Exploring Optimal Foraging Behaviorin *Peromyscus maniculatis:* Resource Use in Various Patch Types

BIOS 569: Practicum in Field Biology
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2014

Abstract:
My experiment explores the foraging behaviors of *Peromyscus maniculatus* in a laboratory setting. Studying the foraging behaviors of widespread *Peromyscus maniculatus* will deepen ecological understanding on a broad scale. This experiment is based on optimal foraging theory's predictions that an animal will continue to forage as long as the benefits out way the costs. I analyzed *Peromyscus maniculatus* foraging decisions when presented with sunflower seeds in three different patch types; clumped, uniform, and random, I hypothesized that mice would forage most efficiently in clumped patch distributions because when seeds float down from trees they are clumped. To test this hypothesis, captured mice were exposed to one of three patch types within a cattle tank and filmed overnight. I recorded total foraging time, total weight consumed, and consumption rate for each trial and analyzed mean differences using an ANOVA. The data I collected revealed no significant differences in the foraging efficiency, total time, or weight of seeds consumed by mice across the three treatment types. Though further experimentation is necessary, my results suggest that *Peromyscus maniculatus* are generalist feeders which are adapted to forage on many different types of food sources, therefore are not adapted to specific resource distribution types.

Introduction:
My experiment explores foraging behaviors in natural environments and mammalian use of past experience to determine learning abilities. Many herbivores, including mice, rely on seeds as a food source since they contain many nutrients and are a relatively reliable food source. One of the main mechanisms for seed dispersal on the University of Notre Dame Environmental Research Center (UNDERC) property, located in the upper peninsula of Michigan, is wind dispersal. Wind dispersal occurs in two primary forms: seeds either float on the breeze or they flutter to the ground (Gurevitch, J. et al 2006). Maple and Coniferous trees predominately use wind dispersal, with seeds shaped so they flutter to the ground. This type of dispersal leads to the commonly found clumped seed distributions occurring under trees after seeds first fall. Understanding the ecological impacts of seed dispersal patterns may give powerful insight into future conservation efforts and strengthen understanding of how human actions effect the natural world. Studying ecology as it pertains to how humans effect nature through microcosmical, controlled experiments can lead to a deeper understanding of the larger effects humans have.

For my experiment I observed foraging behaviors of *Peromyscus maniculatus* (forest deer mice) looking for insight in consumption rates and how they relate to different patch types. Forest deer mice are widespread across North America, and therefore their foraging behavior in the Upper Peninsula may model mice behavior across the country. Specifically I will be looking at the optimal foraging behaviors of *Peromyscus maniculatus.* The basic procedure for determining optimal utilization of time or energy budgets is as follows: an activity should be enlarged as long as the resulting gain in time spent per unit food exceeds the loss which includes foraging time, predation risk, and opportunity costs (Macarthur and Eric 1966, Brown 1988). This is the premise of optimal foraging theory and suggests *Peromyscus maniculatus* will continue to look for food as long as they gain more energy than they loose. This makes it more beneficial to the mouse to stay in a larger patch because it greatly reduces the traveling/search time. This also suggests that the mice will consume food faster since they do not have to travel or search for the food once they find a patch. A study done by Marsh *et al.* showed that koalas (*Phascolarctos cinereus*) foraged and stayed longer in larger trees than smaller ones (Marsh et al. 2013), this insinuates that *Peromyscus maniculatus* will follow the same pattern and consume faster and more in an area where the food is clumped. Cynthia E. Rebar analyzed learning behaviors of two mice species, the kangaroo rat and the pocket mouse. Her hypothesis that wide-ranging kangaroo rats use past experiences while foraging, while pocket mice inhabiting the same environment do not, was evidentially supported (Rebar 1995). Rebars study insinuates not only that some mice have the ability to learn, but, because I believe that mice will have had prior experience with a clumped pattern in their natural environment, that mice participating in that treatment will adopt to it better which would lead to a faster consumption rate. Through my experiment, I seek to understand how natural seed dispersal patterns affect foraging behavior. My hypotheses is as follows; when *Peromyscus maniculatus* are presented with three resource patch types: clumped, uniform, and random, the consumption rate in the clumped patches will be the fastest because clumped resource patches resemble what is found in nature.

Methods:

For this experiment, the materials that are needed will be broken up into three categories*; field equipment, lab equipment, and statistical analysis*.

Field equipment: All mice will be trapped on UNDERC Property which comprises approximately 3035 hectares on the border between Wisconsin and the Upper Peninsula of Michigan (46° 13' N, 89° 32' W). We will utilize Sherman traps (7.62 x 8.89 x 22.86 cm; H. B. Sherman Traps, Inc., Tallahassee FL) The traps will be spaced out grids with 25 traps per grid spaced at 15m each. Each of the traps will be baited with rolled oats and black oil sunflower seeds. Upon initial capture, all animals were identified as *Peromyscus maniculatus* (based on ear length; Kurta 1995), sexed, weighed, measured and individually marked with ear tags (monel 1; National Band and Tag Co., Newport, KY).

Lab Equipment: The protocol for the experiment is as follows. In the lab, a 91 gallon cattle tank that has a depth of 58cm and a 251.33cm circumference to hold the mice will be required. To analyze foraging behavior of *Peromyscus maniculatus* we will be burying raw shelled sunflower seeds in sand based on a circular grid with 19 points where each point is 15cm apart as shown in Figure 1. The three pattern types are random, uniform and clumped. For each foraging pattern 38 seeds will be used. In the uniform pattern, two seeds will be used at each point. In the random pattern a random number generator will be used to determine if 0, 1, 2 or 3 seeds will be in each point. For the clumped pattern, I used eight points in two sets of four. Each group of four will

contain 19 seeds, three points will get 5 seeds and the fourth will get 4 seeds. The points that get four seeds are determined by a random number generator. I will use sand and will normalize the sunflower seeds. We will also use infrared lights and cameras to record mice foraging behavior. We will be recording between 10pm-2am, 30min per trial period (Tosa 2010 unpublished). Before each trial, all seeds will be weighed, by point, and their weights recorded. After each trial the seeds will be collected and weighed. Any weight gain by the seeds will be attributed to measuring error and it will be assumed that the mouse consumed nothing. Weight lost will be calculated by subtracting the starting weight from the finishing weight. To analyze the mouse foraging behavior I record the amount of time mice forage (foraging defined as stopping and eating) and divide total seed weight consumed (g) by total Units seeds consumed per time will be my determined foraging rate.
Statistical Analysis: For the statistical analysis a one-way ANOVA will be utilized to compare the differences between my three treatments in regards to total weight consumed, total foraging time, and consumption rate. We have both a dependent variable (# seeds/unit time) and an independent variable for each experiment (patch type and prior experience). The ANOVA assumes independence and true randomization of data collection which is why it is the best test for this experiment. To verify that my data has a normal and independent distribution I will use the Shapiro-Wilk normality test. For all statistical analysis I will be using R-software (Gentlemen and Ihaka, Statistics Department of the University of Auckland).

Results:
I collected the data of three different treatments for three categories. They were the total amount of food consumed in grams, the total amount of time spent foraging, and the consumption rate in g/s. I took the means for each of the three treatments in these categories. For food consumption, the mean amount of food consumed in the Clumped treatment was 0.8192 g, for Uniform it was 0.7628 g, and for Random it was 0.7222 g. The means for the total time spent foraging are as follows; For Clumped it was 410.8 s, for Uniform it was 353.3 s, and for Random it was 298.9 s. Lastly for consumption rate the means were 0.004 for Clumped, 0.002878 for Uniform, and 0.002847 for Random.

For my experiment I ran three ANOVAs on the total amount of food consumed in grams, the total amount of time spent foraging, and the consumption rate in g/s. The results for the Shapiro-Wilk normality test, using $p<0.05$ to determine significance, were; p= 0.338, 0.06117, and 0.8803 respectively. The consumption rate data had to be normalized using a logarithmic method, There were no significant differences found in any of my analyses again using $p<0.05$. For all of the ANOVAs the degrees of freedom (df) were (2,27). For the total weight consumption the F value was 0.179 and the p value 0.837. For total amount of time spent foraging the F value was 0.498 and the p value 0.613. For the consumption rate the F value was 0.114 and the p value was 0.893.

Discussion:

The purpose of this study is to explore the foraging behaviors of *Peromyscus maniculatus* (forest deer mice) in response to experimentally controlled patch types. Macarthur and Eric (1966) described optimal foraging theory as the continued foraging of an animal so long as the benefits outweigh the costs. Specifically in relation to my experiment, each of my treatments has different search time associated with it, as well as different rewards in each spot so optimal foraging theory will act differently in each case. Coupling their principles with the suggested natural occurrence of clumped distributions of seeds observed in the U.S. North Woods where this study occurred (UNDERC), I hypothesized that if I gave mice a clumped, random, and uniform treatment that they would consume seeds significantly faster in the clumped distribution than in evenly distributed patches, and consume seeds at the slowest rate in patches where seeds were randomly distributed. While my hypothesis was unsupported by my results, graphs of the means for consumption rate, foraging time, and weight consumed (Figures 2, 3, and 4) do show a general trend that mice foraged faster and more in a clumped distribution. Laboratory trials revealed no significant differences in foraging rate, total weight seeds consumed, or total foraging time across the three patch types. Therefore looking into the evolved foraging behaviors of mice is important.

Mice base their foraging decisions on assessments of resource quality in a given patch. A study conducted by Jones *et al. (*2001) explored resource partitioning by two types of desert mice. In the results they found that *A. cahirinus* was a relatively inefficient forager who gave up foraging early when food patches were relatively rich, a "cream skimmer" (sensu Brown et al. 1994, Jones *et al.* 2001). This description of that mouse species certainly matched what I observed in my video. All of the mice that I looked at generally trended toward eating some of the food in the patches and then going to other patches before coming back to the first one and eating more. This idea of going back and forth between patches also could relate to the idea presented in a study by Brown and Mitchell (1989) as well as a similar study by Morris and Davidson (2000); animals that cannot assess resource abundance within a patch, or differences between patches, can nevertheless optimize their foraging if they leave patches after a fixed search-time irrespective of resource density (Brown and Mitchell 1989, Morris and Davidson 2000). Since all of my patches were covered by a thin layer of sand, the mouse could not easily asses the amount of food in the area and had to actively explore to find the food. Therefore to optimally forage, the animal will leave a patch after a set period of time which draws correlations to both my observations and the Jones *et al* (2001) study.

To fully analyze my results it is vital to look carefully at my observations as well as the limitations of a lab experiment. From my observations in regards to foraging time and total weight consumed, it seemed that the mice, on average, spent the same amount of time per seed. Therefore mice who found larger clumps of seeds, as found in the clumped distributions, ate more seeds, which raised both overall foraging time and total weight consumed. The main difference between the three treatments would then become the search time required for each treatment. A point to consider when analyzing my experiment was that my sample size could have been bigger helping to lend more credence to my experiment. Then the main limitation of any lab experiment is that it does not accurately represent that which occurs in nature. While this can be useful to look at specific behaviors, when the experiment goes in a different direction than originally thought, natural processes that the experiment doesn't cover need to be looked over for answers.

Generalist foragers as well as different distribution patterns of food sources is an important consideration when looking at mice. *Peromyscus* sp. eat many different types of food including seeds, fruits, and arthropods (Rose *et al* 2014, Reid *et al* 2013). Mice are generalist feeders with an added genetic advantage due to "behavioral plasticity brought about by the decoupling of genetics and behavior" (EOL) This plasticity allows them to adapt quickly do different foraging situations which is helpful given the varying distribution of seeds, fruits, and arthropods (Smith and McWilliams 2014, McCreadie and Bedwell 2014). I believe that my study can be a useful branching point to see if *Peromyscus maniculatus* experiences as a generalist feeder could be why it was able to forage with equal efficiency in all three treatments.

Since *Peromyscus maniculatus* are generalist feeders, they may not have shown expected optimal foraging behavior because their food sources and patterns are highly variable. This experiment has given me the opportunity to explore small scale behavior in a lab and to make available information that can help shed light on large scale ecological movements. Some of the considerations which would be interesting to experiment on to see if they have differences in the results would be the amount of time that the mice have in the tank, the size of the tank, and the distance each food patch is from each other. It would be interesting to know if any of these factors would have an effect on the mice. This experiment on mouse foraging behaviors has provided some insightful new information and opened up opportunities for follow-up experiments to shed unique information on the topic.

Acknowledgements:
Many thanks go first and foremost to both Dr. Michael J. Cramer and Lauren Eckert ☺ for helping to guide me in the creation, design and implementation of my project as well as patience in helping set up and trap our grids. I also would like to extend a warm thanks to Marisa McNally and Kaya Moore for help with trapping as well as keeping each other sane as we all went through the processes of mice experiments. Thanks are also due to Gary Belovsvky for the introduction to the UNDERC program, and of course to the extremely generous Bernard J. Hank Family Endowment for funding my stay and research here on the UNDERC property. Lastly, but certainly not least, I would like to thank all of the faculty, staff, and students on property who supported me in my endeavors.

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Figures:

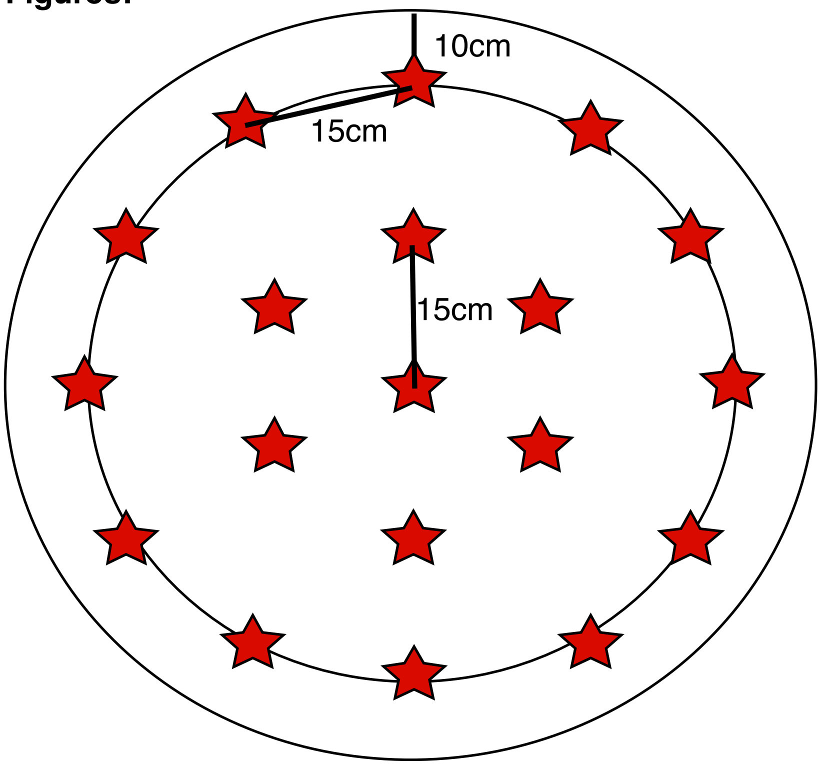

Figure 1: Cattle Tank Set Up This depicts the set up of my cattle tank. The red stars represent where each of the 19 food points went. Each food point is 10cm away from the edge of the tank and 15cm away from each other food point.

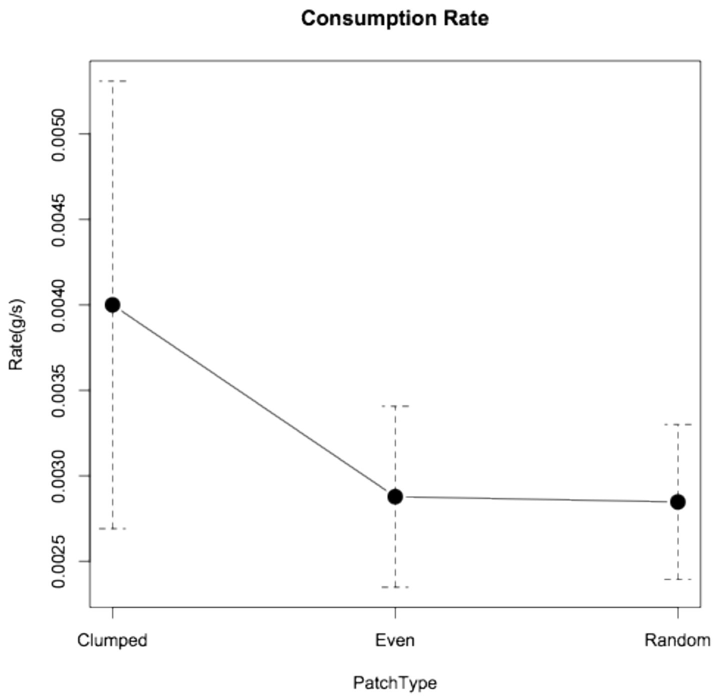

Figure 2: Consumption Rate This graph shows the mean values for each of the three treatments with standard error bars included. Even with no significance, there is a trend showing that mice in the clumped distribution ate faster than those in the Uniform or Random distributions. DF(2,27), F= 0.114, p= 0.893

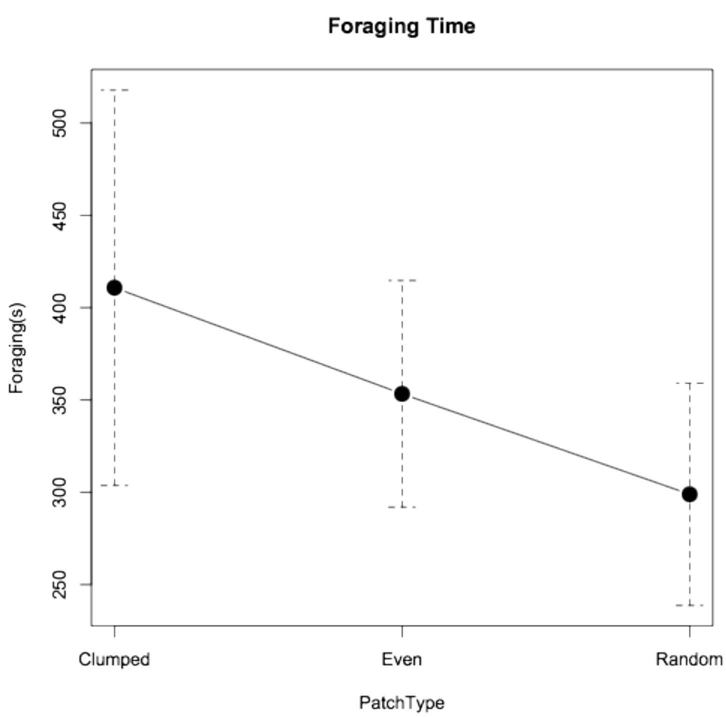

Figure 3: Foraging Time This graph depicts the mean values of total foraging time for the three treatments with standard error bars included. Though no significance was

found, there is a definite trend showing that mice foraged the most in the Clumped distribution then in the Uniform distribution, and lastly in the Random distribution. DF(2,27), F= 0.498, p= 0.613

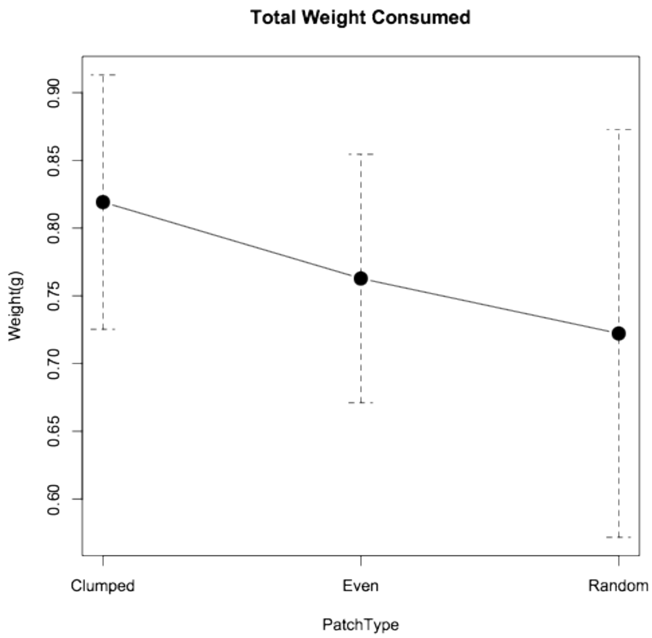

Figure 4: Total Weight Consumed This graph shows the mean value of weight consumed for each of the three treatments with standard error bars. While the Clumped distribution had on average the most weight consumed, the Random distribution had the most variety of weight consumed which could imply that some mice found the larger clumps of food first and others found the smaller clumps of food first. DF(2,27), F= 0.179, p= 0.893