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The effects of traffic noise and distance on the degradation of cricket frog calls

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The effects of traffic noise and distance on the degradation of cricket frog calls

by

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Abstract

The effects of traffic noise and distance on the degradation of cricket frog calls

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The extent to which noise pollution affects amphibian acoustic mating systems is unknown. If mating calls are generally masked by traffic noise, it could potentially have a serious impact on threatened amphibian populations, unless acclimation or adaptation mitigates the effect. Blanchard's cricket frog (*Acris blanchardi*) is abundant in high-noise areas and is known for adaptive changes in call traits on a regional scale. We measured the degradation of call bouts recorded from five different cricket frog habitats at several distances. In addition, traffic noise was recorded and played back concurrently with the call bouts at a range of different amplitudes. Call bouts from different habitats were degraded to different extents by distance and noise level, however no clear pattern emerged based on either dominant frequency or habitat. Impact of traffic noise on *A. blanchardi* populations will be variable, but negative since it does degrade call fidelity at all observed frequencies.

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Chapter 1: Introduction

Urban and industrial development is increasing worldwide, while amphibian populations are declining. Because of this, interest in various aspects of amphibian conservation is very high. Recent studies have investigated the effects of anthropogenic noise on anuran behavior. Since frogs use vocalization to attract mates, interference and masking may cause a vocal shift, in a parallel to a phenomenon observed in birds (Slabbekorn & Peet 2003). Among observed responses to anthropogenic noise are change in call rate (Sun & Narins 2005), timing (Lengagne 2008), and frequency (Parris et al. 2009).

Changes in frequency could be adaptive in response to introduced interference. If a given mating call becomes less similar in frequency to the interfering noise, it may escape the interference and avoid negative effects on reliable transmission (fidelity). Animals calling from less than 1 m above the ground generally improve their transmission efficiency (in terms of distance) by increasing dominant frequency, which may compensate for interference (Boncoraglio & Saino 2007). Calls with high frequencies may themselves be easier to localize (Konishi 1970). However, the fidelity of calls with different dominant frequencies has not been empirically compared under different noise regimes.

Blanchard's cricket frog, *Acris blanchardi* is a widespread species that inhabits several different acoustic environments (Gamble et al. 2008; formerly considered a subspecies of *A. crepitans*). *Acris blanchardi* has previously served as a system for studying anuran vocal communication (Capranica et al. 1973; Ryan & Wilczynski 1988). Its dominant frequency varies substantially across Central Texas with longitude as well as habitat type (Ryan & Wilczynski 1991). Populations that reside in forests, which are a more physically complex environment for sound transmission, have higher dominant frequency (Ryan & Wilczynski 1991), which may vary as much as 750 Hz over distances of ~200 km. However, they are always higher-pitched than most traffic noise (Parris et al. 2009), suggesting that to minimize the effect of interference, acclimation or adaptation should be in the direction of increased frequency.

Documenting selection pressure using empirical evidence is an important component in any hypothesis of adaptation. In this case the mechanism of selection is hypothesized to be the reduction in male fitness caused by a decrease in females' ability to find mates, given reduced fidelity or range of male signals. If higher-pitched calls have greater fidelity or effective transmission distance on background of traffic noise, it follows that some selection pressure may exist on *A. blanchardi* populations to call at a higher pitch when those populations are exposed to heavy traffic noise. In that case, populations may be evolving to increase their pitch and reduce the negative effects of that noise, in accordance with the general Acoustic Adaptation Hypothesis (Ey & Fischer 2009). Populations are unlikely to already be at the highest pitch possible due to a general preference for *Acris* females for low-pitched calls (Ryan et al. 1992). This may also create a counterbalance to any selection for higher pitch, and the direction of local selection may be decided by the tradeoff between the detectability and desirability of the male signal.

To test the possibility that high-pitched calls have greater fidelity over a longer range when competing with traffic noise, I recorded call bouts from several locations with varying frequencies. After recording call bouts from different sites, I played them back under controlled conditions. This approach allowed the same call bout to be compared across different propagation distances and different levels of traffic noise. Cross-correlation analysis was used to quantify auditory degradation (or masking) by computing the similarity between the same call under different conditions (Ryan et al. 1990).

I predict that call bouts with higher dominant frequencies will experience less degradation in the presence of increased traffic noise. They may also experience less degradation when distance is increased as well. Conversely, the lowest-frequency call should be the most degraded. Furthermore, call bouts recorded from heavily vegetated and/or high-noise sites should have higher dominant frequencies, (Ryan & Wilczynski 1991), Parris et al. 2009).

Chapter 2: Materials and Methods

Call bout recordings were obtained from *A. blanchardi* populations at six different sites in Central Texas, and one in East Texas. Five of the sites were made available by their owners and by the Texas EcoLab program, the other two were public parks. Five of the sites were forested, two of them open habitat. Three of them had high levels of traffic noise (>50 dB at the frog microhabitat), and four did not.

The first site was located in the Lost Pines of Bastrop County and had the EcoLab designation Bastrop 4. It was heavily forested and had a low traffic noise. Subsequently this site is referred to as “Forest Low 1” or “FL1.”

The second site was located in Bastrop County (Bastrop 10) and was a forested habitat with high traffic noise. Subsequently this site is referred to as “Forest High 1” or “FH1.”

The third site was located in Bastrop County (Bastrop 2012-11) and was an open habitat with high traffic noise. Subsequently this site is referred to as “Open High” or “OH.”

The fourth site was located in Travis County (Travis 6) and was an open habitat with low traffic noise. Subsequently this site is referred to as “Open Low” or “OL.”

The fifth site was also located in Travis County in the public Barton Creek Greenbelt. It was a forested habitat with high traffic noise, and subsequently referred to as “Forest High 2” or “FH2.”

The sixth site was located in Williamson County (Williamson 1) and was a forested habitat with low traffic noise. Subsequently this site is referred to as “Forest Low 2” or “FL2.”

The seventh site was located on Lake Livingston in the East Texas Piney Woods, a forested but low-noise area. Subsequently this site is referred to as “Forest Low 3” or “FL3.” Note that this site is some distance from the rest, which are nearby (Figure 1). The calls of seventy-nine total individuals were recorded from the seven sites. Recordings of call bouts were made with a Marantz PMD660 recorder and Sennheiser ME66 microphone between 2011 and 2013.

The microphone was held approximately 1 m from a calling individual. The temperature of each individual was measured in the field using a Genica infrared non-contact thermometer. The median dominant frequency of each individual’s call bout was taken. Each recorded individual’s call bout was reduced to a sample of ten calls. The dominant frequencies from each set of recordings were compared with each other with one-way ANOVA in R to determine if significant differences (alpha = .05) existed between different populations.

I recorded a sample of road noise with a Marantz PMD660 while standing directly beneath three four-lane bridges where they cross the Colorado River in Austin. This sample of road noise was used for the playback experiment.

The playback experiment was performed in the field, at the same EcoLab site as OH, on a calm, clear day. Two SME-AFS field speakers were set up facing in the same direction 2 m apart. Each speaker was connected to a Marantz PMD660 sound recorder, one containing the call bouts, one containing the road noise. Markers were placed at 2, 4, 8, and 16 m distance from the speakers; these distances were chosen to sample the auditory space of *Acris blanchardi* (Ryan et al. 1990). The sampling rate was 441,000 Hz.

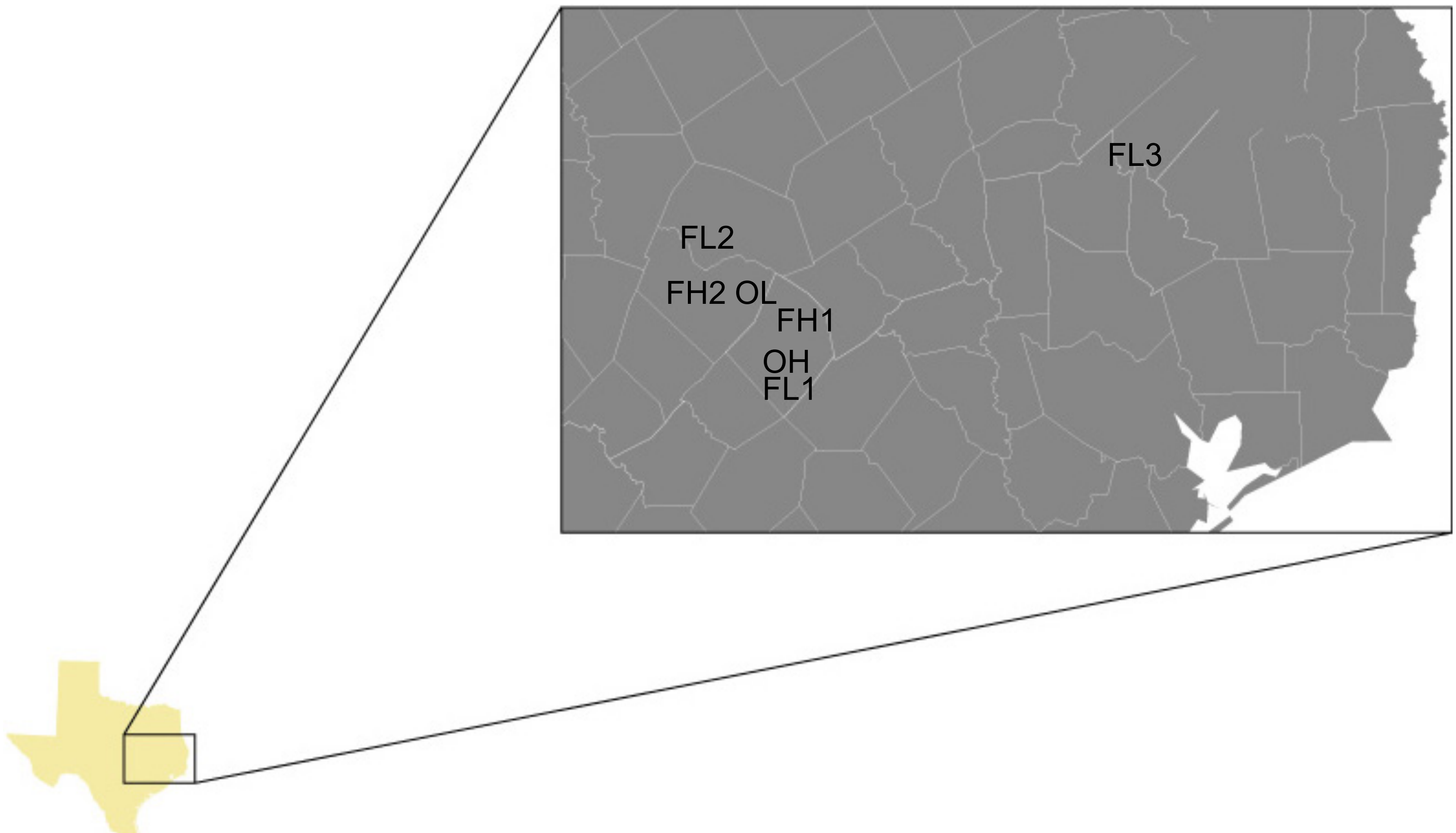

Figure 1: Map of localities. FH2 = Barton Creek Greenbelt. FL1 = Bastrop 4. FH1 = Bastrop 10. OH = Bastrop 2012-11 (playback experiments were later performed here as well).FL3 = Lake Livingston. OL = Travis 6. FL2 = Williamson 1.

A RadioShack® Sound Level Meter was used to calibrate the speakers at a distance of 2 m. The “call bout” speaker (Figure 2; Speaker 1) was set to maximum volume, which for all sample calls still resulted in an SPL less than the 90 dB SPL (re. 20 microPascals) at 2 m recommended by Burmeister (1999). The “city noise” speaker (Figure 2; Speaker 2) was either not used (0 dB SPL) or broadcast at an amplitude of 60 dB SPL , 70 dB SPL, or 80 dB SPL.

A third Marantz PMD660 recorder and Sennheiser ME66 microphone were set up at the 2 m marker to record each bout of 10 calls in succession, played from the “call bout” speaker. Subsequently, we recorded these calls again while the “city noise” speaker also played at 60, then 70, then 80 dB SPL. Finally, we repeated this process at the 4 m, 8 m, and 16 m markers. In this way, we captured each of the seventy-nine recordings with background noise of 0, 60, 70, and 80 dB SPL at each of the distances 2 m, 4 m, 8 m, and 16 m, for a total of 16 recordings for every individual’s call bout (total 1264 recordings).

After the 1264 recordings were made, they were fast-Fourier transformed using SIGNAL 4.0 (Engineering Design, Belmont, MA, USA) to produce spectrograms. Cross-correlation analyses were made between the spectrograms of pairs of these recordings. Cross-correlations between unrelated sounds (call bouts and road noise) and somewhat related sounds (different call bouts to each other) were performed to establish a baseline, ruling out the possibility of spurious correlations. Exactly as expected, call bouts showed almost no correlation with road noise, and calls of different individuals had a positive, but low correlation with each other.

Two sets of cross-correlation coefficients were produced, designated "amplitude coefficients" and "distance coefficients." The amplitude coefficients (Figure 2;

Comparison 1) measure degradation caused by road noise at 2, 4, 8, and 16 m. The distance coefficients (Figure 2; Comparison 2) measure degradation caused by distance without road noise.

The first set of coefficients, the amplitude coefficients, compared the playback of an individual 10-call sample in the absence of road noise to the same playback at the same distance from the speaker, in the presence of road noise i.e., between playbacks with 0 and 60 dB SPL noise at 2 m.

The second set of coefficients, the distance coefficients, compared playbacks that were 2 m away from the speaker with the playback of the same individual taken at a greater distance from the speaker. This set was designated the "distance coefficients" because they each measure the effect of distance on the playback of one call bout. No road noise was played back during any of these recordings.

These sets of coefficients were imported into R (R Development Core Team 2011). Both sets of coefficients were tested for normality with a Q-Q plot. Both appeared to sufficiently meet the assumption of normality; squaring the amplitude coefficients eliminated some mild skew. A model I nested three-way ANOVA was performed in R on each set to determine which variables (locality, individual [nested within locality], distance, amount of noise, and dominant frequency) co-varied with the cross-correlation coefficients, and were therefore important in transmission.

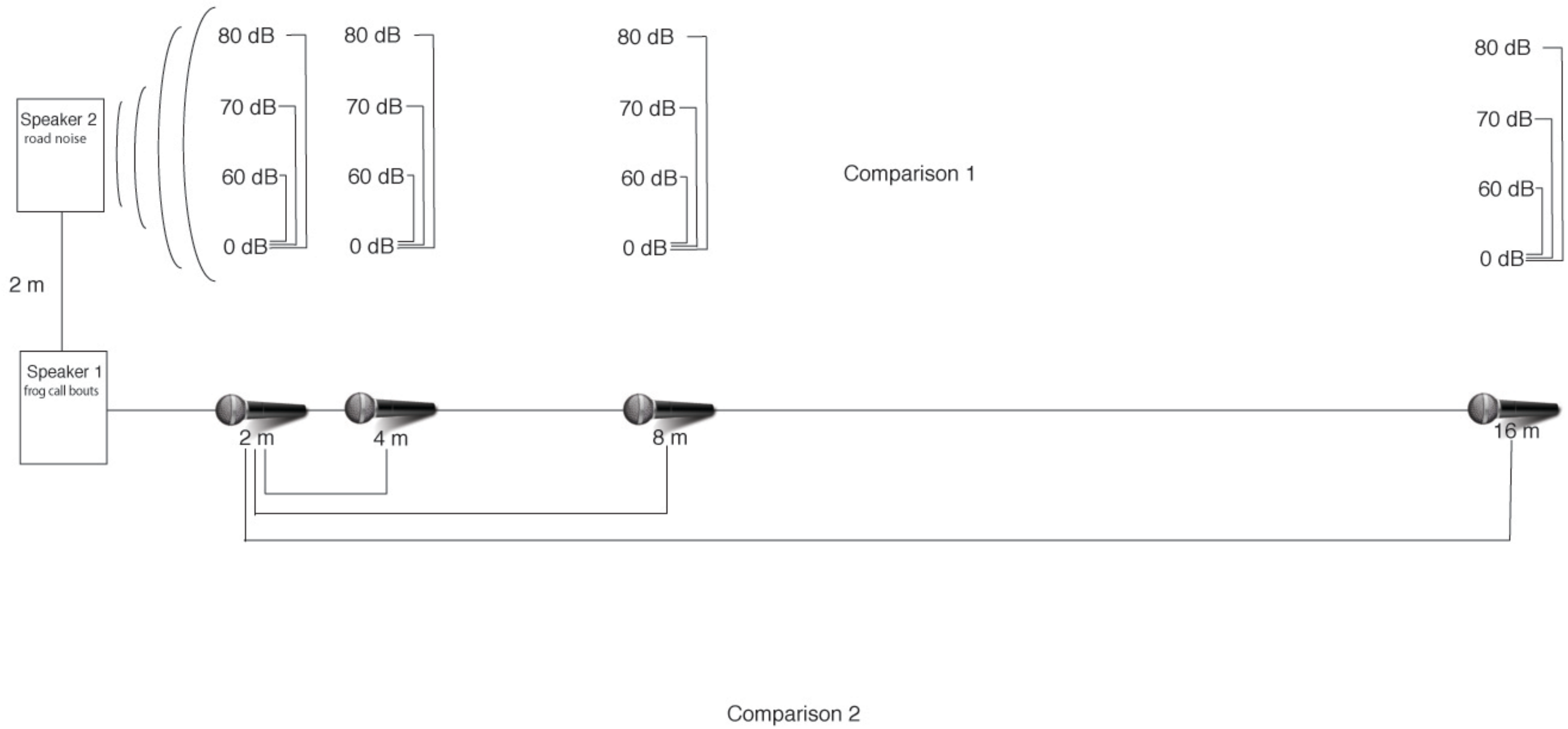

Figure 2: The experimental setup. Speaker 1 plays back *Acris blanchardi* calls. Speaker 2 plays back city noise. The microphone records the playbacks of all calls with all amplitudes of city noise at each of the distances. The playbacks are compared to each other with cross-correlation analysis, first by finding the cross-correlation between a call at 0 dB SPL and a call at 65, 80, or 100 dB SPL at a given distance (Comparison 1), second by finding the cross-correlation between a call at 2 m and a call at 4, 8, and 16 m with no road noise (Comparison 2).

Chapter 3: Results

<u>Differences in Dominant Frequency among Localities</u>

The 79 individuals recorded varied in dominant frequency from 3249 to 4537 Hz, with a mean of 3736 Hz. Localities differed in their mean dominant frequency (Table 1), with the urban frogs of the FH2 having the highest-pitched calls. Despite their proximity to a major roadway, the frogs at FH1 had the lowest-pitched calls.

The dominant frequencies of the original recordings were compared with one-way ANOVA and Tukey's HSD using R. Overall, mean dominant frequency was significantly different among the localities. ($F = 18.7$, $P < 0.001$) Some localities did not demonstrate significant ($P < 0.05$) differences from one another. The call bouts from sites FL1, OL, and FL2 were not significantly different from one another in dominant frequency, but all were significantly lower-pitched than any of the call bouts from sites OH, FH2 and FL3. The call bouts recorded at FH1 are significantly lower-pitched than all others, except those from FL1. The *Acris* calls at OH, FH2, and FL3 are also not significantly different from each other.

These can be considered three "clusters" of call frequency—the individuals from localities FL1, OL, and FL2 have a mean of 3674 Hz (standard deviation 179.4), while those from OH, FH2, and FL3 have a mean of 4025 Hz (standard deviation 203.9). The frogs of FH1 have the lowest pitched calls, with a mean dominant frequency of 3432 Hz (standard deviation 120.0).

Locality	Bastrop 4 (FL1)	Bastrop 10 (FH1)	Bastrop 2012-11 (OH)	Barton Creek Greenbelt (FH2)	Lake Livingston (FL3)	Travis 6 (OL)	Williamson 1 (FL2)
Features	Forested (Lost Pines), low noise	Forested, high noise	Open, high noise	Forested, high noise	Forested (E. Texas Piney Woods), low noise	Open, low noise	Forested, low noise
Mean dominant frequency (Hz)	3604±192.2 (3289-3913)	3432±120.0 (3249-3601)	4068±235.6 (3249-3601)	4078±180.8 (3830-4262)	3930±173.0 (3651-4166)	3680±145.4 (3453-3887)	3738±170.9 (3375-4036)
Mean cross-correlation coefficient (CCC)	0.783±0.173 (0.138-0.995)	0.788±0.159 (0.262-1.000)	0.796±0.158 (0.351-0.99)	0.633±0.236 (0.153-0.974)	0.700±0.218 (0.186-1.000)	0.807±0.187 (0.173-1.000)	0.814±0.132 (0.424-0.995)
Mean CCC, 0/60 dB SPL only	0.912±0.111 (0.224-0.995)	0.902±0.083 (0.638-0.992)	0.908±0.078 (0.634-0.990)	0.852±0.103 (0.618-0.974)	0.885±0.140 (0.28-0.987)	0.904±0.101 (0.478-1.000)	0.897±0.085 (0.680-0.995)
Mean CCC value, 0/70 dB SPL only	0.811±0.119 (0.223-0.964)	0.819±0.104 (0.571-0.971)	0.823±0.110 (0.591-0.955)	0.628±0.144 (0.335-0.873)	0.739±0.135 (0.218-1.000)	0.819±0.174 (0.366-0.996)	0.839±0.103 (0.518-0.962)
Mean CCC value, 0/80 dB SPL only	0.625±0.146 (0.138-0.912)	0.644±0.153 (0.262-0.875)	0.657±0.156 (0.351-0.902)	0.407±0.200 (0.153-0.810)	0.477±0.137 (0.186-0.747)	0.711±0.212 (0.173-0.967)	0.705±0.124 (0.424-0.911)

Table 1: Summary of the cross-correlation coefficients between call bout playbacks with and without road noise (Figure 2; Comparison 1). Each locality is listed with the mean dominant frequency of call bouts recorded, the mean of all cross-correlation coefficients taken between call bout playbacks with and without road noise, and the mean of cross-correlation coefficients taken between call bout playbacks with a specific amplitude of road noise (60, 70, or 80 dB SPL) and without road noise (0 dB SPL).

Playback Experiment

For the playback experiment, two sets of cross-correlation coefficients were made between recordings from a given individual. The first set, "amplitude coefficients," differed in the volume of city noise that was played back along with the recording (i.e., between 0 and 60 dB SPL noise at 2 m) and the second set, "distance coefficients," differed in distance from the speaker (i.e., between playbacks at 2 and 4 m at 0 dB SPL noise). In other words, the amplitude coefficients show how each call is degraded by background noise at a given distance (Figure 2; Comparison 1) and the distance coefficients show the extent to which each call was degraded by distance at a given level of background noise (Figure 2; Comparison 2).

Amplitude Coefficients

Each of 79 call bout playbacks was subjected to 12 CCAs. As a result, there were 948 treatments in this analysis. Two treatments (from the same individual, locality Travis 6, 2m at 70 dB SPL and 8m at 60 dB SPL) were unusable due to error in recording. Each treatment was characterized by five variables: distance from the speaker, locality, individual (nested within locality), amplitude of road noise, and cross-correlation coefficient.

The resulting cross-correlation coefficients (CCCs, between 0 and 1) represent fidelity of each sound's spectrogram with road noise interference to the same sound without road noise interference. The 948 CCCs ranged from 0.138 to 1.000. Their mean was 0.772 and their median was 0.819, with a standard deviation of .184. This shows us that in general, spectrograms of a given call bout remained similar (high CCCs) even with road noise interference.

The amplitude of road noise had an inverse relationship with CCCs in general. Mean CCCs for every population were lower for the 0-70 dB SPL comparison than for the 0-60dB SPL comparison, and lower still for the 0-80dB SPL comparison (Table 1).

Nested four-way analysis of variance (ANOVA) found that the variables locality (df = 6, F-value = 35.994, $P < 0.001$), distance from speaker (df = 1, F-value = 152.486, $P < 0.001$), and road noise amplitude (df = 1, F-value = 1403.142, $P < 0.001$) all had a highly significant effect on cross-correlation. Dominant frequency had a significant effect (df = 1, F = 10.431, P = 0.001). It also found that most interaction terms between the variables were significant as well (distance-locality interaction df = 6, F = 4.897, $P < 0.001$; distance-noise df = 1, F = 90.023, $P < 0.001$; locality-noise df = 6, F = 12.106, $P < 0.001$; distance-frequency df = 1, F = 0.412, P = 0.52; locality-frequency df = 6, F = 18.084, $P < 0.001$; noise-frequency df = 1, F = 3.368, P = 0.07; distance-locality-individual df = 71, F = 4.680, $P < 0.001$; distance-locality-noise df = 6, F = 2.713, P = 0.013; distance-noise-frequency df = 1, F = 0.912, P = 0.340; distance-noise-frequency df = 6, F = 4.095, $P < 0.001$, distance-locality-individual-noise df = 71, F = 1.345, $P > 0.03$). Dominant frequency had no significant interactions except with locality.

	Probabiiity of F
Distance	**<0.001**
Road noise amplitude	**<0.001**
Locality	**<0.001**
Dominant frequency	**0.001**
Distance:road noise	**<0.001**
Distance:locality	**<0.001**
Distance:dominant frequency	0.521
Road noise:locality	**<0.001**
Road noise:dominant frequency	0.067
Locality:dominant frequency	**<0.001**
Distance:locality/individual	**<0.001**
Distance:locality:road noise	0.013
Distance:road noise:dominant frequency	0.340
Locality:road noise:dominant frequency	**<0.001**
Distance:locality/individual:road noise	0.035

Table 2: Four-way nested ANOVA results for cross-correlation analysis between different amplitudes of traffic noise at a given distance (Figure 2; Comparison 1). Significance level = 0.05. Factors are separated by colons; a nested relationship is indicated by a slash. Significant results are bolded. Distance, road noise amplitude, locality, and dominant frequency were all significant, as were most interaction terms.

I used one-way ANOVA on each individual variable (distance, locality, individual, individual nested within locality, road noise amplitude, dominant frequency) and reaffirmed that each is significant in determining the degree of degradation (Table 2).

Distance Coefficients

Each of 79 playback recordings was subjected to three cross-correlation analyses. Each of these treatments had the variables distance, locality, individual (nested within locality), and cross-correlation coefficient. One treatment (third individual from FL1 at 16m) was unusable due to recording error.

These CCCs had a mean of .895, a median of .9165 and a standard deviation of .095. Fidelity decreased with distance for individuals of every locality (Table 4). Nested three-way analysis of variance (ANOVA) found that distance from speaker had a highly significant effect on cross-correlation coefficients (df = 1, F = 74.680, $P < 0.001$). Locality, in contrast, did not have an effect on CCCs (df = 6, F = 1.686, P = 0.1). The interaction between distance and locality was not significant (df = 6, F = 1.836, P = 0.09) but that between distance, locality, and individual was (df = 71, F = 1.832, $P < 0.01$).

One-way ANOVA analysis of each individual variable (distance, locality, individual nested within locality, dominant frequency) found that only distance had a significant effect on degradation. There is likely no major effect of locality or dominant frequency on degradation over distance.

Locality	Bastrop 4 (FL1)	Bastrop 10 (FH1)	Bastrop 2012-11 (OH)	Barton Creek Greenbelt FH2	Lake Livingston (FL3)	Travis 6 (OL)	Williamson 1 (FL2)
Features	Forested (Lost Pines), low noise	Forested, high noise	Open, high noise	Forested, high noise	Forested (E. Texas Piney Woods), low noise	Open, low noise	orested, low noise
Mean dominant frequency (Hz)	3604±192.2 (3289-3913)	3432±120.0 (3249-3601)	4068±235.6 (3249-3601)	4078±180.8 (3830-4262)	3930±173.0 (3651-4166)	3680±145.4 (3453-3887)	3738±170.9 (3375-4036)
Mean cross-correlation coefficient (CCC)	0.887±0.121 (0.235-0.986)	0.918±0.058 (0.754-0.986)	0.908±0.063 (0.730-0.985)	0.854±0.104 (0.637-0.975)	0.888±0.133 (0.227-0.979)	0.894±0.080 (0.658-0.987)	0.900±0.058 (0.731-0.975)
Mean CCC, 2m / 4m only	0.939±0.049 (0.790-0.986)	0.938±0.043 (0.856-0.986)	0.913±0.067 (0.795-0.978)	0.861±0.095 (0.714-0.944)	0.950±0.015 (0.927-0.969)	0.927±0.059 (0.790-0.987)	0.932±0.037 (0.852-0.975)
Mean CCC, 2m / 8m only	0.893±0.164 (0.235-0.978)	0.934±0.062 (0.774-0.985)	0.946±0.034 (0.886-0.985)	0.888±0.119 (0.694-0.975)	0.936±0.032 (0.883-0.979)	0.928±0.030 (0.884-0.976)	0.925±0.027 (0.886-0.970)
Mean CCC, 2m / 16m only	0.824±0.094 (0.549-0.924)	0.880±0.053 (0.754-0.935)	0.866±0.061 (0.730-0.923)	0.812±0.105 (0.637-0.906)	0.779±0.189 (0.227-0.900)	0.828±0.093 (0.658-0.947)	0.842±0.054 (0.731-0.903)

Table 3: Summary of the cross-correlation coefficients between call bout playbacks at 2 m and at a greater distance (4, 8, or 16 m). Each locality is listed with some salient features, the mean dominant frequency of call bouts recorded from there, the mean of all cross-correlation coefficients taken between call bout playbacks at varying distances, and the mean of cross-correlation coefficients taken between call bout playbacks at 2 m and at a specific greater distance (4, 8, or 16 m). These playbacks were performed without road noise (0 dB SPL).

	Pr(>F)
Distance	**<0.001**
Locality	0.128
Dominant frequency	0.156
Distance : locality	0.096
Distance : dominant frequency	0.206
Locality : dominant frequency	0.104
Distance : locality / individual	**0.001**

Table 4: Three-way nested ANOVA results for cross-correlation analysis between call bout playbacks at different distances from the speaker (Figure 2; Comparison 2). Significance level = 0.05. Factors are separated by colons; a nested relationship is indicated by a slash. Significant results are bolded. Distance was significant (i.e. calls degrade more over greater distances) but locality and dominant frequency were not significant.

Chapter 4: Discussion

Since anurans increase the frequency of their calls in complex environments (Ryan et al. 1990; Ryan & Wilczynski 1991) and in the presence of traffic noise (Parris et al. 2009; Cunnington & Fahrig 2010), my predictions were that populations of *A. blanchardi* from eastern, forested sites would have higher frequencies than populations from western, grassland sites, that the transmission of an *A. blanchardi* call bout would be degraded by traffic noise and by distance, but that bouts with higher dominant frequencies would be less degraded.

Overall, the results indicate that individuals from different localities differ significantly in their transmission ability across distance and different levels of interference. However, they did not fully adhere to the predicted pattern, suggesting other factors at work. I also confirmed that background noise negatively affects transmission over distance.

The Relationship Between Locality and Dominant Frequency

Ryan and Wilczynski (1991) found that both longitude and habitat are correlated with the dominant frequency of *Acris blanchardi* in Texas: its calls increase in pitch going east and in closed habitats such as forests. My additional prediction was that populations subjected to high amounts of noise, such as urban populations, will also demonstrate higher-pitched calls.

These two hypotheses cannot completely describe my data. It is true that the *Acris blanchardi* of Lake Livingston, located far to the east of my other sites and highly forested, do have higher-pitched calls. The rest of my sites are geographically proximate (within 50 miles; Figure 1). Barton Creek Greenbelt's *Acris* have high-pitched calls, which could be explained by their high-noise environment within the city of Austin. But it is unclear why the *Acris* of Bastrop 2012-11 (OH) should join this high-frequency cluster while their more heavily-wooded neighbors to the west and east (FH1 and FL1) call at lower frequencies. OH is transiently subjected to high road noise, but so is FH1.

<u>Playback Experiment: Amplitude Coefficients</u>

The 79 *Acris* calls differed substantially in their ability to overcome interfering road noise. As expected, increasing the amplitude of road noise increased degradation in the call, as measured by cross-correlation analysis. Increasing the distance between the call speaker and the receiver microphone also increases degradation. The null hypothesis that locality of the individual that made the initial call would have no effect on this degradation was rejected.

My hypothesis that calls from forested or high-noise localities would demonstrate superior fidelity through traffic noise was shown to be false. This would predict low fidelity in *Acris* calls recorded from OL, and these had the second-highest fidelity. There is an apparent relationship between dominant frequency and the ability to retain high fidelity through traffic noise, but the effect has a strong interaction with locality. This indicates that dominant frequency is just one of many features of the call may be responsible for the differences. Indeed, individuals at OL and FL2 are in the cluster of low frequencies, and the two sites whose individuals demonstrated the lowest fidelity (FH2 and FL3) were in the cluster of high frequencies.

Playback Experiment: Distance Coefficients

I found no effect of locality on a call's ability to be transmitted over distance. This suggests that *Acris* in all populations face similar challenges with regards to the degradation of calls over distance. Distance not only has a negative effect on transmission itself, but also on the call's ability to overcome road noise. This indicates that particular care should be taken in more fragmented or sparse *Acris* habitats to minimize exposure to traffic and other sources of loud noise. This is similar to the findings of other workers on other frog species—anthropogenic noise represents a conservation concern (Lengagne 2008, Parris et al. 2009, Sun & Narins 2005).

I also did not find evidence to confirm the hypothesis that higher dominant frequency (at a height of <1 m) increases fidelity over distance, as was found by Boncoraglio and Saino (2007). No relationship was found between dominant frequency and transmission over distance in the absence of interfering road noise.

Conclusion

The purpose of this project was to determine if evolving higher dominant frequency would be adaptive for Texas *Acris blanchardi* that are subjected to high levels of low-frequency noise. This would be analogous to the higher frequencies evolved by *A. blanchardi* to adapt to the acoustic environment in the Lost Pines area (Ryan and Wilczynski 1991). I have found limited evidence to support this hypothesis. There is a positive relationship between dominant frequency and fidelity of transmission through traffic noise. However, it is entangled with the effect of locality. This is also not a consistent effect (see Table 1, FH2 for instance).

My data suggest that populations of *Acris blanchardi* will differ substantially in their ability to overcome the low-frequency anthropogenic noise that is becoming ubiquitous in their habitat (see CCCs in Table 1). The features of their call that account for this variation are still not clear, since I examined only dominant frequency.

Perhaps most importantly, I have shown that populations of *Acris blanchardi* are not necessarily well-adapted to the acoustic environments they currently reside in. The individuals of Barton Creek Greenbelt, which are constantly exposed to traffic noise, had the poorest signal fidelity given exposure to traffic noise. There are many potential reasons for this, such as insufficient speed of adaptation, inability to acclimate, gene flow, and temperature variation in calls that have not been accounted for (Wagner 1989). I can only conclude that high levels of low-frequency anthropogenic noise will have a serious impact on the communication system of *A. blanchardi*, despite those calls being much higher-pitched, and that females may not be able to compensate for the increased difficulty in finding mates.

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