Bioacoustic variation of the western meadowlark (*Sturnella neglecta)* in response to increased traffic noise

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2019

Abstract

Songbirds emit sounds, calls or songs to communicate and interact with their environment. These songs are adapted to better suit their habitat to avoid sound overlap and noise masking. Increasing anthropogenic noise has forced some songbirds to increase their pitch or to adapt their song structure to enhance their song's efficiency. Grasslands are seldom the focus of bioacoustics studies despite being a highly threatened ecosystem. Western meadowlarks (*Sturnella neglecta)* are common grassland birds with a large song repertoire. This study aims to identify any differences in song composition (phrases) and physical features (minimum and maximum frequency) between two western meadowlark populations as a response to noise disruption. Western Meadowlarks from the National Bison Range (low noise disruption) and the Ninepipe Wildlife Refuge (high noise disruption) were recorded. Sonograms were created for these recordings. Maximum and minimum frequencies were extracted and compared, as well as frequency range. Types of phrases were identified and classified for each site. These were indicative of song composition and song diversity. On average, the NWR appeared to have higher maximum and minimum frequency values. Frequency range size was similar for both sites. Song composition (combination and appearance of types of phrases) varied between sites, but song diversity was similar.

Keywords: grasslands, western meadowlark, bioacoustics, frequency, song composition

Introduction

Different species emit sounds to communicate; some do it to defend a territory or to find a potential mate. Some birds use songs and calls to interact with other organisms or individuals. To clearly communicate a message, these sounds need to be perceived by other individuals. Bird songs and calls are often adapted to their environments, mitigating the degradation of the sound and spreading the song more efficiently. However, changes in the environment and an increase in noise can greatly affect the efficiency of songs, further affecting the overall fitness and survival of the individual or its species (Taylor & Francis Group 2017). Because songs are adapted to the environment, different populations of the same species can have different songs if the conditions of their habitats are different.

Songbirds are exposed to a wide variety of sounds and noises coming from different sources, such as other organisms, atmospheric conditions or the components of their natural environment (Curry *et al.* 2017). Some bird species have adapted their sounds and songs to avoid overlapping (Nemeth *et al*. 2013). Variation in song structure and elements within a species and among different species can happen due to different levels of background noise (Curry *et al.* 2017; Tumer & Brainard 2007). Anthropogenic noise has become more prevalent in terrestrial habitats due to traffic, urbanization, increasing human activities and other noise sources (Curry *et al.* 2017). Understanding how noise pollution and background noise affects the behavior and song structure of bird songs is important if we want to mitigate the effects of increasing noise levels on wildlife.

Previous studies have shown that songs of birds in cities tend to vary from the songs of their conspecifics found in forests or more natural areas (Nemeth *et al*. 2013). Songbirds can react differently when exposed to different types of noise and background noise levels depending on their behavior, learning capability and sensitivity (Williams 2004). Songbirds from different communities, or closely related species can have a completely different reaction to noises. Some have a greater plasticity or frequency range, and others may have a greater repertoire of songs (Curry *et al*. 2017). Birds with bigger song repertoires may use songs that are more easily heard over background noise or in their acoustic environment (Derryberry 2007). The bird species *Sturnella neglecta* (western meadowlark) has a varied song repertoire and commonly switches songs (Aweida M.K 1995). However, few studies have focused on the western meadowlark's song structure and how it varies between habitats with different acoustic conditions.

S. neglecta can easily be found in the grasslands of Western Montana. Grasslands are home to a wide variety of songbirds, but they are also one of the most threatened ecosystems (U.S Fish & Wildlife Service 2012). Most studies have focused on the effect city noises have on bird songs, but we know little of the effect other human activities in other environments can have on bird songs, including those that may not be as harsh as cities in terms of noise disruption. Grasslands have less human presence and as a result, a different amount of noise disruption when compared to cities. Nevertheless, songbirds can be sensitive to changes in noise level and it is difficult to decide at which point a species will start showing changes or adaptations in their songs due to background noise. More studies are needed to assess the effect that human activities have on *S. neglecta* to understand how these birds adapt to acoustic changes in their environment.

The National Bison Range (NBR) and the Ninepipe Wildlife Refuge (NWR) are only about 17,219.98 m (10.7 mi) apart, but their acoustic conditions vary greatly. Ninepipe Wildlife Refuge is closer to the highway, so the edges of the refuge are subject to more noise disruption caused by frequent traffic. For this study, the songs of western meadowlarks from both sites were recorded. This allowed us to create sonograms to obtain a visual representation of their songs. Sonograms allow us to obtain song minimum and maximum frequency (pitch), which greatly affects song propagation (Boncoraglio & Saino 2007). We also wanted to see if song variability and composition were different between the NBR and NWR. Song elements, such as syllables, notes or phrases can help us visualize the songs and understand differences in song structures and songbird adaptation to different environments (Ranjard & Ross 2007; Elody & Fischer 2009). For this study, we identified the types of song phrases recorded from both sites. As phrases are building blocks of a song, they may serve as indicators of the overall physical features of the song. Some birds with song repertoires sequentially associate (or cluster) songs of different types, so that certain song types may occur together repeatedly. With such a large song repertoire, it is possible the western meadowlark population in the NWR prefers some types of songs or a combination of them more often, thus differing from the songs emitted by the population found at the NBR. The songs from the NWR may be better suited for the higher noise levels present at this site, enabling western meadowlarks to communicate and interact more easily and efficiently.

The questions addressed in this study are: 1) Are there any differences in song physical features and structure for two distinct western meadowlark populations depending on habitat?, 2) Are any particular types of songs more prominent in one site than the other?, and 3) Could traffic noise be a determining factor in the western meadowlark's song adaptation to its environment? I hypothesized that 1) western meadowlarks at the NWR would emit songs with higher frequency range to avoid overlap with traffic noise; 2) the frequency range for the western meadowlarks at the NBR would be larger due to more available acoustic space; 3) Traffic noise would be much more intense at the NWR, thus obligating western meadowlarks to adapt their song to an environment with enhanced noise disruption.

Methods

Study Sites

The National Bison Range and Ninepipe Wildlife Refuge are both administered by the U.S. Fish and Wildlife Service as part of the National Wildlife Refuge System. The NBR is an 18,500-acre range, and the environment is mostly composed of open grasslands. The Ninepipe Wildlife Refuge is a 1,770-acre wetland complex that also contains over 800 glacial potholes. Some areas are just off the US Highway 93, and about 1207.008 m (0.75 mi) south of the junction with Secondary Route 212. Six locations were selected at the NBR and eight locations were selected at NWR. Figure 1 presents a map with the study locations marked for each site.

Study Species

Sturnella neglecta, the western meadowlark, is a medium sized bird that mostly nests on the ground in open grasslands. They can be seen in Western North America and Central America and are very common in both the NBR and NWR. The western meadowlark has a varied song repertoire, and it is known to switch songs easily.

Procedure

For the NBR we recorded 6 birds in two days (7/11/2019 and 7/12/2019); 3 birds each day. For the NWR, we recorded 4 birds in two days (7/26/2019 and 7/27/2019). On July 29th and July 31st, we went to the NWR to record more birds, but didn't find any.

Only one bird was recorded per each location to avoid wrongly attributing song characteristics due to mixing songs from different birds. We obtained around 5 recordings of approximately 30 s for each bird whenever possible; sometimes we could only obtain 3 as the bird would stop singing.

To record, we used a shotgun microphone (Audio Technica AT875R) powered by an audio recorder (Tascam DR-40). To minimize capturing unwanted noise in the field and handling noise, we used a windshield and a microphone boompole. We went to the field from 6:00 am to 8:00 am. To keep consistency, we spent around 20 minutes at each location.

To stimulate western meadowlarks to sing, we used playback. Ideally, recordings should start a couple of seconds before the birds start singing, so a pre-recording setting was set on the Tascam DR-4O audio recorder. As soon as the bird started singing, we hit the recording button and pointed the microphone directly at the singing bird at the closest possible distance without disturbing the bird. This process was repeated 5 times for each bird. The recordings were saved as uncompressed files (WAV).

Song analysis

To analyze the recordings, we used the sound analysis software program Raven, created by the Bioacoustics Research Program of Cornell Lab of Ornithology. I created sonograms (Figure 2) for each recording and extracted the maximum and minimum frequency of each phrase for each recording. The maximum and minimum frequency values for the phrases of each recording were averaged. I also subtracted the maximum frequency from the minimum frequency to obtain frequency range. This resulted in one maximum and minimum frequency value per recording. I identified and classified phrase types for each recording. After identifying each of the phrases, I counted how many phrase types appeared per recording and per site.

Statistical analysis

Statistical analyses were done using statistical softwares Mystat and Rstudio. Figures and graphs were created on Mystat and Excel. I used the Shapiro-Wilks test to test for normality for maximum and minimum frequency data. A Two-Sample T-test was used to see if there was any difference in the minimum frequency between populations from both sites. For the maximum frequency and frequency range, I used Kruskal-Wallis tests. Because phrase type and phrase counts served as indicators for song composition for each site, I used Principal Component Analysis (PCA) to see if some phrase types or combinations of phrase types were more prevalent in one site. After obtaining PCA factor scores for each site, I used a T-test to see if there were any differences between the sites. I calculated a Shannon Diversity Index for each sample to see if there was more song diversity in one of the sites. A T-test was used to compare Shannon Index (song diversity) between sites.

Results

In total, I obtained 23 samples for the NBR and 18 samples for NWR. The variability of the minimum frequencies between sites was considerable, although not strictly significant (df= 39, p=0.060). Figure 3 shows that the average minimum frequency for the NWR is slightly higher than the minimum frequency for the NBR. Differences in maximum frequencies between both sites was significant (df=1, p=0.020). Figure 3 shows that the average maximum frequency for the NWR is higher than the maximum frequency at the NBR. Frequency range between both sites did not appear to differ (df=1, p= 0.18031). Figure 4 shows that while the frequency range size between both sites is similar, the frequency range for the NWR includes higher frequencies than the NBR.

I identified 20 phrase types in total. With a Linear PCA analysis, I obtained PCA factor scores for each sample (Table 1). There appeared to be a significant difference for combinations and usage of song types between sites (df=29, F=4.216, p=0.046) (Figure 5). Lastly, there did not appear to be a significant difference between Shannon Index for song diversity between sites (df=39, F=0.2895, p=0.5936).

Discussion

The minimum frequency for the population at the NBR was on average lower than the minimum frequency for the population at the NWR (Figure 3). Although the difference was not strictly significant, the minimum frequencies between the sites were different enough to indicate they may differ in future studies, ideally with a bigger sample size. There was a significant difference for the maximum frequencies between the sites. On average, the frequencies were higher at the NWR than at the NBR.

In environments with dense and high vegetation, low frequencies are generally less degraded than high ones as atmospheric and vegetational absorption, scattering and reverberation are greater for high frequencies (Boncoraglio & Saino 2007). However, this situation is reversed when the sounds are transmitted close to the ground (below 1 m) because of greater interference between direct and reflected paths (Boncoraglio & Saino 2007). Western meadowlarks nest on the ground, and many of their activities and interactions happen close to the ground. If high frequency songs are less degraded than lower ones at a short distance from the ground, then it is possible western meadowlarks emit high frequency songs to enhance their song's efficiency in an environment with high noise disruption caused by anthropogenic noise, such as traffic. Taylor and Francis Group (2017) report some studies that show the North American Flycatcher sings songs at a lower range of frequencies in response to traffic noise levels. However, behavioral (more activity closer or further from the ground, etc.) and habitat differences (dense foliage, mainly grasses, etc.) may explain why some songbirds choose lower frequency songs when exposed to traffic noise. The North American Flycatcher, as opposed to the Western Meadowlark, spends more time at a higher distance from the ground and their habitats tend to have denser foliage. Dense foliage affects both amplitude and frequency modulations (Boncoraglio & Saino 2007).

Other studies have shown that birds in cities tend to have a higher frequency than their conspecifics found in forests or more natural areas (Nemeth *et al*. 2013). Nemeth et al. (2013) proposed that perhaps it is not frequency shifts that mitigate the effects of noise disruption, but rather singing louder. Nemeth et al. (2013) showed that frequency and amplitude are strongly positively correlated in the common blackbird (*Turdus merula*), a successful urban colonizer with little masking by low-frequency traffic noise.

This could also explain the case for the western meadowlark. Western meadowlarks at the NWR may choose to emit high-frequency songs because they can be produced at high amplitudes, which results in louder songs (Nemeth *et al*. 2013). However, this study neither refuses nor supports this idea, as amplitude was not measured due to lack of control of field conditions that could greatly affect amplitude, such as wind and distance from the source.

Frequency range size was not significantly different between the sites. Elody and Fischer (2009) pooled a great amount of bioacoustics studies and found that frequency range is one of the acoustic variables most often adjusted to the environment. However, it is important to note that most studies have focused on species with simple or little song repertoire variation. The western meadowlark has a large and varied song repertoire, and it may rely more on structuring its songs with song elements (phrases, syllables, etc.) that increase the song's efficiency and propagation with the least energy cost, rather than expanding or shrinking its frequency range. However, more studies and a larger sample size are needed to address this idea.

Song structure and overall composition are important characteristics that allow us to see if differing song types translate into adaptations for enhanced song efficiency and better communication in an environment. In this study, the composition of phrases between the two sites is significantly different. This means that certain combinations of types of phrases or the appearances of certain types of phrases are more prevalent in one site than at the other. Because phrases are building blocks for songs, different types of phrases may serve as indicators for different types of songs. This could mean that some types of songs are more efficient and more easily spread at the NWR than at the NBR. Interestingly, when comparing Shannon Index for song diversity between the NWR and the NBR, no significant difference was found. This is an indication that while certain types and type combinations of phrases are more prevalent in one site, both sites have similar numbers for phrase types and similar occurrences for each of those phrase types.

In conclusion, the maximum frequency was different between the sites, with the NWR having a higher frequency on average. The minimum frequency was different enough to still consider this physical characteristic as one of importance for future studies. The size of the frequency range did not differ between sites, but the NWR included higher frequency values than the NBR. The phrase composition is different between sites, but both sites have similar song diversity. The hypotheses were partly supported. Traffic noise appears to be a determining factor in the western meadowlark's song adaptation to the bioacoustics conditions of the environment, though we cannot be sure if it is the sole or the most important factor.

More studies with a larger sample size are needed to better understand how the western meadowlark adapts to environments with noise disruption. Besides traffic noise, other noise sources such as other birds or individuals need to be considered. Time of season, variability of elevation and other abiotic factors such as wind and temperature need also be considered. Finally, the addition of amplitude measures would greatly improve our understanding of the song's variations in different bioacoustics conditions.

Acknowledgements

I want to thank the University of Notre Dame, Gary Belovsky and the Hank Family for presenting me with the exciting opportunity to conduct research at UNDERC-West. Thanks to José Enrique Fernández for funding my program expenses. I am grateful to the National Bison Range and Ninepipe Wildlife Refuge for allowing me and trusting me to conduct my study in sites under their management. Thanks to David Flagel, for assisting us in every way that he could, and making our research a little easier. To the best advisor and TA, Zoë Goodrow, thank you for being so supportive and helpful, but most of all, thank you for being a friend during my time at UNDERC-West. I would like to thank Zoë Goodrow, Suheily M. Arce Lugo, Shirley LeClair-Bernal, Eileen Reeves, and Eric Laate for their help in choosing my sites and collecting data. A most enthusiastic thanks to Kate Berrett, Gary Belovsky and Zoë Goodrow for their help in doing statistical tests and analyzing my data. To the UNDERC-West class, thank you for making every experience such a fun adventure.

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A

B

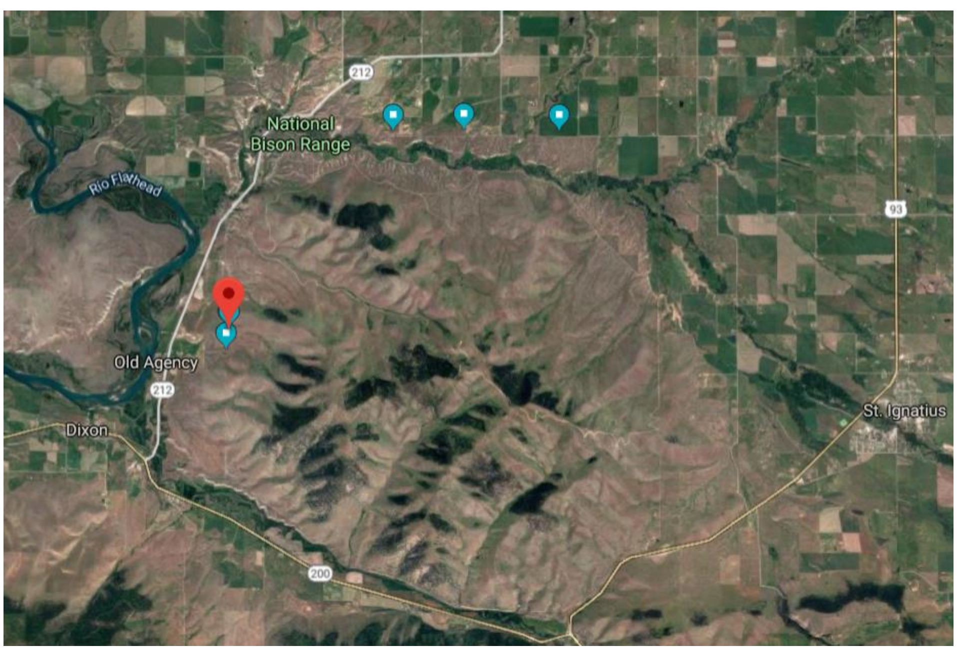
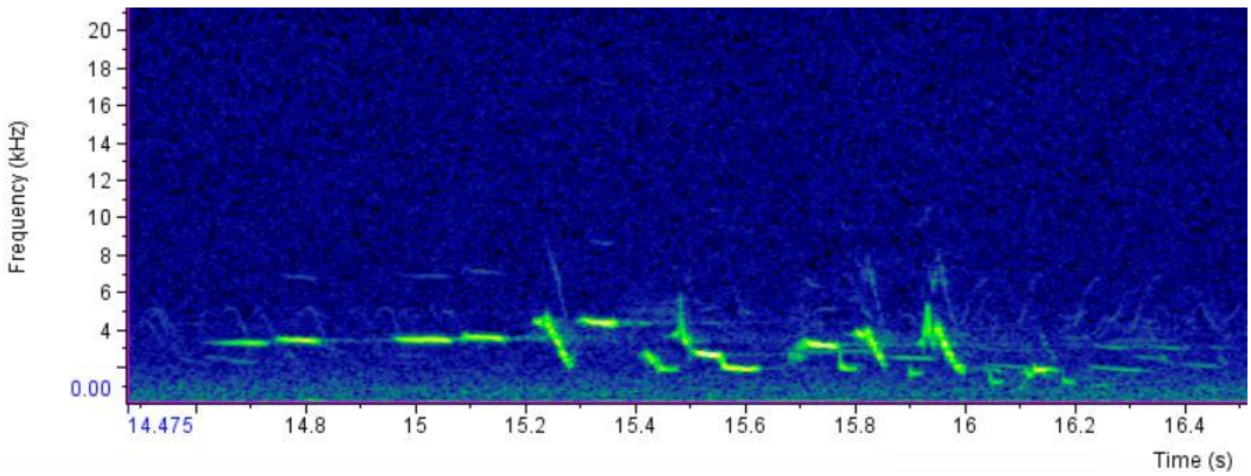


Figure 1. A) Study locations at the Ninepipe Wildlife Refuge represented with blue and red pins. B) Study locations at the National Bison Range represented with blue and red pins.

A



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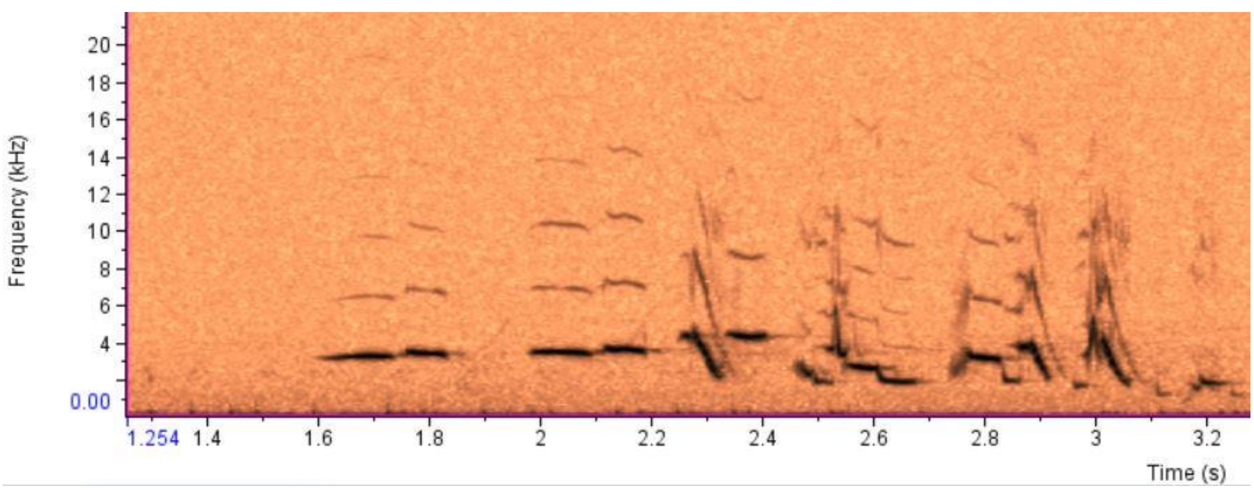

Figure 2. Sonograms as they appeared on the sound analysis program Raven. Sonogram A and B represent the same type of phrase, identified as phrase B. Sonogram A came from a recording of a different bird from sonogram B.

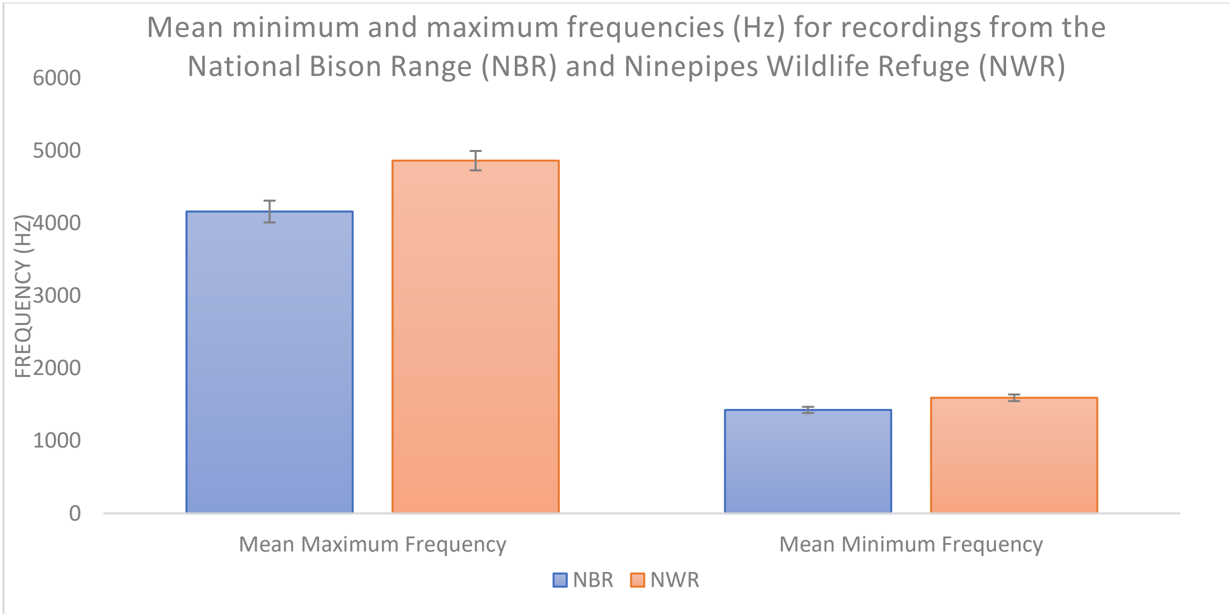

Figure 3. Mean minimum and maximum frequencies for the National Bison Range and Ninepipe Wildlife Refuge. On average, the NWR appears to have a higher maximum and minimum frequency.

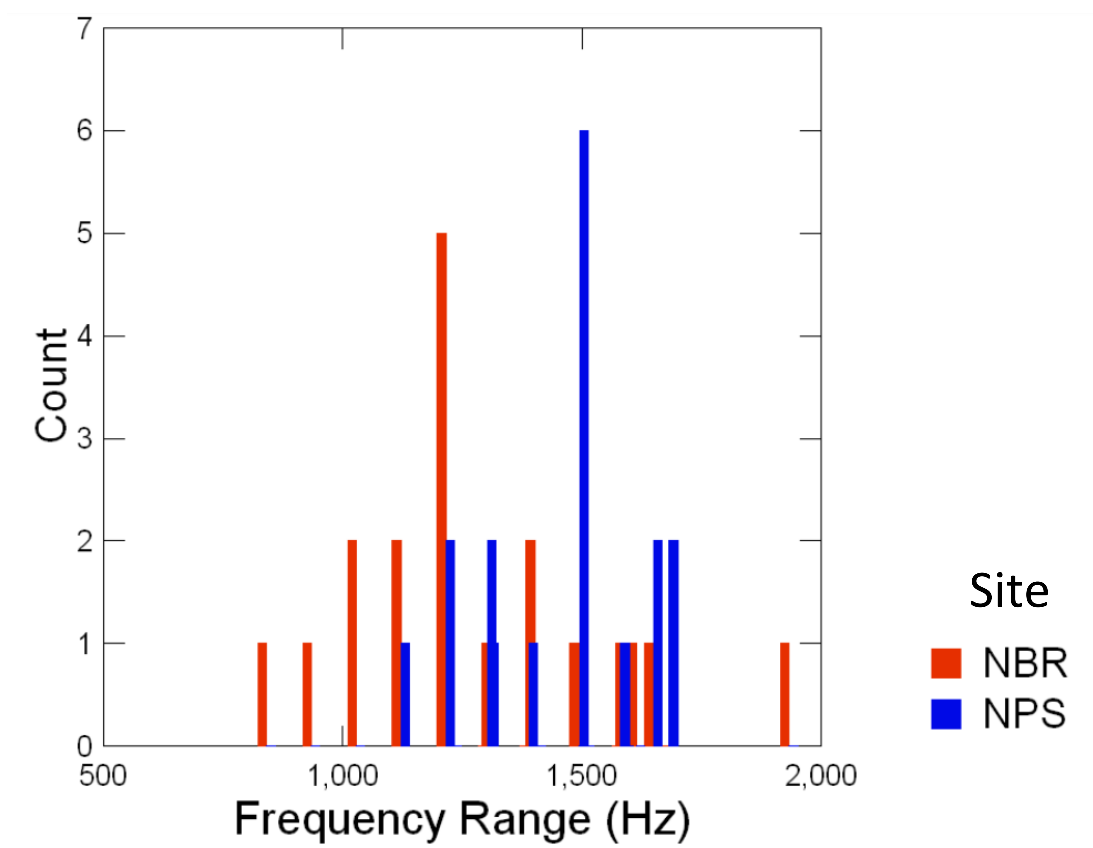

Figure 4. Frequency range for both the National Bison Range and Ninepipe Wildlife Refuge. The NWR frequency range tends to include higher frequency values than the NBR.

Table 1: PCA Factor Scores for each sample from the National Bison Range and Ninepipe Wildlife Refuge

Site	Sample	PCA Factor Scores
NBR	1	-3.0697
NBR	2	-1.7414
NBR	3	-8.44769
NBR	4	-1.2148
NBR	5	0.09137
NBR	6	0.129296
NBR	7	0.129297
NBR	8	0.14064
NBR	9	0.1182
NBR	10	0.14746
NBR	11	0.14747
NBR	12	0.16724
NBR	13	0.19853
NBR	14	0.51531
NBR	15	0.4944
NBR	16	0.041288
NBR	17	0.16723547
NBR	18	0.19853
NBR	19	0.28497
NBR	20	0.29624
NBR	21	0.20322
NBR	22	0.8947
NBR	23	0.447656
NPS	1	0.42399
NPS	2	0.45102
NPS	3	0.26218
NPS	4	0.356599
NPS	5	0.26218
NPS	6	0.356599
NPS	7	1.0799
NPS	8	.77898
NPS	9	0.98549
NPS	10	0.85309
NPS	11	1.492927
NPS	12	0.18457753
NPS	13	0.18457754
NPS	14	0.1475
NPS	15	0.30314013
NPS	16	0.58272246
NPS	17	0.58078171
NPS	18	0.37427239

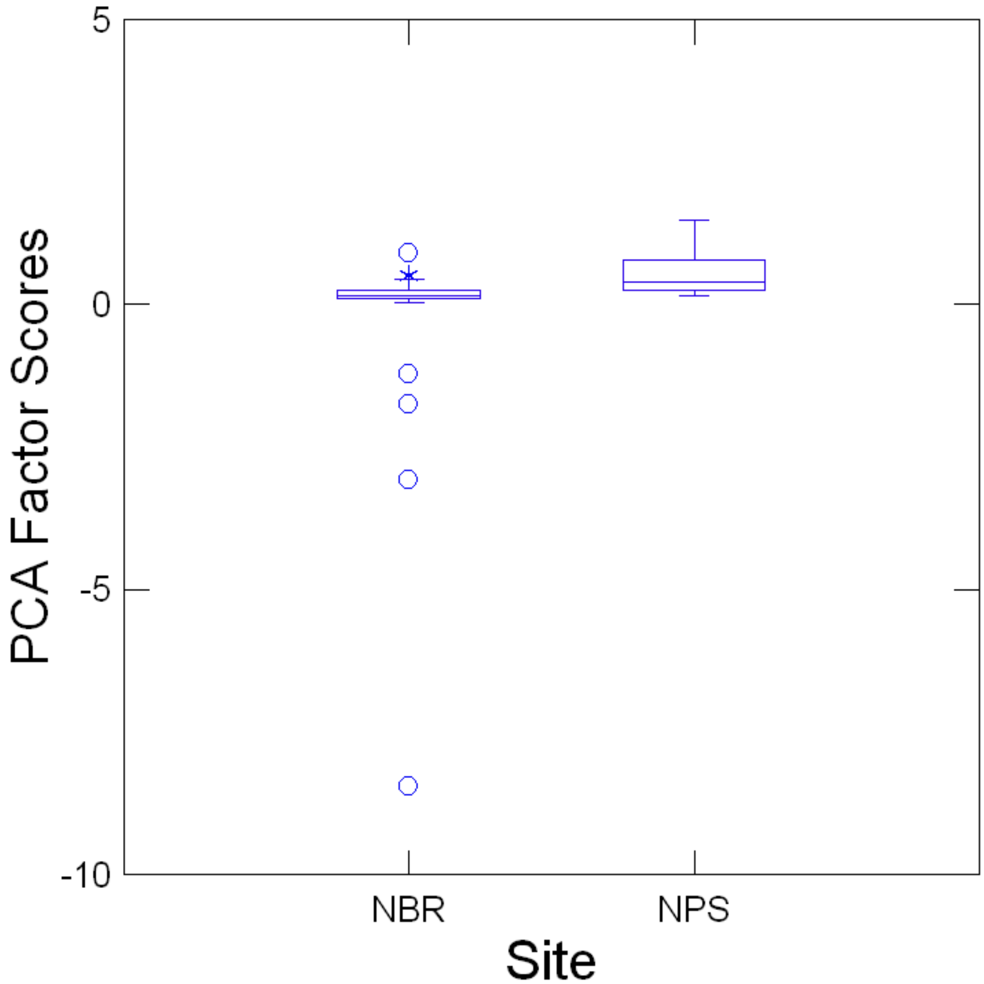

Figure 5. Boxplot representing PCA factor scores for the National Bison Range and Ninepipe Wildlife Refuge. Phrase composition between sites is significantly different.