

The Effects of Food Distance and Quality on Eastern Gray Squirrel Foraging Preferences

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Introduction

To survive, prey organisms must both find enough food and avoid predators, and there are trade-offs between these two necessities. To find food, an organism must forage in its environment, risking predation. Organisms balance food intake and this danger, which is the basis of the “optimal foraging theory,” which posits that organisms will maximize energy gains while minimizing energy costs (including predation risk) while foraging (St. Juliana et al., 2017).

For animals that are frequently preyed upon, like rodents, optimal foraging is especially important, and the risk of predation dictates their foraging behavior. For example, white-footed mice (*Peromyscus leucopus*) forage more during darker nights (Jacob et al., 2017) and gerbils (*Gerbillus andersoni allenbyi* and *Gerbillus nanus*) forage more in higher vegetation and in nights with less illumination (St. Juliana et al., 2017). Both conditions (darkness and increased vegetation) lower predation risk, thereby reducing foraging costs and allowing greater risk-taking and longer foraging periods. However, it remains unknown whether eastern grey squirrels (*Sciurus carolinensis*) also exhibit this optimal foraging behavior, especially when they are offered food in different forms, are frequently disturbed by predators in a suburban environment, and must travel varying distances to reach their foraging area.

In this study, we attempted to resolve some of these questions regarding the eastern gray squirrel by measuring their giving-up densities (GUDs), or the weight of food at each feeding spot (density) at which the squirrels stopped foraging (St. Juliana et al., 2017). A lower GUD implies more foraging and more food eaten. We hypothesized that foraging squirrels would prefer food from a tray that was closer to a tree more than food from a tray that was farther from a tree, and we predicted that the squirrels would have lower GUDs in the closer tray than in the farther tray. We hypothesized and predicted this because food farther from a tree has a higher predation risk for squirrels, and, according to optimal foraging theory, squirrels should spend less time foraging in areas with higher predation risk and thus have higher GUDs in these areas. We expected this to be especially true given the location of this experiment, which is exposed and frequently disturbed by domestic dogs (*Canus familiaris*). The presence of domestic dogs and cats has been shown to reduce rodents' foraging activity (Mahlaba et al., 2017).

Additionally, we hypothesized that squirrels would prefer food from a tray that was close to a tree and had unshelled peanuts more than food from a tray that was far from a tree and had shelled peanuts. We predicted that these squirrels would have lower GUDs in the close and unshelled peanut tray, and higher GUDs in the far and shelled peanut tray. We hypothesized and predicted this because although shelled peanuts are a more attractive food source because they require less energy to consume, they are farther from a tree and thus pose a greater risk of predation. In an area frequently disturbed by predators such as domestic dogs, we predicted that the risk of predation would outweigh the benefits of eating shelled peanuts, and that squirrels would prefer a lower-energy reward with lower predation risk by eating unshelled peanuts close to a tree.

Methods

We performed these experiments in Northbrook, Illinois, United States of America (42°7'15" N 87°51'33" W) in a suburban backyard. The yard was fenced in and dominated by short grass, with intermittent shade from large trees. In both experiments, we filled two 60 x 30.5 x 6.5cm trays one-third full of sand. We placed one tray close (0.5 meters) and one far (8.5 meters) from a large sugar maple (*Acer saccharum*) in one of the yard's

corners, which connected the tree to the fences and to multiple other large trees and dense vegetation. We placed specific amounts of peanuts in both trays, burying most and leaving some partially exposed so the squirrels knew food was present. We left the squirrels to forage, and at the end of each trial, we sifted through the trays and weighed the remaining peanuts in each tray using a Pelouze X1 kitchen scale to determine the GUDs. We also noted the start and end times, the temperatures, and the weather for each trial. We discarded the data from a trial if both trays had no peanuts, if one tray had all its peanuts and the other had none, or if both trays had all their peanuts remaining. Finally, between (never during) trials at random intervals for both experiments one and two, we set three domestic dogs free in the yard to disturb the squirrels as part of the dogs' regular routine.

Experiment 1

We placed 45 grams of unshelled peanuts in each tray. After an initial 2-hour acclimatization period, we began with 30-minute trials and gradually decreased the duration to 15-20 minutes as the squirrels were conditioned to eat from the trays. We conducted 32 trials, averaging 25 minutes each, over eight days in November (11-5-24 to 11-12-24), in the late mornings and afternoons. We used a one-tailed paired T-test in Microsoft Excel to analyze this data.

Experiment 2

We buried 29 unshelled peanut kernels (with between one and three kernels per peanut shell) in the tray close to the tree, and 22.7 grams of shelled peanuts in the tray far from the tree. We conducted 19 trials, averaging 20 minutes per trial. We did this experiment over four days in November (11-14-24 to 11-17-24) in the late mornings and early afternoons. We used a one-tailed paired T-test in Microsoft Excel to analyze this data.

Results

For the first experiment, we placed two trays with unshelled peanuts at different distances from a tree. Averaged over 32 total trials, with the average trial length being 25 minutes, the tray close to the tree had significantly lower GUDs than the tray far from the tree (Fig. 1) ($p < 0.001$).

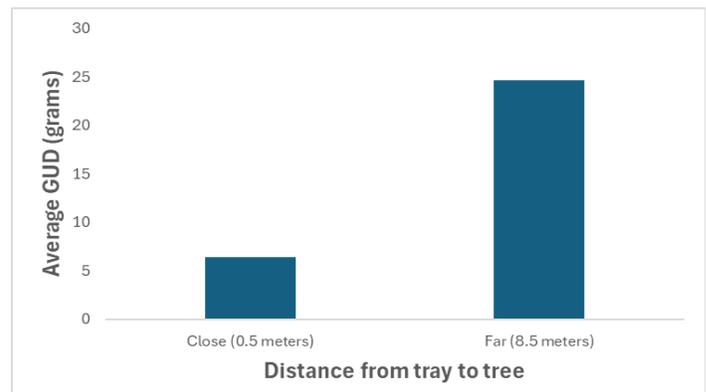


Figure 1. The average GUDs for trays at varying distances from tree cover. We filled two trays with sand, one-third full, and buried 45 grams of unshelled peanuts in each. We placed one tray close (0.5 meters) to a tree, and one tray far (8.5 meters) from a tree. We measured the GUDs for each tray after each trial for 32 total trials (with an average trial length of 25 minutes) and performed a paired one-tailed T-test via Microsoft Excel. We discarded trials with no peanuts eaten in either tray, all peanuts eaten in both trays, or all eaten in one and none in the other. The tray close to the tree had significantly lower GUDs than the tray far from the tree ($p < 0.001$).

For the second experiment, we placed one tray with unshelled peanuts close to a tree and one tray with shelled peanuts far from a tree. Averaged over 19 trials, with the average trial length being 20 minutes, the tray close to the tree with unshelled peanuts had significantly lower GUDs than the tray farther from the tree with shelled peanuts (Fig. 2) ($p=0.028$).

*This author wrote this paper for Biology 220: Ecology and Evolution taught by Dr. Josh Hedge.

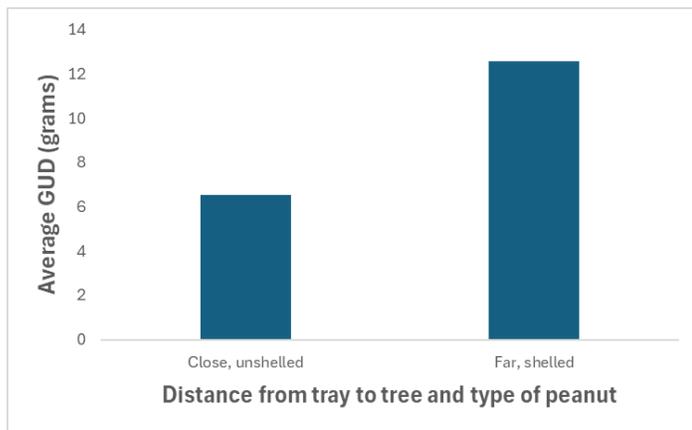


Figure 2. The average GUDs for trays at varying distances to tree cover and varying food rewards. We filled two trays with sand, one-third of the way. We buried 29 unshelled peanuts (each kernel inside a peanut shell counted as one peanut) in the tray close (0.5 meters) to a tree, and 23 grams of shelled peanuts in the tray far (8.5 meters) from a tree. We measured the GUDs for each tray after each trial for 19 total trials (with an average trial length of 20 minutes) and performed a paired one-tailed T-test via Microsoft Excel. We discarded trials with no peanuts eaten in either tray, all peanuts eaten in both trays, or all eaten in one and none in the other. The tray close to the tree with unshelled peanuts had significantly lower GUDs than the tray farther from the tree with shelled peanuts (Fig. 2) ($p=0.024$).

We did not observe any other predators or instances of successful hunting by the domestic dogs. Additionally, during both experiments, we saw blue jays (*Cyanocitta cristata*) taking peanuts (mostly unshelled) from the trays, but these were rare events. Finally, we observed intense competition among the squirrels: sometimes five were foraging at once, and only one would use a tray at a time.

Discussion

In the first experiment, we observed that the GUDs of the close tray were significantly lower than the GUDs of the far tray. Thus, we reject the null hypothesis that there would be no relationship between tray distance and GUD. In the second experiment, we observed that the GUDs of the close and unshelled peanut tray were significantly lower than the GUDs of the far and shelled peanut tray. Thus, we reject the null hypothesis that there is no relationship between tray distance, food quality, and GUD. We observed only minor sources of error in this study, mainly weather variation, blue jays taking peanuts, and intense intraspecific competition among the squirrels. The first two errors likely did not affect our results, as blue jay sightings were rare and the weather varied only slightly. With regards to the intraspecific competition, we are unsure what effect it had on the experiment, if any. Most probably, it had a leveling effect, lowering the GUDs for both trays in both experiments. Because food was scarcer due to competition, the squirrels had to forage more in both trays. However, more experiments would be needed to confirm this. In any case, these errors are unlikely to have changed the overall trends in our results.

These results are what we expected. From both experiments, we saw that squirrels optimize their foraging for low risk by foraging close to tree cover. The squirrels' preference in the second experiment for the close, unshelled peanuts is also what we expected according to this logic. The increased cost and predation risk for the far, shelled tray were amplified by frequent disturbances in the area from three domestic dogs. While these individuals were extremely inefficient predators with zero recorded captures, they still represented a threat that increased GUDs at the far tray. Thus, the risk of predation outweighed the benefits of a more energy-efficient food source, as we predicted. This result agrees with research reporting that rodents forage less in areas disturbed by domestic cats and dogs (Mahlaba et al., 2017). These results also agree with other research on optimal foraging in rodents. For example, the behavior of white-footed mice in response to illumination levels and vegetation cover (Jacob et al., 2017) and the behavior of gerbils in response to moonlight and cloud

cover (St. Juliana et al., 2017) follow optimal foraging theory. Illumination, vegetation, and cloud cover all affect predation risk, and these organisms increased their GUDs in response to this increased predation risk.

Thus, this experiment adds to a growing body of research reporting the optimal foraging behavior of rodents, specifically their decreased foraging in response to increased predation risk. This is especially important in a world that is increasingly developed, urbanized, and deforested. As cover for rodents and indeed any animals is removed, individuals will be forced to forage farther away and subject themselves to increasing predation risk and decreasing energy gain, which will harm populations and thus their biodiversity. Increased vegetation, especially tree cover, could be added to open, deforested, or urban areas to provide organisms with safe places to forage at lower predation risk. Thus, planting and conserving vegetation would allow us to align with the optimal foraging strategies of endangered animals by providing foraging areas where they can forage at lower GUDs to gain more energy with lower risk.

Future studies could determine whether predation risk or the cost of travel is the more important factor for GUDs, as this was unclear in our study. Although we assumed predation to be the more important factor, because the area is frequently disturbed by predators, and the eight-meter distance between the trays represents a relatively small energy cost, this is not necessarily true. This is because the farther trays cost more energy to reach *and* are more open to predation (both of which would raise GUDs). Furthermore, studies could be conducted to determine the effects of optimal foraging behaviors in endangered populations and areas, particularly in fragmented habitats where organisms may need to cross dangerous edge areas to forage. This would allow us to determine what we can do to increase their energy gains and decrease their costs, for example, by planting vegetation or restoring habitat.

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