Spectral Complexity within River Soundscapes: Quantifying the spectral signature of running water in differing terrain morphologies in the Big Creek watershed, Central Idaho

A DeVlieg Undergraduate Research Scholar ***Progress Report***

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INTRODUCTION

Sound is an integral part of every ecosystem. The sounds found within an ecosystem make up the soundscape, and fall within three main categories 1) the *biophony*, sounds produced by living organisms, 2) the *anthrophony*, sounds produced specifically by humans, and 3) the *geophony*, sounds produced by non-living sources such as running water and wind (Pijanowski et al, 2011). Studies have indicated that excess anthropogenic sound can cause damage to ecosystems (Francis et al. 2013), however, studies examining river sound, its complexity, and impacts, are less common. Existing water-based sound studies focus on sonic signatures of turbulence (Tonolla et al, 2009), impact of sound in marine environments (Moore et al, 2012), or the general interactions of landscape features and sound (A. Mazaris et al, 2009) , leaving the sound produced by exclusively by rivers and streams virtually unexamined. This study examines the geophony of the Big Creek drainage of the Frank Church River of No Return Wilderness (Frank Church Wilderness). The Frank Church Wilderness is the largest contiguous wilderness area in the lower forty-eight, consisting of 2,366,757 acres of incredibly varied landscapes, comprising an environment strongly suited for this research, and allowing for comparisons between different terrain morphologies. These comparisons were used to assess whether riparian characteristics affect the spectral signature of river sound, and to then examine the complexity of the Big Creek geophonic soundscape.

This survey will examine and compare the changes in dB level, L_{eq}, and the distributions of frequencies across the three test sites, forest, riparian, and scree slope, in order to develop a more complete picture of river sound. Studies have found using L_{eq} values to be one of the strongest metrics for making comparisons between sites (Gonzalo et al, 2015), however examination of frequency distributions is particularly important when examining and describing environments where there are high bird and mammal concentrations, as background sound in certain frequency ranges affects both animals' ability to communicate and can create a signal masking effect (Bee et al, 2007, Lengangne, 2008).

MATERIALS AND METHODS

Sample collection
All recordings were taken between May and June 2016, along Big Creek (Figure 1). Sites were chosen upon arrival to Big Creek with the following criteria: 1) the site was within walking distance to ensure that measurements could be taken at approximately the same time each day, 2) The three sites were significantly different from each other in terms of river bank landscape/morphology. Time of recording was chosen to be early morning to minimize wind interference and air traffic noise, as well as to maintain a relatively constant temperature.

Recordings were taken at a height of one meter above the ground, and at distances of one meter, ten meters, and fifty meters from the river. Recordings were five minutes in length. In addition, a three-minute long L_{eq} measurement was taken simultaneously with each recording, and minimum and maximum un-weighted dB values were recorded for each river recording, for calibration purposes. These dB values and the L_{eq} values were later calibrated using a Larson Davis dB meter.

Recordings were taken using a Sennheiser shotgun mic (https://en-us.sennheiser.com/shot-gun-microphone-cameras-video-recordings-mke-400) with a Roland-05 recorder (https://www.roland.com/us/products/r-05/). L_{eq} measurements and dB minimum and maximum measurements were taken with a micW (http://www.mic-w.com/product.php?id=3), using a sound pressure-monitoring app, SPLnFFT, on an iPhone.

Statistical Methods

Analysis was conducted using the Seewave package in the statistics software R-Cran (https://CRAN.R-project.org/package=seewave), and JMP statistical analysis tools.
Power spectra figures coupled with frequency percentile data values obtained in R provided information on frequency distributions, and sound pressure level comparisons were made using spectrogram plots obtained in R and averaged minimum and maximum dB values from the micW calibration mic. JMP was used to calculate P- values as well as to determine statistical significance of relationships between site and distance, site and sound pressure level, distance and sound pressure level, site and frequency percentile, and distance and frequency percentile.

RESULTS

Averaged L_{eq} values, maximum dB(F) values, and Frequency percentile values were not found to be significantly different across sites. Minimum dB (F) however, was significantly different ($P<0.0001$ by analysis of variance ANOVA) and a Turkey HSD test showed relationships between sites (Figure 2). F_{90} values and average minimum dB (F) for the forest site were significantly different compared to the riparian and the scree sites an are summarized in table 1. All sites exhibited drop off in sound pressure level as distance from sound source increased, though the drop off varied between sites (figure 2). Frequency distributions were similar across all sites and distances, with the highest amplitude frequencies exhibited in the 1^{st} frequency band (0kHz- 2kHz). This is congruent with other findings, demonstrating that bio-phonetic sounds generally occur in the low frequency ranges. (Pijanowski et al, 2011).

DISCUSSION

Our results indicated that significant differences between sites consisted mainly of sound pressure level differences. All three sites exhibited similar frequency distributions, mainly in the 0kHz-2kHz range, which is typical of geophonic sound. An interesting observation is seen in the forest spectrogram at 50 meters (figure 4). At 1 meter and 10 meters, the frequencies at the forest site occupy the 0-15 kHz range. At 50 meters, the frequency range decreases to aproximately 0-6 kHz range, and bird song frequencies can be observed in the 10- 15kHz range previously occupied by only river produced frequencies. Although birds were observed at all recording sites, at all distances from the river, the forest site is the only site in which the bird song frequencies become visible.

Our results indicated that riparian characteristics have some effect on propagation of river noise, although this effect is not always significantly different from the propagation of noise across non riparian areas.

The similarity between all three sites indicates that though rivers serve as a constant source of noise in an ecosystem, the signature of that noise, both in terms of sound pressure level and frequency distribution, is specific to running water.

Continuing research should focus on the importance and effect of river sound on ecosystems. Variables such as predator and prey density, effects of seasonality and climate change on river levels and associated noise increases, as well as studies which examine the effects on ecosystems of river noise in contrast to anthropogenic noise or other noises of similar amplitude. Long time series data would be useful in acquiring data sets that span multiple seasons and give a more complete picture of river noise.

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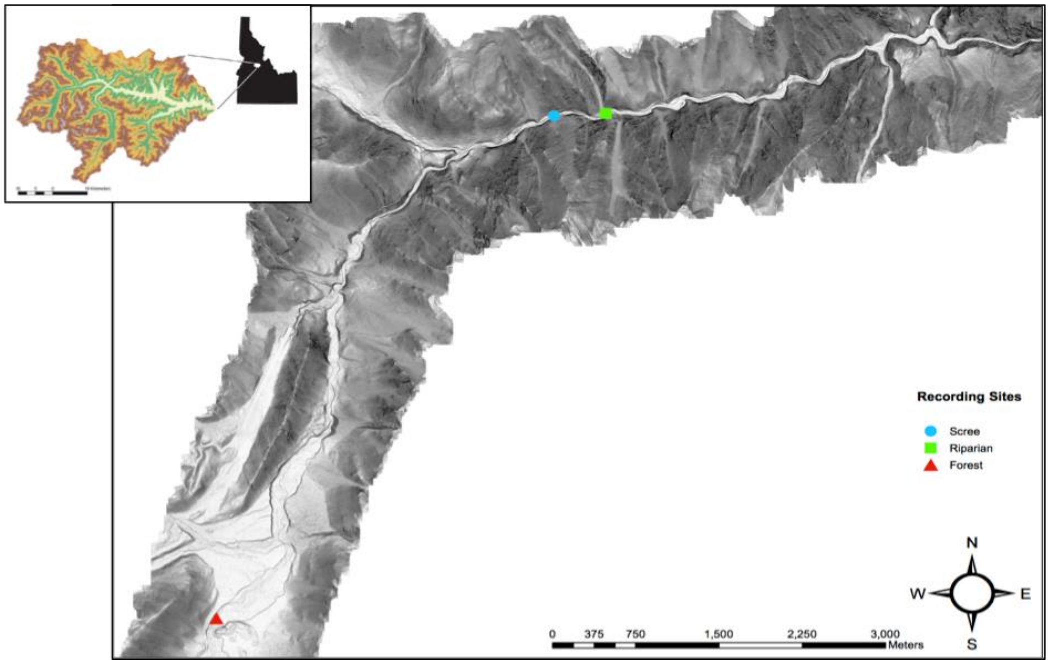

Figure 1 Map of Big Creek Drainage with three recording sites marked. The forest site is shown as a red triangle, the scree as a blue circle and the riparian as a green square.

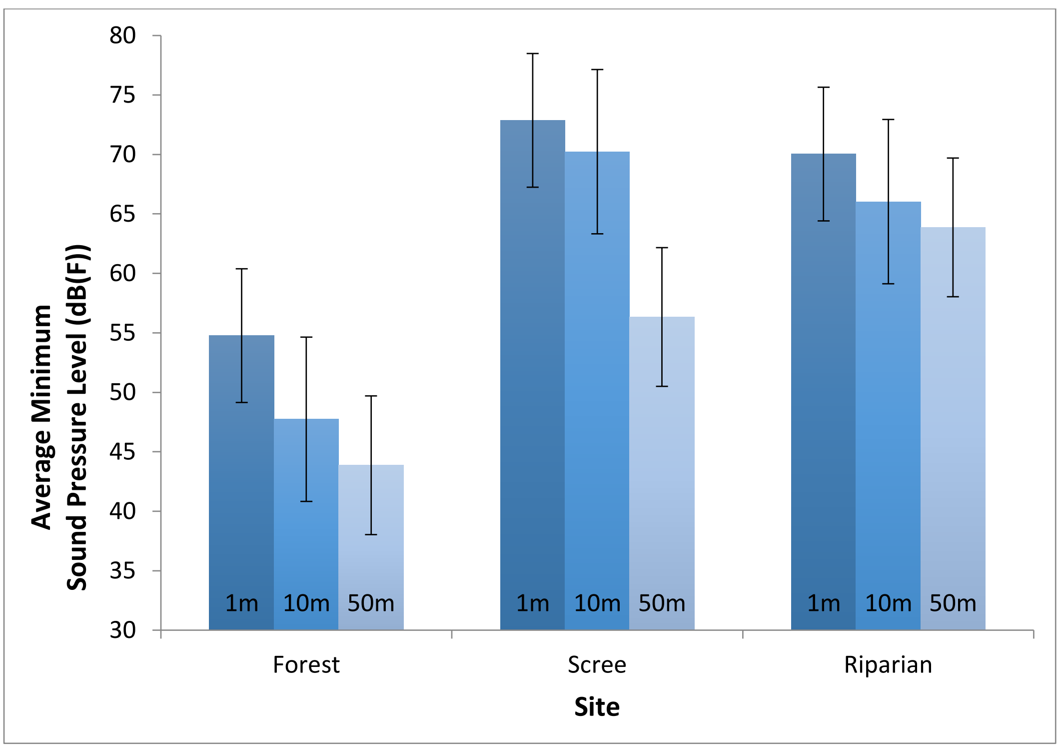

Figure 2. Average minimum unweighted decibel levels for three sites, forest, scree, and riparian, over three distances, 1 m, 10 m, and 50 m, from sound source. Error bars for standard error are included. Letters above collums indicate relationships of sites to one another, with similar letters being not significantly different from one another. Forest average minimum dB (F) values were significantly different from both the scree and riparian (p<0.0001)

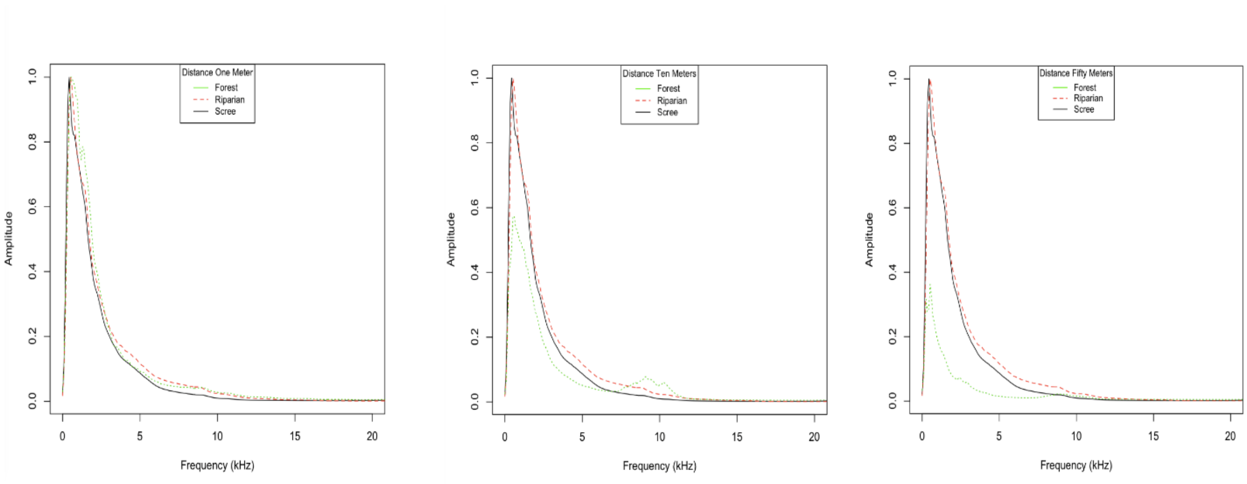

Figure 3 Power spectra of each site, at distances 1m, 10m, and 50m. Amplitude is shown on the y-axis as percent of maximum relative the maximum amplitude of the sample. Frequency is shown along the x-axis in kHz. Green dotted lines indicate forest sites, red dotted lines indicate riparian sites, and black solid lines indicate scree sites.

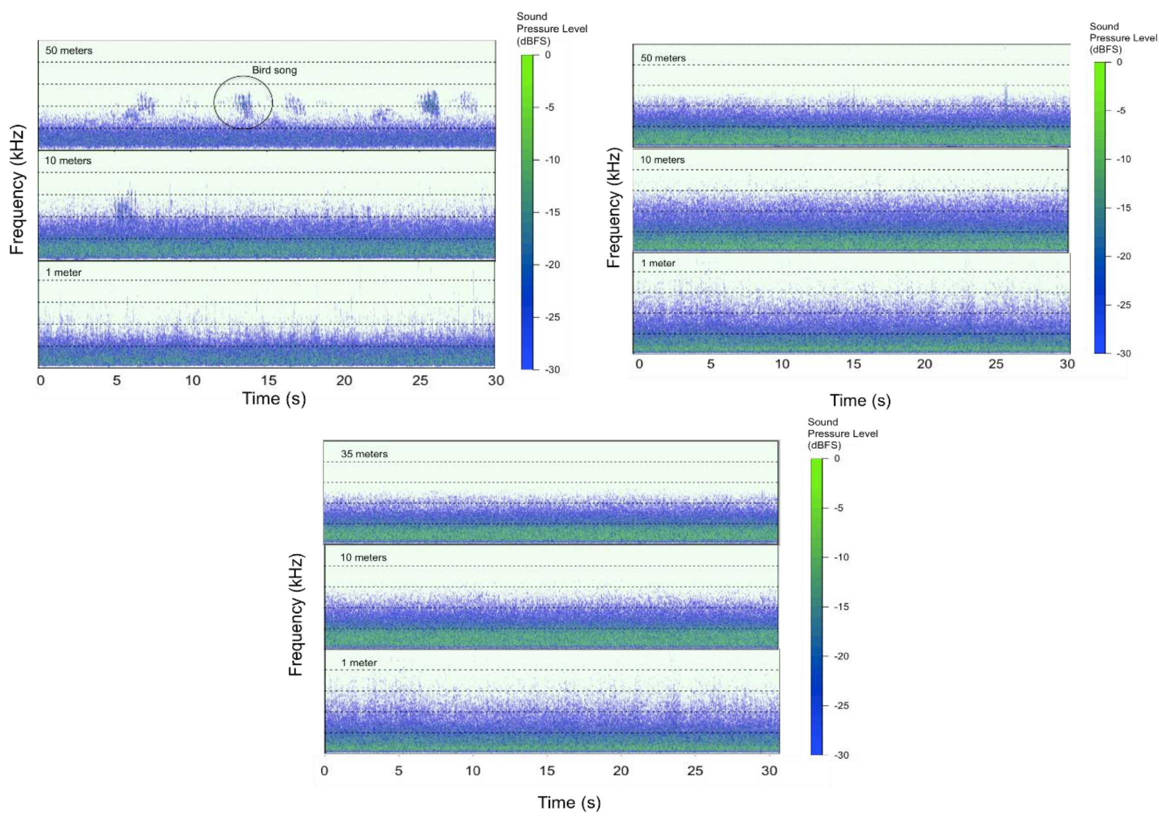

Figure 4. Spectrograms of each primary site, from top left to bottom, Forest, Scree, and Riparian. Three distances from sound source (Big Creek) are shown, 1 meter, 10 meters, and 50 meters. Frequency is shown on the y-axis as a logarithmic scale extending from 0 kHz to 20 kHz. The z-axis (color) describes sound pressure levels in dB (unweighted); the color scaling used for all three panels is indicated by the color bar on the right hand edge.