Acoustic and Behavioral Responses of the Little Brown Bat (*Myotis lucifugus*) in Response to Anthropogenic Noise and Light Stimuli

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Introduction

With human populations increasing exponentially each year, human-generated noise and light also increases at a quick rate (Swaddle et al., 2015). With these increases in anthropogenic stimuli environmental ecosystems have been drastically affected for many animal species. Bats make great indicator species allowing scientists to measure how changes in their natural environment are affecting them as well as other species in the area (Stone et al., 2015).

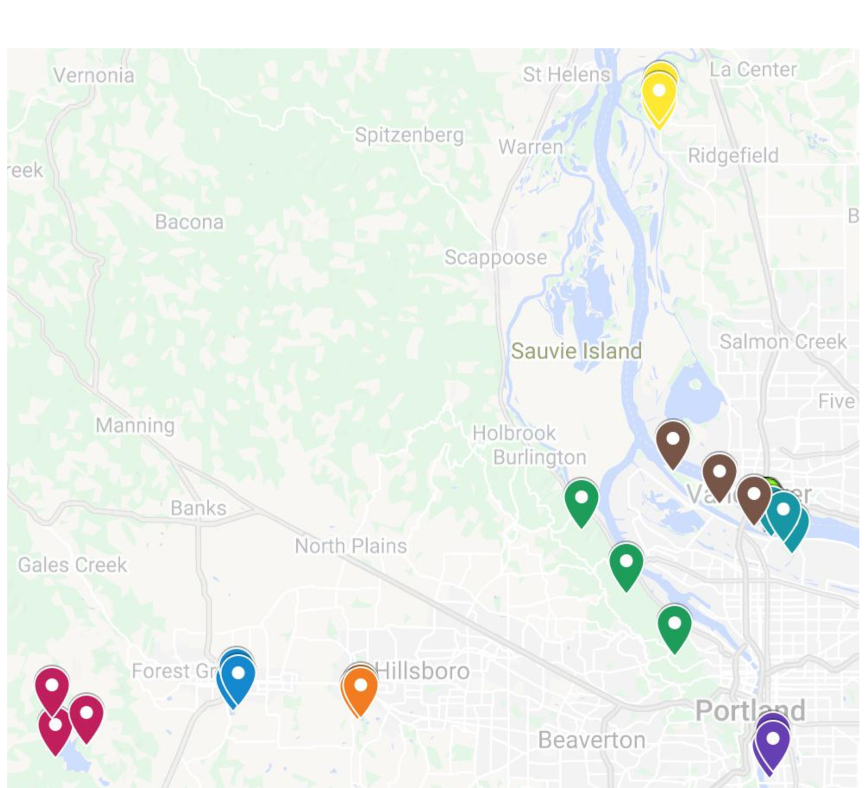
Do bats alter their vocalizations and behavior depending on anthropogenic stimuli, both noise and light, found within their environment?

Animals, both terrestrial and aquatic, can be affected by both human-generated noise and light. Anthropogenic noise has been found to mask vocalizations made by terrestrial birds and *mammals* as well as many oceanic species, especially cetaceans that use echolocations (Templeton, 2016; Weilgart, 2006). Anthropogenic light has been found to disrupt the circadian rhythm of both terrestrial and aquatic animals (Bennie et al., 2015).

Bats are fundamental players within our changing ecosystems. Not only are they important pollinators for some plants but they also are very vital for pest control. Insectivorous bats help control insect populations everywhere in the world and inadvertently aid in the public health of human populations through consumption of insects with the potential to contain dangerous diseases (Boyles et al., 2011). Bats have also been found to be very important to our rural communities as well. Their guano is a wonderful resource used by many farms for the use of fertilizations (Voigt & Kingston, 2015). Loss of these animals would be very detrimental for both natural and human environments.

Previous studies have found that anthropogenic noise from infrastructures alter bats echolocation calls by interfering with bats signal receptors and processing (Bunkley et al., 2015). Bats have been shown to increase their call frequency as well as their amplitude when exposed to traffic noise conditions (Bunkley et al., 2015). Anthropogenic light has been found to cause bats in urban environments to leave their dens later than those found in more rural areas, putting a strain on their hunting effectiveness (Boldough et al., 2007). Studies have also discovered the possibility that bats could use anthropogenic light as a way to increase their hunting success with insects attracted to the lights. The *Myotis* species studied in this research, however, did not use the artificial light for hunting signifying a potentially greater disturbance to these species from anthropogenic light than other species (Rydell, 1992).

While previous studies have focused on only one of the above stimuli, we wanted to look at how anthropogenic noise and light might affect bat echolocation vocalizations and behavior together. As far as we know, this type of study has not been done before (Swaddle et al., 2015). We hypothesized that bats might increase the amplitude of the sound, not necessarily the frequency in response to any masking effects caused by the anthropogenic noise. In response to anthropogenic light, we hypothesized that the bats would come out of their dens to hunt later and their vocalizations would become faster in order to try and locate food quicker to make up for lost time.



Potential Test Sites. Map showing the 8 test sites, each a different color, along with the three sampling locations within each site. Samples will be collected on three consecutive nights producing 24 total trips to each site. Testing will be done between the hours of dusk and midnight each night.

Proposed Method

Target Species

Myotis bats are some of the most common bats found in America with 7 species found specifically in Oregon. The little brown bat (*Myotis lucifugus*) is the most prominent and therefore the target species for our study. They are small bats with wingspans of 25cm or less (Nathusii, 2006). Like all bat species found in Oregon, they exclusively eat insects, using echolocation to navigate and obtain their prey (Nathusii, 2006).

Materials

Base noise levels within each environment will be found using the Casella™, CEL-242 Digital Sound Level Meter (Left).
Light levels, as measured through illuminance (lumens), will be assessed by location. Areas with greater human influence and thereby anthropogenic illuminance will be categorized as, High Light Illuminance and rural areas with low anthropogenic illuminance, as Low Light Illuminance.

The Echo Meter Touch Bat Detector™, Recorder and Analyzer (right), along with the accompanying smartphone application will be used for recording echolocation vocalizations.

Additional recordings will also be collected using a Sennheiser™, ME66 shotgun microphone connected to a Marantz™ PMD661 digital recorder allowing for accurate measurements on ambient noise levels and for later use on bat species identification by echolocation calls, as needed.

Design and Procedure

We will test 8 different sites within OR and WA with varying degrees of anthropogenic light and noise found within the environments. Six sites are of the low illuminance category and include nature reserves with varying levels of anthropogenic noise disturbances. Two sites will be located within highly populated, urban areas of Portland, Oregon for measures of high illuminance and anthropogenic noise. Scan sampling will be used for recordings of all echolocation-emitting subjects. An estimated 24 trips will be necessary for adequate power, first to measure the base noise levels and second to measure the echolocation of multiple bat subjects within each of these locations. Sampling will take place between dusk and midnight when the bats should be at their most active and each site will be sampled over three consecutive nights hopefully gathering results from multiple individuals each time.

Proposed Results

Recordings taken in the field will be analyzed using Raven acoustic analysis software (Raven Pro 1.5; Bioacoustics Research Program 2017). Echolocation calls will be selected, averaged over each site, and compared with the other locations of varying anthropogenic noise and light levels. Variables extracted from the recordings will be as follows: Average frequency (kHz), minimum frequency (kHz), maximum frequency (kHz), number of clicks, quickness of clicks, bandwidth, and call type. Additionally, moon phase will be recorded and covaried against the illuminance levels measured by area as well as any weather variables (e.g., temperature, dew point, humidity, air particulate, and wind speed) that could affect insect and thereby bat by activity.

Appropriate statistical tests will be run through RStudio statistical software (v.3.5.2). Comparison of extracted variables between test sites as well as between treatment types will be will be tested using one-way ANOVA testing. When comparing the sites to one another, a 2 by 6 ANOVA test will be run. Pairwise comparisons will be conduced using a Bonferroni correction to ascertain which between group means were significantly different. For all significant main effects and interactions, an effect size estimate will be calculated to determine the magnitude of significance.

Implications

Results from this study would be a unique addition to the literature since, as far as we know, no current studies have looked at the implications to bat populations in response to both anthropogenic sound and light (Swaddle et al., 2015). With these results, we might have a better understanding of both the potential positive and negative impacts of these human-generated stimuli. Bats are essential players within ecosystems aiding in plant pollination, insect population control and even fertilization of essential farm land (Kasso & Balakrishnan, 2013). The increase in anthropogenic light and noise could lead to the loss or relocation of specific bat species severely displaced by these disturbances.

Illuminating areas where bats forage and/or roost can alter their hunting patterns and hibernation behaviors as well as effect other animals species found in those areas (Stone et al., 2015). While there are considerable conservation concerns regarding the effects light can have on bat emergence and foraging behavior, there is a potential upside on the ability to control bat movements using light. (Stone et al., 2015; Boldough et al., 2007)

Masking components coming from the increase in human-generated noise has been shown to mask prey noises making it more difficult for bats to locate prey as well as force them to alter their echolocation calls accordingly (Schaub et al., 2008; Bunkley et al., 2015). From these studies, the disastrous effects of noise have been brought to light allowing for conservation efforts to gradually increase (Schaub et al., 2008).

A study combining these two variables would allow for conservationists to look at the combined effects rather than separate variables and make more informed decisions on conserving these essential animals in found around us.

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