

Within Day Temporal Variation Within Plant-Pollinator Networks

By Drake Gascon

Mentor: Dr. Paul CaraDonna

Abstract

Plant-pollinator networks are useful tools for understanding species interactions and biodiversity. The structure of interactions within plant-pollinator networks have provided insight into the potential stability and persistence of ecological communities. Current studies of plant-pollinator networks have primarily focused on a temporally static view. These studies have given insight on general patterns within networks, however the temporally static view they take gives less insight on the various temporal scales at which interactions can change, form, and dissolve. If networks have temporally dependent variables, then constructing networks at different time scales can provide information on structural changes that could be overlooked at different temporal scales. Therefore we want to know if plant-pollinator networks change within a day. What we do know is that plant-pollinator network structure and stability can change over years and within seasons, but we know a lot less about the assembly and disassembly of interactions within days. By focusing on the temporal variation within a day, we improve our understanding of changes to structure and stability of plant-pollinator networks that are meaningful for plant and pollinator ecology. With the use of network metrics like nestedness, connectance, and specialization we can acquire empirical data to show whether there is change to the structure and stability of the network. We find that there seems to be changes occurring between the plant and pollinators, suggesting dynamic aspects.

Introduction

Ecological communities are based on populations of species that are linked by interactions. The interactions within these networks are complex and dynamic, and can lead to rapid shifts in the interspecific links that make up a network (Bascompte and Jordano 2007; CaraDonna et al. 2017; CaraDonna et al. 2021). Among these networks are pollination networks that are responsible for an important ecological service that terrestrial biodiversity is responsible for (Kearns et al., 1998). Current observation of networks are often derived from a mostly temporally static view, whereby interactions are assumed not to vary temporally. Nevertheless, this approach has uncovered a series of general patterns in regards to structure and stability of networks (Pascual and Dunne 2005, Poisot and Stouffer 2014). However, when including temporal variation and different temporal scales other dimensions and aspects of the interaction networks can be observed and investigated. We know that network structure can change within a season and across a year but very little is known about the change that can occur within a day. By examining network interactions within a day we can learn more about the assembly and disassembly. When examining a temporal scale within a day, previous studies have concluded that there is variability within the network. For example, links between species can change, form, and dissolve within a twenty-four hour period (Baldock et al. 2011), yet the extent to which network structure varies at these fine time scales remains poorly understood (CaraDonna et al. 2021).

In this study we examined the within-day temporal dynamics of subalpine plant-pollinator networks at the Rocky Mountain Biological Laboratory in Gothic, Colorado, USA. At this location we set up our study site within three distinct habitat types where we observed interactions for four weeks. Our research objective was to understand how the structure of plant-pollinator networks varies within a day, and the potential drivers underlying such variation. We

hypothesize that if there is variation in pollinator abundance, diet, and interactions over a day, then this this will influence the structural properties of a network across the day. On the other hand, even with such variation within the network, we may still see the same general network structure throughout the day. By looking at the interactions of a network within a day we can gain insight on their ability to form and dissolve bonds. This will help us to better understand how changes in structure and stability occur. This will help us to gain meaningful information for plant and pollinator ecology. Our objective is gain insight on interactions at a finer time scale so that plant-pollinator networks can be better studied and monitored for future use.

Methods

Study Location

Within-day plant-pollinator interaction data was collected within the Research Meadow near the Rocky Mountain Biological Laboratory, Gothic Colorado. It is a sub-alpine meadow surrounded by an aspen forest. Interaction data was collected during the month of July on a weekly basis. Within the study site six transects were set up and labeled veg or beef. The naming comes from there being a fence within the meadow to keep cows from trampling sites within the meadow. However, three sites were outside of the fence where the cows would graze (no cows grazed during our four weeks of surveying) so they were labeled as beef transects and the transects inside the fence were labeled as veg. This study is not affected by herbivory, and is not an aspect of this research.

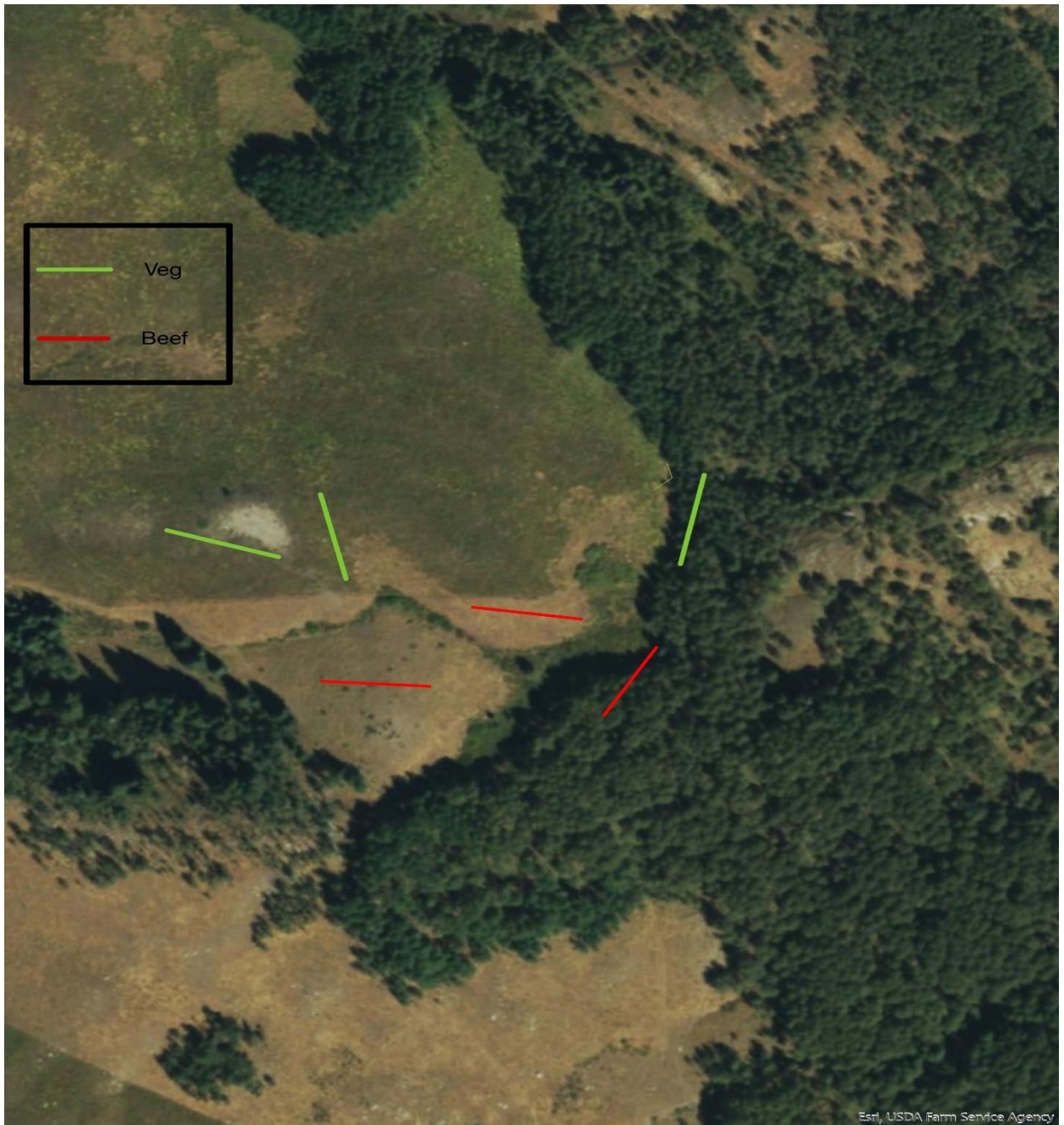


Figure 1: Study location at the Research Meadow near the Rocky Mountain Biological Laboratory, Gothic Colorado. Each line represents a transect which are categorized by beef (red) and veg (green).

Interaction sampling

Six 40 x 5 meter transects were set up with in the meadow. The six transects were broken up into pairs, with a pair in three separate habitat types: wet meadow, dry meadow, and aspen meadow. These three habitat types include the major areas for which pollinator activity is observed in this ecosystem.

Data collection will occur three times a week, within each day being broken up into 5 two-hour time blocks: 08:00-10:00, 10:00-12:00, 12:00-14:00, 14:00-16:00, and 16:00-18:00. Each transect was surveyed for twenty minutes, at an approximate rate of two meters per minute. Within those twenty minutes, surveyors would walk along a center line of the current transect at a slow pass and monitor the area within a 2.5-meter distance from the centerline. During surveys, plant-pollinator interactions were recorded focusing on the dominant pollinators in this system—bumble bees (*Bombus spp.*). We identified all bumble bee visits to plants, recording the species identity of bumble bees, the flowering plants they visit, and whether the bee has a pollen load (suggesting that they are visiting plants for pollen).

Analysis of ecological network structure.

We quantified the within-day structure of plant-pollinator interactions for each time bin using three commonly used network structural properties: nestedness (weighted NODF), connectance, and specialization (H_2'). Nestedness is determined by the amount of specialist that interact with generalist species. To calculate it we used the NODF algorithm of Almeida Neto et al. (2008). Values for nestedness range from 0 to 100, however 100 is a theoretical maximum with most networks having a value below the maximum. Connectance is a simple measure of network complexity and is calculated using the proportion of realized links out of all the possible

within a network (Bascompte & Jordano, 2014). Specialization characterizes the level of specialization in a network with a frequency-based metric within a bipartite network (Blüthgen et al., 2006). Specialization can be used to describe niche partitioning between plants and pollinators. To calculate these metrics our interaction data from each respective time bin was pooled together from the four weeks of data collections. Each of the five-time bins had four values when going into analysis.

Results

Network Metrics

A total of 381 interactions were observed by 9 different *Bombus* species to 20 different flower species. When analyzing the within-day structure of plant-pollinator networks (nestedness, connectance, and specialization) we observed evidence for slight trends occur within each network metric. With nestedness there seems to be a decrease of this value as the day goes on. While overall connectance seems to increase as the day goes on. With specialization there is no overall trend, but between the first block and the last block, there seems to be a more specialized network occurring later in the day. Overall, our data suggests that networks are dynamic as the day goes on, but these dynamic aspects are not enough to alter the structural properties of the network based off of our statistical analysis.

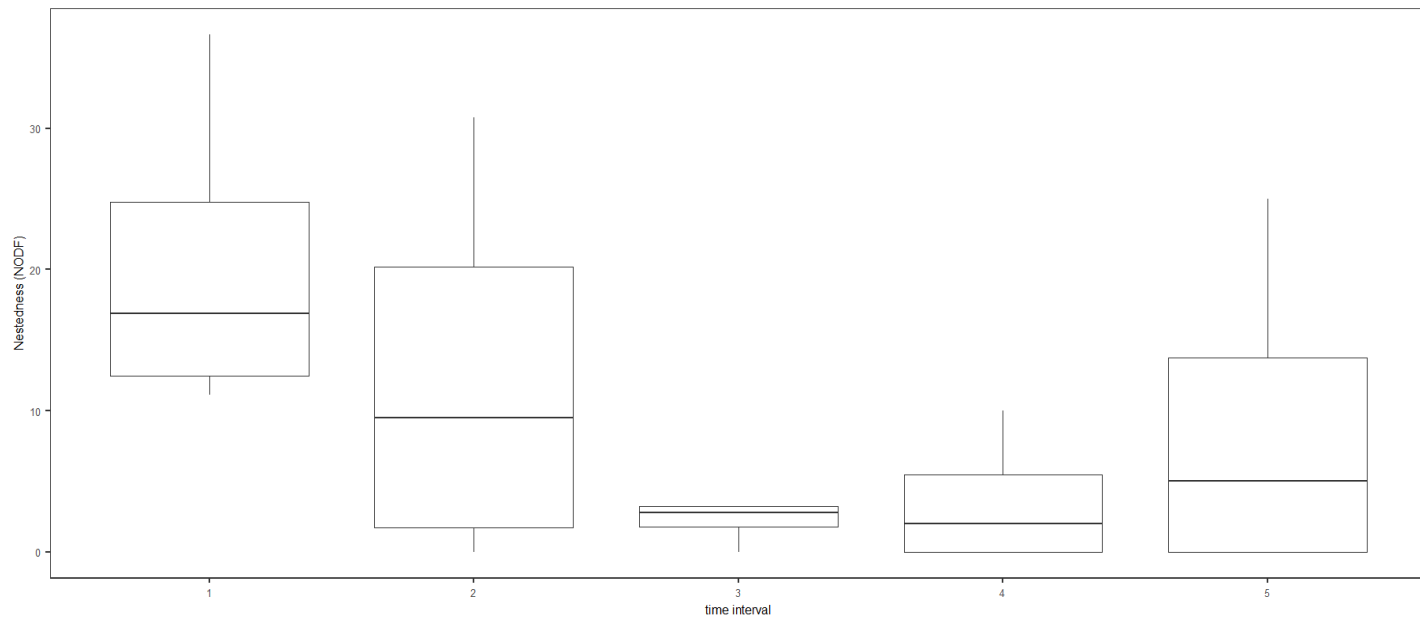


Figure 2: Nestedness graph of all five time bins, slight trend suggesting that nestedness decreases as the day goes on, P value = 0.0669

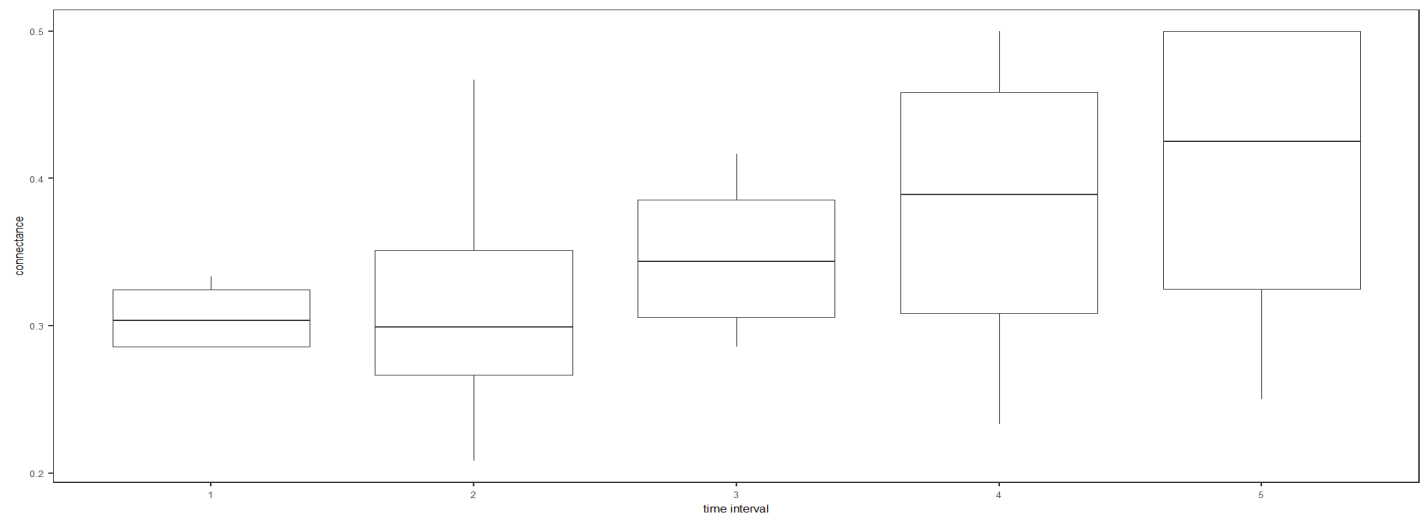


Figure 3: Connectance graph of all five time bins, slight trend suggesting connectance increases as day goes on, P value = 0.089

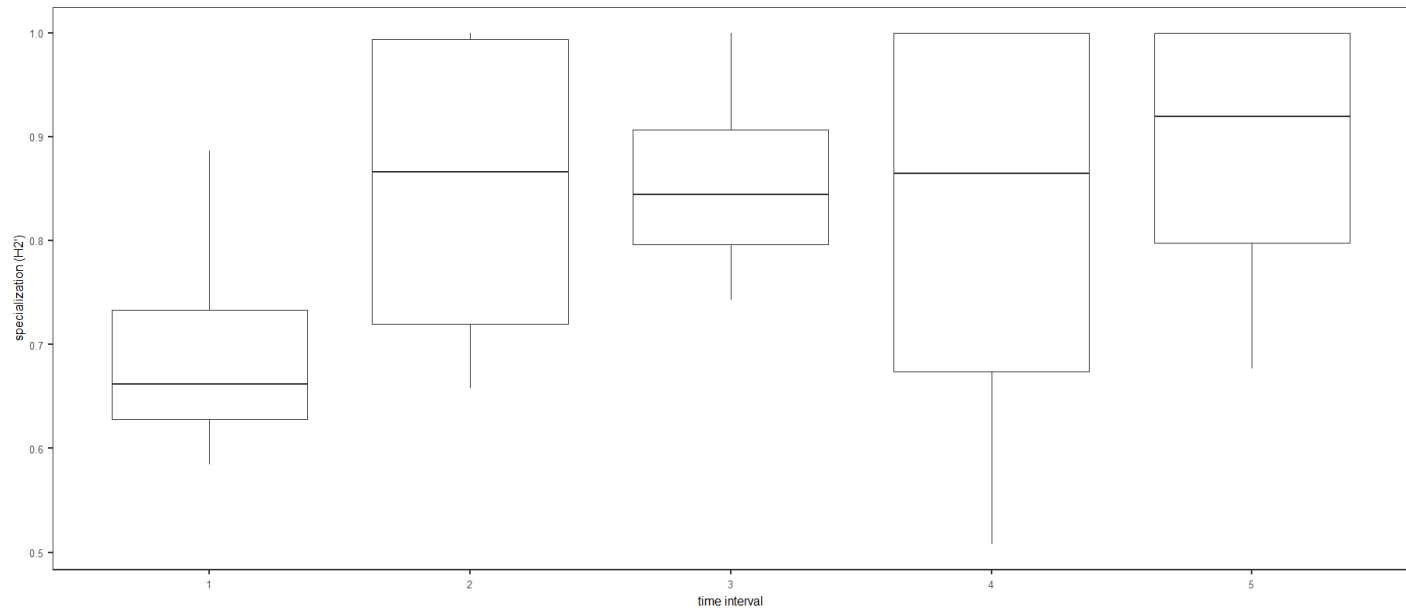


Figure 4: Specialization graph of all five time bins, no continues trend occurring, however when comparing start of day to end of day, specialization increases, P value = 0.219

Constructed Network Plots

An overall network (fig 5) was created for all the data, it was constructed from a temporally static view. Five other networks were also made for each individual time block. These networks were constructed from the four weeks of data that was pooled together and are analyzed with a temporally dynamic view. Within the first time (fig 6) bin *Bombus bifarius* is very active, with *Bombus appositus* and *Bombus flavifrons* being almost as active. In the second time bin (fig 7) *Bombus bifarius* is even more active. *Bombus appositus* and *Bombus flavifrons* are less active during this time bin. In time bin three (fig 8), *Bombus bifarius* is still very active, but *Bombus flavifrons* is now starting to be more active during this time. During time bin four (fig 9), the network is starting to become more specialized with fewer species being present. In time bin five (fig 10) the network is very specialized.

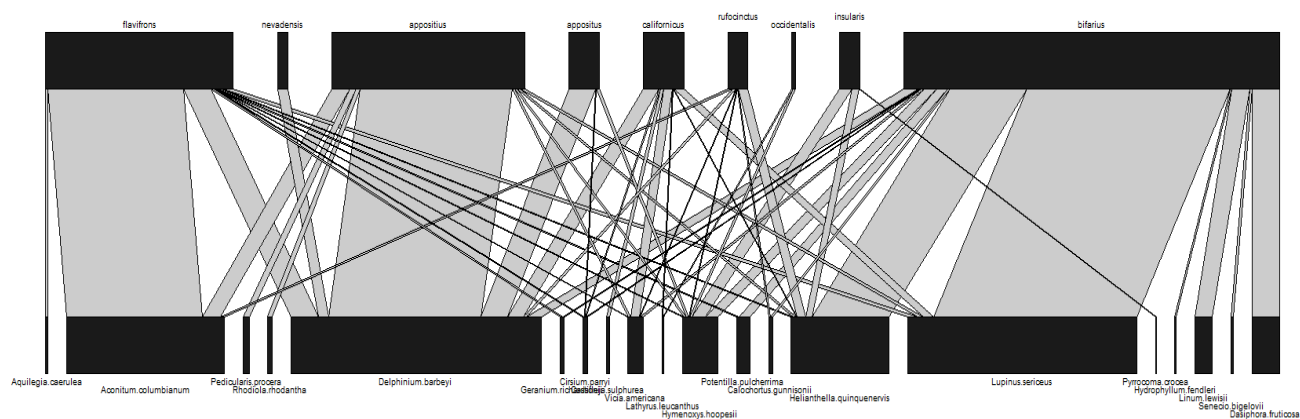


Figure 5: Overall network, all data pooled together

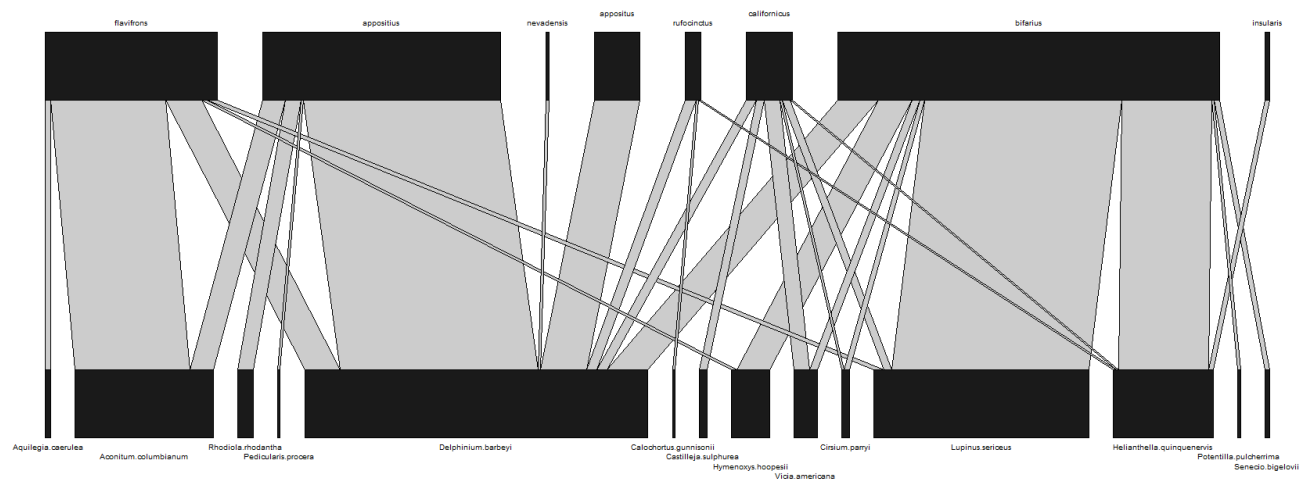


Figure 6: Time Bin 1, 8am – 10am

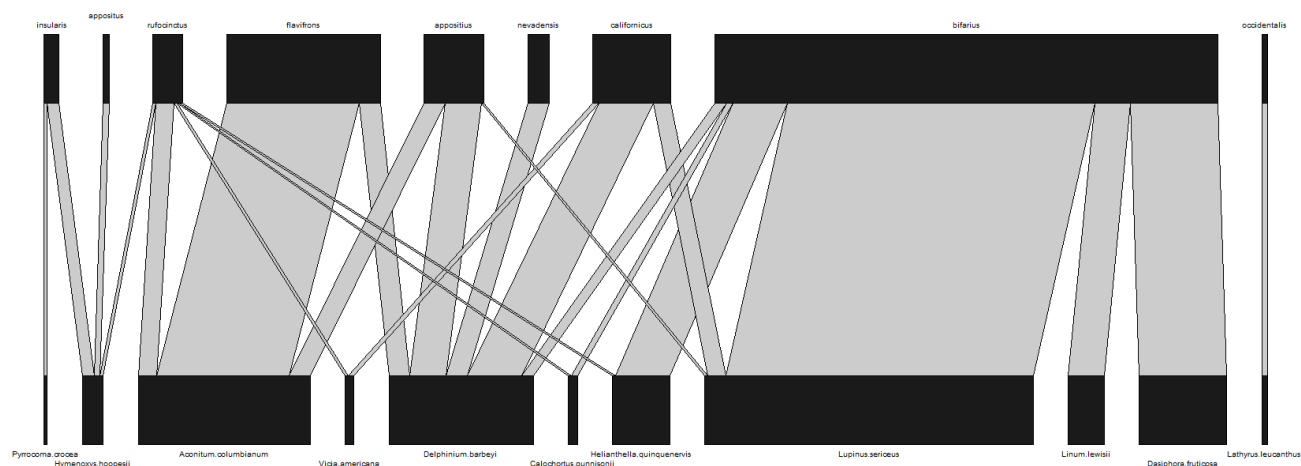


Figure 7: Time Bin 2, 10am – 12pm

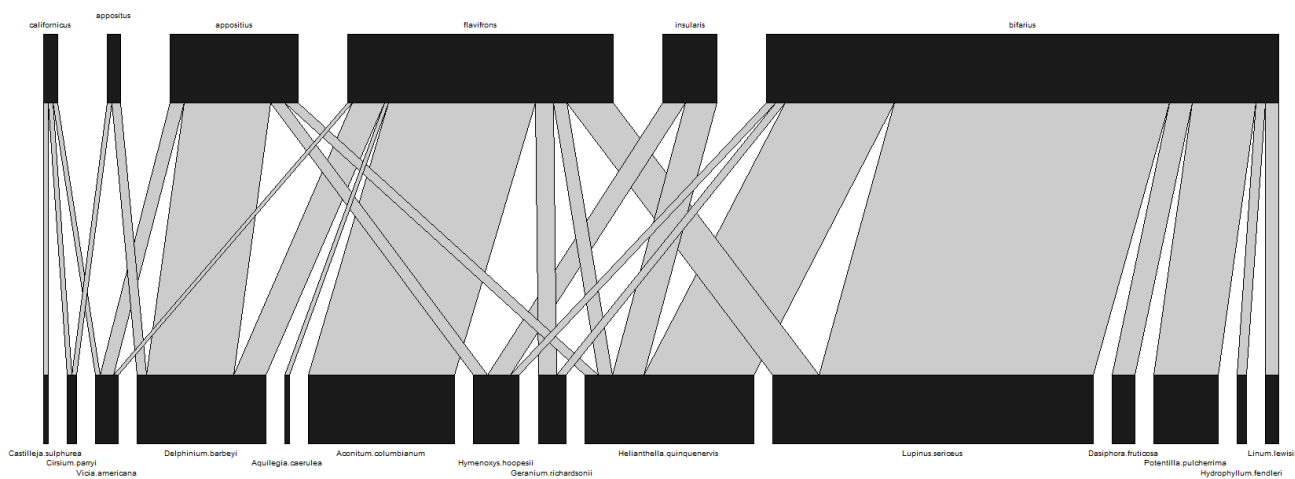


Figure 8: Time Bin 3, 12pm – 14pm

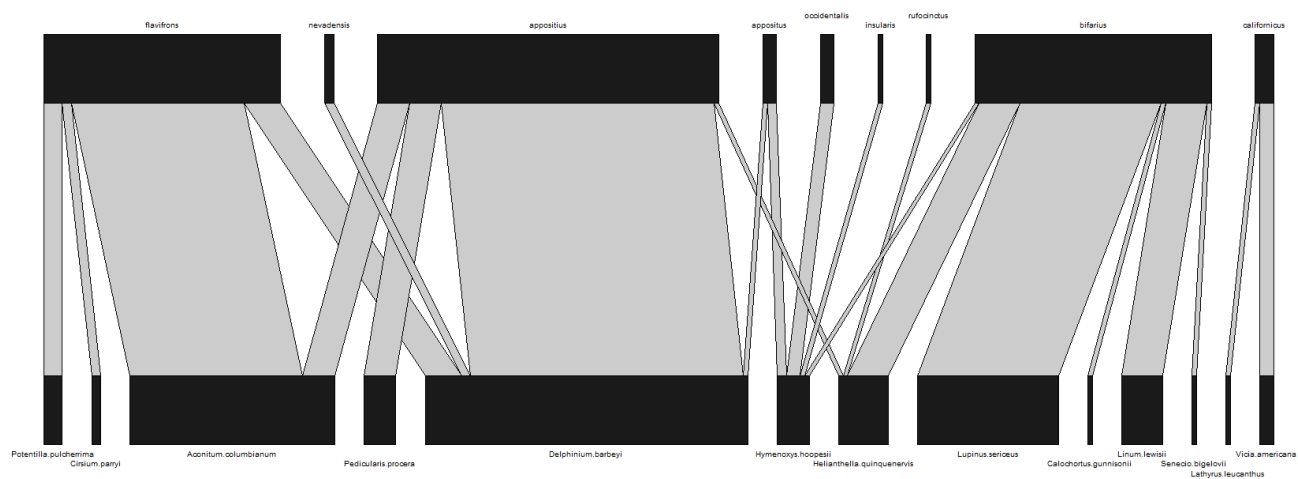


Figure 9: Time Bin 4, 14pm – 16pm

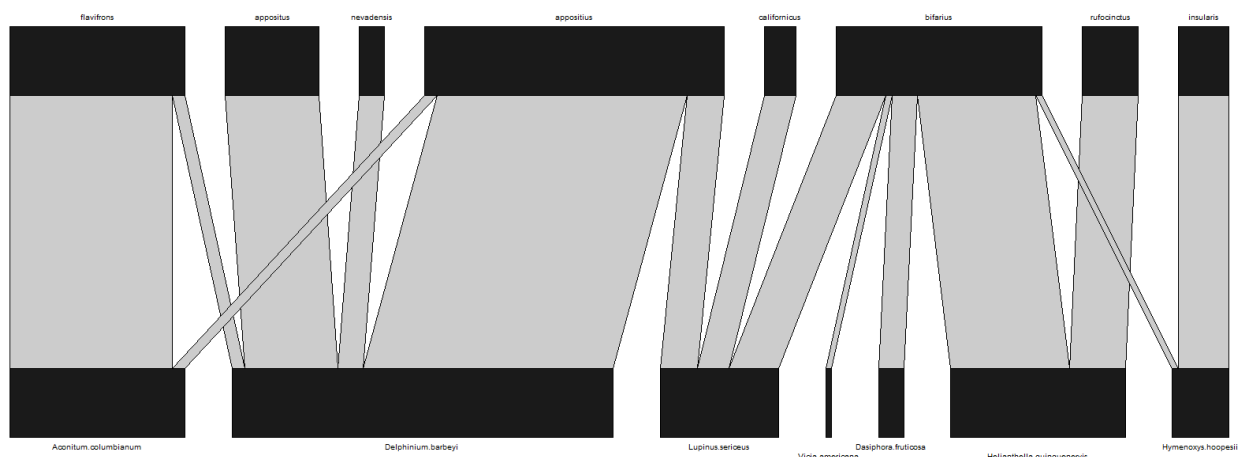


Figure 10: Time Bin 5, 16pm – 18pm

Discussion

The purpose of this study was to better understand the assembly and disassembly of plant-pollinator interactions at a finer time scale. We know that over the course of time within boarded temporal scales, changes occur within a network. Throughout these different temporal scales, we can gather information of a networks structure (CaraDonna et al., 2021). We sought to determine the extent in temporal variation that occurs within a day because it is not as well understood when compared to broader time scales. We hypothesized that variation in pollinator abundance, diet, and interactions over a day could affect structural properties of plant-pollinator networks. However, our statistical analysis showed that there was no significant difference with the network metrics we analyzed. The networks we crested did show that were changes in interactions as the day went on which goes along with our second hypothesis. Even though there were changes in pollinator abundance, diet, and interactions over a day it was not enough to alter network metrics. However, our results suggest that interpretation of network structure can be different among different time scales which was also determined in a study done by Schwarz et al. (2020). Based off of this an argument can be made that plant pollinator networks are temporally dynamic, which is more applicable to plant and pollinator ecology. Further study is needed to find more meaningful conclusions for the temporal dimensions of plant-pollinator networks, by continuing to study this we can gain further insight on not just how interactions can form and dissolve, but also how species and communities respond to change.

Works Cited

- Bascompte, J., & Jordano, P. (2007). Plant-Animal Mutualistic Networks: The Architecture of Biodiversity. *Annual Review of Ecology, Evolution, and Systematics*, 38(1), 567–593. <https://doi.org/10.1146/annurev.ecolsys.38.091206.095818>
- Bascompte, J., & Jordano, P. (2014). *Mutualistic networks*. Princeton Univ. Press.
- Blüthgen, N., Menzel, F., & Blüthgen, N. (2006). Measuring specialization in species interaction networks. *BMC Ecology*, 6(1), 9. <https://doi.org/10.1186/1472-6785-6-9>
- CaraDonna, P. J., Burkle, L. A., Schwarz, B., Resasco, J., Knight, T. M., Benadi, G., Blüthgen, N., Dormann, C. F., Fang, Q., Fründ, J., Gauzens, B., Kaiser-Bunbury, C. N., Winfree, R., & Vázquez, D. P. (2021). Seeing through the static: The temporal dimension of plant–animal mutualistic interactions. *Ecology Letters*, 24(1), 149–161. <https://doi.org/10.1111/ele.13623>
- Kearns, C. A., Inouye, D. W., & Waser, N. M. (1998). ENDANGERED MUTUALISMS: The Conservation of Plant-Pollinator Interactions. *Annual Review of Ecology and Systematics*, 29(1), 83–112. <https://doi.org/10.1146/annurev.ecolsys.29.1.83>
- Pascual, M. M., & Dunne, J. (2005). *Ecological Networks: Linking Structure to Dynamics*. Oxford University Press.
- Poisot, T., & Stou, D. B. (2014). Beyond species: Why ecological interaction networks vary through space and time. *Oikos*, 124: 243-251.