Foraging Behavior of Eastern Chipmunks between Two Levels of Human Presence

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Abstract Animals are known to exhibit different temperaments when living in human proximity. Eastern chipmunks (*Tamias striatus*) specifically behave more boldly and are more docile when their territories are in proximity to human structures. Differences in behavior across a gradient of human disturbance can indicate underlying differences in personality across the gradient. Changes in average personalities of a species may alter the fitness of the species. Eastern chipmunks, capable of living near many levels of human disturbance, can be studied for the effects of human disturbance on foraging behavior. I used giving-up density (GUD) to compare the foraging behaviors of chipmunks at two sites in the woods and two sites near buildings and human traffic at the University of Notre Dame Environmental Research Center – East. I found that chipmunks living far from human disturbance began using the seed trays more slowly, preferred to forage at sites farther from the road, and did not take as many seeds as chipmunks near human structures. Videos of foraging at each of the four plots suggested an increase in speed of seed collection for chipmunks living at the sites near human structures, indicating bolder foraging patterns with less time spent immobile. The divergence in foraging behavior of chipmunks living near human disturbance may indicate a divergence in temperament of chipmunks living near human structures, based on the adaptive nature of different traits in human-disturbed areas, and a depression in expression of certain temperaments that were adaptive in pristine areas.

Introduction

When animals are exposed to humans and the modified environments that humans create, they may undergo physiological and behavioral changes. For example, Magellanic penguins unaccustomed to human presence display physiological symptoms of stress if they experience tourists walking by their breeding ground, whereas penguins accustomed to tourists do not respond with the same physiological stress (Fowler 1999). When first hatched, penguin chicks have higher stress if their nest is in a tourist-visited area, and they seem to adapt physiologically so that as adults they do not experience this stress if they are accustomed to frequent human presence. Also, chicks raised near tourist sites tend not to flee in the presence of humans, although those raised in areas undisturbed by humans tend to flee when humans are closer than 9m (Walker *et al.* 2005). These studies show how animal behavior may change to adapt to human presence in their habitat. Differences in behavior between individuals, if consistent across time and situation indicate differences in personality. Personality differences are an important part of a species' diversity, as different personalities enhance survival in different situations (Réale *et al*. 2007).

Eastern chipmunks (*Tamias striatus)* are a species found throughout the eastern United States, and are foragers adapted to well-established deciduous eastern forests. In addition, they also successfully inhabit less forested areas and fragmented forests (Mahan and Yahner 1996). Juveniles, pressured by territorial adults, disperse to new habitats, sometimes in less preferable areas, such as forest edges and areas near humans (Yahner 1978). In residential areas, chipmunks readily use the small corridors of bushes and woods surrounding lawns to travel and hide (Baack and Switzer 2000). Because chipmunks spend much of their time within their own territories and defend their territories from other chipmunks, each individual within a small area experiences a certain level of human disturbance. Martin and Réale (2007) found that chipmunks indeed had different temperaments when they lived closer to human-frequented areas. These traits make *T. striatus* a good subject to study differences in personality in animals exposed to varying degrees of interaction with humans.

Foraging is a key behavior in chipmunks, but differences in foraging have not been studied in relation to chipmunk personality differences. Observation of an animal's foraging in its habitat may provide a more realistic indicator how differences in personality affect fitness than tests that remove the animal from its environment, such as the tests done by Martin and Réale (2007), in which chipmunks were trapped and observed in a box and their behaviors were quantified to develop a behavior profile.

Foraging carries a heightened risk of predation. Foraging animals move more slowly or not at all and are focused on food, which may result in decreased vigilance for predators. Foraging individuals may display varying levels of vigilance, balancing the competing goals of being vigilant and collecting food (Baack and Switzer, 2000). This tradeoff may differ in individuals depending on their personalities. For example, more curious and docile chipmunks that tend to live in more populated areas might exhibit a weaker anti-predator response and forage more boldly.

To assess foraging differences between animals with close and far proximity to humans, I used trays to assess giving-up density (GUD), which is a measure of the degree to which an animal will continue to search for food through a seed-sand matrix. The amount of seeds left on a tray after leaving the tray out all day as a foraging opportunity reflects the density of seeds at which foragers give up on that foraging opportunity and look for a new source of food (Bowers, Jeffereson and Kuebler, 1993).

The level of an animal's vigilance can be observed by their behaviors in the field when at feeding stations. Non-invasive study of this behavior is possible using video cameras, allowing observation of foraging and food collection by chipmunks in their habitats and providing an opportunity to compare behaviors in this common activity (Aschemeier and Maher 2011).

Martin and Réale (2007) identified personality differences due to human disturbance such that chipmunks living near people were more bold, docile and explorative. I expected that the group exposed to more human disturbance would forage in a bolder manner: responding less quickly, with less vigilance, and less tendency to flee while foraging. These results would make sense in light of the need to be bold enough to function when living in the threatening environment of a human-disturbed environment. Less bold chipmunks would be too timid to collect sufficient food or find a mate if living in the frequent presence of humans and human environments. Indeed, Martin and Réale (2007) note that differences in temperament may affect individuals' abilities to occupy areas with more human disturbance, such that less docile, less bold chipmunks would be unable to successfully live in areas near people.

This study looked at the interaction of foraging behavior and temperament differences due to proximity to humans. It investigated the effect of human proximity on chipmunk foraging behavior and temperament by determining whether chipmunks living in areas with high and low levels of human disturbance exhibit different foraging behaviors, which may be based on different temperaments. If *T. striatus* do in fact disperse unevenly depending on their temperament, as Fraser *et al.* (2001) found, it may lead to temperament differences between populations, which can cause differential foraging behaviors across a human-disturbance gradient.

Materials and Methods

We created four grids to compare the foraging at different levels of human disturbance, two grids in the woods near human disturbed areas and two in the woods at least 1.5 km from any buildings or other human habitation. Having both sets of traps in the woods eliminated the confounding variable of different habitat types between the two populations. Each grid consisted of 25 traps in a 5X5 trap grid with 15m spacing. A straight stretch of a one-lane, dirt road transected each grid so that ten of the traps were on one side of the road and fifteen on the other side. The ten traps nearest to the road on each site of the road were placed in lines ten meters from the road, meaning that the three lines that were assigned three seed trays each were at 10, 25, and 40m from the road and each seed tray was at least 30 m from the next.

Chipmunks at the four grid sites were trapped using Sherman traps baited with oats and sunflower seeds and Tomahawk traps baited with peanut butter and apples. Trapped *T. striatus* were weighed, ear-tagged and given zip-tie collars with colored beads identifiable from a distance. The GUD tests were performed using 1.5 liters of sand and 25 grams of black oil sunflower seeds, the same proportions used by Bowers Jeffereson and Kuebler (1993) in their study of *T. striatus* and *Sciurus carolinensis* foraging. Seeds were dried in a drying oven at 150C for two hours before being put on the feeding trays and before being weighed to ensure that the weights were accurate, as the weight of 25 grams of seeds can fluctuate by at least 1.5 grams due to moisture in the air.

The behaviors of animals while they are foraging were observed using 10 Bushnell cameras. Five cameras were set at each site for one day for the 10 hours that the trays held the seed-sand matrix. Efficiency of foraging was measured by the number of seeds collected in a ten second interval. More vigilant behavior was quantified by the number of times the chipmunk looked up or scanned the area while foraging.

The behavior while foraging was analyzed statistically using two-sample t-tests with proximity to humans as the grouping variable to compare number of seeds eaten, number of times looking up, and number of times scanning the area within a ten second clip of the video. Each t-test plotted human proximity versus a different behavior with videos of individual chipmunks as replicates, choosing videos that were at least thirty minutes apart from each other. The interaction of subsequent days and proximity was analyzed using a repeated measures ANOVA, and the interaction of distance to the road and human proximity was analyzed using a two-way ANOVA. Both ANOVAS used amount eaten as the dependent variable. All statistics were established as significant if $p < 0.05$.

Results

The chi-squared analysis of the amount eaten at the grids near and far from human structures indicates that significantly more trays on the grids near human habitation were highly foraged (less than 10 grams of seeds left: $\chi 2 = 14.42$, df = 2, $p < 0.001$ Table 1). Out of 72 trials on the two grids near human habitation, 25 trays were highly foraged; giving low GUDs of below 10 grams and 9 were moderately foraged, giving moderate GUDs of between 10 and 20 grams of seeds left. Out of 72 trials on the other two grids far from human habitation, only 16 trays were highly foraged and none were moderately foraged.

A repeated measures ANOVA revealed a significant variation in the amount of seeds left by the interaction of day and proximity ($F_{3,102} = 4.82$, $p = 0.004$; Figure 1). The data was checked for normality using a two-sample variance test of the amount left grouped by near and far grids, and found to be acceptable because of the similar variances of the amount left at near and far grids ($F_{71,71} = 0.86$, $p = 0.53$) . Foraging at the sites far from human habitation was significantly lower for the first two days and then increased to a level comparable to trays near human habitation.

A two-way ANOVA found that the interaction of human proximity and tray distance to the road had a significant effect on the amount of seeds remaining on a tray ($F_{2,138} = 10.59$, $p<.001$, Figure 2). Chipmunks living near human habitation foraged somewhat equally at trays at all three distances from the road, while chipmunks living far from human disturbance took more seeds at the trays far from the road, indicating that chipmunks near human structures are not as afraid of being near roads.

There was an increase in number of seeds collected on the trays near human structures (t_{17} = -2.633, p = 0.0174, Figure 3). An average of more than four seeds was collected at these trays during a ten second interval of foraging captured on video, as compared to an average of two seeds at the sites far from human structures. This increase in efficiency of foraging did not lead to a detectable decrease in vigilant behaviors: between the grids near human disturbance and the far grids, there was no significant difference in number of times a chipmunk looked up (t_{17} = -0.496, p- value = 0.626) or number of times it scanned (t_{17} = 0.303, p-value = 0.766) over a ten second period of video.

Discussion

The data shows two main ways in which proximity to human disturbed areas affects chipmunk foraging. First, the chipmunks at sites that were not near human disturbance foraged less, with only 16 trays at the sites far from human disturbance highly foraged. This may indicate that there is a greater amount of naturally occurring food available for foraging in sites far from human disturbance. The fact that none of the far trays were moderately foraged may indicate that chipmunks far from human disturbance chose only trays that were in the safest places. This is consistent with the less bold behavior seen in chipmunks far from human habitation (Martin and Réale 2007). Another explanation may be that foraging mammals living near more urban areas are more food-limited, as was hypothesized by Bowers and Breland (1996).

The lower amount of trays that were highly or moderately foraged may also indicate lower chipmunk densities at the sites far from human habitation. There were twelve chipmunks caught at the near sites and only seven known at the far sites. This lower density of chipmunks is unexpected, considering that chipmunks do not alter home range due to supplemented food that might be available near human disturbed areas (Lacki *et al*, 1984). Further studies might study whether there are indeed higher densities near people, and explore causes for this.

It is surprising that the populations of chipmunks on grids near human disturbance did not prefer to forage at trays farther from the road, especially considering that the roads transecting the grids near human disturbance received much more traffic: during 3 hours from 9:00 am-12:00pm, when chipmunks are active, ten cars and three bikers passed the road transecting the wet lab grid. During the same time on the grids far from building and human habitation, a maximum of four cars might use the parts of the road transecting those grids. This finding may be explained by the observation that chipmunks displayed the same latency to move across a road regardless of the traffic level (McGregor *et al.* 2008). So the minimum distance near roads at which chipmunks will forage is based much more heavily on the individual's boldness, not on the traffic on the road. It may be that chipmunks are not cognizant that the roads are the source of cars. Chipmunks may simply understand that roads are more dangerous because they are clearings, and chipmunks avoid clearings because of the increased risk of predation (Bowers *et al.* 1993).

The results of the GUD studies suggest that differences in foraging behavior, including a greater number of areas being foraged, earlier use of novel foraging sites, and a lack of fear of foraging closer to a road, are present in populations living in human-disturbed areas compared to more pristine habitats. The reason for differential foraging patterns in chipmunks living closer to human disturbance can be at least partially explained by the differences in temperament seen in chipmunks living in areas more frequented by tourists (Martin and Réale 2007).

The mechanisms of the differences in feeding were analyzed using videos of the foraging trays. Based on the small set of data collected by video of five trays from each of the four grids for one day per grid, the chipmunks near human disturbance collect more seeds on average, and are therefore more efficient foragers (Figure 3). The lack of a significant difference in amount of vigilant behaviors (looking up and scanning during foraging) may be due to a difference in the length of time spent looking up and scanning, a measure which was not taken into account when analyzing the videos. The lower efficiency of seed collection in chipmunks far from human structures despite the similarity in vigilant behaviors across the human disturbance gradient could also be due to a lower boldness in chipmunks far from human structures, resulting in more seconds spent immobile during foraging. Diurnal rodents such as chipmunks are characterized by spending time immobile, perhaps as a defense against hawks and other predators which hunt mainly by sight (Hofer 1970). It is also possible that ten seconds is not a long enough duration to detect differences in vigilance behavior.

If chipmunk populations respond to their environment with different foraging behaviors depending on their proximity to humans, then populations may be diverging in personality based on proximity to human-disturbed areas. If populations take time to develop temperaments that are adaptive to human structures, populations whose habitat suddenly became a human-inhabited area might be less fit to thrive in such an altered habitat. Another implication is that populations in human-impacted areas may have less diversity in their personality traits and therefore suffer a fitness cost. Populations in human-disturbed areas may be adapting to display behaviors that are only beneficial in human-impacted areas, diverging from the chipmunks adapted to live in pristine areas and losing the temperament traits associated with chipmunks living far from human disturbance. Future studies should look at the foraging behavior and survivorship of chipmunks brought from human-impacted areas to pristine areas, and vice-versa.

If chipmunks living near human structures forage more quickly with less time spent immobile, this increased boldness may make them easier prey for predators that tend to co-occur with human habitation, such as cats and dogs. Temperament differences such that the populations near people are less fearful in their foraging behaviors could lead to increases in deaths to chipmunks or other prey animals adapted to foraging near human structures. This could reduce chipmunk populations in those areas. Alternatively, this increased predation risk could be a factor balancing out the increased prevalence of bold traits, so that similar temperaments are selected for in populations of chipmunks in human disturbed areas with predators and in non-human-disturbed areas (Boyer *et al.* 2010).

Improvements to this study include doing the study over a longer period of time, setting up the cameras for multiple days over several weeks, studying the GUD at grids in order to increase the sample sizes, and determining more exact measure of chipmunk abundance, in order to account for the differences in foraging based on number of chipmunks at each grid site.

Future studies could look at even more human-disturbed plots, such as those in woods near a suburban development and plots near a large agricultural field, mimicking the road-transected grid on which foraging trays were set so that all four levels of human disturbance could be compared along a gradient of human disturbance. Chipmunks showed different foraging behaviors, which may be based on different temperaments between chipmunks living near and far from human structures, and the magnitude of these differences in foraging behaviors can be analyzed by looking at sites that are more impacted by human development than the sites at UNDERC - East.

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Tables

Table 1. Number of trays with high, medium and low amounts of seeds eaten on grids near versus far from human habitation ($\chi 2 = 14.42$, df = 2, $p < 0.001$). Chi-square expected values are in parentheses.

Amount eaten	**Far**	**Near**
High (<15 grams)	16 (20.5)	25 (20.5)
Medium (5-15 grams)	0 (4.5)	9 (4.5)
Low (>5 grams)	56 (47)	38 (47)
Total	72	72

Figures

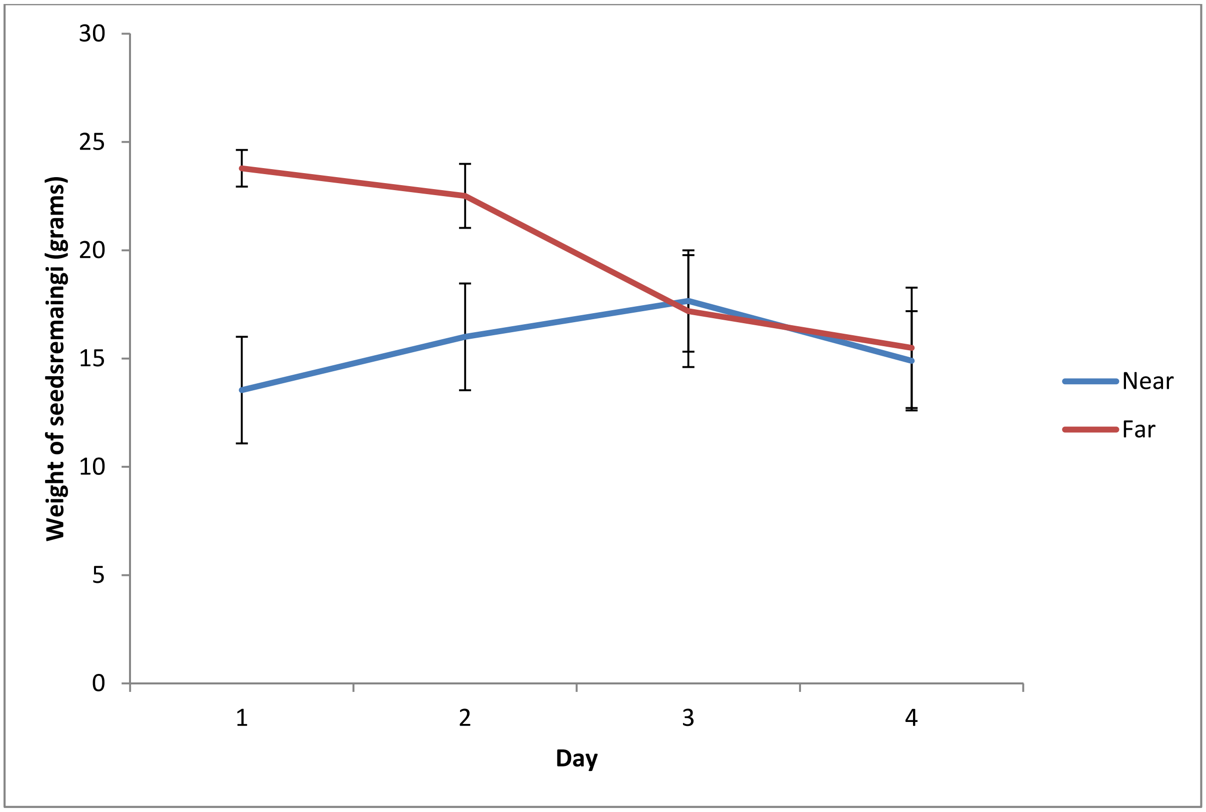

Figure 1. Results of repeated measures ANOVA marking the differences in number of seeds remaining over four subsequent trial days at sites near human structures versus sites far from human structures ($F_{3,102} = 4.82$, $p = 0.004$).

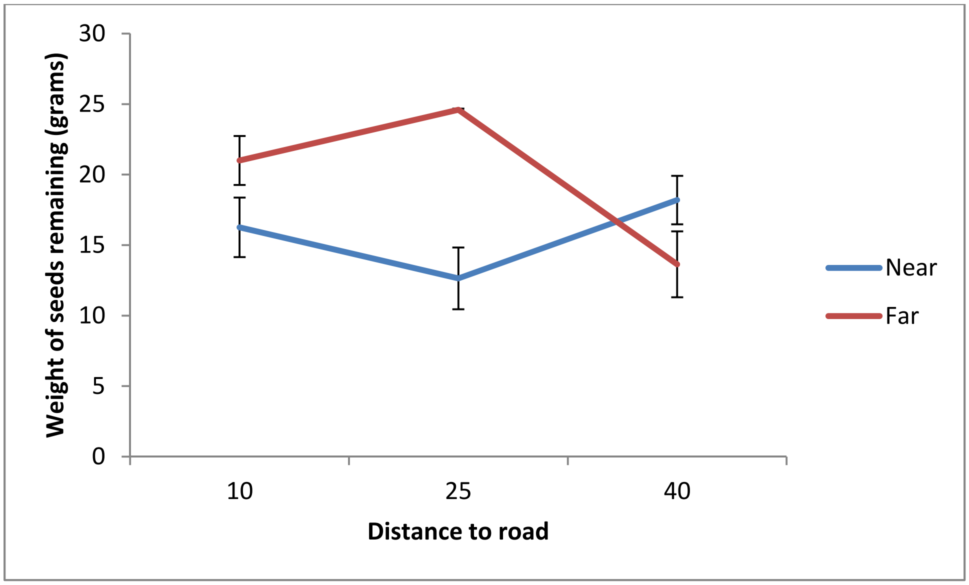

Figure 2. Results of an ANOVA showing the amount of seeds left on trays at different distances from the road, separating the results of sites near and far from human structures ($F_{2,138} = 10.59$, $p<.001$).

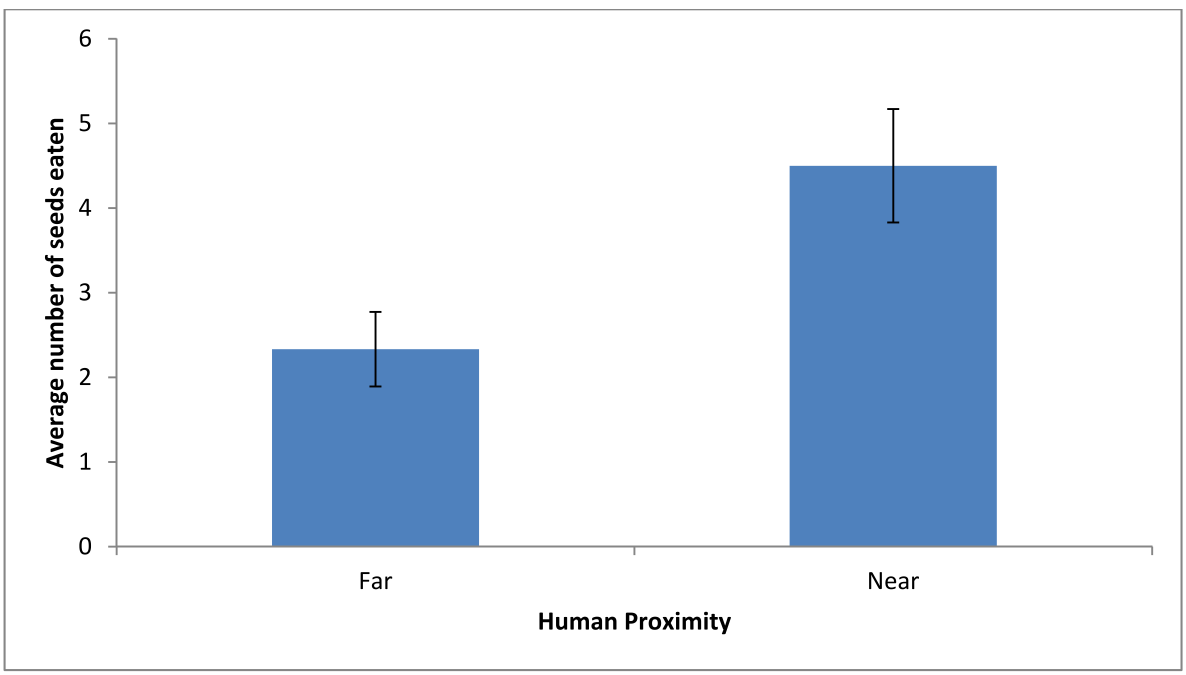

Figure 3. Average number of seeds eaten within a ten second period on the videos of trays near and far from human disturbance ($t_{17} = -2.633$, $p = 0.0174$).