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The Effects of Anthropogenic Ambient Noise and Habitat Vegetation on Common Yellowthroat Song

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Capstone Body

I. Introduction

Many animals use visual and sound signals to transmit information to nearby conspecifics (Alcock 1979, Catchpole 1995). Birds, especially songbirds, are well known for their use of complex and diverse songs to convey identity, status, health and territory boundaries to potential mates and competitors (Catchpole 1995, Collins 2004). In order for a sound signal to be useful in transmitting information, it must be heard by others. Audibility depends on the physiological hearing characteristics of the receiver, and the interaction of song characteristics with background noise and transmission properties of the acoustic environment which the sound travels through (Marten and Marler 1977).

The active space of a song is the total area surrounding the source of sound in which a signal is audible and, its quality is conserved to the extent that the sound is recognizable and still transmitting its information effectively (reviewed in Slabbekoorn 2004). Sound radiates out from its source in a spherical shape (Morton 1975, Marten and Marler 1977) that can be represented by concentric waves radiating out from a rock dropped in water. This spherical shape of radiating sound waves is one of the reasons that sound is an effective signal; sound travels omni-directionally (Slabbekoorn 2004). Because sound travels in energy waves, it can be transmitted over long distances, and unlike colorful plumage, sound does not require light to be detected and can be transmitted in the dark (Slabbekoorn 2004). These three reasons make song an advantageous and effective signal type used for long distance communication.

However, sound signals are limited by the habitat through which they travel. The acoustic adaptation hypothesis (Morton 1975) posits that bird song characteristics are shaped by selection for effective transmission, which, in turn, is determined by the physical and structural characteristics of the habitat, including barriers such as trees and leaves. Sounds are not perfectly conserved as they travel away from the emitter. Attenuation is the decrease in amplitude of a signal as it travels away from its source (Slabbekoorn et al. 2002, Slabbekoorn 2004). Higher frequency sounds attenuate faster than lower frequency sounds (Marten and Marler 1977, Slabbekoorn 2004). This fact is illustrated by the observation that low pitched noises, such as the boom from an explosion, are heard over long distances while high pitched whistles can not be heard at the same distance.

Sounds are also degraded by scattering and bouncing off objects to form echoes as they travel. Degradation is any change in the frequency, timing and/or structural characteristics of a song (Slabbekoorn 2004). The amount and type of degradation is dependant on the structure of the habitat. A sound traveling through the relatively still air in the understory of a forest is reflected by leaves and tree trunks; this is known as reverberation (Slabbekoorn 2004). The song of a bird singing from the top of the grass in an open field will not experience as much degradation due to reflection off objects, but will be degraded by air turbulence in this open habitat (Morton 1975). High pitched sounds degrade faster than low pitched sound waves in the forest because the high frequency, shorter wavelength songs will bounce of an object, but the low frequency, long wavelength sounds can bend around the object (Slabbekoorn 2004). The differential affects of reverberations on high and low frequency noises drive the selection of characteristic sound types in different habitats (Morton 1975). Slabbekoorn et al. (2002) recorded and examined the songs of African birds from forest habitats and found that forest birds with narrow frequency bandwidth songs can actually benefit from reverberations; simple notes with amplitude concentrated in a small band transmit further and louder than songs with notes of widely varying frequency.

Finally, background ambient noise is also a major influence on song transmission and reception. For an advertising song, one would predict that a bird is under selection to transmit the song as far as possible. In order to do this, a bird must sing as loud as physiologically possible to be heard over long distances and also, to be heard over the background noise. In a natural habitat, birds must compete with ambient noise, which includes wind, running water and other animals' noise. For instance, chaffinches that sing near streams and waterfalls repeat song types before switching to a new song type to increase serial redundancy in noisy habitats (Brumm and Slater 2006). Birds also compete with neighbor's songs –especially during the crowded dawn chorus— and have been found to sing opportunistically in the quiet moments (Brumm 2006a).

Unfortunately, pristine habitats are becoming rarer as the human population grows exponentially and our infrastructure increasingly invades natural habitats (Meyer and Turner 1992). Many birds do not live in natural wilderness areas, but within close proximity to human settlements, roads, power-lines, or under the paths of airplanes. The acoustic environment of urban areas is characterized by a loud band of low frequency noise (Slabbekoorn and Peet 2003) generated by machinery, boats, planes, and most importantly cars. When singing, urban birds have to compete with anthropogenic noise; it is an acoustic habitat characteristic just as much as vegetation structure. A couple studies have been conducted that examine how birds alter their songs in order to make them more audible in loud urban environments. Researchers have found that urban robins sing at night to avoid daytime clamor (Fuller et al. 2007), and that great tits increase the minimum frequency of their songs in urban noise (Slabbekoorn and Peet 2003).

A well known, negative affect of human growth on natural populations is habitat destruction. Deforestation of North American forests is predicted to have caused bird extinctions in these areas (Pimm and Askins 1995). However as the previously mentioned studies highlight, human urbanization can also cause more subtle, but meaningful effects on the behavior of natural bird populations. Although the studies that find song modification in response to ambient noise demonstrate intriguing patterns, they are few in number. Therefore, in order to add to the small body of studies testing whether birds alter their songs in response to human noise, I examined the songs of the common yellowthroat warbler (*Geothlypis trichas*) in a variety of acoustic habitats ranging from near pristine wilderness to an urban park.

Yellowthroats singing near loud anthropogenic noises might change their songs in a way that makes them more distinct and noticeable in these environments. Birds have been adapting to habitat noise before human noise was an issue and it is assumed that the mechanisms of adaptation in natural environments are the same ones used for urban noise pressures (Brumm 2006b). Three confirmed avenues for sound change are 1) increases in amplitude corresponding to increasing background noise (Brumm and Todt 2003), 2) temporal changes in song characteristics or opportunistic singing in quiet moments (Brumm and Slater 2006, Brumm 2006, Planque and Slabbekoorn 2008), and 3) changes in frequency to avoid masking by background noises (Slabbekorn and Peet 2003).

Yellowthroat warblers sing at a relatively low frequency compared to other North American warbler species (Lemon et al. 1981). Because urban noise caused by cars and other types of motors is concentrated in the low frequencies (Brumm 2006, Slabbekoorn and Peet 2002), I predict that yellowthroats will increase the minimum frequency of their songs near urban noise to shift the song into a quieter frequency range. Although a complex song, especially a warble, is comprised of many phones, or notes, it a unit (Hulse 2002) so if minimum frequency shifts, maximum frequency should change in the same manner. If motor noises influence song, minimum and maximum frequency will be negatively correlated with distance of bird from road and positively correlated with amplitude of ambient noise.

Temporal predictions concerning birdsong are based on the observation that anthropogenic noises, especially car noises, often recur throughout the day, but are relatively momentary when they do occur. For example, a series of cars passing by does not emit a continuous stream of noise, but a series of drones in increasing then decreasing frequency and amplitude. In order for birds to adjust to this ambient noise pattern, they should sing shorter songs that fit in the quiet moments and, their songs should be more complex to be distinguished from the background of traffic noise if car episodes are not avoided. Therefore, further from the road, where amplitude of ambient noise is lower, song length should increase and number of notes per second (a measure of warble speed or complexity) should decrease. I have designed my honors thesis field research project to test these predictions. The following describes my process, results and interpretation of the patterns found in my data.

II Methods

A. Study System

The common yellowthroat warbler, *Geothlypis trichas*, is a migratory songbird that breeds in most of North America and is present in New York from mid April to late October (Guzy and Richison 1999). It spends its winters in the southern US, Mexico, and Central America. Male yellowthroats arrive in breeding areas about a week earlier than females and begin to sing to establish territories (Guzy and Richison 1999). When females arrive, they select a mate based on territory quality and the sexually selected traits of song (Richison 1995), black mask (Thusius et al. 2001), and yellow, melanin-based bib (Tarof et al) (Appendix 1). Yellowthroats are socially monogamous, meaning that they form breeding pairs that last for a whole season; however, they are also known to solicit extra-pair copulation (Guzy and Richardson 1999, Thusius et al. 2001). Yellowthroats are insectivorous, gleaning insects from leaves of trees and bushes. In New York State they are usually found in open areas with bushes or reeds next to water, or on the forest edge (personal observation).

Figure 1: Locations of recorded yellowthroats (red triangles) and major highways in New York State.

B. Measuring Song and Ambient Noise

Male yellowthroats were located by sound in public, protected areas around New York State and in one private property with a large breeding population. Sites were chosen to give the greatest variety of ambient noise conditions, ranging from within meters of the busy New York State Thruway to more pristine wilderness areas in the Adirondacks Park (Figure 1). As soon as a bird was located, 15 minutes of continuous song recording at a constant volume commenced. Recordings were made standing as close to the bird's singing perch as possible (without flushing it) and pointing the microphone directly at the bird. Immediately after the song recording, 15 seconds of bird-song free ambient noise was recorded by holding the microphone straight overhead under the perch from which the bird sang. A total of 57 birds were recorded and all recordings were made with Marantz PMD670 digital recorder. Songs were recorded using a unidirectional Sennheiser microphone and ambient noise was recorded using a Sennheiser omni-directional shotgun microphone. For both types of recordings, the microphone was mounted on a stabilizer to reduce movement and feedback from the hand of the researcher. Vegetation coverage of the bird's singing perch was measured using a densitometer held horizontally at breast height directly underneath the perch from which the bird was singing. Densitometer readings were recorded in the four cardinal directions and averaged for each site. Date, time, and GPS coordinates were also recorded.

Digital song recordings were uploaded to a computer and converted into digital sonograms using Raven Sound Analysis Software 1.2 (Appendix 2). One minute of song with at least two song bouts was randomly chosen to be analyzed as the sample for each bird. All bouts within that minute were analyzed using the selection box to precisely measure song beginning and end time, and minimum and maximum frequency. Minimum frequency was subtracted from maximum frequency to calculate bandwidth, and beginning time was subtracted from end time to find the length of song in seconds. The maximum frequency (Hz) measurement in Raven was used to find the loudest frequency of song sung by the bird for each bout. The number of separate notes in a song was counted to give the measure notes, and this number was divided by the length of song in seconds to give a measure of notes per second (NPS) or the speed of warble. This measure is similar to trill rate, but since warblers do not trill, NPS was used as a density of notes per second of song. A high density of notes per second produces a more complex sounding song, so NPS can also be considered a measure of song complexity. Since multiple bouts were sung in one minute, song measurements from those bouts were averaged to give single values for each song characteristic for each bird.

One second of ambient sound with no bird songs or recorder movement noises was chosen to analyze the amplitude of the background noise. Since the maximum song frequency of any bird measured was 7765 Hz, ambient noise was measured in 999 Hz intervals from 0 to 7999 Hz. Amplitude of ambient noise was evaluated using the root mean square of amplitude (RMS) measurement for each interval of 999Hz that was filtered out of the rest of the ambient frequencies (following Slabbekoorn and Smith 2002) using Raven Sound Analysis Software 1.2. This measure averages the amplitude of all frequency noises within the 999Hz bandwidth intervals. Since there were seven measures of ambient noise for each bird, SPSS statistical software was used to collapse these variable across all birds using a principal component analysis (PCA). I also calculated Pearson correlation coefficient and significance of correlations between song measures, ambient PC scores, distance from the road, and a measure of vegetation cover. Significance was considered to be any probability value less than 0.05.

C. Measurement of Distance to Urbanization

The GPS coordinates of each bird were mapped using ArcGIS (Figure 1). County road maps of all the counties in which birds were recorded were also added as layers on the map. Google Maps™ were used as the criterion for what constituted a major road with frequent traffic. Gold roads are major highways, and yellow roads are busy roads while white roads are quieter streets. Distance to the closer of the yellow or gold road from each bird point was measured using the distance measurement tool in ArcGIS. ArcGIS roads were evaluated by visually matching the gold and yellow roads in Google Maps™ with the roads in ArGIS.

III. Results

A. Ambient Noise, Disturbance Measures and Time Effects

The principal component analysis (PCA) collapsed the seven frequency ranges of ambient noise by extracting two principal components (PC's) that explained 83.79% of variation in ambient noise amplitude, with PC1 contributing 60.93% and PC2 contributing 22.86%. Component loadings indicate PC1 was positively associated with noise from the 4000 Hz to 7999 Hz range, while PC2 was positively associated with ambient noise from the 0 Hz to 3999 Hz range (Table 1). Neither time of day nor date were correlated with PC1 nor PC2 scores of RMS ambient noise (Table 2).

Table 1. Component loadings from PCA of seven frequency intervals of ambient noise.

	Components	
Frequency Range (Hz)	PC1	PC2
0-999	-0.006	0.737
1000-1999	0.059	0.891
2000-2999	0.409	0.879
3000-3999	0.661	0.606
4000-4999	0.815	0.432
5000-5999	0.968	0.166
6000-6999	0.960	0.078
7000-7999	0.935	-0.021

Table 2. Pearson correlations (R) between ambient PC scores 1 and 2 and distance from road (N=55), percent cover (N=56), date and time of day (N=57). Significance at P<0.05 is noted as *.

	Distance from road	Percent cover	Date	Time
PC1 ambient score	-0.126	0.107	0.082	0.173
PC2 ambient score	-0.449**	-0.292*	-0.114	-0.173

As predicted PC2 score of ambient amplitude was negatively correlated with distance from the road (Table 2 and Figure 2A). Percent vegetation cover at the location of the singing bird was also negatively correlated with PC2 of ambient noise (Table 2 and Figure 2B), but was not associated with PC1 (Table 2).

B. Song Characteristics

Time of day was negatively correlated with only one of the song characteristics, NPS (Table 3). Date, measured as days since beginning of study was also negatively was correlated only with NPS (Table 3).

Several song characteristics were correlated with each other (Table 4). Minimum frequency of song was positively correlated with maximum frequency of song and negatively correlated with the number of notes in a song (Table 4). Bandwidth was negatively correlated with minimum frequency, but was also positively correlated with maximum frequency (Table 4). Bandwidth was positively correlated with song length, but was negatively correlated with NPS (Table 4). Finally, the number of notes in a song was positively associated with the length of the song (Table 4).

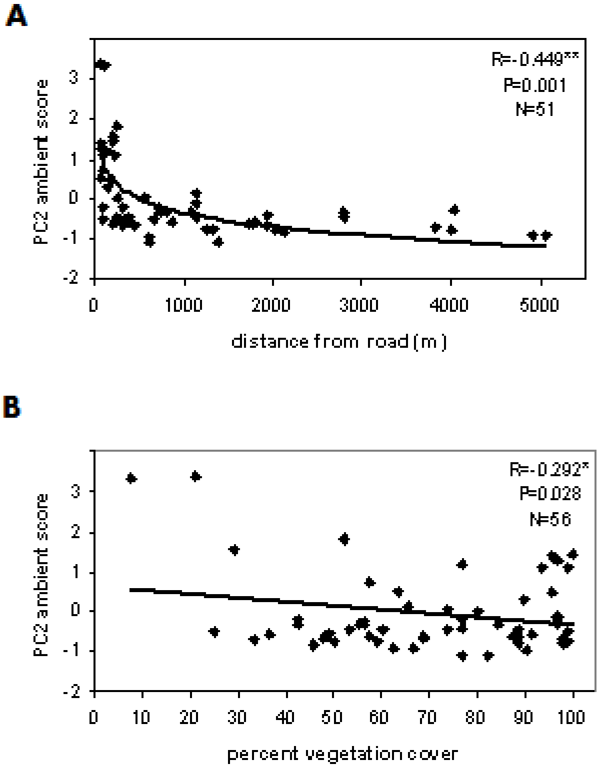

Figure 2. Relations between PC2 ambient amplitude score and distance of bird from road (A) and percent vegetation cover (B). Lines are drawn to illustrate relationships

Table 3. Pearson Correlation Coefficients (R) of five song characteristics with date and time of day. Significance at the P<0.05 is noted as *, and P<0.01 is noted as **, N=57.

	Minimum Frequency	Maximum Frequency	Band-width	MaxFreq	NPS	Length
Date	0.032	0.076	0.041	-0.254	-0.558**	-0.085
Time	-0.093	0.081	-0.161	-0.174	-0.388**	0.131

Table 4. Pearson correlations (R) between all combinations of song characteristics.* denotes significance at P<0.05 (2 tailed), ** denotes significance at P<0.01, N=57.

	Minimum Frequency	Maximum Frequency	Bandwidth	MaxFreq	Length	Notes
Maximum Frequency	.413**					
Bandwidth	-.535**	.549**				
MaxFreq	.234	.221	-.009			
Song Length	-.191	.102	.271*	.018		
Notes	-.293*	-.051	.223	-.074	.573**	
NPS	.246	-.098	-.317*	.410**	-.064	.025

C. Song Characteristics and Disturbance Measure Relationships

Despite the negative correlation between PC2 score of ambient amplitude and distance from the road (Figure 2A), there was no significant correlation between PC1 or PC2 of ambient noise amplitude and any song characteristic (Table 5). Also distance from the road was unrelated to minimum song frequency (Table 5). No other song characteristics were associated with distance of a bird from the nearest major road (Table 5). Although there was no correlation between ambient noise and minimum song frequency in the full data set, there was a significant difference in minimum song frequency between the quietest location, the Moose River Wilderness in the Adirondack Park (mean= 2359 Hz) and the loudest location meters from the New York State Thruway at Montezuma National Wildlife Refuge (mean= 2945 Hz) (P= 0.034, df=6). For these two locations PC1 scores of ambient noise were not significantly different (P= 0.312, df=6), but PC2 scores were significantly different (P= 0.000, df=6).

Table 5. Pearson correlations (R) between five song measures, and distance to road, and both PC scores of ambient noise. N= 55 (for distance), and for PC's N=57.

	Min	Max	Bandwidth	Maxfreq	Length	NPS
Distance	-0.055	-0.121	-0.061	0.021	-0.116	-0.026
PC1amb	0.029	-0.044	-0.068	0.054	0.015	0.220
PC2amb	-0.046	-0.080	-0.033	-0.042	-0.009	0.100

Cover was not associated with distance from road (R= -0.030 P=0.829). However, increasing cover was significantly correlated with frequency bandwidth (Figure 3). There was initially significance between percent vegetation cover and notes per second (NPS) (R= -0.272, P=0.045), but when the effect of date on NPS was extracted, this association was no longer significant (F=2.316, P=.134).

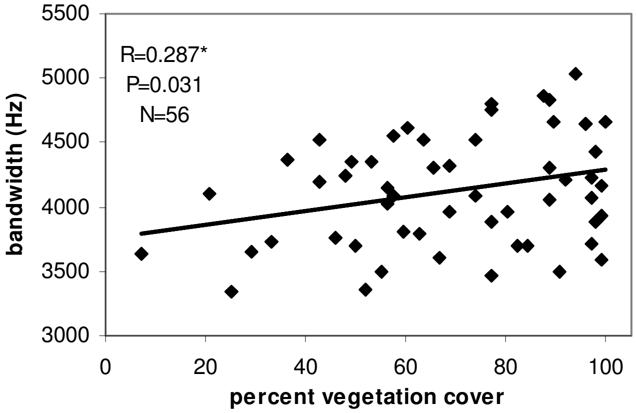

Figure 3. Relationship between frequency bandwidth and percent vegetation cover. Line is drawn to illustrate relationship.

IV. Discussion

Although the amplitude of ambient noise for various frequencies followed the predicted pattern of decreasing with increasing distance from road, and most of the song characteristics were correlated to each other in predictable ways, there was no link between background noise and song characteristics in the total data set. This indicates that the songs of these yellowthroats are not altered by anthropogenic urban noise, at least in the form of traffic. The significant difference in minimum frequency found for the two extreme ambient noise habitats, suggests that perhaps frequency change is underway in the loudest habitat where it is a more severe selective pressure compared with the intermediate background noise habitats. The measure of ambient noise is reliable and resistant to bias of types of ambient noise recorded. However, the measurement of distance from road could be misleading because it does not account for other loud anthropogenic noise sources that were encountered in this study such as motorboat noises from nearby waterways and locations under loud, low level, routinely used airplane paths.

However, the lack of correlation between background noise and song characteristics is probably a true indication that common yellowthroat song is not affected by anthropogenic acoustic disturbance. This makes sense because, although yellowthroats may live close to cities, they are not urban birds like the city dwelling great tits (*Parus major*), whose songs have been affected by anthropogenic ambient noise (Slabbekoorn and den Boer-Visser 2006).

Yellowthroats prefer un-mowed grasslands and brushy areas next to water – habitats not usually found in cities. One study indicated that when a managed grassland habitat was experimentally mowed, yellowthroats vacated the area (Zuckerburg and Vickery 2006). Therefore the mowed lawns in cities deter yellowthroats, and the brushy grasslands they prefer necessitate that they live in the suburban outskirts of town, not the urban center.

It is suspected that yellowthroats can learn songs from neighbors (Guzy and Richison 1999), but this dataset suggests that they are not selectively learning, and thus singing the neighbors' songs that transmit well in the presence of anthropogenic noise (Slabbekoorn and Ripmeester 2008). If behavioral plasticity is not a possible avenue for song adaptation in yellowthroats, perhaps they are adapting on a longer time scale. An evolutionary population wide behavioral reaction to a new habitat takes a very long time, and since most of the United States highways were built after 1956 (www.nysdot.gov), the birds that live in the adjacent habitats have not had long to adapt. This same conclusion was drawn by the authors of a study which found that anthropogenic masking was not responsible for the minimum frequency shift in a song dialect of sunbirds living in a housing development built in the 1950's (Leader et al. 2005). In contrast to the birds subject to recent habitat alteration in the previously mentioned study and the current one, the great tits that changed their song were recorded in archaic London and Paris (Slabbekoorn and Peet 2003) where populations of great tits have probably resided for hundreds of years.

Yellowthroat songs have not been under selective pressure from urban noise for very long, but they have adapted their songs to the natural habitat conditions they have evolved in. Birdsong is not shaped solely by the need to avoid background noise, but also to sing in frequencies that transmit well through its habitat. Marten and Marler (1977) transmitted and recorded different frequencies through open and closed habitats to determine which frequencies were prone to excess attenuation in which habitat. A certain amount of attenuation can be expected because of spherical spreading of noise, but any attenuation above this level is caused by habitat barriers and conditions such as wind and temperature gradients (Morton 1975, Marten and Marler 1977).

Common yellowthroats usually sing between two and five meters off the ground in open or edge habitats (Guzy and Richison 1999) and their minimum frequency ranges from 2000 Hz to 3245 Hz. Morton and Marler's data for all singing heights in an open habitat shows a conspicuous dip in excess attenuation rate (db/100m) at 2500 Hz with a rise in excess attenuation above this frequency. The average minimum frequency for these 57 yellowthroats was 2542 Hz. Therefore, the yellowthroats' minimum song is currently located at the frequency that has the least excess attenuation, and is therefore probably transmitting the best of all frequencies in yellowthroat song. Thus minimum frequency could be considered a crucial frequency in yellowthroat song. If this is the case, one would expect that yellowthroats would decrease the transmission capability of their songs by lifting their minimum frequency out of this range and into a frequency of higher attenuation. It appears that frequency dependent attenuation, a natural selective pressure, exerts a greater selective pressure on yellowthroat minimum song frequency than the more recent masking by anthropogenic ambient noise, and this is the reason that I found no significant correlation between minimum song frequency and distance to road or PC scores of RMS ambient noise.

Maximum frequency is also subject to selection to avoid frequency dependent attenuation and was predicted to be correlated with minimum frequency. This prediction was met; minimum frequency not only correlated with maximum frequency, but was also negatively correlated with bandwidth, song length and the number of notes in a song. Several other song characteristics were associated with each other confirming that birdsong is a single unit and its characteristics are interrelated. The mean maximum song frequency of yellowthroat song was 6663 Hz. Although Marten and Marler (1975) did not find that this to be a low point for excess attenuation, rather a plateau, the amount of excess attenuation only increases as frequency increases above 6000 Hz. These birds seem to be trading off the transmission costs of background masking with frequency dependent attenuation, so shifting the whole song upward in frequency may not necessarily increase a male yellowthroat's ability to transmit his song.

Frequency of maximum amplitude, which was predicted to increase with increasing ambient noise and decrease with distance to the road was not correlated with either of these measures, and interestingly, was not correlated to any other song characteristic except notes per second. The relationship between these two song components suggests that as the frequency of the loudest note in a song increases, so does the speed of the warble. Since neither minimum nor maximum frequency were correlated with disturbance measures, it is not surprising that frequency of max amplitude was not correlated with them either. The fact that frequency of maximum amplitude was not correlated with any other spectral characteristic suggests that it is a random song characteristic either highly variable within birds and/or within bouts of one single bird. Morton (1975) found the birds in edge habitats, like the common yellowthroat, have a larger variance in frequency of maximum amplitude compared with birds in high forest or low forest habitats.

The prediction that the temporal patterns of bird song would change with urban noise disturbances was unsupported by the data. It appears that yellowthroats are not shortening their songs to sing in quiet moments. Perhaps instead of altering the length or speed of warble of their songs, they sing opportunistically in quiet moments. I observed yellowthroats frequently starting a song immediately after a song of another species ended, and also singing in between car passes. In a playback experiment examining nightingale song timing, nightingales were found to avoid acoustic interference by avoiding singing during another species song and preferentially starting song in quiet intervals (Brumm 2006). If birds can sing opportunistically in response to other bird species songs, it is reasonable to assume that they can do the same with cars, especially because a car can be heard approaching before it is close enough to mask song.

Increasing cover was associated with decreasing ambient noise in the frequency interval from 0 Hz to 4999 Hz (PC2 ambient score). This result probably is more related to the fact that forests muffle noises rather than an association with ambient car noises, as distance to road was not associated with cover. However, percent vegetation cover was positively associated with bandwidth. This makes sense if one considers that the warblers that live in edge habitats are subject to low frequency attenuation in open fields, *and* high frequency attenuation in forested areas (Marten and Marler 1977, Slabbekoorn 2002). Therefore, as cover changes from a completely open field to an edge habitat that is half covered with vegetation and half open, increasing bandwidth would be beneficial for maximum transmission in a heterogeneous habitat.

The correlation between bandwidth and cover, and the spectral location of minimum frequency in confirmed a zone of low excess attenuation for an open or edge habitat, suggest that these 57 common yellowthroats sampled in New York State are responding more to structural habitat pressures on sound transmission than pressures from masking due to anthropogenic noise. Although disturbance in the form of ambient noise may not be a strong selective pressure on song, disturbance in the form of vegetation alteration by humans may be, as suggested by this study. Noise transmission experiments, especially sound playbacks, should be conducted in habitats with a variety of anthropogenic background noise conditions, and with varying amounts of vegetation disturbance to test whether song characteristics are more altered by vegetation cover engineered by humans, or anthropogenic ambient noise.

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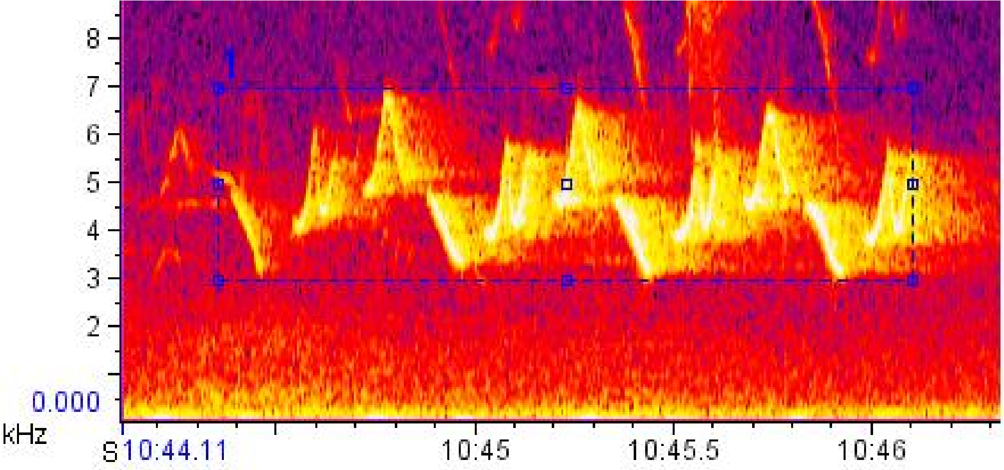
Appendices

Appendix 1. Photo of singing male common yellowthroat warbler (*Geothlypis trichas*).

Source: http://www.learnbirdsongs.com/birdsong.php?id=28

Appendix 2. Spectrogram of common yellowthroat warbler (*Geothlypis trichas*) song bout from Raven Sound Analysis Software 1.3. Loud, low pitched ambient noise is visible as the yellow line across the bottom of the spectrogram. The blue box drawn around the ascending and descending repetitive warble was used to precisely measure the time and frequency parameters of each song.



Capstone Summary

Destruction of many plant and animal species' habitats, caused by human population growth, has had significant impacts on natural populations, sometimes leading to endangered status or ultimately, extinction. Because habitat destruction can cause these grave consequences, it is often the focus of how human growth can negatively influence natural populations. However, it has recently been found that urbanization can have more subtle influences on animal populations by affecting their behavior. For instance, a study of a common European bird species, the great tit, found that when individuals live, and therefore sing, close to urban noise, the lowest pitch of their song increases compared with individuals living nearby in a quiet forest (Slabbekoorn and Peet 2002). Human caused urban noise from cars, planes and other types of motors is concentrated in the low frequency spectrum of sound. Therefore, great tits near loud and low frequency human noises increased their lowest note to avoid background noise which would mask their song.

For male birds, singing is far more than entertaining; singing signals the availability and quality of the male to potential mates, as well as the location of his territory. Therefore, singing attracts females to inspect the "real estate" that he controls, and indicates the boundaries to keep competing males out. Since song is used to communicate with mates and competitors, it is paramount in reproduction, and thus, survival of a species. The idea of humans unknowingly changing the communication of another species intrigues me, and it is what drives the question of my thesis research. Using the common yellowthroat warbler, I asked if males living near cities or busy roads changed the frequency or timing of their songs so that they are more clearly heard over background noises caused specifically by cars.

To answer this question I recorded 57 male yellowthroats from all over New York State in a variety of acoustic habitats ranging from near pristine and quiet in the Adirondack Park, to deafeningly loud areas meters from the New York State Thruway at Montezuma National Wildlife Refuge. I recorded each bird for fifteen minutes, then immediately took a recording of the ambient noise using a specialized microphone, which collected sound coming from every direction. I recorded the Global Positioning System coordinates of each bird to later make a map used to measure the distance of each recorded bird from the closest major road. While in the field, I also measured vegetation cover using a mirror-grid to count the number of squares that contain sky, rather than plant material. To perform a detailed analysis of the frequencies, lengths, and patterns of notes in each song, I used Raven Sound Analysis Software, a computer program that coverts digital sound files into spectrograms. A spectrogram is a graph of frequency (kilohertz, kHz), versus time, with volume (amplitude) shown as the color of the note where the brightest, white areas are the loudest, and black is near silence (Figure 1). I ran statistical analyses to determine if ambient noise and distance from the road were associated with measures of pitch and timing of song.

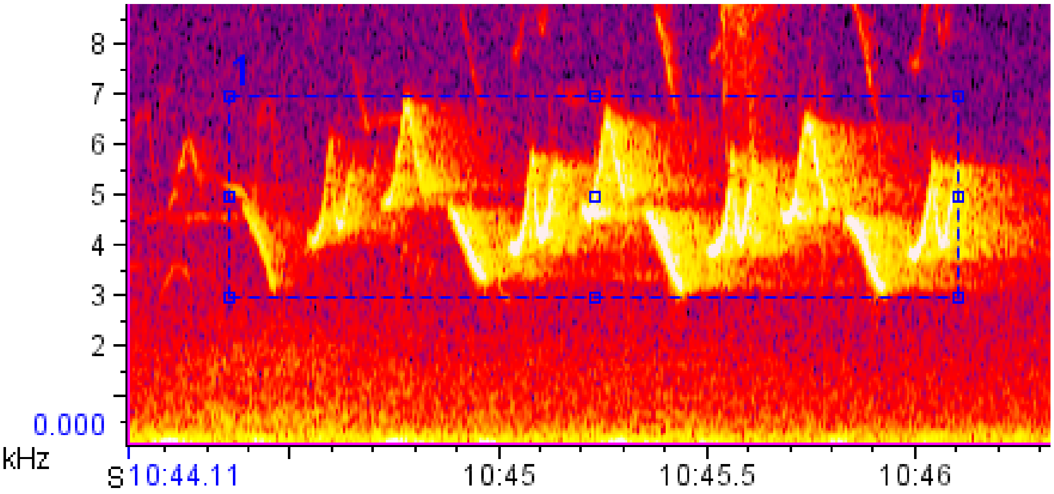


Figure 1. Spectrogram of a common yellowthroat warbler song bout. Loud, low pitched ambient noise is visible as the yellow band across the bottom of the spectrogram. The blue box drawn around the ascending and descending repetitive warble was used to precisely measure the time and frequency parameters of each song.

As expected, I found that the ambient noise of locations that were further from the road were quieter than locations close to the road. This correlation was strongly supported in the low frequency sounds but not in the high frequencies indicating that the increase in ambient noise closer to the road is due to the low frequency rumble of cars, not some other high pitched noise. Although the low frequency ambient noise was correlated with increasing disturbance closer to roads, ambient noise was not correlated with any measure of song. None of the song measures were correlated with distance to road either. Therefore, my data indicated that common yellowthroat warblers are not changing their songs in response to the low frequency ambient noise generated by cars.

After consulting the literature on the sound transmission properties of habitats, I found a very plausible reason why these birds are not altering their minimum frequency in response to background noise. Data from sound transmission experiments through different habitats show that in open habitats, a zone of very clear transmission, with minimal loss of volume (attenuation) occurs at almost exactly the same frequency as the average minimum frequency of the yellowthroat songs sampled in this study. Therefore, the yellowthroats' minimum song frequency is currently located at the frequency that is transmitting the best of all frequencies in yellowthroat song. Thus, minimum frequency could be considered a crucial frequency in yellowthroat song. If this is the case, one would expect that yellowthroats would diminish the transmission capability of their songs by lifting their minimum frequency out of this range and into a frequency of higher attenuation. Perhaps, the consideration of frequency dependent attenuation is more important than the masking by anthropogenic ambient noise.

Although my main hypothesis focusing on the effects of background noise was unsupported by the data, I did find some interesting significant correlations between vegetation cover and both ambient noise and a few song characteristics. However, in order to understand why vegetation cover would have an affect on song, one must understand the patterns of song transmission through different habitats. Sound radiates out from its source in a spherical shape, but not indefinitely; sound signals are limited by the habitat they travel though. Bird song characteristics are shaped by selection for effective transmission, which, in turn, is determined by the physical and structural characteristics of the habitat such as barriers like trees and leaves.

Attenuation is the decrease in strength of a signal as it travels away from its source. Higher frequency sounds attenuate faster than lower frequency sounds (Marten and Marler 1977, Slabbekorn 2004). Sounds are also degraded by scattering and bouncing off objects to form echoes as they travel. Degradation is any change in the frequency, timing and/or structural characteristics of a song (Slabbekoorn 2004) and the amount and type of degradation is dependant on the structure of the habitat. A sound traveling through the relatively still air in the understory of a forest is reflected by leaves and tree trunks; this is known as reverberation (Slabbekoorn 2004). The song of a bird singing from the top of the grass in an open field will not experience as much degradation due to reflection off objects, but its frequencies will be degraded by air turbulence in this open habitat (Morton 1975). High pitched sounds degrade faster than low pitched sound waves in the forest because the high frequency, shorter wavelength songs will bounce off an object, but the low frequency, long wavelength sounds can bend around the object (Slabbekoorn 2002). The differential effects of reverberations on high and low frequency noises drive the selection of characteristic sound types in different habitats (Morton 1975).

My data are in agreement with these transmission patterns, and show that vegetation structure affects an important song measure. I found that as cover increased, the volume of low frequency ambient noise decreased. This makes sense as one considers that vegetated areas are more enclosed, and sounds will not transmit as far in these areas. I also found that as the vegetation became thicker, bandwidth (the total spread of frequencies) increased, perhaps due to quieter ambient noise. Since cover was negatively correlated with ambient noise, densely vegetated areas are quieter, and free of background noise. Following my original hypothesis, when low frequency background noise is loud, birds should avoid singing in this range and sing at higher frequencies. Bandwidth is strongly associated with the minimum frequency of sound, so as the lowest note of the song becomes higher, the bird is restricted into a smaller range of frequency in which it can sing. Small birds sing high pitched sounds because they are physically limited to sing only the songs that their small bodies can produce. When ambient noise is absent, birds are not pressured to avoid singing in the low frequency range, and they should sing with the largest bandwidth possible. Since densely covered areas are quiet, it makes sense that these yellowthroats are singing at their maximum capacity in terms of broadest frequency range.

This finding relating cover to a song characteristic, and the spectral location of minimum frequency in a confirmed zone of superior transmission, suggest that the common yellowthroats sampled in this study are responding more to structural habitat pressures on sound transmission than pressures from masking due to anthropogenic noise. Although the disturbance of sound may not actually be “disturbing” the birds, disturbance in the form of altered vegetation appears to be affecting yellowthroat song. Humans ubiquitously cut down trees, trim bushes, mow lawns and clear fields to plant crops. Our habitat engineering surprisingly affects bird behavior more than our noisy machines, at least for the song of this species. To parse out the mechanics of this interaction, transmission studies in disturbed and pristine habitat should be conducted. In retrospect, my study, conducted because of my interest in subtle impacts of human alterations of habitats proved that even I was focusing on the somewhat obvious association of anthropogenic urban noise and song, while overlooking the more obscure, but important, association of human shaped vegetation patterns and song characteristics.

Capstone Summary Sources Cited

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