August 21, 2012

Raven's Manzanita (*Arctostaphylos montana* ssp. *ravenii*) and Franciscan Manzanita (*Arctostaphylos franciscana*):

A Study of Their Flowering Periods and the Pollinators They Attract

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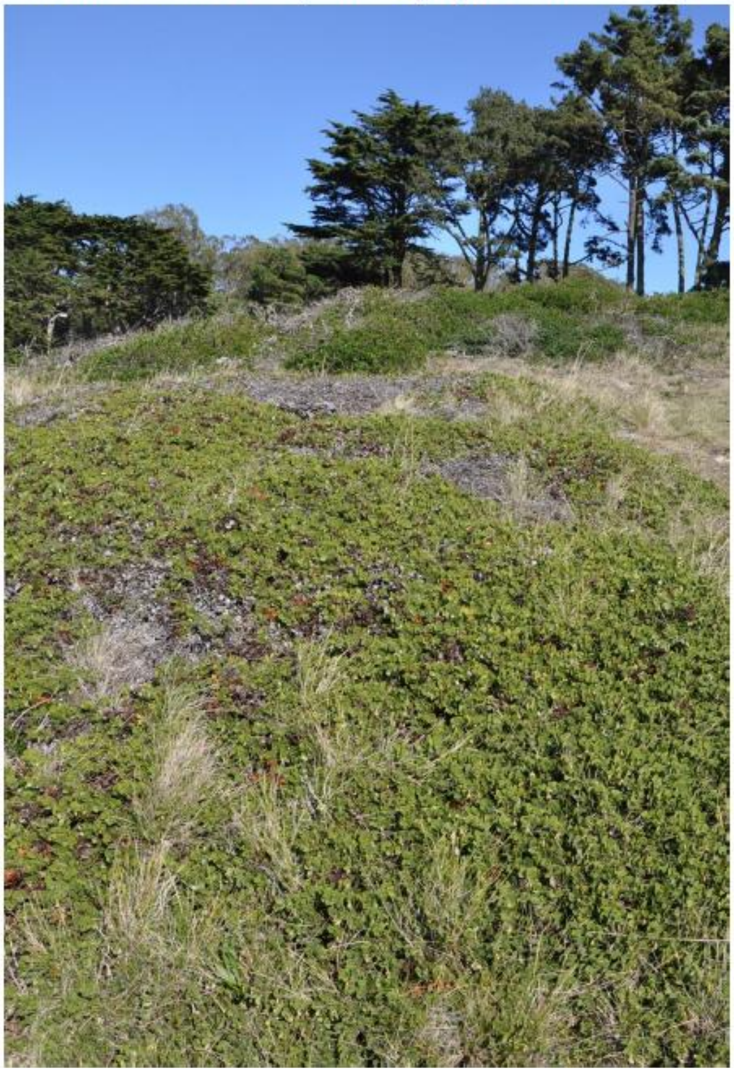
Background and Objectives

The Presidio of San Francisco stands as a natural refuge for some of the last remaining native habitat in the city. Home to hundreds of plant and wildlife species, this national park features of variety of habitats from serpentine grassland to tidal marsh. Stewards of the park restore and maintain these precious resources with the goal of protecting both common and rare native inhabitants.

Two of the Presidio's rare finds are evergreen shrubs endemic to San Francisco and of the genus *Arctostaphylos*. In 1952, the Raven's manzanita (*Arctostaphylos montana* ssp. *ravenii*) was discovered by Peter Raven on a chaparral serpentine grassland overlooking the Pacific Ocean in the Presidio (see Image 1; Parker and Frey, 2010). This tetraploid species is an obligate seeder and is able to reproduce both by self-fertilization and through insect pollination (Parker and Frey, 2010). Considered the last of its kind, *A. montana* ssp. *ravenii* is protected as an endangered species by both the U.S. Federal Endangered Species Act of 1973 and the California Endangered Species Act (U.S. Fish and Wildlife Service, 2003 and Parker and Frey, 2010). In 1987 and 1988, 63 clone cuttings from this mother plant were planted at various restoration sites throughout the Presidio in the hope of recovering the species's population (Parker and Frey, 2010).

Image 1. Raven's Manzanita (*Arctostaphylos montana* ssp. *ravenii*)



The Franciscan manzanita (*Arctostaphylos franciscana*) was thought to be extinct for seventy years until 2009 when an individual was discovered along the Doyle Drive highway in the Presidio (see Image 2; "Native

Plants" and Parker and Frey, 2010). This individual was subsequently transplanted in January 2010 to a serpentine grassland restoration site in the park. *A. franciscana* is a diploid species, and possibly one of the parent species, or the progeny of the parent species, of *A. montana* ssp. *ravenii* (U.S. Fish and Wildlife Service, 2003). Approximately 70 clone cuttings from the Franciscan manzanita mother plant were planted in the park in March 2012, as the species is currently being considered for federal endangered species status (U.S. Fish and Wildlife Service, 2011).

Image 2. Franciscan Manzanita (*Arctostaphylos franciscana*)

The survival of these plants also depends on flower production, pollination, and seed development. In their 2003 Recovery Plan for Coastal Plants of the Northern San Francisco Peninsula, the U.S. Fish and Wildlife Service prioritizes to "monitor flower production, timing, insect visitors to flowers, seed set, and seed dispersal" of the Raven's manzanita mother plant as well as states that "production of flowers…should be monitored" for the Raven's manzanita clones (U.S. Fish and Wildlife Service, 2003). In 2010, Mark Frey, former ecologist for the Presidio Trust, and Dr. Tom Parker, professor of biology at San Francisco State University, updated these monitoring goals for the manzanita species: "Another recommended study would involve quantifying the phenology and the pollination ecology of *A. montana* subsp. *ravenii,* [and] *A. franciscana*… the goal of this study is to understand how to create combinations of species so that there is a continuing flowering period for the community as a whole,… maximizing the reproductive potential of any of the species involved" (Parker and Frey, 2010).

The first objective in this project, therefore, is to monitor the flowering times and abundances of both manzanita mother plants and the Raven's clones. The second objective aims to observe the abundance and diversity of pollinators visiting each plant, as well as any pollinator species cross-over between the two plant species. The results of these observations will provide more information as to the health of these plants and their capacity to both produce flowers and attract pollinators, which may lead to more successful reproduction in the future. More will also be learned about the advantages of planting the clone cuttings at particular restoration sites and establishing sites containing both the Raven's and the Franciscan manzanita species.

Methods

In this study, I first inspected the locations of the manzanitas in October 2011 with Shelley Estelle, the Biological Technician overseeing the restoration of both sites at which the plants are located. We determined the location of the Franciscan manzanita mother plant (Franciscan mother), the Raven's manzanita mother plant (Raven's mother), five Raven's manzanita clones below the mother plant (Clones 1-5), and one Raven's manzanita clone adjacent to the mother plant (Adjacent Clone). Following this inspection, I went out on my own beginning October 21, 2011 to conduct preliminary monitoring and photographing of all eight plants, including: their exact locations, conditions, physical characterizations, and the general weather conditions around each of them. On November 10, 2011, I began visiting the plants every to every other week (depending on my availability) and recorded the temperature, weather conditions, time of day, plant condition, wildlife visits, and appearance of flower buds for each plant. I based the timing of the study on Dr. Tom Parker's account of the inflorescences of *A. montana* ssp. *ravenii* maturing after fall and early-winter rains, then flowering in mid-winter to early spring (Parker and Frey, 2010). On days that I visited the plants, I monitored all eight plants for 1-5 minutes each sometime between 9:30am-12pm or 1-4pm. Starting on January 23, 2012, I also measured wind speed at each site using a Dwyer wind meter.

During this time period, in addition to field monitoring, I began researching academic papers concerning the manzanita plants and local bee species. I reached out to Dr. John Hafernik, Professor of Ecology at San Francisco State University, in order to learn about bee identification out in the field and to obtain written resources regarding different local bee species and how to identify them. I also contacted Dr. Tom Parker in order to learn more about manzanita flower growth and to obtain written resources concerning the life cycles of manzanita bushes. Tania Pollak, formerly of the Presidio Trust, shared with me bee samples she had collected and pinned. Additional written resources were bestowed upon me by Mark Frey, Christa Conforti, Peter Ehrlich, and Shelley Estelle, all of the Presidio Trust.

When I surveyed the first open flowers on the plants on January 23, 2012, I attempted to count the number of open flowers on each plant; however, the great abundance of flowers made this task unrealistic for my purposes. Consequently, I characterized each plant's amount of open flowers into one of five categories: none, few, some, many, or covered. "None" indicated no open flowers were present; "few" indicated a handful of open flowers were present; "some" indicated a portion of the plant had open flowers; "many" indicated a large portion of the plant had open flowers; and "covered" indicated that most of the plant had open flowers. I characterized open flowers as those in which the "reproductive parts are visible," as outlined by the USA National Phenology Network's plant phenophase definitions ("Frequently Asked Questions").

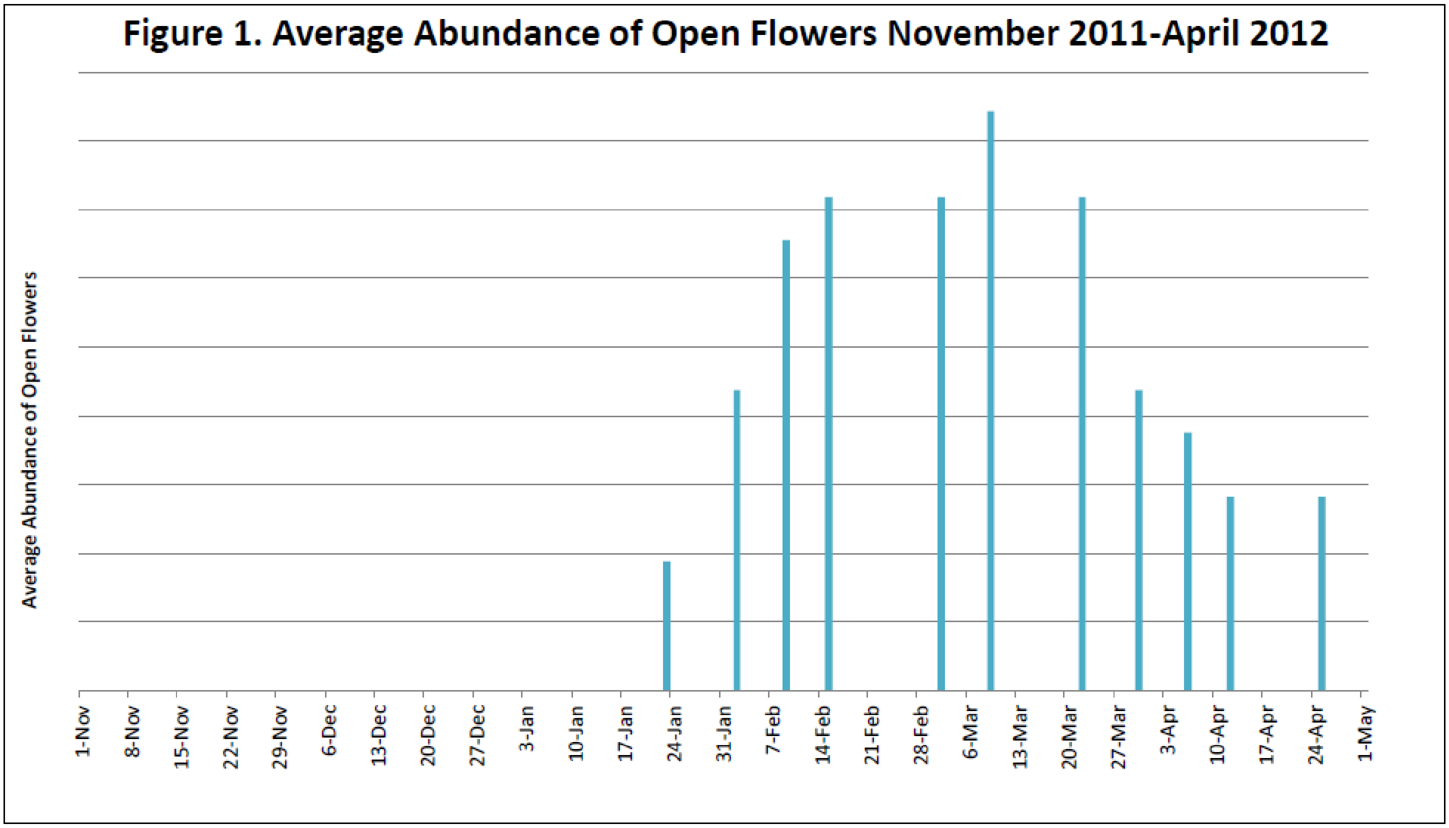
When I first monitored bees visiting the plants' open flowers on February 2, 2012, I decided to save time by monitoring only one of the five Raven's manzanita clones at the site below the mother plant. I chose Clone 2 because of its large size and, therefore, possible greater abundance of flowers, which theoretically would attract more bees. In total, I monitored the Raven's mother, Franciscan mother, Clone 2, and Adjacent Clone. I monitored each plant by walking the perimeter of the plant for 5-30 minutes between either 9:30am-12pm or 1-4pm that day. I based monitoring time on the size of the plant, spending more time monitoring the larger plants, which would theoretically attract more bees. I counted the number of instances when I saw a bee pollinating an open flower. With the abundance of bees, the abundance of flowers, the locations of the flowers (frequently tucked under the leaves), and the quickness of the bees, I was not able to count the explicit number of individual bees visiting the plants. Therefore, instances that I recorded as bee pollination visits may have happened by the same or by different bees. I categorized bees by genus, such as honey bee (*Apis*) or bumble bee (*Bombus*), and size, such as small, medium, or large. If I was not able to identify the bee, I labeled it as "unknown." I also took photographs of the bees in order to try to identify them to species, with the help of Dr. John Hafernik.

Results

I recorded observations of the 8 manzanita plants from November 2011 through April 2012. During that period, I first noted open flowers on Clones 1-3, Clone 5, and Adjacent Clone on January 23, 2012, and on the Raven's mother, Clone 4, and Franciscan mother on February 2, 2012 (see Image 3). Peak flowering time was March 9 for the Raven's mother, February 9 and 15 for Clone 1, March 9 and 22 for Clone 2, March 9 for Clone 3, March 9 for Clone 5, March 2 for the Adjacent Clone, and March 9 and 22 for the Franciscan mother. Clone 4 did not have a peak flowering time.

Image 3. Open Flower on Clone 3 January 23, 2012

In order to quantify open flower abundance, I assigned numerical values to each category of abundance: none = 0, few = 5, some = 10, many = 15, and covered = 20. I then averaged these values across all 8 plants to obtain a graph of change in open flower abundance over time (see Figure 1).



As Figure 1 shows, open flower abundance across all 8 plants rose dramatically from late January to mid-February, then plateaued until early March when it spiked to its highest value, followed by a steady decline until mid-April. From mid-April until the end of April the abundance levels remained unchanged because all 8 plants had an abundance of "few" open flowers.

The emergence of open flowers also coincided with precipitation amounts in San Francisco. As Figure 2 shows, precipitation levels in the city remained low until late January, the same time open flowers were first viewed on the manzanita plants ("Weather History").

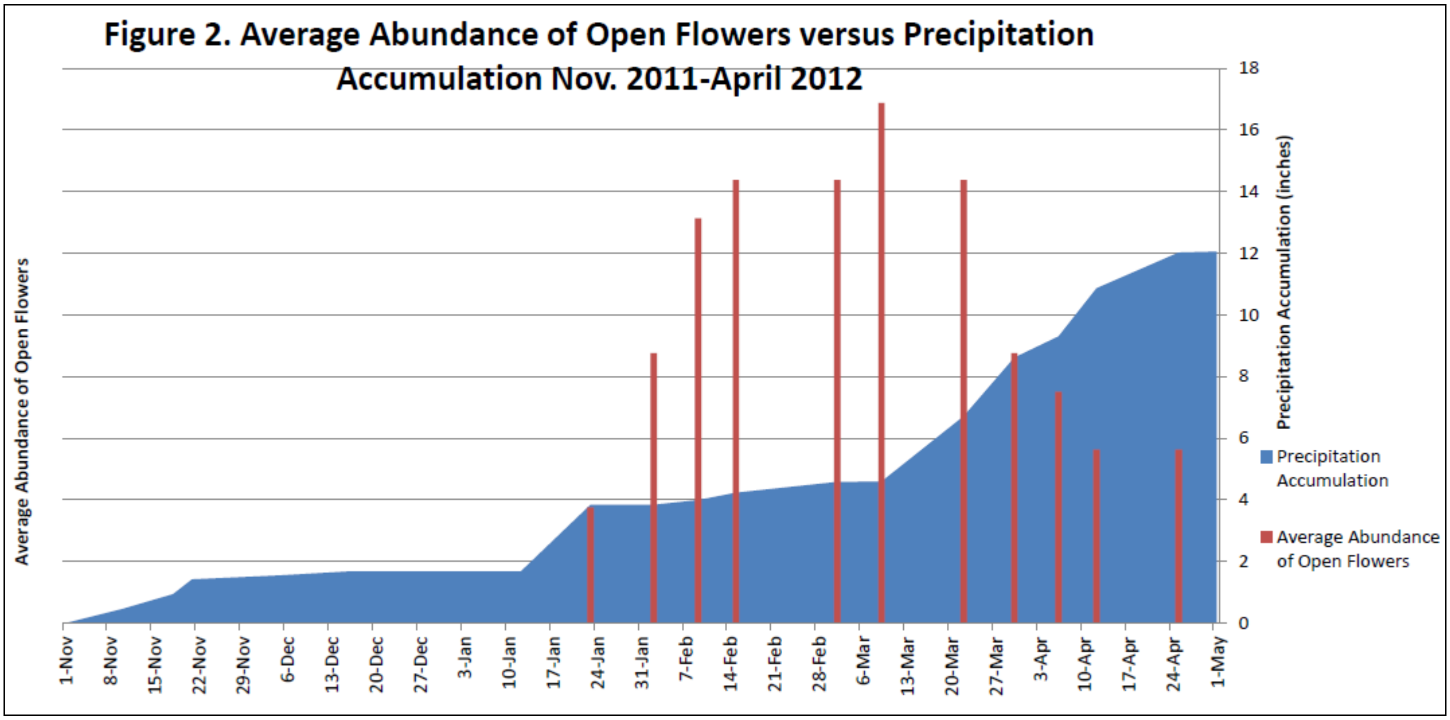


Figure 2. Average Abundance of Open Flowers versus Precipitation Accumulation Nov. 2011-April 2012

I first noted bees pollinating the open flowers on February 2, 2012, and from then until April 6, 2012, I recorded 325 instances of bees pollinating flowers on the Raven's mother, Franciscan mother, Clone 2 and Adjacent Clone. Bee observations climbed throughout February, spiked in early March, and then dropped until mid-April when no bees were observed pollinating (see Figure 3).

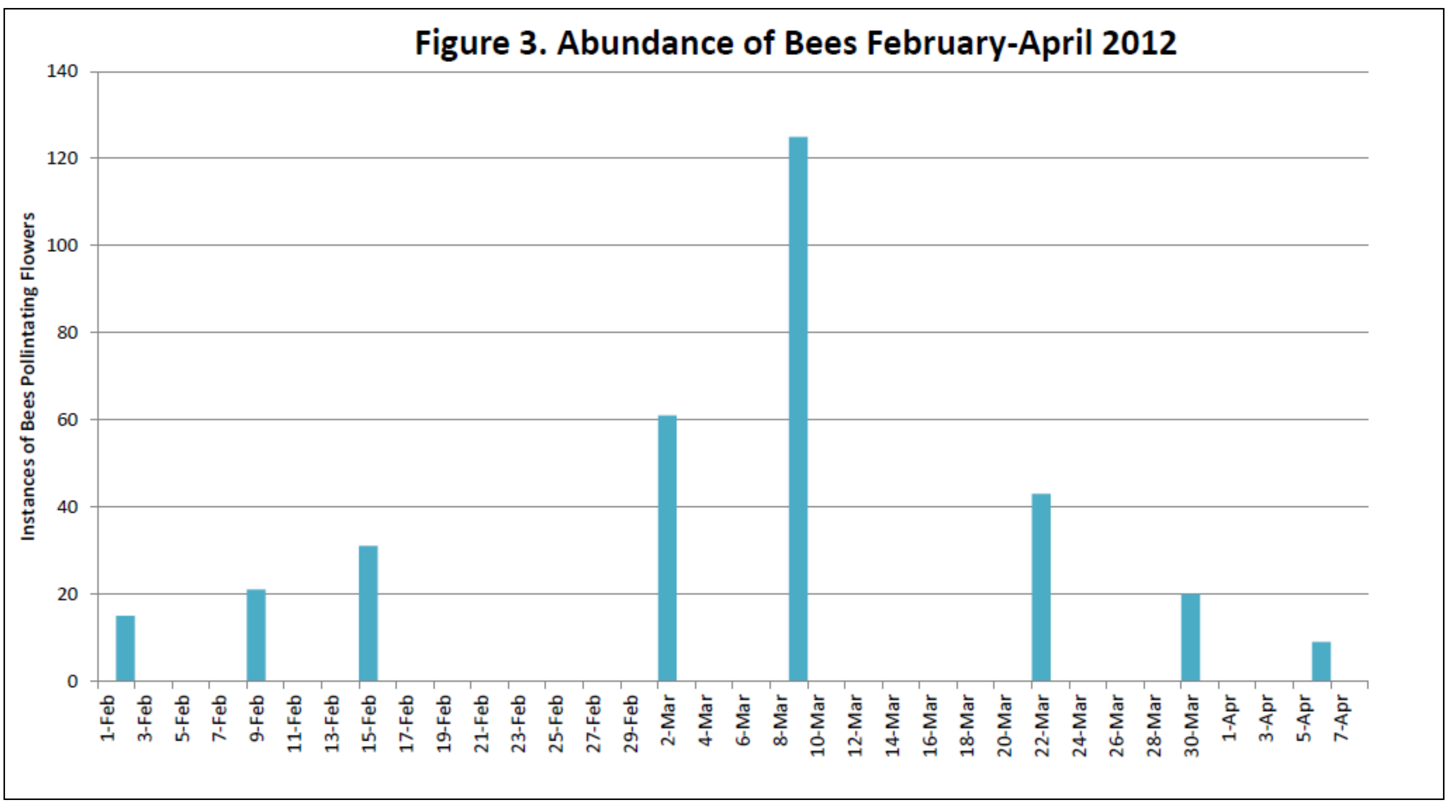
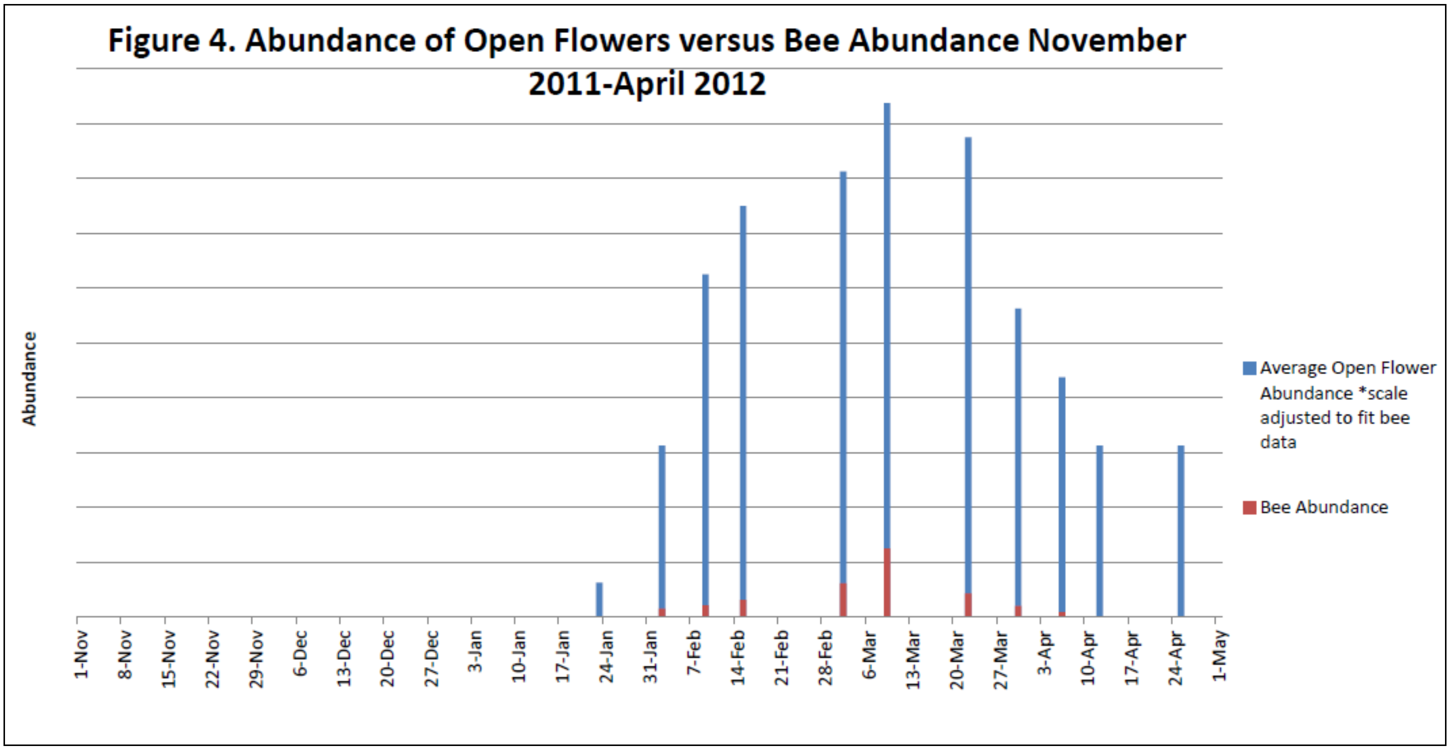
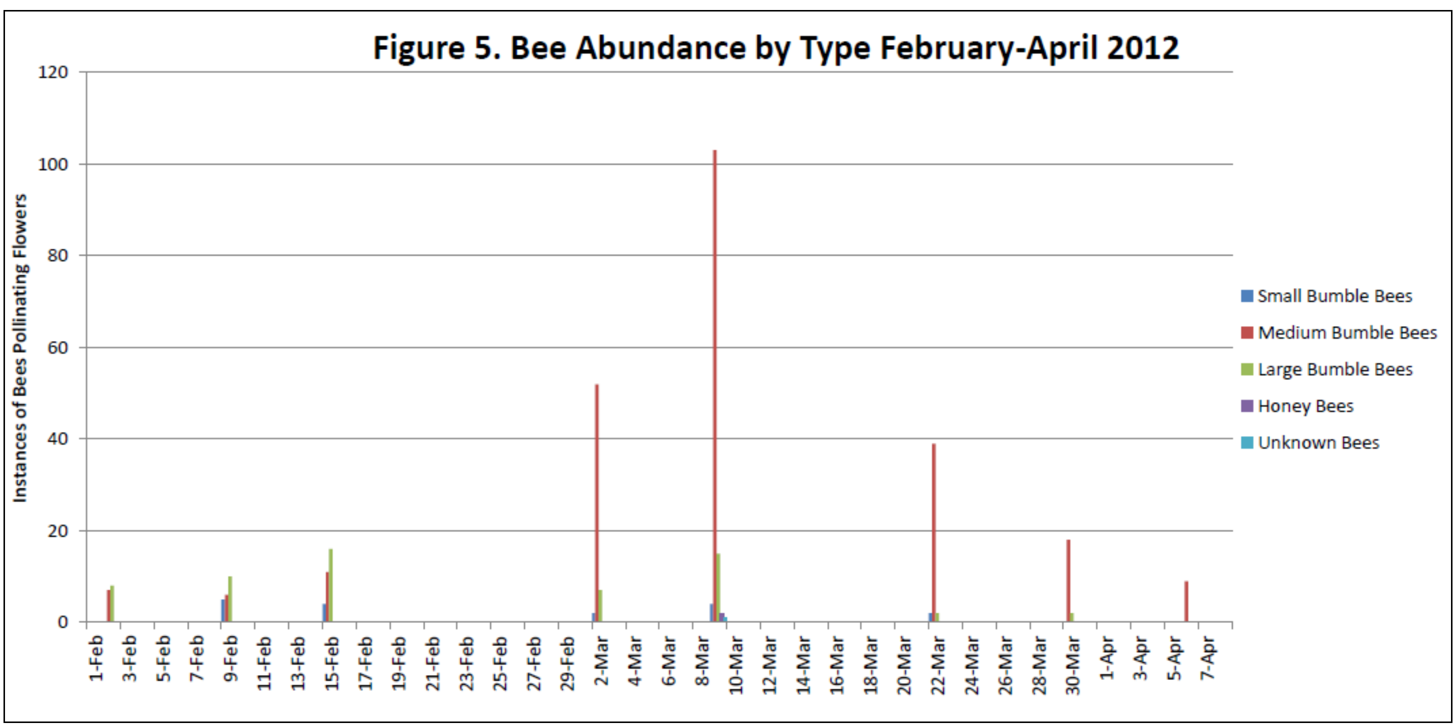


Figure 3. Abundance of Bees February-April 2012

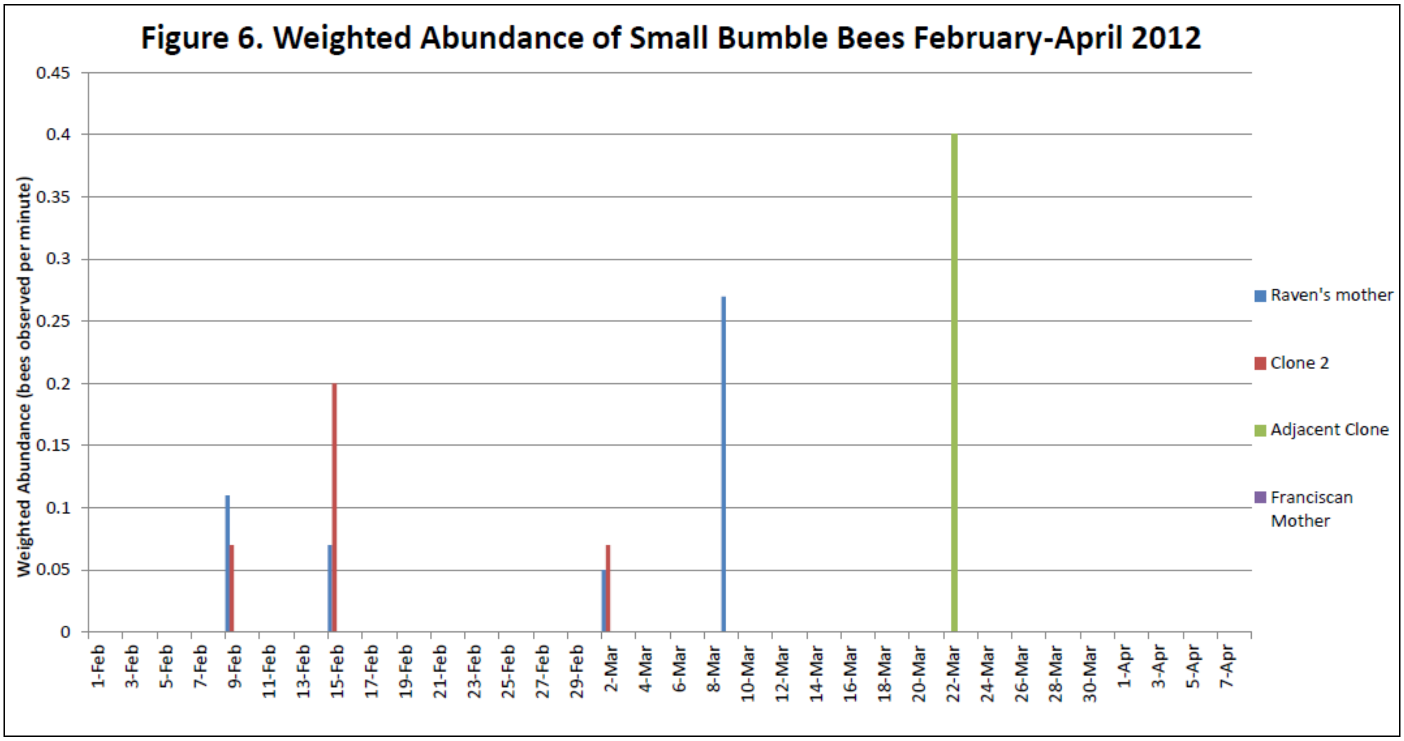
As Figure 4 shows, bee presence coincided with the presence of open flowers in the previous four plants, and both abundances were at their highest levels in early March.



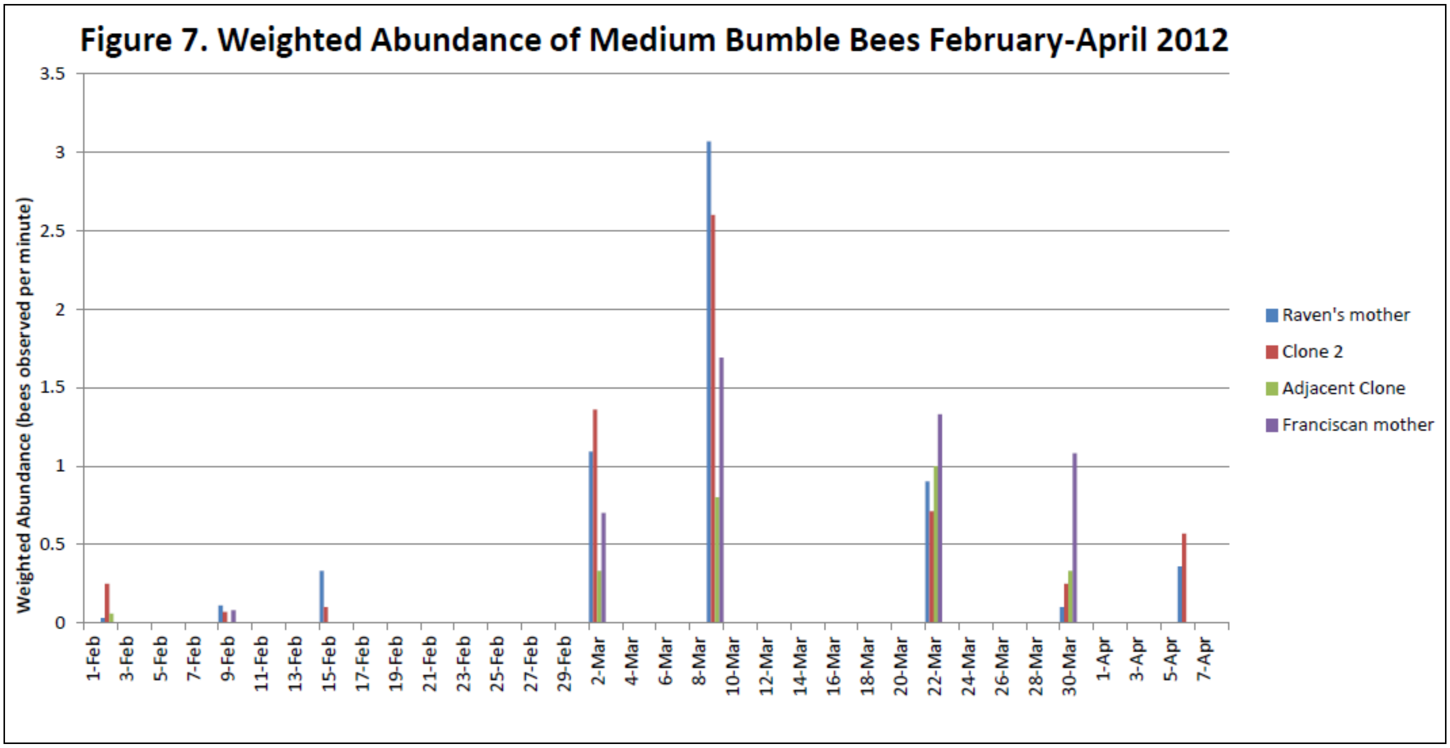
I identified the bees monitored as bumble bees, honey bees or unknown bees and further characterized bumble bees as small, medium, or large (see Figure 5). The majority of bees observed were in the "medium bumble bee" category (245 observations), followed by "large bumble bees" (60 observations), "small bumble bees" (17 observations), "honey bees" (2 observations), and finally "unknown bees" (1 observation). The "unknown bee" observation was made because the particular specimen flew by too quickly to identify. Observations of medium bumble bees followed the general trend of spiking in early March, as did the honey bees and unknown bees, while observations of small and large bumble bees had additional peaks in early and mid-February, respectively.



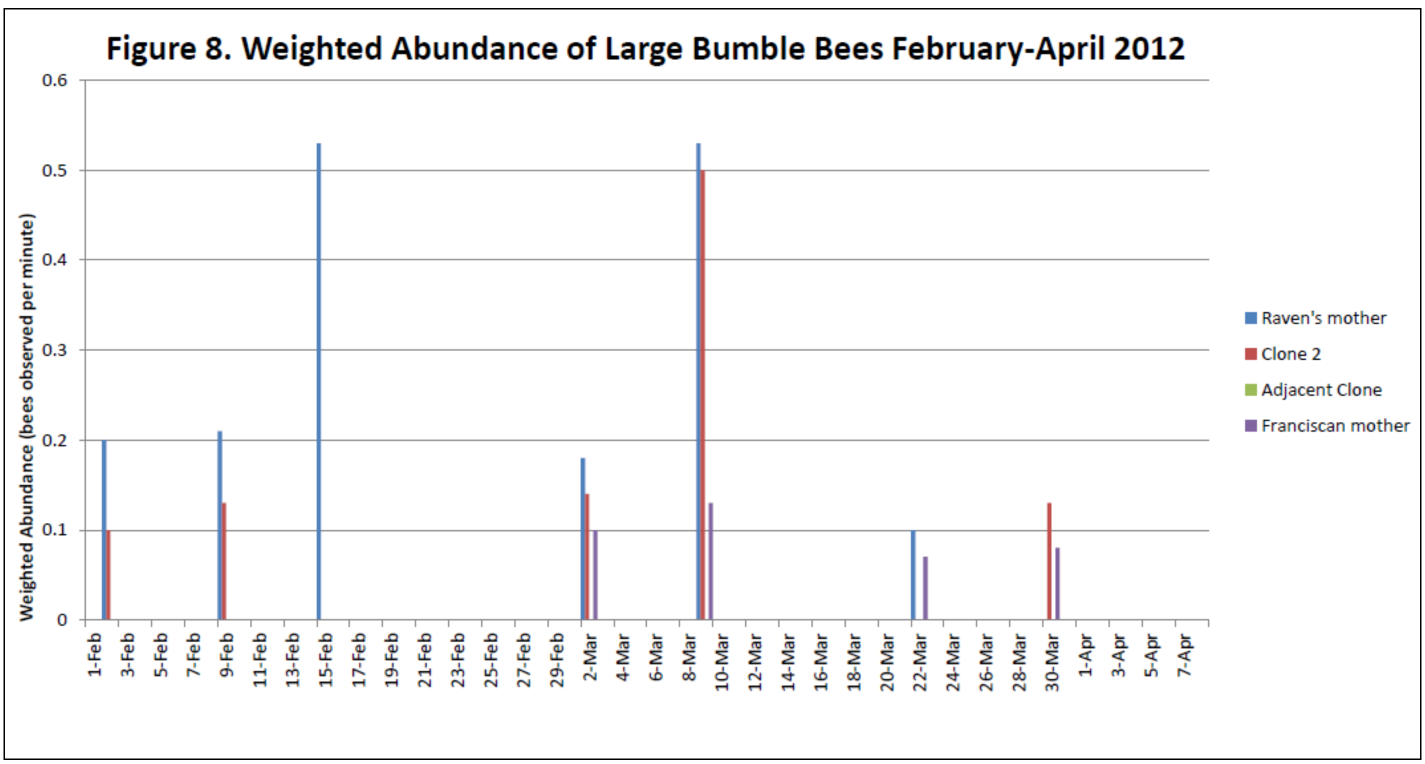
To better compare the number of bees that visited each specific plant, I determined the weighted abundance of each type of bee at each of the four plants by calculating the number of bees that visited that plant per minute of observation (see Figures 6-8). I conducted these calculations only for bumbles bees because I observed honey bees only visiting the Raven's mother and unknown bees only visiting Clone 2. As Figure 6 shows, small bumble bees visited the Adjacent Clone most per minute, with the highest weighted abundance in late March (which was also the only time they were observed visiting this plant). The Raven's mother followed with two spikes in weighted abundance, the smaller in early February and the larger in early March. Clone 2 had the next highest spike, in mid-February, while no small bumble bees visited the Franciscan mother.



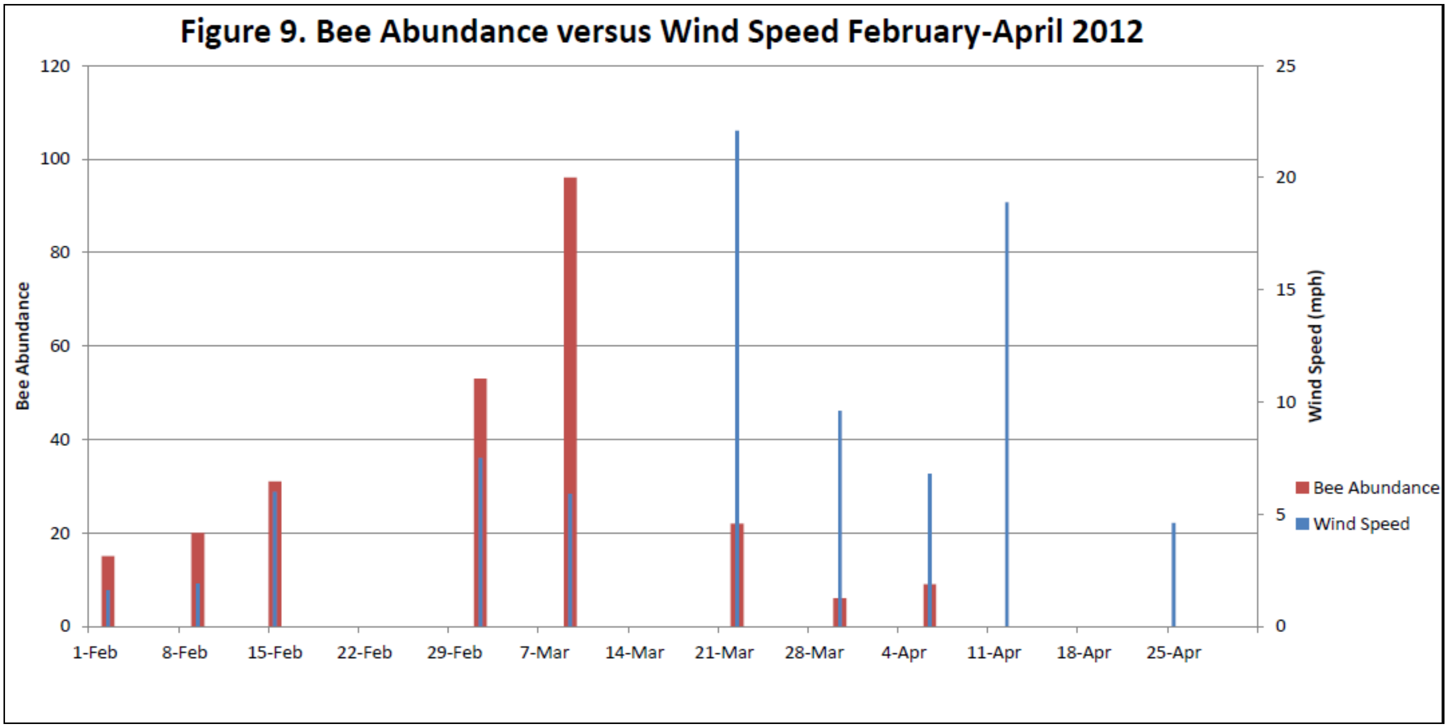
As Figure 7 shows, medium bumble bees visited the Raven's mother most per minute, spiking in weighted abundance in early March. Clone 2 followed closely behind with a major spike in early March and two small spikes, one in early February and one in early April. The Franciscan mother had the next highest spike, in early March. Medium bumble bees visited the Adjacent Clone the least, it having the smallest spike in weighted abundance, which was in late March.



As Figure 8 shows, large bumble bees visited the Raven's mother most per minute, with equally-high weighted abundances in mid-February and again in early March. Clone 2 followed closely behind with a major spike in early March and two small spikes, one in early February and one in late March. The Franciscan mother had the next highest spikes, one in early March and a smaller one in late March. No large bumble bees visited the Adjacent Clone.



I also measured bee observations against wind speed to determine if wind appeared to have an effect on the number of bees visiting the plants. I narrowed this calculation down to only the three plants being monitored for bee visits around the same restoration site: the Raven's mother, Clone 2 and Adjacent Clone. All three had similar wind speed measurements due to the fact that they are all located along the coast, unlike the Franciscan mother, which is located more inland and thus more protected from the wind. Measuring the total bee observation abundances against the average wind speeds for these three plants, wind does not appear to have a correlation with bee abundance as abundance initially increases; yet the two may have a relationship as abundance later drops off (see Figure 9). Bee abundance rose from early February through early March as wind speeds fluctuated, suggesting that wind did not affect bee visits. As wind speeds spiked in late March and again in mid-April, however, bee abundance also dropped. In addition, a slight spike in bee abundance in early April coincided with a decline in wind speeds.



In addition to identifying bees by sight, I took a number of photographs of the observed bees in order to attempt to further classify them. I sent these photographs to Dr. John Hafernik for species confirmation. We identified most bumble bees as either *Bombus vosnesenskii* (see Images 4-5), or *Bombus melanopygus* (see Images 6-7). We also identified the honey bee as the European species, *Apis mellifera* (see Image 8).

Image 4. *Bombus vosnesenskii* on Franciscan Mother March 2, 2012

Image 5. *Bombus vosnesenskii* on Raven's Mother March 2, 2012

Image 6. *Bombus melanopygus* on Adjacent Clone February 2, 2012

Image 7. *Bombus melanopygus* on Clone 2 March 9, 2012

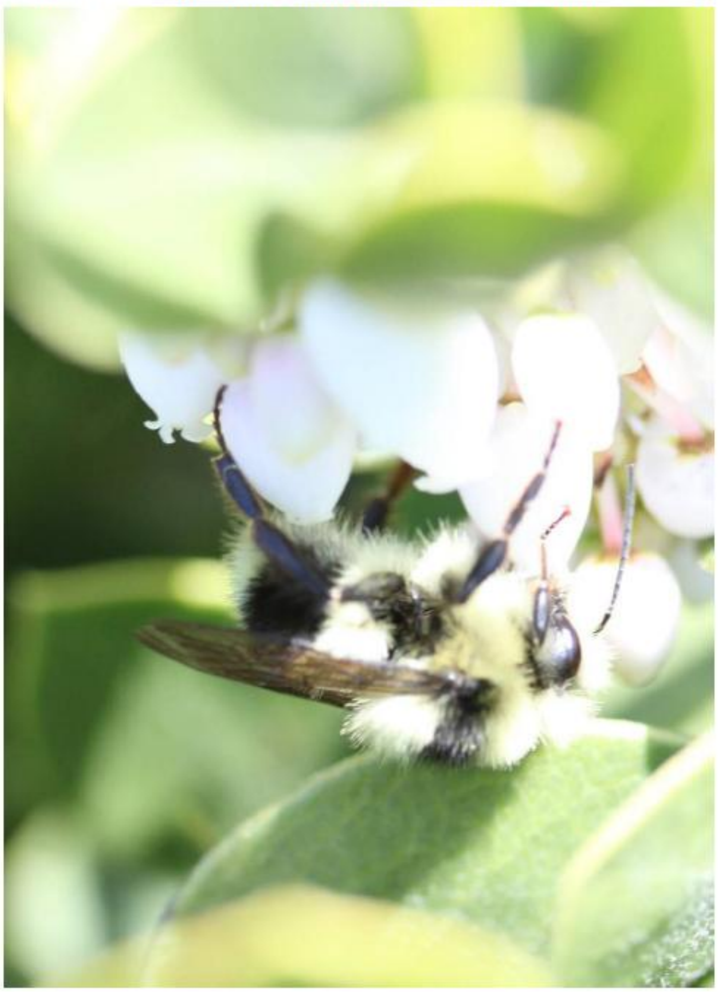


Image 8. *Apis mellifera* on Raven's Mother March 9, 2012

Furthermore, over the course of the study, I noted a variety of other insects on all the plants: common flies, moths, yellow jackets, gnat flies, lady bugs, caterpillars, beetles, and spittle bugs. Most of these specimens were observed flying around the plant or sitting on the plant's leaves. I was able to photograph and identify some of the flies with the help of Dr. Hafernik (see Images 9-12).

Image 9. Common fly on Franciscan Mother April 6, 2012

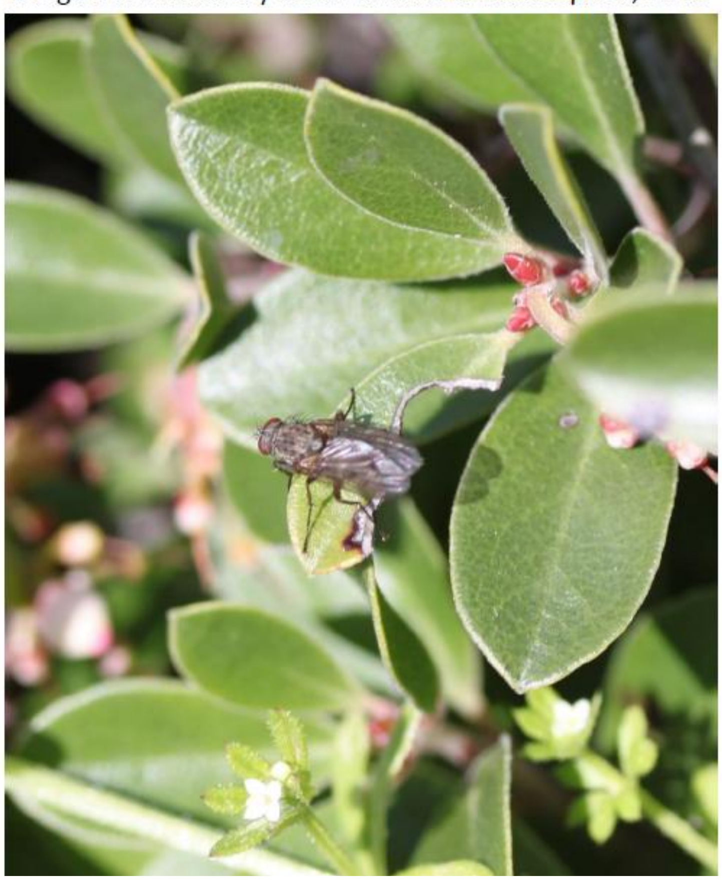


Image 10. Syrphidae (hover fly) on Raven's Mother February 2, 2012

Image 11. Bibionidae (march fly) on Raven's Mother April 6, 2012

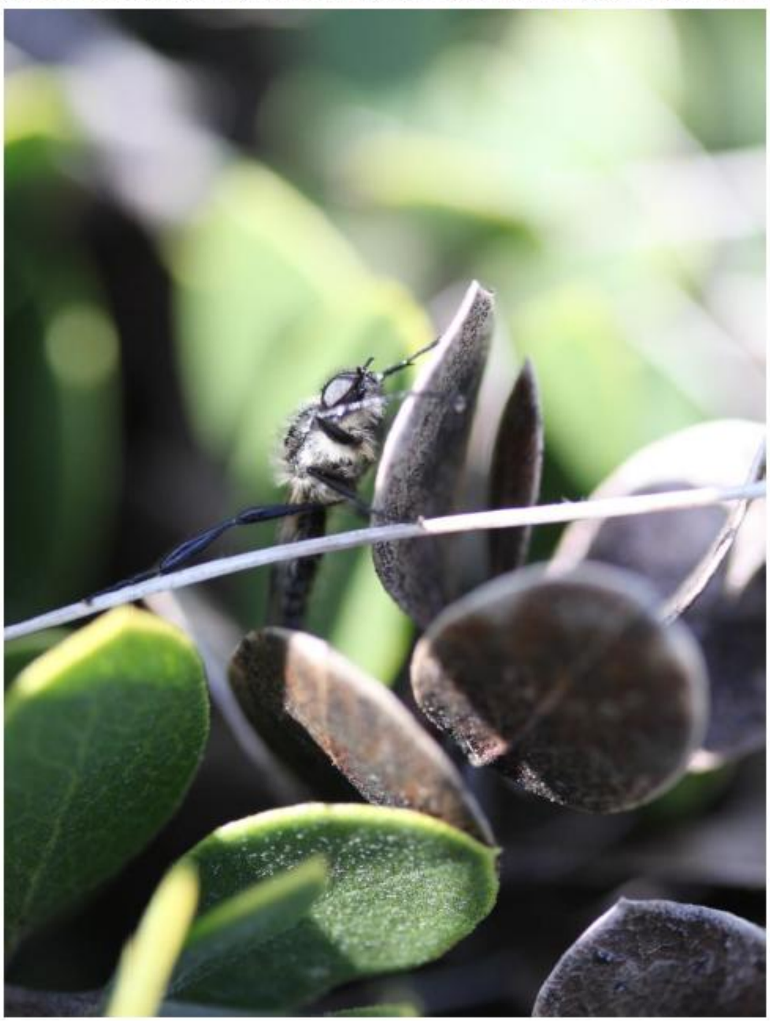


Image 12. Bibionidae (march fly) on Clone 2 April 6, 2012

I was also able to photograph a yellow jacket and a bee fly each drinking nectar from the manzanita's flowers, and thereby most-likely pollinating the plant indirectly (see Images 13-14).

Image 13. Vespidae (yellow jacket) on Clone 3 February 15, 2012

Image 14. Bombyliidae (bee fly) on Franciscan Mother March 22, 2012

Discussion

All the manzanita plants flowered late January through mid-April, which is slightly later than Dr. Tom Parker's account of *A. montana* ssp. *ravenii* flowering in mid-winter to early spring (Parker and Frey, 2010). This shift may be due to the low levels of precipitation for the season and/or the late date of the rise in precipitation, as shown in Figure 10 ("Weather History"). Ongoing studies should measure precipitation and flowering times over many years in order to get a more accurate account of both.

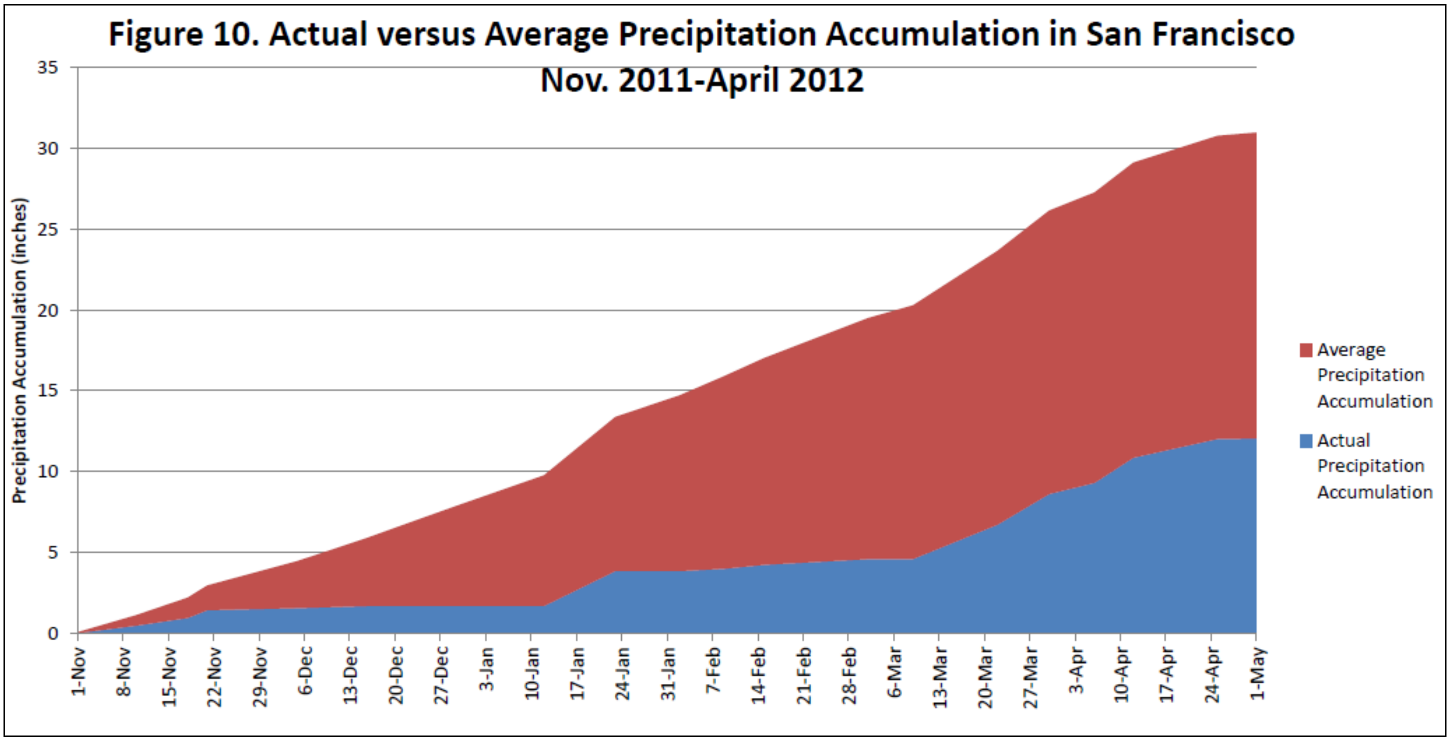


Figure 10. Actual versus Average Precipitation Accumulation in San Francisco Nov. 2011-April 2012

Accurately measuring the abundance of open flowers was a challenge for me due to the sheer amount of flowers on each plant as well as the physical placement of the flowers. Further research should determine a more precise method for measuring open flowers, such as using smaller plants, only measuring certain portions of the plants, or establishing a precise mathematical method of estimation.

Bee abundance indeed spiked at the same time of the season as open flower abundance, both in early March. Furthermore, as open flower abundance dropped, so did bee abundance. This suggests that open flower abundance was the main factor affecting bee abundance. Precipitation accumulation throughout the study period did not appear to affect bee abundance because bee abundance in fact increased along with precipitation accumulation. Wind speed fluctuated during the rise in bee abundance, and thus did not seem to affect bee numbers, either. Although wind speed rose to an average of 26 miles-per-hour along the coast in late March, bees were still very much present. It is therefore understandable that most of the observed bees were bumble bees, which have a lot of hair to protect them from the cold wind (Mader *et al.*, 2011).

Bumble bees are also some of the first to emerge in early spring, or in this case, late winter (Mader *et al.*, 2011). The mid-winter to early spring flowering times of the manzanitas coincide with bumble bee emergence times, and so it is logical that most bees observed were bumble bees. Most bumble bees were identified by Dr. Hafernik and me as *Bombus vosnesenskii* or *Bombus melanopygus*: both species are common to the area, and thus are the best conclusion based on the photographs taken. Yet other similar species may also have been present, as well as bee species of lengths 0.5 inches or less, which are difficult to view because of their small size and quick flight. In future studies, more accurate observation and identification could be made from netting or collecting the specimens over longer observation sessions. Netting could also allow for more accurate observations of other invertebrates pollinating the plants.

As I observed the bees, I was also able to identify them better over time. Consequently, my later identifications were probably more precise than my earlier ones. After months of observations, I can also now speculate that most of the "medium" bumble bees were in fact *B. melanopygus* queens, while the "large" bumble bees were *B. vosnesenskii* queens, and the "small" bumble bees were workers of both of these species (Mader *et al.*, 2011). Therefore, my data suggests that, in all, I mostly observed *B. melanopygus* queens pollinating the plants. It also suggests that both *B. melanopygus* and *B. vosnesenskii* queens visited the Raven's mother the most per minute, followed by Clone 2 and then the Franciscan mother, while *B. melanopygus* and *B. vosnesenskii* workers visited the Adjacent Clone the most per minute.

With regard to pollinator species cross-over, there was very little difference between the Raven's and Franciscan plants. I did not observe any small bumble bees, honey bees, or unknown bees visiting the Franciscan mother, but these absences may have had very little to do with the plant and much more to do with my monitoring methods and/or times. More accurate observation and identification methods in the future could lead to more detailed results comparing the pollinator species for these plants.

In all, this project provides a baseline for further surveys of the Raven's and Franciscan manzanitas. Monitoring these plants over more years, and possibly at different sites, could provide more information as to: their average flowering times and how weather affects these times; the timeline of flower pollination; the variety of invertebrates directly and indirectly pollinating the plants; and the similarities and differences between data sets of the two manzanita species.

Acknowledgements

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References

Flora of North America Editorial Committee. 2009. Flora of North America: North of Mexico. Oxford University Press, New York. 8: 406-445.

"Frequently Asked Questions." USA National Phenology Network website. http://www.usanpn.org/participate/faq#flowers.

Mader, Eric, Matthew Shepherd, Mace Vaughan, Scott Hoffman Black and Gretchen LeBuhn. 2011. Attracting Native Pollinators: Protecting North America's Bees and Butterflies. Storey Publishing, Massachusetts.

"Native Plants." The Presidio Trust website. http://www.presidio.gov/about/Pages/native-plants.aspx.

Parker, V. Thomas and Mark Frey. 2010. Management of *Arctostaphylos montana* subsp. r*avenii* in the Presidio of San Francisco. Report to The Presidio Trust. 3-4, 6, 9-10, 14, 16, 20, 33, 35, 46.

Stephen, W. P., G. E. Bohart, P. F. Torchio. 1969. The Biology and External Morphology of Bees. Agricultural Experiment Station, Oregon.

Thorp, Robbin W., Peter C. Schroeder, Carol S. Ferguson. 2002. Bumble Bees: Boisterous Pollinators of Native California Flowers. *Fremontia*. 30: 26-31.

U.S. Fish and Wildlife Service. 2003. Recovery Plan for Coastal Plants of the Northern San Francisco Peninsula. 61, 113, 196.

U.S. Fish and Wildlife Service. 2011. Endangered and threatened wildlife and plants; 12-month Petition Finding and Proposed Listing of *Arctostaphylos franciscana* as Endangered. 76 FR 55623-55638.

Van Den Berg, Jessica, Chris Quock, John Hafernik. 2010. Comparative Study of Bee Diversity in Restored Habitats in the Presidio, San Francisco. Report to The Presidio Trust.

"Weather History." Weather Underground website. http://www.wunderground.com/history/.

Wood, Hannah, Vicki Moore, Cynthia Fenter, Meghan Culpepper, Jamie Nicolloff, John Hafernik. 2005. Bee Diversity in Restored Habitats in the Presidio, San Francisco. Report to The Presidio Trust.