Analysis of Foraging Behavior in Water Striders

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Abstract The foraging behaviors expressed by an individual may depend upon the state of that individual and local environmental condition. Understanding how abiotic conditions affect feeding behaviors may elucidate how animals choose where to forage and how much energy to expend on feeding. Water striders, *Gerris remigis*, are abundant insects that inhabit slow moving waters. I conducted two types of experiments on the water striders to (1) determine the effect of stream velocity on the preference of foraging habitat and (2) to examine whether the preference for location is controlled by current velocity or food availability. In the first set of experiments, the stream velocities were manipulated so that one side of the creek was faster than the other. I predicted that the water striders would tend to congregate in the swifter moving current because either instinctual behavior associated faster water current with a greater probability of obtaining food, or the side with greater flow carries more food items. This idea coincides with the rule of thumb decision making process. Results showed that there are consistently more water striders in the faster current. In the second set of experiments, I attempted to disentangle the effects of food and current. I predicted that the water striders would move over to the slower current when food availability increased to decrease the energy spent battling the current. Results show that there was movement towards the slower current with the food, but it was not statistically significant. These results allowed me to suggest an optimal foraging theory for the water strider.

Introduction

Behavioral ecology is the study of adaptive behavioral responses to changing ecological conditions (Sih, 1992). One of the most interesting aspects of animal behavior is looking at how predators decide when, where and how long to eat. This behavior can be attributed to the optimal foraging theory. One of the issues under optimal foraging theory is determining the type of food that would bring about the highest rate of energy acquisition. The amount of energy that the predator receives is directly proportional to the energy gained by consuming the prey minus the amount of energy spent foraging. When predators become more adept at capturing and consuming prey, they get more to eat, and their birthrate increases, their death-rate decreases, or both (Abrams 2001). The survival of an individual depends on its ability to acquire resources, the more efficient it is at obtaining these resources, the more successful it is.

Water striders, *Gerris remigis*, are relatively common insects that live on the surface film of creeks and streams. They are easily distinguished by their ability to skim over the surface of the water. This species differs from many other aquatic insects in that adult water striders are primarily wingless and the few that do have wings are reluctant to fly (Fairbairn, 1986). These insects are constantly on the hunt for prey flowing down with the water current. The prey taken by species of *Gerris* consists of various soft-bodied arthropods, mainly insects trapped in the surface film, either land insects blown from the shores or emerging adult insects with aquatic larvae (Andersen 1982). Factors such as current velocity and food availability can alter their foraging behaviors. Adult *G. remigis* are found primarily where surface currents range between 5 and 10 cm s^{-1}, and tend not to be found in currents exceeding 15 cm s^{-1} (Fairbairn 1988). Previous research topics have focused on the sexual behaviors of these water striders (Sih 1992), while few projects have been done on their distribution along streams. This experiment looks at how stream current plays in altering the water strider's foraging behaviors.

Previous experiments have shown that water striders did have a preference in current speed (Fairbairn 1988). But Fairbairn's experiments examined the movements of the water striders in relation to their physiologically-based behavioral differences. The current experiment can provide insight into basic animal behaviors on optimal foraging. Information obtained can allow us to understand the behavioral patterns of the water striders and determine which form of decision-making system is utilized: the rule of thumb or the cost benefit analysis.

This experiment tests the hypothesis that water striders use current velocity as a rule of thumb for locating areas of high food availability in a creek channel. Cross sections of a stream where the main current flows are likely to carry more floating debris, including food. Over generations, the water striders may have learned that there is more food within the faster main current. Simple rules of thumb developed from the insects' past experiences are used to simplify the complex analysis involved in these evaluations. If this hypothesis were true, then even when food is screened out from the flow, the water striders would still prefer faster moving waters. An alternative hypothesis is that the water striders are randomly looking around for the food. Their distribution is not determined by the water current but is in fact based on where they have obtained the most prey. With this hypothesis, the optimal foraging theory comes into play. The cost benefit analysis done by the water striders may show that they are willing to actively seek prey throughout a gradient of stream velocities. The cost would be the energy required to fight the current, strong or weak, and the benefit is obtaining more food. When we know what alternative decisions are possible and understand the most important tradeoffs arising from them under a given set of constraints, we should be able to predict which decision will yield the greatest foraging success under a given set of conditions (Kramer 2001).

Methods

Study Site The experiment was conducted out in the field in Strawberry Creek, Berkeley. Field experiments included obtaining counts of water striders in the creek depending on their location. Observations were made at the same time each day to minimize confounding factors. In order to alter the stream velocities, man made dams and diversions were erected. Screens were used to filter out the naturally occurring food source flowing down the creek. The food source used in these experiments was the adult fruit fly, *Drosophila melanogaster*.

The field experiment was located in the Strawberry Creek near the junction point of the two forks. The site was chosen due to its morphology and abundance of water striders. In this section of the creek, the channel is fairly straight, thus preventing eddies and other varying stream velocities to occur. The inlet to the study site flows through a broken check dam on the left hand side of the creek. Initial observations showed that the water current was faster on the right hand side of the creek compared to the left. This was mainly due to the debris and the shallowness on the left hand side of the creek. The outlet to this system is a large cascade that spans the entire width of the creek, thus allowing the water to flow unrestricted out of the study site.

The rocks that are present upstream from the creek and along the banks were used to create diversions for the creek. To remove the incoming food source for the water striders, a fine mesh was erected at the inlet of the study site. By placing the mesh in the inlet, the food source available for the water striders would mostly be limited to the *Drosophila melanogaster* that is provided in the experiment. Flightless fruit fly cultures were obtained on line through an insect hobbyist site. The culture contains flightless fruit flies, pupae, larvae and eggs which would provide a constant supply of fruit flies. In order to determine the relative creek velocities, an orange and stopwatch was used by measuring out a set distance of "X" meters and time in seconds how long it took for the orange to travel the distance.

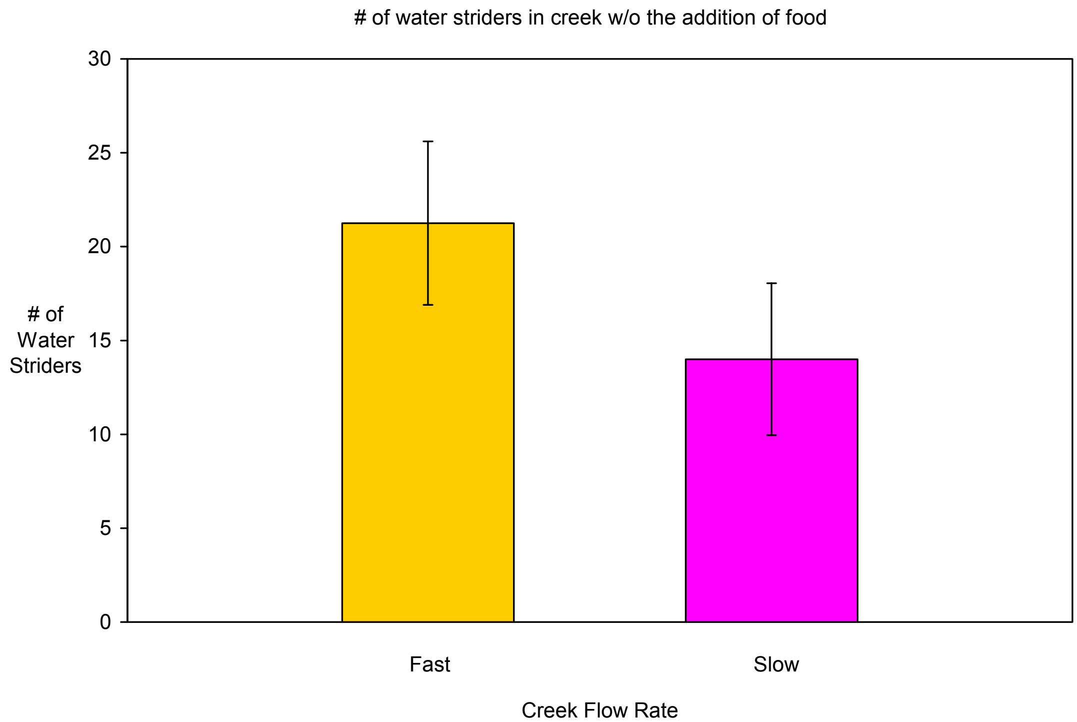
Sampling Procedure Preliminary observations were made to make sure there were enough water striders in the creek to conduct the experiment. There should be an ample amount of water striders in the creek so that significance can be easily determined using statistical analysis. During this time, the relative stream velocities on either side of the bank were recorded. The measurements for flow rates were made a quarter of the creek's width away from the banks in order to standardize the observations. The flow rates were calculated by measuring out one meter on each side of the creek and then observing how long it took for an orange to travel that distance. After the preliminary measurements, rocks were relocated near the inlet to divert water to the opposite side of the creek from the side where flow is presently strongest. Make certain that one side of the creek has a faster flow rate than the other. Also keep in mind that the flow rates must be less than 15 cm s^{-1} or else the water striders would cling onto shore, move over to the slower side due to huge amount of energy required from being washed downstream, or simply move downstream beyond the experimental area (Fairbairn 1988). Small rocks were then laid down on the middle of the creek bed in order to demarcate the left or right hand side of the creek. Leave the creek alone for two hours after the alterations so that the water striders can adjust to the different flow rates. The number of water striders on each side of the creek was then recorded. The counts of water striders were made by walking the entire length of the study area. The observations were first made in the faster moving current and then another pass for the slower current. Any water striders that may be in the middle were disregarded in the final data. This experiment is to test the hypothesis that foraging behavior of the water striders is tuned only to the velocity of the water current and not to the availability of the food. The experiment was done twelve different times to see whether the response were significant.

To test the second hypothesis, *Drosophila melanogaster* was added to the slower portion of the creek. The procedure was similar to the first experiment, but in this second set of experiments, the inlet water was passed through the mesh to filter out any upstream food source. The only incoming food source would be the *Drosophila melanogaster.* From the previous experiment, it was found that water striders acclimated to their new surroundings as fast as one hour. After altering the creek, the water striders were given two hours to move to their respective areas in the creek. The *Drosophila* was then introduced to the slower moving current. The addition of the food source, roughly five fruit fly individuals, continued every 10 minutes so that there was a constant supply of food in the slower moving current. The number of water striders in each respective bank was then recorded and the experiment done eight more times to make sure the results were significant.

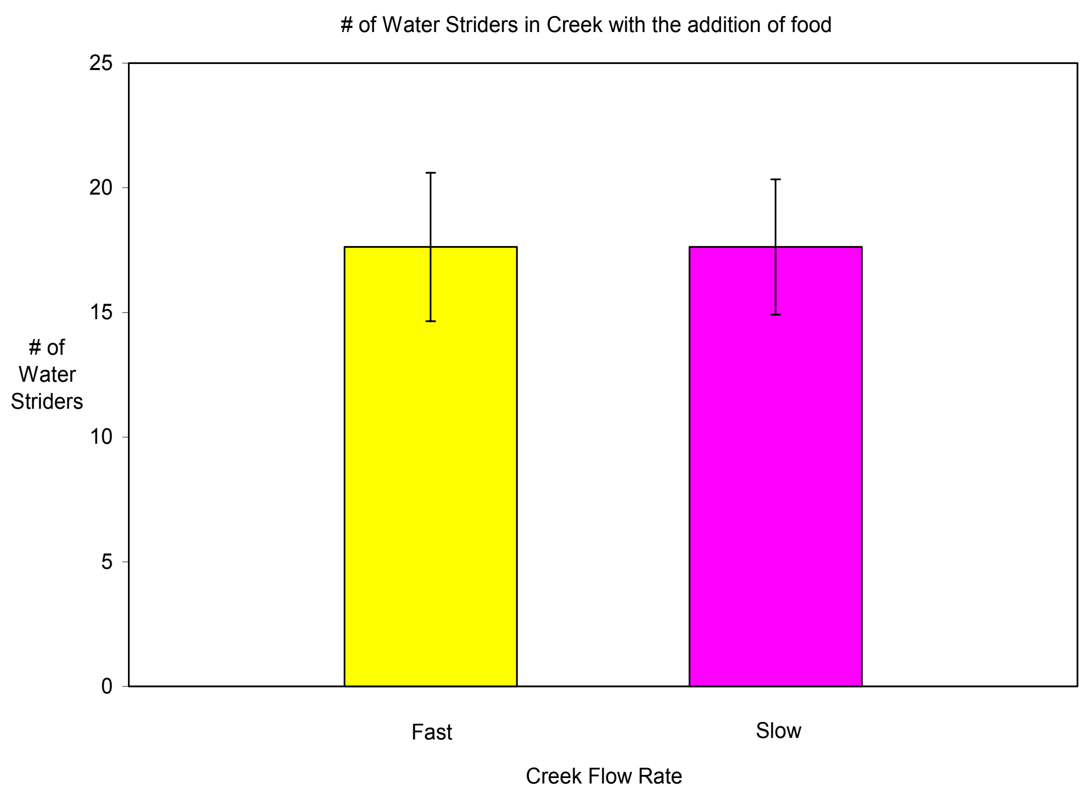
Statistical Analysis Variables for both hypotheses included the flow rate and the number water striders. To analyze the data, a bar graph showing the averages of the results was used to visualize whether there were more water striders in the fast or slow moving current. A paired t-test was then implemented to determine the significance of the data.

Results

The results for the first hypothesis showed that there were more water striders in the faster moving current compared to the slow current. The faster current had an average velocity of 8 cm s^{-1} while the slower current had an average velocity of 5 cm s^{-1}. The time scale of the experiment and data collection was between noon and 3 pm. There were more water striders in the faster side of the creek (21.3 $\pm$ 4.4) than the slow side (14.0 $\pm$ 4.0) after the current was manipulated ($n=12$; $t=8.58$; $P<0.0001$). The water velocities for the second experiment were similar to the first experiment. Results showed that there was no clear preference between the faster side of the creek (17.6 $\pm$ 3.0) or the slower side (17.8 $\pm$ 2.7) after the introduction of the food ($n=8$; $t=-0.08$; $P>0.94$). Below are bar graphs that show the averages of water striders in the creek without and with the addition of the food.



# of water striders in creek w/o the addition of food
30
25
20
15
10
5
0
of
Water
Striders
Fast
Slow
Creek Flow Rate



# of Water Striders in Creek with the addition of food
25
20
15
10
5
0
of
Water
Striders
Fast
Slow
Creek Flow Rate

Discussion

The first experiment showed that the water striders did tend to migrate towards the faster moving current. Why would the water strider tend to congregate towards the swifter moving waters? Making a decision involves choosing the alternative that is likely to produce the most desirable outcome. Determining just what constitutes a likely desirable outcome is a subjective process. Outcomes are viewed as gains or losses relative to the status quo: will the water strider obtain more food or waste energy searching for food? The results from this experiment indicate that the water striders were willing to take a calculated risk to venture into the faster current for food. The risk in this case is expending excess energy to battle the fast moving current assuming that there is a higher probability of obtaining prey. In the first hypothesis, the rule of thumb decision-making system is evident. Observations showed that the water strider's instincts tell them to relocate to the faster moving water. Without altering other factors but the stream velocity, it is clear that the stream velocity plays a part in the water strider's dispersal in the creek.

The second objective of this experiment was to determine whether the water striders were drawn to the faster current due to their instincts or the fact that there was simply more food flowing down the faster current. The removal of incoming food source in the fast current in conjunction with the addition of fruit flies in the slower current, allowed the experiment to test whether food availability was the only factor concerning placement. From the second set of experiments, results showed that there was no significant relocation of the water striders to the side with more food. The paired t-test concludes that there were no significant differences between the two stream velocities. This implies that the water striders, once in their relative positions did not randomly move across the stream to look for food. The water strider distributions were more evenly spread out between the two sides with differences between the means dropping from 7.25 to 0.13. Even though the data was not statistically significant, there was still a shift in the preferences of sides after the introduction of the food. With the availability of food, the average number of water striders in the slower section increased while the numbers in the faster section decreased. Food availability is clearly a factor in how the water striders make their foraging decisions. Both the rule of thumb and cost benefit analysis systems seems to be used by the water strider. In the first experiment, the water strider utilizes the rule of thumb analysis while on the second experiment, it uses the cost benefit analysis.

There may be a few explanations for the results of these two experiments. One explanation is that the water striders continued to migrate over to the faster current due to their instincts. Over evolutionary time, their instincts may have been attuned to the simple notion that faster currents result in more food. Through data analysis, this has been shown to be a likely explanation for their movements. An explanation for the second set of data is that the water striders that had already migrated to the faster current simply were not aware of the abundance of food in the slower current. An increase in food availability and a decrease in energy required to obtain this food should correspond with a higher average in the slower flow. It is intuitive in the human rule of thumb decision-making that one would not expend more energy than is required to obtain food. Future research should look into the idea of adding the *Drosophila* simultaneously as the flow rate is being altered. Results may show that more water striders would remain in the slower moving current, thus further proving the rule of thumb theory. The time and weather conditions of the observations may have also played a part in discrepancies in the data. Since water striders are cold blooded, the presence or absence of the sun has an impact on their distribution in the creek. On cold and cloudy days there were less water striders out and about in the creek while there were greater numbers during sunny days. The different type of vegetation along the creek may also have contributed to some errors in the experiment. On the left bank there was English ivy while on the right bank there was mostly dirt and roots. During the second set of experiments, the English ivy may have provided another source of food thus causing the water striders to remain on that side of the creek.

These experiments have given insight on how the water striders determine their relative positions in the creek. A possible optimal foraging theory for these insects can be deducted: the water strider may be assessing conditions based on food availability and current velocities. The success of a species depends on its ability to make the right decision at the right times. With the water strider, it uses both the rule of thumb and cost benefit analysis systems to be effective scavengers.

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