Investigating eastern gray squirrel (*Sciurus carolinensis*) feeding behaviors in open and shaded habitats in the presence of a red fox (*Vulpes vulpes*)

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Eastern gray squirrel (*Sciurus carolinensis*) feeding behavior often varies in different surroundings. Moreover, predation decreases gray squirrel foraging activity and influences the types of areas in which they choose to forage. We examined whether shaded areas help gray squirrels hide from predators, allowing them to eat more food as opposed to being in open areas. Our hypothesis stated that in the presence of predator urine, squirrels will eat more nuts in shaded areas as opposed to open areas. The experiment was conducted in four sites: two shaded and two open. There were two controlled sites (one open and one shaded area without red fox urine) and two experimental sites (one open and one shaded area with red fox urine). Using the Two-way ANOVA with a critical p-value of 0.05, our results show that in the absence of predators, there was no significant difference in number of nuts eaten by squirrels in both open and shaded areas. However in the presence of predators, squirrels ate significantly more nuts in the open area than in the shaded. This suggests that gray squirrel feeding activity is higher in open areas than in shaded areas in the presence of predators. Our hypothesis is therefore rejected.

Keywords: Eastern gray squirrel (*Sciurus carolinensis*), feeding behavior, foraging, habitats, open, predator, red fox, shaded

Eastern gray squirrels (*Sciurus carolinensis*) are found in most of the eastern half of the United States, from eastern Texas to the Atlantic Coast (Skibiel et al. 2002). They can inhabit a wide range of habitats and consume a large variety of food (Skibiel et al. 2002). However, they prefer to live in areas with hardwood trees and primarily feed on hardwood nuts, seeds, fungi, insects, and fruits (Skibiel et al. 2002).

Eastern gray squirrels vary in foraging activity depending on the environments they are in. Studies show that squirrel foraging activity during the winter is higher in the sun than in the shade; yet, their foraging activity is the same in both the sun and the shade during the spring or summer (Kilpatrick, 2003). Predation decreases gray squirrels feeding activity (Brown et al., 1992). Moreover, places where gray squirrels choose to eat and the amounts of food they eat depend on how safe they feel. Hence, the risk of predation can influence the environment in which these squirrels choose to forage (Brown et al. 1992).

In this study, we wanted to test whether a relationship existed between predation and habitat (open vs. shaded), and whether this affects the foraging activity of gray squirrels. We examined whether shaded areas help gray squirrels to hide from predators, allowing them to eat more food as opposed to being in an open area. For this experiment, we hypothesized that in the presence of predator urine, squirrels will eat more nuts in shaded areas as opposed to open areas. Shaded areas were assumed to be areas that were fully covered in the shadows of many trees whereas open areas had no trees in the direct testing area.

This research is important to help determine what type of habitat is beneficial for squirrels. It could also help us determine what type of area is best to examine squirrel-predator interactions. Lastly, our study could further help us explain gray squirrels choices to live in areas full of trees, since trees provide them with a lot of shade.

MATERIALS AND METHODS

The experimental subjects that were used to carry out this research were the eastern gray squirrels, *S. carolinensis*. The experimental equipment that was used for this research consisted of colored flags, red fox (*V. vulpes*) urine, cotton balls, styrofoam plates, GIANT® Lightly Salted Party Peanuts, and latex gloves. The study was conducted in four targeted areas: two of the areas were shaded and two were open. Given the time of day that squirrels are known to forage heavily, the experiment was conducted in the late afternoon between 5pm and 6pm. There were two variable sites and two controlled sites. The two variable and controlled sites each consisted of a shaded and open area. These sites were identically set up with four flags surrounding the area and a plate of nuts placed in the center of the area. In the variable sites red fox urine was used to mimic the presence of a predator. In the controlled sites red fox urine was not used (meaning there was an absence of a predator) as a way to monitor normal foraging behavior.

Additionally, the sites were identified by four colored flags, each 15ft. apart from the other to create a model square. In the center of each plot 40 peanut halves were splayed on a white styrofoam plate. In the variable sites latex gloves were used to place two cotton balls sprayed with red fox urine one foot on either side of the plate.

These steps were repeated over a period of five days; each day we placed the nuts in the selected area and within an hour-long period the number of nuts that were eaten were noted according to each visitation. One visitation by a squirrel was considered to be one trial. This trial was defined as a squirrel entering the marked site and eating the nuts from the plate. The temperature and weather conditions were recorded (Table 1) to make sure that the weather was as near constant as could be for these trials.

To analyze the nut counts a Two-Way ANOVA statistical test was used. This was appropriate because our data was continuous and we observed the possible relationship between predation and habitat type to see how it would affect squirrel foraging behavior. The data was presented in tables, a frequency table and a line graph. A p-value of .05 was used to determine statistical significance.

RESULTS

A total of 53 trials (visitations) were conducted over the five days (Table 2). 28 of those trials were from the open habitat with no predators, 12 were from the shaded habitat with no predators, 8 were from the open habitat with predators, and 5 were from the shaded habitat with predators. Upon implementing a Two-Way ANOVA analysis we found the number of trials per set up, sum of the number of nuts per area, the mean number of nuts per area, the sum of the number of nuts per area squared, variance, standard deviation, and standard error (Table 3). A total of 454 nuts were eaten throughout the trials. 260 nuts were eaten in the two open areas, 194 nuts were eaten in the shaded areas, 343 nuts were eaten in the no predator areas and 111 nuts were eaten in the predator areas. These results were graphically represented in Figure 1. 165 nuts were eaten in the no predator open area with a mean of 5.8929 nuts per trial. 178 nuts were eaten in the no predator shaded area with a mean of 14.8333 nuts per trial. 95 nuts were eaten in the open predator area with a mean of 7.2222 nuts per trial. 16 nuts were eaten in the shaded predator area with a mean of 3.2 nuts per trial. We found p-values for comparison of the habitats, the presence of predators, and habitat x predator presence comparison. The habitat p-value equaled 0.009 which was statistically significant, the predator presence p-value equaled 1 which was not statistically significant, and the habitat x predators p-value was equal to <0.0001 which was

statistically significant.

DISCUSSION

The Eastern gray squirrel, *S. carolinensis*, ate a significantly larger number of nuts in the open area as opposed to the shaded areas (Table 2). However, there was no significant difference in the number of nuts eaten in the presence or absence of predators (Table 2). Once the two variables were combined, the outcome of experiment showed that when no predator scent was present, there was no significant difference in the feeding activity in open or shaded areas (Table 3; Fig. 1). On the other hand, when the predator scent was present, the gray squirrel preferred to feed in the open area rather than the shaded area (Fig. 1). The presence of the predator showed that there was a difference in squirrel feeding activity depending on whether it was in the open or shaded area. These results did not support our hypothesis that in the presence of predator urine the squirrels would eat more nuts in the shaded area as opposed to the open area. The shaded area did not help the squirrels hide from the predators.

We believe that the results may not have supported our hypothesis because the shade may have made it easier for our hypothetical predators to hide and thus sneak up on the squirrels. Being aware of this, the squirrels fed more in open areas because it would be easier for them to detect any approaching predators. Several experimental errors could have affected our results as well. For example, the fact that the predator urine was diluted and kept in the refrigerator may have weakened the strength of the scent. As a result, the squirrels may not have been as deterred from the open area with the predator urine (Table 2). Secondly, since the data shows that predation alone was not significant, it may have just been that the squirrels on campus are not predisposed to reacting to predators because of the lack of predators on campus. Lastly, the presence of birds

may have also affected the results in that when a squirrel started to forage in the shaded area with predator urine, the birds violently attacked the squirrels, which prevented them from even having the opportunity to approach the nuts.

Our methods could be improved by using more concentrated urine in areas tested with the predator presence. We could also have a longer observation time in terms of watching the squirrel's behavior for more hours as well as for a period of time greater than 5 days (perhaps 10 days instead).

Our results appeared to expand on our research findings. Although our data did not quite refute the Kilpatrick (2003) study, it did give a different perspective on feeding behavior of *S. carolinensis*. Unlike Kilpatrick (2003) , our study focused on how feeding behavior changed in open and shaded areas with the presence of predators, which is supplemental to their research. In support of Brown et. al. (1992) our results found predation affects feeding pattern and more specifically *S. carolinensis* prefers to feed in open areas versus shaded areas especially in the presence of predators.

There can be further research to investigate squirrel feeding patterns. A frequent problem with our experiment was avoiding inclement or constantly changing weather. It is of interest to find the effects of weather patterns on how *S. carolinensis* finds food. Also our campus contained mostly domesticated animals that are used to high levels of human traffic and low predation. Further experimentation on feeding pattern in the wild would be done to see if non-domestic conditions change how the *S. carolinensis* respond to predators in the different habitats. Our experiment also used red fox urine instead of other predators that could have been used such as hawks, owls, raccoons, domestic and feral cats, or large snakes. *S. carolinensis* also share the

habitat they live in with other animals so feeding habits may change according to nearby species such as *Aves* and *Rodentia.*

LITERATURE CITED

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TABLES AND FIGURES

Day	Time	Temperature
1	5:07	21°C/sunny
2	5:15	18°C/cloudy
3	5:13	27°C/partly sunny
4	5:21	21°C/sunny
5	5:05	27°C/partly cloudy

Table 1. Temperature, time and weather log over the five trial days.

Trial	Predator	Habitat	Number of Nuts
1	NO	OPEN	4
2	NO	OPEN	5
3	NO	OPEN	5
4	NO	OPEN	8
5	NO	OPEN	6
6	NO	OPEN	7
7	NO	OPEN	4
8	NO	OPEN	5
9	NO	OPEN	8
10	NO	OPEN	7
11	NO	OPEN	6
12	NO	OPEN	6
13	NO	OPEN	4
14	NO	OPEN	5
15	NO	OPEN	4
16	NO	OPEN	7
17	NO	OPEN	6
18	NO	OPEN	5
19	NO	OPEN	4
20	NO	OPEN	8
21	NO	OPEN	6
22	NO	OPEN	7
23	NO	OPEN	5
24	NO	OPEN	4
25	NO	OPEN	6
26	NO	OPEN	8
27	NO	OPEN	6
28	NO	OPEN	9
29	NO	SHADED	7
30	NO	SHADED	21
31	NO	SHADED	12
32	NO	SHADED	40
33	NO	SHADED	5
34	NO	SHADED	19
35	NO	SHADED	6

36	NO	SHADED	17
37	NO	SHADED	11
38	NO	SHADED	23
39	NO	SHADED	5
40	NO	SHADED	12
41	YES	OPEN	18
42	YES	OPEN	7
43	YES	OPEN	11
44	YES	OPEN	5
45	YES	OPEN	13
46	YES	OPEN	17
47	YES	OPEN	9
48	YES	OPEN	15
49	YES	SHADED	3
50	YES	SHADED	2
51	YES	SHADED	4
52	YES	SHADED	5
53	YES	SHADED	2

Table 2. Number of nuts eaten per trial the presence or absence of predators was noted, and whether the habitat was shaded or open habitats.

	No Predator	Predator	Total
Open	28	8	36
	165	95	260
	5.8929	11.875	7.2222
	1031	1283	2314
	2.17	22.13	12.46
	1.47	4.7	3.53
	0.28	1.66	0.59
Shaded	12	5	17
	178	16	194
	14.8333	3.2	11.4118
	3764	58	3822
	102.15	1.7	100.51
	10.11	1.3	10.03
	2.92	0.58	2.43
Total	40	13	53
	343	111	454
	8.575	8.5385	8.566
	4795	1341	6136
	47.53	32.77	43.21
	6.89	5.72	6.57
	1.09	1.59	0.9

Table 3. Two-way ANOVA analysis table. Item 1 = N (number of trials), Item 2 = ΣX (sum of the number of nuts), Item 3 = Mean (number of nuts per trial), Item 4 = ΣX^2, Item 5 = Variance, Item 6 = Std. Dev., and Item 7 = Std. Err.

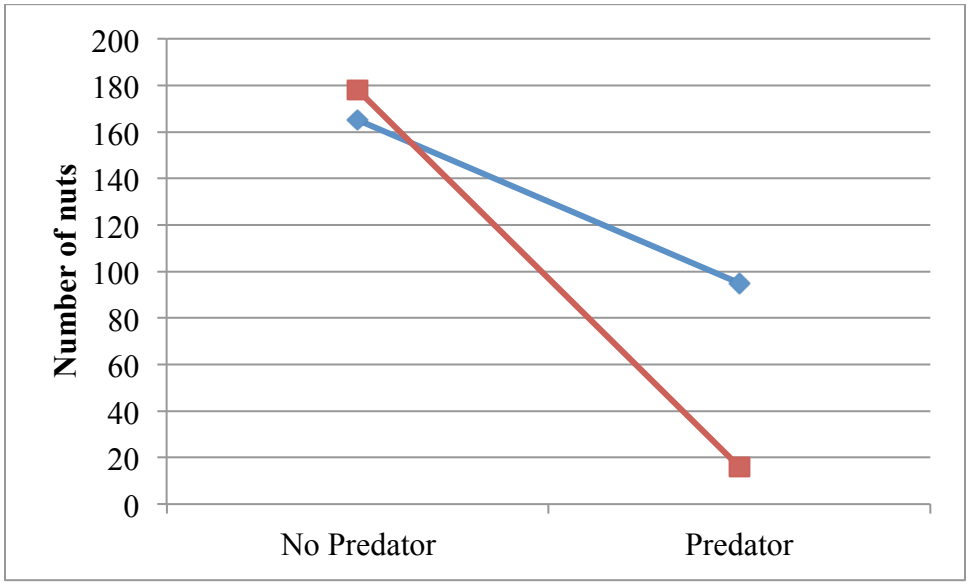

Figure 1. Graph presenting total number of nuts consumed in the two habitats in the presence or absence of predators. The blue line represents open habitats and the red line represents shaded habitats.