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AUGUST 2008

SARRACENIA PURPUREA: EFFECTS OF PITCHER LEAF SIZE, DENSITY, AND COLORATION ON SPECIES RICHNESS AND MASS OF ORGANIC MATERIAL FOUND INSIDE

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ABSTRACT

The purpose of our study was to examine the relationships between morphological characteristics of pitcher leaves and the amount and types of organic material inside of them. At Bryant Bog, in Pellston, MI, we located 40 pitcher plants and randomly sampled one pitcher leaf from each. We measured the pitcher size (length, mouth diameter, keel width), recorded the color, and collected all of the decaying organic material inside of it. Under a microscope, we identified whole macroscopic invertebrates in each of the samples. We filtered the contents, and dried them in an oven. We then calculated the dry mass of the material inside of the pitcher. We discovered that species richness was positively correlated with both pitcher density and mouth diameter. Mouth diameter was also positively correlated with the mass of the organic material inside of the pitcher. Color was not found to be correlated with biomass or species richness. Like other carnivorous plants, *Sarracenia purpurea* attracts potential prey with morphological characteristics such as size and leaf density.

INTRODUCTION

Sarracenia purpurea, or the North American pitcher plant, is a species of carnivorous plants found in North America. Carnivorous plants are typically found in areas with high light levels, abundant water, and low nutrient levels, such as bogs (Benzing 1987). However, carnivorous pitcher plants have low photosynthetic rates compared to other plants (Farnsworth & Ellison 2007). Therefore, these plants need to derive nutrients and energy from other sources. Carnivorous plants obtain nutrients by decomposing prey, such as ants, flies, and wasps that get stuck inside their trap*s* (Ellison & Gotelli. 2001). Along with water, carnivorous plants employ characteristics such as hairs to keep the prey trapped inside (CITE). Some species even use digestive enzymes to break down the prey (Ellison & Gotelli 2001).

Since trapping prey is the main source of nutrient acquisition for the pitcher plants, attraction of potential prey is vital for the plant's survival. Previous research has explored the many potential attractive traits of carnivorous plants such as the pitcher plant. These characteristics include nectar, odor, pitcher size, and pitcher coloration (Benzing 1987).

Sarracenia purpurea has evolved pitcher-shaped leaves that fill up with water to aid in prey capture (Ellison & Gotelli 2002). Cresswell's 1998 research on *Nepenthes ampullaria* revealed that larger pitchers in the species accumulated more organic material than the small ones did. Newell and Nastase (1998) concluded that insects were more attracted to *S. purpurea* pitchers that were completely red than green. Shafer and Ruxton (2008) studied coloration in *S. purpurea* and found that insects were more attracted to pitchers that were red than those that were completely green.

Morphological characteristics are thus vital in the attraction of prey. While much research has been done concerning carnivorous plants and prey attraction, not much has been specific to *Sarracenia purpurea* and species richness. In our study, we investigated potential relationships between what we find inside of the *S. purpurea* pitchers (insects and other organic material) and physical characteristics (size, pitcher density, color intensity). We expect to see an increase in species richness and organic material inside of the pitcher with increasing pitcher size, density (the number of pitcher leaves in one plant), and color intensity (amount of red venation).

METHODS

Site Description

Bryant Bog is a small bog by Douglas Lake, in Pellston, Michigan. The bog was surrounded by leather leaf plants, which extended onto the sphagnum moss mat. Coniferous trees such as spruce and fir also were scattered around the main bog pool. Pitcher plants were found somewhat hidden under the vegetation, surrounding the bog pond.

Data Collection

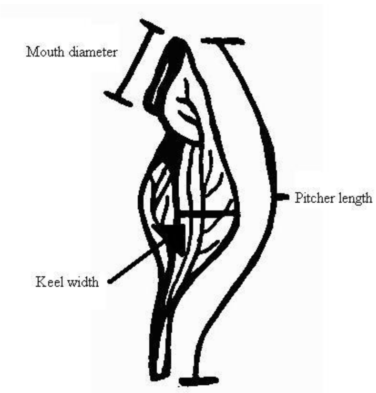

Figure 1: Diagram of measurements of *Sarracenia purpurea.* Note: all measurements are straight, and mouth diameter is a measure of the actual mouth opening and not the hood tip as seemingly indicated by the figure.

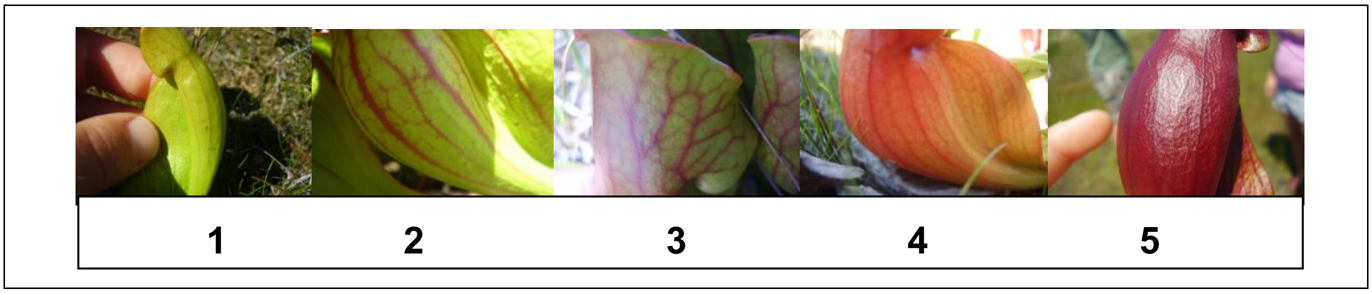

Figure 2: Color scale, based on intensity of red venation of *Sarracenia purpurea*

In two days of data collection, we located 40 different pitcher plants. We measured a single pitcher's length, keel width, and mouth diameter from each plant using digital calipers accurate to 0.001mm. We rated the pitcher's color on a scale based on amount of red venation (Figure 2).

We removed the contents of the pitcher using turkey basters and medicine droppers. We rinsed each pitcher once to make sure all the contents were removed, and placed the contents in a zip lock bag. Under the microscope, we identified all of the whole macro-invertebrates present in each pitcher. We then filtered the contents from each pitcher using a vacuum pump. After drying the contents in an oven at 60*F, we weighed each sample to obtain a mass of the organic material found in each pitcher.

Data analysis

We organized our results to examine relationships between the species richness and mass of the organic material with the pitchers' morphological characteristics. In SPSS, we ran regression analyses between species richness and pitcher morphological characteristics (pitcher size, density), and T-tests to compare color with the species richness. Our critical p-value was 0.05. We did the same with organic biomass and the morphological characters.

RESULTS

Species richness & morphological traits

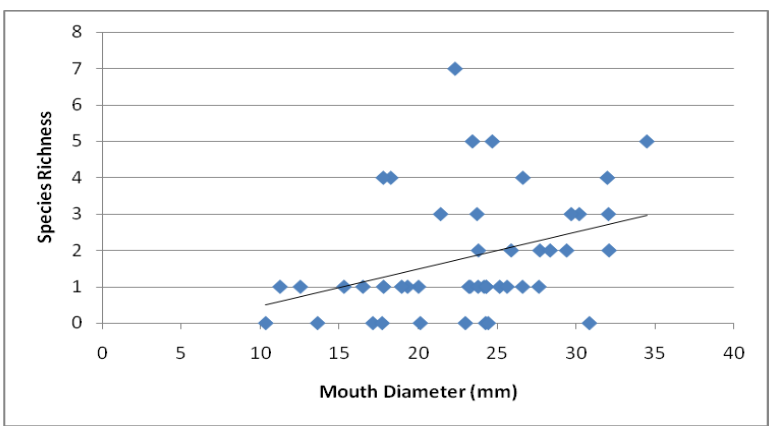

Figure 3: Species richness of whole macroinvertebrates found inside Sarracenea purpurea pitcher leaves compared to mouth diameter.

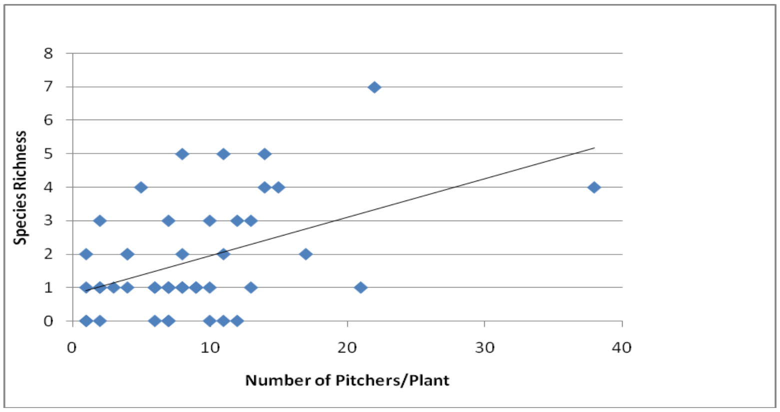

Figure 5: Species richness of whole macroinvertebrates found inside Sarracenea purpurea pitcher leaves compared to pitcher density (# pitcher leaves/plant).

The dominant species found in the pitchers were of the following orders: Hymenoptera (ants and wasps), Diptera (flies), and Collembola (springtails). Regression analysis revealed a positive correlation between species richness found within the pitcher and mouth diameter ($R^2=0.217$, df=44, p= 0.017). As mouth diameter increased, the number of different species of whole identifiable macroinvertebrates increased as well (Figure 3). The pitchers with the largest mouth diameters had approximately identifiable 3 different species, while the pitchers with the smallest mouth diameters had less than 1 species present, on average (Figure 3). Regression analysis also revealed a positive correlation between species richness and pitcher density (Figure 4). As the number of pitcher leaves per plant increased, the number of different species found in the plant also increased ($R^2= 0.123$, df=44, p= 0.001). The pitchers sampled from the smallest groups had approximately 1 identifiable species inside, whereas pitchers sampled from the largest groups had about 5 species (Figure 4). Species richness was not found to be positively correlated with pitcher length, keel width, or pitcher color ($p>0.05$ for all analyses).

Organic Biomass & Morphological traits

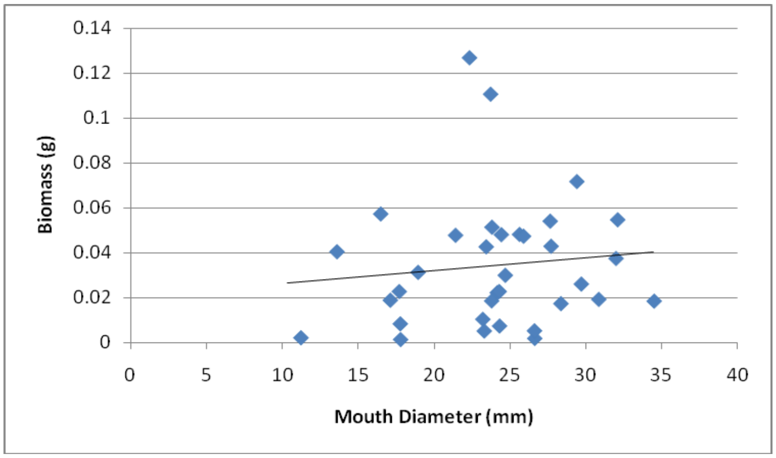

Figure 3: Mass of decaying organic material inside of Sarracenea purpurea pitcher leaves compared to mouth diameter.

Regression analysis also revealed a positive significant correlation between the mass of the organic material inside of the pitcher and the mouth diameter (Figure 4). As diameter increased, the mass of the organic decomposing material also increased (R^2=0.096, df=44, p=0.036). The mass of the organic material was not found to be correlated with color, pitcher length, keel width, or pitcher density (p>0.05 for all analyses).

DISCUSSION

Hypothesis 1-

Our first hypothesis was that species richness and organic mass will increase with increasing pitcher size, and our results for mouth diameter were supportive. The size of the diameter of the opening allows for a greater opening, allowing for more organisms to go into the pitcher. Our results for pitcher length and keel width were not significant, but this could be due to differences in our group members' measuring techniques. Also, pitcher keel widths varied but not according to their general size. Mouth diameter is a good way to study size because it is ultimately the opening that allows for the prey to enter the pitcher. Previous research supports that with increasing pitcher size, the total mass of captured prey increased as well (Green and Horner 2007). Green and Horner (2007) randomly selected *Sarracenia alata* plants along a transect at three different bogs in Kisatchie National Forest, Louisiana. They placed cotton balls in the bottom of the pitchers to mark the beginning of the prey capture study, and left the plants for a month. They returned and measured pitcher height (from lip along the rib to substrate), pitcher mouth opening and red coloration. They brought the pitchers and their contents back to the lab and similar to our study they identified both the intact insects found, and dried and weighed the total organic content of each pitcher. Green and Horner (2007) found that, unlike our study, there was no correlation between plant characteristics (such as size, coloration, nectar) and the number of intact insects found in the pitchers. They did find that pitcher size influences prey capture; the larger the pitcher, the greater the prey capture (Green and Horner 2007).

Cresswell's (1998) research also supports our observations. Cresswell (1998) sampled 164 pitchers from 34 different , *Nepenthes ampullaria* plants in Sungei Ingei Conservation Area, Brunei. He recorded morphological characteristics (such as size and color) and the mass of the organic material inside of the pitcher. He resampled the pitchers 2 weeks later to record the accumulation of organic material and concluded that larger pitchers accumulated more necromass (decaying organic material) than the smaller pitchers (Cresswell 1998). Larger pitchers allow for the accumulation of more organic material. Larger mouths allow for more chance of prey capture. Larger pitchers may also be more attractive to potential prey, as smaller pitchers may be more difficult to find. In our study, many of the pitcher plants were hidden under woody bushes, and it was hard for even us to locate them.

Hypothesis 2-

Our second hypothesis, concerning pitcher density, is also supported by our data. Cresswell's

1991 study, however, concluded the opposite. Cresswell (1991) studied the insect prey over over 200 *S. purpurea* plants in a bog in Brighton, MI. Cresswell (1991) manipulated pitcher densities into 4x4 and 1x1 meter quadrats. His results did not support an effect of pitcher density on the rate of prey capture; rather that prey capture success was unevenly divided among the pitchers (Cresswell 1991). Our study, however, counted pitcher density as purely the number of pitcher leaves existing on the plant we were sampling, rather than an area like Cresswell's experiment. We considered a plant as a grouping of pitcher leaves within a half-meter radius, and studied the effects of pitcher number within a closer radius. This could explain the difference between our results.

Hypothesis 3-

Our third hypothesis, stating that increased color intensity will increase the species richness and organic mass found in the pitcher, is not supported by our results. In their study, Green and Horner (2007) also concluded that red coloration was not important in the determination of prey capture in *Sarracenia alata.* Schaefer and Ruxton (2008), concluded that contrasting colors (such as the red venation) were not necessary in attraction of prey, and may not even increase the number of potential prey. Schaefer and Ruxton (2008) bought 20 *Nepenthes ventricosa* plants and artificially colored the control group completely green and the experimental group pitchers completely red with acrylic and tempera paints (mixed to reduce olfactory biases). They concluded that insects were more attracted to the plants that were all red, which suggests the red is an evolutionary adaptation by carnivorous plants for prey attraction (Schaefer & Ruxton 2008). It has been suggested that insects are attracted to UV signals, which can be released by the red color (Newell & Nastase 1998). Their study concludes that color contrast (aka red venation) may not be necessary, the importance is that the pitcher is different from the background (Schaefer & Ruxton 2008).

Newell and Nastase's 1998 study on *Sarracenia purpurea,* however, concluded that greater red venation resulted in more visits from potential prey. They videotaped 70 pitcher plants in Pakim Pond, New Jersey, to monitor visiting organisms and determine prey catching efficiency. They determined that increased red venation attracted more insects, potentially due to the nectar and UV-reflection produced by the red veins (Newell & Nastase 1998).

The reason we did not get significant positive relationship between increased prey capture and increased coloration could be due to the fact that of all the pitchers we sampled, none of them ranked a 3,4, or 5 on our scale. All of our pitcher leaves were completely green, some with a bit of red venation, but for the most part the coloration did not vary enough to produce any significant findings. The slight venation differences we found may not have been enough to cause a difference in locating abilities of potential prey.

General limitations

Our study did have some limitations. Many of the pitchers had holes in them- which looked like they could have been insect-inducted. These holes could allow for potential escape routes for trapped prey, or might drain the water which helps trap insects. Also, our sampling was done on two different days. There was a rainstorm on one of the days between the samplings, and this could have affected the composition inside of the pitchers. Cresswell (1991) found that spiders spun webs inside of pitcher openings, which could prevent pitcher function up to 10% on trapping days. Although we did not notice any spider webs in our pitchers during sampling, we did not take into account potential outside interferences with prey-catching abilities of the pitchers. Further research might study the effects of such interferences and whether carnivorous plants have evolved ways to deal with them

Another limitation to our study is that species' richness can only be compared within the environment where the pitchers were sampled. The prey captured by the pitcher density depends heavily on the environment, and what is there. Adler and Malmqvst (2004) found that 85% of the captured species were black flies, and over 97% of these captured black flies were only 2 different species. Some environments may be more species' rich than others, in general. Our results can be applied to *Sarracenea purpurea* pitchers, but only to those in similar environments to the bog we sampled. An interesting topic for further study is how much species richness changes according to morphological characters and habitat.

CONCLUSIONS

Morphological characteristics are of great importance to the attraction and capture of prey for carnivorous plants. *Sarracenea purpurea*, the Northern pitcher plant, relies on nutrients from decomposing insects for its survival. Increasing pitcher mouth diameter and increasing density of pitchers per plant were correlated with an increase of both the species richness found inside the pitcher, as well as the mass of the organic decomposing material. Coloration did not have an effect in our study, but further research is necessary to explore the effects and variations of color in *Sarracenea purpurea* across different habitats.

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