Snooping for Safety: Eastern Gray Squirrels (Sciurus carolinensis) Eavesdropping on Tufted Titmice (Baeolophus bicolor) Alarm Calls

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Abstract

Mammals and birds have developed alarm calls to protect and warn their kin of predators. Tufted titmice (*Baeolophus bicolor)* in particular have developed predator-specific alarm calls. Many avian species listen to tufted titmouse calls to gain information for increasing their own safety, also known as eavesdropping. Few studies have looked at whether mammal species eavesdrop on avian alarm calls, yet small birds and mammals often share the same predator species. In order to broaden understanding of eavesdropping responses among birds and mammals more generally, I tested for Eastern gray squirrel (*Sciurus carolinensis*) response to tufted titmice alarm calls. Audio playbacks of titmouse alarm calls, given in 3 different specific risk situations, and a control call were used on squirrels and their behaviors before and after playbacks were recorded. The squirrels exhibited strong antipredator behaviors in response to titmouse alarms but not controls and they discriminate between alarm types. We conclude that Eastern gray squirrels eavesdrop on tufted titmice alarm calls to help avoid predation.

Keywords: alarm call, eavesdrop, antipredator behavior, gray squirrel, titmouse

Introduction

Mammals and birds have developed alarm calls (Hollen & Radford, 2009) known to alert their own kin to predators (Greene & Meagher, 1998). When other species use such signals to avoid risks, this is called eavesdropping (Waterman & Mai, 2020). Tufted titmice (*Baeolophus bicolor*) make varied and reliable alarm calls for many different predation risks (Sieving et al., 2010) and numerous species of birds are known to use these calls to avoid danger. The tufted titmouse is a common species with exceptional communicative complexity (a model for language evolution; Krams et al., 2012). Moreover, many bird species associate with titmice in time and space to gain information about predators (Hetrick & Sieving, 2012), when they should engage in risk sensitive behaviors (Huang et al. 2012) and enhance foraging efficiency (Sieving et al., 2004).

Eastern gray squirrels (*Sciurus carolinensis*) are found in the same wooded habitats throughout Eastern North America as tufted titmice making them an excellent study species. Tufted titmice and Eastern gray squirrels also share similar predators such as hawks and owls (Chow et al., 2021). Animals rely heavily on communication with similar and different species for adaptive decision-making. We explored if Eastern gray squirrels also use titmouse alarm calls for their own protection. Only one other study addresses mammal use of titmouse signals in which eastern chipmunks (*Tamis striatus*) eavesdropped on tufted titmice alarm calls (Schmidt et al., 2008). This study aims to test two hypotheses. First, we expect that if the squirrels eavesdrop on titmouse alarms that the behavior given to alarm calls will be distinctive from those exhibited when squirrels are exposed to controls. Secondly, if squirrel eavesdropping is highly discriminating then we expect that the squirrels should react the strongest to titmouse calls given to predator species that represent the highest level of danger to the squirrels.

Methods and Materials

Study Area

This study mainly took place in Gainesville, Florida with a few samples taken from Volusia County, Florida. Natural areas in Gainesville served as the main places where samples were collected as both tufted titmice and eastern gray squirrels occur there. The sampling locations were standardized as grassy areas with trees mainly on University of Florida natural areas. Some of the sampling locations include Natural Area Teaching Laboratory (29.6355553, -82.3675674), Loblolly Woods (29.6599265, -82.3693071), and McCarty Woods (29.6451553, -82.3441510). It is important trees were present for every site as trees are a safe place for squirrels to escape from predators.

Playbacks and Materials

In order to see if eastern gray squirrels eavesdrop on tufted titmice alarm calls, playbacks were used as a way to elicit, observe, and record this behavior. Three different tufted titmice calls were used as playbacks, which are the high seet call, an eastern screech owl (*Megascops asio)* alarm call, and a great-horned owl (*Bubo virginianus*) alarm call. A high seet call is when a hawk that is hunting on the wing passes close by, threatening attack and is a high danger situation. Playback of acoustic cues involves the use of digital recordings broadcast through a portable speaker and are commonly practiced in avian ecology (Bai, 2021). All three playback types used as alarm calls were recorded when titmice were calling in response to live predators of each species (Sieving and Hetrick 2012). A green tree frog call (*Hyla cinerea*) was used as the control stimulus as their call is common where eastern gray squirrels and tufted titmice occur and should not represent any danger (see Figure 1). These playbacks were standardized through Adobe Audition acoustic software to last 19 to 21 seconds and featured three repetitions of the specific call within the time limit.

For this experiment, a portable Bluetooth speaker was placed about 15 to 30 meters away from an eastern gray squirrel to ensure that the squirrel could hear the playbacks (Jackson et al., 1997). Videos were recorded on a cellular device of the squirrel's baseline behavior for one minute, then a playback file was broadcast through the speaker and the behavior of the squirrel was recorded for one minute more. The four different treatment playbacks were selected randomly throughout samples taken during field work a total of nine individuals were collected for each treatment (n=36). The distance between the speaker and the squirrel was recorded for each sample and calculated by using a range finder. The coordinates of the squirrel locations were also noted using a GPS and digital map. All samples were independent in that there was sufficient distance between them that one squirrel never heard the playback to another squirrel (250m). Any squirrels that were alarmed by my presence were not used for data analysis to avoid bias.

Data Analysis

The behaviors observed from the videos of the squirrels were characterized and quantified as count or duration metrics. The reaction latency to the playback (time between stimulus initiation and first behavior change) and the time spent exhibiting vigilant were noted from the videos. Vigilance time was defined as the time squirrels spent exhibiting antipredator behaviors. A tobit regression was used to show a linear relationship for vigilance time and reaction latency based on type of call and distance from the speaker. A tobit regression was the best for this calculation as analysis was restricted to 60 total seconds of observation. For showing the predicted baseline and antipredator behaviors based on count data, a multilevel mixed-effect model with poisson link function was used in order to see the mean for the behaviors for each call and trail period. All graphs portray predicted marginal means and 95% confidence intervals. All analyses were accomplished using Stata version 17.0 B/E.

Results

Squirrel Vigilance and Latency

A total of 36 different squirrels were recorded for their behaviors before and after the playbacks. The squirrels had the longest predicted vigilance time for the great-horned owl and eastern screech owl alarm calls (Figure 2A). The shortest predicted vigilance time was the green tree frog control call. All tufted titmice alarm calls used had low reaction latency and the green tree frog call had very high reaction latency (Figure 2B). The tufted titmice alarm call reactions for vigilance time and reaction latency were all statistically different from those observed for the green tree frog call (p=0.0003; p=0.0002).

Squirrel Behavior

The predicted number of antipredator behaviors after the playbacks were greater in the great-horned owl and eastern screech owl alarm calls. The predicted antipredator behaviors decreased after the predicted antipredator behaviors decreased after the frog playback was broadcast but significantly increased after all three alarm calls were used (Figure 3). This shows distinctly different reactions to alarm versus control calls. The number of antipredator behaviors before the playbacks are relatively similar between all calls indicating no biased results were used. Note that in all cases (Figures 2 and 3), reactions to the two owl alarm calls were stronger than to the hawk attack call.

Discussion

Our results show that eastern gray squirrels also utilize titmouse calls, establishing that the eavesdropping network of titmice includes at least two species of mammals (chipmunks also; Schmidt et al. 2008) and many birds species (Huang et al. 2012; Jones and Sieving 2019), broadening our understanding of the interconnectedness of animal community networks. Eastern gray squirrels also had distinct reactions to different alarm calls indicating that the squirrels can understand which predator is present from the call. In contrast to birds, who are much warier of the high seet call owing to the fact that hawks on the wing are much more dangerous to small birds than perched owls of any species (Hetrick and Sieving 2012), both squirrels (this study) and chipmunks (Schmidt et al. 2008) exhibit higher alarm states when titmice are calling about owls.

This study adds to the growing realization that many taxa share survival information with each other (Ridley et al. 2014) and understanding animal communication networks will advance knowledge of the drivers of ecological community dynamics (Reichert et al. 2021). Given the importance of vocal signals in animal communities, soundscape conservation is a high priority for protecting animal community dynamics in the face of anthropogenic activities and influence (e.g., Barivolova et al. 2021).

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Supporting Figures/Tables

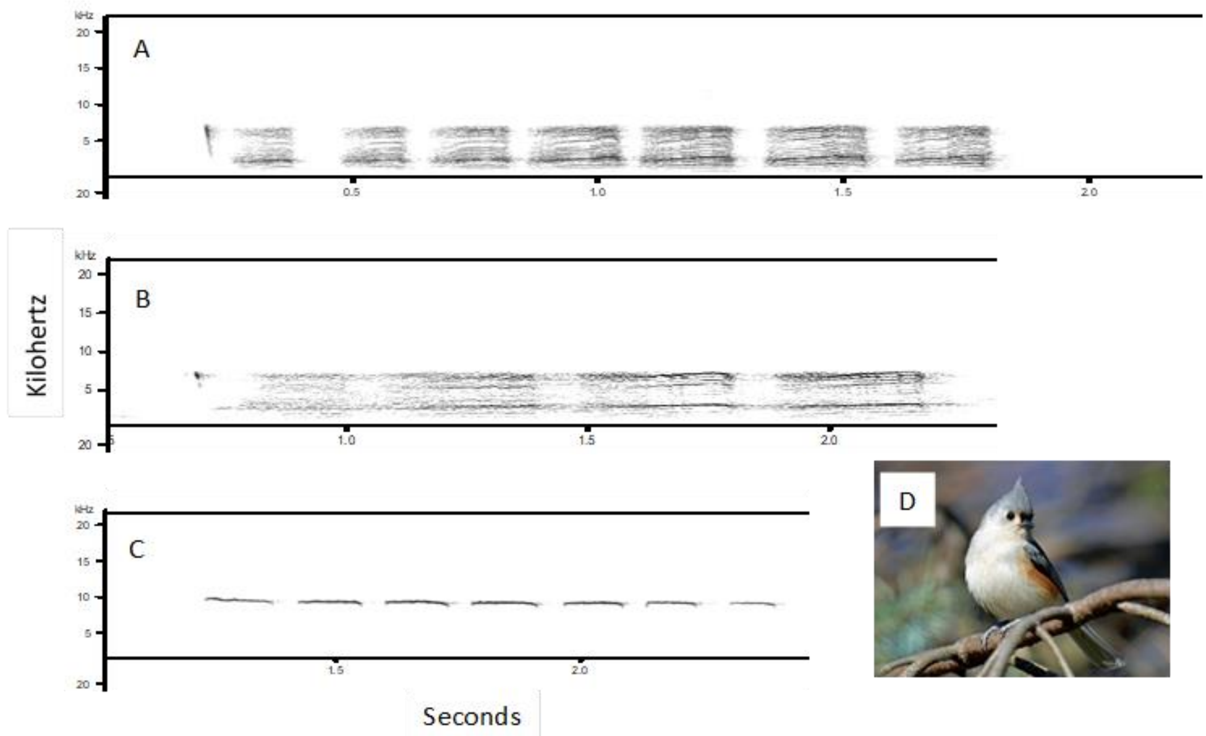

Figure 1. Typical sonograms of the 3 tufted titmouse calls used in this study. Calls pictured were recorded when live titmice were exposed to the following predator stimuli; (A) eastern screech owl (small owl), (B) great horned owl (large owl), and (C) attacking hawk. (D) Tufted titmouse adult (graphic). Call of the treefrog not shown.

Table 1. Eastern Gray Squirrel Behaviors and Descriptions

Behavior	Description	Behavior Class
Foraging	Actively eating or searching ground for food	Baseline
Grooming	Fixing or cleaning fur	Baseline
Laying Down	Body flat on a surface	Vigilant
Head Down	Head pointed lower than shoulders	Baseline
Head Up	Head pointed above shoulders	Vigilant
Tail Twitch	Light tail movement that does not fully curve the tail	Baseline
Tail Flag	Rapid tail movement that fully curves the tail	Vigilant
Climb Up	Going up a tree	Vigilant
Climb Down	Going down a tree	Baseline
Looking Up	Head pointed up when on a tree	Vigilant
Sit Up	Sat up on back two legs and two front legs off the ground (often occurs when eating)	Baseline
Freeze	Body is still and no movement occurs	Vigilant
Call	Any vocalization	Vigilant
Run	Rapid movement where legs fully extent	Vigilant

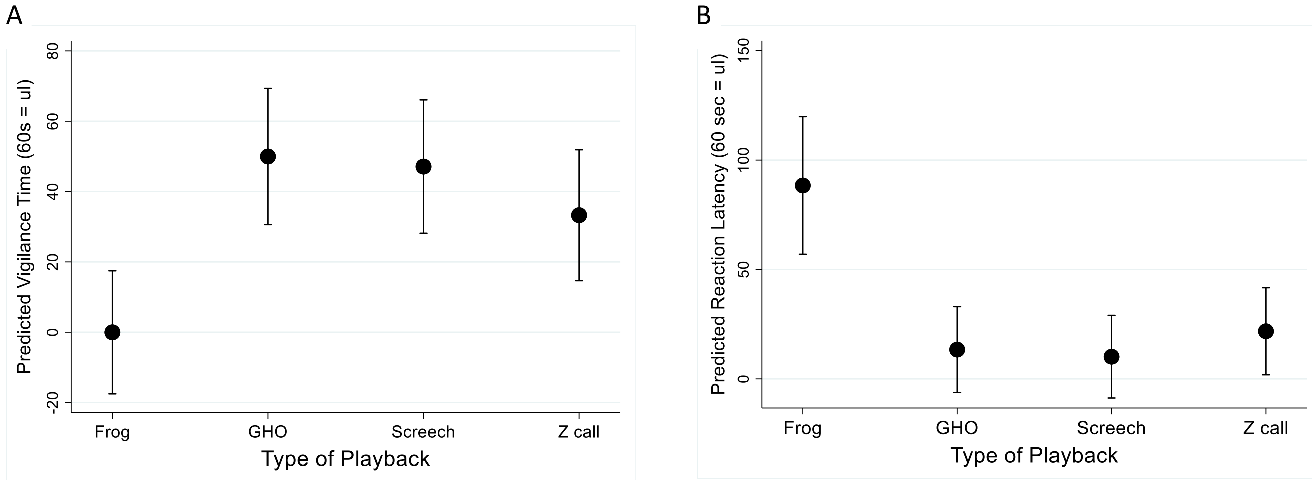

Figure 2. Predicted vigilance time (A) and reaction latency (B) exhibited by squirrels for each call. "GHO" stands for great-horned owl and "Z call" is the high seet call.

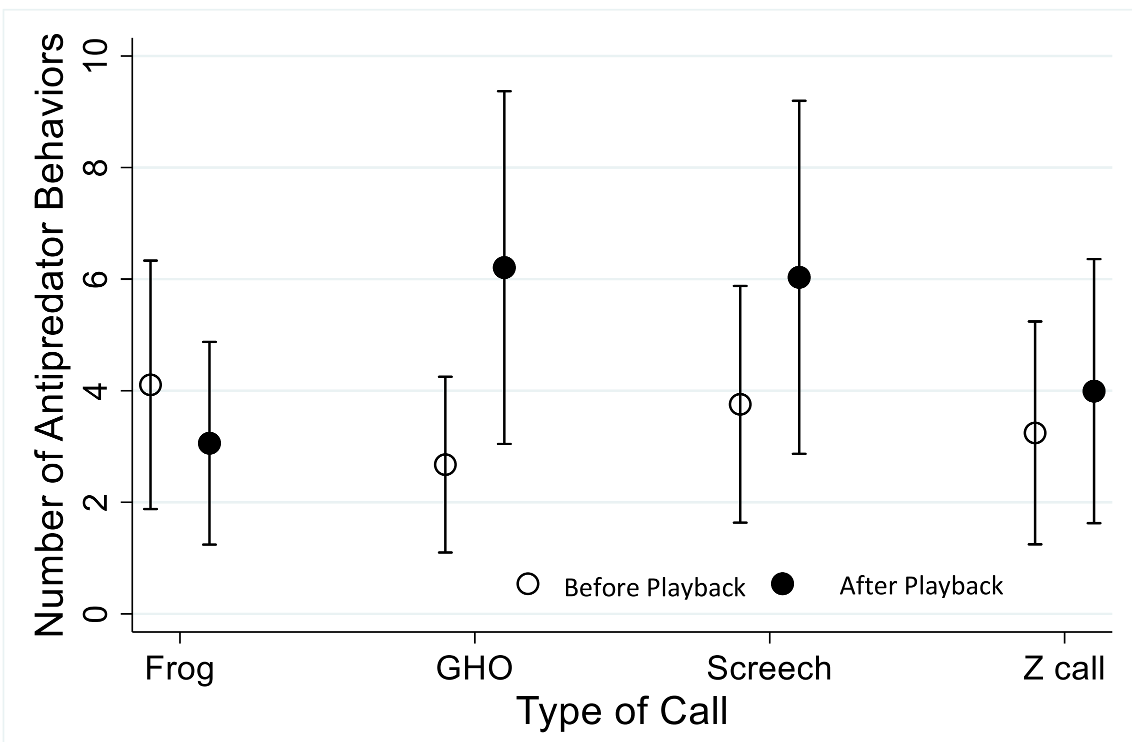

Figure 3. Marginal predicted mean number of different antipredator behaviors exhibited by squirrels before and after playback, of each type of call stimulus, respectively. "GHO" stands for great-horned owl and "Z call" is the high seet call.