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Risk Behavior of *Peromyscus* spp. in Clear-cut, Saw Timber, and Mature Forest Stands

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Summer of 2012

ABSTRACT

Organisms that are observed to alter their behaviors in the presence of predators are said to be practicing risk behaviors. These behaviors are enacted to reduce the perceivable risk of being attacked when exposed to threats. Reduced foraging is one such behavior. According to the optimum foraging theory, organisms want to spend the least amount of energy as possible to obtain the most of higher quality foods. An organism's behavior may be influenced by the quantity and quality of food present at a foraging patch, the amount of cover available, and other environmental factors that reduce or increase the chance of encountering a potential predator. In my study the foraging cost of predation of *Peromyscus spp*. are compared across three successional forest stages; clear cuts (0-10 years), saw timber (40-80 years) and old growth (80+ years) forests, in attempts to understand how forest management practices impact prey behavior. I hypothesized that clear cuts with the highest percent of ground cover will have lower giving up densities (GUD) than other treatments. *Peromyscus spp.* are an important food source for state-threatened bobcats (*Lynx rufus)* and state-endangered timber rattlesnakes (*Crotalus horridus*) so results may prove useful for management of these species. Five food trays were placed at random intervals along 200 ft transects in the three successional stages with three replications. Each feeding station consisted of a track pad and an aluminum pan filled with 1 l. of sand and 5 g. of millet seed. GUD was found using the weight proportion of grams of millet left to the initial amount at each tray. While GUD varied among stands, saw-aged stands appeared to have had risk behaviors practiced at lower levels than in clear-cuts and mature-aged stands despite having the lowest cover available. Variation in GUD could have been caused by a variety of factors that are difficult to control for including locally more preferable food and local predators.

Keywords: successional stages, forest management, giving up density, risk behaviors, *Peromyscus spp.*, clear cut, saw timber, mature forest

INTRODUCTION

According to optimal foraging theory, organisms attempt to maximize their net energy intake per unit of time by using the least amount of energy to consume the highest quality of food (Pyke et al. 1977). They accomplish this by selecting food patches high in nutrition or density. Organisms will often alter their behavior and seek out a new site at the point where the costs of foraging at a particular food patch outweigh the gains (Brown 1988). This threshold can be found by quantifying foraging cost, or the animals' giving-up density (GUD), at a particular time and site. Morris and Davidson (2000) measured GUD by mixing a predetermined number of millet seeds into a tray of sand. The millet was easily found and consumed initially, but as the cost of foraging increased, seed density in the tray decreased. When the organism abandoned (or "gave-up" on) a tray, the remaining millet seed was divided by the initial amount and the resulting proportion represented the relative foraging cost.

The increased amount of time exposed to predators is an example of a foraging cost. Organisms that travel and feed in groups experience a lower foraging cost than those who are solitary and may not alter their behavior in the presence of predators. Numerous other papers, however, report that solitary consumers will dramatically alter their survival strategies when exposed to predators (Clarke 1983, Jacob and Brown 2000, Kotler et al. 1991, Orrock and Danielson 2004). These actions are called "risk behaviors." *Peromyscus* spp. and other rodents have been found to practice risk behaviors under different scenarios. For example, Morris and Davidson (2000) found rodents to avoid forest edges where there is an increased rate of vertebrate predation. According to Kotler et al. (1991) higher foraging rates occurred in microhabitats with high vegetation cover and lower levels of avian predation. Just as intriguing, areas near escape routes were found to be more intensely foraged by rodents than those without (Thorson et al. 1998).

Timber production in Ohio employs over 119,000 people and contributes $15 billon to Ohio's economy (Ohio Division of Natural Resources 2006) and large state forests such as the Vinton Furnace Experimental State Forest in southeastern Ohio help supply timber. Harvest practices can have dramatic effects on cover and food availability for small mammals and understanding how these actions impact rodent behavior can help improve trapping techniques for future research projects involving these organisms. Furthermore, rodents like deer mice (*Peromyscus maniculatus*) and white-footed mice (*Peromyscus leucopus*) are commonly consumed not only by many predatory birds, snakes, and large mammals, but also by the state-threatened bobcat (*Lynx rufus;* Nussbaum and Maser 1940) and the state-endangered timber rattlesnake (*Crotalus horridus*; Martin and Means 2000). There needs to be a thorough understanding of how harvesting practices impact prey availability for these species. The objective of this research project is to determine the GUD of prey species as a measurement of risk behavior in three forest successional stages: clear-cut, saw timber, and mature forests.

MATERIALS & METHODS

Study Sites

Research was conducted at the Vinton Furnace State Experimental Forest in Vinton County, OH. This section of state-owned land has been a valuable source of information for numerous scholarly articles and is one of the largest spans of forest left in the state. Both deer mice (*Peromyscus maniculatus*) and white-footed mice (*Peromyscus leucopus*) are found in the area, as well as predators including the coyote (*Canis latrans*), bobcat (*Lynx rufus),* red fox (*Vulpes vulpes*) and gray fox (*Urocyon cinereoargenteus*).

Study sites within this forest were selected by age-class and include clear-cut stands (1-10 years), saw timber stands (40-79 years), and mature stands (80+ years). Three replicates were examined for each age class for a total of 9 study sites.

Feeding Stations

GUD was calculated by use of aluminum trays (9”x13”x2”) containing 5 grams of millet seed mixed into 1 liter of commercially available sand. According to trials ran by Jacob & Brown (2000) millet seeds returned reasonable GUDs, whereas other seeds such as pumpkin or sunflower seeds had abnormally low GUDs. This is likely because these seeds were perceived as a high quality food item worth the risks of being completely foraged in most any environmental condition they tested.

Each tray was placed at 15.2 meter intervals along a 122 meter transect located in the approximate middle of each stand. Each feeding tray was placed on a 2x2-foot sheet of plastic covered in agricultural limestone. The fine powder served as a track pad to ascertain the identification of small mammal visitors. Based on preliminary trapping in the area, each of the selected sites experience similar densities of *Peromyscus* spp. which were relatively more abundant than other small mammals detected during the surveys. To further confirm the identification of visitors to these trays, a motion-detecting camera was placed at the middle feeding station in each transect. Bait stations, track pads, and cameras were set 3 days prior to data collection to allow time for the local wildlife to become accustomed to their presence. The experiment ran for 4 days at each transect with bait station maintenance occurring in the evenings and data collection taking place in the mornings. Agricultural limestone was reapplied as needed. Data collection involved using a sieve to separate millet seed from sand so to determine proportions of millet seeds remaining in the trays.

Vulnerability Measurements

Because GUD is associated with risk behaviors, other factors involving prey cover within the immediate area of each bait station were noted. Both *Peromyscus leucopus* and *Peromyscus maniculatus* use arboreal and ground cavities as refuges (Wolff and Hurlbutt 1982), so distance to the nearest tree with a diameter at breast height (DBH) of at least 12.7 cm was measured and all ground cavities within a 91.44 cm radius with a diameter of at least 2.54 cm were counted. I observed that recently harvested forests can result in high quantities of woody debris which can serve as cover for *Peromyscus* spp. as noted by Manning & Edge (2008). To measure the usefulness of this debris as cover—notably at clear-cuts—the depth of the debris above solid ground was measured. The robel pole method (Robel et al. 1970) was used to quantify vegetation cover as its density could affect the location of *Peromyscus* spp. according to multiple sources (Vickery 1981, Yahner 1982,) and the study species has been found to forage more beneath vegetative cover than exposed areas (Orrock et. al. 2004, Wolfe & Summerlin 1989). Lastly, where *Peromyscus* spp. have been found to exhibit risk behaviors, some weather conditions are thought to be correlated with GUD. Orrock & Danielson (2004) found GUDs to increase as the moon phase approached full and decrease on nights with precipitation. Furthermore, in a study of predator-prey interactions with short-eared owls (*Asio flammeus*) and deer mice, Clarke (1983) found that *Peromyscus* spp. movement decreased as replicated moonlight increased. Therefore, my study also monitored moon phase, precipitation, temperature, and cloud cover for the duration of the experiment.

Statistics

All data were entered in to Microsoft Excel and statistical analyses were completed using R (R Development Core Team 2012) with package lme4 (Bates et al. 2012). Measurements at each flag were averaged within the sites and linear effects mixed models were used to test GUD (with flag within each site as a random effect) with different effects including nearest tree distance, nearest woody debris, debris depth, % cover, moon phase, and prior-determined combinations of the aforementioned. Models followed a hierarchical design and were compared using an ANOVA. Tukey multiple comparisons of means were used to test successional stage as an effect of GUD and again for successional stage as an effect of mean cover.

RESULTS

GUDs for each treatment varied among successional stages. Saw-aged forests had lower GUDs than clear-cuts and mature forest stands (Tukey's test, $P < 0.05$) (Figure 1.) I found no significant difference in GUD considering percent cover, nearest tree distance, nearest woody debris, and debris depth. Nor was there any significance was found with moon phase or any weather measurements. Percent cover offered by vegetation was found to be significant across different successional stages ($p<.0001$) where percent cover was found significantly higher in clear-cut stands than in saw-aged or mature forest stands (Tukey's test, $p < 0.05$) (Figure 2).

DISCUSSION

Results indicated GUDs being higher than expected in clear-cut stands which suggested that mice foraged less in those areas (Figure 1). There was more foraging occurring in saw-aged forests than in either clear cuts or mature successional stage forests. This does not support previous research where GUD has been linked to cover (Orrick and Danielson 2004). Clear-cuts had more cover than saw- or mature-aged forests and furthermore saw-aged forests had the lowest cover measurements of all.

There are several explanations for the inflated GUDs of clear-cut sites. First, the study was conducted in mid- to late-summer when blackberries were fruiting. A majority of the clear-cut sites had abundant blackberries. Increased food abundance decreases the costs associated with travel time allowing *Peromyscus* spp. to be more selective. The naturally occurring food patches may have supplied more favorable food items than the artificial food patches.

Furthermore, predator presence could have raised GUD values in clear-cut and mature forests. Coyotes, bobcats, & eastern screech owls (*Megascops asio*) frequent the clear-cut areas. Additionally, barred owls (*Strix varia*) are a major predator of deer mice and prefer mature forest habitats because of the increased likelihood of finding nesting cavities among the older stems. Therefore, mice in these mature forests may perceive greater risk than in younger stands. To add to this risk, there were first-hand observations of rattlesnakes occurring at and around mature forest stands during the time of this study.

Brown (1988) found that GUD consistently differed in response to the species being studied, microhabitat, date, & station. Knowing that, and based on the findings of my study I concluded that while *Peromyscus* spp. behavior does vary with forest successional stage in southeastern Ohio, these changes cannot be attributed to cover alone.

Future Work

Additional research done on this topic would benefit by isolating variables that affect rodent behavior by using a grid design. By having the trays in close proximity, one would ensure they are accessible by the same individuals affected by the same predators. This would reduce error caused by variation among different sites' food patches and exposure to predators. Research would also benefit from a long-term approach where each season is investigated. While there were many foraging patches in late summer, *Peromyscus* spp. will behave differently in the winter and spring months when food is scarcer.

FIGURES

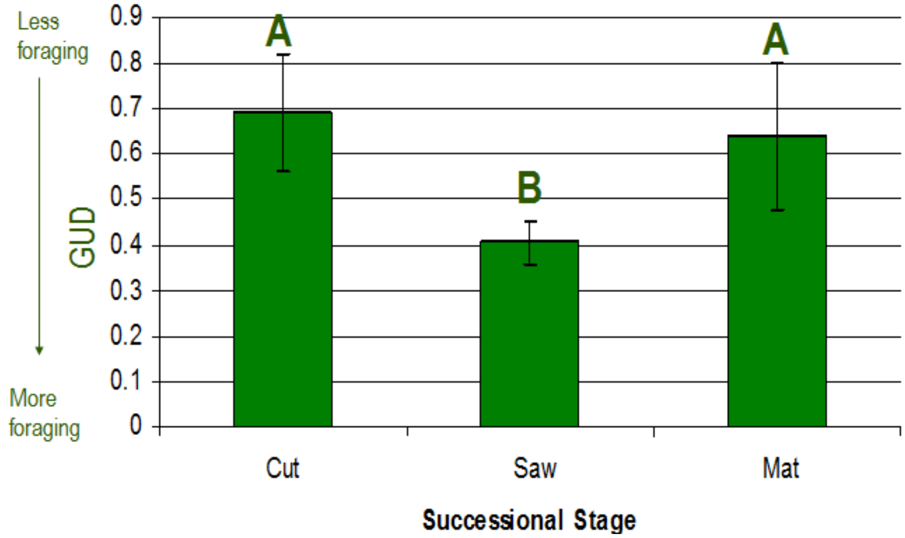

Figure 1. Comparison of giving-up densities in each treatment/successional stage. Means with the same letter do not differ (Tukey's test, p<0.05)

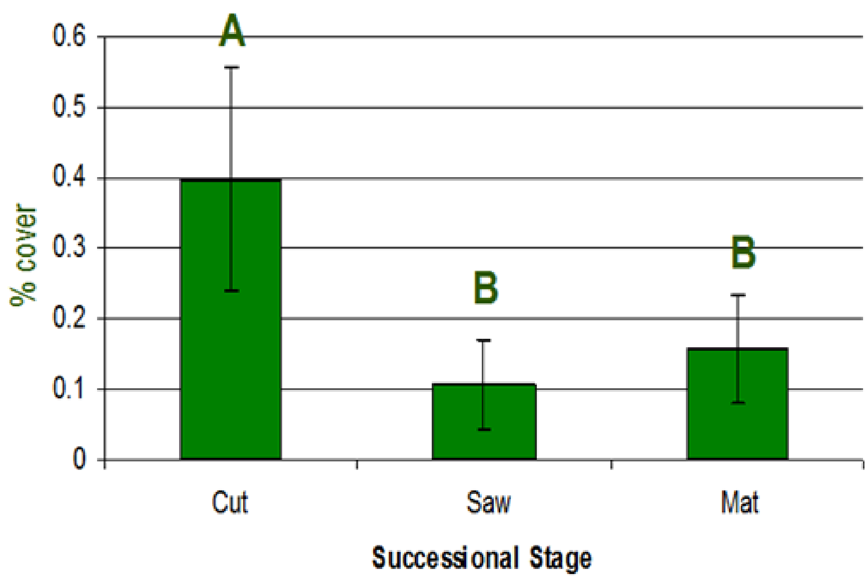

Figure 2. Comparison of percent cover in each treatment/successional stage. Means with the same letter do not differ (Tukey's test, p< 0.05)

AKNOWLEGEMENTS

I would like to thank Dr. Suzie Prange for all of her guidance and time spent helping me in the planning and carrying out of my methods and for the knowledge she shared with me over the summer. I would also like to thank the District 4 “Peromyscus Crew” for their company in the field and for help in learning small mammal identification techniques and handling, and the faculty involved with OSU’s Terrestrial Wildlife Ecology Lab (TWEL) for the opportunity to become involved in the field of wildlife management and research first-hand. Lastly, I would like to thank Dr. Robert Gates for all of his tireless support and help with statistical programs used for, and in the revisions of this project.

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