The Effects of Simulated Competition on Foraging Behavior in *Sciurus carolinensis*

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Introduction

Ecological communities are often shaped by competition between individuals for a shared limited resource (Rohde 2011). Competition may be between individuals of the same species (intraspecific competition) or between individuals of different species (interspecific competition). In forest communities, squirrels and other rodents rely on the same food sources and are still able to coexist. Gray squirrels (*Sciurus carolinensis*) have been known to strategically forage in order to maximize energy intake and minimize exposure to predators (Lima et al., 1985). However, it is unclear if *S. carolinensis* take into account competitors when calculating optimal foraging levels.

Sciurus carolinensis are generally not aggressive towards each other, with the exception being during autumn, in order to deter immigrants from invading (Koprowski, 1994). Otherwise, territoriality is uncommon, and often home ranges overlap (Lewis, 1980). Therefore, *S. carolinensis* are typically expected to compete exploitatively and not through direct interference. There is also evidence that a social hierarchy within species can be constructed based on body size, which discourages overt aggression (Gurnell, 2004). Nonetheless, the influence of competitors on the foraging habits of *S. carolinensis* is not fully understood.

Initially, two preliminary studies were conducted in order to assess the feeding habits of local squirrels. These data, although insignificant, was used in order to design an experiment to evaluate the effects of competition on the foraging habits of *S. carolinensis*. Because *S. carolinensis* are not known to be offensive, we hypothesize that these squirrels will be more likely to forage from a vacant food source than a food source with competitors present. Our goal is to better understand the dynamics of competition in a population of *S. carolinensis*.

Methods

Intraspecific and interspecific competition between squirrels and chipmunks were studied at the Forest Park Beach in Lake Forest, Illinois. Data were collected during two-hour intervals anytime between 12:00 P.M. and 4:00 P.M. during October and November 2012. The temperature ranged from 0° to 15° C.

Preliminary Study 1
Two 58 by 29 by 6 cm trays filled partially with sand were placed next to trees about 20 m apart from each other. In each tray, 50.0 g of 'critter mix' were left lying on the surface of the sand. Behind one of the trays, a 30 by 100 cm mirror was placed perpendicular to the ground. The other tray was left as a control. For the entire duration of all trials, the experimenters were present making observations. At the end of each trial, the 'critter mix' was collected from the sand using a sieve. The remaining food was weighed using an analytical balance.

*The authors wrote the paper for Biology 220: Ecology and Evolution.

Preliminary Study 2
Three trays (58 x 29 x 6 cm) filled partially with sand were placed out in the open approximately 20 m away from each other. In each tray 100 unshelled peanuts were evenly dispersed on top of the sand. Behind one of the trays, a small squirrel doll (18 x 14 x 6 cm) was placed standing upright against the tray. Behind another tray, a large squirrel doll (20 x 20 x 9 cm) was positioned in the same fashion. The third tray served as a control. At the end of each trial, the remaining peanuts were collected and counted.

Experimental Design
From what was observed from the two preliminary studies, a final experiment was designed to evaluate the effect of intraspecific and interspecific competition on squirrels' foraging habits.

Three trays (58 x 29 x 6 cm) filled partially with sand were placed about 20 m away from each other in a triangular formation in between trees. In each tray 50.0 g of unshelled peanuts were placed on the surface of the sand. The large squirrel doll was placed behind one of the trays. A chipmunk doll (15 x 12 x 9 cm) was rested up against another tray. The third tray was left alone as a control. At the end of each trial, the remaining peanuts were collected using a sieve and measured on an analytical balance. A total of ten trials were completed. With the exception of trial 2, the trays were left at the testing site without the experimenters present.

In order to measure how competition affected the squirrels' foraging routines, we quantified the giving-up density. Giving-up density (GUD) is the density of peanuts remaining in each tray after a trial. A one-way ANOVA test was run to assess the difference in GUD among all conditions. In addition, a Tukey post-hoc test was conducted to ascertain that the difference between means of GUD for all groups was statistically significant.

Results

We assumed that the GUD would be the same among all conditions if the squirrels' foraging was unaffected by simulated competition. However, the difference in mean GUD between groups (Figure 1), as ascertained by a one-way ANOVA ($F_{2,27} = 13.285$, $p < 0.001$) is statistically significant. Mean GUD is greater in the squirrel condition than in the control (Figure 1; $p = 0.043$). The mean GUD is even greater in the chipmunk condition (Figure 1; $p = 0.038$).

A Tukey post-hoc test comparing the mean of each condition to the mean of every other group showed statistically significant differences in means for all combinations (Table 1; $p < 0.05$).

When the experimenters stayed and observed the trial, most of the food was left untouched in all trays (trial 2). Additionally, the control group was the only condition that ever had a 0.00 g GUD in any of the trials.

Discussion

As expected, *S. carolinensis* was found to forage more from the trays that lacked competitors over the trays with simulated competitors. This finding supports our original hypothesis. However, we did not speculate that there would be a significant difference between the GUD in the squirrel condition and the GUD in the chipmunk condition because both animals are considered competitors. These results suggest that interspecific competition presents a stronger pressure on foraging behavior than intraspecific competition. It is possible that the presence of the chipmunk doll decreases the value of the food source more so than the squirrel doll. Following Optimal Foraging Theory (OFT), it is expected that the squirrels would forage more from the food source that has the highest value with regards to visible competitors (Lewis, 1982). It is also important to note that the squirrel doll was present in one of the preliminary observational studies, but the chipmunk doll was not. Therefore, the local squirrels may have acclimated to the foreign squirrel doll. Accordingly, the squirrels were then more likely to approach the squirrel doll than the chipmunk doll because they had learned that the squirrel doll was harmless (Lewis, 1980).

Squirrels were more likely to avoid any competition and forage at the vacant food source. In addition, for all of the trials, the squirrel and chipmunk dolls were left undisturbed. These findings support the suggestion that squirrels compete exploitatively and not through direct interference. Furthermore, the results from trial two, where most of the food was left untouched, imply that human presence negatively affects the value of a food patch. This concurs with the pattern observed in the first preliminary study where food was left mostly untouched for most of the trials while experimenters were present. Within forest communities, the pressure present due to interspecific and intraspecific competition affects the value of each food patch. Due to these varying values, the inhabitants of this community prefer to deplete the patch with the highest value to them first (Lewis, 1980). In the case of *S. carolinensis*, the presence of other squirrels, chipmunks, and even humans negatively affects the value of each patch, and thus shapes the foraging distribution by squirrels in the area.

The results of this study imply that many factors influence the optimal foraging strategies of *S. carolinensis*. Future research should be conducted to assess the extent to which human presence affects squirrel foraging. In addition, making the squirrel and chipmunk dolls more realistic could further improve this current study. Squirrels are known to have an exceptional sense of smell (Stapanian & Smith, 1984). Therefore, if the dolls smelled like actual animals, the results of this study may be altered. Furthermore, the experiment should be conducted at other testing sites and at different times of year in order to distinguish if our results can be extended to other populations. Understanding what other factors have an effect on the value of a food patch can help generate a better understanding of the species composition and distribution within a forest community.

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Appendix

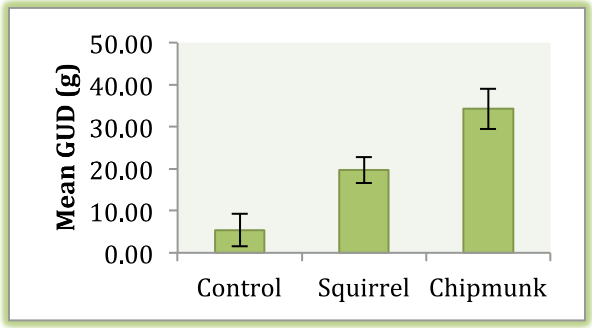

Figure 1. Column graph illustrating the mean GUD in grams for all three conditions.

Table 1. Tukey post-hoc test showing statistically significant differences in the means of each group to every other group.

Multiple Comparisons - Post-hoc Test

Dependent Variable: GUD (g)

(I) Group		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Control	Squirrel	-14.34500*	5.61673	.043	-28.2712	-.4188
	Chipmunk	-28.95200*	5.61673	.000	-42.8782	-15.0258
Squirrel	Control	14.34500*	5.61673	.043	.4188	28.2712
	Chipmunk	-14.60700*	5.61673	.038	-28.5332	-.6808
Chipmunk	Control	28.95200*	5.61673	.000	15.0258	42.8782
	Squirrel	14.60700*	5.61673	.038	.6808	28.5332

*. The mean difference is significant at the 0.05 level.