

Effects of Climate Changes on Ecologically Important Bees and Flowers

Student: Hildreth Rocha

Mentor: Dr. Rebecca E. Irwin,
Michael Stemkovski

Independent Research and Course/ REU

Abstract:

Climate warming affects the phenology, abundance and distributions of plants and pollinators. Despite this, there is still limited knowledge on how temperature affects plant-pollinator mutualisms. The ongoing project with Dr. Rebecca E. Irwin in collaboration with David Inouye has been gathering data at the Rocky Mountain Biological Laboratory (Colorado, USA). We are studying bee phenology and abundance, and flower phenology and abundance, and how those relationships have been changing over time as they are impacted by climate change. We have used historical data from 2009 - 2016 to determine if the increase in temperature causes phenological mismatches. Our results showed that flowers are reacting to temperature changes and may be blooming earlier, leaving a bee pollinator without food resources. Thus, bees are altering their flower visitations over the years and how flower abundance at any given site has been changing as well.

Introduction:

There is evidence that humans have increased greenhouse gas emission and warmed Earth at a rate exceeding natural climate fluctuations, leading to climatic changes. These new conditions have stressed our biodiversity and altered animal behavior (Karl et al 2003). Winters could be more variable, and summers could be longer. Anthropogenic temperature increases have the potential to affect the phenology and local abundance of plants and pollinators (Hegland et al 2009). These changes have caused snow to melt earlier, flowering plants to bloom earlier than previous years, and foraging species to come out of hibernation earlier (Inouye 2008). This could result in a loss of biodiversity of flowers and subsequent effects on pollinators, herbivores, and seed predators that have previously depended on those plants (Inouye 2008). The decline of pollinator diversity or abundance can potentially cause declines of plant species, even to extinction. This can occur if a plant blooms too early and its pollinators have not emerged or vice versa if a pollinator emerges and a plant has yet to bloom. Around eighty - ninety percent of wild plant species are directly dependent on insect pollination for fruit and seed set (Potts et al 2010), so this may be detrimental for some plant species.

Eighty to ninety percent of flower species rely on pollination by insects yet little is known about the insect's population trends (Gezon et al 2015). Bees are important pollinators globally since they pollinate many plants and may maintain biodiversity through a wide range of interactions with flowering plants. Some native bees have adapted to pollinate specific flowers whereas others are generalists and pollinate a wide range of flowering plants. Bees and angiosperms have coevolved in a mutualistic relationship (Faisal 2008, Jordano 1987). Bees disperse pollen from flower to flower, and play a significant role in the reproductive success of the plants they visit and are in turn rewarded with nectar and pollen food resources. Phenological mismatches could result in a failure by a pollinator to find pollen and nectar, or failure of a flower to be pollinated (Inouye 2008), especially if bees and flowers respond to climate change using different cues or at different rates. The phenology of flowers at the Rocky Mountain Biological Laboratory (RMBL) (Colorado, USA) is strongly influenced by date of snowmelt (Inouye 2008).

To monitor the response of plants and pollinators to climate change, Dr. Rebecca E. Irwin, in collaboration with David Inouye, has been monitoring the phenology and abundance of bees and flowers since 2009. This long-term study is currently conducted at RMBL.

We hope that the historical data can answer a few unanswered questions. We gathered data to understand: Which flowers bees visit the most and if these flower populations are

changing over time? Along with this, which bees are important for certain flowers and if those flowers are changing over time? The goals of this project were the following; 1) to continue gathering field data, 2) to analyze data for correlations between bee and flower visitations, 3) to determine if these visitation patterns have changed over time, and 4) to create graphs to depict these changes.

Methods:

Selecting sites: There are sixteen sites being sampled in the Gunnison Valley along an elevation gradient. The nine sites located near Gothic are willow (*w*) dominated, veratrum (*v*) dominated and dry (*d*) meadow sites: Tuttle – *v*, Willey – *w*, Davids – *d*, Beaver – *v*, Seans – *d*, Gothic – *w*, Little – *v*, Hill – *d*, and Copper – *w*. There are four Almont sites at low elevation – Almont Curve, Almont, CDOT and Lypps. One mid elevation site, Rustlers. And two high elevation sites located in Elko and Mexican Cut. All sites are located on the RMBL research map.

Site layout: All sixteen sites are set up using the same methodology. There are two 45 meter transect lines running approximately perpendicular. Due to natural obstacles, such as bushes and large boulders, the transect lines are not perfect. Every three meters are flagged and wooden stakes were also used to indicate the beginning and end of each transect line. Where the flags are placed, a “bee bowl” is also placed. There are fifteen bowls on each transect line, thirty in total, therefore ten of each color bowl. Each transect line contains three 2 x 2 m plots (six plots total per site) where flowers are surveyed. The flower plots were randomly placed on either side of the transect lines.

Materials and Routine:

Bee Bowls: Bees begin their foraging in the warmth of the sun and therefore it is essential to get an early start to get the most reliable data. First, bee bowls filled with soapy water are set at every blue flag along each transect. Bee bowls were shallow, hexagonal shaped, 6 oz. plastic weigh boats that have been painted fluorescent yellow or blue, or are left unpainted (white). To be able to survey the abundance of bees, a standard bee monitoring protocol was used. The soap used was unscented blue Dawn dish soap because the scent of scented dish soaps can deter insects. Bee bowls are placed at the beginning of one wooden stake, and placed in the color pattern *white yellow blue* spaced 3 meters apart. This was then repeated in the other transect line and sites in a single day. Time of day was recorded once the bee bowls were completely set. Bee bowls were set out between 0800 and 1700, the peak hours of pollinator activity (Gezon et al 2015).

Netting: Once done placing traps out in all the sites, hand netting was done for an hour total sampling effort in the morning and again in the afternoon in each site using a butterfly net. This method was used to catch larger-bodied bees. Bee catching time was an hour in total and time was stopped while in contact with any bee. Netting was done by haphazardly walking around the site and searching for bees foraging on flowers. Each bee caught was put into a vial filled with a small amount of 70% ethanol and labeled with reference to flower it was caught on, site, date, AM or PM, and person. When a *Bombus* bee was caught during netting the bee was placed in a “bee squeezer” and a paint pen was used to mark the thorax. The bee squeezer had a small plastic cylinder and a plunger with a wooden handle. There was a piece of mesh that kept the bee inside and allowed the bee to be marked carefully. These bees were identified in the field, recorded, then released. Any bees with markings were not counted.

Flower plots: Each site had six 2x2 meter flower plots. Within each plot, we counted the number of plants in bloom of each species, and on 10 haphazardly chosen plants we counted the number of flowers per plant. For these data for each species, we calculated the number of flowers per plot. These flowers were identified using David Inouye's plant guide. Any flowers that were in bloom outside of the plots were also surveyed. This was to see an overview of flower abundance for any certain site. If flowers could not be identified, a sample was removed and identified using herbarium specimens and dichotomous keys.

Bee Bowls: When all netting was complete, we returned to the first site where the bowls were placed. These bee bowls' contents were separated into three vials labeled "B", "W", and "Y" each corresponding to the color of the bowl. Each vial was previously filled about half way with 70% ethanol. The outsides of each vial were also labeled with the site name and date. All bees were stored in the vials and taken to the lab to be pinned, labeled, and identified. Time of day was recorded when bee bowls were picked up. This method of catching was used to catch smaller-bodied bees as opposed to using the netting for larger-bodied bees. This method also accounts for the most percentage of bees caught.

Lab: Back at the lab, all data sheets were stored. Bees that were not identified right away were placed in the freezer. Bees were then pinned, identified, labeled and set to dry. Bees coming out of the ethanol were washed in water to remove the excess ethanol. After transferring them into water, they were softly shaken for about twenty seconds. Bees were then dried by placing them on a paper towel, then further dried by placing them into a mason jar and using a hair dryer. This process allowed for their hairs to be fluffed which made identification easier. Different types of bees have hairs located on their bodies in different places because of their pollen collecting strategies. Once a bee was dry, it was pinned appropriately. This was done with their wings off their bodies because wings are also important identification details. When everything was completed and identified, the data was entered in Microsoft Excel spreadsheets. Labels were also made for the dry bees and added to their pins. Flowering phenology data was also recorded into Microsoft Excel spreadsheets.

Data analysis: We used existing historical data compiled from 2009 to 2016 to assess relationships between bee and flower visitations. We ran R analyses to answer the questions and showed the data analysis on pie charts and graphs. We did this for all bee species available on database as a group, and broke it down further into three elevation gradient blocks. Flowers and bees were considered "important" if the bee visited the other organism greater than 3%. For the analysis, the Mexican Cut block was excluded because there were only eighty-eight visitations and were not considered important on a large-scale analysis.

Results:

Over eight years and 16 sites each year, a total of 23,572 bees have been sampled. This includes netting samples and those bees captured by bee bowls. 2,256 bees account for total sampled bees on flowers that were released and 21,315 bees have been captured by bee bowls. With a total of 92 flower species, 3 bowl colors, and 28 different types of bees, in all sixteen sites and all bees there were only 5 "important" flowers. There was a conflict with this finding because three of those flowers were only found at low elevations. Therefore, site blocks were used to divide the data into *high*, *mid* and *low* elevations. This gave Mexican Cut (*high elevation*) site block seven "important" flower species. Gothic (*mid- elevation*) site block four "important" flower species. And Almont (*low elevation*) site block eleven "important" flower species.

Gothic – Seen in Figure 2 Gothic site block had four flowers that had greater than 3% bee visitations. These flower visitation rates are then broken into percentages in Figures *Taraxacum officinale* (3G), *Potentilla pulcherrima* (4G), *Heliomeris multiflora* (5G), and *Pseudocymopterus montanus* (G6) were respectively visited 41.72%, 24.42%, 4.65%, and 3.90%.

It was interesting to see that the capture rate of the bowls was highest for yellow. This matches the colors of important flowers in all four of the Gothic site blocks. This is seen in Figure 2. We can then say that the bees in the Gothic community have higher visitation rates to yellow flowers.

Almont – Seen in Figure 8 Almont site block had eleven flowers that had greater than 3% bee visitations. These flowers' visitation rates are seen in Figures *Opuntia polyacantha* (9A), *Pediocactus simpsonii* (10A), *Taraxacum officinale* (11A), *Erigeron sp.* (12A), *Potentilla hippiana*, *Eriogonum racemosum*, *Lupinus argenteus*, *Physaria acutifolia*, *Senecio interrimus*, *Oreocarya flavoculata*, and *Chrysothamnus viscidiflorus* were respectively visited 11.93%, 10.86%, 10.09%, 9.17%, 6.12%, 5.66%, 4.89%, 4.89%, 3.67%, 3.52%, and 3.06%.

The bees caught on bee bowls at these sites are seen in Figure 13. The highest capture rate was 38.23% on a white bee bowl.

Discussion:

Our results suggest that climate change occurring in Gothic has been altering which flowers are readily available for when a particular bee species emerges. Flower populations have been changing over time. Gothic only had four “important” flower species and interestingly all four are yellow flowers. This was an interesting finding because in the Gothic site block, all important flowers were yellow. A different story is to be told with the flower *Potentilla pulcherrima*. This flower may only be “important” because it is highly abundant. It would be interesting to account for flower abundance to see if these additional variables change the trends seen in the graphs. This factor can be accounted for with the data taken from flower plots to determine floral abundance and density at that site for any given year. We also notice in our *Taraxacum officinale* graphs that 2009 data is non-existent. Looking again at floral abundance we can account for this missing data point. We notice that this plant has had increasing floral bloom years and has been invading some of our sites.

Almont also has similar trends seen. Bees are altering their flower visitation rates throughout the years. These results are not as strong because two of our four Almont sites, shown in Map 4, have only been sampled for the last two years. The trends in graphs 9A – 12A are skewed because the first couple of years all had zero percent visitation rates.

The Mexican Cut site block did not have enough bee visitations throughout the years. We can speculate that it is because of the surrounding soils. There are nearby streams that constantly keep the soil moisture high, even after snow melt. This does not provide adequate nesting grounds for bees. It is also at a high elevation, shown in Map 2.

To strengthen the results of this study, we would like to include flower abundance in the calculations and see if any highly-visited flowers are only important because they are highly abundant. This would probably decrease the important flowers for each site and we can then conclude the true important flowers. Due to time constraints, the last question was unable to be answered. This would be interesting to know because it determines if bee visitations are also being altered. In the future, we would like to answer this after correctly answered the second question, if flower visitation rates are changing over time.

Literature cited:

Faisal, Arif Mohammad. "Climate change and phenology." *New Age* 3 (2008).

Gezon, Zachariah J., Eli S. Wyman, John S. Ascher, David W. Inouye, and Rebecca E. Irwin. "The effect of repeated, lethal sampling on wild bee abundance and diversity." *Methods in Ecology and Evolution* 6, no. 9 (2015): 1044-1054.

Hegland, Stein Joar, Anders Nielsen, Amparo Lázaro, Anne-Line Bjerknes, and Ørjan Totland. "How does climate warming affect plant-pollinator interactions?" *Ecology letters* 12, no. 2 (2009): 184-195.

Inouye, David W. "Effects of Climate Change on Phenology, Frost Damage, and Floral Abundance of Montane Wildflowers." *Ecology* Vol. 89, No. 2 (2008): 353-362.

Jordano, Pedro. "Patterns of mutualistic interactions in pollination and seed dispersal: connectance, dependence asymmetries, and coevolution." *The American Naturalist* 129, no. 5 (1987): 657-677.

Karl, Thomas R., and Kevin E. Trenberth. "Modern global climate change." *Science* 302, no. 5651 (2003): 1719-1723.

Kerns, Carol Ann and David William Inouye. "Pollinators, Flowering Plants, and Conservation Biology." *BioScience* Vol. 47, No. 5 (1997):297-307.

Wilson, Joseph S. and Olivia Messinger Carril, *The Bees In Your Backyard* (New Jersey: Princeton University Press, 2016)

Tables and Figures:

Gothic

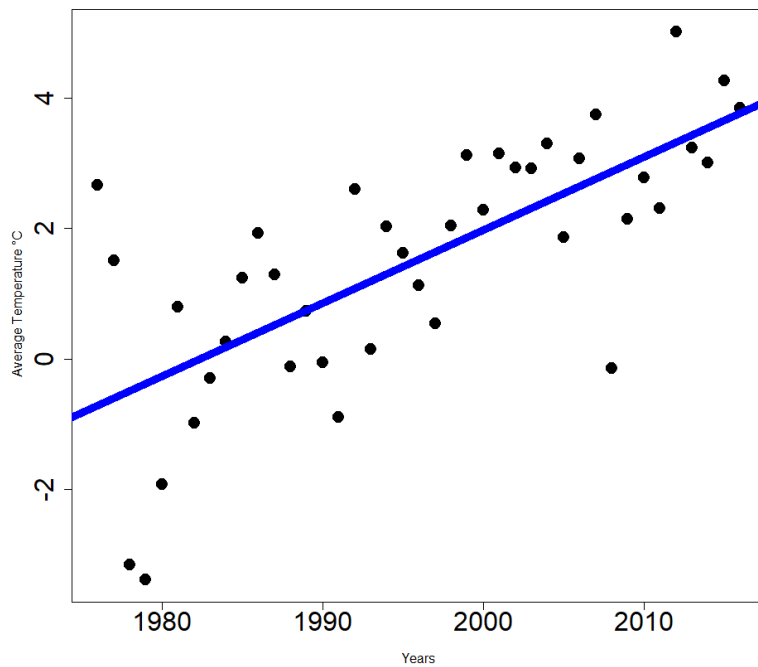


Figure 1: Average temperature graph throughout the years 1976-2016 in Gothic.

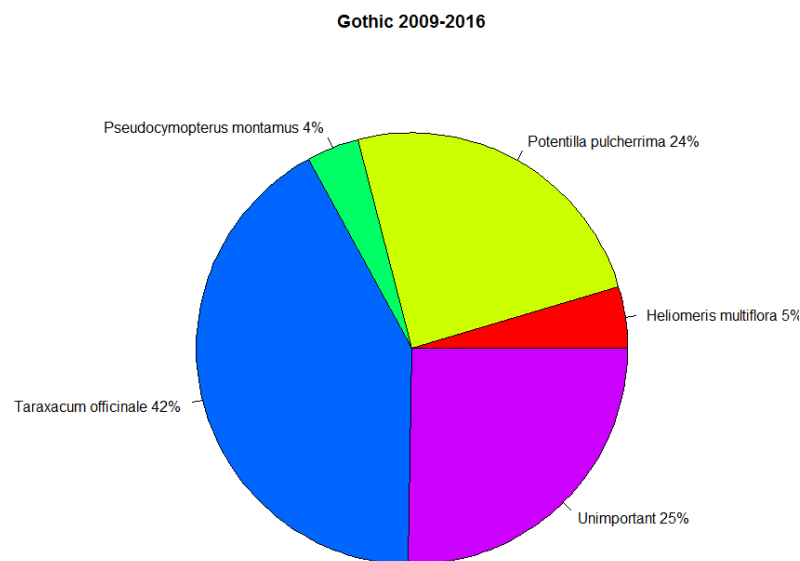


Figure 2: The important flowers (greater than 3% bee visitations) for years 2009 – 2016. These flowers had the highest bee visitation percentages.

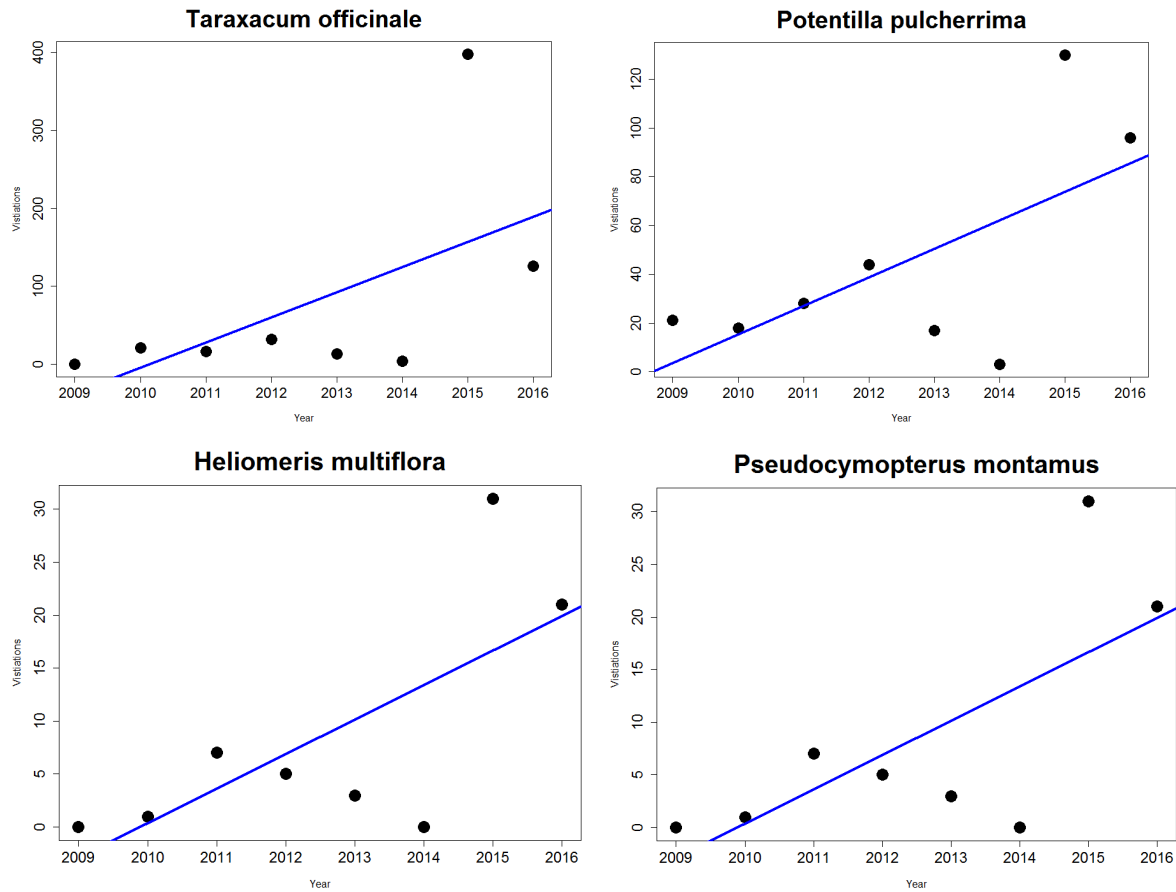


Figure 3G (*Taraxacum officinale*), 4G (*Potentilla pulcherrima*), 5G (*Heliomeris multiflora*) and 6G (*Pseudocymopterus montamus*) – Gothic block important flowers broken down into years.

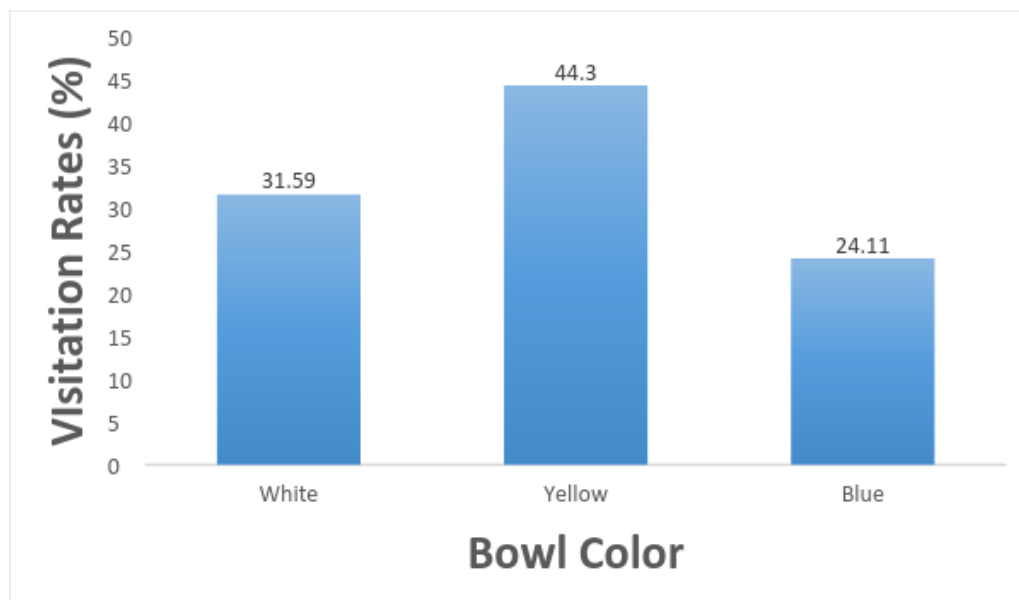


Figure 7: Bowl visitation rates of all bees on years 2009-2016. The highest bowl visited in the accumulated years was yellow.

Almont

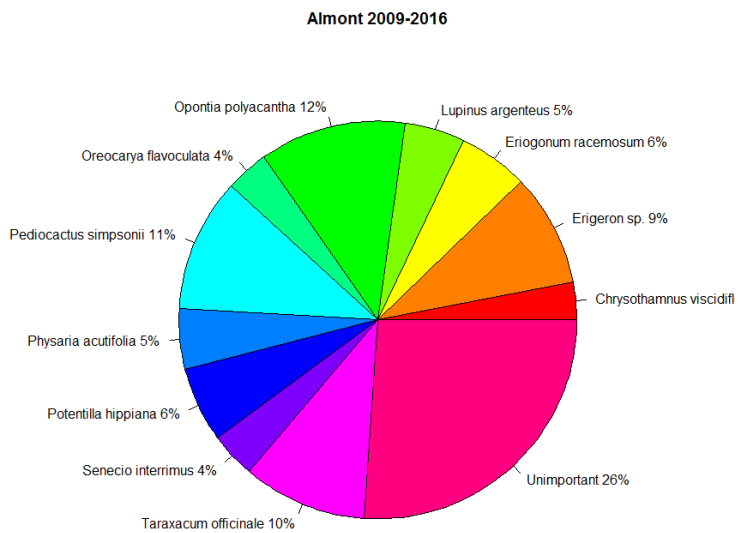
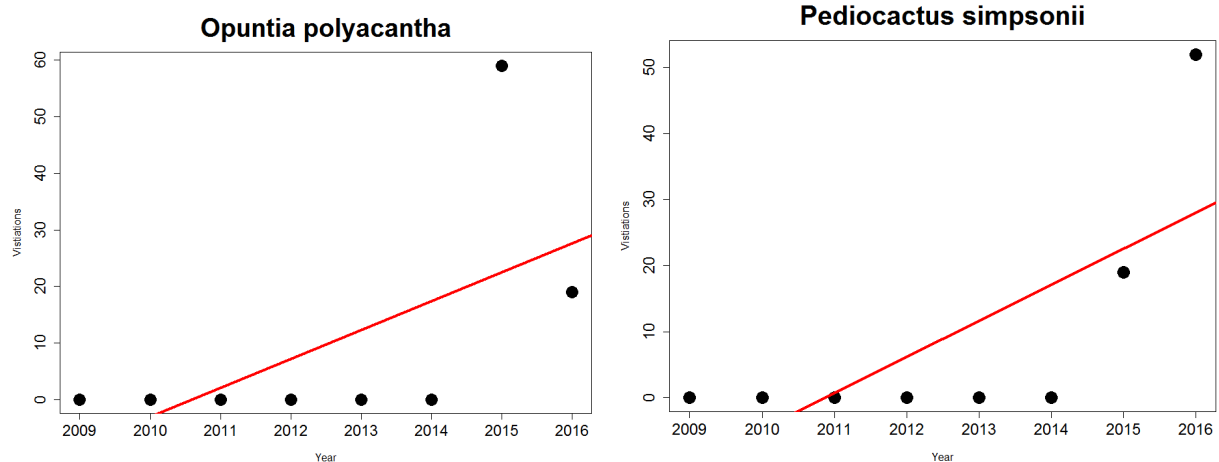


Figure 8: Almont Block depicting the important flowers (greater than 3% bee visitations) for years 2009 – 2016. These flowers had the highest bee visitation percentages.



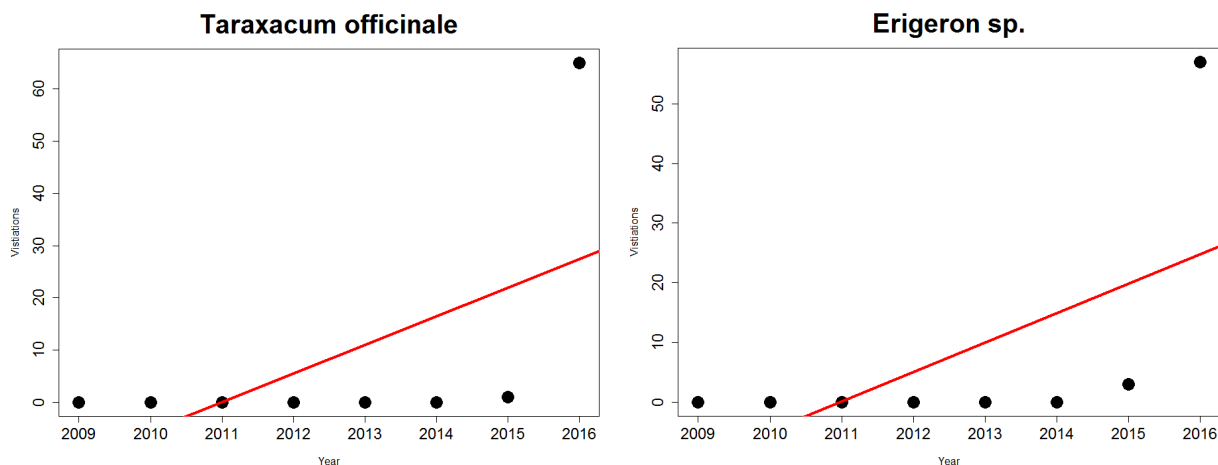


Figure 9A (*Opuntia polyacantha*), 10A (*Pediocactus simpsonii*), 11A (*Taraxacum officinale*) and 12A (*Erigeron sp.*): Almont block important flowers by year.

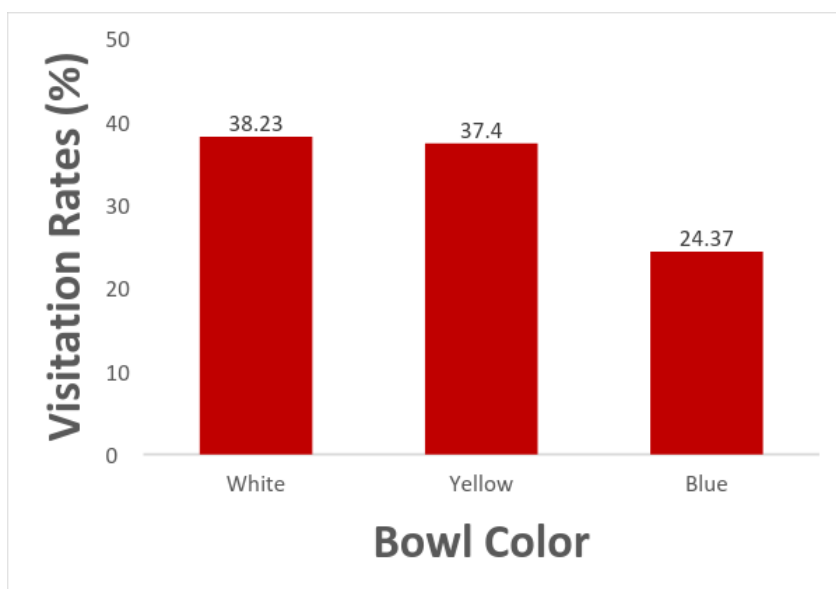
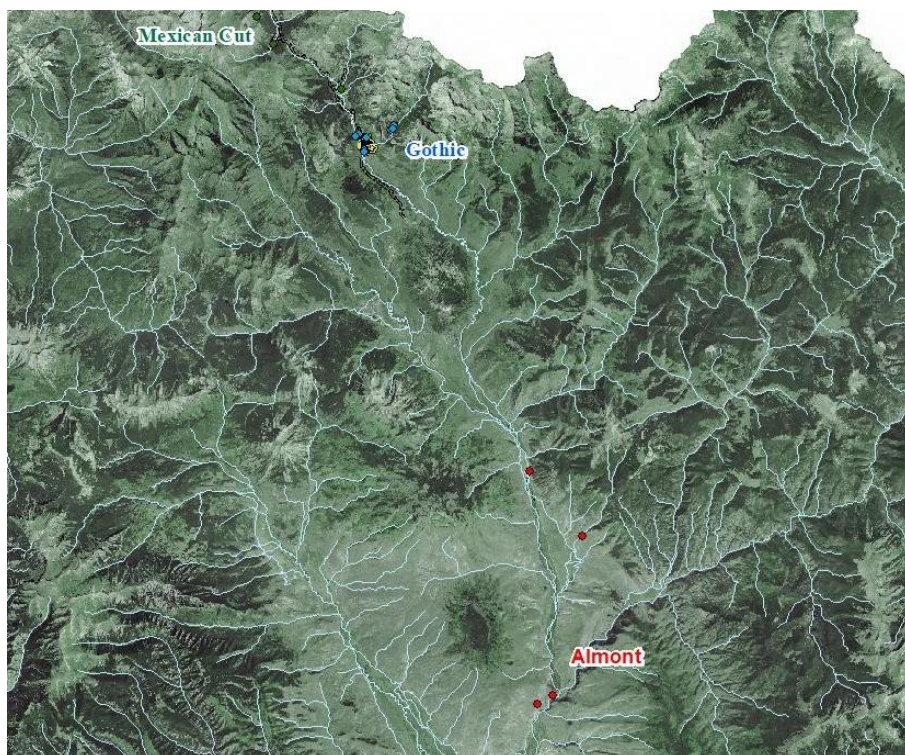
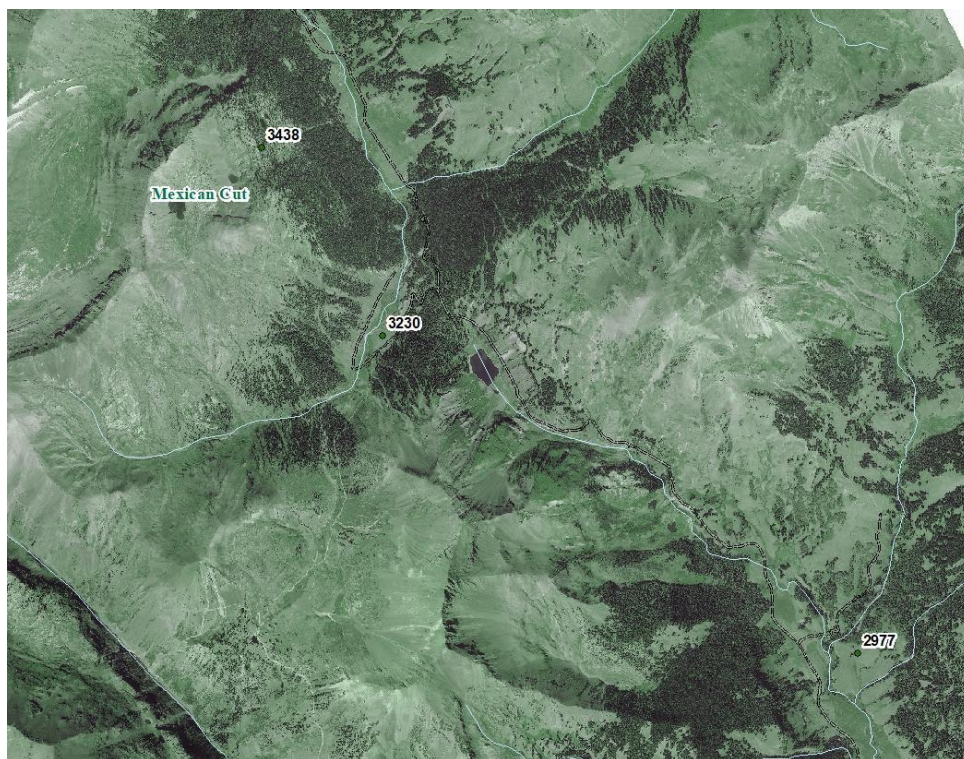


Figure 13: Bowl visitation rates of all bees on years 2009-2016. The highest visited bowl in all the years was white.



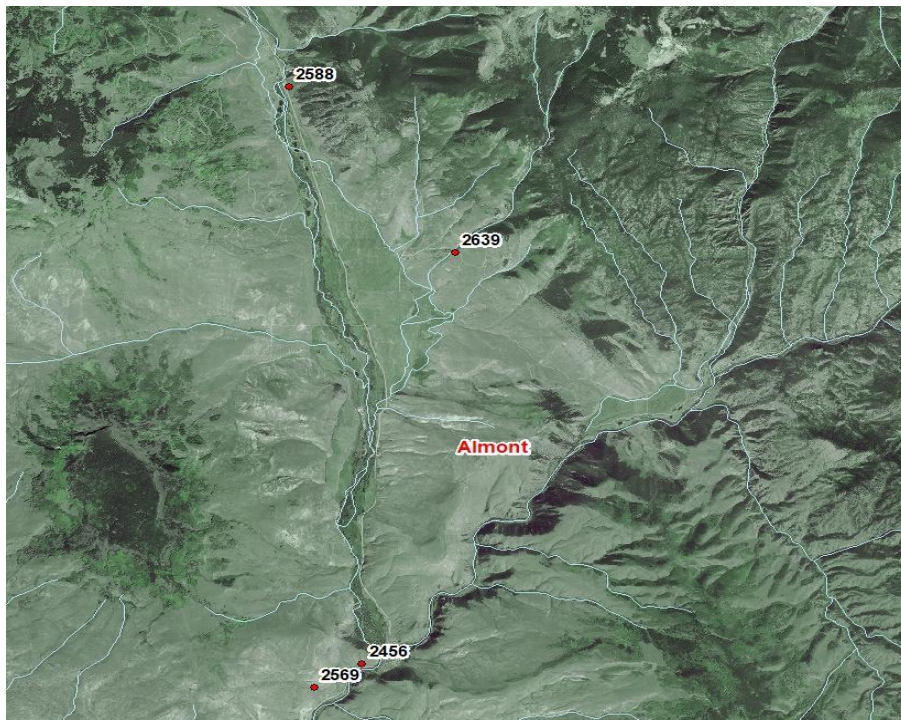
Map 1: All sites (Mexican Cut at a high elevation gradient, Gothic at a mid-elevation gradient, and Almont at a low elevation gradient).



Map 2: Mexican Cut with three sites and their displayed elevation values.



Map 3: Gothic in yellow and nine sites surrounding the town site and their elevation values.



Map 4: Almont with four sites and their displayed elevation values.