

**Effects of Floral Diversity and Density on Fly (Diptera: *Bombyliidae* and *Syrphidae*) Floral Foraging
Fidelity in Subalpine Meadows**

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Abstract:

Foraging behavior of pollinators is an extensively researched topic. Research on bee, butterfly, and hummingbird foraging behavior has led to a greater understanding of the impacts of plant community composition on foraging behavior. This research has been further enhanced by fly foraging behavior and its importance in ecosystems. In order to determine the relationship flies have with the plant community we are examining the effects of flower species diversity and conspecific floral density on fly (Diptera: Syrphidae and Bombyliidae) foraging fidelity. Fly foraging fidelity was seen to be effected by both of these floral community characteristics. It was observed that as flower species diversity increased we saw a decrease in foraging fidelity. Also as conspecific floral density increased we observed an increase in foraging fidelity. Future topics of interest may involve the impact of these effects, conspecific floral densities and floral species diversity, on plant fitness along with other variables which may impact fly foraging fidelity.

Introduction:

Extensive research on bee, butterfly, and hummingbird foraging behavior has lead to a greater understanding of the importance of foragers as pollinators and plant community impacts on this foraging. Fly foraging research, however limited, has begun to identify the importance of flies as pollinators (Kearns 2001) With more research we may be able to better understand the importance of Dipteran pollinators. (Kearns 2001). As noted in Kearns et al. (2001), flies may contribute significantly to the pollination of North American flowers and research has revealed the importance of Dipteran pollinators across the globe (El-Moursey 1999). In New England, Florida, and even in Egypt Dipteran pollination has been studied and provided insight on how flies act as major pollinators for wildflowers. (El-Moursey 1999;DeyRup 1988; Grimaldi 1988). Fly pollination, namely Syrphidae and Bombyliidae, is a

major way genetic material is spread in sub-alpine and alpine environments (Kearns 2000, 1999), constituting 50-80% of the flower visitors at high altitude (Primack 1983).

Some Dipterans are known to consume pollen and nectar as a food source. While feeding, these flies collect pollen on their bodies and have the potential to carry it to conspecific flowering plants (Kearns 2001, Goulson 2000). This movement between conspecific plants is floral fidelity. This movement between conspecific flowers is necessary to ensure pollen transfer to the appropriate species (Waser 1986). While many species of flower foragers can collect pollen, heterospecific floral movement may actually inhibit pollination. This movement of pollen to heterospecific floral species removes pollen from the system, in that the pollen may not reach a conspecific plant, and also may block stigmas, in that pollen from conspecific species may not be able to enter the stigma (Waser 1986). A pollinator is only effective if it is able to move pollen between conspecific flowering plants (Waser 1986). Fly foraging on conspecific flowers has been shown to be caused by restrictions on cognitive abilities, physical morphologies of flies and flowers, competition between and within foraging species, reward and energy usage (Waser 1986).

With a greater understanding of the potential importance of flies as pollinators and the impacts climate change and anthropogenic pressures are having on fly species, we may be able to assess risk species or dangers to fly species (Kearns 2001). Flies have been found to be key pollinators in various environments (Kearns 2001). Flies may act as redundant pollinators in many environments but also have been identified as important pollinators for plant species. In Egypt it was observed that flies may be dependent on individual species of flower to support their foraging and flowers dependent on these flies for pollination (El-Moursy 1999). However, the limited information on the importance of fly species in ecosystems has resulted in only one species on the endangered species list. This individual species on the endangered species list may not be representative of the fly community which is at risk of

extinction (Kearns 2001) but instead a lack of data. Examples of this lack of data can be found in Moldenke et al (1976) where the assessment of diversity and abundance of flies may not have accounted for all species (Kearns 2001). This research provides a way to understand pollinator interactions.

The pressures placed upon flower community composition effecting species diversity and density in subalpine zones, like those in the area surrounding the Rocky Mountain Research Laboratory, by climate change (Inouye 2008) may have an influence on pollinator foraging patterns. Pollination research has found that resource partitioning caused by competition of pollinators on floral species and flower morphology may be driving factors behind fly foraging patterns (El-Moursey 1999). Hegland and Boeke (2006) and Feinsinger (1986), observed that floral abundances may affect foraging patterns within a plot to a greater extent than species diversity within a plot at the "local scale". This research describes plant community effects on fly foraging fidelity in the Colorado Rocky Mountains surrounding Rocky Mountain Biological Laboratory (RMBL) by asking two questions: i. What is the effects of floral species diversity on fly foraging fidelity ii. What are the effects of floral density on fly foraging fidelity. By selecting meadows with varying floral community diversity and floral density I was able to observe the significance of each effect, in combination on fly foraging fidelity.

Methods:

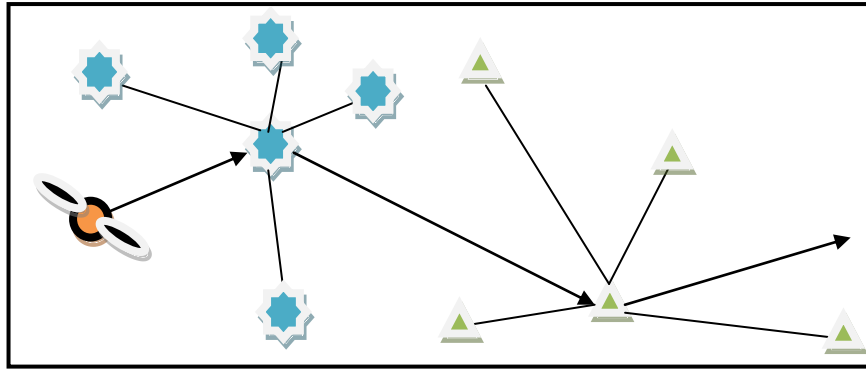
Site selection and floral species abundance surveys:

I selected 13 sites in the area surrounding RMBL for this study. Sites were placed in Washington Gulch Road , Emerald lake and Crested Butte, Colorado. I selected each site based upon the number of flowering species, three or more species per plot, in order to study a spectrum of flower diversity and density. Each site contained a minimum of two fly flower species, flowers arranged with their pollen and/or nectar easily accessible (i.e. flower families: Asteraceae, Linaceae, Rosaceae) in order to provide

the flies with multiple foraging options. At each site I arranged a 20 x 20 meter plot. Before fly foraging observations I analyzed floral species abundance using two 20 x 1 meter transects, 7 meters from the edges of the plot and from each other. To reduce the potential impact of floral sampling on insect foraging, I allowed for 30 minutes between flower counts and foraging observations. The number of flowering plants and the number of flower units per plant were recorded. Flower units were marked as umbels or single flowers depending on the species (Hoffman 2005).

Foraging Observations and Local Floral Density:

Foraging observations took place from July 1st till August 10th 2012 between the times of 10am-3pm. I did not record observations on days of high wind, precipitation or high cloud cover. During days when the weather worsened, observations stopped and continued the following day if necessary. Five to nine (5-9) flies of families Bombyliidae and Syrphidae were followed in each plot. Upon entering a plot, I followed the first fly I saw for 10 minutes or until it traveled more than 25m from the edge of the plot or was lost from sight. 25 meters was selected as a site buffer while following flies because flies may have not remained within the plot for the entirety of each observation and the floral composition usually remained consistent between that of the plot and the surrounding area for this distance. While following fly movements, flags were placed directly underneath each flowering plant visited, either during or after the visitation. Flower visitations were identified as a fly landing on a flower; flowers encountered, indicated by hovering but not landing, were not marked. For each fly foraging observation, encountering of conspecific or heterospecific flowers while foraging, was noted. After each individual observation the distance between each visited flower and the closest four (4) conspecific flowering plants was measured (*Model 1*). These measurements provided the local floral density. Flowers visited by the fly were used in these local floral density measurements if the flower was one of the closest four flowers to another visited flower.



Model 1: Model of flower density measurements. Fly movement indicated by arrows, different flower species indicated by different shapes. Lines without arrows connecting each shape indicate conspecific distances measured.

Analysis:

The potential correlation between flower density and flower species diversity resulted in analysis of both factors concurrently. To analyze the effect of conspecific flower density on Syrphidae and Bombyliidae foraging fidelity I calculated a percentage of heterospecific flower species visits per site using average heterospecific flower visits per fly. I then averaged the distance to the nearest conspecific flowers for each flower visit to obtain an average flower density for visits within a site. I analyzed data using R statistics package version 2.13. Using mixed effect modeling outlined in Bolker et al. I compared the effect of floral species, ranging from 3-14 species, and conspecific floral density on fly foraging fidelity on the percent heterospecific visits averaged per site. These effects are graphed separately on figures 1 and 2. In order to evaluate these effects on each fly family I graphed each effect separately (Figures 3,4).

Results:

Conspecific Floral Density:

Conspecific floral density and flower species diversity both had a significant effect on fly foraging patterns ($P = .00649$). In sites where conspecific flower types were higher in density, with flower distances ranging from an average of 20 to 150 cm apart, flies displayed higher a lower percentage of heterospecific flower visits. While at lower densities, flies displayed a greater percentage of heterospecific flower visits (*Figure 1*). Syrphids and Bombyliidae, when analyzed together and separately displayed a similar trend (*Figure 3*). Syrphid and Bombyliidae heterospecific flower visits increased as the average distance to the nearest conspecific flower increased.

Floral Species Diversity:

Floral species diversity effected fly foraging fidelity by increasing heterospecific visits as flower species increased. However, when analyzed separately, Bombyliidae displayed an increase in heterospecific flower visits as floral species increased. Syrphidae displayed a decrease in heterospecific floral visits as species increased at each site (*Figure 4*). This result displays an overall decrease in foraging fidelity as flower species increased, per plot, for both Syrphidae and Bombyliidae flies.

Discussion:

As mentioned previously, floral abundance and floral species diversity has been observed to have an effect on pollinator foraging (Hegland and Boeke 2006, Feinsinger 1986). The sites sampled by this observational study have found that floral density and conspecific floral density both have an effect on the foraging patterns observed in Syrphid and Bombyliid flies. Syrphidae and Bombyliidae movements seem to be highly dependent on floral density. As distance between conspecific flowers increases the chance of a heterospecific movement increases leading to decreased foraging fidelity. These results are in agreement with the effects of floral density observed by Hegland and Boeke (2006) and provide further evidence of the effects of floral density on pollinator foraging fidelity. Flower species diversity, on the other hand, had the opposite effect on fly foraging fidelity than was described by Hegland and

Boeke (2006). Foragers displayed an increased foraging fidelity as flower species increased, however this was an effect of competition between foragers rather than floral species themselves. This study observed that as flower species within a site increased the number of heterospecific visits increased resulting in reduced fly foraging fidelity.

This observational experiment displays the importance of flower community densities and species diversity as important affecters on fly pollinator species *Diptera: Bombyliidae* and *Syrphidae*. As human populations grow, anthropogenic pressures will continue to affect species abundances and diversity (Bankowska 1980). Anthropogenic effects on pollinators and flower community composition will likely have an effect on foraging fidelity in flies (Kearns 2001). These pressures may be leading to the extinction of many species (Schipper et al. 2008). If human activity is affecting flower community composition, and this in turn is effecting fly foraging, further research may display effects on future plant fitness. Because flies are major pollinators in high elevation meadows we may be able to determine the possible effects of climate change on flower community composition and its impacts on fly foraging fidelity. Changes in fly foraging may have implications in effecting plant fitness in upcoming years through effecting potential pollination.

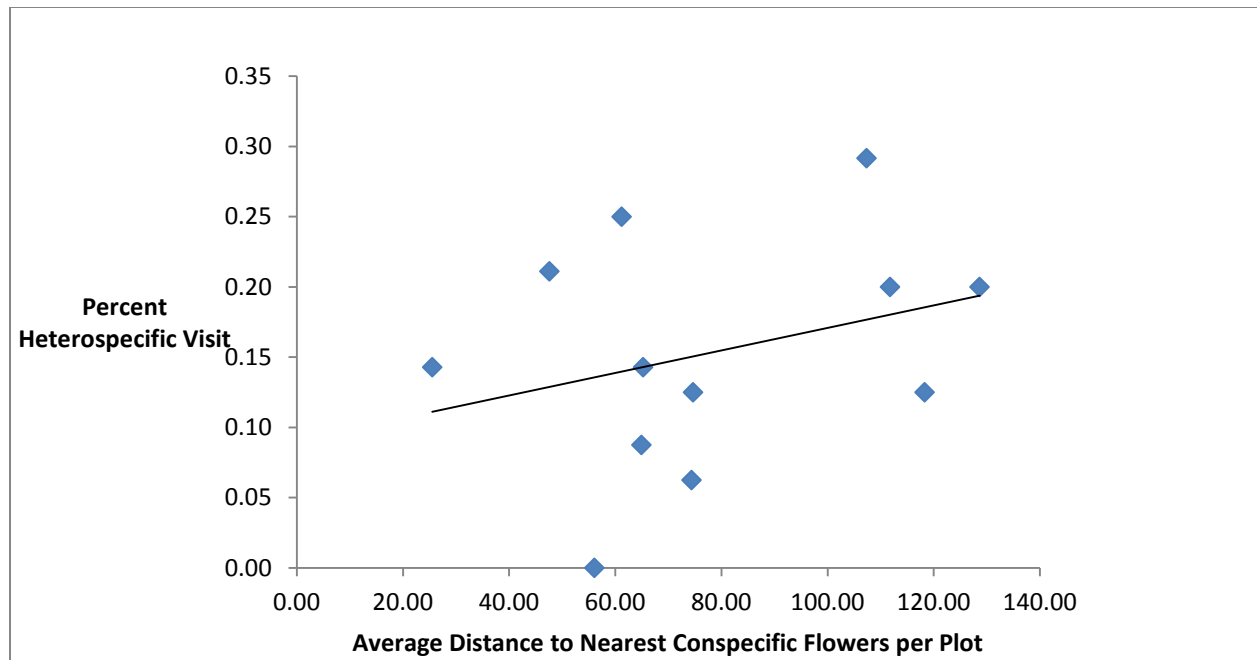


Figure 1: Effect of conspecific flower distance on heterospecific visits averaged per plot. ($R^2 = .0953$) As the average distance to the nearest conspecific flower in each plot increases the number of heterospecific visits increases for each fly in each plot.

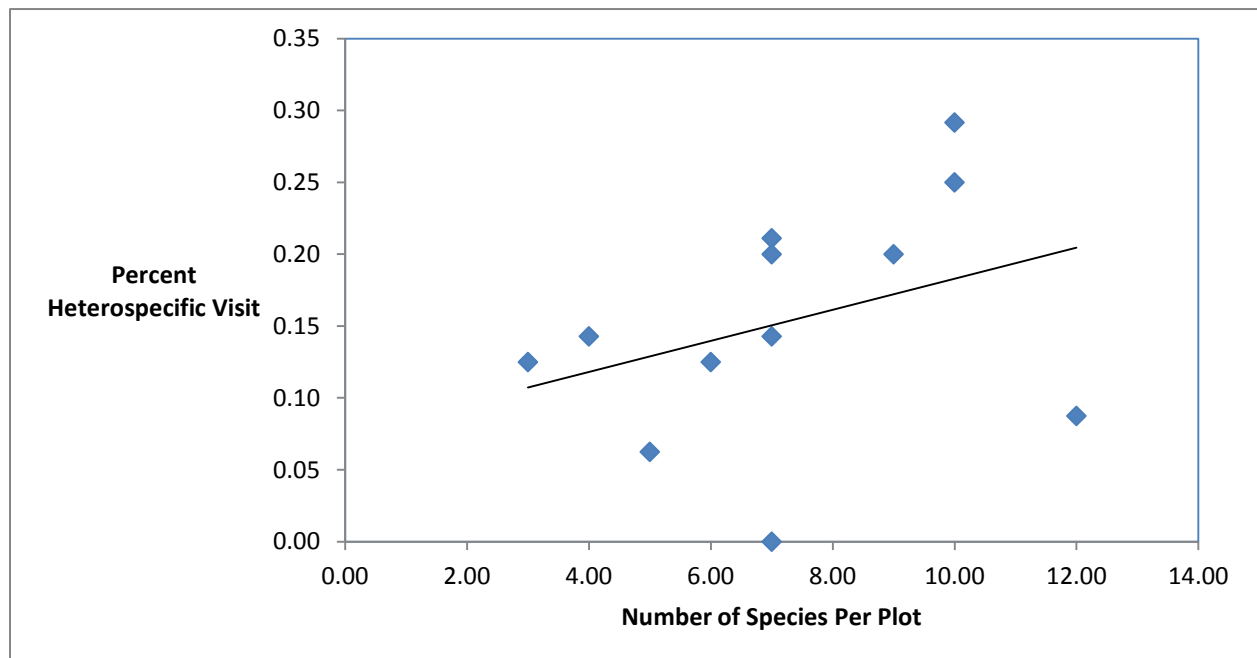


Figure 2: Effect of flower species diversity on heterospecific visits averaged per plot. The black linear regression displays the effect of species diversity on percent heterospecific visits in each plot ($R^2 = .1203$).

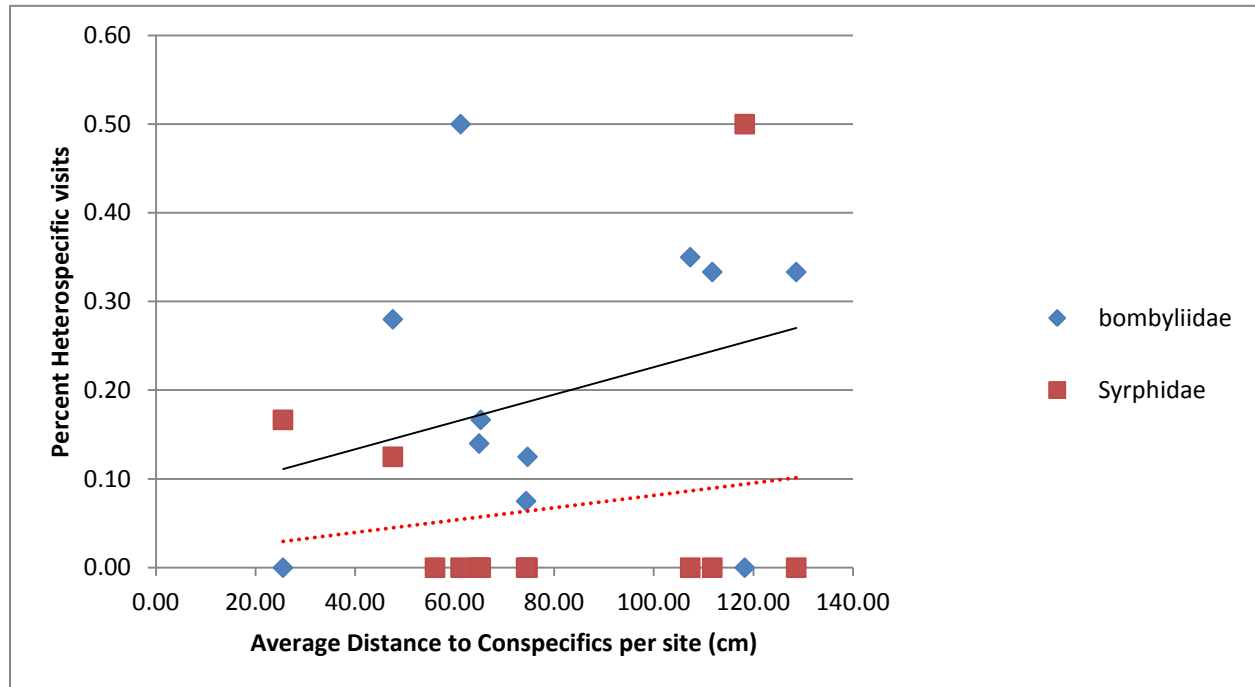


Figure 3: Syrphid and Bombyliidae response to increasing average distances of conspecific flowers, averaged per site. The black linear regression displays the Bombyliidae trend as density decreases ($R^2 = 0.0869$); Red dotted linear regression displays Syrphidae trends as density decreases ($R^2 = 0.0219$).

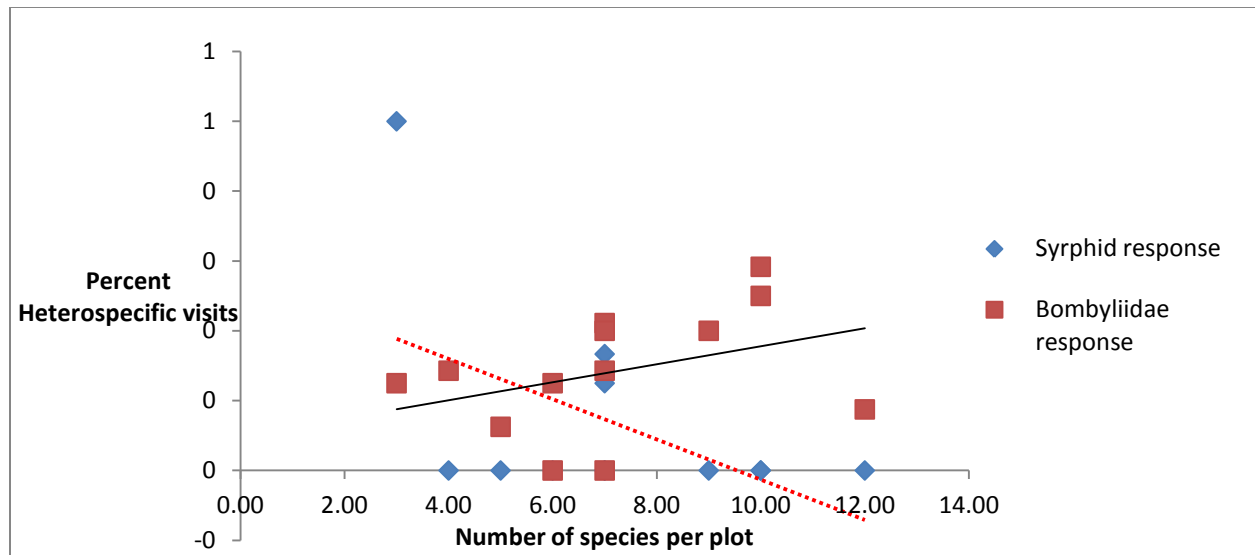


Figure 4: Syrphid and Bombyliidae response to increasing number of species per plot. The black linear regression displays the Bombyliidae trend as flower species increases ($R^2 = 0.1347$); Red dotted linear regression displays Syrphidae trends as flower species increases ($R^2 = 0.2627$).

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