

Effects of Temperature and Competitor Abundance on Bumble Bee Foraging

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Abstract

The role of plant-pollinator interactions is essential for successful plant and pollinator reproduction, thus influencing community assembly of both plants and animals within an ecosystem. Pollinators exhibit competitive behavior in order to collect adequate quantities of pollen and nectar, and bees in particular heavily rely on these floral resources to provide for their colony. Pollinator competition can largely determine the makeup of plant and pollinator species within an ecosystem, as well as how their competitive behavior may contribute to the function of an ecosystem as a whole. With climate change on the rise, the dynamics of pollination competition may be disrupted and negatively affect the ecosystem. Therefore, it is important that we gain a better understanding of how environmental conditions influence the foraging and competitive behavior exhibited in pollinators so that we can predict how climate change might cause these behaviors to shift. This study focuses on the native bumble bees of the Rocky Mountains, and how temperature and time of day may influence the intensity of competitive behavior in the bumble bees. Data was collected at five different sites during the summer when the bumble bees were out foraging. Three rounds of bumble bee surveys were conducted at each site visit, accounting for the differences in observed behavior throughout the day. Our results suggest that competitor abundance plays the largest role in the bumble bees' competitive behavior, however this factor may affect different *Bombus* species in different ways or more significantly than others. Our data collection was limited due to constraints of time, however we were still able to find significant results for the *Bombus* species that were captured the most, suggesting that additional *Bombus* species may be found to follow similar trends if we have enough data on them.

Introduction

Plant-pollinator interactions play an important role in the ecosystem by influencing community assembly of both plants and animals. Plants rely on pollination for their reproductive success and in turn pollinators rely on these plants for nutritional resources (Mitchell et al., 2009). Both plants and animals exhibit interspecific competition for pollination (Temeles et al., 2016), as plants compete for pollinator visitation and animals compete for pollinating plants to get sufficient nectar rewards. Bees are a unique group of pollinators as nectar rewards are not the only driving factor for their pollination. Pollen is an important part of reproductive success for bees as pollen is a resource fed to bee larvae (Peat & Goulson, 2005), thus the ability to forage efficiently is vital for bees to successfully support their colony (Balfour et al., 2015). Like other pollinators, bees also

engage in pollination competition, which has been shown to heavily influence the contribution of the bees to the function of an ecosystem through interactions with other competitors (Brosi & Briggs, 2013). Bumblebees in particular exhibit active exploitative competition (Balfour et al., 2015) and competitive release (Inouye, 1978), which helps shape the flower-visitor communities in their ecosystem. However, bumblebees cannot effectively pollinate until adequate weather and temperature conditions are met (Peat & Goulson, 2005), thus they cannot exhibit competitive behavior until these conditions are met as well.

While it is known that bumble bees require specific standards in conditions of weather and temperature to actively forage, there is little known about how this may affect the degree to which competitive behavior in bumble bees is exhibited. Additionally, little is known about how temperature may affect the relative 'attractiveness' of floral resources to bumble bees, potentially influencing bumble bees' foraging behavior. There may be observed patterns of some flowers being pollinated earlier in the day, suggesting that there is a race to acquire the flower's resources before they become depleted. These ideas have raised the question of whether temperature and time of day affect the intensity of competitive behavior with pollinators. Studying how these environmental factors can affect competitive behavior in pollinators could give us a greater understanding of how these behaviors may be impacted by climate change. As discussed above, competition plays an important role in plant-pollinator interactions and can greatly influence the structure and function of plant and animal communities in an ecosystem. As climate conditions begin to change significantly, both plants and animals may respond differently and disrupt the dynamics of pollination competition.

There are three main expected results that could come from these questions. First, it is expected that visitation rates to flower species will have significant differences during specific hours of the day. Previous research from Peat and Goulson show that there are specific weather conditions that are optimal for bumble bees to begin foraging, thus implying that there are specific hours of the day when these optimal conditions are met. More bumble bees would then be expected to be observed visiting flowers during these times than during other hours of the day. Second, it is expected that flower species will be visited most frequently by a single species of bumble bee while there is an abundance of bees out foraging. Inouye points out that bumble bees only visit a diverse number of flowers when there are more resources available from these flowers. If there are more bees out at the same time foraging, then it is likely that each bee will keep to an exclusive number of flowers to ensure they have a reliable source of pollen and nectar. Finally, it is expected that there

will be a correlation between temperatures during hours of the day when “exclusive” flower visitation rates are high. A study done by Gonulkirmaz-Cancalar et al. revealed that bumble bees have the ability to associate factors such as time of day with floral reward, suggesting that through experience these bumble bees can change their foraging behavior to match with known times of the day when rewards are greater (2023). It is possible that bumble bees can associate certain times of the day with more floral rewards, and these greater rewards could be the result of the flower responding to a temperature that is frequent during that time of the day.

Methods

We established a total of five sites for this study that were located in: Brush Creek (Figure 1), Kebler Pass (Figure 2), Rustler Gulch (Figure 3), Stupid Falls (Figure 4), and Washington Gulch (Figure 5). At each site, we delineated a 50x50 meter plot. We placed a HOBO pendant (UA-001-08) in the center of each plot for the duration of this study to measure temperature at five-minute intervals. For each sampling day, we conducted 2–3 rounds of bumble bee surveys. Each round consisted of 30 minutes of active sampling, with timing paused during the handling of bumble bees. To account for variation in foraging behavior throughout the day, we began surveys at distinct points in the day — roughly 10:00am, 12:00pm, and 2:00pm. During each round, a team member would patrol the entire plot in a haphazard manner and catch any bumble bees they observed interacting with the reproductive parts of a flower. A 30-minute timer was kept on person during these patrols to pause whenever a bee was captured, starting the timer again once the bee was successfully collected. These bees were collected non-lethally in a 30-mL centrifuge tube; researchers would note the time the bee was captured, rounding it to the nearest fifth minute to match with temperature data, and the flower species it was collected upon. The collected bees were kept in an ice cooler to chill them enough and render them immobile so we could properly identify their species, at which point we allowed the bees to return to ambient temperature and return to foraging.

Using RStudio software, we used a generalized linear model to answer our main questions. We included the proportion of visits that each focal bee species made to a specific floral partner during distinct sampling rounds as our response variable, and used bee abundance and average temperature per round as fixed effects. An additional GLM was generated to examine differences in competitive foraging behavior between queen bees and their workers, as a number of queen bees were collected at the beginning of the season. In this model, we added caste (workers or queens) as an interaction term, with predictors and response variables otherwise identical to the previous model.

Results

Between June 25 and August 4 of 2024, we collected 448 bumble bees from 12 different species (Figure 6). Our most common bumble bee species were *Bombus appositus*, *Bombus bifarius*, and *Bombus flavifrons*, accounting for 69% of our total observations. We collected bees from 29 different floral species. In total, 26% of interactions made up our two most common interactions, *B. bifarius* visiting *P. fruticosa* and *B. appositus* visiting *D. barbeyi*. Because these interactions were the only ones with enough data points for us to build robust statistical models with, our subsequent analyses focused on them.

How does time of day affect flower visitation rates with pollinators?

We found that average temperature and total bee abundance were both significantly related to sampling round. Average temperature was found to increase with each round (Figure 7), while bee abundance was found to vary non-linearly with each round (Figure 8). Bee abundance was not significantly different between rounds 1 and 2, whereas bee abundance significantly dropped at round 3. While we initially planned to use time, average temperature, and bee abundance as predictor variables for our subsequent GLMs, we had to exclude round from our analyses due to this correlation.

How do flower visitation rates vary with different abundances of pollinators?

To analyze how bumble bee foraging may differ in response to competitor abundances, we used a GLM and looked at how the likelihood of both *B. appositus* and *B. bifarius* visiting their most common floral partners (*D. barbeyi* and *P. fruticosa*, respectively) might change with bumble bee abundance. The models rendered a marginally significant value for the effect of competitor abundance on *B. appositus* (Figure 9) and an insignificant value for *B. bifarius* (Figure 10). Both of these trends showed negative relationships between bumble bee abundance and the proportion of preferred flower visits. Although the values for *B. bifarius* was insignificant, it still had a stronger negative relationship than *B. appositus*. This is most likely due to *B. bifarius* having a smaller sample size than *B. appositus*. On the other hand, while *B. appositus* had a significant negative relationship for bee abundance, its likelihood of visiting its preferred flower still remained very likely across all values of total bee abundance.

How does temperature affect competitive foraging behavior between species of bumble bees?

We found insignificant values for the effect of temperature on foraging patterns both bumble bee species. Interestingly when we looked at the direction of these non-significant values, the relationship between average temperature and proportion of preferred visits was found to be the opposite for both species. While *B. appositus* was less likely to visit *D. barbeyi* as average temperature increased (Figure 11), *B. bifarius* was more likely to visit *P. fruticosa* as average temperature increased (Figure 12).

Caste Differences in Foraging Behaviors

Enough *B. appositus* queens were caught to generate a GLM that included the interaction between caste and the independent variables of relative bumble bee abundance and average temperature. The results were only found to be statistically significant for the *B. appositus* workers in regards to their relationship to relative bumble bee abundance and proportion of *D. barbeyi* visits. However, the workers had a negative relationship for proportion of *D. barbeyi* visits and both relative bumble bee abundance (Figure 13) and average temperature (Figure 14), while the queen bees did not respond to either variables and were 100% likely to visit *D. barbeyi* regardless of relative bumble bee abundance and average temperature.

Discussion:

The significant relationships between time, bumble bee abundance, and temperature suggests that flower visitation rates do indeed change throughout the day, with these changes mediated by both environmental (temperature) and biological (competitor abundance) variables. In particular, the finding that bumble bee abundance is lower in the afternoon round is consistent with our observations in the field, in which noticeably fewer bumble bees were flying and foraging by 2pm. Similarly, our experience in the field and prior data has found that temperatures tend to increase throughout the day, and do not begin declining until closer to sunset, which is well after we completed our bumble bee surveys each day.

The data used from *B. appositus* and *B. bifarius* suggests that bumble bee abundance and average temperature do affect flower visitation rates, however competitor abundance appeared to have a more significant effect on foraging behavior than average temperature. Additionally, the opposing relationships for average temperature and proportion of preferred flower visits between the two *Bombus* species suggests that certain species may respond differently to environmental variables

than others. However, because these observed relationships were insignificant and our limited data only allowed us to view these relationships for two of the *Bombus* species, it is still up for interpretation on whether these variables would play a role for additional species.

It is unsurprising that the queen *B. appositus* had different foraging behavior from its workers, this is most likely due to the fact that queen bees actively forage early in the season before a high abundance of pollinators have emerged and thus the queens do not have a need to compete with others. However, because we were only able to look at the queens of *B. appositus* and it was rendered insignificant, we cannot conclude that this is an active trend for all species or colonies.

Despite limited data with multiple insignificant values, this was not the case for all results, suggesting that with more data we would likely see more significant values. We may also find that certain *Bombus* species are more sensitive to these environmental variables if significant values are found with limited data still. Additional data collection in future bumble bee foraging seasons would be beneficial to add to our results, as their seasons are short and limit our ability to capture an abundant amount of bumble bees within the given time frame. Additionally, it would be interesting to consider more environmental variables that may play a role in the production of floral resources. It was suggested in our expected results that floral rewards may respond to environmental conditions that bumble bees can recognize, and these conditions may not be limited to just temperature. The sites that were used to collect our data had an abundance of flowers for the local bumble bees to forage, therefore there is the possibility that these bumble bees did not need to exhibit high levels of competitive behavior. Additionally, only a select few *Bombus* species were found at each site compared to the total *Bombus* species that are found in the Rocky Mountains. It would be interesting to see how the data may change if we had more *Bombus* species to look at, as well as sites that vary in flower abundance.

References

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Figure 1 First site located near Brush Creek off of Crested Butte, Colorado.



Figure 2 Second site located in Kebler Pass of Colorado.



Figure 3 Third site located in Rustler's Gulch within Gunnison National Forest, Colorado.



Figure 4 Fourth site located near Stupid Falls, Colorado.



Figure 5 Fifth site located near Washington Gulch, Colorado.

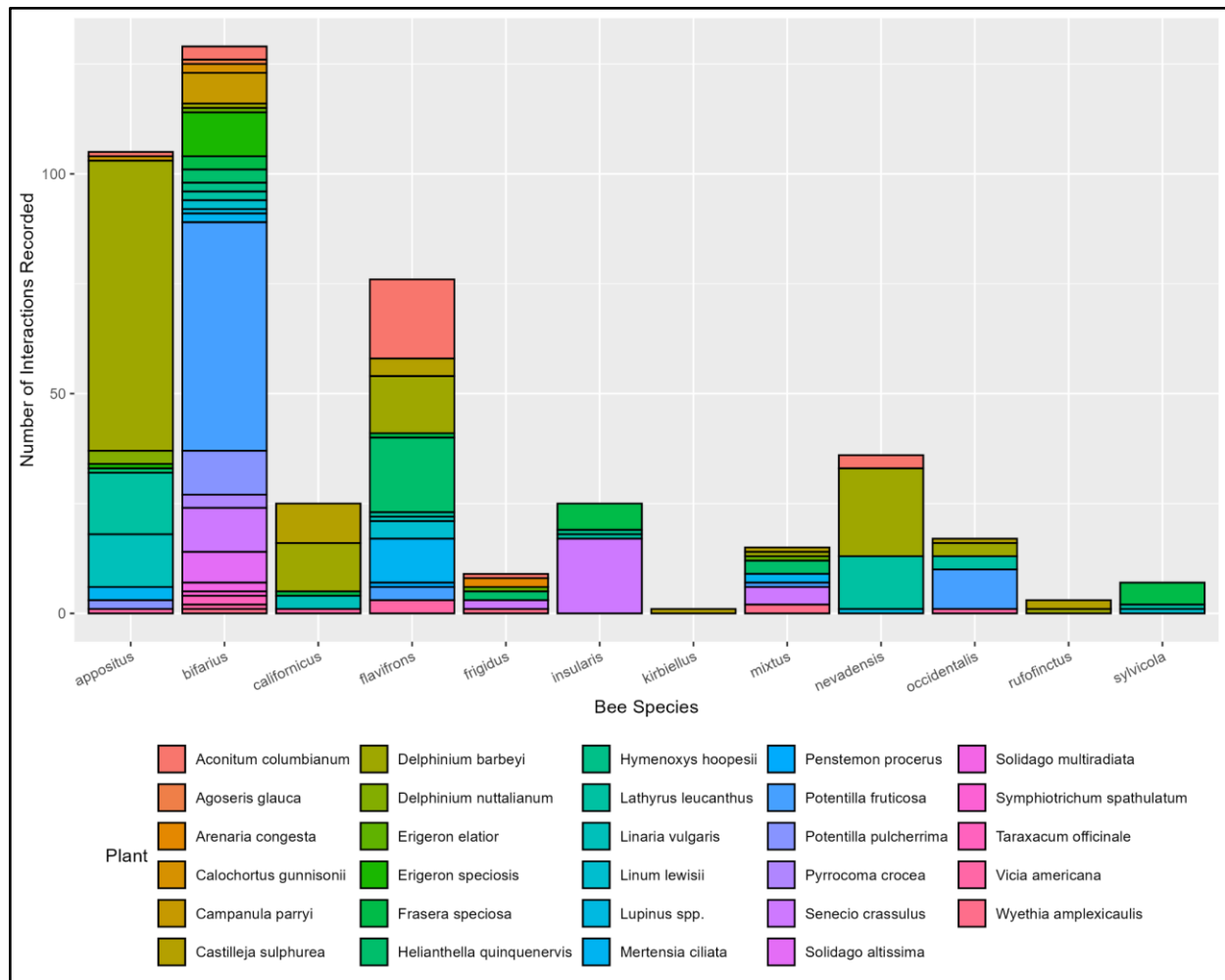


Figure 6 Total bumble bee tally reveals that *B. appositus* and *B. bifarius* were the most abundant species observed and collected, which were most often found on *Delphinium barbeyi* and *Potentilla fruticosa*, respectively

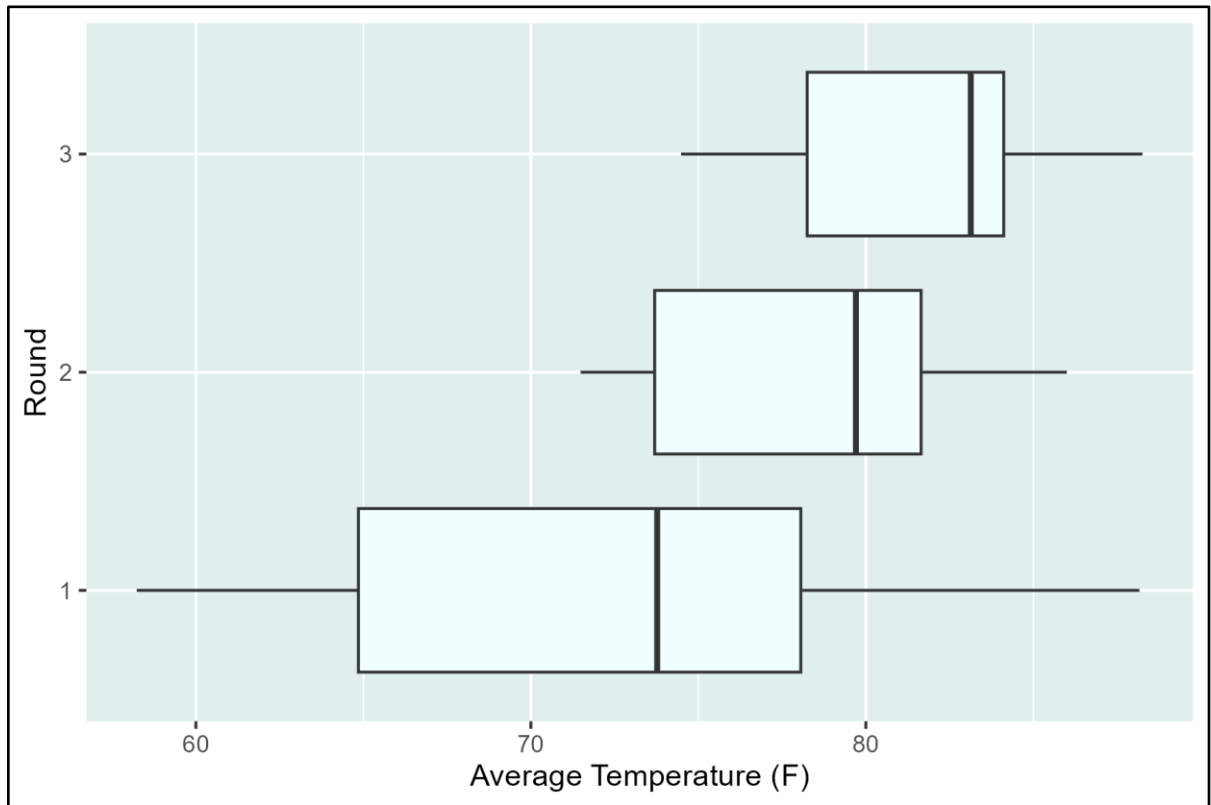


Figure 7 Average temperature significantly increased with each round, having a p value of 0.0054.

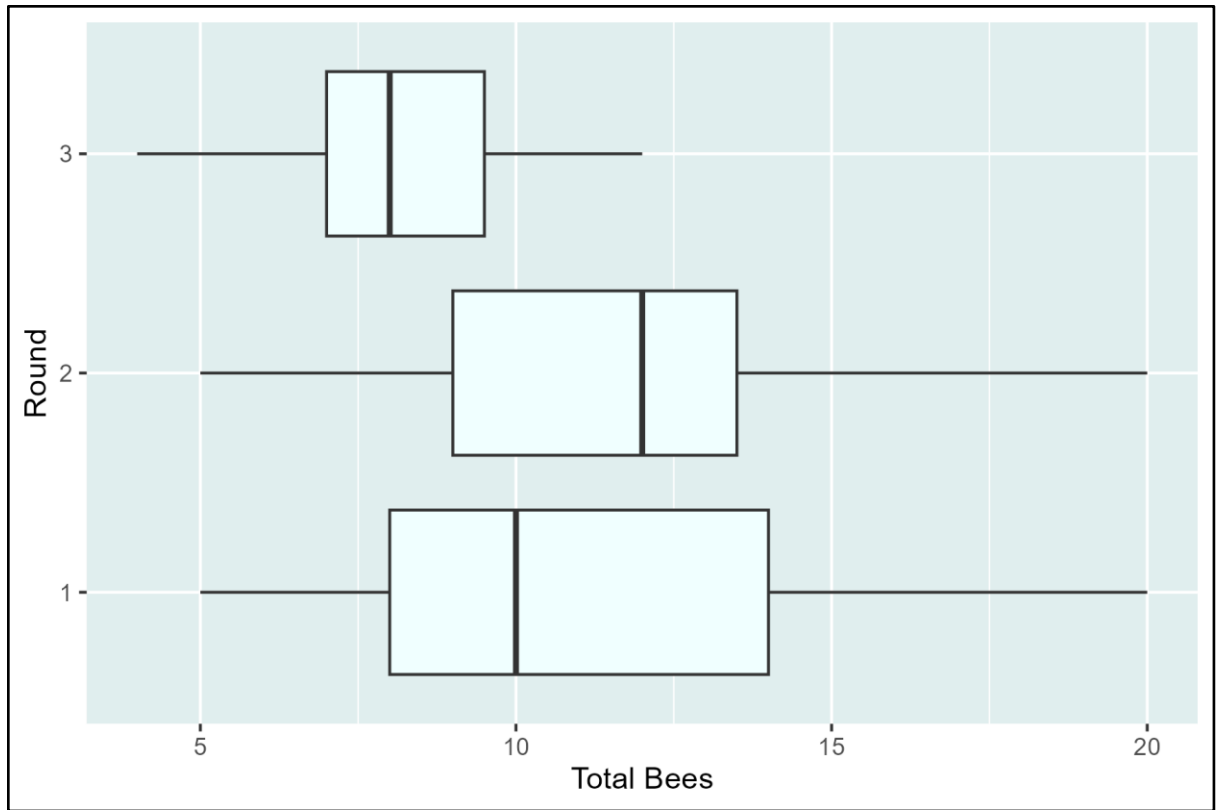


Figure 8 Relative bumble bee abundance was similar for both round 1 and 2, however the abundance significantly decreases at round 3. The abundance is measured by the total number of bumble bees that were caught during each round, and the data rendered a p value of 0.033.

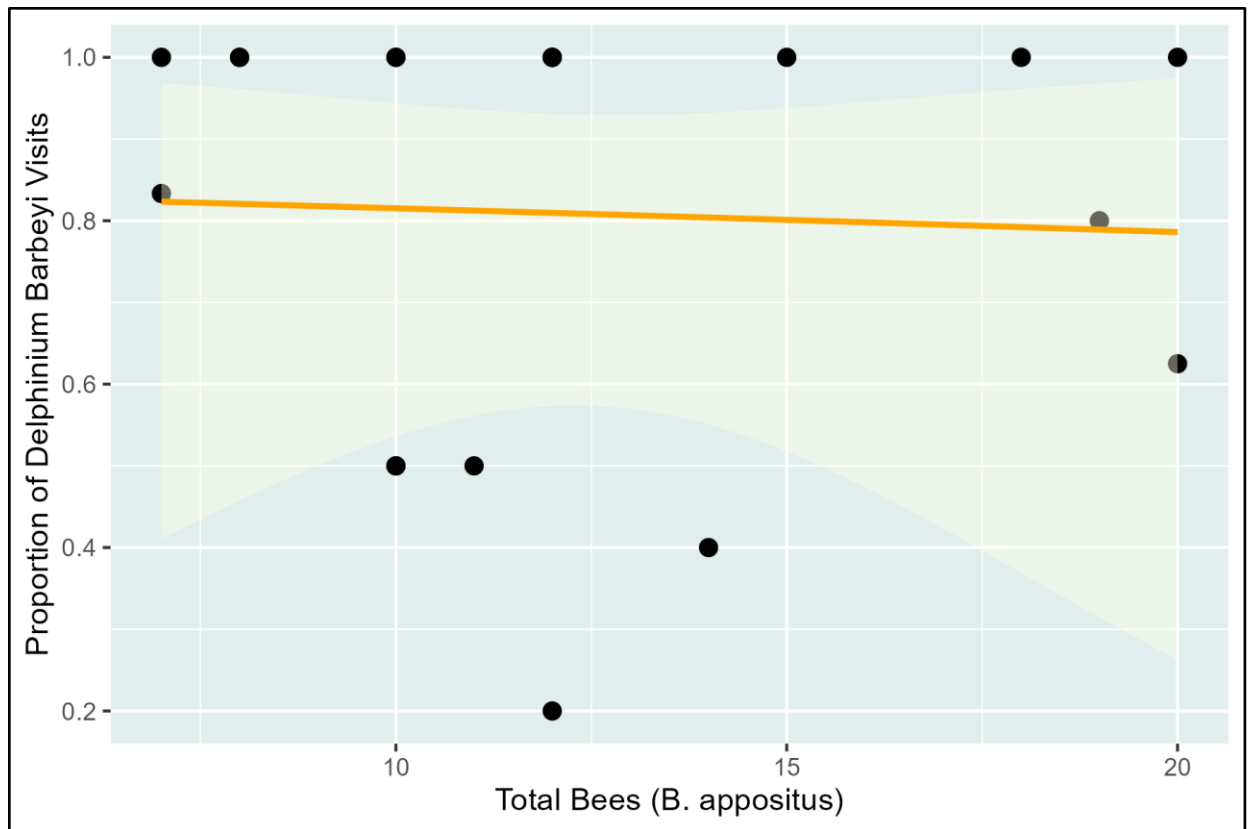


Figure 9 The probability of *B. appositus* visiting *D. barbeyi* decreased at a marginally significant level as relative bumble bee abundance increased, having a p value of 0.075.

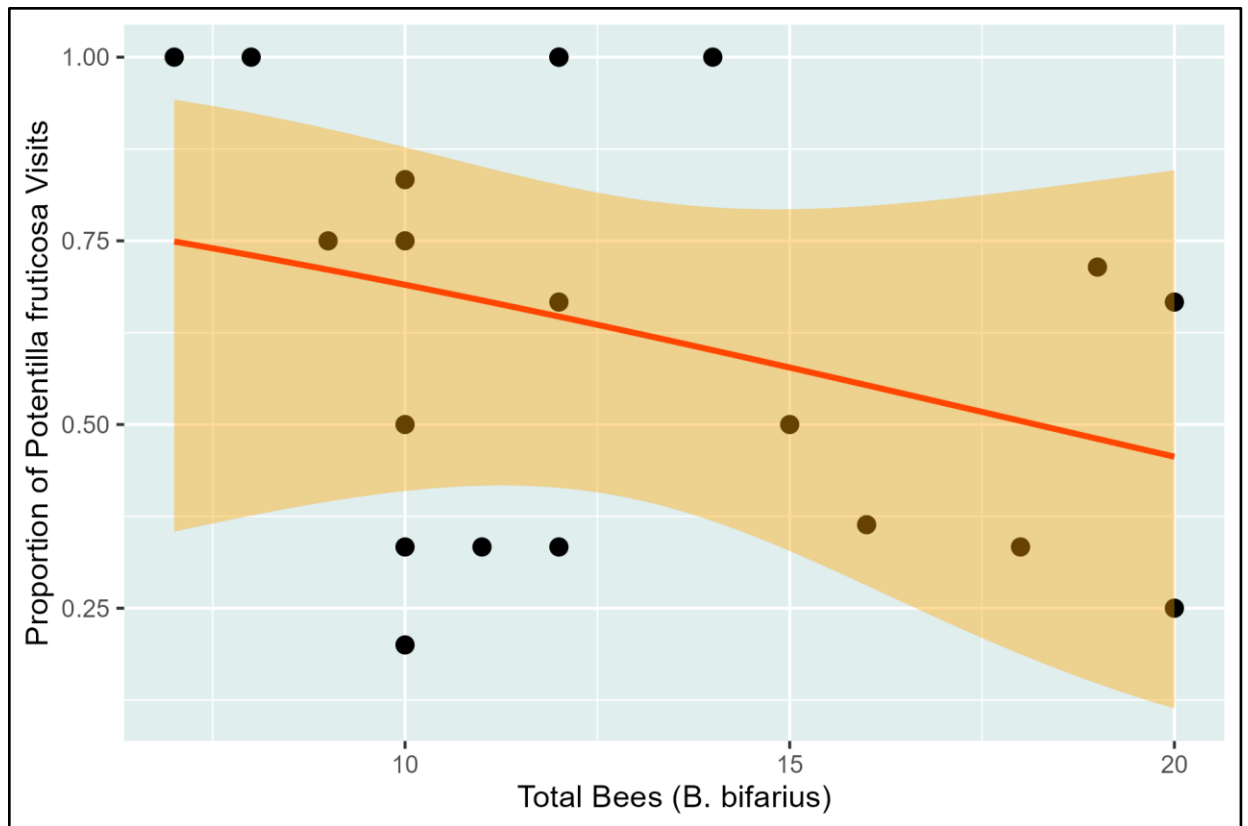


Figure 10 The probability that *B. bifarius* would visit *P. fruticosa* decreased as relative bumble bee abundance increased, however this was found at an insignificant level with a p value of 0.85.

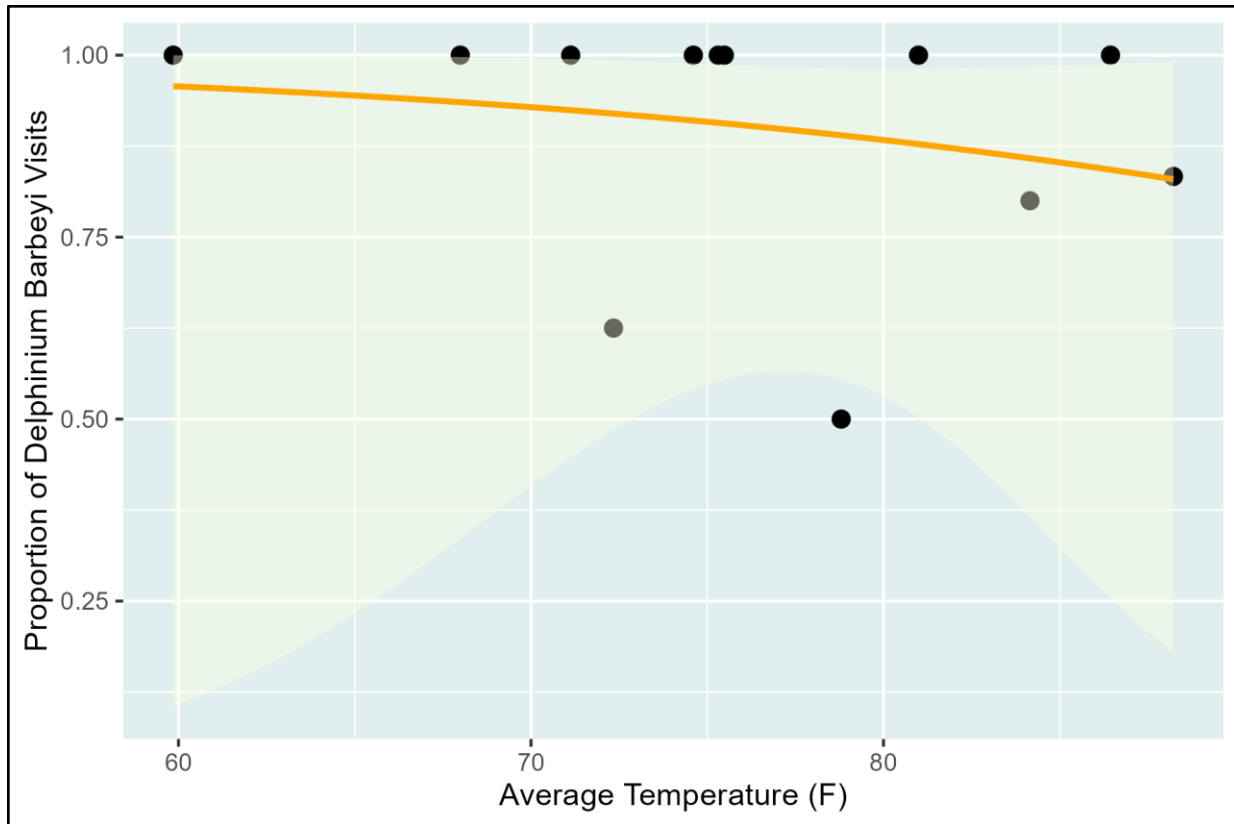


Figure 11 The results for *B. appositus* and the likelihood of visiting *D. barbeyi* as average temperature increased were insignificant, having a p value of 0.76. However, the model still displayed a negative relationship for average temperature and proportion of *D. barbeyi* visits.

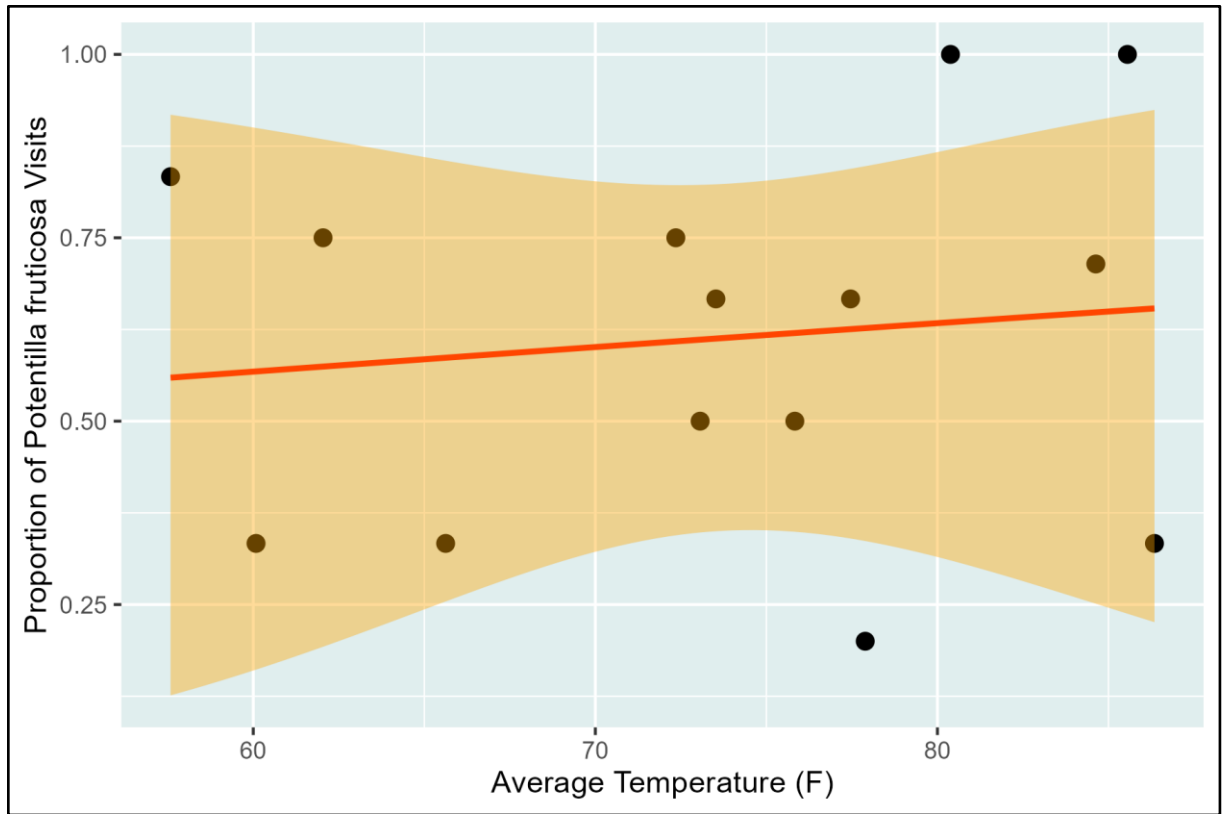


Figure 12 A positive relationship was found between average temperature and proportion of *P. fruticosa* visits for *B. bifarius*, however at an insignificant level with a p value of 0.71

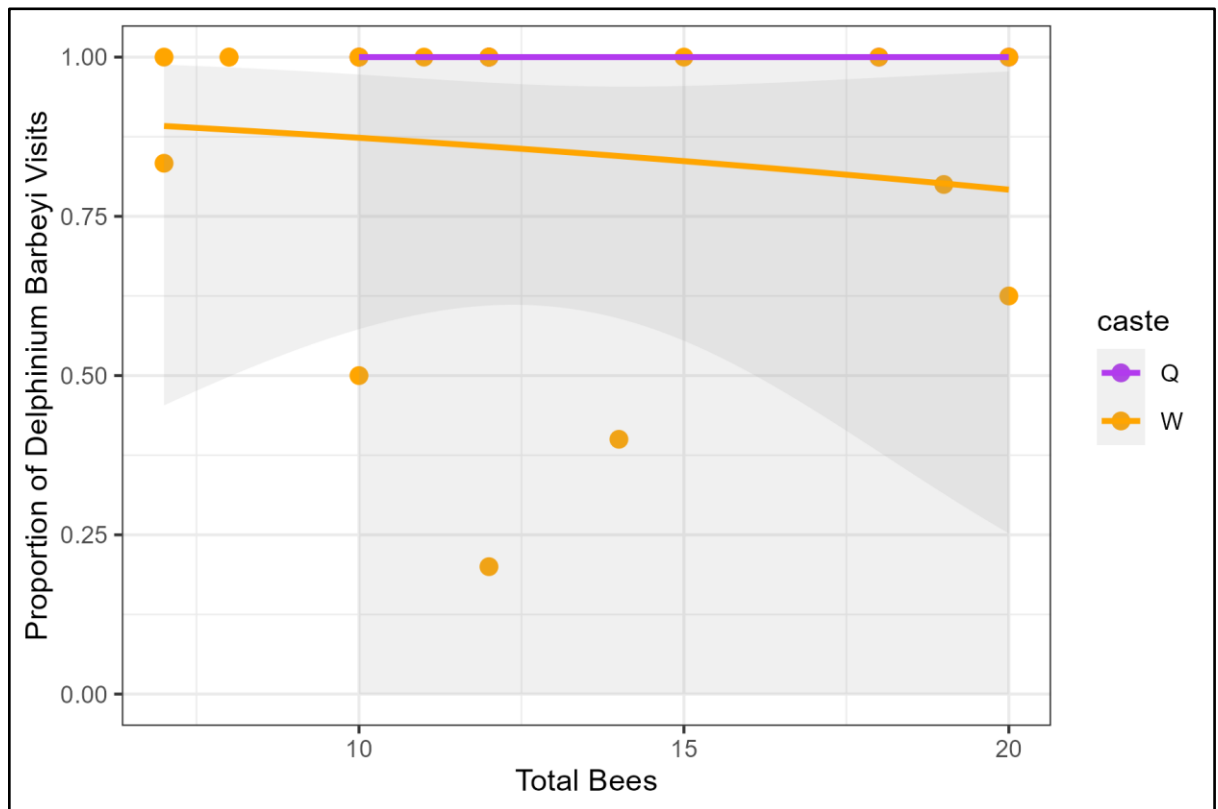


Figure 13 Comparing the queen and workers of *B. appositus* to relative bumble bee abundance and proportion of *D. barbeyi* visits, a significant negative relationship for the workers was found that had a p value of 0.075. On the other hand, the queens' proportions of *D. barbeyi* visits did not change with relative bumble bee abundance and rendered a p value of 1.0.

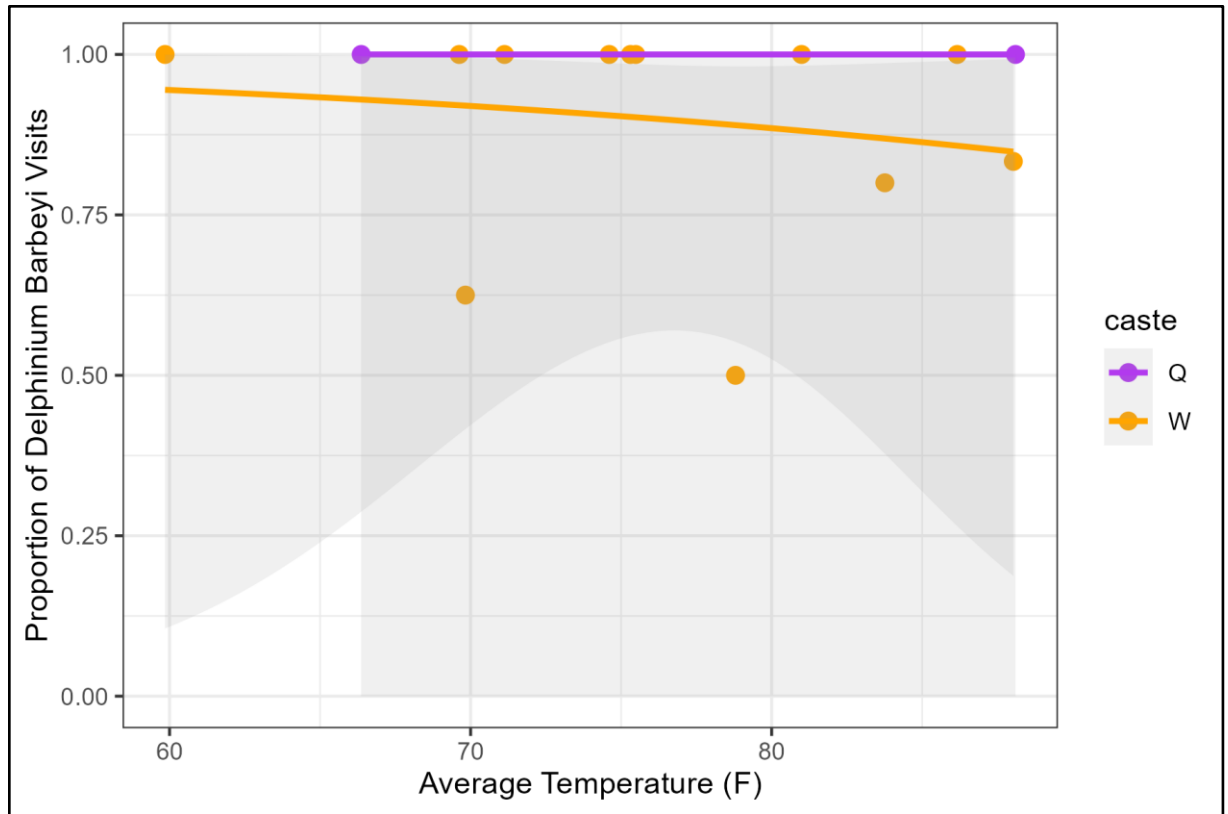


Figure 14 Comparing the queen and workers of *B. appositus* to average temperature and proportion of *D. barbeyi* visits, a negative relationship for the workers was found, although nonsignificant which had a p value of 0.93. On the other hand, the queens' proportions of *D. barbeyi* visits did not change with average temperature and rendered a p value of 1.0.