Differential levels of human traffic on a university campus and the effects on *Sciurus carolinesis* foraging behavior

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We observed *Scuirus carolinesis* foraging behavior on University of Maryland's campus. Well over 25,000 students, faculty and staff move about the campus daily. Several other studies concluded that squirrels in highly urbanized areas such as this campus have habituated to human presence. This means squirrels did not respond to human presence in the same way they would when encountering other potential predators, such as foxes. We examined the effect of human presence on squirrel foraging in two distinct periods: high and low traffic. Our high traffic period consisted of the time in between classes, 15 minutes before the hour, when there are hundreds of students walking from one class to the other. The time when students are in class was used as our low traffic period. We predicted squirrels would not be affected by high levels of human traffic, as other studies have shown that squirrels tend to adapt to humans as low-risk predators. Our experimental set-up was a heavily travelled pathway. Using sunflower seeds to lure squirrels, we recorded the number of approaches to the seeds, the duration of each foraging session, and what caused them to move away from the seeds, if that were to happen. Our results showed no significant difference between high traffic and low traffic times for duration of foraging or in the number of approaches attempted by squirrels. This allows for further research on what types of human traffic may deter squirrels from foraging and what foods will encourage them to engage in risky behavior.

Keywords: grey squirrel foraging, high traffic, low traffic, predatory response, urbanization

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Humans have increasingly encroached on the habitats of other mammals as urbanization spreads. Thus, interactions between humans and the animals around them have become of interest in several studies. Many studies have been conducted to assess interactions with humans by other mammals, and it has been shown that behavior towards humans is altered to deal with "predation risk" (Beale and Monaghan 2004, Frid and Dill, 2001). In a typical scenario in the wild between a potential predator and prey, animals have a series of options to evade predation. These behavioral responses are what are expected of mammals with constant and frequent interaction with humans, since humans are potential predators. *Scuirus carolinesis*, or eastern grey squirrels, have started displacing red squirrels in many habitats in North America (Mooney and Cleland, 2001) and Europe (Bertolino, 2008). This is due to overlapping niches of both species, with the invasive grey squirrel having a competitive advantage. Because of their rise in population and consequent replacement of another species, it is important to study their behavior in the event of further ecological consequences.

In a study conducted to quantify behavioral responses to human populations, grey squirrels in highly-urbanized areas tended to have lower **G**iving-**U**p **D**ensities (GUD) meaning they valued food more so than the areas with low predation rates and smaller populations of squirrels (Bowers, M. and Breland, B., 1996). In another study, squirrels displayed lower GUDs with food that was smaller in size versus food items that were larger. This was due to the trade-off between the risk of being predated and foraging to gain resources (Lima et al, 1985). Aside from size, how "cacheable" the food was affected squirrel risk behaviors, as well (Van der Merwe, et al. 2007). Additionally, it was concluded that in areas with high human traffic, grey squirrels tend to have lower response distances to human contact compared to a wooded area with low levels of human traffic (Cooper et al, 2008).

In our study, we expanded these ideas by examining the differences in foraging behavior when students are in between classes as opposed to in class. These times are used to measure whether squirrels will respond to high levels of human traffic by foraging less. Therefore, we predict that the differential levels of human activity due to the changing of classes on a highly-urbanized university campus should not have an effect on foraging attempts or duration, because the predation risk is much lower due to adaptation to human interactions.

METHODS AND MATERIALS

To assess the potential effects of differing human activity levels on *S. carolinensis* foraging, we developed a study utilizing the campus at University of Maryland, College Park. We identified the highest traffic area on the campus as McKeldin Mall during the hours of 11:00 am to 1:00 pm. After surveying the mall for areas where squirrels were present, we selected a location close to Symons Hall complete with bushes and trees for our study location. This area covered by vegetation would be more conducive to the scansorial tendencies of the squirrels. The same location was utilized throughout the duration of the study.

15 minute intervals were used to monitor both "low traffic" sessions where most people were in class, and "high traffic" sessions where class changes were occurring. Sunflower seeds were selected for the food source, as they had been used in previous studies (Lima, 1985). The seeds were placed out at 11:15 am for squirrels to investigate prior to data collection. Our periods of data collection are discussed in Table 1.

During time periods when data was collected, the number of attempts the squirrel made to approach the food and duration of the visit was recorded. This design was repeated on Monday, Wednesday, and Friday since most students have 50 minute long classes on these days. These students schedules would most closely conform to the periods of high and low traffic

specified in our study. This design was repeated for five days beginning 4/25/12 and ending 5/4/12. Approaches were recorded as any movement towards the pile of sunflower seeds where food was handled. Foraging duration was then measured from the moment of handling until the approach ended with more than a step away from the seed pile. Duration was recorded to the nearest second.

To assess the data we collected, we utilized a t-test for duration of foraging and a goodness of fit chi-square test for the number of approaches on a given study day. The alpha value used to approximate statistical significance in the GOF chi-square test was 0.05.

RESULTS

In total, ten trial periods were expected, however during 50% of the trials, we failed to observe any squirrel activity. This was, in part, due to extensive on-campus activities which likely affected normal squirrel behavior. This will be addressed in more detail in the following section.

Statistical analysis for number of approaches -- The chi-square goodness of fit test was used to evaluate our hypothesis regarding approach attempt. A confidence interval of 95% was used. Degrees of freedom for both the low traffic and high traffic approach number is 4. The mean average approach number during low traffic (2.6 approaches) was less than the the mean average approach number during high traffic (4.8 approaches). Refer to Figure 1 for total approach attempts on each trial date.

Null Hypothesis A: High traffic approach attempts = Low traffic approach attempts

We found that grey squirrels did not approach differently to high and low periods of human traffic (Chi-square goodness of fit: chi-square value = 2.6 and 8.5, $p > 0.05$, $df = 4$) as we failed to reject the null hypothesis.

Statistical Analysis for Foraging Duration -- The duration of foraging was assessed using a Student's t-test. The mean foraging duration during low traffic (213 seconds) was greater than and the mean foraging duration during high traffic (114 seconds). Refer to Figure 2 for average foraging duration during each trial date.

Null Hypothesis B: High traffic approach duration = Low traffic approach duration.

Given the results of the t-test : t = -1.03, p = 0.05, tcrit = 1.69, we failed to reject the null hypothesis. Thus, there is no significant difference between foraging duration in high and low traffic periods.

DISCUSSION

Through our data analysis we were able to confirm our original hypothesis that squirrel foraging behavior is not significantly affected by human interactions. The goodness of fit chi-square test proved that there was no statistical difference between the high traffic approach attempts and low traffic approach attempts. The t-test also proved that there was no difference between high traffic approach duration and low traffic approach duration. Therefore, we failed to reject our null hypothesis and conclude that there is no difference between high traffic approach attempts and duration compared to low traffic approach attempts and duration. This is also in agreeance with what was written in the existing literature (Beale and Monaghan, 2004).

Additionally, we were able to make some anecdotal notes during our study regarding what forms of human interaction seemed to deter squirrels most. Instead of simply being deterred from continuous foraging when a human walked by the food site, there were other factors which contributed to desistance of foraging. Some of these other factors include a golf cart driving on the sidewalk adjacent to the site, a human riding his skateboard and larger parties of humans, particularly those making more noise.

Our study was limited by a number of factors, first and foremost being number of trials. Because of the University of Maryland course structure, we were limited to Monday, Wednesday and Friday during the hours of 11:00 am to 1:00 pm where there would be sufficient traffic to be considered high traffic. In addition, although we determined McKeldin Mall to contain most of the traffic, the Mall also serves as the venue for several large activities throughout the year, two of which happened to occur during out data collection period. These activities brought large tents, vehicles, machinery and animals that are not normally encountered by campus squirrels, likely prompting them to take cover instead of engaging in routine foraging behavior.

Furthermore, our experiment was conducted at a time during which squirrels do not tend to forage. Normal foraging behavior occurs during dawn or dusk for the squirrels (when students are not in class) thus limiting the number of squirrels that are out foraging during our selected time frame. Another limitation was that the squirrels we observed did not represent the entire population. We didn't have any effective means of distinguishing between a squirrel that had previously visited from a new visitor. The best way to do this would have been to mark the squirrels as they approached but within the scope of our experiment this would interfere with the behavior of the squirrels because we would actively be disrupting them when approaching them to mark them. Also, because we could not mark the squirrels, we could not identify the squirrels that had abnormal foraging behavior. In particular, a squirrel observed during one day's trials, was significantly more erratic than previously observed squirrels. Its actions were in comparison to the two other squirrels who approached the seed pile on that day - if we had been able to mark each squirrel, then abnormal behavior could be accounted for - or simply solved by increasing the number of conducted trials.

Due to these limitations, we have provided ample opportunity for future research. For

example, researchers can test for a particular type of traffic that may cause the most marked differences in foraging behavior. In our study there were multiple means of traffic, such as people walking, people riding their bicycles, and other means of transportation. While people walking and people on bicycles were not deterrents for this population of squirrels, research done on other squirrels can test which modes of transportation provided the greatest deterrent for foraging behavior. Further, one could examine the risk behavior associated with different types of food. Van der Merwe, et al. found that if food was better able to be stored in the ground (had a hull), the squirrels would engage in riskier behavior to obtain that food.

Our study contributes to further understanding the effect of human population expansion on squirrels. As natural squirrel inhabitants disappear, we will continue to see squirrel adaptation. As we predicted, no difference in foraging duration was found, supporting the idea that squirrels have adapted to humans, especially in areas of very high human traffic. The more practical application of our study would be in addressing grey squirrel overpopulation. Although overpopulation is not a major problem in the United States, introduced populations of the grey squirrel in Europe have caused a significant decrease in native squirrel populations. Now that we have further confirmed that human traffic does not deter squirrel foraging behavior, we can work to control squirrel population another way.

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FIGURES

Table 1 - Experimental timeline**; l**ocation of study by Symons Hall and specific times used are listed below

Time Period	**Designation**	**Notes**
11:15 AM - 11:30 AM	Food placed out	No data collection
11:30 AM -11:45 AM	Low Traffic	In between classes
11:45 AM - 12:00 PM	High Traffic	Class Change
12:00 PM - 12:30 PM	Break	No data collection
12:30 PM - 12:45 PM	Low Traffic	In between classes
12:45 PM - 1:00 PM	High Traffic	Class Change

Figure 1 - This chart summarizes the data collected for number of approaches per trial date; each attempt was recorded and summed for a total for each day

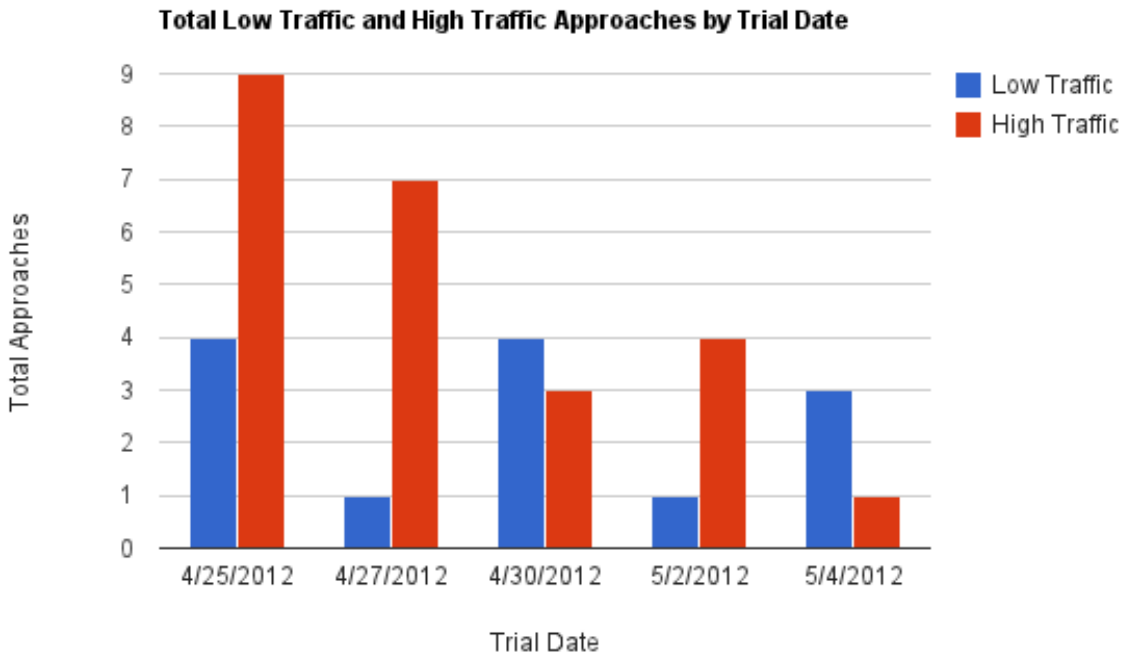

Figure 2 - This chart summarizes the data collected for duration of each approach in seconds; each attempt was recorded in seconds and the average was used for each day