Is there an interaction between venation and nectar pattern for prey capture in the carnivorous plant *Sarracenia purpurea*?

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ABSTRACT

From pollination and seed dispersal to taste and volatiles, plants employ a wealth of strategies to signal animal mutualists and threats alike. Some of the more unusual include those of the carnivorous plants, which both lure insects as prey and attract them as pollinators. Many carnivorous plants are thought to utilize color signals in the form of flower mimicry. One such example is the purple pitcher plant (*Sarracenia purpurea* L.), which lives in peat bogs across northeastern North America. The red venation pattern caused by anthocyanins in the leaves in *S. purpurea* was hypothesized to attract insects, but recent studies have shown greater support for extra-floral nectaries as the primary attractant. This is supported by the fact that ants, which are a primary food source for pitcher plants and are high in nitrogen, cannot see red, and therefore cannot be using red color cues to find pitcher plants.

However, color may still play a role: extra floral nectaries occur on the red veins near the opening of the pitcher. Here, I use artificial "pseudopitchers" to show a synergistic effect of nectar and color on diversity and abundance of prey capture. Arthropods that do not rely as heavily on the nectar or volatile cues could be driving this effect. Surprisingly, nectar alone did not have significant effects on prey capture, although a previous study of similar design found nectar to be the primary factor of prey attraction in *S. purpurea*.

INTRODUCTION

All organisms must acquire nutrients for survival, but among plants this need takes on an additional challenge: actively foraging for nutrients is not an option. Plants from nutrient-poor habitats across the world have evolved a unique approach to this obstacle – by attracting and digesting insects, they can make the nutrients do the traveling (Juniper *et al.* 1989). These "carnivorous plants" invest energy into attracting their prey and are rewarded with nitrogen, phosphorous, and potassium, all limiting nutrients in the acidic bogs and mountain tops where they are most commonly found (Ellison and Adamec 2018).

The purple pitcher plant, *Sarracenia purpurea*, is one such carnivorous plant. It lives in dystrophic bogs of the north- and mid-eastern United States and the southeast of Canada (Ellison and Adamec 2018). Like other pitcher plants, *S. purpurea* catches mainly ants, which are high in nitrogen relative to other arthropod prey (Wakefield et al 2005). Additional reported prey for *S.*

purpurea includes wasps, spiders, mites, springtails, flies, and a myriad of other orders (Heard 1998). More recently, the spotted salamander (*Ambystoma maculatum* Shaw) has been reported as a major and highly nutritious seasonal food source for northern plants, which are caught when the salamanders are metamorphosing and leaving the water (Moldowan 2019). Once the plant has flowered, new *S. purpurea* pitchers produce a sugary secretion to attract prey; these extra floral nectaries in which the secretion is produced localize along red veins on the upper inside surface of the pitcher (Ellison and Adamec 2018). The new leaves (>20 days old) are the most successful at catching prey and are most acidic around 30 days post-opening (Fish and Hall 1978).

Among carnivorous plants, *Sarracenia pupurea* is well studied, yet there remains doubt about how these plants attract their insect prey (Ellison and Adamec 2018). The red leaves stand out against the green foliage of *S. purpurea*'s neighbors, leading researchers to believe that the red coloration caused by anthocyanins is an adaptation for attracting insects (Juniper *et al.* 1989). Other unrelated but morphologically or ecologically similar carnivorous plants also employ red coloration, including many *Drosera* sp. (sundews), *Nepenthes* sp. (Asian pitcher plants), and *Cephalotus follicularis* (Australian pitcher plants), as well as *Sarracenia*'s sister genus *Heliamphora* (the sun pitchers of South America). Recently, this long-held hypothesis of color-based insect attraction has come into doubt in *Sarracenia purpurea*. Based on their experiments using 'pseudopitchers' (red and green painted 50 mL centrifuge tubes) placed in bogs, Ellison and Bennett (2009) argue that nectar, not coloration, is the critical factor for insect attraction. Those pseudopitchers baited with corn syrup, which mimics the plants' extra floral nectaries, attracted significantly more insects than unbaited traps, whereas redness of the pseudopitcher had no effect on prey capture (Ellison and Bennet 2009). If redness is not important for attracting insects, why do pitcher plants invest energy in the production of anthocyanins? Other bog and montane species produce red pigments to protect against intense UV in open areas (Gould 2004), including sympatric *Sphagnum* mosses (personal observation). Pitchers in the sun are redder than those in the shade, which would fit with a UV protection hypothesis (Schnell 2002). However, in a greenhouse experiment using Asian pitcher plants (*Nepenthes*) Schaefer and Ruxton (2008) painted pitchers fully red or green and observed red-painted pitchers catching more insects than green-painted ones. Additionally, if anthocyanin production were solely for protection against free radicals caused by UV damage, much of the leaf surface area would remain unprotected because of the acute localization of pigments. Yet *S. purpurea* has a consistent contrasting "veining" pattern of red coloration across the top portion of each pitcher, leaving much of the leaf area comparatively unprotected from UV radiation (**Figure 1a**). Even very red pitchers from full sun habitats retain a contrast between the background red and the red of the veins (**Figure 1b**), indicating that the general red pigmentation could protect against UV damage, but the cause or potential advantage of conserved venation patterns remains unexplained by this hypothesis. While anthocyanin production can also be a symptom of nutrient stress in plants, the consistency with which *S. purpurea* produces net-like veining patterns in the same area of the leaf makes this explanation unlikely (Ellison and Adamec 2018). However, in sunny, dystrophic systems like those favored by *Sarracenia,* nutrient stress and UV protection become difficult to disentangle. In a separate hypothesis, Joel *et al* (1985) noted that the red veins on many pitchers are lined with extra floral nectaries (glands on a plant that secrete nectar to attract insects that are not part of the flower). This caused them to postulate that these coloration patterns could guide insects to the nectaries, thereby increasing the capture success of the plants, but to date, no experimental evidence for this hypothesis has been published (Ellison and Adamec 2018). I predict that pseudopitchers with nectar on the red veins will capture a greater diversity and quantity of prey than any other control or experimental group.

METHODS

Per the methods of Ellison and Bennett (2009), I placed artificial pitcher plants ('pseudopitchers') in a bog containing *Sarracenia purpurea* and recorded prey capture between different color and nectar treatments. By using a proxy such as an artificial pitcher leaf, I was able to independently manipulate the placement of nectar relative to red venation, as well as reduce my study's impact on the plants themselves. I used 50 mL Falcon tubes (Thermo Fisher Scientific, Pittsburgh, PA, USA) as a proxy for one pitcher leaf, which approximate the pitchers in volume, height and bore (Ellison and Bennet 2009). I painted the upper ¾ with two even coats of 'Fresh Foliage' and added 'Burgundy' acrylic paint (Plaid Enterprises, Norcross, GA, USA) in a veining pattern similar to the real pitchers (Figure 2). To approximate the "hoods" of *S. purpurea*, I painted trapezoids cut from sheet protectors (Walmart, Bentonville, AK, USA) and used hot glue to attach them to the rim of the Falcon tubes. To ensure that the capture surface of the hoods remained smooth, I painted two coats of red venation on the back of each hood, then added the green background as a second layer behind the veins. Karo corn syrup (from here on "nectar") (ACH food companies, Oakbrook Terrace, IL, USA) was dotted on the unpainted surfaces of the pitcher hoods to simulate extra floral nectary sugar production by the plant. Corn syrup contains a mixture of fructose and glucose, like all plant nectars (Ellison and Bennett 2009), and also is viscous enough to be placed with specificity on a vertical surface. To increase concentration and viscosity, I cooked the corn syrup for the last triall on medium heat for 10 minutes. Before being placed in the bog, each pitcher was filled with 15 mL of deionized water.

To test my hypothesis that the red venation on *S. purpurea* lids guide insects to extra floral nectaries, I used three levels: 1) tubes approximating real pitchers, with red venation and dots of 'nectar' (corn syrup) along the red veins, 2) tubes with the same red patterning, but with the nectaries on the green portions, and 3) tubes with red venation with nectar streaked randomly over both red and green portions. I also included four control groups: 1) entirely green pitchers with corn syrup applied similarly to the first group, 2) red venation without nectar to separate the effects of color and nectar attractant, 3) unpainted pitchers with nectar, and 4) unpainted without nectar. In total, there were seven types of pseudopitchers (Table 1).

All experiments were conducted in Bolger Bog in the University of Notre Dame Environmental Research Center (UNDERC) property in Gogebic County, Michigan. Bolger Bog is an acidic, dystrophic bog that supports *S. purpurea* on a floating sphagnum mat. A total of nine, 50 meter transects were set end-to-end around the open water of the bog such that each transect was tangent to the shoreline (Figure 3). Because much of the habitat further from the water's edge was tussocks of tall grass unsuitable for pitcher plants, this method helped ensure that the transects contained the open sphagnum mat habitat where *S. purpurea* grows. Even so, one transect contained only tall grass and had no pitcher plants nearby; therefore, this transect was not used. We randomly selected two points on each of the remaining eight transects and created a 3 by 3 meter grid with this point as its center. In one case, this placed a grid fully within the tall grass habitat, so a new random point was chosen on this transect. We randomly placed pseudopitchers on seven of the nine vertices of each grid such that every grid contained exactly one of each type of pseudopitcher. Pseudopitchers were left in the bog for three days. This was repeated three times over the course of the summer, including while plants were flowering and after new pitchers began to open. The data were pooled across temporal replicates to homogenize differences in weather conditions and changing insect populations over the summer. We identified prey to order for each pseudopitcher. In 16 cases this was not possible, so those counts were placed in an "indeterminate" category.

As an additional control, reflectance and absorbance spectra of artificial pitchers must match (at least approximately) the spectra of real *S. purpurea*. This is particularly important to do quantitatively, since insects can see into the UV spectrum and might be affected by visual cues that are invisible to humans. Ellison and Bennett (2009) also observed this control in their experiment, and I therefore used exactly the same paint to maintain this control in the absence of a spectrometer.

Finally, to control for light levels (which can also serve as a proxy for temperature) e, both of which could affect insect activity, I collected foliage cover at each site. Foliage cover was collected using a densitometer (Forest Densiometers Model-C, Bartlesville, OK, USA) held just above the mouth of each pseudopitcher. One reading was taken facing north to normalize any orientation bias from the instrument.

Data Analysis

Data analysis was performed in R Studio (Version 1.1.456, © 2009-2018 RStudio, Inc.). Using the boxCox function, I transformed the data for normality. Due to constraints of the assignment, I approached this as continuous data even though prey capture was count data. Shannon diversity index and Simpson index were calculated for each pseudopitcher and averaged for analysis with a seven level Kruskal-Wallis test and Nemenyi posthoc test. To assess the effect of nectar pattern and coloration while controlling for light level, I ran a two-way ANCOVA using foliage cover as a covariate. Nectar and coloration were 4- and 3-category factors, respectively, and total number of prey caught per pitcher as the response variable. Because the interaction term in the ANCOVA was significant, I also ran a Kruskal-Wallis and Nemenyi posthoc analysis to examine the differences between different treatment groups, which combined the two factors.

RESULTS

All pseudopitchers were successfully recovered from the bog in each trial, though some were found with the hood partially or fully detached. 8 of 112 pseudopitchers caught no prey in any of the three trials. Ants composed 47% of all prey captured, followed by mites (23%) and springtails (10%). All other groups fell below 6% of the total prey captured.

To examine the effects of color and nectar on prey capture while controlling for light levels, I ran an ANCOVA with percent foliage cover at each pseudopitcher as a covariate (df = 1, F = 0.621, p = 0.43). Color (df = 2, F= 23.927, p = 2.83e-9) and nectar (df = 3 F = 2.901, p = 0.0385) were both significant . The interaction term also had significance (1 df, F = 0.0621, and p = 0.009). However, the posthoc analysis revealed no significant interactions within the nectar factor, and only showed significance between the uncolored control and the two colored treatments (uncolored-green: p = 0.0002; uncolored-red veined: p = 0.0000). Because the covariate of the ANCOVA was not significant, I also ran a Kruskal-Wallis test with the untransformed prey capture data (df = 6, p-value = $7.918e^{-8}$) and to establish significance of the Shannon (df = 6, p-value = $7.826e^{-6}$) and Simpson diversity indices (df = 6, p-value = $3.412e^{-5}$). The Nemenyi posthoc test results are shown for each as symbols in Figures 6 and 7.

DISCUSSION

In a follow-up to Ellison and Bennet's experiment on the interaction between coloration and nectar in *Sarracenia purpurea,* the purple pitcher plant, I found contrasting results to the earlier study (2009). Ellison and Bennet (2009) only found significance when examining pseudopitchers with and without nectar, and concluded that this, not coloration, was the primary attractant of prey. Despite nectar type being a significant predictor of prey capture, a post hoc analysis revealed that the levels themselves were not different. One of the more puzzling outcomes of this experiment was the visual trend in the data showing pseudopitchers without nectar catching more insects (Figure 5). This pattern contrasts with Ellison and Bennet's finding that nectar significantly increased capture success. Perhaps some of the unexplained variation in prey capture is due to slipperiness of the hood. The viscosity of the corn syrup could give insects a foothold that they otherwise did not have on hoods without nectar.

Ellison and Bennet (2009) also describe color as having no significant effect on prey capture. This study found a significant difference between the uncolored controls and both the green and red-veined groups. Having some color definitely increased prey capture, a control that Ellison and Bennet did not include (2009). However, though the red veined pseudopitchers did have higher average prey captures, the difference between the groups was not significant.

While the red veined pseudopitchers were not statistically more successful than entirely green pseudopitchers, the data did show a significant interaction term between color and nectar. The core aim of this study was to determine if nectar localizing along the red veins increased prey capture. The significance of the interaction term supports the original hypothesis that these two factors are affecting one another in some way. The pseudopitchers with nectar on the red veins caught the greatest number and diversity of prey, but this was not a significant result.

One roadblock to thorough data analysis is the distribution of the data. For the purposes of this assignment, we treated count data as continuous in order to transform Poisson-distributed data into a normal distribution. Further statistical analyses designed for the original Poisson-distributed data at later date could reveal more meaningful results.

Insects could potentially be more active or abundant in high light or temperature conditions (Zamora et al 1999), so to control for this, I included foliage cover for each pseudopitcher site as a covariate in my analysis. It was not a significant factor, but the values did not change when the covariate was removed, so I left it in the model for the entirety of the analysis. This result in and of itself is surprising, since foliage cover (which can also be interpreted as a proxy for light levels) ranged from 0 to 100 percent. This variability in habitat type for potential prey arthropods was hypothesized to have a significant effect on prey capture, likely as a function of prey abundance in that area.

Based on preliminary data, I determined that 3 consecutive days without rain events would result in the highest prey captures. I initially attempted to avoid rain events in determining when to put my pitchers in the bog, but due to time constraints and frequent rain, the latter two trials did experience moderate precipitation. Data collection spanned twenty days and occurred during early, mid, and late flowering, as well as the onset of new pitcher opening. Newly opened pitchers (defined as within the first twenty days of opening) attract the most prey (Fish and Hall 1978). The presence of new pitchers could have a deleterious effect on pseudopitcher capture by diverting more insects to *S. purpurea* pitchers. On the other hand, there could be an additive benefit to having attractive pitchers nearby that bring flying insects into the area. Both this and the variability in weather were the rationale for pooling the data, because the potential effects of each would be diluted.

While the pseudopitchers did not appear to perfectly match the color of *S. purpurea*, they passed several metrics of blending in; one pseudopitcher was parasitized by a leaf-rolling caterpillar, another by a spider that built its web across the pitcher opening, as happens in real pitcher plants. More than once, a pseudopitcher was mistaken for a real pitcher by the researchers themselves. I also found frass containing paint chips and the corresponding marks where the surface of the pseudopitcher "leaf" had been chewed.

A future experiment could include a 3 by 3 factorial design, which would allow for greater flexibility in teasing out the effects of different factors. For example, as the design stands in this experiment, only one group was entirely green, so trying to compare across the green level of the color factor is impossible. Additionally, while the rest of the pseudopitcher design had been tested by Ellison and Bennet (2009) with a spectrometer to determine similarity of absorbance/reflectance spectra to *S. purpurea* leaves, the hood was of my own design, and due to equipment limitations could not be tested in the same way. Because of the way the hoods were put together, the insects viewed the venation pattern through the sheet protector material, which could have affected particularly the UV reflectance spectrum. Ants can see into the UV (Briscoe and Chittlea 2001) and they are a major nutrient source for *S. purpurea* due to high in nitrogen content (Wakefield et al 2005). A future study could ensure that the reflectance/absorbance spectrum matched that of real *S. purpurea* hoods.

While the results of this study can neither support nor rule out color as a factor for insect attraction, it seems worth examining other possibilities for the function or cause of red venation on *S. purpurea*. Perhaps colored venation has no adaptive function and is simply a morphologically obvious pleiotropic effect. Additionally, if the anthocyanins produced by *S. purpurea* are really a symptom of nutrient stress, localization of the metabolic byproduct could occur by vascular tissue. Finally, by protecting vascular tissue from UV damage, there could be a reduction in damage to any sugars or other nutrients carried in the vascular system.

The uncolored pitchers captured the least diversity, while pseudopitchers with red veins and nectar captured the most, and the green and nectarless red veined controls fell intermediately. Within those three major groups, pseudopitchers with nectar captured greater diversity than those without, though the difference was not significant. However, there was a significant difference in Shannon diversity and prey capture between the red-viened, nectarless control, and the treatment with nectar on the veins, but not between that control and any of the red-veined controls with nectar. To say it another way, if a pseudopitcher had nectar, it only significantly increase prey capture and diversity if it was on the red veins. Per the findings of Ellison and Bennet (2009), nectar is the primary attractant of prey in *S. purpurea*. However, it perhaps warrants further investigation if red venation could attract a greater diversity of prey, thereby helping plants increase prey capture when ants are not available. Additionally, while ants are high in nitrogen, carnivorous plants are limited by more than just nitrogen, and could be balancing their diets through diversity.

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TABLES

Group	Pigmentation	Nectar
1	Red veins	On veins
2	Red veins	Not on veins
3	Red veins	Random
4	Red veins	None
5	Entirely green	"On veins"
6	Uncolored	"On veins"
7	Uncolored	None

Table 1. Short tabular description of experimental and control groups. "Uncolored" pseudopitchers were completely unpainted, "entirely green" was painted in an even green coat, and "red veins" had a red venation pattern added over the green layer. Under nectar, "on veins" had nectar (corn syrup) dotted along the red veins, while "not on veins" had nectar only on green portions. Groups 5 and 6 did not have red veins for the nectar to be dotted on, but the nectar pattern of Group 1 was approximated.

FIGURES

Figure 1. A) Typical venation on the hood of *Sarracenia purpurea*. B) *S. purpurea* in full sun showing an overall red coloration while retaining a contrast with the venation pattern.

Figure 2. Example 'pseudopitchers' made of 50 mL Falcon tube and a sheet protector 'hood'. From left to right: pitcher with red veins, pitcher with only green ("sans veins") and colorless control.

Figure 3. Transects around Bolger Bog at University of Notre Dame Environmental Research Center in the western Upper Peninsula of Michigan. All transects were 50 m in length and contained a tangent point to the water's edge. The red transect was not used due to it being poor pitcher plant habitat.

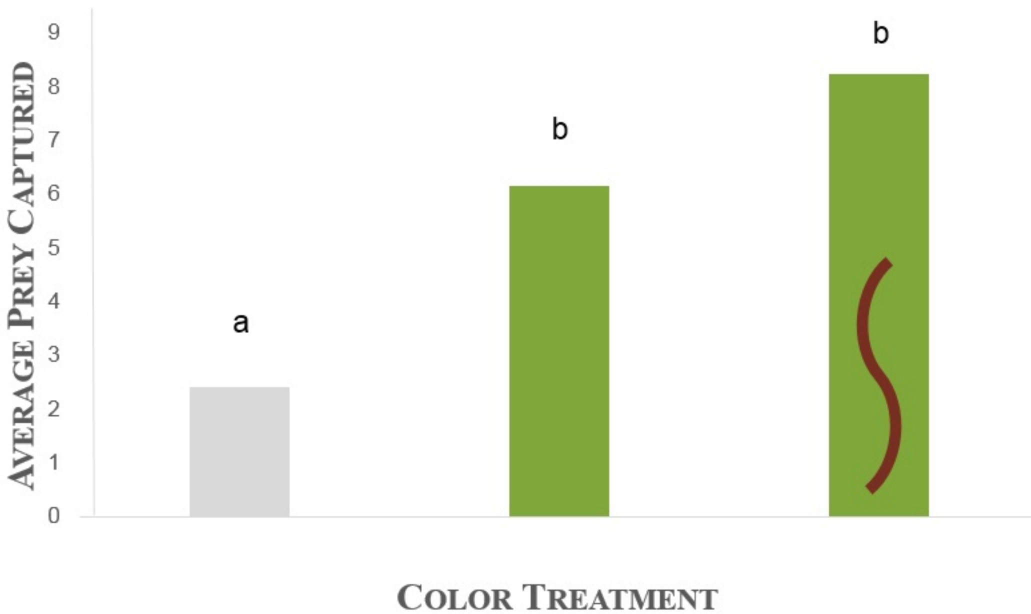

Figure 4. Coloration of pitcher tubes in relation to prey capture counts. Results of a two-way ANCOVA with light level as a covariate and a Tukey posthoc analysis show a significant difference between the unpainted controls, but not between color treatments. Treatments are distinguished with color of the bar and presence of a red line.

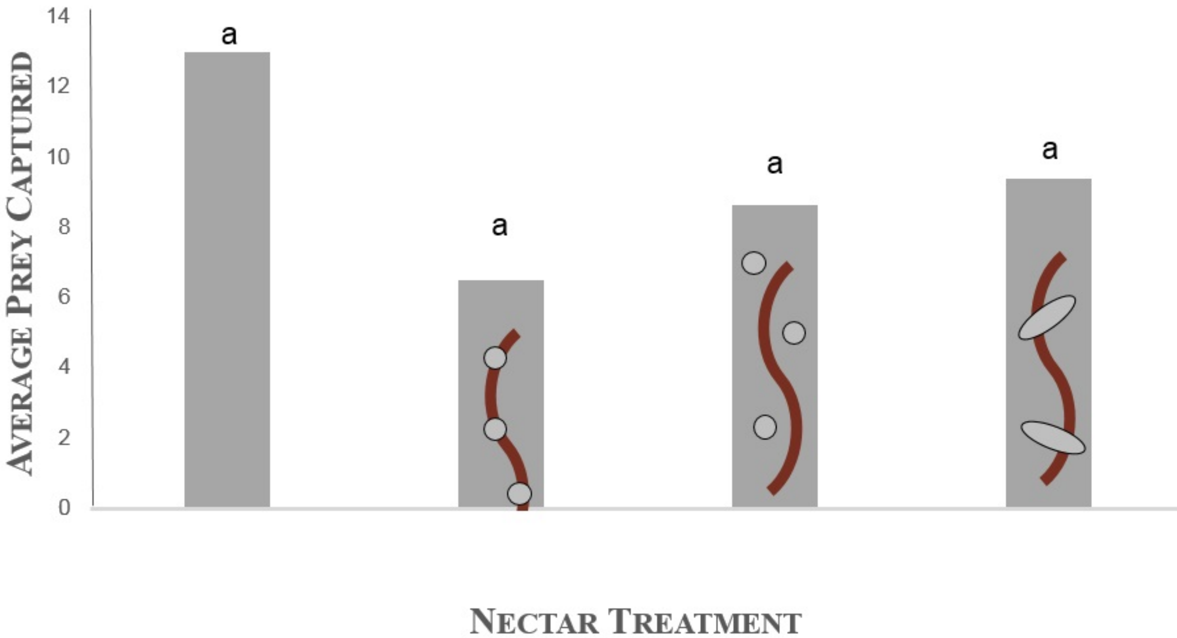

Figure 5. Nectar pattern and prey capture counts. A two-way ANCOVA with light levels as a covariate showed a significant result ($p = 0.03847$) for nectar, but a Tukey posthoc analysis reveals no significant interactions between nectar treatments. Treatments are distinguished with gray dots for presence and arrangement of nectar.

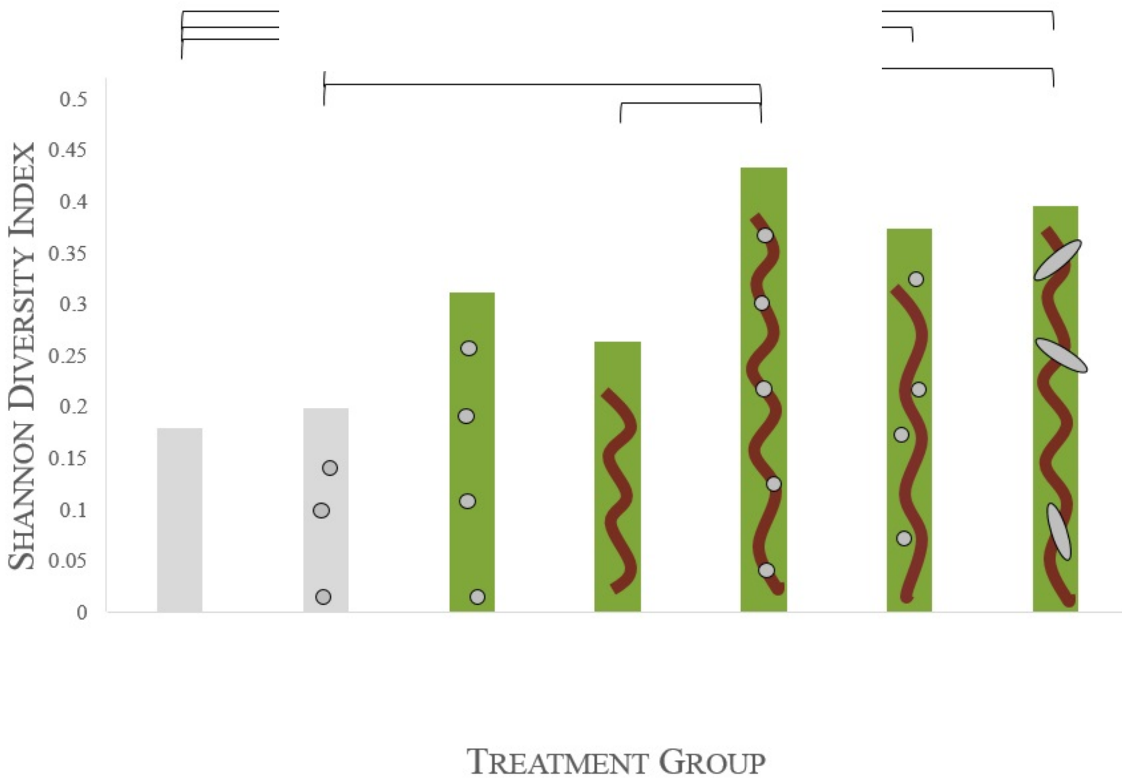

Figure 6. Shannon Diversity Index across the seven treatment groups. The Shannon Diversity Index was calculated for each pseudopitcher. The average index value for each of the seven treatment groups is plotted. Those treatments which are significantly different from one another are shown with a bracket. Treatments are distinguished with color, red lines, and gray dots for presence and arrangement of nectar.

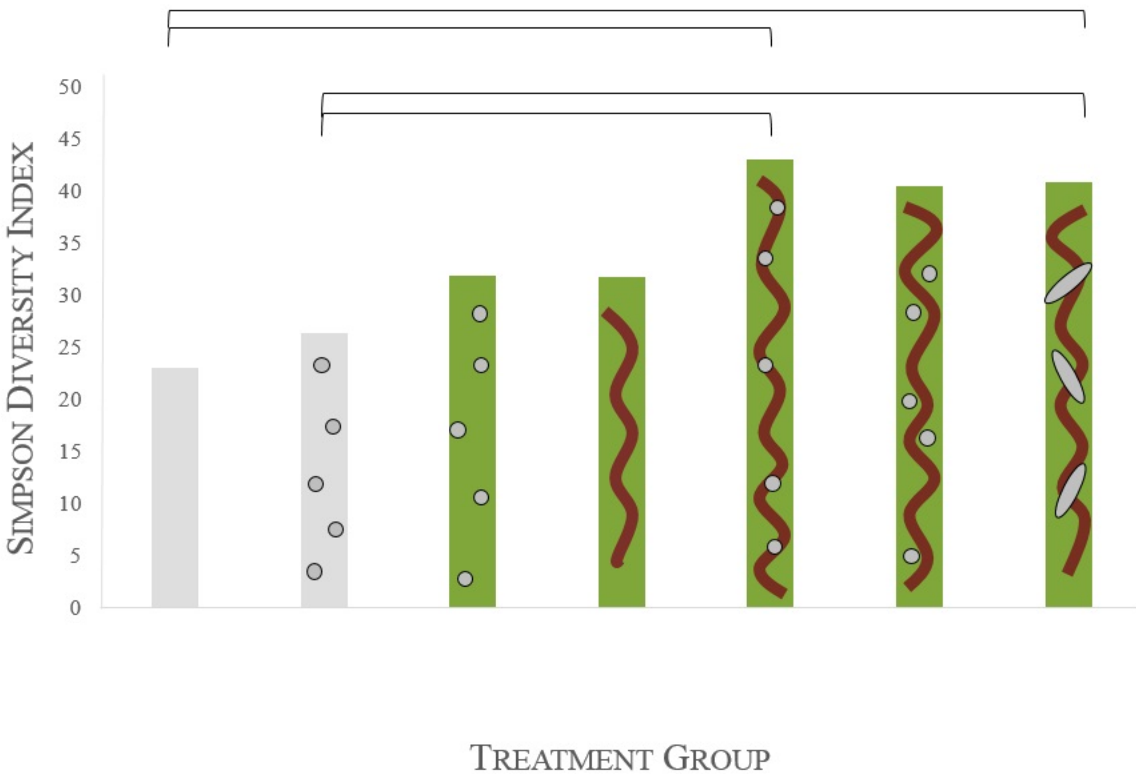

Figure 7. Simpson Diversity Index across the seven treatment groups. The Simpson Diversity Index was calculated for each pseudopitcher. The average index value for each of the seven treatment groups is plotted. Those treatments which are significantly different from one another are shown with a bracket. Treatments are distinguished with color, red lines, and gray dots for presence and arrangement of nectar.

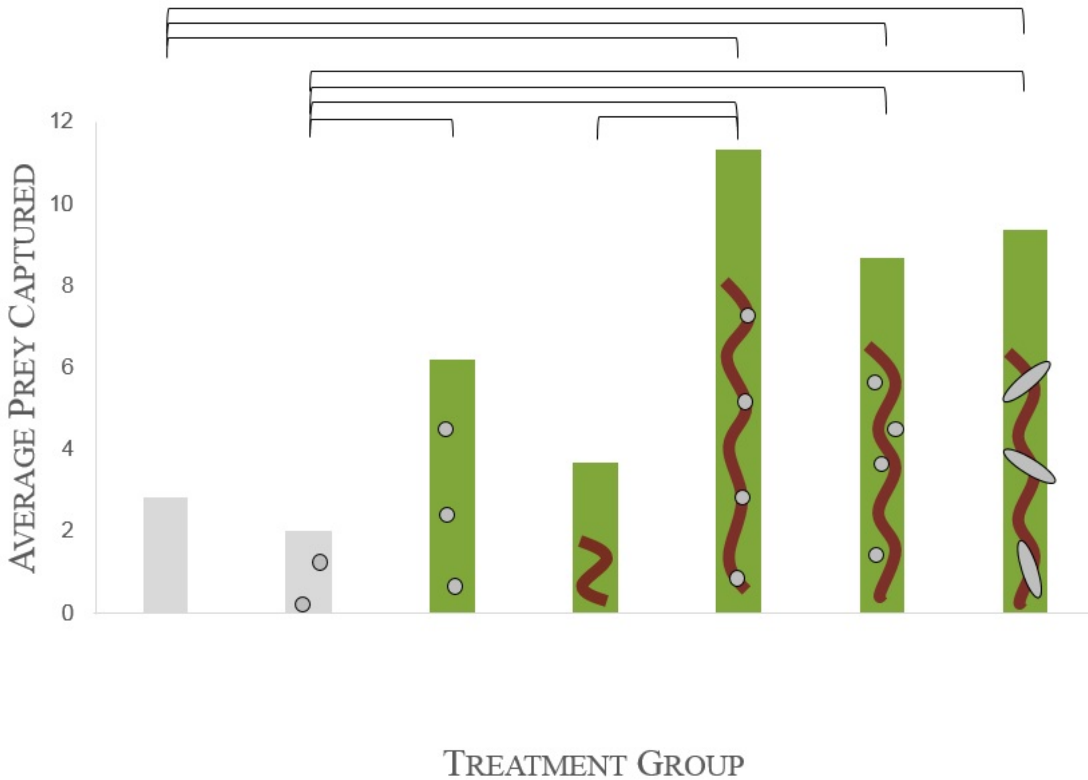

Figure 8. Average prey captured by each of seven treatments. Those treatments which are significantly different from one another are shown with a bracket. Treatments are distinguished with color, red lines, and gray dots for presence and arrangement of nectar.

APPENDIX

Transect	Plot	Color	Nectar	Light	Distance	Sum (prey)	Simpson	Shannon
1	1	sans	sans	30.16	4.7	16	2.23614	0.347614
1	1	sans	lines	69.68	2.8	3	1.393822	0.231002
1	1	green	lines	44.72	5.7	6	2.102804	0.323311
1	1	red	sans	10.4	3.6	10	2.549133	0.431048
1	1	red	lines	29.12	3.15	56	2.607568	0.445895
1	1	red	offlines	8.32	2.4	21	2.29932	0.404228
1	1	red	random	55.12	2.25	7	1.510481	0.249962
1	2	sans	sans	55.12	5	0	1	0
1	2	sans	lines	19.76	6	1	1.064449	0.052693
1	2	green	lines	15.6	2.7	4	1.614525	0.256875
1	2	red	sans	33.28	5.55	5	1.221093	0.16076
1	2	red	lines	26	4.4	20	2.522167	0.418437
1	2	red	offlines	28.08	3.9	16	2.326923	0.411787
1	2	red	random	44.72	5.25	31	2.69403	0.510773
2	1	sans	sans	46.8	4.25	0	1	0
2	1	sans	lines	99.84	3.5	2	1.219512	0.123181
2	1	green	lines	86.32	5	6	1.441397	0.234591
2	1	red	sans	89.44	1.2	4	1.526718	0.268409
2	1	red	lines	93.6	4.4	10	2.574468	0.424754
2	1	red	offlines	53.04	4.05	2	2	0.26265
2	1	red	random	47.84	2.15	9	3.5	0.526869
2	2	sans	sans	72.8	3.3	2	1.588235	0.259085
2	2	sans	lines	91.52	3.05	2	2	0.32874
2	2	green	lines	73.84	3.8	3	1.753623	0.28781
2	2	red	sans	81.12	4.55	2	3	0.41629
2	2	red	lines	90.48	4.95	6	3.266667	0.483898
2	2	red	offlines	50.96	6.6	1	1	0
2	2	red	random	79.04	6.05	4	3.769231	0.558941
3	1	sans	sans	85.28	2.5	0	1	0
3	1	sans	lines	87.36	1.6	0	1	0
3	1	green	lines	9.36	1.8	4	2.314286	0.355009
3	1	red	sans	13.52	1.6	10	1	0
3	1	red	lines	91.52	2	2	2.272727	0.36008
3	1	red	offlines	85.28	2.3	8	2.909091	0.410069
3	1	red	random	75.92	0.05	14	2.238579	0.344792
3	2	sans	sans	24.96	5.25	2	2	0.32874
3	2	sans	lines	3.12	5.2	0	1	0
3	2	green	lines	75.92	5.55	10	2.042017	0.36687
3	2	red	sans	12.48	2.7	1	1	0
3	2	red	lines	86.32	4.25	11	3.595745	0.535322
3	2	red	offlines	36.4	2.05	22	4.447368	0.660488
3	2	red	random	32.24	3.6	13	3.313725	0.522088
4	1	sans	sans	89.44	10	5	1.470588	0.189614
4	1	sans	lines	0	10	1	1.19802	0.115434
4	1	green	lines	3.12	10	6	1.452261	0.259659

4	1	red	sans	29.12	10	3	1.226158	0.1473
4	1	red	lines	10.4	10	12	1.9	0.389028
4	1	red	offlines	31.2	10	8	3.368421	0.590961
4	1	red	random	1.04	10	14	2.022936	0.383606
4	2	sans	sans	87.36	2.7	7	2.050633	0.313649
4	2	sans	lines	27.04	1.85	4	2	0.32874
4	2	green	lines	70.72	1.1	4	1.945946	0.312217
4	2	red	sans	71.76	2.2	1	1.219512	0.123181
4	2	red	lines	76.96	1.85	9	3.461538	0.563768
4	2	red	offlines	19.76	20	13	5.487805	0.684527
4	2	red	random	86.32	1.5	7	2.922078	0.500844
5	1	sans	sans	2.08	3.65	2	1.324324	0.155403
5	1	sans	lines	2.08	3.05	2	1.219512	0.123181
5	1	green	lines	12.48	0.65	5	2.813953	0.490533
5	1	red	sans	15.6	1.6	3	2.571429	0.383245
5	1	red	lines	1.04	1.85	8	2.864407	0.406734
5	1	red	offlines	83.2	1.8	8	2.133333	0.341128
5	1	red	random	4.16	2.45	9	2.372549	0.401582
5	2	sans	sans	20.8	10	1	1.246154	0.132181
5	2	sans	lines	6.24	10	2	2	0.26265
5	2	green	lines	2.08	10	3	1.724138	0.231471
5	2	red	sans	4.16	10	2	1.342466	0.192924
5	2	red	lines	8.32	10	7	1.731591	0.310738
5	2	red	offlines	36.4	10	1	1.124514	0.084772
5	2	red	random	3.12	10	1	1.19802	0.115434
6	1	sans	sans	12.48	10	3	1.80597	0.335565
6	1	sans	lines	3.12	10	0	1	0
6	1	green	lines	3.12	10	14	2.363636	0.359873
6	1	red	sans	20.8	10	6	1.972678	0.357342
6	1	red	lines	28.08	10	4	1.857143	0.299451
6	1	red	offlines	10.4	10	5	2.133333	0.341128
6	1	red	random	10.4	10	2	1.342466	0.192924
6	2	sans	sans	3.12	10	1	1.142132	0.09281
6	2	sans	lines	7.28	10	1	1.124514	0.084772
6	2	green	lines	9.36	10	2	1.28	0.142767
6	2	red	sans	18.72	10	1	1.19802	0.115434
6	2	red	lines	6.24	10	6	2.666667	0.427019
6	2	red	offlines	43.68	10	5	1.710059	0.229551
6	2	red	random	5.2	10	5	1.923077	0.25502
7	1	sans	sans	91.52	4.25	0	1	0
7	1	sans	lines	96.72	4.75	3	2.666667	0.393974
7	1	green	lines	95.68	2.9	2	2	0.26265
7	1	red	sans	88.4	2.85	2	2.666667	0.393974
7	1	red	lines	22.88	2.1	11	3.26087	0.481243
7	1	red	offlines	81.12	3.1	10	1.80597	0.335565
7	1	red	random	67.6	4.55	9	2.4	0.407395
7	2	sans	sans	5.2	2.25	4	2.076923	0.379953
7	2	sans	lines	39.52	0	5	2.571429	0.467693
7	2	green	lines	8.32	1.75	25	1.425743	0.258278

7	2	red	sans	13.52	2.5	3	3.571429	0.504794
7	2	red	lines	10.4	2.5	11	3.358209	0.516263
7	2	red	offlines	88.4	1.65	5	2.793103	0.401983
7	2	red	random	13.52	1.85	14	2.150442	0.312947
8	1	sans	sans	16.64	10	3	2.133333	0.341128
8	1	sans	lines	20.8	10	4	1.97561	0.260306
8	1	green	lines	74.88	10	7	3	0.46035
8	1	red	sans	89.44	10	4	1.256506	0.135513
8	1	red	lines	85.28	10	6	2.578947	0.43718
8	1	red	offlines	5.2	10	10	3.115385	0.518716
8	1	red	random	75.92	10	6	4.263158	0.577083
8	2	sans	sans	39.52	10	0	0	0
8	2	sans	lines	95.68	10	2	3	0.41629
8	2	green	lines	54.08	10	3	2.666667	0.393974
8	2	red	sans	82.16	10	4	4.5	0.591389
8	2	red	lines	79.04	10	4	2.612903	0.435405
8	2	red	offlines	0	10	5	1.855072	0.294598

S2

Treatment group	Averaged Simpson Index	Averaged Shannon Index	Average Prey Captured
Uncolored no nectar	23.07	0.18	2.8
Uncolored w/ nectar	26.43	0.20	2.0
Green w/ nectar	31.94	0.31	6.19
Red veins no nectar	31.82	0.26	3.69
Red veins nectar on lines	43.13	0.43	11.31
Red veins nectar off lines	40.51	0.37	8.69
Red veins nectar random	40.89	0.40	9.38

Appendix 2. Simpson and Shannon Diversity Indices averaged for each treatment group. The Shannon and Simpson index for each pseudopitcher was calculated. The results were averaged across the 16 replicated in each of the seven treatment groups.

Color treatment	Average prey	Nectar treatment	Average prey
No nectar	13	Uncolored	2.4
Nectar along red veins	6.5	Green paint only	6.2
Nectar not on red veins	8.7	With red veins	8.3
Nectar streaked randomly	9.4		

Appendix 3. Average prey captured in different nectar and color types.