THE EFFECTS OF TRAFFIC NOISE ON SINGING BEHAVIOR OF VEERIES

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Abstract. The anthropogenic sounds that accompany highly populated urban environments, such as noise from cars and traffic, can alter vocal communications between animals, in particular, the vocal communication of songbirds. Interference in communication can decrease the likelihood of successful mate selection and breeding, resulting in overall decreases in species richness, or population density. Other studies have confirmed that anthropogenic noise can alter the frequency and structure of different species' songs, as well as biodiversity patterns. Therefore, we set out to examine the effects of this acoustically challenging environment on local species. Veeries (*Catharus fuscescens*) were selected for their deep-woods proclivity and complex song with the expectation that they would be representative of species sensitive to acoustic disturbances. We examined Veery songs recorded in forest and wetlands habitats with no road noise and as compared to song samples taken from forested "phantom road" sites where we played recorded traffic noise. The forest control site had a general trend of lower bottommost frequencies when compared to the wetland control site and the two forest roads sites. Additionally, one wetland-habitat control site contained considerably more masking events by other bird species, suggesting a greater avian biodiversity. Although these results are statistically non-significant this is most likely due to a very small sample size (n =3). This preliminary study points towards several interesting patterns that could be further analyzed in future experiments and useful for later conservation efforts.

INTRODUCTION

Urbanization is a quickly expanding threat to the world's biodiversity. Many individual components of urban environments have affected the reproductive habits of bird species. Artificial light in urban areas may affect the reproductive success of Blue Tits. In cities with artificial light, Blue Tits sang earlier in the morning and had a greater paternity gain (more extra-pair offspring) in comparison to forest areas (Kempenaers et al. 2010). Numerous other aspects of urban landscapes affect wildlife health and biodiversity. Ecologists identified that areas with higher human-made structures (electricity poles, telephone cables, light posts) became preferential habitat areas with common bird species, but not with rare bird species in west-central Mexico. Researchers found that domestic dogs and cats, however, appeared to be a prominent threat to all bird species (Macgragor 2011). Furthermore, arguably one of the most common pieces of urban areas, roads, are also known for heavily affecting wildlife biodiversity and population density.

Roads pose many different threats to the ecological environment. Air pollution, automobile collisions, habitat loss, and road noise can all affect the number of species able to live in urban environments. Road noise, however, may hinder vocal communication between organisms. Vocal communication is an important aspect of reproductive success and territory defense, both necessary elements of fitness. Avian populations, in particular, depend on vocal communication for their reproductive efforts (Bradbury and Vehrencamp 1998). There are serious consequences for bird populations if individuals are not able to sing and hear song properly.

The effects of road noise on the singing behavior of many different passerine species have been investigated. Several studies have dealt directly with the effects of road noise on avian vocalizations in a single species. Wood et al. (2006) used real-time anthropogenic sounds on the sidewalks of Portland, Oregon. Scientists picked out Song Sparrows on accessible, public sidewalks and paths, recorded their songs, and then the subsequent amounts of background noise. Birds on sidewalks sang songs with higher lowest frequency notes than those in forests, possibly in order to avoid masking by low-frequency anthropogenic noise (Wood et al. 2006).

Another study suggested many urban Great Tit bird songs were shorter and faster than forest individuals' songs (Slabbekoorn et al. 2006). In addition, this study also correlated higher overall frequencies in songs in response to greater anthropogenic background noise. However, taking song samples from real anthropogenic conditions may introduce many other factors of roads into the results. Playing recorded traffic noise in avian habitat is an innovative way to assure the effects on song are from sound alone. McClure et al. (2013) set up a series of speakers over many forested habitats and played recorded traffic noise for about 10 hours, following a regular traffic flow, creating a "phantom road." They concluded that species richness decreased while the roads were on in comparison to when the roads were off. The control sites of their experiment also had higher species richness. (McClure et al. 2013). Ecologists are striving to know more about how bird communities will react to urbanization so as to project and generalize the reaction of many different bird species. However, in order to do this, it is important to investigate as many individual species as possible.

We used several of our own phantom road sites, following McClure et al. methods, on the grounds of the Cary Institute of Ecosystem Studies (Millbrook, NY) to investigate the differences in Veery song in the presence of road noise. Veeries are a ground foraging, deep-woods, Neo-tropical migrant. We selected this species for our investigation because their complex song extends into the frequency range of anthropogenic noise (1 to 2 kHz). Additionally, because they are typically not found in urban sites, they are a desirable representative for birds potentially sensitive to acoustic disturbance.

We expected (1) Veeries to have higher lowest frequencies at phantom road sites in order to avoid masking by traffic noise (2) A greater frequency range (greater delta frequencies) at control sites. If control-site Veeries were not raising their lowest frequencies, the frequency range of their song will be greater. And we expected (3) fewer masking events by other bird species at phantom road sites, due to a projected species richness decrease.

MATERIALS AND METHODS

Sampling Site

Sound samples were collected at the Cary Institute of Ecosystem Studies. Specific locations within the campus are as located on the map (figure 1). Three of the forest sample sites were classic eastern temperate deciduous oak, maple, and hickory forests, while the wetlands site was characterized by tall grassy meadows, and some forest.

Assembly and Operation of Phantom Roads

Three roads were activated in this experiment. Each road extended for 150 m, and consisted of 7 speaker stations located about 21 m away from one another. Each speaker station was composed of a metal post that held a Braven 625S speaker and an iPod Shuffle in a plastic, rain-proof container. A plastic, gallon-sized, spray-painted container was attached to the top of the metal post to further protect against rain damage and camouflage the speaker.

The speakers played a ten-hour recording of traffic noise recorded on New York State Route 44, adjacent to the Cary Institute property. The recording was edited to remove all non-traffic noises such as birds or talking. The speakers played Monday through Friday between 6 and 7 am to between 4 and 5 pm in order to simulate the traffic flow of a regular work-week. The recording, once initially turned on, did not play at full volume; it increased steadily for thirty minutes. Once at full-volume, the speakers could be heard at 59.1 dB from 10 m distance. During the last fifteen minutes of playing time, the volume would decrease from its maximum volume level to silence.

Veery Singing Samples

Each of the three phantom road sites, named the “Spillway,” the “Dump,” and “Canoe Hill North,” were sampled twice resulting in six sampling events for the experimental effect. The other inactive phantom road sites were not chosen for control sampling due to a lack of Veery singing; therefore, the “Carys” and the “Lowlands” were selected as control sites, because there was known Veery singing at these locations.

They were sampled from three times each, totaling in six sampling events. The samples were taken as consecutively as possible from June 10, 2014 to June 30, 2014. Samples could not be taken if it was raining. At each of the road and control sites, sampling occurred for two and a half hours between the hours of 6 and 9 am. At road sites, the speakers were turned on and allowed to meet their maximum volume after one half hour, then sampling occurred for two hours. Sound recordings were taken using a Marantz PMD660 recorder was used along with a Sennhiezer shotgun microphone. During each sampling event, we attempted to sample as many individuals as possible. Occasionally during few counter-singing events, two birds were able to be recorded simultaneously.

Song Analysis

Song files were analyzed using Raven Pro 1.4 software. Measurements for high frequency (Hz), low frequency (Hz), peak frequency (Hz), delta frequency (Hz, delta frequency = high frequency – low frequency) and energy (dB) were taken for each acceptable song file. Masking events by other birds were also considered as a brief survey of biodiversity at the sites. Song files were not used if they were not loud enough to see the detail of the upper and lower voice, necessary to achieve the most accurate results for high and low frequency. The energy measurement was used to judge whether or not the masking events were loud enough to disrupt the Veery song. Masking songs over 70 dB were considered as masks. The delta frequency measurement was used to determine the frequency range of songs. Final peak frequency results did not include the masked song files, as the energy differences between different bird songs would not yield an accurate measurement for the peak frequency achieved during the Veery song.

Statistical Analysis

Analysis was performed using a combination of Microsoft Excel as well as JMP statistics software. JMP was used to perform nonparametric Wilcoxin-Kruskall Wallis Tests. The Wilcoxin-Kruskall Wallis Test was used because our data was not normally distributed, due to a small sample size, and as an alternative to a student’s t-test. Microsoft Excel was used to analyze the masking events and mask species.

RESULTS

Nine individual birds were sampled at control sites, and ten birds were sampled at road sites. The samples collected about 12 ± 1.54 (mean and standard error) songs per bird. A total of 114 songs were collected from the two control sites (The “Carys” and the “Lowlands”) and 116 songs collected from the three road sites (the "Spillway," the "Dump" and "Canoe Hill North"). There was no singing by Veeries at the Canoe Hill North road site.

Several different methods of analyses were used on the data set. Initially, we analyzed the set as though each song were its own sample (n = 116), then as though each bird were its own sample (n = 10), and finally as though each road were its own sample (n = 3). The final method of analyses was considered as the most reasonable and accurate analysis method (proper/pseudo replication).

In analyzing the songs as separate samples, the bottommost frequencies of phantom road songs were higher than the control sites, (Z = -5.84, p = <.0001) The high frequency measurement showed no relationship between locations (Z = -0.954, p = .3394), nor did peak frequency (Z = -.497, p = .6182). Delta frequency was significantly higher at the control site (figure 3, Z = 3.13, p = .0017).

With each bird as its own sample (n = 10), the trends apparent in the first analyses were switched. The means were taken per individual for each of the measurements. The low frequencies were lower per bird at the phantom road sites (Z = 0.939 p = 0.327) The high frequencies showed a slightly smaller range in average frequencies at the phantom road sites (Z = -1.18, p = 0.221). The peak frequency showed no trends at either site because there was such a large variation between the measurements (Z = 0.776, p = 0.414). The average delta frequency showed a much higher range on the phantom road sites (Z = -1.59, p = .103).

Considering each road as its own sample in proper replication (n = 3), the results showed interesting trends. The lowest bottommost frequency was lower at only the Carys control site, and the Lowlands control site mimicked the higher low frequency trends in the two road sites (p = <.0001, H = 64.39). The Spillway and the Lowlands sites had slightly higher highest frequencies than the other two sites (figure 6, p = 0.0085, H = 11.69). The peak frequencies showed no differences between sites (p = 0.303, H = 3.6). The delta frequency was greatest at the Carys site, while the other three sites remained around the same trend (p = 0.0018, H = 15.06).

The Lowlands site had the greatest number of masks, as well as a greater number of species that provided the masks. There were a total of 22 masks at the Lowlands site, 7 at the Carys, 8 at the Dump, and 4 at the Spillway. The Spillway, The Dump, and the Carys all had a relatively similar set of species (Table 1). The Lowlands site had considerably more masking events than the other sites (figure 3).

DISCUSSION

Because the study was preliminary, it was important to analyze any possible relationships or trends. Therefore, it was interesting and useful to analyze the potential of all pseudo replications. Trends and patterns founds in these pseudo replications may be analyzed in further experiments. However, the investigation per location was used for analysis as proper replication.

We expected the song's lowest frequencies to be lower at control sites and higher at phantom road sites. This was the expectation because the Veeries may attempt to avoid being masked by the low-frequency traffic noise (1-2 kHz). The delta frequencies were also expected to be lower at phantom road sites to compliment this effect. If the lowest frequencies were being raised and the highest frequencies remained unaffected in both experimental and control instances, then the total delta frequency would be smaller at the road sites. In addition, as the original phantom road experiment suggested (McClure et al. 2013), we expected there to be biodiversity decreases at phantom road sites comparative to control sites, which we attempted to monitor through measuring masking events. Therefore, we expected fewer masking events at phantom road sites in comparison to control sites.

The lowest frequency proved to be lesser at one of the control sites, the Carys, which had a similar forest habitat to the two phantom road sites. However, the Lowlands site, selected for its active Veery population, was also occupied with many other bird species because of its mixed wetlands-forest habitat. This was evident in the number of masking events; the lowlands had significantly more masking events compared to the Carys and both phantom road sites.

This amount of masking events may be responsible for the higher low frequencies in the absence of our phantom road noise. The higher low frequencies at the Lowlands and the two phantom road sites affected the delta frequency measurement. The Carys had an overall higher delta frequency measurement because of its lower bottommost frequency. The peak frequency measurements did not reveal any interesting trends. These results suggest it is possible that the phantom roads challenge the Veery population acoustically as much as the noisy Lowlands. There are several studies that confirm singing behavior changes in response to noisy natural environments. Air turbulence causes King Penguins (*Aptenodytes patagonicus*) to change their calling patterns (Lengage et al. 1999). Chaffinches that sing near torrential water or waterfalls had higher lowest frequencies. They also sang more repetitions of one song type more often than chaffinches further from the water (Brumm et al. 2006).

However, it is worth noting that the frequency shifts in the Lowlands are not completely consistent with the conclusions expressed in Wood et al. 2006; their study suggested that the sparrows had higher lowest frequencies in order to avoid masking by anthropogenic noise (under 1 to 2 kHz). Bird song occurs in a much higher range than anthropogenic noise, usually between 2 to 8 kHz. Therefore shifting the lowest frequency of their song would not prevent them from being masked by other birds. Although not as consistently loud as the road noise at the phantom road sites, the Lowlands site does have a paved road that sees a small amount of traffic, as well as occasional ground maintenance such as lawn mowing. Lawn mowers can actually reach about 88 to 91 dB, weed whackers up to 96 dB (Noise Pollution Clearing House). This paints the Lowlands as less of a control site, and more as an intermediate-urban site, which would be the most consistent with our results.

The masking events at the phantom road sites did not differ substantially from the Carys site, suggesting that there was not a dramatic difference in the number of birds present. The masking species identified were not exactly similar at each site. The species that was found at multiple sites was the Red-Eyed Vireos, at both the Carys and the Dump. The Common Yellowthroat was found at the Lowlands and the Carys, and Veeries had overlapped other Veeries during counter-singing events at the Lowlands, the Spillway, and the Dump. Wood Thrushes and Red-Eyed Vireos were found at the Carys and at the Dump. Only the Spillway and the Lowlands had species unique to their sites. The Lowlands contained Yellow Warblers, Swamp Sparrows, and Red-Winged Blackbirds, all species known for their preference in swampy habitat. Ovenbirds masks were only found at the Spillway. With a larger sample size it is estimated there may have been more species overlaps between the forest habitats and a greater number of species found at the forest sites.

A previous study at the Cary Institute of Ecosystem Studies concluded that Veeries were challenged acoustically during the dawn chorus, experiencing making 2.4 times per 10-song sequence at dawn and 1.2 times per 10-song sequence at dusk (Belinsky et al. 2012). This study suggests that the competition during the dawn chorus encourages Veery singing at dusk. The changes in song frequency were not recorded; although it is evident the Veeries were experiencing competition and adjusting their singing schedule accordingly. Because the sampling time for our study was after the majority of the dawn chorus and our sample size was small, it may have been more difficult for us to capture the range of species singing in our sampling sites.

Other research projects have suggested that birdsongs above a certain frequency will not be altered by anthropogenic noise because they are out of masking range. A study in Australia monitored Grey Shrike-

Thrushes and Grey Fantails in forest and road sites. The higher song of the Fantail was unaffected by the noise, while the Shrike-Thrushes sang with higher frequency in the presence of traffic noise. Fewer birds overall were found closer to the roads (Parris et al. 2009). In addition to performing more studies on the reactions of individual species, categorizing bird songs by frequency range could help generalize and project the effects that acoustic disturbances could have on the avian community.

Altogether, this is very useful preliminary data in understanding the Veery's tolerance to noise disturbances. In future experiments, it would be useful to control for habitat to confirm the relationship between road noise and low frequency changes in song. It would also be worthwhile to investigate the differences in effects between noisy natural and unnatural environments, or continue with an urban noise gradient, creating roads of increasing noise severity. Results of further experiments could aid conservation biologists and engineers in making important, and species-saving, land-use decisions, such as incorporating more green-patched areas in cities and towns. Cities with "green patches," or areas of forest habitats within cities, have greater avian species richness than areas without (Warren et al. 2013).

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APPENDIX

TABLE 1. Masking species at each site.

	Lowlands	**Carys**	**Spillway**	**Dump**
Masking Species	Swamp Sparrow	Common Yellowthroat	Ovenbird	Veery
	Yellow Warbler	Wood Thrush		Red-Eyed Vireo
	Common Yellowthroat	Red-Eyed Vireo		Wood Thrush
	Veery			
	Red-Eyed Vireo			

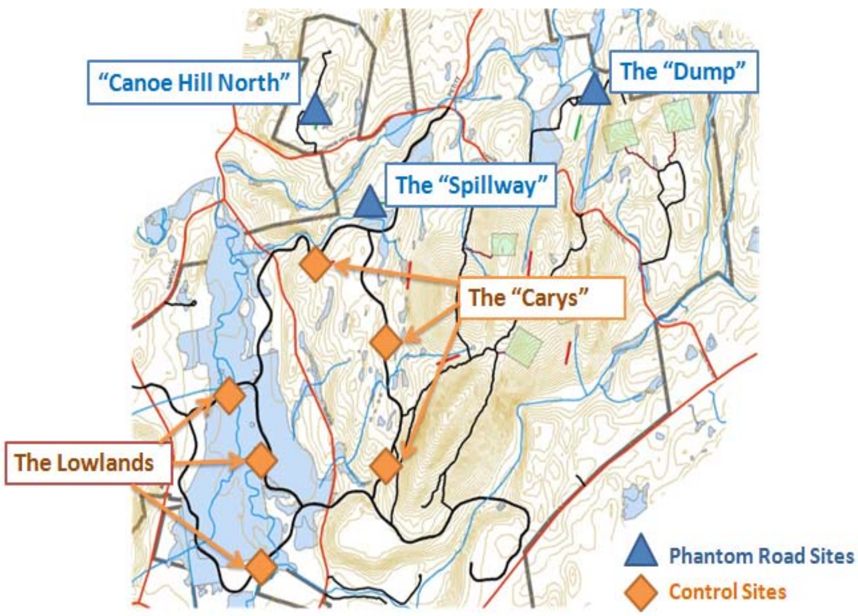

FIGURE 1. Cary Institute Campus and Sampling Sites.

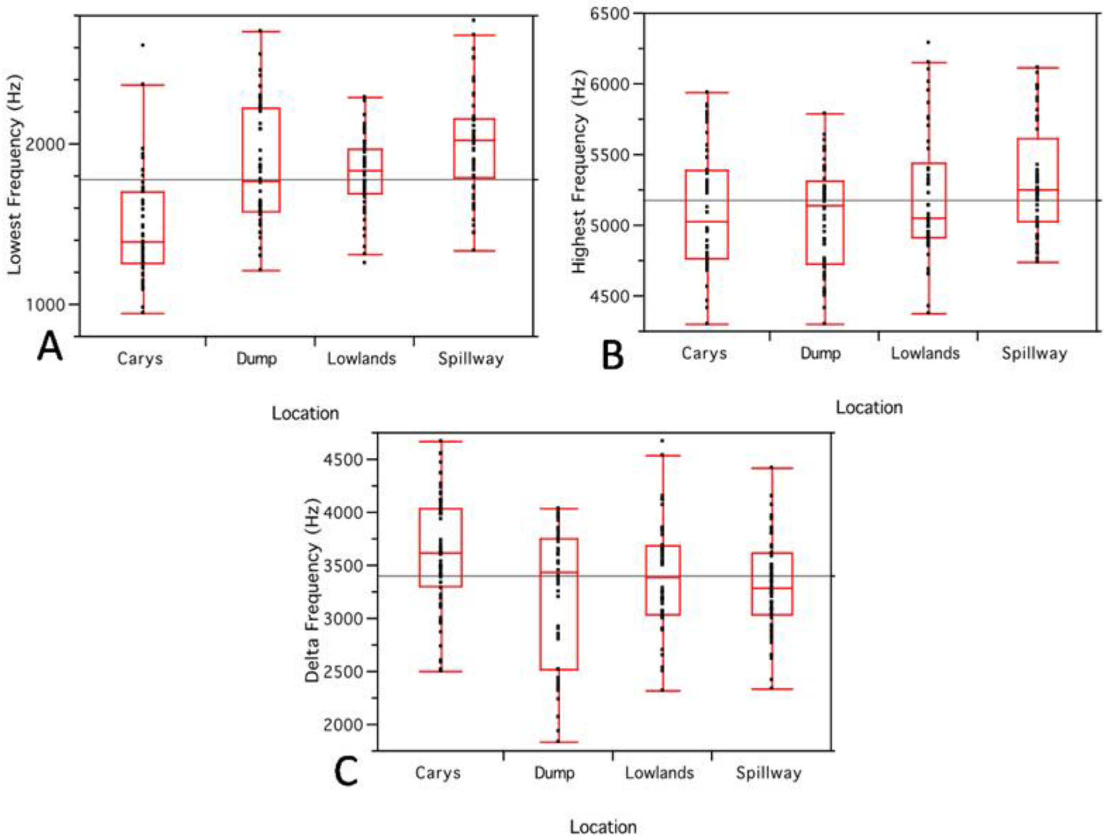

FIGURE 2. Proper replication by location; Carys and Lowlands are control sites, Dump and Spillway are phantom road sites: (A) Lowest frequency measurement (B) Highest Frequency measurement (C) Delta Frequency Measurement.

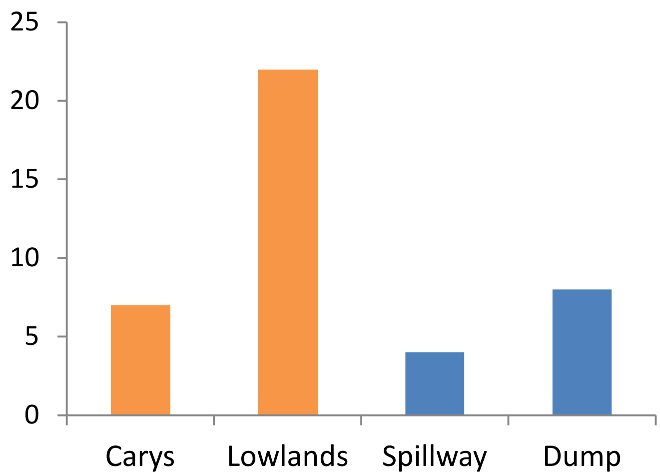

FIGURE 3. Masking events at each location.