

2024 Grant Report

Project: Phytotelmata Tell All - Modeling the role of dispersal in community assembly

Nicole Burroughs

North Carolina State University - College of Agriculture and Life Sciences

1st Year PhD Student

Project Summary

When ecologically similar species arrive in the same habitat, several paths are possible for their persistence in the community: some paths lead to increased diversity, others lead to degradation of diversity, and still others may lead to community cycling. Recent developments in “Modern Coexistence Theory” (MCT) have enabled the prediction of the complete map of all possible community assembly pathways based on species interaction outcomes, termed “invasion graphs” [1, 2]. These graphs rely only on species interactions; however, community diversity is determined by the dynamic interplay of both species interactions and dispersal during the process of community assembly [3]. Unraveling the complexity of these mechanisms will be essential to predicting the diversity and composition of assembled communities that, in turn, will determine their function and resilience in the face of environmental disturbances [4, 5]. As we learn more about the dynamics of species interactions in our lab, it becomes important to understand how the frequency and timing of our focal species dispersal might alter predicted assembly outcomes. To this end, we conducted a field experiment monitoring microbial dispersal ability over set distances.

Our overarching question was: **How do species-specific differences in dispersal constrain the pathways by which community assembly is most likely to occur?** To investigate, we designed a field experiment to answer three sub-questions using the microbial community that assembles within the leaves of the carnivorous pitcher plant, *Sarracenia purpurea*:

1) How do protist species differ in dispersal ability?

We will measure natural dispersal events into new habitat patches from a controlled source population in the field.

2) What mechanisms do protists rely on for dispersal between habitat patches, and does the importance of each mechanism differ among species?

We will exploit differences in abiotic versus biotic dispersal agents to determine how species move among patches and test whether these explain overall differences in dispersal ability.

3) Is protist dispersal ability correlated with competitive ability?

We will test for a diversity promoting trade-off in dispersal and competitive ability by combining field dispersal estimates with lab measurements of species interactions.

4) How do realistic species arrival orders constrain end state diversity and species composition?

We will compare the end state diversity and species compositions of simulated community assembly under ‘equal dispersal ability’ versus ‘empirical dispersal ability.’

We will use the data gathered during the field season to test for a relationship between species’ competitive ability (modeled previously in our lab) and dispersal ability. We likely amend the project design within the next year and continue to gather data on protist dispersal rates with the goal of comparing dispersal-naive and dispersal-informed model scenarios to ask whether realistic species arrival orders constrain end state diversity and species composition.

NCNPS Significance

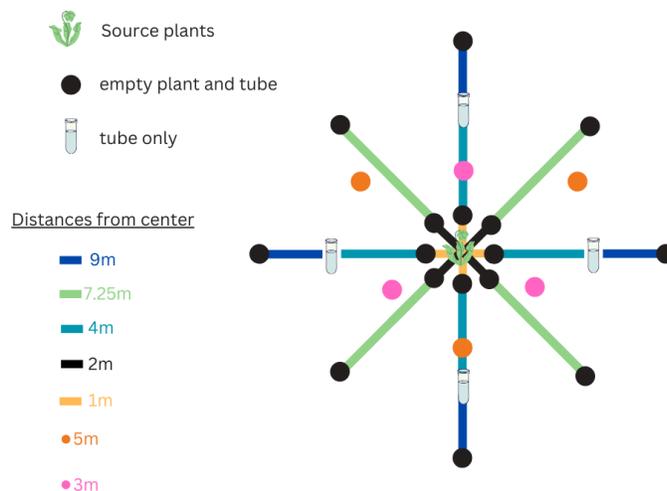
This project contributes to a larger body of research highlighting the importance of phytotelmata - water-filled cavities in terrestrial plants - to the advancement of community assembly theory [6, 5, 14, 16, 17]. The use of the NC-native, *Sarracenia purpurea*, as a model system not only primes the theory for addressing pitcher plant conservation concerns, but also establishes a connection between pitchers and the development of ecological theory capable of galvanizing interdisciplinary support for the preservation of the plants and their wetland habitats. I intend to use the data from this project to justify a citizen science project involving NC schools, development of conservation curricula, and the characteristics of wind dispersal in pitcher plant communities as the second chapter of my PhD dissertation.

Field Setup

We were able to construct the array in the proposed field location (Gates bog- Lat: 45.591739, Lon: -84.671767) using 25 plants and 29, 50mL centrifuge tubes mimicking the fluid retention and size of the pitcher environment. The experimental bog had become largely overgrown with dense bush. Wind is thought to be the primary dispersal method used by the microbes in this study, but was greatly reduced in areas with thick vegetation near the ground. We decided to confine the array to an area of the bog covered in sedges rather than have the wind almost entirely blocked by the bush, resulting in the reduction of the overall size of the array to 18 - rather than 30 - meters in diameter. Due to issues with plant delivery, excessive local heat, and resulting delayed recovery as evidenced by reduced pitcher development, the original array design was amended to accommodate plant availability as illustrated in Figure 1.

Fig. 1

Adjusted Dispersal Array



We inoculated 3 central plants with our focal protist species following a randomized block design on the morning of Monday, July 22nd and , and monitored for invasion success in the surrounding protist-free plants using our two-step screening process to ensure the detection of all protist arrivals until the following Sunday evening: July 28th. We sampled both tubes and pitchers twice daily for the duration of the experiment, taking 1mL at morning time points for invasion detection, and 2mL at evening time points: one for invasion detection, and one for freezing and later DNA analysis.

Preliminary Results

Pitcher plant leaves were invaded approximately nine times more frequently than tubes over the course of the experiment. Pitchers were found to contain protists at nearly every other measurement (avg. 1.55 protist detections per pitcher, per day), far outpacing what we expected to see in terms of protist dispersal from a single point of origin. The frequency of this invasion may mean that mosquitos are a dominant, and highly efficient, dispersal vector for microbes in this system. Alternatively, it is possible that the sterilization method we had tested on plants in a lab setting was not sufficient for killing protists in the field. We had previously confirmed that filling pitcher leaves with sterile media at temperatures higher than 45 degrees celsius was sufficient to heat-kill protozoan life in pitchers where it had been previously well established (~1000 protists per mL media). However, the field application of this method may have been less effective for pitcher plants. Our field sterilization method seems to have been more effective for the 50mL tubes placed next to plants at each point in the array (avg. 0.18 protist detections per tube, per day). It is also likely that mosquitos did not view the tubes as suitable oviposition locations, resulting in the exclusion of mosquito-facilitated dispersal as we had anticipated. However, the frequency of pitcher leaf invasion, and detection of relatively dense cultures at initial pitcher sampling points diminishes our surety that the center of the array remained the lone viable source population of our experimental protists for the duration of the experiment. Frozen samples collected for DNA analysis should reveal the identity of the microbes we found at each time and location, whether they were our experimental protists or opportunists from the surrounding environment or vegetation, and help us discern whether the invasion rate we observed was truly representative of dispersal frequency or flawed sterilization techniques.

Samples taken from both pitchers and tubes were visually assessed for the presence of protists immediately after the samples were taken, and again after a 24-hour incubation period. Separate linear models of invasion success in pitchers and tubes produced no significant effect of distance on protist detection frequency (Plant effect of distance- $p=0.471$, $R^2=0.026$) (Tube effect of distance- $p=0.743$, $R^2= 0.005$). The lack of correlation between these two variables suggests one of the three following explanations: the sterilization method we used was not effective in the field, protists from outside sources (soil, grasses, etc.) were frequently colonizing the open habitat, or the range of distances we used was too constrained to expose trends in long- versus short-distance dispersal.

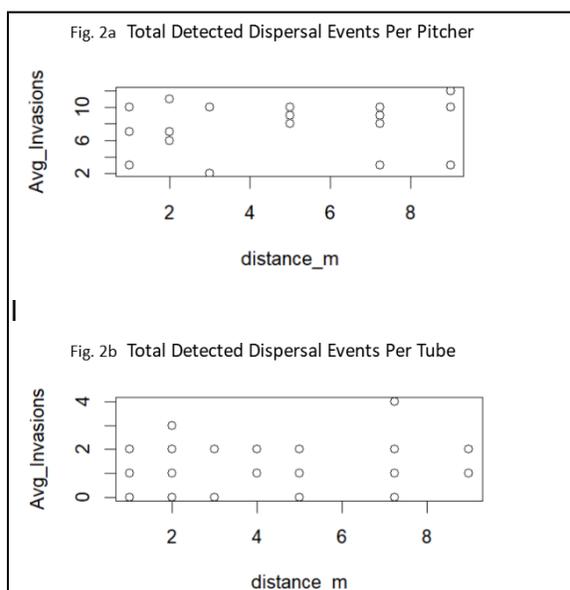


Figure 2 - Total number of invasions detected at either the initial sampling point or after 24-hour sample incubation through the duration of the experiment plotted against distance. Data for pitcher plant leaves (2a) and 50mL centrifuge tubes (2b) shown separately. Each open circle represents a single tube or leaf replicate at a given distance.

Next Steps

I will continue my analysis and hope to conduct a second iteration of this experiment again next summer after making the needed adjustments to the sterilization protocol. We will perhaps seek out an alternative bog location with less tall grass and shrub cover. Additionally, overwintering the plants at the biological station should allow them to recover and better withstand future sterilization treatments. I will work through identifying the organisms in frozen samples and slide mounts to better understand whether outside organisms or pitcher plant protists are the primary source of the colonizations we saw. I anticipate that identifying the species present will yield data better suited to telling the story of dispersal as it relates exclusively to our selected experimental species.

Funding Allocation

I am endlessly thankful to the members and board of the North Carolina Native Plant Society. This project would not have been possible without the foundation's critical support. The funds provided by NCNPS were allocated towards the purchase of pitcher plants, pots and drip trays for field installation, and sphagnum/pearlite growth medium for the experimental plants (Total: \$800). Other funding sources were used for the remainder of the cost of these items.

Photos:

Overwintering tank-



Array Setup-



Array location-



Experimental tube/plant-



References:

- [1] Hofbauer, J., & Schreiber, S. J. (2022). Permanence via invasion graphs: Incorporating community assembly into modern coexistence theory. *Journal of Mathematical Biology*, 85(5), 54. <https://doi.org/10.1007/s00285-022-01815-2>
- [2] Spaak, J. W., & Schreiber, S. J. (2023). Building modern coexistence theory from the ground up: The role of community assembly. *Ecology Letters*, 26(11), 1840–1861. <https://doi.org/10.1111/ele.14302>
- [3] Zou, H.-X., & Rudolf, V. H. W. (2023). Priority effects determine how dispersal affects biodiversity in seasonal metacommunities. *The American Naturalist*, 202(2), 140–151. <https://doi.org/10.1086/725039>
- [4] Bittleston, L. S., Gralka, M., Leventhal, G. E., Mizrahi, I., & Cordero Sanchez, O. X. (2020). Context-dependent dynamics lead to the assembly of functionally distinct pitcher-plant microbiomes.
- [5] Saavedra, S., Rohr, R. P., Bascompte, J., Godoy, O., Kraft, N. J. B., & Levine, J. M. (2017). A structural approach for understanding multispecies coexistence. *Ecological Monographs*, 87(3), 470–486. <https://doi.org/10.1002/ecm.1263>