

Low to Mid Elevational Resurvey of Bumble bee Distributions in Response to Climate Change

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Abstract

In 1974, Graham Pyke conducted a study that examined *Bombus* spp. distributions along five transects around the Rocky Mountain Biological Laboratory area in Crested Butte, CO. The study was repeated in 2007 and within the intervening 33-year period, it showed that certain species of bumble bees had shifted higher in elevation due to climate change. The study has been repeated every five to seven years since 2007 with the most recent re-survey carried out in 2014. These studies are intended to use bumble bees as an ideal indicator of climate change due to their rapid life cycle. In 2019, I repeated the study using only low to mid-elevation sites to determine whether there was an increase or decrease in relative abundance compared to 2014. Data was collected by capturing bumble bees, identifying them in the field, and also taking photos of bumble bees in a clear cylindrical PVC tube to confirm field identifications. I also recorded the flower species the bumble bees were collected off of. Floral surveys were also conducted to assess whether floral distributions affected bumble bee distributions. We found a general increase in low-elevation species and a general decrease in high-elevation species over the elevation range that I studied, with the exception of one species. Comparison of floral phenology over a short period of time suggested that some plants were present in 2014 that were not present in 2019, which may be attributed to climate change or successional changes in the sites over time. The findings indicated that bumble bee species composition at each site has slightly shifted, but a larger sampling over the entire elevation range will help indicate whether these slight shifts are due to climate change or other unmeasured factors.

Introduction

Climate change is considered one of the largest anthropogenic factors affecting ecosystems today. Effects of climate change, including rising CO₂ levels that alter the biophysical environment by increasing the temperature, pH level, and nutrient availability have a direct impact on the ability of organisms to survive, grow, and reproduce. Often, the populations of species react with extinction or dispersal (Sears and Angilleta, 2011). As a result, the abundance and distribution of populations are impacted (Parmesan, 2006; Ogilvie et al., 2017). It is crucial to understand a species' altered relationships with its environment as the communities will shift as a whole. Pollinators are crucial to the flora and fauna of ecosystems. Climate change could affect the phenology, abundance, and distributions of plants and pollinators. Their interactions can also change if flowers have an earlier blooming schedule and if pollinators maintain the same emergence schedule. Alterations in trophic energy flow and plant-herbivore interactions have already been recorded (Durant et al., 2007). Pollination interactions are mutualistic and benefit biodiversity by providing food and reproductive success for the species in the relationship.

Bumble bees (*Bombus spp.*) are important and effective pollinators in agriculture and natural systems noted particularly for their size, tongues, and pollination behavior (Cameron et al., 2018). They are eusocial insects, consisting of three castes: queen, workers, and males which each appear at different intervals of the breeding season. After spring queens have foraged for a new nest, workers start to emerge around early summer with males and daughter queens emerging in late summer. Declines in bumble bee populations in North America have been attributed to the introduction of an invasive parasite (Goulson, Lye, and Darvill, 2007), although other factors may include habitat loss and pesticide usage (Szabo et al., 2012). Moreover, climate change is a big concern in declining bumble bee populations, especially in montane regions as

extreme shifts in climate have been experienced (Nogués-Bravo et al., 2007). As a result, some bumble bee species have shifted in latitude and elevation (Pyke et al., 2016; Kerr et al., 2015). In earlier snowmelt years, increased temperature will generally indicate that flowers will be blooming earlier while bumble bees and other pollinators are not changing at the same rate as the flowering species. (Kudo and Cooper, 2019), although it is uncertain whether this phenomenon is region specific.

In 1974, a survey of bumble bees was taken along with the plants they visit and in 2007 with an intervening 33-year period to account for the impact of climate change at the Rocky Mountain Biological Laboratory (RMBL) in Gothic, CO. These distributions were measured again in 2014. The results of the study done by Pyke et al. suggested that significant shifts were observed on bumble bee queens and workers and the relationship between plants and pollinators experienced asynchrony as plants at lower elevations flowered earlier. By measuring the number of bumble bees at sites that have been previously sampled, data can be compared to test for the effects of climate change on bumble bee populations every five to seven years. Without enough pollination resources, we predict that the early flowering plants will lose out on pollination while bumble bees will move to higher elevations where the temperature remains consistent with their preferred flowering time to find food. A decline in bumble bee populations at the lower elevations may not necessarily indicate that bumble bees as a genus are declining but rather that it is migrating. Using bumble bees as a model species is crucial as it may provide insights on how other pollinators react to climate change.

This study seeks to draw further conclusions to the previous study in relation to how *Bombus spp.* distributions vary as a result of a changing climate. The objectives of this study are to expand the prior studies by resurveying the transects again to 1) assess whether bumble bee

distributions have continued to change, and 2) investigate whether the relative abundances of bees across elevational gradients have changed. We hypothesize that bumble bee distributions will vary at each of the different sites. Since we are primarily sampling low to mid elevation sites, certain species of bumble bees more commonly found in lower elevations in previous surveys will be found in mid elevation sites while low elevation sites will experience a change in community composition compared to the results from 2014 and potentially an invasion of the bumble bee *Bombus huntii* which has historically occurred at lower elevations than those sampled in this study. I also predict that the relative abundance of some bumble bee species will shift due to climate change.

Methods

Elevational Gradients

Throughout the period of June 28 to August 2, 2019, low and mid elevation sites were sampled along Gothic Road. Over an elevational gradient of 287 m, ranging from the town of Crested Butte, CO (approx. elevation 2715 m) with a maximum elevation of 3002 m, sites at low and mid elevations are already established by Dr. Graham Pyke in 1974 and have been resurveyed in 2007 by Tim Miller and in 2014 by Jessica Zung. The original sites were five transects ranging in elevation from Gothic Road to Schofield. Only 2 of the five transects are resurveyed in 2019. The sites are resurveyed once a week for around thirty minutes to one and a half hours per site depending on time constraints. Helpers and I walked through the sites to identify bumble bees by species and caste as well as overall floral abundance. Bumble bees were identified through a guide created by RMBL scientists of all the common *Bombus* species found around the Rocky Mountain Biological Laboratory area.

Table 1. Description of Sites surveyed 2019

Site	Elevation (m)	Longitude (d m)	Latitude (d m)	Total time (min)
GOTH 3	2906	38°58.19501'	-106°59.73042'	272
GOTH 4	2909	38°58.34186'	-106°59.80924'	315
GOTH 5	2924	38°58.93918'	-107°00.41508'	331
GOTH 6	2948	38°59.19830'	-107°00.56376'	155
GOTH 7	2975-3000	38°59.46405'	-107°00.82889'	166
GOTH 8	3002	38°59.82252'	-107°01.06513'	62

Bumble bee-plant interactions

As a bumble bee is observed on a flower, I captured it using a hand net and placed in a photo booth, which consisted of a small see-through PVC cylinder with a crevice for the bumble bee to sit in and a smaller PVC cylinder on top to hold the bumble bee in place as a camera fits on top to take multiple images of the individual to confirm our field identifications. A photograph was also taken of the plant that the bumble bee was caught off. Once sufficient pictures have been taken for identification, the bumble bee was transferred to a bee squeezer, made of a plastic tube cylinder with a fabric mesh covering on one end and a piece of foam plunger on the other where the bumble bee will be pushed against the mesh and marked with a paint pen on its thorax to avoid encounters with the same individual and released.

Figure 1. View of a Photo Booth, top view (left), top view (right)



Floral Abundance

At each site, during each survey, a floral survey was also conducted to determine the abundance of flowers in accordance to bee preference. According to Miller et al. (2007), a 4-point rank scale was used to establish plant abundance as follows:

Table 2. Description of the ranking system used to quantify floral abundance.

Rank	Description
1	One to several occurrence
2	Scattered occurrence
3	Moderately abundant
4	A Dominant Species

Plants were identified using *Wild about Wildflowers: Extreme Botanizing in Crested Butte, Wildflower Capital of Colorado* (2006) by Katherine Darrow.

Analysis

Our estimates of bee distributions were compared with the most recent prior survey from 2014. All data from 2019 was used leading up to August 2. The *Bombus* species for each site were separated and counted, and from these data I calculated proportions of each bee species sampled. I used the proportion data in two proportion z-tests were used to determine whether the dominant species at each site had increased or decreased in abundance. In 2014 and 2019, bees were divided into respective proportions and categorized according to the four most prevalent species at each of the similar sites: GOTH 3-GOTH 8. No Bonferroni Corrections were used and raw P-values are reported. Bees that do did not fall within the dominant species categories are were categorized as “Other.” All statistical analyses were conducted in R.

Results

Bee Relative Abundance

In 2014, there were 1,474 bees over 94.4 hours of netting compared to 108 bees in 2019 over 36.61 hours of netting. Similar species in both 2014 and 2019 included *B. bifarius*, *B. appositus*, *B. flavifrons*, and *B. sylvicola* in the highest quantity. Other similar species are were *B. mixtus*, *B. melanopygus*, *B. occidentalis*, *B. rufocinctus*, *B. nevadensis*, *B. Centralis*, *B. insularis* and *B. fervidus* (previously *B. californicus*). Species that were present in 2014 but not in 2019 were *B. balteatus*, *B. frigidus*, and *B. suckleyi*. The most abundant bee in 2014 was *B. flavifrons* with 395 captures while in 2019, *B. bifarius* is was the most commonly encountered with 32 captures. The least common species found in 2014 was *B. centralis* with only 1 capture whereas in 2019, *B. centralis* was caught 9 times.

Figure 2. Total number of bumble bees caught in 2019 in all sites

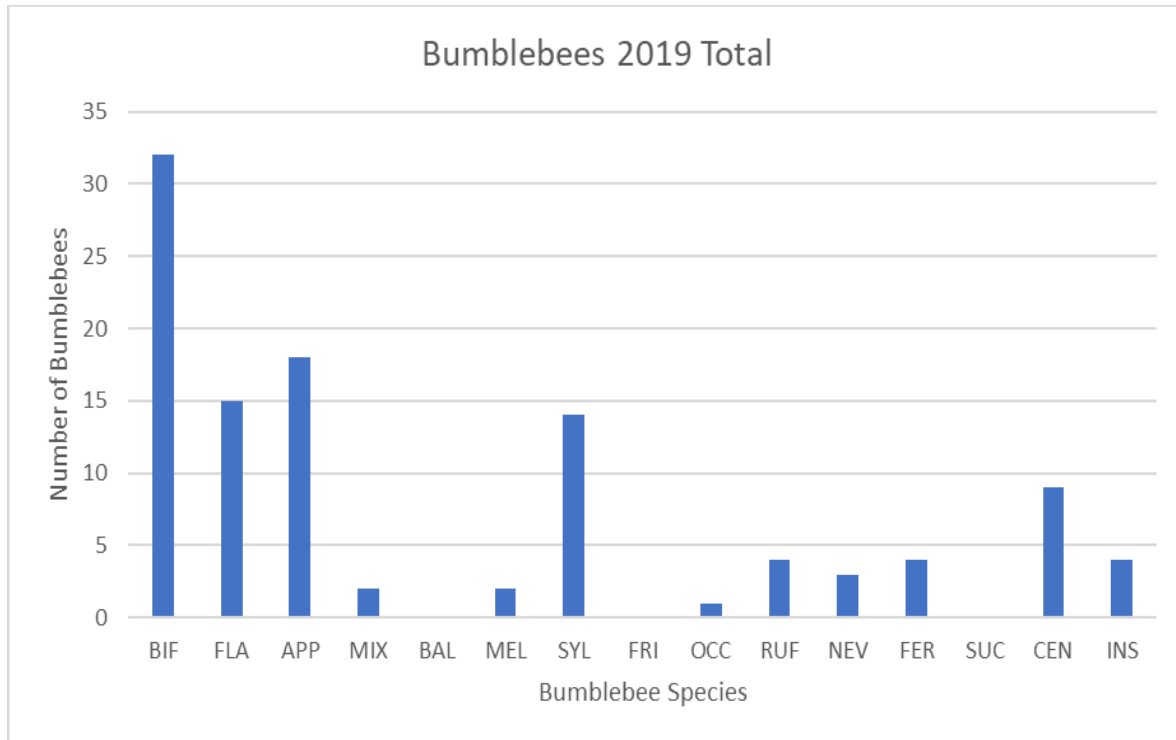
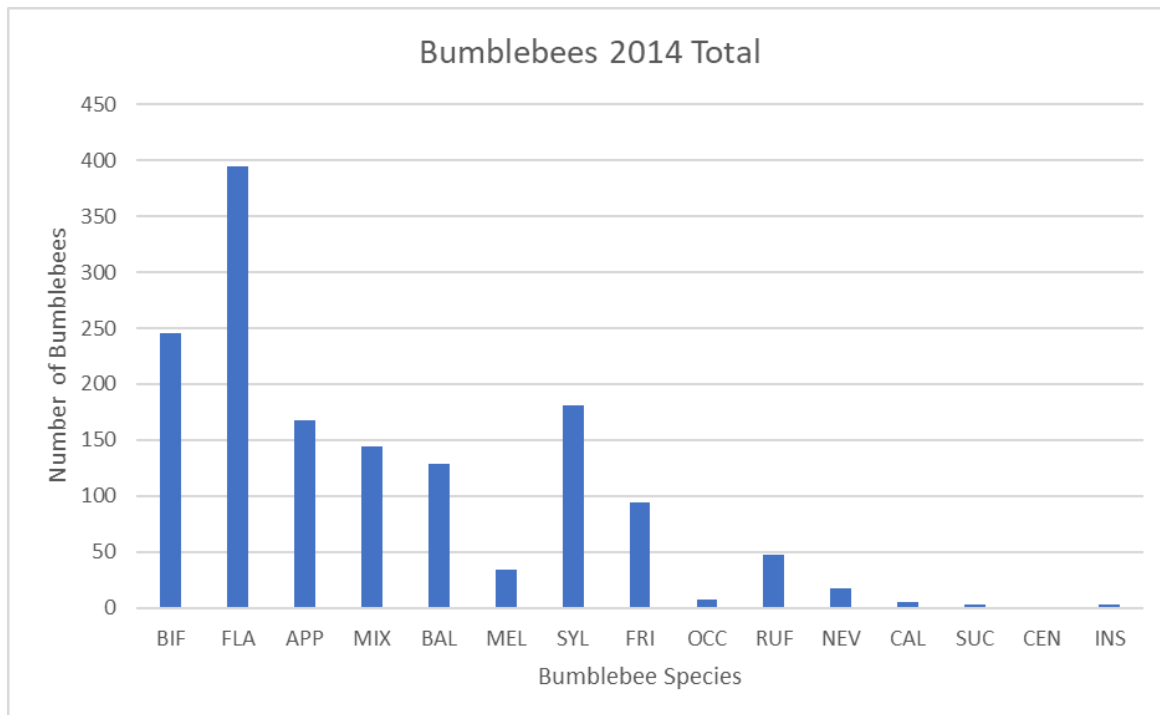
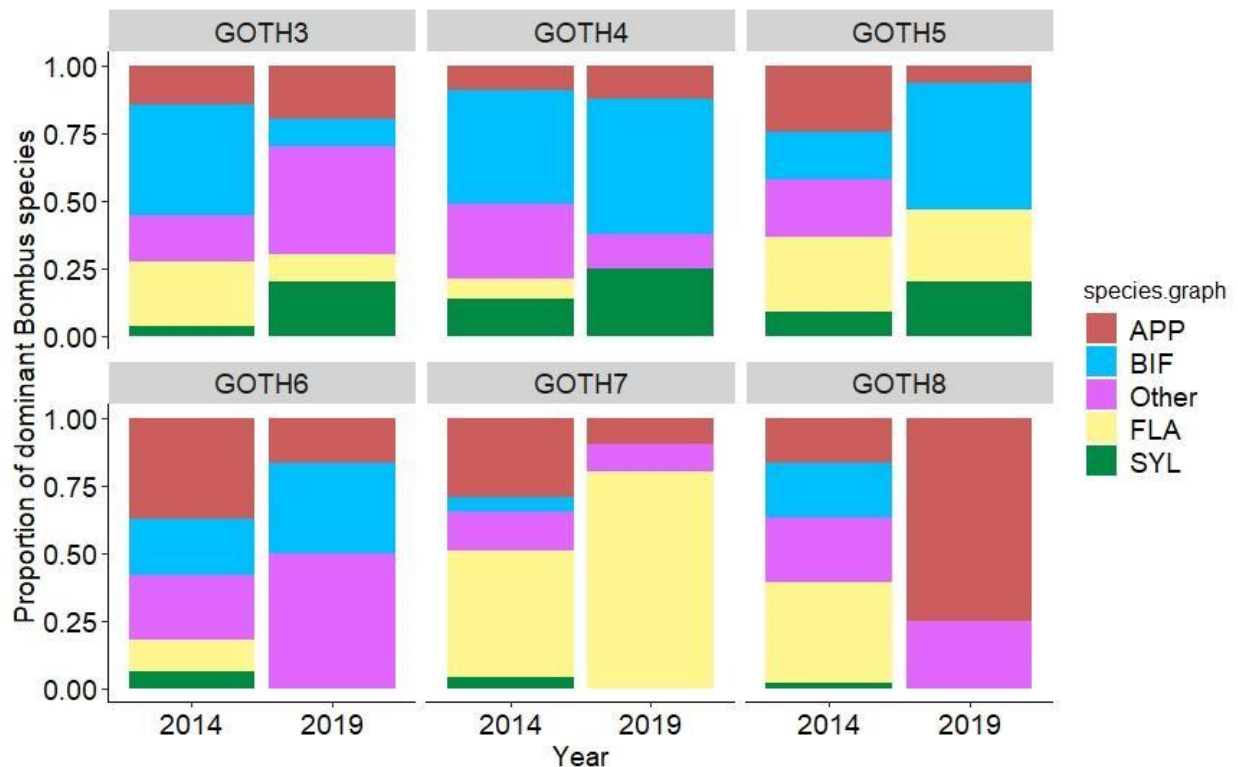


Figure 3. Total Number of Bumble bees caught in 2014 at all sites



Figures 2 and 3 show the total number of bumble bees caught in 2019 and 2014, respectively. In both of the figures, *B. appositus*, *B. melanopygus*, *B. occidentalis*, *B. rufocinctus*, and *B. sylvicola* remained similar in proportion while there was an overall increase in 2019 for *B. bifarius*, *B. nevadensis*, *B. fervidus*, *B. centralis*, and *B. insularis*, which are all low to mid-elevation species. In 2019, the presence of *B. flavifrons*, *B. mixtus*, *B. balteatus*, *B. frigidus*, and *B. suckleyi* have diminished. It should be noted that *B. flavifrons*, *B. mixtus*, *B. balteatus*, and *B. frigidus*, are primarily mid to high elevation species, while *B. suckleyi* is a low to mid-elevation species.

Figure 4. Distributions of Four Dominant *Bombus* Species over similar sites



Only six sites were used in comparison with the data from 2014 with an emphasis on four dominant *Bombus* species: *B. appositus*, *B. bifarius*, *B. flavifrons*, and *B. sylvicola*. Other similar

species in both 2014 and 2019 were denoted as “Other” since there was insufficient data to compare them individually. With each of the sites and dominant species, a two-proportion z-test was used to determine whether the dominant species increased or decreased in abundance (Table 3). For *B. bifarius*, there was no significant change in abundance in GOTH 3, GOTH 4, and GOTH 6 but *B. bifarius* in GOTH 5, GOTH 7, and GOTH 8 experienced significant change in relative abundance. The overall proportion of *B. bifarius* increased for GOTH 4, GOTH 5, and GOTH 6 and decreased for GOTH 3, GOTH 7, and GOTH 8. For *B. appositus*, there was no significant increase in abundance in any site except for GOTH 8. The proportion of *B. appositus* increased for GOTH 3, GOTH 4, and GOTH 8 in comparison to 2014 and decreased for GOTH 5, GOTH 6, and GOTH 7. *B. flavifrons* showed no significant change in any sites except for GOTH 4 and GOTH 6, which both did not have any encounters with *B. flavifrons* in 2019. The proportion of *B. flavifrons* increased in 2019 in GOTH 7 and decreased in all other sites. The presence of *B. sylvicola* did not have any significant changes in any sites except for GOTH 5. The proportion of *B. sylvicola* increased in 2019 in GOTH 3, GOTH 4, and GOTH 5 but was not recorded in GOTH 6, GOTH 7, and GOTH 8. In total, none of the “Other” bees experienced a significant change in abundance except for GOTH 5. The proportion of “Other” bumble bees experienced an increase in GOTH 3, GOTH 6, and GOTH 8 and a decrease in GOTH 4 and GOTH 7 and no non-dominant species was caught in GOTH 5 in 2019.

Table 3. Proportions and p Values of Dominant Species and Site. Significant p-values are bolded at the $P < 0.05$ level.

Species	Site	Proportion 2014	Proportion 2019	P
BIF	GOTH 3	0.4096386	0.1000000	0.1178
BIF	GOTH 4	0.4186047	0.5000000	0.9696

BIF	GOTH 5	0.1754386	0.4666667	0.04324
BIF	GOTH 6	0.2089552	0.3333333	0.8489
BIF	GOTH 7	0.05333333	0	No data
BIF	GOTH 8	0.2037037	0	No data
APP	GOTH 3	0.1445783	0.2000000	1
APP	GOTH 4	0.09302326	0.1250000	1
APP	GOTH 5	0.24561404	0.0666667	0.2456
APP	GOTH 6	0.3731343	0.1666667	0.5708
APP	GOTH 7	0.2933333	0.1000000	0.3608
APP	GOTH 8	0.1666667	0.7500000	0.0324
FLA	GOTH 3	0.2409639	0.1000000	0.5439
FLA	GOTH 4	0.06976744	0	No data
FLA	GOTH 5	0.2807018	0.2666667	1
FLA	GOTH 6	0.119403	0	No data
FLA	GOTH 7	0.4666667	0.8000000	0.1002
FLA	GOTH 8	0.3703704	0	0.07688
SYL	GOTH 3	0.03614458	0.2000000	0.1532
SYL	GOTH 4	0.1395349	0.2500000	0.7952
SYL	GOTH 5	0.2807018	0.2666667	1
,SYL	GOTH 6	0.05970149	0	No data
SYL	GOTH 7	0.04	0	No data
SYL	GOTH 8	0.01851852	0	No data
Other	GOTH 3	0.1686747	0.400000	0.185

Other	GOTH 4	0.2790698	0.125000	0.6338
Other	GOTH 5	0.2105263	0	No data
Other	GOTH 6	0.238806	0.500000	0.3621
Other	GOTH 7	0.1466667	0.100000	1
Other	GOTH 8	0.2407407	0.250000	1

Only *B. bifarius* in GOTH 5 and *B. appositus* in GOTH 8 have increased in relative abundance compared to 2014.

Bee Floral Preferences

Figure 4. Bumblebee floral preferences 2019

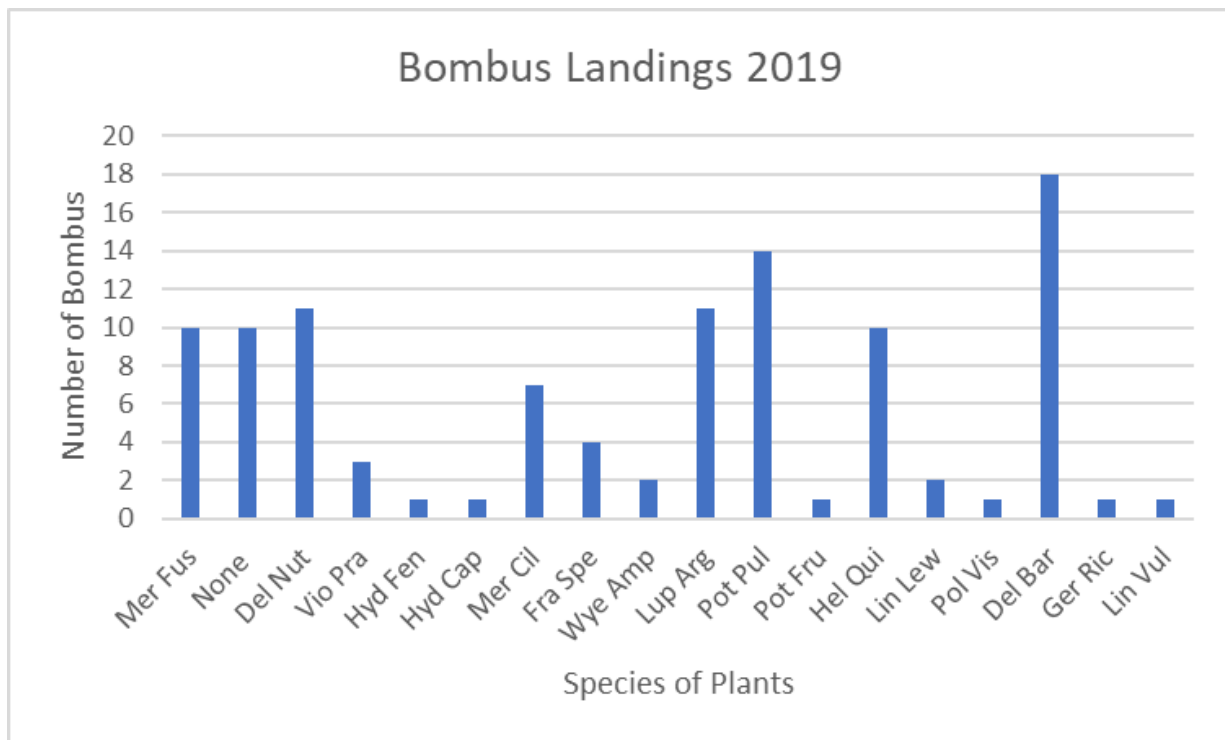
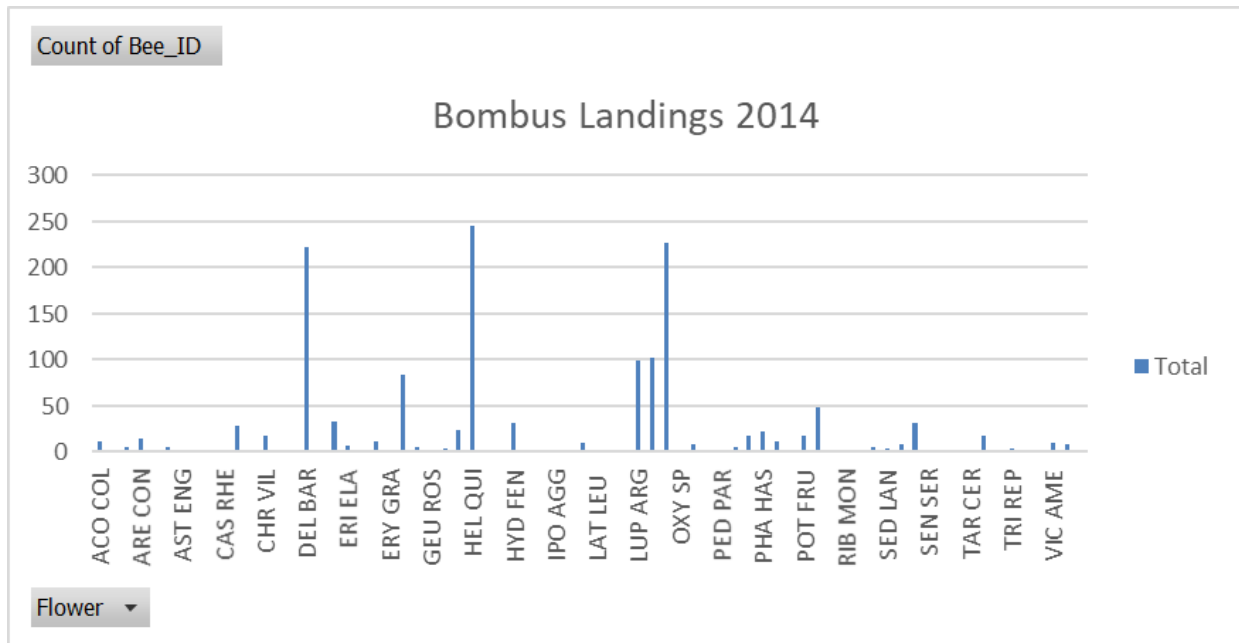


Figure 5. Bumble bee floral preferences 2014



Figures 4 and 5 show the number of bumble bees that landed on each different species of flowers in 2019 and 2014, respectively. The most preferred species in 2019 are *Delphinium barbeyi*, *Potentilla pulcherrima*, *Delphinium nuttallianum*, and *Lupinus argenteus* whereas in 2014, the plants with the most recorded bumble bee landings are *Helianthella quinquenervis*, *Delphinium barbeyi*, and *Lupinus argenteus*.

Discussion

Bee Relative Abundance

Many reasons may attribute to the discrepancy in bees caught in 2014 and 2019. Annual climatic variation may have played a role in the small number of workers found in 2019. Since 2019 was a late snowmelt year, three of five of the original transects at higher elevations were unable to be sampled, which lead to no evidence of high elevation bees such as *B. frigidus* in 2019. In 2019, bumble bee workers also emerged later in the season, more towards mid-July

rather than the beginning of July when they would normally be expected to emerge. In early July, most of the bees caught were queens. At the conclusion of sampling, bumble bee workers may be at the peak of their season, further contributing to lower numbers in 2019.

In 2019, *B. bifarius*, *B. nevedensis*, *B. fervidus*, *B. centralis*, and *B. insularis* experienced an increase in relative abundance. According to *The Bumble Bees of Colorado: A Pictorial Identification and Information Guide*, all five of the *Bombus* species are mid or low-elevation bumble bees. Previous colonies of bumble bees may have been impacted by the early snowmelt of 2018 around the RMBL area and may have experienced a shift in elevation. Further sampling is needed over a broader range to understand whether bumble bee populations are truly shifting in elevation since only the low to mid elevation sites were surveyed in 2019.

Floral Preference

Bumble bees prefer certain flowers. While some species attract many bumble bees, others do not attract bumble bees at all. Although preferred flowers in 2014 are found in abundance in 2019, bumble bees are shown to prefer slightly different plants. While the *Delphinium* genus remains popular, *Potentilla spp.* is found commonly throughout the sites in 2019, which may be why bumble bees are more likely to be found on *Potentilla spp.* As bumble bees were commonly found on *Helianthella quinquenervis* in 2014, most *Helianthella quinquenervis* plants have yet to bloom in certain sites in 2019 due to the late snowmelt and early period of sampling. Flowers follow certain phenology schedules and due to the late emergence of bumble bee workers as well as certain species of plants, bumble bees may have shown a slight preference in available plants at the time of their emergence.

Conclusion

In the Rocky Mountains, climate change may be defined as the variation in snowmelt period along with warmer and drier weather which may affect the distribution of several bumble bee species. Changes in relative abundance indicate an overall increase in low to mid elevation *Bombus* species such as *B. bifarius* and *B. appositus* and a decrease for high-elevation species such as *B. flavifrons*, *B. mixtus*, *B. balteatus*, and *B. frigidus*. Compared to 2014, *B. suckleyi*, a low to mid elevation species such as *B. sylvicola*, *B. melanopygus*, *B. occidentalis*, and *B. rufocinctus* remained relatively similar in proportion in both years. One possible reason why some bumble bee species are not affected could be due to adaptations in tongue length and the plants they feed on. Throughout my sampling, bumble bees tend to prefer certain species of plants, particularly *Delphinium spp.*, *Mertensia spp.*, *Frasera speciosa* and *Helianthella quinquenervis*. 2019 was also one of the years with an increased relative abundance of *Frasera speciosa*, which flowers once in its lifetime, in response to high precipitation approx. 7 years earlier. *F. speciosa* is primarily pollinated by *Bombus*, which may affect the overall community composition of bumble bees near mid elevations.

The floral data indicate that floral presence remained mostly similar for some sites while other sites had a completely different plant distribution in 2014 that was not present in 2019 which may be a possible cause in the lower bumble bee count in 2019. A change in floral distributions may lead to a shift in relative abundance depending on the availability of floral host plants as bumblebees have floral host preferences. Competition from queens and workers at the lower elevations may lead to a shift in community composition at lower-mid elevation sites.

However, sampling only two of the original five transects do not show much in terms of general fluctuations in an overall picture. In order to understand the full range of bumble bee distributions, a study must include extremely low elevation sites as well as much higher

elevations to show the relative abundance of bumble bees over a repeated timeframe. With the late emergence of bumble bees, it may be necessary to sample into the end of the bumble bee season to understand whether bumble bee distributions have shifted. Since there is a new generation of bumble bees every year, bumble bees are able to adapt to the rapidly shifting effects of climate change with equal speed in response. Overall, bumble bees are not necessarily declining in population size but could be shifting in terms of phenology and relative abundance.

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