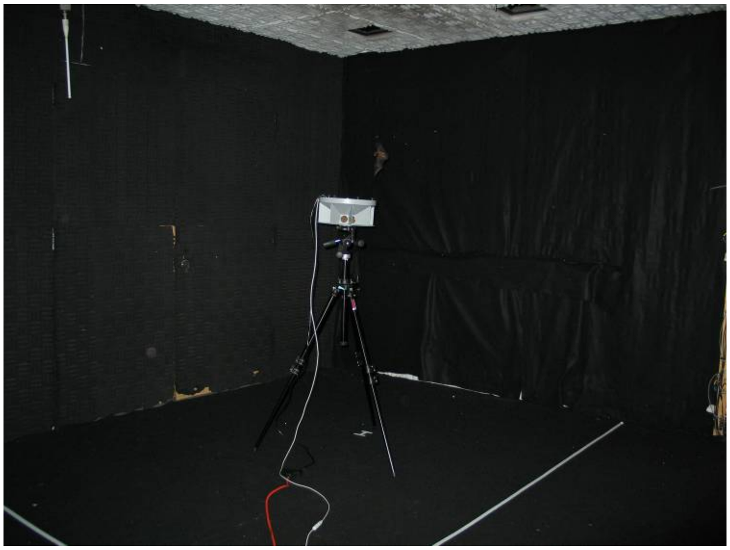
Responses of the big brown bat, *Eptesicus fuscus*, to an acoustic deterrent device in a lab setting



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COVER PHOTOS:

Upper: Big brown bat, *Eptesicus fuscus* (M. D. Tuttle, Bat Conservation International).

Lower left: A female big brown bat flies behind the deterring device while it is turned off (E. B. Arnett, Bat Conservation International).

Lower right: University of Maryland Ph.D. student Genevieve Spanjer demonstrates "jamming" software used by the deterrent device to her advisor, Dr. Cindy Moss (E.B. Arnett, Bat Conservation International).

Big brown bat, Eptesicus fuscus (M. D. Tuttle, Bat Conservation International)

Abstract

Documented bat fatalities from collisions with wind turbines have prompted the search for a means to discourage bats from approaching them. Because echolocating bats depend upon sensitive ultrasonic hearing for orientation and prey capture, broadcasting ultrasound from turbines may disrupt or “jam” their perception of echoes and serve as a deterrent. I tested the response of bats to a prototype eight speaker deterrent emitting broadband white noise at frequencies from 12.5 to 112.5 kHz at about 100 dB SPL per speaker at 1 m. I tested the effect of broadcasting ultrasound on bats flying in feeding or non-feeding trials with the acoustic deterrent device placed among four quadrants in a flight chamber. In half the trials, the acoustic deterrent broadcast broadband noise, and in half the trials, the device remained silent. Bats in feeding trials were presented with a tethered mealworm in the same quadrant as the device.

In non-feeding trials, bats landed in the quadrant containing the device significantly less when it was broadcasting broadband noise (1.7% vs. 22.4%, $p = 0.00375$). In feeding trials, bats never successfully took a tethered mealworm when the device broadcast sound but captured mealworms near the device in about 1/3 of trials when it was silent. Bats in both feeding and non-feeding trials flew through the quadrant containing the device significantly less when it broadcast noise than when it remained silent (non-feeding trials: $n =136$, $p = 0.0035$, one-sided test; feeding trails: $n = 132$, $p = 0.0103$, one-sided test). While bats’ avoidance of the active device was not absolute, these results indicate that broadcasting broadband noise shows promise as a means to deter bats from approaching wind turbines.

Introduction

In recent years, documented bat fatalities from collisions with wind turbines (e.g., Johnson et al. 2003, Johnson et al. 2004, Arnett 2005) have prompted a growing concern about the effect of wind energy development upon bat populations. This, in turn, has lead to a search for effective methods of deterring bats from approaching wind turbines as a means to protect bat populations.

Echolocating bats produce high frequency vocal signals and perceive their surroundings by listening to the features of the echoes reflecting off targets in the path of the sound beam. Thus, these bats depend heavily on auditory function for orientation, prey capture, communication, and obstacle avoidance. Previous studies have indicated that bats are attracted by some high frequency sounds, including the distress calls of conspecifics or other bat species (e.g. Ryan et al. 1985, Russ et al. 2004), the “feeding buzzes” (high repetition rate calls emitted as a bat hones in on its prey) of other bats (e.g., Barclay 1982), and some communicative vocalizations produced by conspecifics (Hill and Greenaway 2005). Conversely, bats of some species avoid certain territorial social calls emitted by conspecifics (e.g., Barlow and Jones 1997), and are deterred by “clicks” emitted by noxious moths (e.g., Hristov and Conner 2005). . Tests of commercial ultrasonic rodent repellers emitting sound at 19 kHz, 23.5 kHz, and 30.7 kHz at 120 dB SPL at ~10cm elicited no response from little brown bats (*Myotis lucifugus*), even when some of the bats were hanging on the device (Hurley and Fenton 1980).

However, because echolocating bats depend upon sensitive ultrasonic hearing, broadcasting ultrasound from turbines may disrupt or "jam" their perception of echoes and serve as a deterrent. Griffin et al. (1963) showed that broadband random ultrasonic noise could mask bat echolocation somewhat but not completely. Such masking of echo perception, or simply broadcasting high intensity sounds at a frequency range to which bats are most sensitive, could create an uncomfortable or disorienting airspace that bats may prefer to avoid.

Here, I investigate the effectiveness of broadcasting broadband ultrasonic noise as an acoustic deterrent for bats. Specifically, I tested the response of captive big brown bats (*Eptesicus fuscus*) to a prototype eight speaker deterrent emitting broadband white noise at frequencies from 12.5 to 112.5 kHz at about 100 dB SPL per speaker at 1 meter. (Figure 1, Figure 2). The objectives of this study were: 1) to determine if bats can be dissuaded from occupying airspace in which broadband noise is being broadcast, 2) to determine if bats will habituate to the sound and cease to be deterred after some passage of time, 3) to determine if the presence of a prey item near the device will provide enough incentive for bats to go near the device, even if they would otherwise avoid it, and 4) to determine if bats in feeding trials will experience difficulty locating and capturing a tethered mealworm within a an airspace in which broadband ultrasonic noise is being broadcast.

Methods

Study Subjects. I tested six adult big brown bats (*Eptesicus fuscus*; 3 females and 3 males) captured in Maryland and maintained at the University of Maryland. Bats were tested under the provisions of University of Maryland Institutional Animal Care and Use Protocol R-06-17. I tested three bats (2 males and 1 female) in non-feeding trials and three bats (2 females and 1 male) in feeding trials (Table 1). Prior to testing, bats were allowed to fly in and freely explore the testing chamber (without the device present) for several days. Bats tested in feeding trials were trained to take a tethered mealworm suspended from the flight room ceiling.

Testing Chamber & Recording Equipment. All trials were conducted in a 7 x 6 x 2.5m anechoic flight chamber at the University of Maryland. Prior to testing, the portion of the room accessible to flying bats and within view of the cameras was divided into quadrants, each measuring approximately 2.75 x 2.5m (Figure 1). Synchronized video and audio recordings were made with two high-speed infrared-sensitive video cameras and a high frequency microphone.

Device. The acoustic deterrent device tested was cylindrical in shape with eight speakers projecting away from the center and slightly upwards (Binary Acoustic Technology). The device was tested while emitting "static" (white noise) at a frequency range of 12.5 to 112.5 kHz at approximately 100 dB SPL per speaker at one meter from the device. It was mounted on a tripod 1.05 m (non-feeding trials) or 1.2 m (feeding trials) from the floor at the base and was placed in approximately the center of each quadrant during all trials (Figure 1).

General Procedure. Non-feeding trials: Each bat was tested in control and experimental trials. Two bats were tested in 40 trials of each type, and the remaining bat was tested in 35 control trials and 36 experimental trials. For control trials, the device was in place but emitted no sound. For experimental trials, the sound emission began prior to releasing the bat. Control and experimental trials, as well as location of the device, were presented in random order each test day, with each combination presented twice to each bat daily (16 trials per bat per test day). For example, a bat might be presented with a control trial wherein the device was in quadrant I, followed by an experimental trial with the device in quadrant IV, then an experimental trial with the device in quadrant I, and so on.

A trial entailed the release of a bat, then allowing it to fly around the room freely. I always released bats from the outside corner of quadrant III, and a non-feeding trial ended when a bat landed or after 30 seconds of flying had elapsed, whichever came first. The first eight seconds of each trial were captured with the high speed cameras and high frequency microphone. Bats were fed a single mealworm following each trial. On days bats were not flown, they were fed in their cage. In addition to audio and video recordings, I recorded the landing location (quadrant), time taken to land, and general observations.

Feeding trials: Feeding trials followed the basic procedure above, except that for each trial a tethered mealworm was suspended slightly above and about 0.3 m to one side of the device. Two bats were tested in 40 control and 40 experimental trials each, and the remaining bat was tested in 36 trials of each type. The exact location of the worm changed with each trial to ensure that the bat had to actively locate it. Feeding trials ended in one of the following ways: 1) the bat landed within the first 120 seconds of release, 2) the bat captured (or knocked down) the mealworm and then landed before 30 seconds had elapsed (total time, as opposed to time elapsed from mealworm capture), 3) the bat captured (or knocked down) the mealworm and then continued to fly until 30 seconds elapsed, or 4) the bat continued to fly without landing, catching the mealworm, or dropping the mealworm for more than 120 seconds. If the bat captured or dropped the mealworm, then the capture (or drop) and the preceding eight seconds were recorded. If the bat failed to contact the mealworm, then the landing and previous eight seconds, or the final eight seconds leading up to 120 seconds of flight, were recorded. All feeding trials were also viewed through a Sony NightShot infrared camera. Bats that did not capture and consume at least five mealworms during the trials were fed five to six mealworms from the tether following trials before being returned to their cage. Bats were fed in their cages on days bats they were not flown.

Data Analysis and Statistical Analysis. For three days of testing per bat, I used the eight-second high speed video clips (8x speed reduction) to count the number of times a bat passed through the quadrant containing the device per trial. A “pass” was scored when a bat flew into the airspace within a given quadrant, and for a second pass to be scored, the bat was required to exit the quadrant, then subsequently re-enter. I only used trials for which I could clearly count how many times the bat passed through the quadrant containing the device. If I watched a trial but was unsure whether the bat passed into a given quadrant, I disregarded this trial and did not use it in the “pass” analysis. Additionally, I counted passes without knowledge of which trials were experimental versus control at the time of analysis.

I used repeated measures ANOVA to compare the average number of times bats passed through the quadrant containing the device on a given bat-day in control versus experimental trails. I also used repeated measures ANOVA to compare the percentage of trials in which bats in control versus experimental trials landed in the same quadrant as the device. Control versus experimental data for feeding and non-feeding trials were compared separately. I used Fisher's Exact Test to compare the total number of feeding trials in which each bat captured the mealworm when the device was emitting sound compared with when it was silent.

Results

Overall, bats in non-feeding trials landed in the same quadrant as the device when it was emitting sound significantly less than under control conditions ($F_{1,4}$= 24.98; p = 0.00375; one-sided test; 115 control trials; 116 experimental trials; 7.5 bat-days for each [1 bat-day = 16 trials for a single bat]; Figure 3). The only bat to land in the same quadrant as the device while it was broadcasting sound (two of 40 trials) did not do so until his thirtieth exposure to the noise. When not broadcasting sound, bats landed in the device quadrant with a frequency of 22.39%, close to the expected value of 25% if the bats randomly distributed their landings among the quadrants.

However, there was no significant difference in the frequency with which bats flying in feeding trials landed in the quadrant containing the device when it emitted sound versus when it was silent ($F_{1,4}$= 0.71; p = 0.223; one-sided test; 116 trials and 7.5 bat-days for each condition; Figure 3).

The average number of times per 8-second video clip from each trial that bats passed through the quadrant containing the device when it was emitting sound was significantly lower than when the device was silent in both non-feeding (70 control and 66 experimental trials used; $F_{1,4}$= 25.99, p = 0.0035, one-sided test) and feeding trails (64 control and 68 experimental trials used; $F_{1,4}$= 13.81, p = 0.0103, one-sided test; Figure 4).

No bat captured a mealworm when the device broadcast sound, and only once did a bat make contact with the worm under experimental conditions. This trial occurred toward the end of the testing period, when the bat had already been exposed to the test conditions for several days. In the absence of sound broadcast, bats successfully captured mealworms in an average of 35.86% of control trials (Figure 5). The number of successful captures in control versus experimental trials was significantly different for each of the three bats tested (Fisher's Exact Tests, $p<0.03$ for each bat, one-sided tests; total n =232 trials)

Discussion

In contrast to previously tested acoustic "repellers" (Hurley and Fenton 1980), the device in the current study shows promise for deterring bats from the surrounding airspace. Bats tended to avoid approaching the device when it was emitting sound, particularly in the non-feeding trials, but not when it was silent. Avoidance was not absolute and appeared to be less pronounced when a prey item was present near the device. Some level of habituation may have occurred. For example, one bat (GR61) avoided landing in the same quadrant with the device broadcasting noise his thirtieth exposure to this condition, but overall, bats tested seemed to remain deterred by the sound at the conclusion of data collection.

This experiment could not conclusively determine whether bats' avoidance of the noise resulted from any impairment of their echolocation, or if they merely found the sound uncomfortable or unpleasant. Previous research indicates that bats' ability to echolocate is quite hardy and is difficult to mask or "jam" unless very specific conditions are met (e.g., Griffin et al. 1963, Møhl and Surlykke 1989). Bats in this study flew without collisions or other apparent "clumsiness" despite the low-light conditions in most trials. The bats' inability to capture mealworms near the device may have resulted from acoustic masking, but it may simply have been caused by bats' desire to avoid the sound being emitted, which may have been unpleasant to them. Further experimentation would be needed to clarify the cause of avoidance and decline in successful capture of prey.

That bats did not capture (or usually even approach) mealworms in the presence of broadband noise and that they flew near the device significantly less when it broadcast sound, show promise for the practical application of this type of acoustic deterrent device. Because of the limited space of the enclosed flight room, this experiment could not judge the effective range of the device. In addition, this study only tested one type of sound, and bats may more readily avoid different sound types, such as erratic pulses of loud, high-frequency or broadband sound, rather than continuous white noise as used in this experiment. Such sound spikes would need to occur at unpredictable intervals, because otherwise bats may be able to time their echolocation calls around the sound spikes. Modifications to the device, such as increasing its ability to transmit noise greater distances or with greater intensity, might also enhance the effectiveness of this type of deterrent method.

While the current combination of sound and device is not yet ideally configured for deterring bats from objects on the scale of wind turbines, this study revealed that broadband sound broadcasts can affect bat behavior and discourage them from approaching the sound source. With further experimentation and modifications, this type of deterrent method may prove successful and imperative for protecting bats from harmful encounters with wind turbine blades.

Acknowledgements

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Table 1. Number of control and experimental test trials conducted.

Trial Type	Number of Bats Tested	Total Number of Control Trials	Total Number of Experimental Trials
Non-feeding	3 (untrained)	115	116
Feeding	3 (trained)	116	116
Total	6	231	232

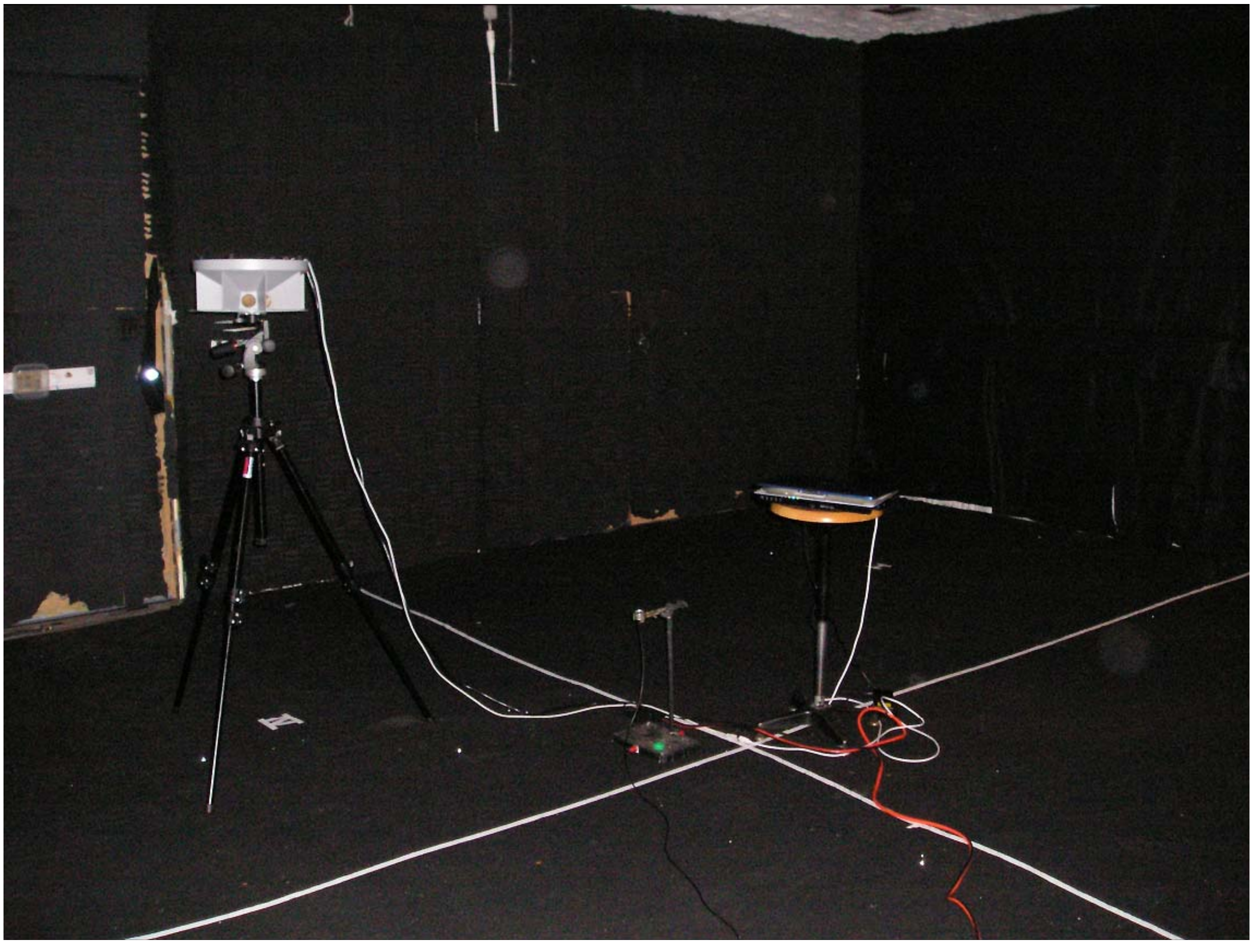

Figure 1. Acoustic deterrent device and flight room set-up. White tape denotes quadrant boundaries

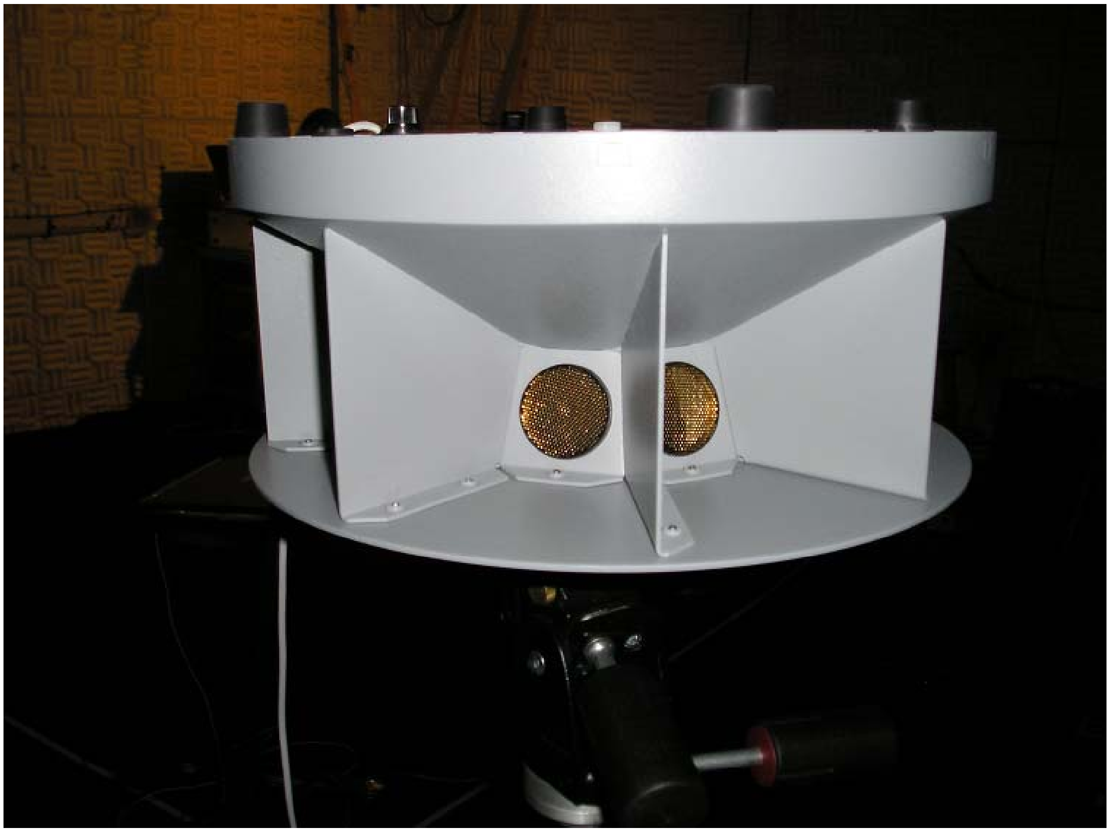

Figure 2. Acoustic deterrent device that was tested. White noise was emitted at frequencies from 12.5 to 112.5 kHz at about 100 dB SPL per speaker at 1 meter.

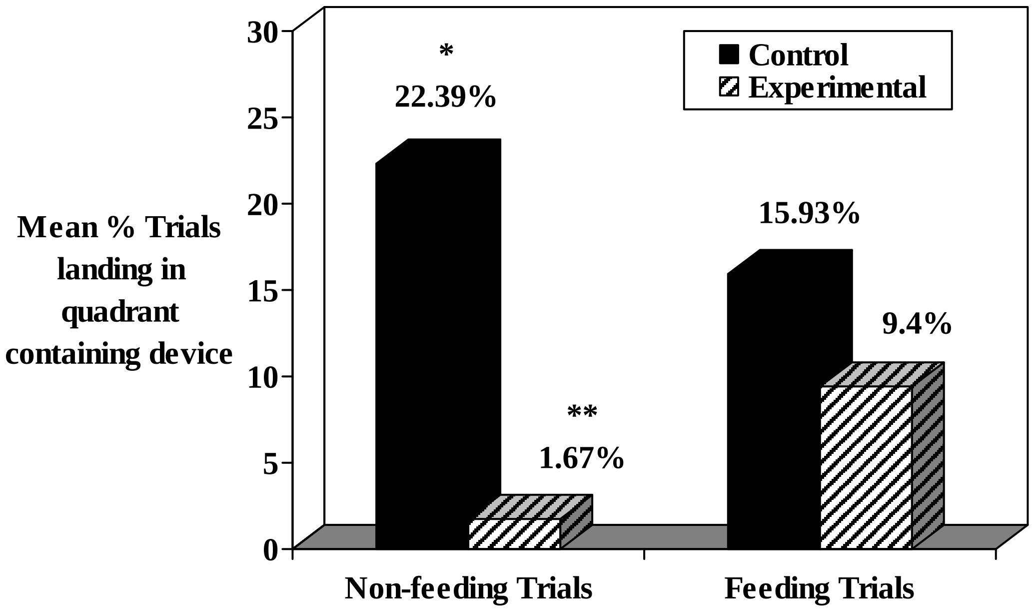

Figure 3. Landing Results. * is significantly different from **.

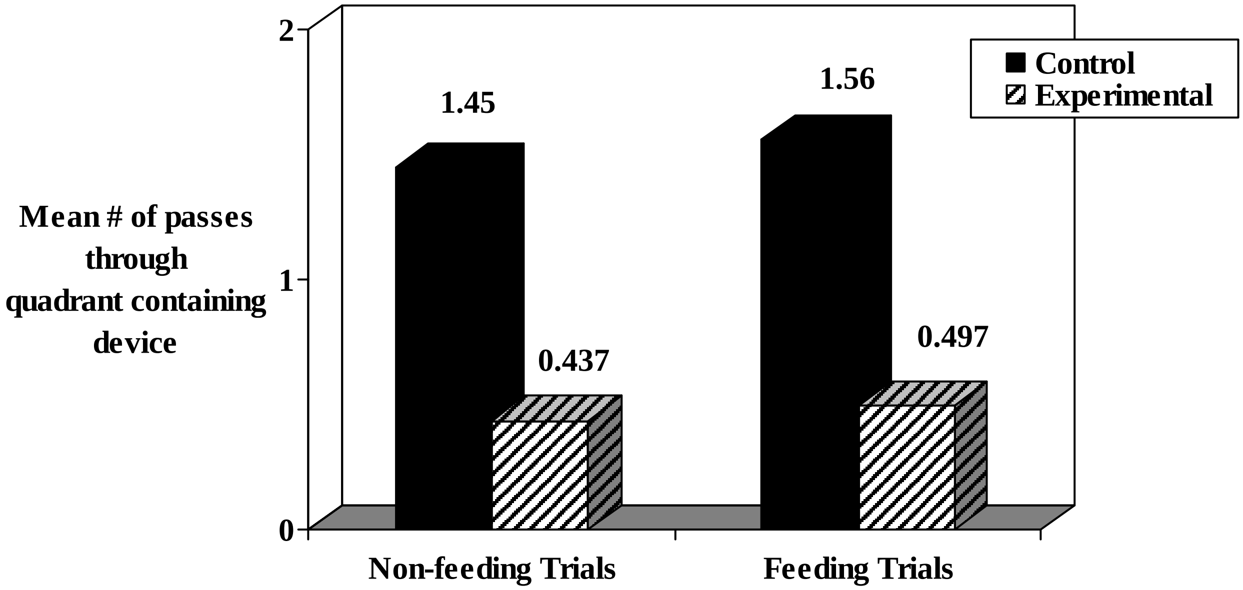

Figure 4. Bats passed through the quadrant containing the device significantly less when it was emitting noise in both non-feeding and feeding trials.

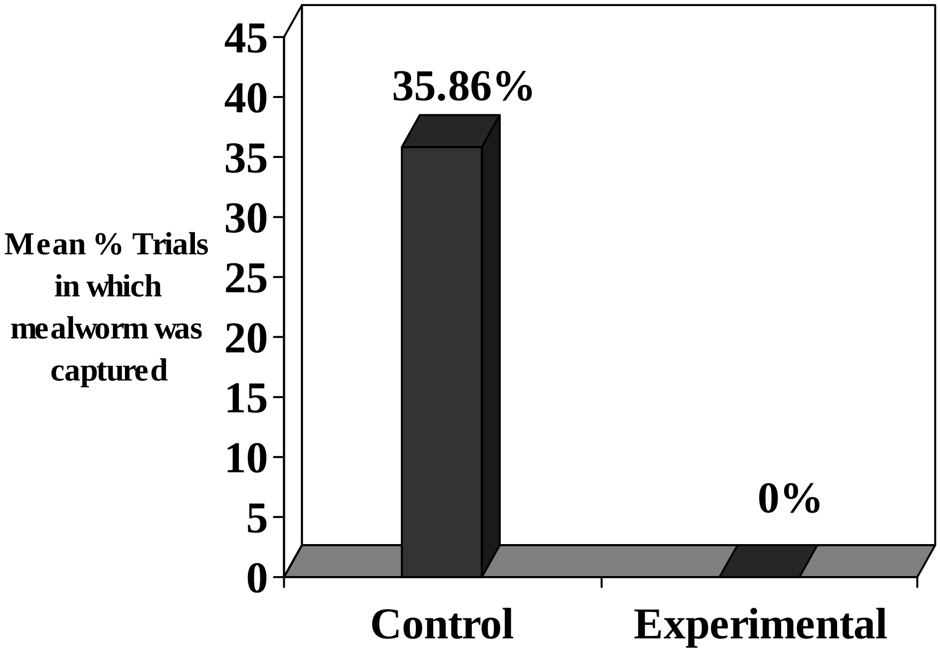

Figure 5. Catching results. The values for control versus experimental trials are significantly different.