Examining the effects of olfactory predator cues on Gray Squirrel (*S. carolinensis)* optimal foraging behavior

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Predation has been observed as an important behavior modifier in Gray Squirrels *Sciurus carolinensis* for forested populations. A study was conducted in an urban environment measuring differences in squirrel foraging behaviors based on the presence of an olfactory predator cue, fox urine. Trials measuring the amount of time spent foraging at fixed corn cobs versus individual kernels of corn were recorded across 5 days at a single site. We determined that there was no relationship between the ratio of total time spent at the cob to total time spent foraging for cue and for non-cue ($t= -1.084$, $df=4.059$, $p=0.3385$). Further studies should compare urban populations to forested populations as well as the importance of different types of sensory cues as modifiers of squirrel foraging behavior.

Key words: Behavior, Cues, Foraging, Predation, Squirrel, Urban

Predation is seen as as a major modifier for certain behavioral characteristics in prey species. Prey species may aggregate in groups to maximize defense capabilities (Alexander 1974), alter their sexual behavior in the presence of a predator (Farr 1974), or induce certain parental behaviors to decrease risk of predation to young (Fox and Krausman 1984). In addition, predator presence can influence foraging behavior of a prey species. It has been noted that prey should reduce the amount of time spent foraging in areas where predators are present (Endler 1986; Abrams 1991; Werner and Anholt 1993). This phenomenon represents a trade-off in foraging capability and risk of mortality. This trade-off has the potential to impact animal behavior on an evolutionary level (Alexander 1974).

There is a growing amount of evidence that a trade-off between optimal foraging and mortality exists in a variety of species. Previous research suggests that an animal foraging in an area where it may be susceptible to predation benefit from carrying the food item into a protected area where it is less susceptible. However, carrying a food item away from the original location represents an energetic cost. A study on foraging behavior in gray squirrels found a trade-off in forest-dwelling squirrels between the predation risk of remaining in an open, susceptible area with a net energetic gain of reducing movement out of the high risk area (Lima et Al. 1985).

Grey squirrels (*Sciurus* carolinensis) are native to North America but were recently introduced to Great Britain, Ireland and South America. They prefer deciduous woodlands but are also found in parks, towns and cities. They are known to feed primarily on hazelnuts, acorns, tree bark, leaves, flowers and will sometimes raid bird's nest for their eggs. Foraging for these squirrels are not as easy because they too have to watch for predators, such as weasels, foxes, bobcats, grey wolves, coyotes, lynx and sometimes humans. Grey squirrels do not have a very effective defense mechanism therefore when foraging they have to be very cautious and aware of their surroundings. Some will travel in groups or depend on rapid tail movement to ward off and confuse their predators. Not only does the risk of predation limit the *S. carolinensis* population and breeding opportunities, but the availability of the tree seeds plays a major part as well (Gurnell 1996).

The trade offs studied by Lima et al. may also be important for squirrels inhabiting areas with a higher degree of urbanization. These squirrels have been shown to forage at greater levels than rural squirrels, possibly exhibiting less sensitivity to predation risk than squirrels inhabiting

less developed areas (Bowers and Breland 1996). However, a trade-off between predation risk and optimal energy gain from foraging may also be apparent in urban populations of squirrels. After careful research and interpretations from other experiments we want to observe squirrel foraging behavior in the presence of a predator cue. We suspect that *S. carolinensis* will optimize their net energy gain by foraging on a high density, non-mobile food source in the absence of an olfactory predator cue. Furthermore, we expect a higher rate of foraging on a lower density food source that can be removed from an open area when an olfactory cue is present.

MATERIALS AND METHODS

Study sites—The study was carried out over a 5-day span with 2-4 trials daily. The study area was conducted in a designated patch of grass on the campus of University of Maryland, College Park. A boxwood hedge and a chain link fence, with one side open, enclosed the area. The lawn contained one tree that had a squirrel nest within it.

Field Methods-- Trials were conducted approximately daily during the squirrels' active foraging times of dawn and dusk. For each trial the experimental area was set up with two forms of dry corn: in loose kernels and on a cob. Two cobs were individually held upright on a wooden stand with a nail driven through the cob for support; this represents the immobile, high density food source. Loose kernels were stripped from the same cobs and dispersed throughout the study area. Total study area covered by the dispersed corn was approximately 2x2 meters.

Fox urine representing the predator was applied to cotton balls that were contained in double sealed in Ziploc bags. To ensure that the fox urine was usable, when not in use the urine was stored in a refrigerator. Two categories of trials were conducted, one set with predator cue and a control set without predator cue. The predator cue treatment trials consisted of the study area set up with the addition of urine-soaked cotton balls that were removed from the bags and placed throughout the study area. Trials without a predator cue treatment were conducted in an identical manner without the urine soaked cotton balls. Each trial was one hour long with five

non-cue trials and equal number predator cue trials. With a stopwatch we recorded the amount of time a squirrel foraged on the cob or corn kernels for each trial. The number of squirrels present and squirrel behavior were recorded along with the associated time signatures. For redundancy to increase our accuracy we also videotaped the activity with a Panasonic HDC-sd60 video camera to ensure that the correct times were documented.

Analytical Methods-- Statistical analysis was done in the statistical computing program R. A Welch two-sample t-test was done to test for significance in the difference between cue and non-cue foraging methods. To test for significance between mean foraging times a two-way ANOVA test was conducted.

RESULTS

We conducted 10 trials over a span of 5 days, gathering a total of 10 hours of data. Mean time spent foraging on kernels with predator cue present (CC) was 15.35 minutes; mean time spent foraging on a cob with predator cue present (CK) was 43.13 minutes; mean time spent foraging on kernels with no predator cue present (NK) was 36.00 minutes; and mean time spent foraging on a cob with no predator cue present (NC) was 23.27 minutes. We compared the proportion of time spent foraging on a cob between non-cue and cue treatments using a Welch two-sample t-test, and found no significant difference found between the cue and non-cue treatments ($t= -1.084$, $df=4.059$, $p=0.34$). The mean proportion of time spent of the cob for the cue treatment was 0.254, and the mean proportion for the no-cue treatment was 2.138 (Figure 1).

To compare amount of time spent foraging between all treatments and food type, we conducted a two-way ANOVA (Figure 2). The ANOVA results demonstrated no significant differences between the mean of the total time spent foraging on the site ($F=0.2222$, $df=3$, $p=0.8795$).

DISCUSSION

Overview of results-- Our results show that our original hypothesis that squirrels forage more on loose kernels in the presence of an olfactory predator cue was not supported. Analysis revealed that the presence of a predator cue had no significant effect on squirrel behavior between foraging on loose kernels or cobs. The data also shows that the predator cue had no effect on total foraging time. In fact, with over 400 minutes of combined foraging, there was less than a four-minute difference in total foraging times between cue and non-cue trials.

Selecting a study site: experimental issues-- Our study had several issues with selecting a site due to multiple confounding variables. One of the main issues was getting the squirrels to come to the site, which involved selecting a site that was close to a nest or a common hangout for squirrels. The placement of nests required our study to choose a site that incidentally had periods of high human traffic. This led to the selection bias for squirrels that were accustomed to the presence of humans. This was made evident during the experiment when we saw the majority of squirrel feeding behavior to be standing and feeding, regardless of whether they were on the cob or foraging for kernels. This was a notable difference contrasting with the videos that we saw in lab that depicted a high amount of mobility in the process of foraging (Blumstein 2001).

Another notable issue was the incidence of one civilian who was observed feeding squirrels around the test site at regular intervals during the experiment. The individual was approached and confessed to feeding these squirrels but no agreement was reached as to the discontinuation of her feeding of the squirrels. The individual only appeared on site during two trials. The presence of this individual likely influenced the foraging behavior of squirrels in a positive manner, allowing the squirrels to become habituated to being fed.

In addition, another notable observation that may have had potential bias as the experiment progressed was the increasing familiarity of the squirrels with our experiment. Each trial was conducted at an identical site with the same squirrels visiting during each trial. Earlier trials saw little to no squirrel activity, but during the later trials we noted progressively higher

squirrel activity, to the point where some squirrels were even waiting for the food to be placed prior to the start of the trial. It is possible that due to the squirrel's familiarity of the area, as well as the fact that there is little cover, could result in them to place less emphasis on olfactory cues and more emphasis on visual cues, thereby rendering the fox urine less effective.

Implications and further research-- We have demonstrated that the urban environment produces noticeable changes in squirrel foraging behavior, or absence thereof. Regardless of predator cues, squirrels show different behavior than those projected by Lima et al. Squirrels in the urban environment were unofficially observed as spending less time foraging and general mobility, and were more comfortable with eating both kernel and cob from a fixed position. This can have implications on future research as well as management techniques. The behavior of these squirrels suggests that olfactory cues do not function as a primary alert for predators, or that squirrels may possess a complete lack of awareness for predators. Therefore management of squirrels in these types of environments may require more aggressive techniques, since sensory deterrents may not be as effective.

For future research, our study shows that urban populations may have many confounding variables that will affect their willingness to approach food that will leave them vulnerable and open to predation. However, while our data suggests potential differences between studies of squirrel behavior in forested areas and urban areas, we did not conduct a direct comparison. For future studies, we recommend a comparison with more trials between urban and forested sites to see if there is truly a difference in squirrel foraging behavior. We also recommend a comparison of the different types of sensory cues (auditory, visual and olfactory) in an urban environment to see which types of cues squirrels rely on the most.

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TABLES AND FIGURES

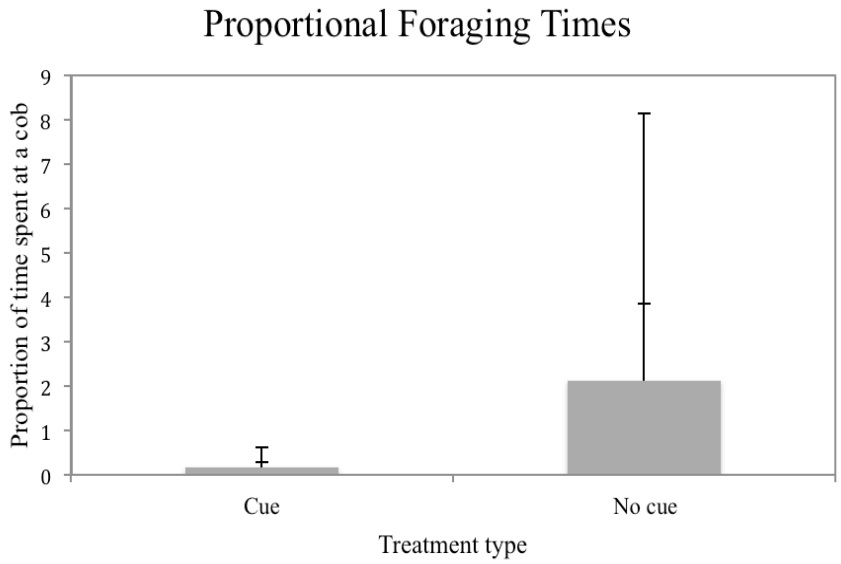

Figure 1: Welch's t-test results comparing proportion of time spent foraging on a cob among both predator cue and no predator cue treatments.

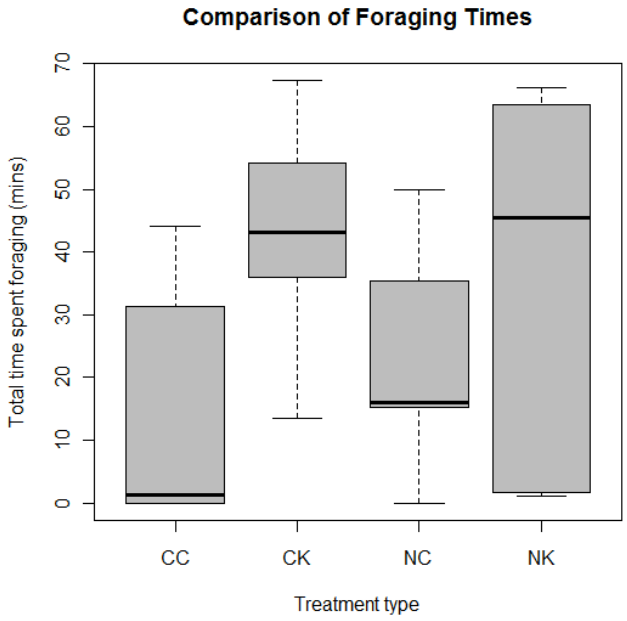

Figure 2: Two-way ANOVA results for kernel and cob foraging times across both treatments. CC represents foraging on a cob with cue treatments; CK represents foraging on kernels with the cue treatments; NC represents foraging on a cob with no cue treatment; and NK represents foraging on kernels with no cue treatment.