# TO EAT OR NOT TO EAT? FOOD DEPRIVATION EFFECTS ON WOODLAND DEER MICE (*PEROMYSCUS MANICULATUS GRACILIS*) FORAGING BEHAVIOR

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Abstract:

The main purpose of this study was to see the response to starvation of the woodland deer mouse (*Peromyscus maniculatus gracilis*). Mice were deprived of food for up to 7 hours in order to see if their foraging decisions change depending on their hunger state. After data collection and statistical analysis, a definite change or response could not be clearly established. We used different variables, like mice length and weight, as possible factors that could determine their food consumption patterns. The results showed that their hunger state barely affected their decisions concerning food preference, since they still chose red maple (*Acer rubrum*) over sugar maple (*Acer saccharum*). This could mean that their food searching behavior implies foraging for long periods of time, which makes my experiment an unusual situation for the mice.

Keywords: Woodland deer mouse, *Acer saccharum*, sugar maple, *Peromyscus maniculatus*, red maple, hunger state, starvation, foraging decisions.

Introduction:

Seeds are an important food resource for many rodents, but the decision to consume or cache seeds when they are encountered can be influenced by numerous factors such as their abundance, nutritional value, and plant secondary compounds (PSC) (Lobo, 2013). For woodland deer mice (*Peromyscus maniculatus gracilis*) these decisions are a daily occurrence. These rodents are mainly granivores, but won't hesitate to supplement their diet. Similar to its relatives, like white-footed mice (*Peromyscus leucopus noveboracensis),* mice choose their nesting sites based on food availability and abundance. This gives the mice a certain assurance that their hunger could be rapidly satiated within a short period of foraging. Being found in the north woods, this species is faced with a habitat dominated by a single tree species (maples, genus *Acer*). The seeds these trees, both sugar maple (*Acer saccharum*) and red maple (*Acer rubrum*), produce are main food source for the *P. maniculatus.*

In ecological studies it has usually has been assumed that an organism's energy acquisition is restricted by various environmental factors, such as the availability of food (Koteja, 1996). On sites where a specific food type is more abundant than others, the assumption of instant preference may seem more accurate. For mice, survival depends on how fast they find food and how well they anticipate the availability of specific food items. If the mouse consumes all the food resources without caching, chances of high starvation and desperation can occur. This is combined with how well adapted they are to dodge attacks from predators. Within these pressures for daily survival, being a food specialist can be either advantageous or disadvantageous. If the mouse is in a current high starvation state, desperate measures for finding food could be made, leading to more risky behavior.

*P. maniculatus* is a food generalist, meaning it can consume food from various sources. However, this species is granivorouse, and even if they can consume many types of food, their preferred food source are seeds. A small mammal decides to eat or store a seed by comparing the seed's present value with the seed's future value (Hsia and Francl, 2099). Foraging rodents calculate the value of a food item with constant consumption and comparison with other seed types they may encounter on foraging journeys. One factor to consider is the seed's nutritional value and efficiency in providing a longer satiation period. Also the value is given by the amount of energy required to achieve it. If the mouse consumes a great portion of low nutritional value seeds, it wastes energy, thus needing more food to recover energetic reserves. The rate and efficiency at which animals are able to acquire, process, and allocate energy are important factors influencing individuals' chances of survival and reproductive success (Calow and Towsend, 1981; Karasov, 1986; Watt, 1986; Towsend,1987). Food is not always available, but caching spares them from facing starvation when natural conditions may impede foraging. This instinctive action suggests that mice are adapted to rapidly respond to hunger.

*P. maniculatus* of the north woods are living in an environment primarily dominated by *A. saccharum* over *A. rubrum*. *A. saccharum* produces seeds that are nearly five times larger in size than those of *A. rubrum*, which may make them more desirable to seed predators (Moles et al. 2003). Because larger seeds contain more energy, and a longer dissemination period means that seeds are exposed to mice over a greater portion of the year (Cramer,2014). Yet, the *P. maniculatus* would eat more red maple (*A. rubrum*) seeds due to their energy content and hunger satiation efficiency. But, does their hunger state interfere with this natural preference? This experiment will test if there is a difference in seed consumption and foraging behavior related to hunger state. Three hypotheses were tested. The first one predicted that since *A. saccharum* is more abundant in the trapping environment, mouse feeding preference will be for its seeds. The second hypothesis stated that the hungrier each mice was, its seed preference would change due to energy needs (*A. saccharum* seeds containing more energy). Finally, an assumption was made towards their decisions, that body size would affect the amount of seeds consumed.

Materials and Methods:

## Study Site

This study was conducted on the property of the University of Notre Dame Research Center (UNDERC), located at 46º 13' N and 89º 39' W between the state of Wisconsin and the Upper Peninsula of Michigan. The land is surrounded by lakes and bogs, along with a vast variety of vegetation. The forest is mostly early successional and is categorized as deciduous. Among the maple (genus *Acer*) tree species the sugar maple (*Acer saccharum*) is more predominant than red maple (*Acer rubrum*). The mouse traps where located on four different places around property dominated by *A. saccharum.*

## Trap setting

Sherman traps baited with a combination of seeds including black oil sunflower seeds, corn, and millet were used to capture mice. Each trapping site consisted in 25 traps each, placed in sets of five within five rows. The measured distance was 15m apart for each line as for each trap location. All captured mice were individually marked, and the following data were collected for each capture: body mass, body length, and sex. Lactating or pregnant females caught were not used for the trials, so they were immediately released.

## Experiment

After the mice were caught they were taken back to the laboratory. There each individual was housed in separate plastic cages (19cm x 29cm x 12.5cm). All mice were provided with bedding, water ad lib., a plastic igloo-like shelter filled with polyester material, and one food pellet. Each mouse was tested twice on subsequent nights, one at 10:00 pm and the other at 12:00 am. Changing their feeding hours was crucial, that way we could test if the starvation rate would affect their foraging and feeding behavior. In order to starve the mice, the food was removed from its cage at 5:00 pm. During the trial maple seeds (approximately 5g of each maple species) were provided. This amount was used to prevent individual mice from consuming all offered seeds, thus masking actual preferences (Cramer, 2014). The seeds were placed in petri dishes and put inside the cages. The next morning the mouse was moved to another cage to make seed gathering more easy and accurate. After picking the seeds out and sorting them by species, the uneaten seeds where then weighed. The amount of seeds consumed was obtained by subtracting the mass of the uneaten seeds from the initial mass placed in each cage (Cramer, 2014). The difference between each seed type would indicate preference.

Statistical Analysis

For the data collected many tests were performed. First the selectivity index was calculated. That was done dividing the proportion eaten by the proportion available for each seed type. After completing that step the total index was calculated by subtracting the two selectivity indices. This number reflects seed preference among mice. Individuals with value of -2 showed a complete preference for *A. rubrum*, while those with a value approaching 2 preferred *A. saccharum.* Those with a value near 0 showed no preference (Cramer, 2014). A Shapiro-Wilk test verified if our data were normally distributed. Because two trials were conducted on each mouse (whether the mice were less or hungrier), a paired t-test tested the mean selectivity index for each hunger state. Also a Pearson test determined if there was a correlation between body size and total amount eaten. This was done in order to see if the seed consumption was affected by this factors.

All statistical analyses were conducted with SYSTAT version 10.0 (Systat Software, Inc.). All mice were handled and cared for according to the parameters of the Institutional Animal Care and Use Committee (IACUC).

Results:

A total of 21 mice where tested. The number of males was greater due to the season in which they were captured, as most of the females where either pregnant or lactating. The age or length of the mice were not a factor for not using them. Each mouse was tested within a period of two nights (the time allowed was four nights at most). A Shapiro-Wilk test verified the normality of the data. For this test the variables were the weight of the mice and the selectivity index for each hunger state (more and less hungry). The distribution of the data was normal for the selectivity, yet not for the weight variable (weight; W: 0.885, $p < 0.001$; selectivity; W: 0.956, $p = 0.115$). A paired t-test was made to verify selectivity index, and it did not vary based on hunger state (less hungry: 0.083, more hungry: 0.108; $t = -0.705$, $df = 20.000$, $p = 0.475$, Figure 3). A Pearson Correlation test indicated that the length and the amount eaten had no relation (coefficient: -0.030, Figure 1). The Spearman Correlation test also indicated no relation between weight and amount eaten (coefficient: -0.075). Their hunger state didn't affect their behavior towards amount of food eaten, a paired t-test was done to verify it ($t= 0.551$, $df= 20$, $p= 0.587$, Figure 2). No relation was found between their hunger state towards their selectivity of seeds eaten and their hunger state (Figure 4). After running all this test, it was clear that the weight of the mice did not affect the seed consumption, and that there was no statistical significance between mouse length, hunger state, and seed consumption or preference.

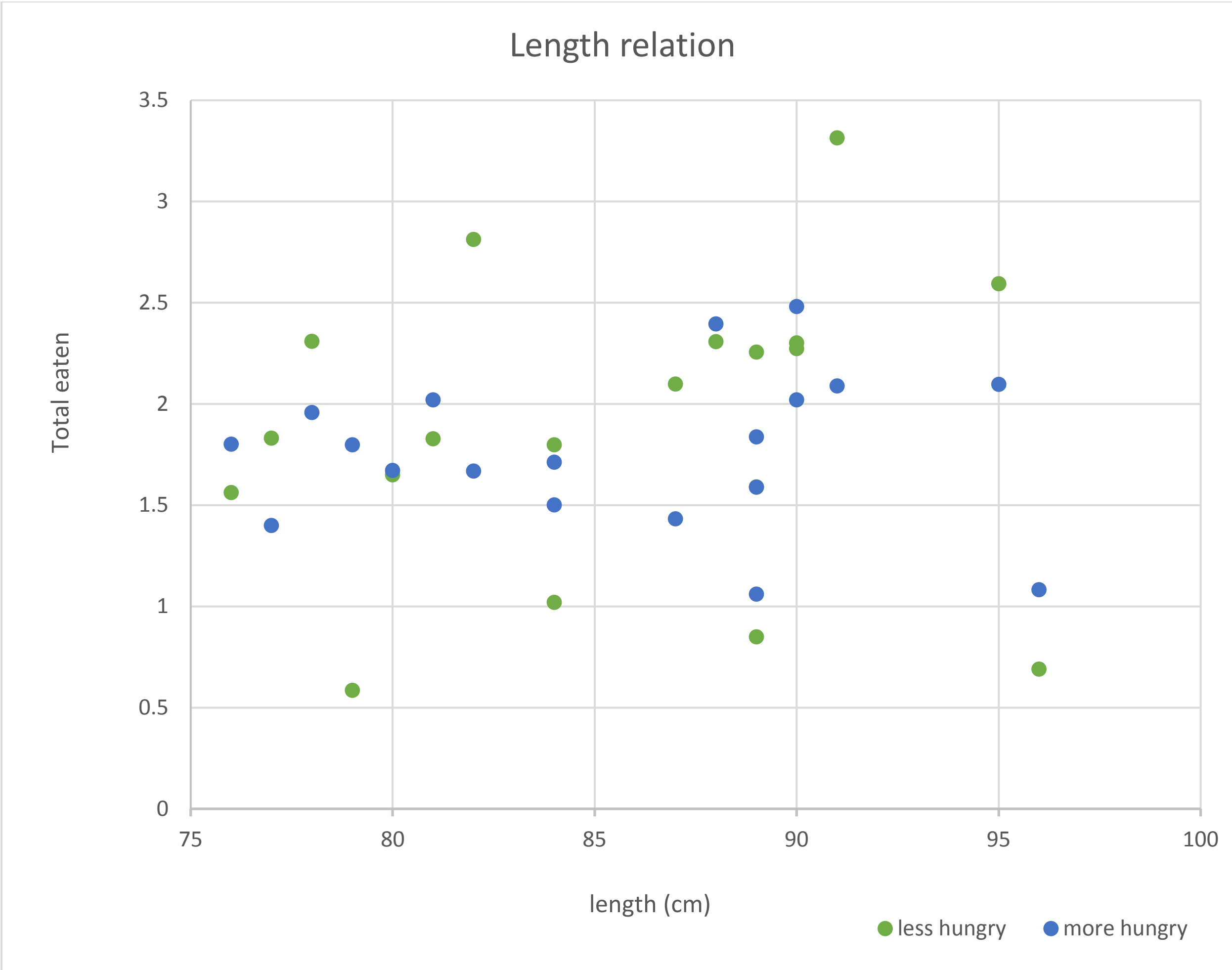


Figure 1) **Comparison between total amount eaten and mice length.** A Pearson Correlation analysis was used to determine the relationship between mouse length and total mass of seeds eaten. Here we can appreciate no relation between their length and feeding (coefficient: -0.030).


Figure 2) **Comparison of mean amounts eaten by mice during feeding trials.** A paired t-test was made to indicate if there was a relation between hunger stage and the total amount they ate. No relation was found (t= 0.551, df= 20, p= 0.587). Error bars represent standard error of mean.

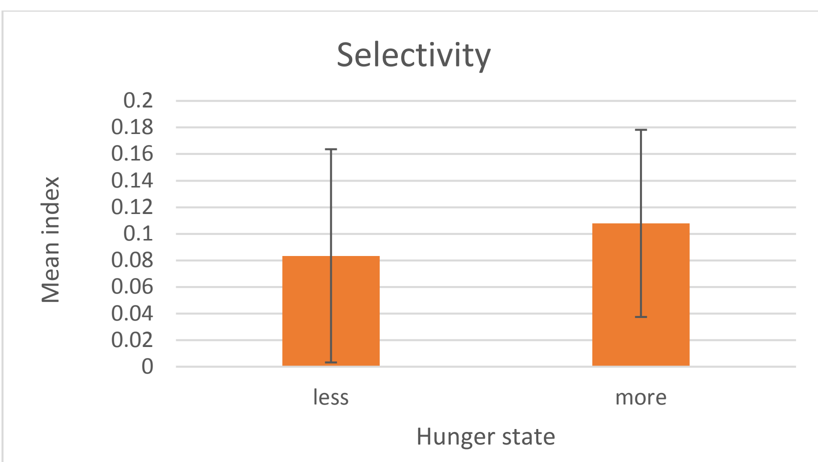


Figure 3) **Comparison of mean selectivity index of amount eaten by mice during trials.** The paired t-test performed shows how the mice's seed preference stays the same regardless of hunger state (t = -0.705, df = 20.000, p = 0.475). Error bars represent standard error of the mean.

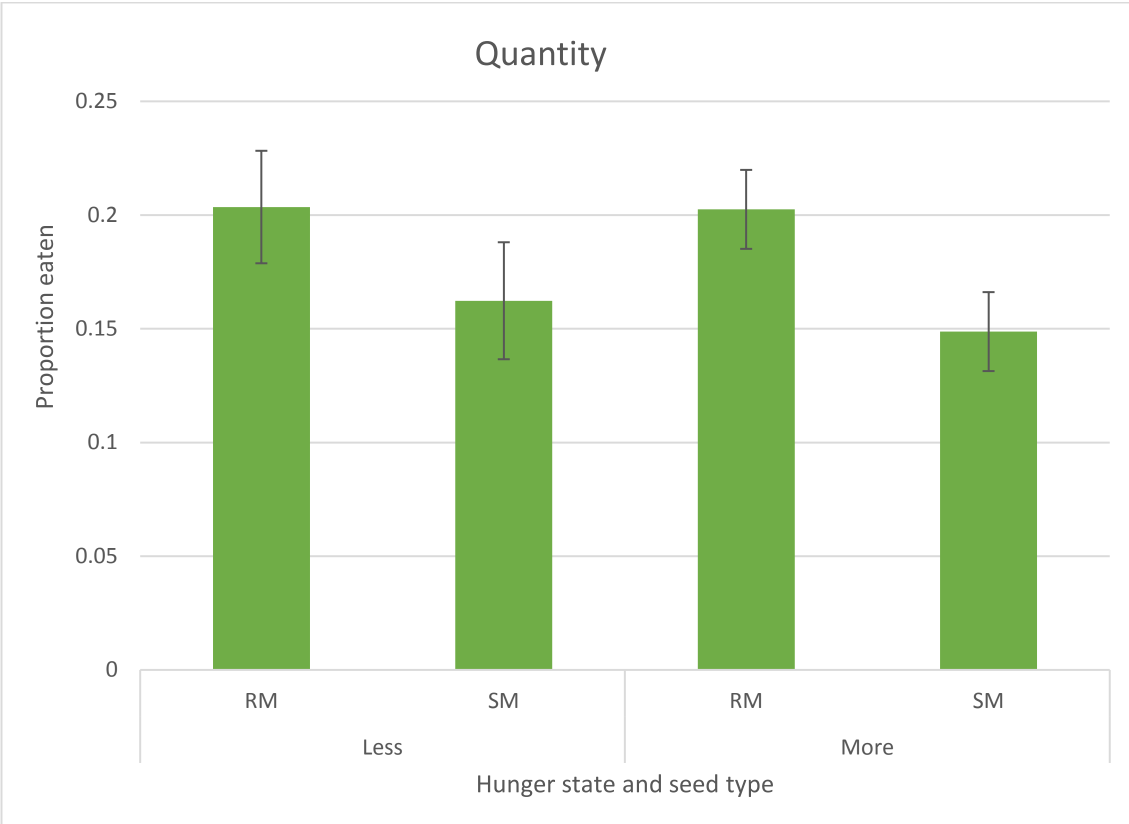


Figure 4) **Proportion eaten of seed types depending hunger state**. This graph shows the results comparing their hunger state and how much of each seed the mice ate. It shows that independent from their hunger state the mice chose red maple (*Acer rubrum*) over sugar maple (*Acer saccharum*) seeds.

Discussion:

After analysis of the data I can say that a relation between hunger states and seed selectivity is not established. Regardless of energy needs, mice still chose the seed with less energetic content. Also there is no relation established between mice length and amount consumed. My prediction expected a change in seed selectivity, but the results showed otherwise. I could not support my hypothesis for this experiment.

My experiment's results may not be statistically significant, but it does provide information about the effects of hunger on mouse foraging decisions. Many reasons can be given that could explain these results. Smaller-bodied mammals have a faster metabolic rate (Vaughan et al. 2000) and thus must eat larger proportions of their body weight, but the absolute amount they eat relative to larger-bodied small mammals may still be less (Hsia and Francl, 2009). Their metabolism is a factor to consider, as it may also be changed or affected by the type of food consumed. Each type of food has an associated average food value and average handling time, both of which are known to the forager (Pyke, 1984). These mice were captured in the forest, which means they forage for foods they are familiar with within their selected territory. In this case mice were predicted to feed on sugar maple (*A. saccharum*) seeds more rather than red maple (*A. rubrum*) seeds. Still, animals sometimes exhibit a variety of foraging models while feeding in the same area on the same food types (Pyke, 1984). Based on this statement I can establish that the thought of the mice consuming what it may appear the logical answer to us is actually not. In this case that thought is that mice don't have a food variety due to the abundance of the same plant species surrounding their homes. But apparently that does not determine the actual preference of the species *P. maniculatus*.

Acquisition of sufficient amounts of food to supply energetic requirements for growth, maintenance, and reproduction is a major limiting factor determining the success of most animal groups (Anderson, 1974). Mice must balance acquisition of resources with avoidance of predators. In order to do this, decisions regarding food search and consumption must be made safely. At high hunger levels familiar stimuli that have reliably resulted in the efficient reduction of hunger control. Behavior to reduce environmental uncertainty is maximal, and at intermediate levels of deprivation the animal should show behaviors that allow a satisfactory reduction of both uncertainty and hunger (Talling et al., 2002). Since mice are nocturnal animals it is hard to determine its actual natural behavior towards the methods it uses to find food when in need for food. Neither its response to hunger nor how the *P. maniculatus* uses its senses to actually determine if whether the seed found will satiate its needs for nutritional value.

An animal's diet may not be constant but may depend on its degree of satiation (Pyke, 1984). If the amount of food available in the forest provides a high satiation rate for the mice, searching for other sources may be a risk the mice may not want to take. However, if the food sources available aren't sufficient to satiate the rodent, diet consistency is not a survival factor. An animal may specialize until it has almost reached satiation and then expand its diet (Pyke,1984). Since the tested mice only had two seed types to choose from, specialization may not have been possible. By the time of satiation, it would have tried both seed types, not giving space for selectivity between them. Other studies (Ebersole and Wilson, 1980) used *Peromyscus leucopus* to test their hunger mechanisms. The tendency of *P. leucopus* to feed less selectively when hungrier may be a mechanism by which this animal increases diet breadth with decreasing food density as predicted by optimal foraging theory. In other words, mice tend to feed with whatever food source they find at the moment in order to get some energy. The use of hunger mechanism should be commonly found only in environments where changes in food density are slow and gradual.

The animal's weight may not be a concerning factor when it comes to food consumption. If the item of consumption has a highly valuable in term of calories and energy storage, the amount needed to satiate the *P. maniculatus*' hunger could be the same for each mouse. A 20g mouse may get the same amount of caloric value by consuming 2 g of red maple (*A. rubrum*), for example, as a 13g mouse consuming 1g of sugar maple (*A. saccharum*). This situation may give us a perception that there is an existing preference, when the case could be seed availability and how the mice use their present value. The present value is the energy that the small mammal can gain by eating the seed immediately. The future value is the small mammal's net energy gain by storing and later eating the seed, after accounting for the energy spent caching the seed and the risk of losing the cache (Hsia and Francl, 2009). Since the *P. maniculatus* were in cages for the trials, and the food was provided at all times, they didn't have to spend their energy trying to look for sufficient food to restore that energy lost. Even if they were starved for five and seven hours, they would have slept through the day hours, as their natural behavior dictates, and when their active time came their hunger wasn't as great as to eat a considerable amount that showed significance in preference.

The different starvation experiments produced a significant negative correlation between fractional hunger category and diet diversity (Ebersole and Wilson, 1980). The actual state of starvation on which the *P. maniculatus* were when tested may be hard to accurately determine. Many factors could be affecting the hunger state of each individual, regardless of the hour it passes without feeding. Age could be one of those factors, but determining it is hard, especially knowing the short life span that the rodents have. Another factor affecting that might have to do with my results could be the mice's response to captivity. Under carefully controlled circumstances, an animal will do as it pleases, and consequently, it is difficult to obtain more than a minimum for information acquisition, storage, and processing (Pyke, 1984). For what I observed, some mice had some particular responses regarding captivity. The majority spend their daily hours sleeping inside their shelters. Though others, the minority, spent most of their time trying to find an escape route, consistently gnawing on the metal parts of the cages, being highly aware of their surroundings. Since these mice could have been hungrier, they might have become less selective with the seeds. The stress that encaging produced and the sudden change of environment are factors to consider when analyzing my data. But since their actual effect is hard to point out now, giving the fact that they were not considered earlier, for future experiments these can be included in the trials.

In conclusion, this experiment did not determine an actual relation between the mice's weight and seed consumption, nor a relation between the hunger state and seed preference. The results also indicated that the mice would rather eat red maple (*A. rubrum*) seeds over sugar maple (*A. saccharum*), even though they differ in abundance on property. Thus, it sparked new interrogatives, how can one determine a mouse's hunger state? If the weight was not a factor for seed consumption, then what is? Working with mice, specifically *Peromyscus maniculatus*, make you more curious about their foraging behavior in actual natural state, and how your results, even though statistically not significant, do mean something in the eyes of science.

Acknowledgments:

I would like to thank Michael J. Cramer for mentoring me and for all his help with wise advises, you rock! To Laura Matthews for helping me out in the field and in the lab as well. Patrick Larson, Hannah Legatzke, Claire Goodfellow, Bethany Hoster, Sam Johnson, Sam Sutton, and Dakota Wagner, thanks for helping me with my research. Sincere thanks to Jose Enrique Fernandez for founding Puerto Rican students for this program, and to the Bernard J. Hank Family Endowment, you make all this experience possible.

References:

Anderson, J. F. 1974. Responses to Starvation in the Spiders Lycosa Lenta Hentz and Filistata Hibernalis (Hentz). Ecology. 55:576- 585.

Cramer, M. J. 2014. Seeds of Doubt: Feeding preferences of White-footed Deer Mice (*Peromyscus leucopus noveoboracensis*) and Woodland Deer Mice (*Peromyscus maniculatus gracilis*) on Maple (Genus Acer) Seeds. Canadian Journal of Zoology. 92: 771- 776.

Ebersole, J.P. and J. C. Wilson. 1980. Optimal Foraging: The Responses of *Peromyscus leucopus* to Experimental Changes in Processing Time and Hunger. Oecologia. 46: 80- 85.

Hsia, J. F. and K. E. Francl. 2009. Post dispersal Sugar Maple (*Acer saccahrum*) Seed Predation by Small Mammals in a Northern Hardwood Forest. The American Midland Naturalist. 162: 213- 223.

Koteja, P. 1996. Limits to the Energy Budget in a Rodent, *Peromyscus maniculatus*: The Central Limitation Hypothesis. Physiological Zoology. 69: 981- 993.

Lobo, N., D. J. Green and J. S. Millar. 2013. Effects of Seed Quality and Abundance and the Foraging Behavior of the Deer Mice. Journal of Mammalogy. 94: 1449- 1459.

Moles, A. T., D. I. Warton and M. Westoby. 2003. Do Small- Seeded Species Have Higher Survival Through Seed Predation Than Larger- Seeded Species? Ecology. 84: 3148- 3161.

Pyke, G. H. 1984. Optimal Foraging Theory: A Critical Review. Annual Review of Ecology and Systematics. 15: 523- 575.

Talling, J. C., I. R. Inglis, K. S. Van Driel, J. Young and S, Giles. 2009. Effect of Hunger on Starlings' Preferences for Food Sources Associated with Variability or Uncertainty. Brill. 139: 1223- 1235.

Vaughan, T. A., J. M. Ryan and N. J. Czaplewski. 2000. Mammalogy. Saunders College Publishing, Philadelphia, Pennsylvania. 565 p.