Flower Color Preference in Native Ohio Bees

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Declining bee populations have recently become a growing concern in the field of conservation science. Reports of colony collapse disorder being responsible for approximately one-third of winter honeybee losses (Kaplan, 2012) have drawn both scientists and concerned citizens to the conservation of both honeybees and native bee species. As gardeners note the infrequency of bee visits to their gardens, many have come to try to tailor their gardens to the needs of these important pollinators. One of the most popular anecdotal observations is that bees seem to prefer blue and purple flowers over their red or white counterparts. Gardening websites and online communities are full of suggestions to plant more lavender, liatris, and other blue or purple plant cultivars.

This notion may not be entirely based on hearsay. Numerous studies have shown innate preferences for blue and purple nectar sources in several types of bees. Bumblebees with no previous foraging experience have been shown to prefer both blue and yellow over all other color stimuli (Simonds & Plowright, 2004). Another study found that when presented with several new colors of artificial flower, bumblebees will revert to their innate color preference even after training to forage on one specific color of artificial flower (Gumbert, 2000). Similarly, flower-naïve honeybees tend to visit blue and green nectar sources more frequently (Giurfa, Núñez, Chittka, & Menzel, 1995). Amaya-Marquez et al. (2008) also found that native blue orchard mason bees chose blue flowers over white or yellow flowers, even when all flower choices contained the same amount of nectar.

A great deal of literature exists addressing the flower preferences of bees in controlled laboratory environments, using artificial flowers and controlled nectar substitutes, however very few studies have addressed the behavior of bees in their natural environment. Therefore, this study attempted to fill a gap in the literature by observing bees and their flower choices in a rural garden habitat. To support the legitimacy of anecdotal reports of blue flower preference, as well as determine whether or not the blue flower preferences found in previous studies hold water outside of the laboratory, this study posed these questions: (1) Will bees on a five-acre plot of land in New Richmond, OH prefer to visit warm-colored flowers (reds, yellows, oranges) or cool-colored flowers (blues, purples, pinks)? (2) Will different types of bees show differing color preferences? The prediction is that bees, overall, will visit cool-colored flowers more often than warm-colored flowers, and that there will be differences between some types of bees. In the observation area, cool-colored plants appear to be visited more frequently by bees, however certain types of bees have been observed gathering in large numbers at one or two specific plants of one color. These preferences have not been scientifically investigated until now. The study described herein sought to do just that.

Methods

While many studies have observed the flower preferences of bees in a laboratory environment, this study sought to determine flower preference in the bees' natural environment, and whether individual bee genera might have flower preferences different from other genera. Two flower color groups were observed: warm colors and cool colors. "Warm" flowers were defined as those containing predominantly red, orange, or yellow petals. "Cool" flowers were defined as those containing predominantly blue, purple, or pink petals.

Observation area

Three gardens on a five-acre property in New Richmond, OH were examined (Fig. 1). The Front Garden area contained approximately 24 yellow/orange plants (most yellow flowers also have orange coloring), 11 red plants, 9 pink plants, and 6 purple plants, for a total of 35 warm plants and 15 cool plants. The Side Garden area contained approximately 2 yellow/orange plants, 1 red plant, 1 pink plant, and 5 purple plants, for a total of 3 warm plants and 6 cool plants. The Planter Boxes area consisted of 5 planter boxes, containing between them approximately 15 yellow/orange plants, 2 red plants, 17 pink plants, and 3 purple plants, for a total of 17 warm plants and 20 cool plants. Between all three observation areas, there were

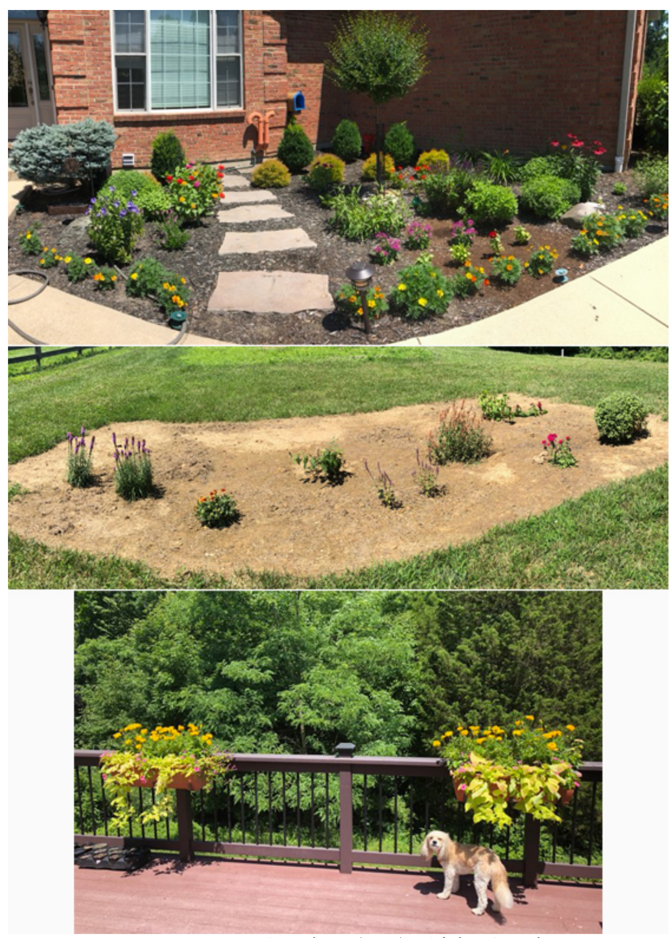

Figure 1. Front Garden (top), Side Garden (middle), and Planter Boxes (bottom)

approximately 41 yellow/orange plants, 14 red plants, 27 pink plants, and 14 purple plants; that means a total of 55 warm plants and 41 cool plants. While the number of individual warm plants was greater than the number of individual cool plants, the warm plants, in general, were smaller and contained fewer flowers, while the cool plants were larger and contained many flowers. For example, in the Front Garden, the yellow/orange marigolds lining the border of the garden are very small and each contain only a few flowers, but the purple balloon flower (far left) and salvia (mid right) have many stalks containing many individual flowers. This helped balance the approximate number of each color flower in the observation areas.

Study Population

This study investigated native bees in the New Richmond, Ohio area, as well as the naturalized Western honey bee (*Apis mellifera*). In order to simplify and streamline the data collection procedure, bees were identified to the most recognizable genus or family:

Species of interest

- Honeybees (*Apis mellifera*)
- Bumblebees (genus *Bombus*)
- Large carpenter bees (genus *Xylocopa*)
- Small carpenter bees (genus *Ceratina*)
- Leaf-cutting bees (genus *Megachile*)
- Mining bees (genus *Andrena*)
- Sweat bees (family *Halictidae*)
- Long-horned bees (genus *Melissodes*)
- Unidentifiable

Mason bees (*Osmia* sp.), although native to the area, were omitted from the study due to their active season having ended before observations began. Native squash bees (*Peponapis pruinosa*) were also omitted as their food source (squash plants, family *Cucurbitaceae*) was not found in or near the observation area. A category for "unidentifiable" bees was included for instances in which a bee was blurred by movement, out of focus, or too deep in shadow to be accurately distinguished from other bees of similar shapes, sizes, and colors (namely, sweat bees and small carpenter bees).

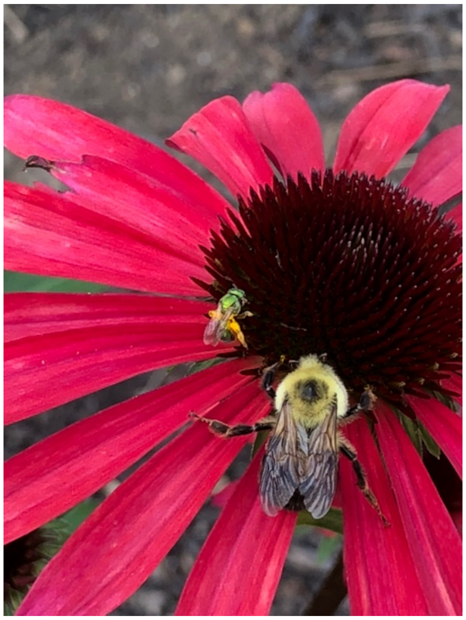

Figure 3. A bumblebee and a sweat bee visiting a warm flower.

Materials

An iPhone 8 Plus camera was used to take pictures of each individual flower on each plant in the observation areas. Photos were taken as quickly as possible to reduce the chance of photographing the same bee at two different flowers. The photos were then reviewed and the number of each type of bee visiting flowers was tallied in an observation chart for each color of flower (Fig. 2). "Visiting" was defined as the bee visibly sitting on the flower, not in flight or with wings open presumably in preparation for flight (Fig. 3). The Ohio Bee Identification Guide (Prajzner & Gardiner, 2015) as well as Iowa State University's Bug Guide (2003) were used to identify the bees in the photos. Temperature and weather information were also recorded at each observation time. A Microsoft Excel spreadsheet was used to compile the data throughout the course of the study and calculate totals. A chi-square test for goodness of fit calculator (Stangroom, 2018) was ultimately used to determine the statistical significance of bees' preferences for the two flower color categories, using an alpha level of 0.05.

Observation time

The study spanned 12 days, from July 2 to July 13, 2018. Observations were conducted three times a day, at 11:00 AM, 2:00 PM, and 5:00 PM. These observation times ensured that data was collected during peak activity times for most bees, and that all plants were in full sun to rule out shade as a factor in flower preference. Data were collected rain or shine, except during thunderstorms (July 2 and 3 at 5:00 PM), as the bees were not active during heavy rain.

Results

Data from all three observation sites over the 12-day study period were pooled to get a total count of bees visiting each flower category. A total of 2,398 bees were observed. The data were also broken down by bee type to determine whether any differences existed between genera

(Table 1). A chi-square test for goodness of fit was conducted for the total number of all bees, as well as for each bee type, using an alpha level of 0.05 (Table 2). During the course of the study, all bees combined visited cool flowers more often than warm flowers ($p < .001$). However, there were differences between types of bees (Fig. 4). Bumblebees and leaf-cutting bees visited warm flowers more often ($p < .001$ and $p = .005$, respectively), while small carpenter bees visited cool flowers more often ($p = .027$). Sweat bees and long-horned bees did not show any preference ($p = .157$ and $p = .108$, respectively), and there were not enough data on honeybees, large carpenter bees, or mining bees to run a chi-square test for those groups.

Table 2

Statistical Significance by Bee Type

Bee type	x^2 value	p-value	Significant?	Preference
Honeybees	*Not enough data*			
Bumblebees	20.694	$p < .001$	Yes	Warm
Lg. Carpenter Bees	*Not enough data*			
Sm. Carpenter Bees	4.916	$p = .027$	Yes	Cool
Leaf-cutting Bees	8.067	$p = .005$	Yes	Warm
Mining Bees	*Not enough data*			
Sweat Bees	1.999	$p = .157$	No	N/A
Long-horned Bees	2.579	$p = .108$	No	N/A
Unidentifiable	131.008	$p < .001$	Yes	Cool
All Bees	**29.506**	$\boldsymbol{p < .001}$	**Yes**	**Cool**

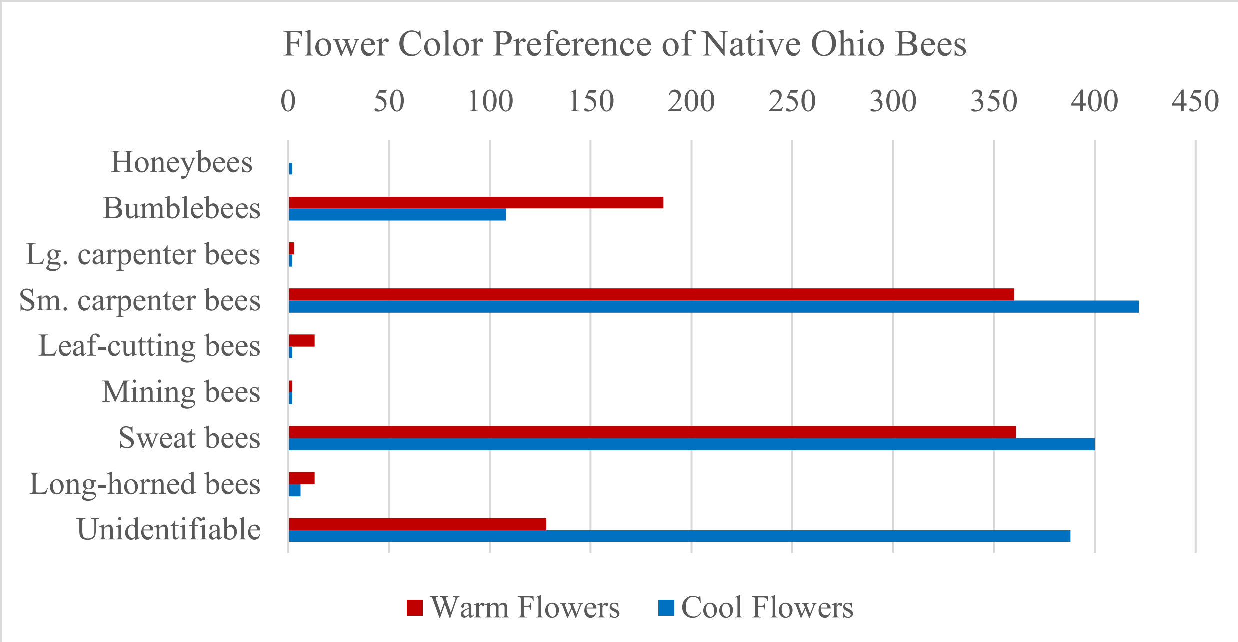

Figure 4. Total number of each type of bee visiting each flower color in New Richmond, OH over 12 days.

Discussion

According to the data collected in this study, despite *Bombus* species and *Megachile* species showing a preference for warm-colored flowers, most bees that visited flowers in New Richmond, OH seemed to have a general preference for cool-colored flowers, even in this specific case where the approximate number of warm-colored flowers slightly exceeded the total number of cool-colored flowers. One reason for the flower choice difference between types of bees might be that warm-color-preferring bee species emerged earlier in the season than the cool-color-preferring bees. Previous studies have shown that while bees have innate color preferences, they also have learned color preferences based on nectar reward. For example, the blue orchard mason bees in the Amaya-Marquez et al. study (2008) showed a decrease in preference for blue flowers when also presented with white flowers containing more nectar. Therefore, older bees may have had time to learn these new color preferences based on the amount of nectar in specific warm-colored flowers. The two warm-color-preferring genera in this study, *Bombus* species and *Megachile* species, both emerge in early spring (Iowa State University, 2003), giving them plenty of time to learn new preferences by the time of observation in early July.

There were a few possible confounding variables that revealed themselves during the course of the experiment. First of all, color is not the only thing that differs between flowers. Size, shape, orientation, proximity to other flowers, and even nectar content differ widely between species. The height of the plant could affect the choices of bees, as well as whether the plant is in sun or shade. Some plants have even evolved specifically to attract certain pollinators and repel others, i.e. certain flowers that attract hummingbirds but are ignored by bees (Lunau et al., 2011). In addition, bees have photoreceptors for ultraviolet light; there are floral markers in some flowers that are only visible in the ultraviolet, which have been shown to attract bees almost as much as differences in human-visible-spectrum colors (Horth, Campbell, & Bray, 2014). Without spectroscopy equipment, detecting the presence of UV floral markers was impossible for this experiment. Another minor inconvenience during the data collection process was that certain types of bees proved more skittish than others and took flight when approached by the camera (most notably, the small carpenter bees). Every attempt was made to wait until the bees were relatively settled before data collection began, but this could still potentially have affected the numbers.

Further experiments might help control for some of these variables. Flowers could be artificially altered to contain more or less nectar, or be planted on top of platforms to control for plant height. To rule out flower form as an interfering variable, using several plants of one species that has two different color variants might also be useful. Trying the experiment again with a higher quality camera could also help to reduce the number of unidentifiable bees in the final dataset, and perhaps clear up whether the inconclusive results for sweat bees were due to many of them ending up in the unidentifiable category. Further field research will also help us to understand how environmental factors—both natural and manmade—affect bees' flower choices.

Conclusion

This experiment succeeded in lending evidence to the common belief that bees are attracted to blue and purple flowers. The data analysis revealed a significant preference for cool flowers by bees visiting the rural garden in New Richmond, OH in general. The results of this and similar experiments could have impacts on a variety of personal, conservation, and even commercial endeavors. Gardeners and conservationists alike can use the knowledge that bees seem to gravitate toward blue and purple flowers when considering what kinds of conditions they want to create in their gardens or restored habitats. It might also be prudent for individuals with bee-sting allergies to avoid planting these flowers around their houses, in order to discourage bees from lingering too close to the house. Bee-friendly flowers could be planted around fields of crops that a farmer wants to be sure are pollinated. Hypothetically, crops could even be genetically engineered to produce flowers of a certain color to help ensure that they get pollinated. Knowing that bees are more likely to visit cool-colored flowers opens up a world of opportunities in regards to how human beings interact and coexist with these important pollinators.

Reflection

This experiment was an important first step for me to hone my research skills. Aspects of experimental design that I thought I was already fairly good at ended up giving me more trouble than I anticipated. What started as an idea for a simple, straightforward first project ended up inundating me with confounding variables and constantly evolving methods. While I am moderately experienced with identifying bees, I was not prepared for the enormous number of bees that would prove unidentifiable simply due to their position inside a tight flower, or the awkward reflection of the sun on their wings. If I ever decide to retry this experiment, I would definitely have to rethink my methods and perhaps try to identify the bees in situ rather than relying on photographs. Given the opportunity, I would also like to try using different colors of the same type of plant to rule out flower shape, size, and height as factors; petunias, Angelonia, zinnias, and butterfly bush are all easily accessible in a variety of colors, and could easily be planted together in a large garden plot.

Even though I had some setbacks and frustrations, I am grateful for the opportunity those obstacles gave me to sharpen my research skills. I found that, contrary to research papers I had done in undergrad, I followed the sources cited in some of my references to find even more detailed evidence to support my project. While I could certainly still benefit from more practice in this area, I feel that this project pointed me in the right direction. I also developed a new way of organizing my sources so that important information was conveniently arranged and ready to cite when it was needed. Overall, this experiment was more of a learning experience than I could have imagined, and will only strengthen my future projects.

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Appendix

Date: Time: Obs. Area: Temp: Weather:	"Warm" Flowers	"Cool" Flowers
Honeybees		
Bumblebees		
Lg. Carpenter bees		
Sm. Carpenter bees		
Leaf-cutting bees		
Mining bees		
Sweat bees		
Long-horned bees		
Unidentifiable		

Figure 2. Data table used to tally number of bees observed.

Table 2

Flower Color Preference for All Bee Types

Bee Type	Visiting Warm	Visiting Cool	Total Observed
Honeybees	0	2	2
Bumblebees	186	108	294
Lg. Carpenter Bees	3	2	5
Sm. Carpenter Bees	360	422	782
Leaf-Cutting Bees	13	2	15
Mining Bees	2	2	4
Sweat Bees	361	400	761
Long-Horned Bees	13	6	19
Unidentifiable	128	388	516
Total	**1066**	**1332**	**2398**

Note: Total bees of each type observed visiting each color of flower in New Richmond, OH.