The effects of anthropogenic noise measured by changes in vigilance behavior in white-throated sparrow (*Zonotrichia albicollis*)

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Abstract

Anthropogenic noise has been shown to increase vigilance behavior in birds. However, no experiment has compared the effects of differing anthropogenic noise types. In this experiment I compared the impact of three different types of anthropogenic noise (road, airport, and white noise) on the vigilance behavior of ten white-throated sparrows. By quantifying the duration of time each bird spent demonstrating vigilant, stressed, or foraging behaviors before, during, and after being exposed to each noise treatment, I was able to determine the impact of each anthropogenic noise. No treatment was found to be significantly more disruptive to vigilance behavior. In future studies a larger sample size would be better suited to address this question.

Introduction

With an ever-increasing human population and decreasing natural habitat, more and more organisms are being exposed to anthropogenic noise. Despite this increased exposure, the effect of anthropogenic noise is still unclear. It is known that anthropogenic noise reduces the distance from which signals can be perceived (Barber et al, 2009). This can lead to alterations in foraging and anti-predator behavior (Barber et al, 2009). Slabbekoorn and Ripmeester (2007) found the majority of anthropogenic noises to be at low frequency and an increase in this noise type potentially detrimental to bird species by increasing stress levels, masking warnings associated with an approaching predator and general interference with acoustic signals. These could potentially affect the fitness of an organism. However, in order to fully understand the impact of anthropogenic noise, it is advantageous to first have a solid understanding of the avian auditory system to determine the type of anthropogenic noise that has the greatest disturbance.

Although several studies have investigated how anthropogenic noise affects bird song (e.g. Mockford and Marshall, 2009), there is little research investigating if noise interferes with the perception of signals or cues by masking them. Quinn et al. (2006) showed that when exposed to white noise birds increase their vigilance behavior while feeding. This is believed to occur because if noise is prohibiting a bird's ability to detect predators using auditory cues, they are then forced to rely more heavily on visual cues and spend more time scanning for predators rather than feeding. Currently, it is unclear if the results of Quinn et al. (2006) are consistent across different types of anthropogenic noise or if birds would increase their vigilance behavior more drastically in certain noise environments. Dent et al. (2009) found that birds could detect the start and end of a signal if noise was constant, but they were less able to detect a signal if noise was not constant. This suggests that in constantly noisy environments, like areas near generators producing consistent white noise, birds may have less difficulty detecting signals than in an environment like a city, where noise is less predictable and less consistent.

In this experiment, I will be measuring the vigilance behavior of white-throated sparrows (*Zonotrichia albicollis*) that are exposed to three different types of anthropogenic noise (airport, road, and white noise). All three noise treatments have differences in amplitude and frequency. White noise has consistent amplitude and frequency with a wide frequency range (Fig 1a.). This is in contrast to road noise, which has rapidly fluctuating amplitude and frequency (Fig. 1b.) and airport noise which has gradually fluctuating amplitude and frequency (Figure 1c.). By determining the change in vigilance behavior I will be able to discern which noise type has the greatest interference with avian hearing based on the highest change in vigilance behavior. I hypothesize that there will be a significant difference on vigilance behavior between the three treatments and road noise will have the greatest disturbance on avian hearing because it fluctuates in frequency most rapidly. A rapidly fluctuating frequency reduces an organism's ability to detect individual sounds, as shown in Dent et al. (2009), and therefore is predicted to result in the greatest increase in vigilance behavior. White noise is the most constant in amplitude and frequency and therefore it is predicted to result the least increase in vigilance behavior. This research will provide information on how to approach potential conservation efforts in the future by identifying which types of anthropogenic noise present the greatest interference of avian hearing.

Methods:

Ten white-throated sparrows (*Zonotrichia albicollis*) were captured using mist nets at the University of Notre Dame Environmental Research Center (UNDERC) located on the border between Wisconsin and the Upper Peninsula of Michigan (FWS permit 22252). All trials were conducted between July 2, 2010 and July 13, 2010. After capture, the birds were held in captivity a minimum of 24 hours before experiments were test (Approved by University of Notre Dame IACUC). The birds were food deprived for 8 to 11 hours before the trial to encourage foraging behavior during the trial. Birds were transported to the location of the study in small canvas bags and then were placed into the cylindrical experimental cage that was 65 cm tall and had a diameter of 74 cm. Cages were placed on the forest floor in a mixed deciduous-coniferous forest. The site of behavioral trials was kept constant for all treatments and birds to reduce variability in light intensity, canopy cover, and distance to the nearest refuge. At the bottom of the cage, approximate 1 cup of mixed seed was distributed on an indoor/outdoor carpet that lined the bottom of the cage. Sony video cameras were placed so that one video camera recorded the birds from the top of the cage and the other from the side of the cage. After starting the cameras the observer retreated to a car blind approximately 20m away.

Within each trial there were three noise treatments. For all birds, all three treatments were run in succession with the order of treatments being chosen at random. For each treatment, the birds were allowed a four-minute acclimation/calming period inside the test cage before the treatment started. Following the acclimation period was two minutes of silence followed by two minutes of noise treatment, and then two minutes of additional silence before the next treatment series began. Trials were run in succession to reduce the duration each bird was in captivity.

The three sound treatments used were airport, road, and white noise. Airport and road noise treatments were collected using an Olympus DS-30 digital voice recorder. The airport noise was collected at Indianapolis International Airport approximately 500m from the runway and was edited using Cool Edit Pro to consist of a series of airplanes taking off (starting from when the observer first heard the airplane and ending when the observer could no longer hear the airplane). The center of frequency for the airport treatment was 516.8 Hz and had an average amplitude of 70.05 dB with a maximum amplitude of 73.5 dB. The road noise was collected at a rest stop along Highway 65 between Indianapolis and West Lafayette, Indiana. The center of frequency for the road treatment was 861.3 Hz. It had an average amplitude of 62.79 dB and a maximum of 75.8 dB. Any bird calls within the audio file were editing out using Cool Edit Pro to make sure that birds were responding to the noise and not hetero specifics. Finally, the white noise was computer generated using Cool Edit Pro. The center of frequency for the white noise treatment was 111997 Hz. The average amplitude was 70.8 dB and had a maximum of 77.9 dB. The range of frequencies for each sound was determined using Raven Pro 1.4. The two minutes prior to noise and after noise exposure formed the baseline of vigilance behavior and was used to see if vigilance behavior changed during or after noise exposure. The mean environmental noise amplitude was 57.8 dB. After the trial period was over birds were taken back to the lab, measured, banded with a Fish and Wildlife Service aluminum band, and then released.

Video recordings of the birds were analyzed for vigilance behavior (quantified here as the duration that the head was up verses down and the rate of head movements during head up behavior) using JWatcher 1.0. Each behavior was quantified before, during, and after noise treatments. Head up was defined as anytime the head was above the midline of the body; head down behavior was anytime the head was below the midline of the body; and stressed behavior was anytime the bird was not on the ground. This behavior usually constituted the birds rapidly flying upwards, clinging onto the sides of the cage, or quickly flying/hopping between the sides of the upper portion of the cage. During bouts of head up, the number of head movements was also coded. A head movement was defined as any movement of the head while in head up behavior. Data was log transformed and nested ANOVAs were used to compare the total time that the bird was doing each behavior (head up, head down, or stressed) within a given noise treatment (here referred to as total duration). The total duration was the dependent variable with time of the behavior (before, during, or after noise) and noise treatment as the independent variables in which the time of the behavior was nested within the type of noise. Tukey post-hoc tests were used to determine which comparisons were statistically significant. Nested ANOVAs were performed for head up, head down, and stressed behavior. Although the total duration of these behaviors are dependent on one another, we felt it was important to analyze all of these behaviors separately to gain the best understanding of the data. All statistical tests were done using SYSTAT 13.

In order to determine the rate at which birds were scanning for predators we calculated head movement rate. Head movement rate was calculated as number of head movements per total time the head up in milliseconds. The data was log transformed and a nested ANOVA was used to compare the head movement rate for the time of behavior and noise treatments for head up behavior.

Additionally, we used a doubly nested ANOVA to test if bird morphotype significantly affected our results since white-throated sparrows are dimorphic (tan and white morphs), but not sexually dimorphic. We captured 5 white morphs and 5 tan morphs. Morph was nested within the time of behavior, which was nested within noise treatment.

Results

Total Duration of Movement

When analyzing the data I considered total duration of each behavioral state (head up, head down, and stressed) before, during, and after each sound type. Across all treatments, the greatest amount of time was spent with the head up with a total of 805.4 seconds (Figure 2). A total of 67.3 seconds were spent with the head down and 209.0 seconds were spent stressed (Figure 2).

There was not a significant difference between the noise treatments for any of the behavioral states ($p=0.342$, Fig. 3). However, the amount of time spent stressed during the road noise treatment was significantly higher during treatment then it was before ($p=.006$) or after ($p<.001$). There was also a significantly lower amount of total time spent head up during the road noise treatment in comparison to before ($p=0.038$) and after ($p=0.027$) the treatment (Figure 2). All other comparisons were found to be insignificant.

Head Movement Rate

Overall there was a significant difference between head movement rate and sound treatment when considering the time of the behavior($F_{0.05, 6, 1019} = 6.724$, $p<0.0001$, Figure 4). There was also a significant difference between airport and road treatment ($p=.008$, Figure 4). Additionally, in the road treatment, movement rate was significantly higher during noise in comparison to both before and after treatment ($p<.001$ and $p=.002$ respectively, Figure 4). In the white noise treatment, movement rate was significantly higher during the noise compared to movement rate before the noise ($p<.001$, Figure 4). All other comparisons were found to be insignificant.

Morphology

Overall white and tan morphs were not significantly different for head up and head down behaviors. Tan morphs did however, spend significantly more time stressed than white morphs ($F_{1, 88}=6.285019$, $p=0.014$). White morph birds also spent a significantly higher amount of total time with their head up during sound treatment than tan morphs ($p=0.016$).

Discussion

Total Duration of Behavioral State

Noise treatment does not appear to significantly affect how much time an organism spends being vigilant, stressed, or foraging based on my data. This is not surprising considering that, with the exception of the road treatment, I did not see birds altering their behavior during the noise treatment. This suggests that contrary to other studies, noise does not affect the vigilance behavior of birds. The results for the road treatment showed that birds significantly altered their head up and stressed behavior during noise treatment. In particular birds were more stressed during road noise and therefore allocated less time to head up behavior (consequentially making that value significant).

These results are contradictory as to what I expected, because when making my predictions I did not account for a stress response. During the road treatment the amount of time stressed during the trial was significantly higher during the noise treatment than both before and after the treatment. This significantly greater amount of time that the birds were stressed could account for the significantly low amount of time spent head up. The amount of time spent stressed could not be spent head up scanning for predators.

This increased stress level during road noise treatment could be attributed to an order effect of the trials.

One variable that I did not account for in my statistical tests was whether behavior varied between the first treatment and the second or third treatment. This could account for why the road treatment had significant differences in behavior during noise and non-noise periods. While trial order was randomized, road noise was randomly chosen as the first treatment five times out of the ten total trials. I observed that when the bird was first introduced to the testing cage, birds were generally stressed. They were given an acclimation period before the trial began but if the road treatment was early in the sequence the bird could still be stressed from transferring between cages. Alternatively, birds may have become satiated by the second and third trials or they may have acclimated to the noise itself. In any of these scenarios, birds would be expected to either respond less to noise or spend less time foraging.

Another problem that I was unable to presently statistically address with my data was to do a repeated measures ANOVA treatment across the different behavioral states. This statistical test would allow me to account for the fact that up, down, and stressed behavior are dependent on one another. That is that if there is more stressed behavior then there is going to be less of either up or down behavior. To properly analyze my data statistically I would need to do nested ANOVAs within a repeated measures ANOVA and this is beyond my statistical understanding presently. At a later date, my mentor will be bringing this data to statistician to properly address these statistical problems. Despite the present lack of significance of our data, there do seem to be some insignificant trends that are worth discussing.

Also, assuming anthropogenic noise does in fact increases vigilance behavior, it would be expected that total time spent head down would decrease and total time head up would increase during treatments. While this is the general trend (although no significant difference) for airport and road noise, it does not hold true for the white noise treatment. Total time head down during the white noise treatment was higher (although not significantly so) during treatment and lower before and after. This is contradictory as to what is expected.

Head Movement Rate

If vigilance increases during noise, I expected birds to scan more often (and thus have a higher head movement rate) when they had their head up. I did find that head movement rate was significantly different among the different noise treatments, suggesting that different types of anthropogenic noise do affect the rate of head movement. The road noise treatment followed the predicted result with significantly higher head movement during the noise in comparison to before the noise. Also as expected, after the noise the movement rate decreased to a level that was not significantly different from the movement rate before the treatment. This trend did not continue with the white noise treatment. Although movement rate did increase from before the noise to during the noise, movement rates stayed elevated after the treatment. This could potentially be caused because of a residual effect of the treatment. The white noise treatment could have caused a heightened sense of awareness that carried over even when the noise stopped. This has some interesting implications for conservation. If this were to hold true for all types of anthropogenic noise then not only would vigilance behavior be affected in the presence of anthropogenic noise but could also have a carry over effect if the organism has been exposed.

Morphology

When first designing the experiment I did not take into consideration their being a difference between the two morphologies of white-throated sparrows. However, studies have shown there are significant behavioral differences between the two (Tuttle 2002). White-morphs tend sing more and are more aggressive during mating season (Tuttle 2002, DeVoogd et al

2004). When taking morphology into consideration I found tan morphs to spend significantly more time stressed and white morphs significantly more time with their head up. Although we found some significant results this data set is too small to draw any definitive conclusions about different reactions between the morphs.

Conclusions

While this data did find some significant results, overall it did not support the hypothesis that certain types of anthropogenic noise has an effect on vigilance behavior and some anthropogenic noises are more disruptive than others. This can be partially explained due to a number of factors. Our sample size was relatively small (10 birds) and when taking into consideration the multiple treatments, time periods, and movements, this small sample size did not leave many degrees of freedom and therefore the statistics are not very strong. We also ran into the problem of individual variability. Some birds showed a noticeable change in behavior between the quite and noise periods. However, other organisms moved very little throughout the entire experiment or stopped moving at some point in the trial presumably due to stress. Also while I tried to standardize the food deprivation time, deprivation did range from eight to eleven hours, which could potentially have an impact on foraging behavior. The birds were also in captivity varying lengths of time. While captivity time kept at a minimum the amount of time each individual bird spent in captivity before the trial varied between one day and a little over a week. This difference in captivity time could have an effect on the bird's stress level and presumably its foraging behavior.

In future experiments these difficulties could be ameliorated. The sample size of the test group needs to be larger to minimize the effect of individual variation. Food deprivation time and amount of time in captivity need to be standardized. Morph type should also be taken into consideration when analyzing the results. Although the data did not support the hypothesis that different anthropogenic noise would disturb avian hearing at differing levels, this is still a topic that could be clarified by additional experimentation in the future.

Acknowledgments

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Figures and Tables

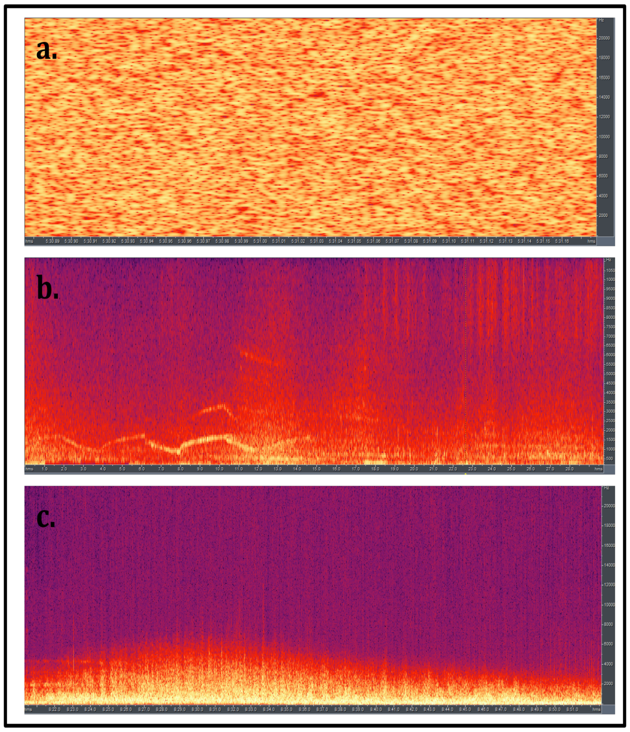

Fig.1 Visualization of noise treatments using Cool Edit Pro. a) white noise, b) road noise, c) airport noise.

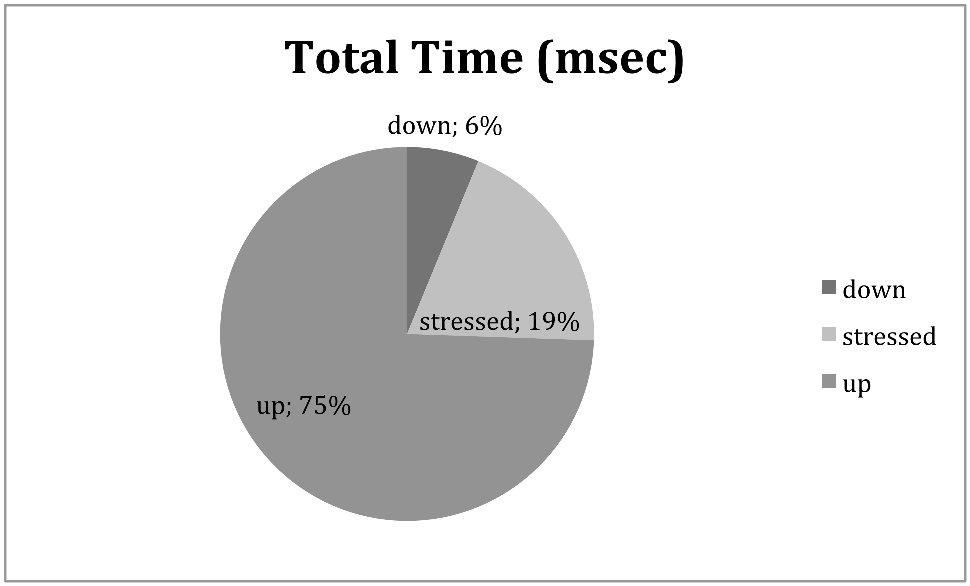

Figure 2. Total allotment of time spent in each of the movements, up, down, and stressed, throughout all noise treatments

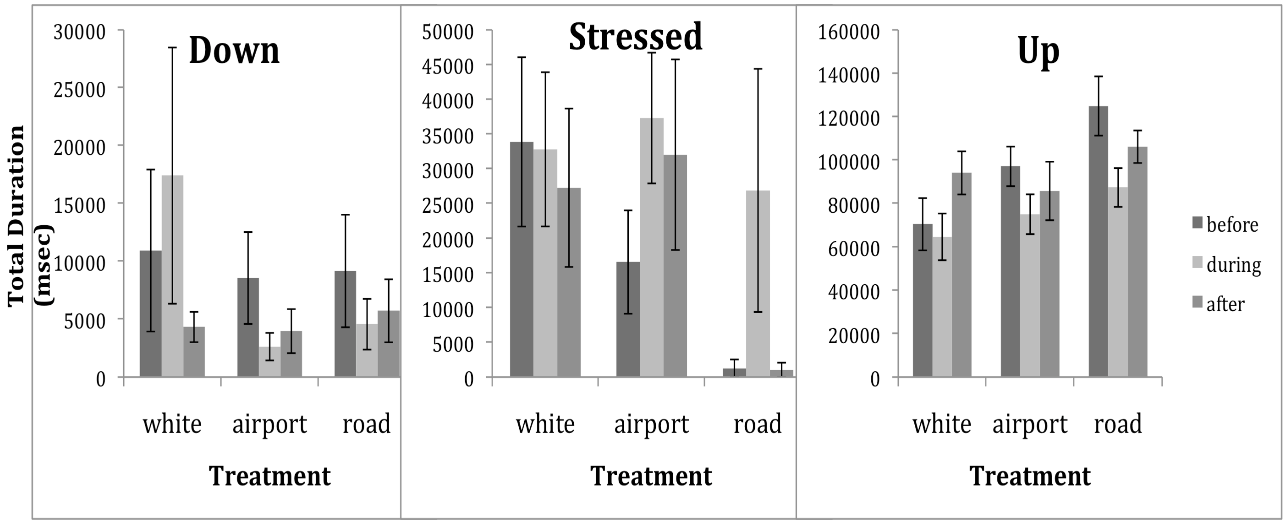

Figure 3. Total Duration (in milliseconds) of time spend head down, head up, and stressed before, during and after each of the three treatments, white, airport, and road noise. Bars are +/- standard error.

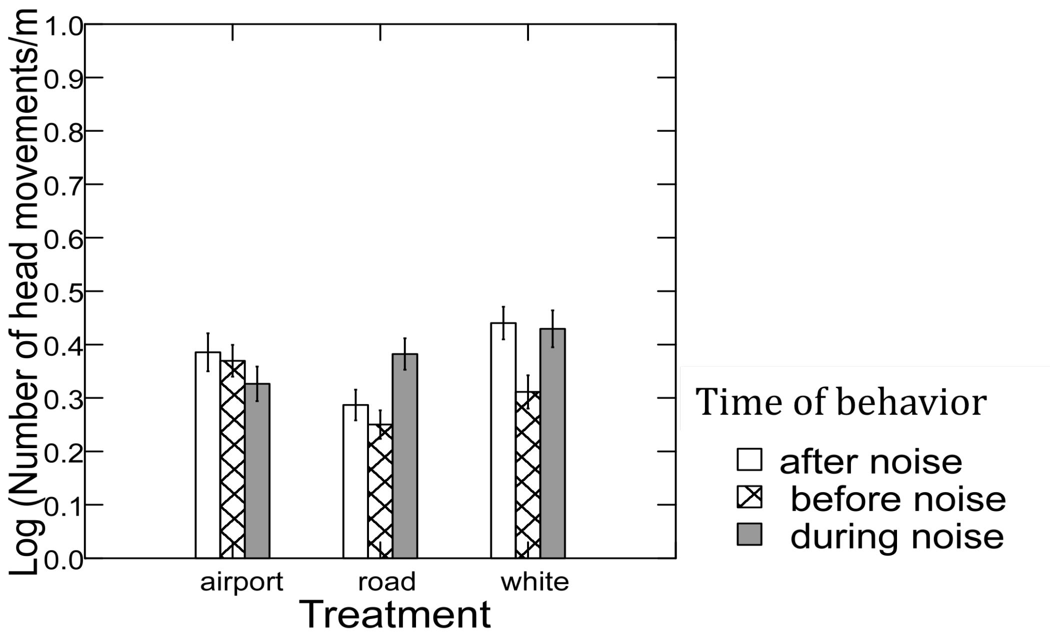

Figure 4. Head movement rate (number of head movements per time of head up in milliseconds before, during, and after airport, road, and white noise treatments. Bars are +/- standard error.

Table 1. Average and maximum decibel level of airport, road, and white noise as well as the control period with no noise.

	Average dB	Maximum dB
Quite	57.8	73.5
White Noise	70.8	77.9
Airport	70.5	86.5
Road	62.79	75.8