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Introduction

The feeding response of Venus flytraps (*Dionaea muscipula*) is widely studied, and many studies have considered the selectivity of prey capture in *D. muscipula* (Lichtner and Williams, 1977; Hutchens and Luken, 2009). The consumption rate of an organism relative to the abundance or availability of its food is known as that organism's functional response (Jeschke et al., 2004). In this study, a functional response curve will be constructed for *D. muscipula* based on its response to increasing availability of small prey in the laboratory.

There are three types of functional response curves that an organism may exhibit (Figure 1; L. Real, 1997). Type I functional responses have been found only in filter feeders, a category that includes carnivorous plants (Jeschke et al., 2004). A type I functional response means that the organism displays a linear increase in consumption rate with increasing food availability up to a maximum point, where the consumption rate becomes constant (Real, 1977). In a type II response, the organism's consumption rate increases in a curvilinear fashion up to a limiting value where the consumption rate levels off. A type III response resembles a sigmoidal curve that also reaches a limiting value where the consumption rate of the organism slows. All three functional responses show an increase in consumption rate with increasing food abundance because the consumer encounters food items more often. The main difference between the three responses is the manner in which the organism's consumption rate increases (Jeschke et al., 2004).

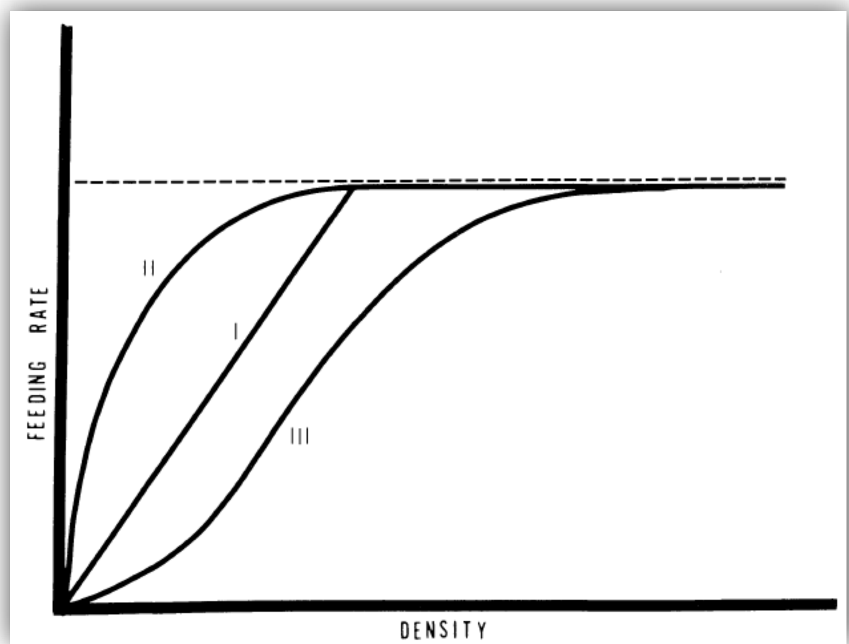

Figure 1. The three types of functional response curves are all similar in that they all reach a maximum threshold at a certain prey density level, but they each differ in how feeding rate increases relative to prey density up to that maximum threshold (Image taken from L. Real, 1997).

Venus flytraps have been shown to capture small insects and arachnids; the flytraps seem to feed opportunistically on what is available (Hutchens and Luken, 2009). Large insects also are captured by *D. muscipula*, and they have a hard time escaping once initial capture has occurred. There is a short period of time after initial capture in which the traps are not completely closed; the traps maintain small openings that may provide a means of escape for small insects. As a prey item struggles, the trap tightens, making escape increasingly less likely (Lichtner and Williams, 1977; Gibson, 1991). Venus flytraps have been shown to capture spiders, ants, and beetles much more often than they capture larger insects in the field (Hutchens and Luken, 2009). A functional response curve constructed from observations of large insects may not be accurate with respect to predator-prey interactions for Venus flytraps because small insects may be captured more often by flytraps. Also, large insects will not have the same chance of escape that smaller insects such as ants will. Though small prey items are more likely to escape than large prey items, flytraps often capture small prey successfully if they are present; the traps will close in response to even minor stimulations of trigger hairs within leaves. Closure is also aided by stimulation of stellate trichomes that cover the plant, which have been shown to increase the sensitivity of trigger hairs (DiPalma et al., 1966).

Knowledge of functional responses is important for various fields of biology including population biology, evolutionary biology, ethology, and physiology because functional responses can provide a wide variety of information such as fitness and mortality risk (Jeschke et al., 2004). This study will hopefully provide a better understanding of the intricate relationship between Venus flytraps and their prey.

I predict that Venus flytraps will elicit a type I functional response because they can capture prey while handling other food items and seem to be able to obtain food items at a maximum rate until all traps are full. These are conditions that must be met for a type I response (Jeschke et al., 2004). In this study, ants will be provided as prey for Venus flytraps to determine the type of functional response exhibited by the plants.

Materials and Methods

In order to determine the functional response of *D. muscipula*, plants were potted separately and different numbers of ants were placed in the pots. Ants were collected from the field. Ant habitats were located, and then ants were collected with a small shovel and placed in a Tupperware container until used. Venus flytraps purchased from a local farm were potted separately and placed on trays with adequate water in a greenhouse setup. Three Venus flytraps were assigned to each of 7 different feeding levels: those receiving 0 ants (the control group), 1 ant, 2 ants, 3 ants, 4 ants, 5 ants, and 6 ants. Therefore, there were three groups of Venus flytraps that contained one plant at each feeding level. Plants were trimmed to possess the minimum number of traps present among all 15 plants after trimming at least one trap per plant, meaning that each plant after trimming had 6 traps. Each potted plant was enclosed by a clear, plastic cup in an effort to retain ants without disturbing photosynthetic processes (Figure 2). The number of ants corresponding to each plant's feeding group was placed in each pot. Observations were made regarding the percent of closed traps, percent of open traps, number of dead ants, and number of live ants once every day for four days. After completion of the observation period, the results from each group of Venus flytraps were plotted on a graph in Microsoft Excel. The average number of ants captured by the plants was also plotted, and the functional response of Venus flytraps was determined visually.

Figure 2. Plants were potted separately and placed in a greenhouse setup, with clear plastic cups as lids to keep ants inside the pots while not interfering with photosynthetic activity.

Results and Discussion

After observing the plants for four days, overall capture of ants was recorded (Table 1). Not all trap closures resulted in captured ants. In group one, there was one empty closed trap in the 3-ant feeding level and one trap had attempted to close in the 5-ant feeding level but became stuck on another trap, forcing it to sit halfway open. In group two, there were two empty closed traps in the 1-ant feeding level, two empty closed traps in the 5-ant feeding level, and one partially closed trap in the 6-ant feeding level. Interestingly, in the second group's 2-ant feeding level, one of the ants captured was halfway out of the trap, though dead (Figure 3). This suggests that in the closed traps that were empty that an ant may have crawled across the trap, but was quick enough to escape or may have been able to escape through tiny spaces between the cilia on the outer edge of the traps. However, the fact that this ant did not escape is evidence that traps may still effectively capture prey that is almost successful at escape. There were no closed, empty traps in group three, but there was one plant in the 4-ant feeding level that had captured an ant but was not closed completely, showing that some ants were much more capable of escape than others.

In the higher feeding levels, few ants were captured relative to the number of ants given. This was shown in all three groups. During the observation period, it was found that a couple of ants were able to escape through tiny openings in the bottom of plant pots. However, the fact that similar data was collected multiple times shows that ant escape (or lack of ant contact with traps) in this study was consistent across three different groups of Venus flytraps and may actually represent the natural relationship between the Venus flytrap and the ants as prey.

The functional response curve for the Venus flytraps was determined visually by observing the plotted number of ants captured in each group and the average number of ants captured (Figure 4). It can be seen that the Venus flytraps exhibited a curvilinear increase up to the 3-ant feeding level, at which point the number of ants captured began to slightly level off. As explained, each functional response differs in the manner by which the number of prey items consumed versus the number of prey items available increases. A curvilinear increase is typical of a type II functional response curve, therefore the functional response visualized in this experiment was determined to be closest to that of a type II functional response. This contradicts the prediction that the Venus flytrap would show a type I functional response, which was based primarily on the parameters set previously that filter feeders have been shown to exhibit a type I functional response because they can capture prey while handling other food items and seem to be able to obtain food items at a maximum rate until all traps are full (Jeschke et al., 2004). This means that the Venus flytrap does not meet both of these conditions necessary to yield a type I functional response, specifically, they are not able to capture food items at a maximum rate until all of their traps are full (while they are able to capture prey while still handling other food items). This may be because Venus flytraps are considered to be passive filter feeders rather than active filter feeders (Jeschke et al., 2004). Passive filter feeders are only able to capture food items that cross directly over their filtering system, in this case, Venus flytraps were only able to capture ants that crossed directly over a leaf trap. If they are totally dependent upon the likelihood that an insect may cross over a trap (and be successfully captured), then they cannot capture insects at a maximum rate.

It has been determined previously that Venus flytraps exhibit a linear increase in prey consumption, a type I functional response curve, when crickets are the prey items in a laboratory set up similar to that used in this experiment (Stewart et al., 2008). The finding that Venus flytraps yield more of a type II functional response with ants could be due to the differences in prey size. As noted, there were a few traps that were closed among the various groups that were found to be empty. When the leaf trap initially closes, there are tiny spaces between the cilia on the outer border of the traps that allow for escape. Ants are a much smaller prey item than crickets, and would be able to escape through these tiny openings. Therefore, cricket capture would have a much higher success rate than ant capture after trap contact with the insect. Also, the smaller size of the ants, along with their ability to dig and more easily travel away from the location of the traps, could make the contact of a trap with an ant less likely than the contact with a cricket inside the laboratory set up used in these experiments. With this in mind, it should be noted again that Venus flytraps have been found to capture ants more often than crickets in the field (Hutchens and Luken, 2009). It could be that in a more open field setting flytraps are more likely to come in contact with ants than with crickets, since crickets would have much more room to move relative to their size than in a small, enclosed plant pot. Therefore, if ants are a more likely and common prey source for the Venus flytrap in nature, it is possible that the type II functional response, or perhaps even a mixture of type I/type II, is the true functional response for the Venus flytrap. In future experiments, it would be beneficial to attempt to determine the functional response of Venus flytraps in the field, if there could be a way to isolate the plants enough to still get valid results. It may also be beneficial to perform further laboratory studies with different insects (such as beetles or arachnids) as a prey source, to see which functional response, type I or type II, is the most prevalent in flytraps. Experiments could also be repeated with ants in which the functional response is determined mathematically rather than visually to verify that type II is the prevalent response observed when ants are the prey source.

Table 1. Total ants captured by each feeding level in group one, two, and three.

Assigned Number of Ants	Number of Ants Captured in Group One	Number of Ants Captured in Group Two	Number of Ants Captured in Group Three
0	0	0	0
1	1	1	1
2	2	2	1
3	2	2	1
4	1	3	3
5	2	0	1
6	1	4	1

Figure 3. In group two's 2-ant feeding level, one ant attempted to escape but was still effectively captured.

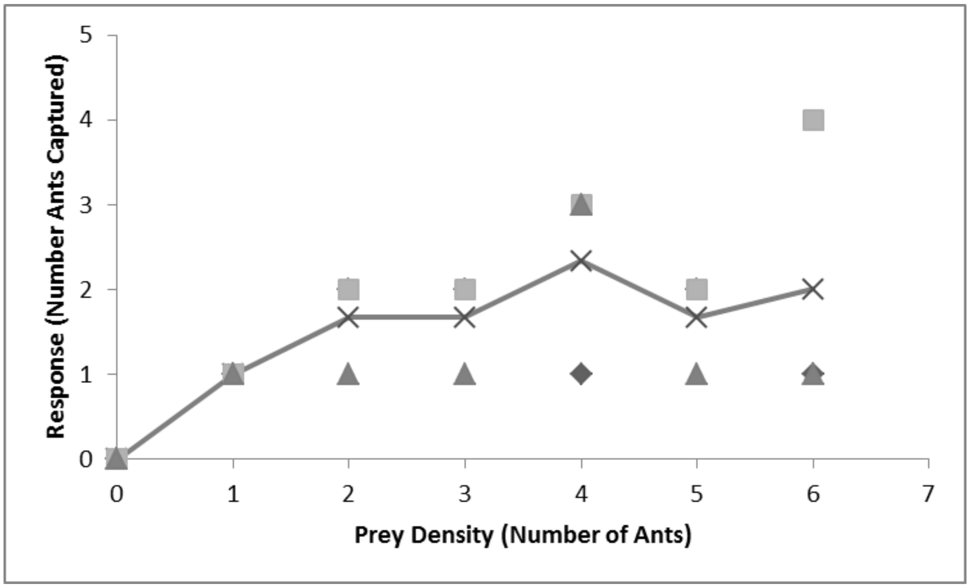

Figure 4. Functional response for each feeding group, showing the number of ants captured versus the number of ants available, or the feeding level (diamonds are group one results, squares are group two results, triangles are group three results, and x's are the average number of ants captured between all three groups). By connecting the average number of ants captured between all three groups, it can be seen that there is a curvilinear increase up to the 3-ant feeding level, at which point signs of hitting a maximum threshold begin to become prevalent.

Conclusion

In this experiment, the functional response of the Venus flytrap was determined by feeding different numbers of ants to flytraps that were separated into three groups which each contained 7 different feeding levels (0-6 ants). After plotting the number of ants captured by each group of flytraps and the average of the ants captured among the three groups versus the number of ants available, the functional response was determined visually and concluded to resemble a type II functional response. It has been shown that while type I functional response has only been shown in filter feeders, not all filter feeders exhibit a type I response (Jeschke et al., 2004). This is likely due to the fact that not all filter feeders can meet the conditions necessary to yield a type I functional response, and seems to be the case of the Venus flytrap which can capture more prey items while still handling previous prey items but cannot capture prey items at a maximum rate due to lack of prey contact with traps and intermittent capture failure. Overall, the finding that Venus flytraps exhibit a type II functional response when determined visually with ants is an insightful one which provides evidence that though Venus flytraps *could* potentially capture insects at a maximum rate on the conditions that both the contact with insects and capture success is also at a maximum rate, it is unlikely that flytraps *will* capture insects at a maximum rate because these two conditions are unlikely to be met.

Literature Cited

DiPalma, J., R. McMichael, and M. DiPalma. 1966. Touch receptor of Venus flytrap, *Dionaea muscipula*. Science 152:539-540.

Gibson, T. 1991. Differential escape of insects from carnivorous plant traps. American Midland Naturalist 125:55-62.

Hutchens, J., and J. Luken. 2009. Prey capture in the Venus flytrap: Collection or selection? Botany 87:1007-1010.

Jeschke, J., M. Kopp, and R. Tollrian. 2004. Consumer food systems: Why type I functional responses are exclusive to filter feeders. Biological Reviews 79:337-349.

Lichtner, F.T. and S.E. Williams. 1977. Prey capture and factors controlling trap narrowing in *Dionaea* (Droseraceae). American Journal of Botany 64:881-886.

Real, L. A. 1977. The kinetics of functional response. The American Naturalist 111:289-300.

Stewart, S., J. Hutchens, and J. Luken. 2008. Functional response of the Venus flytrap (*Dionaea muscipula*). *2008 Association of Southeastern Biologists Meeting.* Lecture conducted from Greenville, SC.