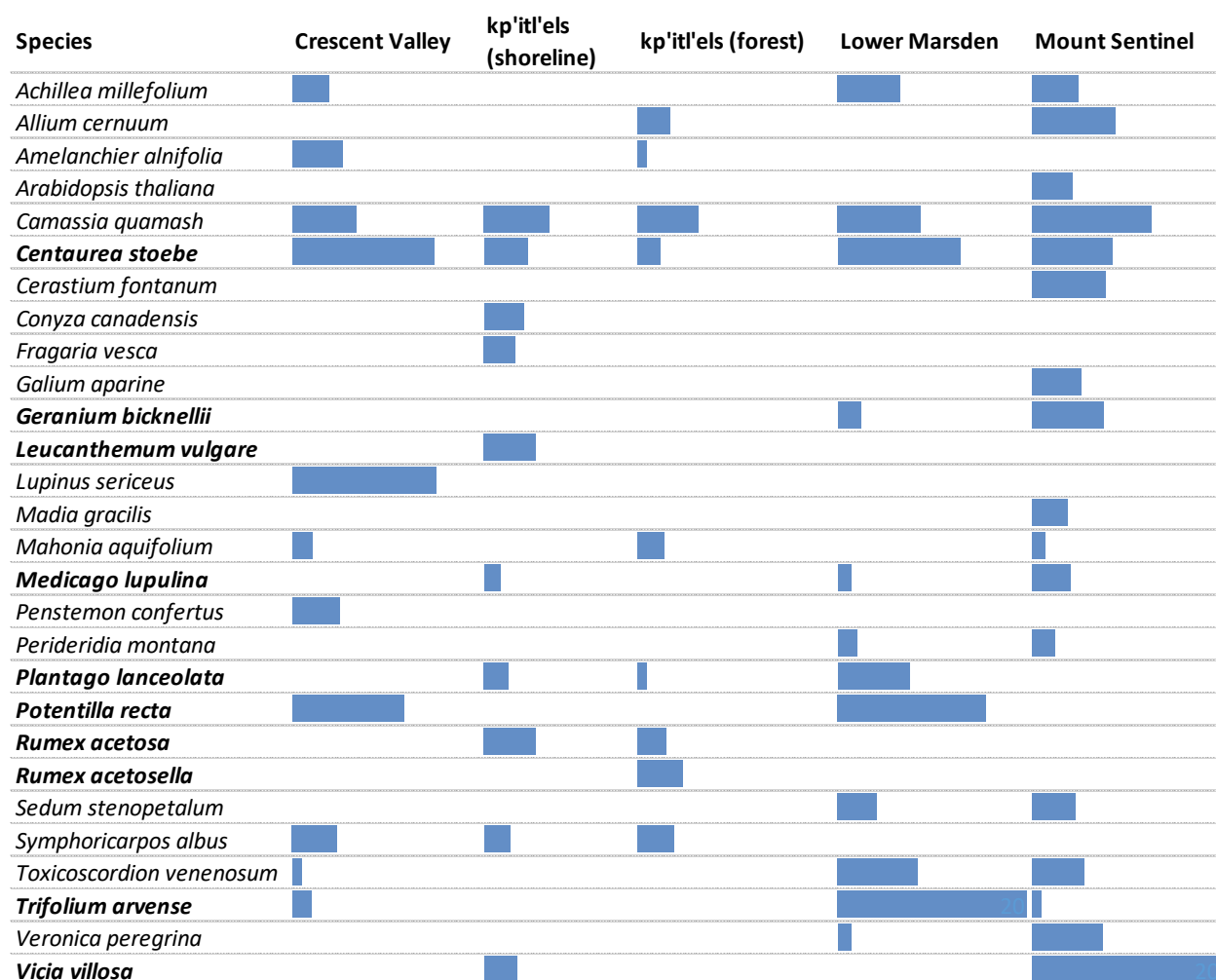


Figure 4. Relative abundance of flowering stems of the 28 most abundant plants at 5 sites. Species in bold are non-native.

5.2 Plant Communities

Plant communities at Lower Marsden, Crescent Valley, and Mount Sentinel were mostly distinct from each other as indicated by the NMDS ordination (Figure 5). At kp'itl'els, we sampled two sub-sites – a shoreline area where bees were collected and a forest in-growth area where camas is a significant component of the understory vegetation. The kp'itl'els shoreline site shared many of the same species with all sites. The in-growth forest plant community shared commonality with all but Crescent Valley, but had several species not shared by any other community. The statistic 'k' refers to the number of dimensions that communities were reduced to, and stress indicates the reduction in information caused by the Non-metric Multidimensional Scaling (NMDS) rotation (0.05 is considered low, indicating minimal loss of community information).

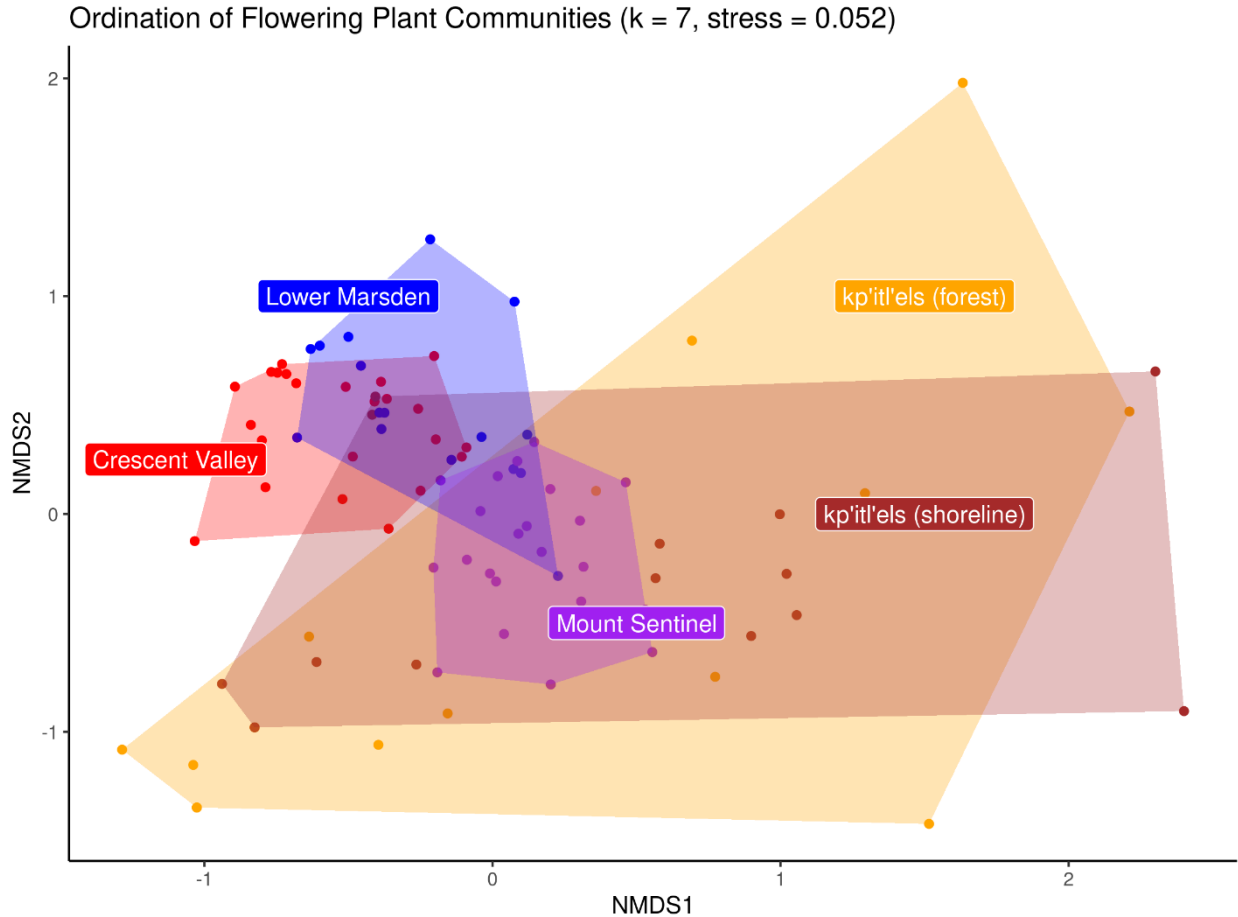


Figure 5. Non-metric multidimensional scaling (NMDS) plots of flowering plant communities at each site, with first and second rotational axes (NMDS1 and NMDS2) displayed on the x- and y-axis.

5.3 Bees

Among the bee species occurrence data, the genus *Bombus* (bumble bees) were the most abundant taxa recruited to the BV traps, representing nearly 45% of all bee specimens captured. *Eucera* (spring long-horned bees), *Agapostemon* (metallic-green sweat bees), *Lasioglossum* (morphologically-monotonous sweat bees), and *Osmia* (mason bees) followed in abundance (Figure 6). These genera are native to the region, speciose, and active through spring and early summer in upland habitats. A checklist of bee species and their conservation status can be found in Appendix 1.

Mount Sentinel had the highest estimated total species richness (80 species), followed by kp'itl'els (63 species), and Lower Marsden (47 species) (Figure 7). Observed richness (curved line) did not come close to the estimated species richness (horizontal line), indicating that sampling intensity was too low to detect all species of native bees active during the sampling period. Similarly, Mount Sentinel had the highest estimated *Bombus* species richness (12 species), followed by kp'itl'els (11 species), and Oxbow Main (8 species); however, observed *Bombus* richness (curved line) was close to estimated species richness (horizontal line), indicating that sampling was sufficiently intense to detect most of the *Bombus* species present at these sites (Figure 6).

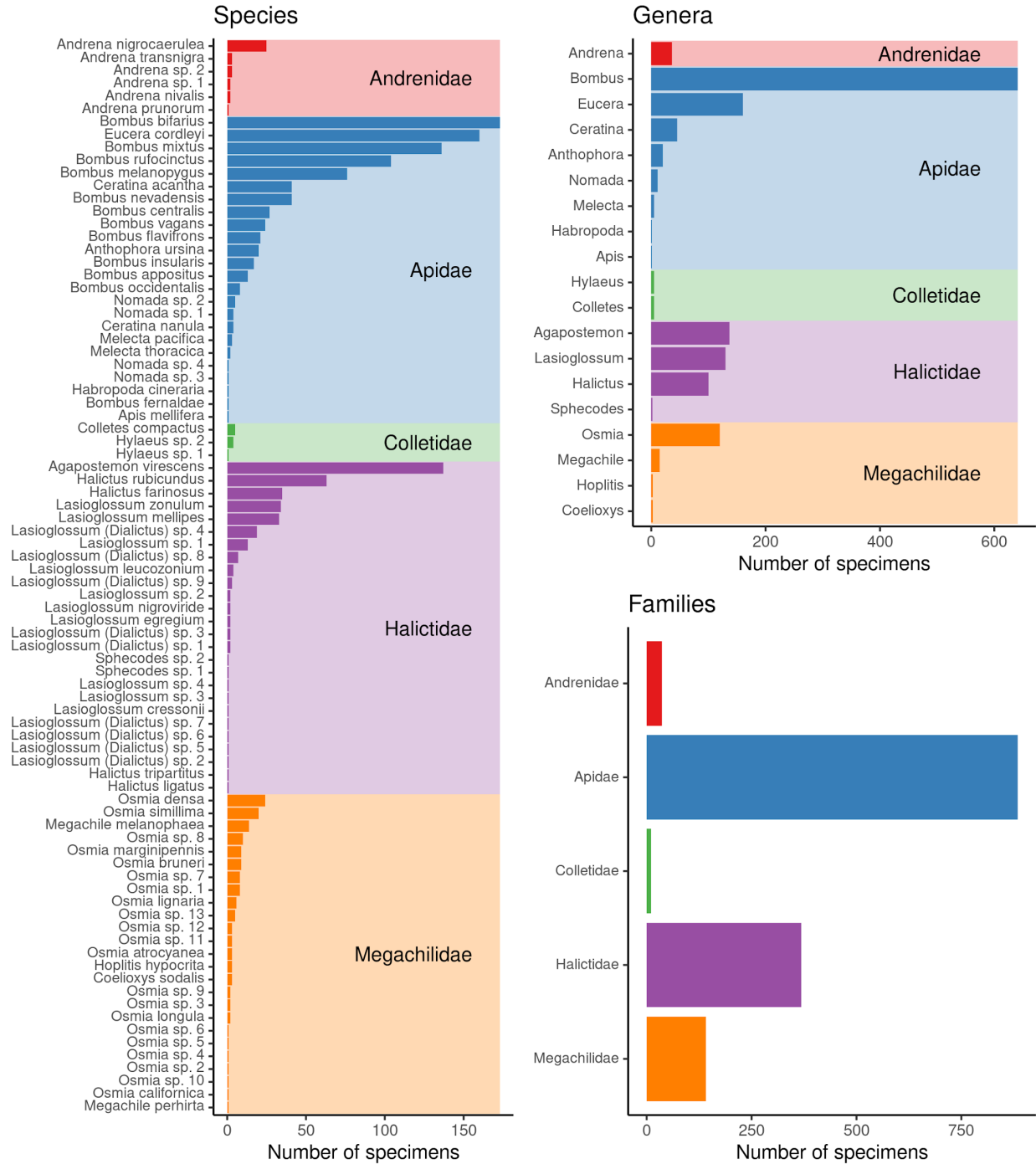


Figure 6. Species, genus, and family-level abundance of bees split into five major families.

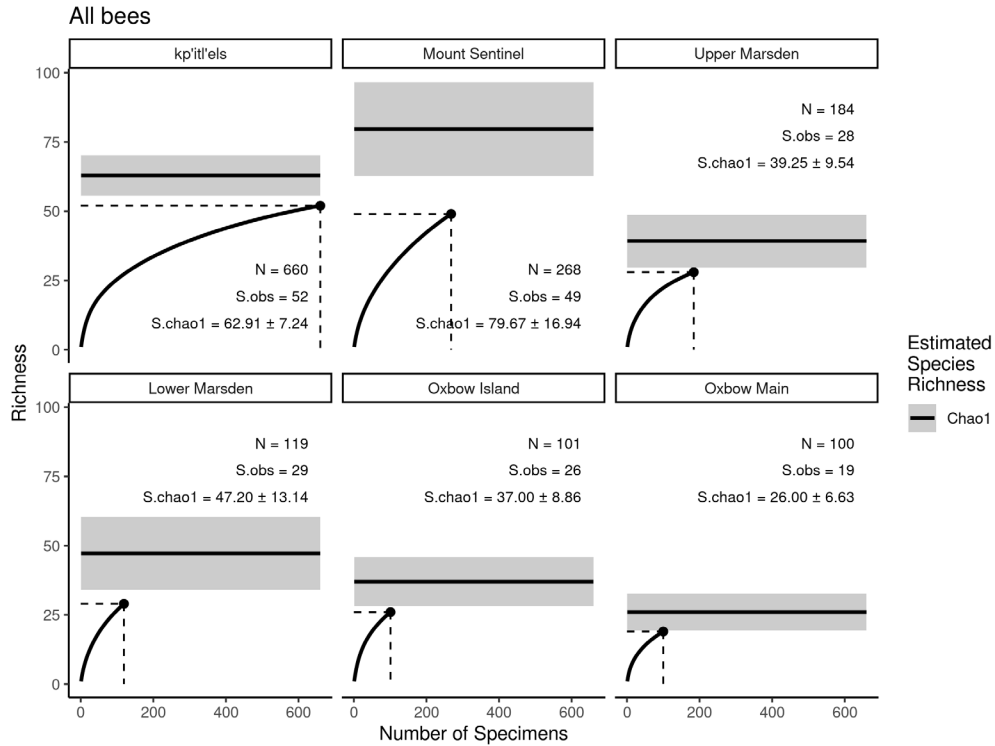


Figure 7. Rarefaction curves for each collection site, along with estimated total species richness. *N* indicates the total number of specimens, *S.obs* indicates the number of observed species, and *S.chao1* indicates estimated total richness using the Chao1 estimator (Chiu et al. 2014).

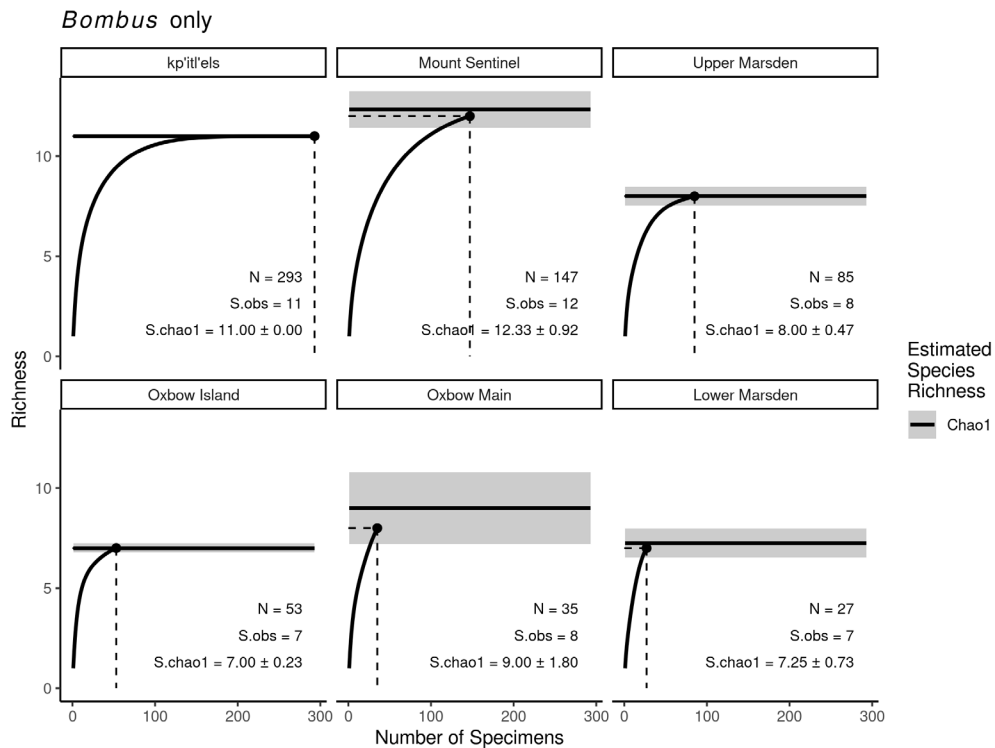


Figure 8. Rarefaction curves for each collection site, along with estimated *Bombus* species richness. *N* indicates the total number of specimens, *S.obs* indicates the number of observed species, and *S.chao1* indicates estimated total richness using the Chao1 estimator (Chiu et al. 2014).

6 Discussion

We established a baseline understanding of the bee and flowering plant communities using camas meadows in the West Kootenays. Bees represent a critical group of pollinators whose use of camas meadow habitats is poorly understood. Collecting baseline data on bees and flowering plants in camas meadows is important given the observed decline of wild bee species provincially and nationally, as well as the cultural significance of camas to Indigenous Peoples. We observed 84 bee species or morphospecies using six camas meadow sites, as well as 106 flowering plant species across six sites. More sampling may be necessary to quantify the total bee communities at these sites (Figure 7), though richness extrapolations for bumble bees separately revealed a fairly complete representation of the occurring species (Figure 8). Additionally, two of the bumble bee species observed are considered to be at risk; *Bombus occidentalis* (Greene, 1858) is blue-listed provincially and assessed as Threatened by COSEWIC (Appendix 1), and *Bombus flavidus* (Eversmann, 1852) is blue-listed provincially (Appendix 1), and it may be declining in other parts of Canada (BC Conservation Data Centre 2021; COSEWIC 2014; Colla et al. 2012).

6.1 Bee and flowering plant relationships in camas meadows

Bee species richness varied between sites, which may be attributed to differences in the richness of flowering plants. Though the assessment of flowering plant richness and abundance was piloted during the 2020 field season, the data produced does allow for preliminary inference about bee-plant relationships. When examining the extrapolated richness of bees (including bumble bees separately) and flowering plant species, similar trends are apparent. Mount Sentinel had the highest plant species richness, followed by kp'it'l'els and Lower Marsden (Appendix 2). Likewise, the extrapolated total bee richness (Figure 7) and bumble bee richness (Figure 8) at these three sites ranked in the same order. This positive relationship between bee and flowering plant diversity is based on the three sites where both bee and flowering plant data were collected, but a similar trend is well documented in other studies (e.g., Tonietto et al. 2017; Forup et al. 2008; Hopwood 2008; Steffan-Dewenter and Tscharrntke 2001). Collecting additional data on the flowering phenology throughout the season is recommended to further illuminate the changes in food resource availability to bees over the growing season and allow for more comprehensive inferences regarding bee-plant richness relationships at different sites.

The identity of flowering plant species may also determine which bee species are present at a given site (Purvis et al. 2020; Warzecha et al. 2018). The bee species observed at our sites are all considered generalist foragers that can use a variety of plant species; however, despite possessing an ability to forage from a variety of plants, generalist foragers often have feeding preferences. This makes it valuable to identify which plant species are present and abundant. At the three sites where data on both bees and flowers were collected, plant species that were consistently highly abundant were common camas, spotted knapweed, and legumes such as vetch and hare's-foot clover. Plants that have open flower structure, such as camas or aster species, have been observed to support higher bee richness, likely due to increased accessibility to nectar, in addition to pollen resources for bees with shorter tongue lengths (Stang et al. 2006). Interestingly, patterns in camas abundance between sites corresponded to patterns in the richness of all bee species and bumble bees alone, with Mount Sentinel containing the highest observed camas abundance, followed by kp'it'l'els and Lower Marsden. This relationship is preliminary, but it does aid support to the potential value of camas for pollinator visitors.

Moreover, three of the most abundant plants in the study are common invasive species in this region (spotted knapweed, hairy vetch, and hare's-foot clover). Concrete information on the role of camas or other flowering plant species (native or introduced) in supporting bee diversity can be provided by observing interactions through net sampling and assembling plant-pollinator networks for these habitats. Quantifying these interactions can also allow for determining which plant species are most used for foraging by bee species at risk.

In addition to floral food resources, nesting locations or nest-building materials represent a critical, but often overlooked, habitat resource that can influence the abundance and diversity of bees. Many bee species establish nests below ground in self-excavated or existing cavities, though others establish nests above ground in hollow stems, tree cavities, or other materials (McFrederick and Lebuhn 2006; Potts et al. 2005; Alford 1975). In our study only ~10% of bee species were known stem or cavity nesting obligates, with the remaining 90% likely nesting on or in the ground. Ground characteristics such as the percent bare soil, slope, and soil compaction have previously been found to be important influences on bee abundance (Purvis et al. 2020; Tonietto et al. 2017; Sardiñas and Kremen 2014; Hopwood 2008; Potts et al. 2005). Future quantification of soil characteristics at each site can allow for investigation of bee nesting resources in camas meadows.

6.2 Bee species at risk supported in camas meadows

The Fernald Cuckoo Bumble Bee (*Bombus flavidus*) and the Western Bumble Bee (*B. occidentalis*) were observed at four camas meadow sites in this study. The Fernald Cuckoo Bumble Bee was observed only at Mount Sentinel and the Western Bumble Bee was observed at Mount Sentinel, Oxbow Island, Lower Marsden, and kp'itl'els, with 63% of the Western Bumble Bee individuals found at kp'itl'els. Knowledge of habitat use is valuable, given that habitat loss or degradation is a commonly cited threat to wild bee species at risk (Goulson et al. 2015; COSEWIC 2014; Colla et al. 2012; Biesmeijer et al. 2006). To compound this, the Fernald Cuckoo Bumble Bee is also a cuckoo species that does not collect food directly but relies on healthy host bumble bee populations to persist, making it additionally vulnerable (Colla et al. 2012). These remnant camas meadows may be important refuges for species at risk affected by habitat loss in other parts of their ranges by providing adequate food and nesting resources to support them or their host species populations. Both Mount Sentinel and kp'itl'els had the highest extrapolated flowering plant species richness and highest camas abundance of the sites where floral resources were quantified. Though the relationship between camas and the Fernald Cuckoo Bumble Bee or the Western Bumble Bee is unknown, the Western Bumble Bee was observed nectaring on camas at Mount Sentinel during the study. The Western Bumble Bee may benefit from the open and easily accessible camas flowers as they are considered to have a shorter tongue length (Arbetman et al. 2017). Observing interactions and creating plant-pollinator networks can help describe floral preference, assist with species at risk recovery planning, and allow for identifying habitats that contain preferred food resources.

7 Conclusions

The diversity of species associated with camas meadows, as observed in this project, highlights the ecological value of this habitat type in addition to the known cultural significance of camas. Future directions will include expanding data on plant species and flowering phenology of all sites, as well as observing plant-pollinator interactions, to better elucidate community relationships in this region. Additionally, planned collection of soil data in 2021 will increase our understanding of abiotic site factors that affect both plants and pollinators and will support initial assessment of nesting bee resources.

The wet meadow habitats that support camas have declined from much of their historic distribution, which signifies the loss of a cultural keystone species, camas, for regional Indigenous communities. Additionally, the paucity of data on the invertebrate fauna using wet meadows—particularly in WK ecosystems—means the extent of ecological damage accompanying habitat loss is not fully known (but see Best 2018, Westcott and Irvine 2010; Morón et al. 2008). By inventorying bee communities—a critical group of pollinators who themselves are facing widespread decline—in camas meadows, we can better understand the function of this culturally important habitat across the landscape.

7.1 Future Directions

Western science is just beginning to recognize the importance of traditional management/relationship practices in creating and maintaining biodiversity at multiple scales (Schuster et al. 2019). Generations of people-plant interrelationships, such as camas cultivation, likely helped to sustain not only the food plants, but myriad other species. The diversity and abundance of invertebrates identified in WK camas meadows could have been promoted and maintained, in part, by thousands of years of sustainable resource management of Indigenous Peoples. Cultivation practices, including selective harvesting, soil aeration and tilling, weeding, clearing by fire and/or flooding, and the purposeful replanting and transplanting of camas bulbs (Beckwith 2004), likely maintained open meadows with high richness of pollinators, flowering plants, and plant-pollinator interactions. Revitalizing traditional land management practices may help reverse the decline in pollinator communities. In the future, we hope to link traditional ecological knowledge and Western science to deepen our understanding of how to restore West Kootenay camas meadows – for people, for pollinators, and for the plants.

8 Recommendations

The study of bee communities in camas meadows needs to continue to better understand the function of this culturally important habitat across the landscape. Specifically, the authors recommend continuing research on flowering phenology, plant-pollinator interactions, and soil.

1. **Flowering Phenology.** Broadening the study of flowering phenology over more sites and over a longer period of time will help better understand plant-bee richness relationships and the changes in food resource availability to bees over the growing season.
2. **Plant-Pollinator Interactions.** More observations of plant-pollinator interactions will result in a better understanding of plant-bee community relationships in this region, the role of native versus introduced plants in supporting bee diversity, and which plant species are most used for

foraging by bee species at risk. Given the occurrence of the listed bee species, Fernald Cuckoo Bumble Bee and Western Bumble Bee, in the region, building a network of plant-pollinator interactions will help describe floral preference, assist with species at risk recovery planning, and allow for identifying habitats that contain preferred food resources.

3. **Soil Data.** Collection of soil data will increase the understanding of abiotic site factors that affect both plants and pollinators and allow for the building of specialized knowledge of ground nesting bee resources.

The baseline data of bee and plant communities documented here can provide a robust argument for conservation and restoration of West Kootenay camas meadows. We recommend the following:

1. Protect existing camas meadows from further degradation by engaging both traditional ecological knowledge and western science.
2. Use Mount Sentinel and kp'itl'els as reference sites for restoration planning, providing information on appropriate plant species for re-introduction to other camas sites.
3. Work collaboratively with the Colville Confederated Tribes to re-introduce traditional land management practices, including camas cultivation methods.
4. Develop restoration plans that include different ways of knowing to deepen the pathway toward the ecocultural restoration of plant-pollinator-people relationships in West Kootenay camas meadows.

9 Acknowledgements

We would like to thank the Fish and Wildlife Compensation Program for support, guidance, and funding this project. Through this program, we were able to significantly advance our knowledge of plant-pollinator diversity in the culturally and ecologically important camas meadows of the West Kootenay. Additional financial and in-kind support came from the Columbia Basin Trust, the Kootenay Native Plant Society, Provincial Invertebrate Specialist (Jennifer Heron), and Janice Arndt.

The study was designed by Valerie Huff (VH), Lincoln Best (LB), and Iraleigh Anderson (IA), and with input from Brenda Beckwith (BB), Shelly Boyd, Samuel Robinson, and Jennifer Heron. Field work was conducted by VH, IA, BB, and Selkirk College Intern Mara Mannaerts. Kayla Tillapaugh also assisted with a day of inventory. LB identified and catalogued all the bee species, with the laboratory support of Emily Purvis (EP). Analysis and writing of the report were a team effort by VH, LB, IA, SR, EP, with editing suggestions from BB.

We are grateful to Selkirk College, the Nature Trust (Chris Bosman), the BC Ministry of Forest, Lands, Natural Resource Operations, and Rural Development (Irene Manley), Regional District of Central Kootenay (Andy Davidoff), BC Parks (Amanda Weber-Roy) for supporting the project, including allowing access to managed lands for survey purposes and supporting eco-cultural revitalization of these lands both now and into the future.

We are grateful to be working on the unceded *təmxʷulaʔxʷ* of the Sinixt people. In particular, we express our gratitude to Shelly Boyd for her cultural guidance on this project, and her support for the revitalization of the Sinixt – itqwa relationship.

Our inspiration often comes from the natural world and from those who have spent their time learning and teaching others about the wonders therein. Brenda Beckwith's doctoral research on camas (University of Victoria) inspired many people across BC who are passionate about the protection and conservation of this beautiful being/plant. This includes Eva Johansson and Valerie Huff, who began the Kootenay Camas Project to learn about our unique camas ecosystems. Lynn Westcott helped us see and understand the diversity of insect visitors to camas meadows and inspired this survey.

And of course, we thank the plants and the bees.

10 References

- Alford, D.V., 1975. Bumblebees. Davis-Poynter Ltd., London, UK.
- Arbetman, M.P., Gleiser, G., Morales, C.L., Williams, P., Aizen, M.A., 2017. Global decline of bumblebees is phylogenetically structured and inversely related to species range size and pathogen incidence. *Proceedings of the Royal Society*, **284**, 20170204. doi:10.1098/rspb.2017.0204.
- Ascher, J. S., Pickering, J. 2013. Discover Life bee species guide and world checklist (Hymenoptera: Apoidea: Anthophila). URL. http://www.discoverlife.org/mp/20q?guide=Apoidea_species [Accessed November 2020]
- B.C. Conservation Data Centre. 2021. BC Species and Ecosystems Explorer. B.C. Minist. of Environ. Victoria, B.C. WWW Document. URL. <https://a100.gov.bc.ca/pub/eswp/>. (Accessed 24 Mar 2021).
- B.C. Ministry of Forests and Range and B.C. Ministry of Environment. 2010. Field Manual for Describing Terrestrial Ecosystems 2nd Edition.
- Beckwith, B. 2004. "The queen root of this clime": ethnoecological investigations of blue camas (*Camassia leichtlinii* (Baker) Wats., *C. quamash* (Pursh) Greene; Liliaceae) and its landscapes on southern Vancouver Island, British Columbia. University of Victoria.
- Best, L.R. 2018. All that the sun promises and more. The biodiversity and floral relationships of native bees in the Pend d'Oreille, British Columbia. Report Prepared for the Waneta Terrestrial Compensation Program, Columbia Power, Castlegar, BC.
- Biesmeijer, J.C., Roberts, S.P.M., Reemer, M., Ohlemuller, 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**, 351–354. <https://doi.org/10.1126/science.1127863>.
- Bouseman, J.K., LaBerge, W. E. 1978. A revision of the genus *Andrena* of the western hemisphere. Part IX. Subgenus *Melandrena*. *Transactions of the American Entomological Society*. 104: 275-389.
- Chiu, C.H., Wang, Y.T., Walther, B.A., Chao, A. 2014. Improved nonparametric lower bound of species richness via a modified Good-Turing frequency formula. *Biometrics* **70**, 671–682.
- Colla, S.R., Gadallah, F., Richardson, L., Wagner, D., Gall, L., 2012. Assessing the conservation status of North American bumble bees using museum records. *Biodiversity and Conservation*, **21**, 3585-3595.
- COSEWIC. 2014. COSEWIC assessment and status report on the Western Bumble Bee *Bombus occidentalis*, the *occidentalis* subspecies (*Bombus occidentalis occidentalis*) and the mckayi subspecies (*Bombus occidentalis mckayi*) in Canada. Committee on the Status of Endangered

- Wildlife in Canada. Ottawa. WWW Document. URL. www.registrelep-sararegistry.gc.ca/default_e.cfm. (Accessed 24 Mar 2021).
- DeSilva, N. 2012. Revision of the cleptoparasitic bee genus *Coelioxys* (Hymenoptera: Megachilidae) in Canada. York University, MSc Thesis, 341 pgs.
- Fish and Wildlife Compensation Program (FWCP). 2019a. Columbia Region: Upland and Dryland Action Plan. August 21, 2019 (V1). <http://fwcp.ca/app/uploads/2019/08/Action-Plan-Columbia-Region-Upland-Dryland-Aug-21-2019.pdf>
- Fish and Wildlife Compensation Program (FWCP). 2019b. Columbia Region: Wetland & Riparian Action Plan August 21, 2019 (V1). <http://fwcp.ca/app/uploads/2019/08/Action-Plan-Columbia-Region-Wetlands-Riparian-Areas-Aug-21-2019.pdf>
- Forup, M.L., Henson, K.S.E., Craze, P.G., Memmott, J., 2008. The restoration of ecological interactions: plant-pollinator networks on ancient and restored heathlands. *J. Appl. Ecol.* 45, 742–752. <https://doi.org/10.1111/j.1365-2664.2007.01390.x>.
- Garibaldi, A., Turner, N. (2004). "Cultural keystone species: implications for ecological conservation and restoration". *Ecology and Society*. 9 (3).
- Gibbs, J. 2010: Revision of the metallic species of *Lasioglossum* (*Dialictus*) in Canada (Hymenoptera, Halictidae, Halictini). *Zootaxa*. 2591: 1–382.
- Goulson, D., Nicholls, E., Botias, C., Rotheray, E.L., 2015. Bee declines driven by combined stress from parasites, pesticides, and lack of flowers. *Science*, **347**, 1255957-1–1255957-9. <https://doi.org/10.1126/science.1255957>.
- Hess, M., Barralis, G., Bleiholder, H., Buhr, L., Eggers, Th., Hack, H., Stauss, R. 1997. Use of the extended BBCH-scale - general for the description of the growth stages of mono- and dicotyledonous weed species. *Weed Research*. 36 (6): 433–441. doi:10.1046/j.1365-3180.1997.d01-70.x.
- Hopwood, J.L., 2008. The contribution of roadside grassland restorations to native bee conservation. *Biol. Conserv.* 141, 2632–2640. <https://doi.org/10.1016/j.biocon.2008.07.026>.
- Hunn, E.S. 1981. On the Relative Contribution of Men and Women to Subsistence among Hunter-Gatherers of the Columbia Plateau: A Comparison with Ethnographic Atlas Summaries. *Journal of Ethnobiology* 1 (1): 124–34.
- Huff, V., Johansson, E. 2012. Camas at the Confluence: Where Ecology and Culture Meet at kp'ítl' els. *Menziesia* 17(3). <https://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=41161>
- Hurd, P.D. Jr., Michener, C. D. 1955. The Megachiline bees of California. (Hymenoptera: Megachilidae). *Bulletin of the California Insect Survey*. 3: 1-247.

- Kruskal, J.B. 1964. Nonmetric multidimensional scaling: a numerical method. *Psychometrika*. 29: 115–129.
- LaBerge, W. E. 1969. A revision of the bees of the genus *Andrena* of the western hemisphere. Part II. *Plastandrena*, *Aporandrena*, *Charitandrena*. *Transactions of the American Entomological Society*. 95: 1-47.
- LaBerge, W. E. 1986. A Revision of the Bees of the Genus *Andrena* of the Western Hemisphere. Part XII. Subgenera *Leucandrena*, *Ptilandrena*, *Scoliandrena* and *Melandrena*. *Transactions of the American Entomological Society*. 112(3):191-248.
- MacKillop, D., Ehman, A. 2016. A Field Guide to Site Classification and Identification for Southeast British Columbia: The South-Central Columbia Mountains. Province of B.C., Victoria, B.C.
- McFrederick, Q.S., Lebuhn, G. 2006. Are urban parks refuges for bumblebees *Bombus* spp. (Hymenoptera: Apidae)? *Biological Conservation*, 129, 372–382.
<https://doi.org/10.1016/j.biocon.2005.11.004>.
- McGinley, R. J. 1986. Studies of Halictinae (Apoidea: Halictidae), I: Revision of New World *Lasioglossum* Curtis. *Smithsonian Contributions in Zoology*. 429: 1-294.
- Michener, C. D. 2007. *The Bees of the World*. Johns Hopkins University Press, Baltimore. 992 pgs.
- Moroń, D., Szentgyörgyi, H., Wantuch, M., Celary, W., Westphal, C., Settele, J., Woyciechowski, M. 2008. Diversity of wild bees in wet meadows: Implications for conservation. *Wetlands*, 28(4) :975-983.
- 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*. R package version 2.5-7. <https://CRAN.R-project.org/package=vegan>
- Parachnowitsch, A. L., Elle, E. 2005. Insect visitation to wildflowers in the endangered Garry Oak, *Quercus garryana*, Ecosystem of British Columbia. *Canadian Field-Naturalist* 119(2): 245-253.
- Potts, S.G., Vulliamy, B., Roberts, S., O'Toole, C., Dafni, A., Ne'Eman, G., Willmer, P., 2005. Role of nesting resources in organizing diverse bee communities in a Mediterranean landscape. *Ecol. Entomol.* 30, 78–85. <https://doi.org/10.1111/j.0307-6946.2005.00662.x>.
- Purvis, E.E.N., Vickruck, J.L., Best, L.R., Devries, J.H., Galpern, P. 2020. Wild bee community recovery in restored grassland-wetland complexes of prairie North America. *Biol. Conserv.* 252, 108829. <https://doi.org/10.1016/j.biocon.2020.108829>.
- R Core Team. 2021. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. <https://www.R-project.org/>.
- Roberts, R. B. 1973a. Bees of Northwestern America: *Agapostemon* (Hymenoptera: Halictidae). Technical Bulletin. Oregon State University. Agricultural Experiment Station. 125.

- Roberts, R. B. 1973b. Bees of Northwestern America: *Halictus* (Hymenoptera: Halictidae). Technical Bulletin. Oregon State University. Agricultural Experiment Station. 126.
- Sardiñas, H.S., Kremen, C., 2014. Evaluating nesting microhabitat for ground-nesting bees using emergence traps. *Basic Appl. Ecol.* 15, 161–168. <https://doi.org/10.1016/j.baae.2014.02.004>.
- Schuster, R., R.R. Germain, J.R. Bennett, N.J. Reo, P. Arcese. 2019. Vertebrate biodiversity on indigenous-managed lands in Australia, Brazil, and Canada equals that in protected areas, *Environmental Science & Policy* 101: 1-6.
- Sheffield, C. S., Ratti, C., Packer, L., Griswold, T. 2011. Leafcutter and Mason Bees of the Genus *Megachile Latreille* (Hymenoptera: Megachilidae) in Canada and Alaska. *Canadian Journal of Arthropod Identification*. No.18.
- Stang, M., Klinkhamer, P.G.L., van der Meijden, E. 2006. Size constraint and flower abundance determine the number of interactions in a plant-flower visitor web. *Oikos*, **112**, 111–121. <https://doi.org/10.1111/j.0030-1299.2006.14199.x>
- Steffan-Dewenter, I., Tschardt, T., 2001. Succession of bee communities on fallows. *Ecography*, 24, 83–93. <https://doi.org/10.1034/j.1600-0587.2001.240110.x>.
- Stephen, W. P. 1954. A revision of the bee genus *Colletes* in America north of Mexico. *University of Kansas Science Bulletin*. 36: 149-527.
- Stevens, M., D.C. Darris, Lambert, S.M. 2001. Ethnobotany, Culture, Management, and Use of Common Camas. *Native Plants Journal* 2(1) 47-53.
- Thoms, A. 2008. The Fire Stones Carry: Ethnographic Records and Archaeological Expectations for Hot-rock Cookery in Western North America. *Journal of Anthropological Archaeology* 27:443–460.
- Tonietto, R.K., Ascher, J.S., Larkin, D.J., 2017. Bee communities along prairie restoration chronosequence: similar abundance and diversity, distinct composition. *Ecol. Appl.* 27, 705–717. <https://doi.org/10.1002/eap.1481>.
- 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**, 32–41. <https://doi.org/10.1111/icad.12264>.
- Westcott, L. Irvine, R. 2010. Native Bee Survey of the Lower Columbia River (Hugh L. Keenleyside Dam to Canada-US Border). Report Prepared for the Fish and Wildlife Compensation Program (Columbia Region), Nelson, BC.
- Wickham, H. ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag New York, 2016.
- Woyciechowski, M. 2008. Diversity of wild bees in wet meadows: implications for conservation. *Wetlands* 28, 975–983.

Appendix A Extended General BBCH Plant Phenology Scale

Phenological Growth Stages (Extended General BBCH-scale Hacket al., 1992)

D = Dicotyledons

M = Monocotyledons

V = Development from vegetative parts or propagated organs.

P = Perennial plants

(Graminoid-specific stages have been excluded)

No code letter is used if the description applies to all groups of plants.

Code	Plant type	Description
<i>Principal growth stage 0: Germination, sprouting, bud development</i>		
00		Dry seed
	V	Perennating or reproductive organs during the resting period (tuber, rhizome, bulb, stolon)
	P	Winter dormancy or resting period
01		Beginning of seed imbibition
	P, V	Beginning of bud swelling
03		Seed imbibition complete
	P, V	End of bud swelling
05		Radicle (root) emerged from seed
	V	Perennating or reproductive organs forming roots
06		Elongation of radicle, formation of root hairs and/or lateral roots
07	D, M	Hypocotyl with cotyledons or shoot breaking through seed coat
	P, V	Beginning of sprouting or bud breaking
08	D	Hypocotyl with cotyledons or shoot growing towards soil surface
	D, M	Emergence: Cotyledons break through soil surface (except hypogeal germination);
09	V	Emergence: Shoot/Leaf breaks through soil surface
	P	Buds show green tips
<i>Principal growth stage 1: Leaf development (main shoot)</i>		
10	M	First true leaf emerged from coleoptile
	D	Cotyledons completely unfolded
	P	First leaves separated
11		First true leaf, leaf pair or whorl unfolded
	P	First leaves unfolded
12		2 true leaves, leaf pairs or whorls unfolded
13		3 true leaves, leaf pairs or whorls unfolded
1 .		Stages continuous till ...
19		9 or more true leaves, leaf pairs or whorls unfolded

<i>Principal growth stage 2: Formation of side shoots / tillering</i>		
21		First side shoot visible
22		2 side shoots visible
23		3 side shoots visible
2 .		Stages continuous till ...
29		9 or more side shoots visible
<i>Principal growth stage 3: Stem elongation /shoot development (main shoot)</i>		
30		Beginning of stem elongation
31		1 visibly extended internode
32		2 visibly extended internode;
33		3 visibly extended internode
3 .		Stages continuous till ...
39		9 or more visibly extended internodes
<i>Principal growth stage 4: vegetative propagation / booting (main shoot)</i>		
40	V	Vegetative reproductive organs begin to develop (rhizomes, stolons, tubers, runners, bulbs)
42	V	First young plant visible
43	V	Vegetative organs have reached 30% of final size
45	V	Vegetative organs have reached 50% of final size
47	V	Vegetative organs have reached 70% of final size
49	V	Constant new development of young plants; vegetative reproductive organs reach final size
<i>Principal growth stage 5: Inflorescence emergence (main shoot) / heading</i>		
51		Inflorescence or flower buds visible
55		First individual flowers visible (still closed)
59		First flower petals visible (in petalled forms)
<i>Principal growth stage 6: Flowering (main shoot)</i>		
60		First flowers open (sporadically)
61		Beginning of flowering: 10% of flowers open
63		30% of flowers open
65		Full flowering: 50% of flowers open, first petals may be fallen
67		Flowering finishing: majority of petals fallen or dry
69		End of flowering: fruit set visible
<i>Principal growth stage 7: Development of fruit</i>		
71		Fruits begin to develop
79		Nearly all fruits have reached final size normal for the species and location
<i>Principal growth stage 8: Ripening or maturity of fruit and seed</i>		
81		Beginning of ripening or fruit coloration
89		Fully ripe
<i>Principal growth stage 9: Senescence, beginning of dormancy</i>		
97		End of leaf fall, plants or above ground parts dead or dormant;
	P, V	Plant resting or dormant

Appendix B Checklist of Plants by Site

Family Scientific Name	English Name	N/E	Crescent Valley	kp'it'lels	Lower Marsden	Mount Sentinel	Oxbow Mainland	Upper Marsden
APIACEAE								
<i>Lomatium triternatum</i>	nine-leaved desert-parsley	N	x					
<i>Perideridia montana</i>	common yampah	N			x	x		x
ASTERACEAE								
<i>Achillea millefolium</i>	yarrow	N	x		x	x		x
<i>Anaphalis margaritacea</i>	pearly everlasting	N	x					
<i>Antennaria howellii</i>	Howell's pussytoes	N			x			
<i>Centaurea stoebe</i>	spotted knapweed	E	x	x	x	x		x
<i>Conyza canadensis</i>	horseweed	N		x				
<i>Hieracium gracile</i>	slender hawkweed	N		x				
<i>Hieracium scouleri</i>	Scouler's hawkweed	N	x					
<i>Hieracium</i> sp.	hawkweed	E						x
<i>Leucanthemum vulgare</i>	oxeye daisy	E	x	x			x	x
<i>Logfia arvensis</i>	field filago	E		x				
<i>Madia gracilis</i>	slender tarweed	N				x		
<i>Microseris nutans</i>	nodding microseris	N			x			
<i>Packera paupercula</i>	Canadian butterweed	N		x				
<i>Symphotrichum subspicatum</i>	Douglas' aster	N		x				
<i>Taraxacum officinale</i>	common dandelion	E	x				x	
<i>Tragopogon dubius</i>	yellow salsify	E	x		x	x		x
BERBERIDACEAE								
<i>Mahonia aquifolium</i>	tall Oregon-grape	N	x	x	x	x		x
BETULACEAE								
<i>Corylus cornuta</i>	beaked hazelnut	N	x					
BORAGINACEAE								
<i>Myosotis arvensis</i>	field forget-me-not	E						x
<i>Myosotis laxa</i>	small-flowered forget-me-not	N		x	x	x		x
BRASSICACEAE								
<i>Arabidopsis thaliana</i>	mouse-ear	E			x	x		x
<i>Boechea stricta</i>	straight-up sunress	N	x					
<i>Brassica</i> sp.	unidentified brassicaceae	E		x				
<i>Sisymbrium altissimum</i>	tall tumble-mustard	E		x				

Family Scientific Name	English Name	N/E	Crescent Valley	kp 'it'lels	Lower Marsden	Mount Sentinel	Oxbow Mainland	Upper Marsden
CAMPANULACEAE								
<i>Campanula rotundifolia</i>	common harebell	N	x					
CAPRIFOLIACEAE								
<i>Symphoricarpos albus</i>	common snowberry	N	x	x	x		x	
<i>Viburnum edule</i>	highbush-cranberry	N					x	
CARYOPHYLLACEAE								
<i>Arenaria serpyllifolia</i>	thyme-leaved sandwort	E	x		x	x		x
<i>Cerastium arvense</i>	field chickweed	N				x		
<i>Cerastium fontanum</i>	mouse-ear chickweed	E	x	x	x	x	x	
<i>Cerastium glomeratum</i>	sticky chickweed	E		x		x		
<i>Silene antirrhina</i>	sleepy catchfly	N				x		x
CLUSIACEAE								
<i>Hypericum perforatum</i>	common St. John's- wort	E		x				
CRASSULACEAE								
<i>Sedum stenopetalum</i>	worm-leaved stonecrop	N			x	x		x
FABACEAE								
<i>Lupinus sericeus</i>	silky lupine	N	x		x			x
<i>Lupinus X.</i>	Russell lupine	X					x	
<i>Medicago lupulina</i>	black medic	E		x	x	x		
<i>Trifolium arvense</i>	hare's-foot clover	E	x		x	x		
<i>Trifolium aureum</i>	yellow clover	E	x	x				x
<i>Trifolium pratense</i>	red clover	E	x		x	x		
<i>Vicia villosa</i>	hairy vetch	E		x		x		
GERANIACEAE								
<i>Geranium bicknellii</i>	Bicknell's geranium	N			x	x		x
HYDRANGACEAE								
<i>Philadelphus lewisii</i>	mock-orange	N			x	x		x
IRIDACEAE								
<i>Sisyrinchium montanum</i>	mountain blue-eyed- grass	N		x				
LAMIACEAE								
<i>Prunella vulgaris</i>	self-heal	N		x				x
LILIACEAE								
<i>Allium cernuum</i>	nodding onion	N		x	x	x		x
<i>Allium schoenoprasum</i>	wild chives	N		x				
<i>Asparagus officinalis</i>	garden asparagus	E		x				
<i>Camassia quamash</i>	common camas	N	x	x	x	x	x	x

Family Scientific Name	English Name	N/E	Crescent Valley	kp 'it'lels	Lower Marsden	Mount Sentinel	Oxbow Mainland	Upper Marsden
<i>Lilium columbianum</i>	tiger lily	N	x					
<i>Maianthemum stellatum</i>	star-flowered false Solomon's-seal	N		x				
<i>Toxicoscordion venosum</i>	meadow death-camas	N	x		x	x		x
<i>Triteleia grandiflora</i>	large-flowered triteleia	N			x	x		x
OLEACEAE								
<i>Ligustrum vulgare</i>	common privet	E					x	
ONAGRACEAE								
<i>Clarkia pulchella</i>	pink fairies	N						x
<i>Epilobium brachycarpum</i>	tall annual willowherb	N						x
<i>Epilobium</i> sp.	willowherb	N			x	x		
ORCHIDACEAE								
<i>Platanthera elegans</i>	elegant rein orchid	N			x			
<i>Platanthera elongata</i>	tall rein orchid	N		x				
OROBANCHACEAE								
<i>Castilleja hispida</i>	harsh paintbrush	N	x			x		x
<i>Orobanche uniflora</i>	naked broomrape	N				x		x
PHRYMACEAE								
<i>Erythranthe guttata</i>	yellow monkey-flower	N						x
PLANTAGINACEAE								
<i>Plantago lanceolata</i>	ribwort plantain	E	x	x	x		x	
POLEMONIACEAE								
<i>Collomia linearis</i>	narrow-leaved collomia	N			x	x		
POLYGONACEAE								
<i>Rumex acetosa</i>	green sorrel	E		x				
<i>Rumex acetosella</i>	sheep sorrel	E	x	x	x	x	x	
PORTULACACEAE								
<i>Montia linearis</i>	narrow-leaved montia	N	x			x		
<i>Montia parvifolia</i>	small-leaved montia	N						x
PRIMULACEAE								
<i>Dodecatheon pulchellum</i>	few-flowered shootingstar	N				x		
RANUNCULACEAE								
<i>Delphinium nuttallianum</i>	upland larkspur	N				x		
<i>Ranunculus acris</i>	meadow buttercup	E					x	
RHAMNACEAE								

Family Scientific Name	English Name	N/E	Crescent Valley	kp 'itl'els	Lower Marsden	Mount Sentinel	Oxbow Mainland	Upper Marsden
<i>Ceanothus sanguineus</i>	redstem ceanothus	N			x			
<i>Rhamnus purshiana</i>	cas cara	N					x	
ROSACEAE								
<i>Amelanchier alnifolia</i>	saskatoon	N	x	x	x		x	x
<i>Crataegus douglasii</i>	black hawthorn	N		x		x	x	
<i>Drymocallis arguta</i>	tall cinquefoil	N	x		x	x	x	x
<i>Fragaria vesca</i>	wood strawberry	N		x	x			x
<i>Holodiscus discolor</i>	oceanspray	N			x	x		x
<i>Physocarpus malvaceus</i>	mallow ninebark	N			x	x		x
<i>Potentilla argentea</i>	silvery cinquefoil	E	x					
<i>Potentilla recta</i>	sulphur cinquefoil	E	x		x	x		x
<i>Prunus virginiana</i>	choke cherry	N				x		x
<i>Rosa gymnocarpa</i>	baldhip rose	N						
<i>Rosa nutkana</i>	Nootka rose	N		x	x	x		
<i>Sorbus sp.</i>	mountain ash	N					x	
<i>Spiraea lucida</i>	shiny-leaved meadowsweet	N	x		x			x
RUBIACEAE								
<i>Galium aparine</i>	cleavers	N				x		x
<i>Galium trifidum</i>	small bedstraw	N				x		
<i>Galium triflorum</i>	sweet-scented bedstraw	N						
SALICACEAE								
<i>Populus trichocarpa</i>	black cottonwood	N		x				
SAXIFRAGACEAE								
<i>Hemieva ranunculifolia</i>	buttercup-leaved suksdorfia	N				x		x
<i>Heuchera cylindrica</i>	round-leaved alumroot	N				x		x
<i>Heuchera glabra</i>	smooth alumroot	N				x		
<i>Lithophragma parviflorum</i>	small-flowered fringecup	N			x	x		x
<i>Micranthes nidifica</i>	meadow saxifrage	N				x		
SCROPHULARIACEAE								
<i>Collinsia parviflora</i>	small-flowered blue- eyed Mary	N				x		x
<i>Penstemon confertus</i>	yellow penstemon	N	x					
<i>Veronica arvensis</i>	wall speedwell	E		x		x		
<i>Veronica peregrina</i>	purslane speedwell	N			x			
<i>Veronica serpyllifolia</i>	thyme-leaved speedwell	E					x	

Family Scientific Name	English Name	N/E	Crescent Valley	kp'it'lels	Lower Marsden	Mount Sentinel	Oxbow Mainland	Upper Marsden
<i>Veronica verna</i>	spring speedwell	E	x			x		x
VALERIANACEAE								
<i>Valerianella locusta</i>	cornsalad	E			x			x
VIOLACEAE								
<i>Viola nephrophylla</i>	northern bog violet	N					x	

Appendix C Checklist of Bees and their Status Rankings

Family	Species	Prov.	BC List	COSEWIC
Andrenidae				
	<i>Andrena nigrocaerulea</i> Cockerell, 1897	S5	No Status	
	<i>Andrena nivalis</i> Smith, 1853	S5	No Status	
	<i>Andrena prunorum</i> Cockerell, 1896	S5	No Status	
	<i>Andrena transnigra</i> Viereck, 1904	S5	No Status	
	<i>Andrena</i> sp. 1			
	<i>Andrena</i> sp. 2			
Colletidae				
	<i>Colletes compactus</i> Cresson, 1868	S4	No Status	
	<i>Hylaeus</i> sp. 1			
	<i>Hylaeus</i> sp. 2			
Halictidae				
	<i>Agapostemon virescens</i> (Fabricius, 1775)	S5	No Status	
	<i>Halictus rubicundus</i> (Christ, 1791)	S5	No Status	
	<i>Halictus farinosus</i> Smith, 1853	S4S5	No Status	
	<i>Halictus ligatus</i> Say, 1837	S5	No Status	
	<i>Halictus tripartitus</i> Cockerell, 1895	S4S5	No Status	
	<i>Lasioglossum cressonii</i> (Robertson, 1890)	S5	No Status	
	<i>Lasioglossum egregium</i> (Vachal, 1904)	SU	No Status	
	<i>Lasioglossum leucozonium</i> (Schrank, 1781)			
	<i>Lasioglossum mellipes</i> (Crawford, 1907)	SU	No Status	
	<i>Lasioglossum nigroviride</i> (Graenicher, 1911)	S5	No Status	

<i>Lasioglossum zonulum</i> (Smith, 1848)	SNA	Exotic	
<i>Lasioglossum</i> sp. 1			
<i>Lasioglossum</i> sp. 2			
<i>Lasioglossum</i> sp. 3			
<i>Lasioglossum</i> sp. 4			
<i>Lasioglossum (Dialictus)</i> sp. 1			
<i>Lasioglossum (Dialictus)</i> sp. 2			
<i>Lasioglossum (Dialictus)</i> sp. 3			
<i>Lasioglossum (Dialictus)</i> sp. 4			
<i>Lasioglossum (Dialictus)</i> sp. 5			
<i>Lasioglossum (Dialictus)</i> sp. 6			
<i>Lasioglossum (Dialictus)</i> sp. 7			
<i>Lasioglossum (Dialictus)</i> sp. 8			
<i>Lasioglossum (Dialictus)</i> sp. 9			
<i>Sphecodes</i> sp. 1			
<i>Sphecodes</i> sp. 2			
Megachilidae			
<i>Coelioxys sodalis</i> Cresson, 1878	S3S4	No Status	
<i>Hoplitis hypocrita</i> (Cockerell, 1906)	SU	No Status	
<i>Osmia atrocyanea</i> Cockerell, 1897	SU	No Status	
<i>Osmia bruneri</i> Cockerell, 1897	SU	No Status	
<i>Osmia californica</i> Cresson, 1864	S4S5	No Status	
<i>Osmia densa</i> Cresson, 1864	S5	No Status	

	<i>Osmia lignaria</i> Say, 1837	S5	No Status	
	<i>Osmia longula</i> Cresson, 1864	S5	No Status	
	<i>Osmia marginipennis</i> Cresson, 1878	SU	No Status	
	<i>Osmia simillima</i> Smith, 1853	S5	No Status	
	<i>Osmia</i> sp. 1			
	<i>Osmia</i> sp. 2			
	<i>Osmia</i> sp. 3			
	<i>Osmia</i> sp. 4			
	<i>Osmia</i> sp. 5			
	<i>Osmia</i> sp. 6			
	<i>Osmia</i> sp. 7			
	<i>Osmia</i> sp. 8			
	<i>Osmia</i> sp. 9			
	<i>Osmia</i> sp. 10			
	<i>Osmia</i> sp. 11			
	<i>Osmia</i> sp. 12			
	<i>Osmia</i> sp. 13			
	<i>Megachile melanophaea</i> Smith, 1853	S5	No Status	
	<i>Megachile perihirta</i> Cockerell, 1898	S5	No Status	
Apidae				
	<i>Anthophora ursina</i> Cresson, 1869	S3S4	No Status	
	<i>Apis mellifera</i> Linnaeus, 1758	SNA	Exotic	
	<i>Bombus appositus</i> Cresson, 1879	S5	Yellow	
	<i>Bombus bifarius</i> Cresson, 1879	S5	Yellow	

<i>Bombus centralis</i> Cresson, 1864	S5	Yellow	
<i>Bombus flavidus</i> Eversmann, 1852	S3S4	Blue	
<i>Bombus flavifrons</i> Cresson, 1864	S5	Yellow	
<i>Bombus insularis</i> (Smith, 1861)	S4?	Yellow	
<i>Bombus melanopygus</i> Nylander, 1848	S5	Yellow	
<i>Bombus mixtus</i> Cresson, 1879	S5	Yellow	
<i>Bombus nevadensis</i> Cresson, 1874	S5	Yellow	
<i>Bombus occidentalis</i> Greene, 1858	S2S4	Blue	T
<i>Bombus rufocinctus</i> Cresson, 1864	S5	Yellow	
<i>Bombus vagans</i> Smith, 1854	S5	Yellow	
<i>Ceratina acantha</i> Provancher, 1895	S5	No Status	
<i>Ceratina nanula</i> Cockerell, 1897	S4S5	No Status	
<i>Eucera cordleyi</i> (Viereck, 1905)	SU	No Status	
<i>Habropoda cineraria</i> (Smith, 1879)	S5	No Status	
<i>Melecta thoracica</i> Cresson, 1875	S2S3	No Status	
<i>Melecta pacifica</i> Cresson, 1879	S2S3	No Status	
<i>Nomada</i> sp. 1			
<i>Nomada</i> sp. 2			
<i>Nomada</i> sp. 3			
<i>Nomada</i> sp. 4			