The Impact of Standing Water Levels on the Dawn Chorus in a Western Migratory Bird Refuge

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ABSTRACT

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The avian dawn chorus takes place in the early morning and is characterized by marked increase of bird vocalization around sunrise. These choruses are very prominent when large bird communities are concentrated in one location, such as in a migratory bird refuge. Because the dawn chorus is such a prominent acoustic event in an ecosystem with large avian populations, monitoring the dawn chorus alone could provide insight into avian activities. It has been shown that many things can impact avian dawn choruses such as Julian Date, precipitation, temperature, lunar phase, and anthropogenic noise. In the U.S. Federal Fish and Wildlife Services Bear River Migratory Bird Refuge (BRMBR) in Utah, there is standing water in wetland units which dry up in the heat of summer. We monitored the refuge from March to August in 2021 using sound level meters at three different locations in the refuge. Using these data, we calculated the overall sound pressure level (OASPL) of the dawn chorus for every day we had a successful recording. Correlating the OASPL of several sites over the year with water levels at the site, we were able to find that there is a strong correlation between decreasing standing water levels and decreasing OASPL indicating a decrease in avian vocalization.

Keywords: Dawn Chorus, Passive Acoustic Monitoring, Spectra, OASPL

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Chapter 1

Introduction

1.1 The Dawn Chorus

The avian dawn chorus is a phenomenon that has captivated the interest of scientists and bird lovers for millennia. The dawn chorus occurs at sunrise when birds vocalize with a much higher intensity than they do otherwise throughout the day. This event typically onsets around civil twilight [1] when the sun is six degrees below the horizon. During this time, birds preform a variety of vocal tasks, such as communicating generally, establishing and defending territory, and performing mating rituals. It has been theorized that birds take advantage of this time of day to sing the most because meteorological conditions allow birdsong to propagate the most effectively [2] [3]. Other theories for the cause of the dawn chorus include social factors and biological clocks [4].

The majority of avian species participate in this morning cacophony, which makes the dawn chorus a spectrally diverse acoustic event and an acoustic manifestation of the biological diversity of the vocal avian community in that area. Several traits have been used to acoustically characterize dawn choruses: intensity, frequency composition, and timing of onset. All of these characteristics have been shown to naturally change with Julian date, weather, phase of the moon, and other natural abiotic factors [1] [5] [6]. The previously-stated characterizing acoustic features of the dawn chorus can also change due to anthropogenic influence. With these examples, we can see that the dawn chorus is dynamic and can be influenced. Understanding and characterizing these influences from a perspective rooted in physical acoustics and independent of specific species could provide valuable insights into the dawn chorus as a general phenomenon.

The specific influence addressed in this study is that of standing water levels in wetlands. This has been studied before by Linke in regard to the entire ecosystems response [7]. In this study we focus on the influence of standing water on the dawn chorus by observing one of the dawn choruses characteristics. The main characteristic of the dawn chorus we are observing is the intensity. Through the use of passive acoustic monitoring of the dawn chorus at Bear River Migratory Bird Refuge (BRMBR) we were able to observe the influence of standing water on average overall sound pressure level (OASPL), finding that areas where standing water dried up had significantly lower-intensity dawn choruses.

1.2 Bear River Migratory Bird Refuge

Bear River Migratory Bird Refuge is a system of wetlands, uplands, open water, and mudflats, located in Northern Utah at the base of the Bear River Watershed. It encompasses 31,202 ha where the Bear River deltas as it flows into Great Salt Lake. Seventy species of birds use the refuge for breeding, while over 210 species depend on the refuge for feeding, molting, and other purposes during migration. The refuge is divided into a series of management units, divided by dikes and waterways, allowing water quantity and depth to be controlled for specific breeding and feeding needs (see Fig. 1.1). Wetlands, like those found at BRMBR, make up only .24% of Utah's area, however, 14% of Utah's bird species use this critical habitat for breeding [8].

Monitoring the activity of species at BRMBR is an important task that requires a lot of work

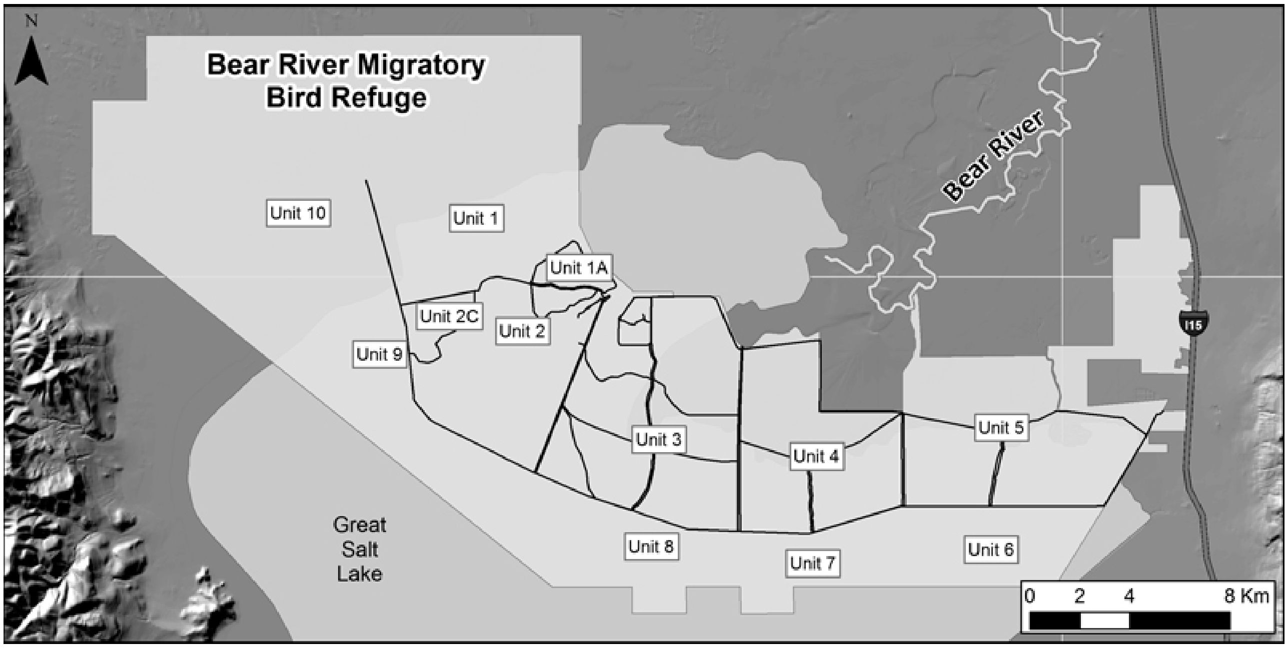

Figure 1.1 A map of bear river. The study took place on the dike running east west between units 4 and 5, and 6 and 7. Map credit to Adrian Welsh [9].

and coordination. Currently they do not employ any form of acoustic techniques in their monitoring efforts for birds. Passive acoustic monitoring could prove to be useful for conservation in areas like BRMBR.

1.3 Passive Acoustic Monitoring

Passive acoustic monitoring is one of the many methods that ecologists use to monitor an ecosystem [10]. It is noninvasive compared to other techniques like taking surveys by hand. The type of passive acoustic monitoring that we deployed for the bulk of this experiment had very low temporal resolution with only one sample per second of acoustic data. Because of this, we are not able to find any species information from our recordings; however we can look at general trends in ways that could prove useful to ecologists if these general trends can be given meaningful biological interpretations. These techniques using relatively small amounts of data to look at general trends could easily be deployed at low costs for a large area.

To further limit the amount of data processed, we have limited this study to focus on the data collected during the dawn chorus. Because of its significance we propose that metrics collected only during the dawn chorus could prove to be helpful when determining the health of an ecosystem. In order to use the dawn chorus as a metric in this way, it is important to understand and characterize normal dawn chorus dynamics and what drives them.

Chapter 2

Methods

To determine the impact that standing water had on the intensity of the dawn chorus, we collected acoustic data at BRMBR, as well as use data giving the water levels of the units surrounding our acoustic recording sites. The acoustic data collection for the project occurred from March 27th to August 15th 2021. Water level data were provided by staff at BRMBR. These data were then correlated to find relationships between acoustic intensity of the dawn chorus and standing water levels near the recording sites.

2.1 Acoustic Data Collection

We collected acoustic data from three recording sites at Bear River which we named site A, B and C (see Fig. 2.1). These sites were located along the dikes running east to west. North and south of the recording sites were wetland units. The wetland units to the south (6 and 7) had running water, while the units to the north (4 and 5) had a few inches of still water when water was present. The wetland units contained a significant amount of vegetation, with vegetation to the south of the meters being fairly consistent and vegetation to the north varying slightly between sites (see Fig. 2.1). The recording sites were surrounded by exclosures to keep unwanted large mammals from

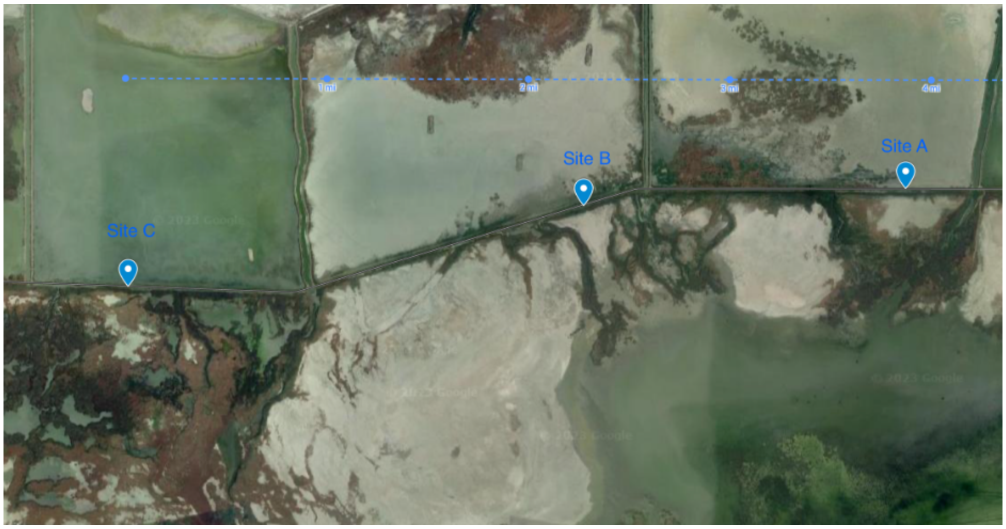

Figure 2.1 A map of the scope of the study. The units to the north are filled with shallow standing water. The units to the south have running water in them. Google Maps (41.4253589, -112.1729874, Eye alt 9.063 km V 6.79.0) Accessed 03/29/2023

disturbing the equipment. The microphone windscreens also had bird spikes on them to prevent any birds from perching or nesting on the equipment.

Site A was on the north side of the dike. This site was characterized by thick vegetation on both the north and south sides (see Fig. 2.2). This site also never dried up to the extent that the other sites did. Site B was located on the south side of the dike closer to the running water. This site also had a substantial amount of vegetation on the north and south borders of the dike (see Fig. 2.3). Site C was located on the north side of the dike and had much less vegetation on the north side of the dike next to the standing water (see Fig. 2.4).

Each acoustic recording site was equipped with a Larson Davis 831-C SoundAdvisor sound level meter (SLM). We chose a ground-based deployment for our microphones to minimize wind noise [11] (see Fig. 2.2). It should be noted that for the first few days of the study, we used a raised microphone deployment method (see Fig. 2.3), but this was changed at all sites after a week. The meters at each site were equipped with solar charging so that they could be continuously deployed. The SLMs were configured to collect flat-weighted one-second Leq in 1/3 octave band spectral

Figure 2.2 A picture of site A facing north toward the standing water. The small black dome in the exclosure is the windscreen on our microphone. This picture was taken mid-study, around May.

Figure 2.3 A picture of site B facing south to the running water. This picture was taken on the first day of deployment. This site has an older deployment for its microphone. This was replaced later in the study with a ground-based measurement setup that matches the one depicted in Fig. 2.2

Figure 2.4 A picture of site C facing north to the still water.

resolution with one second temporal resolution. One-second Leq is a sound level metric that reports a single pressure level that, if played over one second, would produce the same amount of energy that a recording over that same second would have. Data were collected every 2-4 weeks when routine maintenance of the equipment was also performed. The SLMs ran continuously from March 27th to August 15th of 2021.

Long-term deployment of the meters proved to have some initial difficulties with power management and out-of-date firmware. These issues caused data loss at site B in mid May and site C from the end of April to mid May.

2.2 Water Level Data

In addition to the acoustic data collected, we used reports from BRMBR staff of the water levels in the northern units. These measurements were taken roughly once every 16 days at each culvert or water structure in the units (see Fig. 2.5). Because our site locations are not directly correlated with culverts or water structures, these data do not directly report the water levels near our recording sites, but rather show general trends for the water levels in the entire unit as a whole. They are most useful to determine roughly when an entire unit goes dry. These data do not have high temporal resolution, however, they can indicate when a unit has completely dried up or in the case of the units near site C, when water is returned to the unit by management. It is significant that Site A did not dry up at the end of the study while site B and C both dried up. It is also significant that site C had water returned to it at the end of the study.

We also took general notes of the soundscape whenever we visited the refuge, noting especially anthropogenic influences on the area. The main acoustic anthropogenic influence was air traffic, due to close proximity to the Ogden airport. The closest road (US Interstate I-15) was 7km away from the closest recording site. There was no noticeable road noise at this distance.

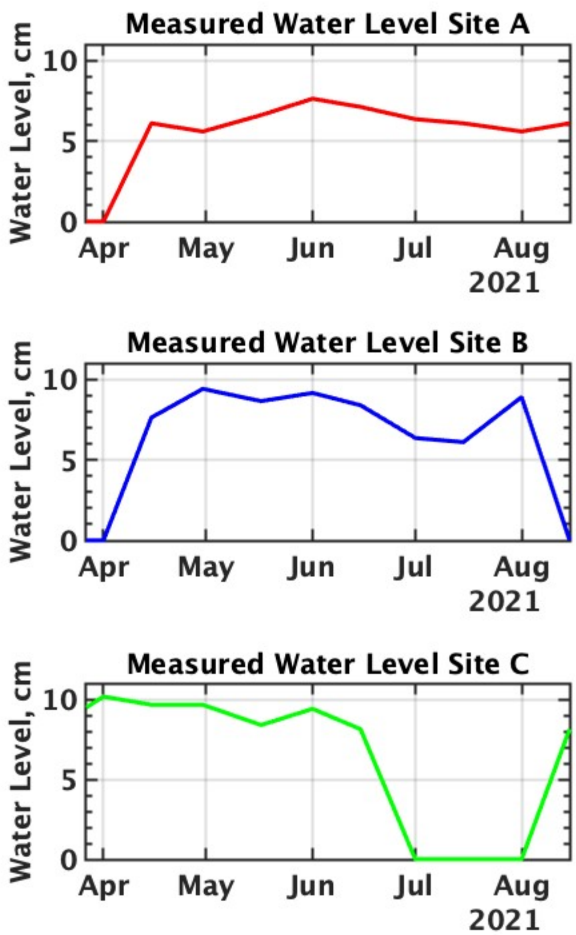

Figure 2.5 Water levels taken about every 16 days at the outlet of each unit.

2.3 Analysis

Using the acoustic data collected over the duration of the study, we produced spectrograms representing 24-hour periods (see Fig. 2.6, 2.7, 2.8). These spectrograms allowed us to visualize the dawn chorus across the 1/3 octave spectra. These dawn choruses were varied from day to day and location to location, but there were a few things that were generally consistent between them. We found that the dawn chorus had acoustic energy mostly concentrated in the 500-10000Hz range, similar to other studies [1]. This was consistent for the duration of the study at all sites. This allowed us to do all of our analysis in these frequency bands, greatly reducing wind noise contamination. Some dawn choruses had energy in a wider range of frequencies than other dawn choruses, but they all mainly used the 500-10000Hz range.

We also found that the dawn chorus correlated very well with civil twilight, like the literature mentioned [1]. This is mostly consistent across all sites; however there can be some deviation which we did not quantify for this study. Quantifying start times is usually done on a per-species basis, making it hard to decide on a standardized way to declare a start time when doing a species-independent study of the dawn chorus. Despite these difficulties, inspection of over 500 spectrograms allowed us to decide that civil twilight correlated strongly enough with the onset of the dawn chorus for the purposes of this study.

Viewing the spectrograms also allowed us to notice differences in duration of the dawn chorus. This varied from day to day, making it hard to systematically analyze the entire duration of the dawn chorus over a large number of days. Because of this difficulty, we also decided to narrow the temporal scope of our analysis to a one hour duration starting at civil twilight. This time frame consistently captured the most intense part of the dawn chorus.

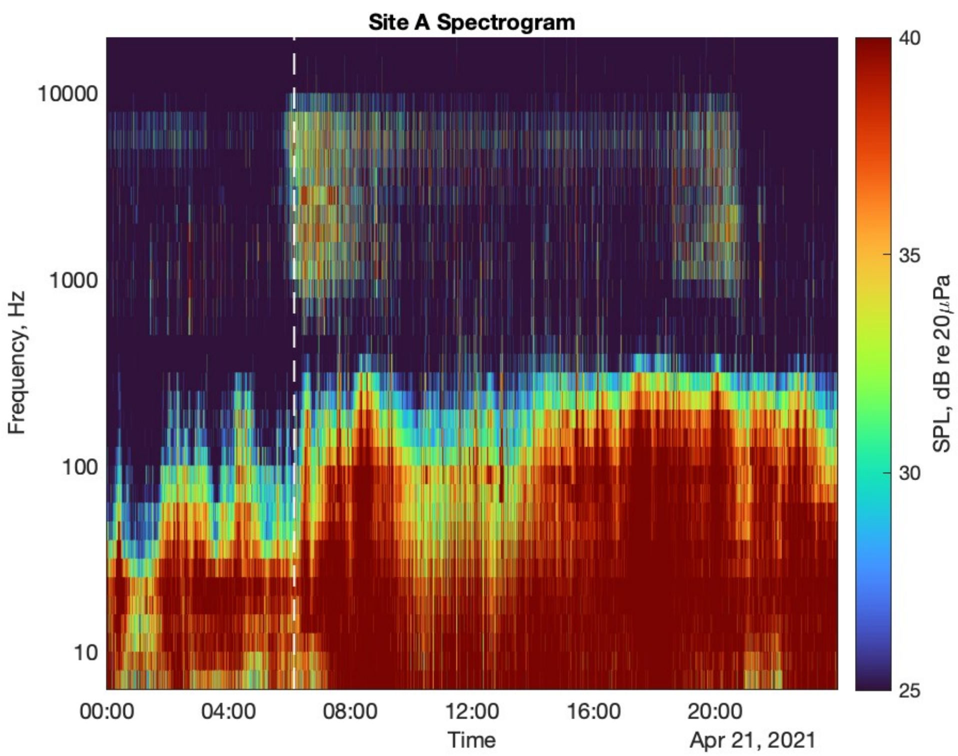

Figure 2.6 A spectrogram from April 21st at site A. The vertical white dotted line represents civil twilight for that day. The intense acoustic activity starting around this time in the frequencies between 500Hz and 10kHz is the dawn chorus.

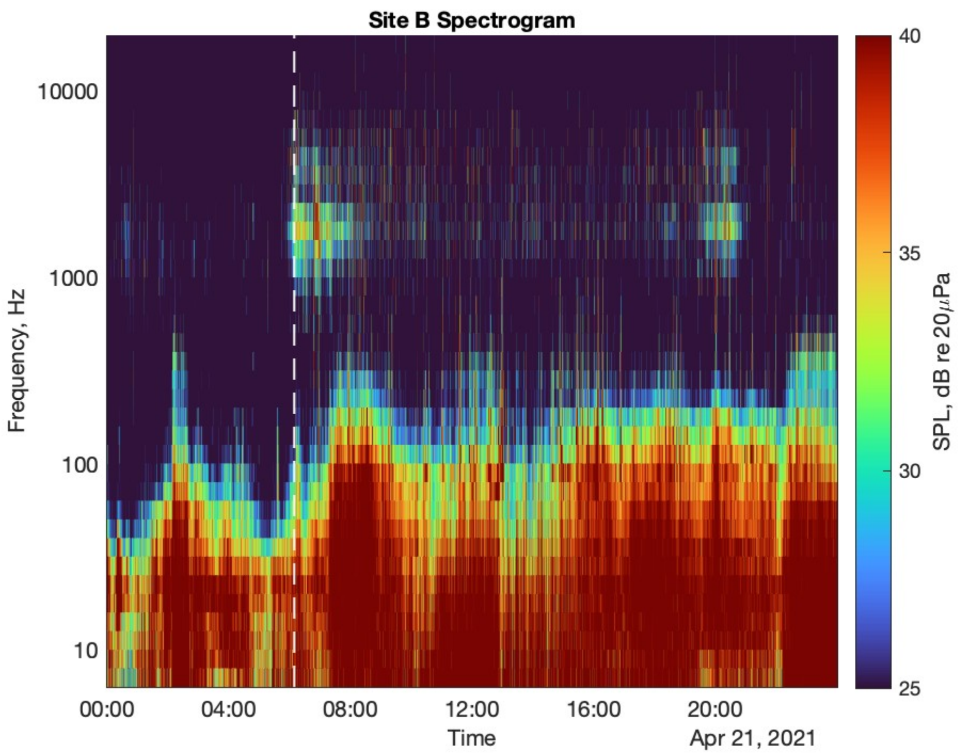

Figure 2.7 A spectrogram from April 21st at site B. This spectrogram has an example of a dawn chorus that does not use a very wide frequency range compared to others.

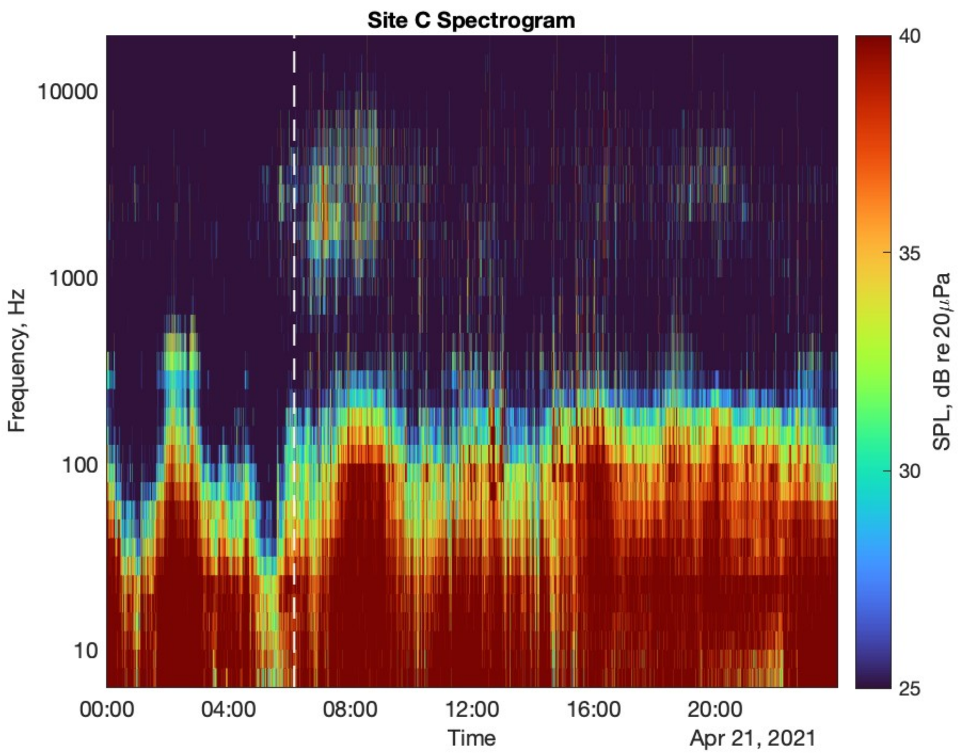

Figure 2.8 A spectrogram from April 21st at site C. This spectrogram includes a dawn chorus that appears to have a start time deviating slightly from civil twilight.

Chapter 3

Results

Having established a justifiable temporal and spectral range to analyze the dawn chorus for a single day, we proceeded to analyze trends over the duration of the study. We calculated the average sound pressure level (SPL) for the dawn chorus for every day of the study at every site and plotted them together (see Fig. 3.1). Immediately, it is apparent that intensity of the dawn chorus is dependent on the time of year across all sites.

With our acoustic data processed and analyzed we plotted the water data that staff at BRMBR provided (see Fig. 2.5). To better understand general trends in our acoustic data, we took each site and plotted the five-day average alongside the water data provided (see Fig. 3.2). These general trends show the importance of reported maximum and minimum SPL as well as the rate at which subsequent dawn choruses lose intensity at a given location.

3.1 Maximum and minimum SPL

Every site had dawn choruses that showed general seasonal dependence. Site A had a peak five-day average level of 55dB around May 31st with a minimum five-day average level of 36dB around August 9th. This change of almost 20dB means that only 1% of the energy that was present in dawn

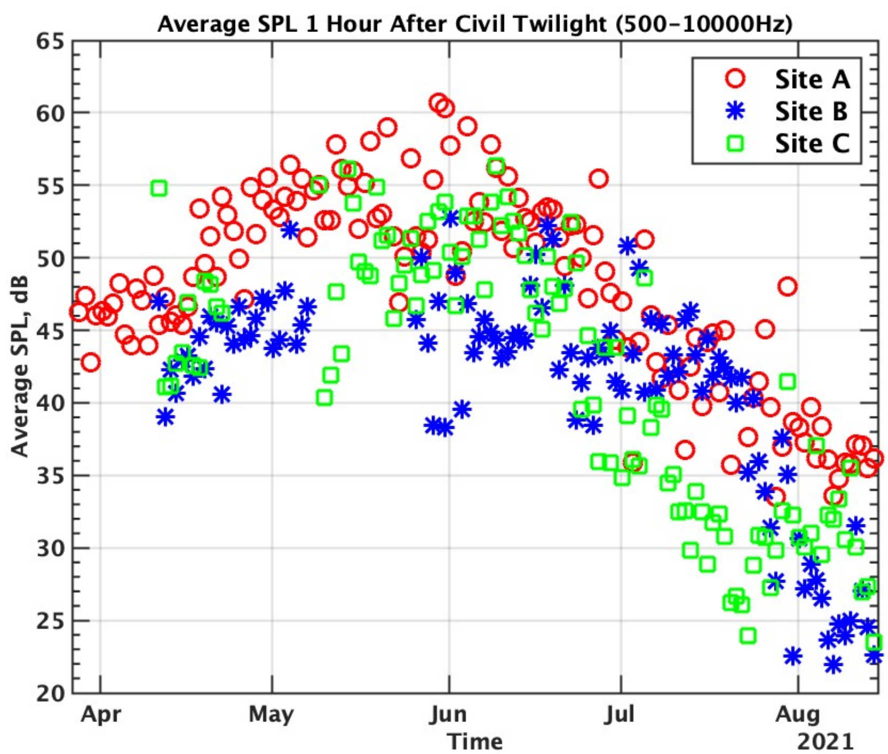

Figure 3.1 The average SPL for the hour after civil twilight for 500-10000Hz.

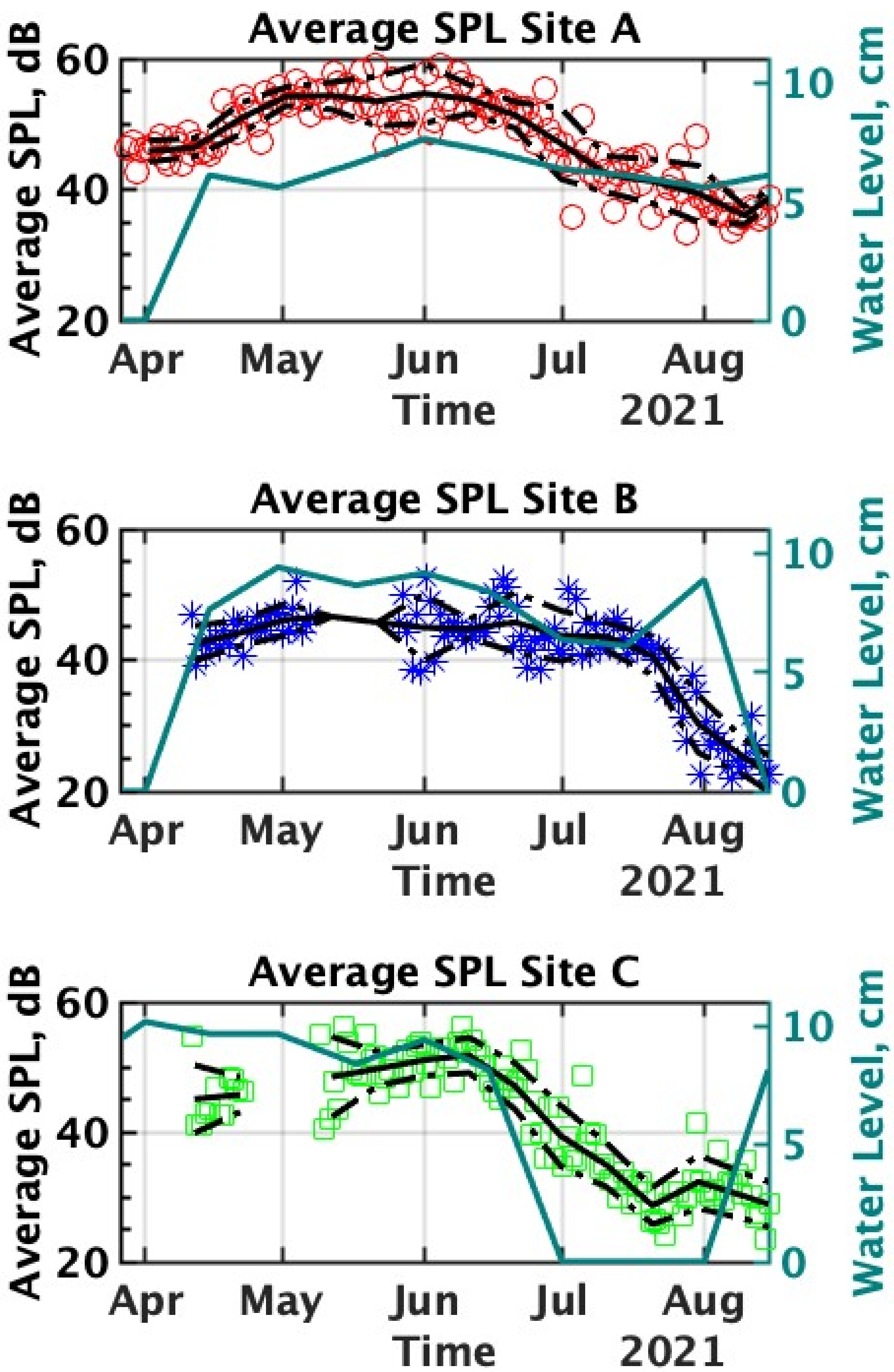

Figure 3.2 Average sound pressure level plotted with water levels. The solid black line is a five-day average, and the dotted black line above and below is plus and minus one standard deviation.

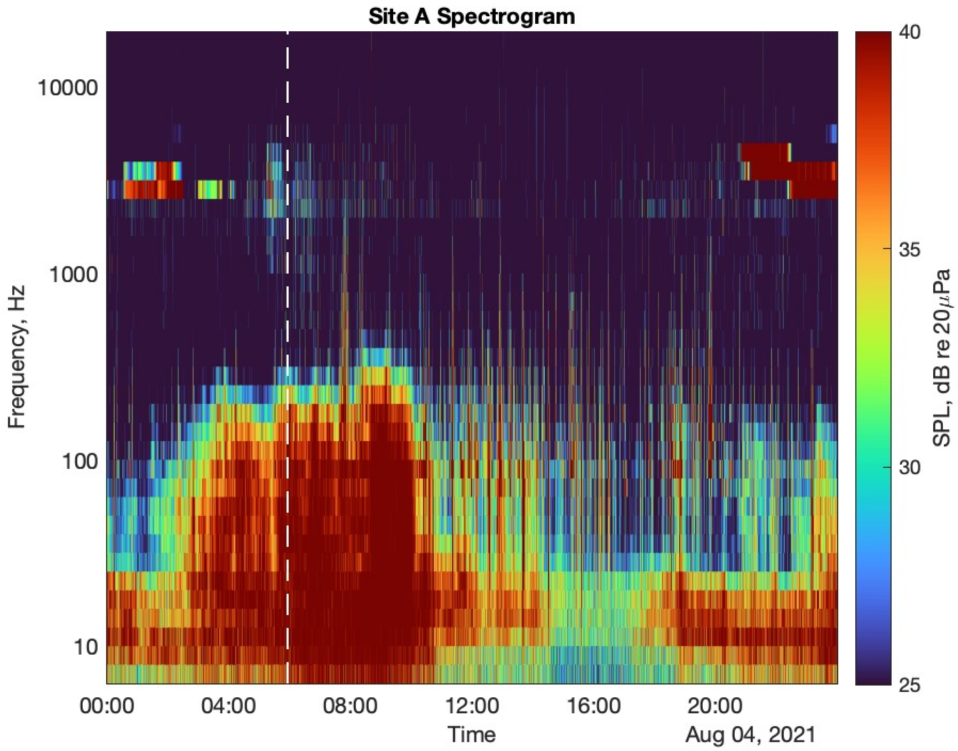

Figure 3.3 A spectrogram from Site A on August 4th. Note the dawn chorus taking place centred around civil twilight with significantly reduced intensity and spectral content. Also note the intense insect noise in the early morning and night

choruses between May and June remains by mid August. Despite this large decrease, it is apparent looking at the spectrogram for August 4th that there still is some semblance of a dawn chorus at this location (see Fig. 3.3).

Site B had a peak intensity around mid May of 47dB. At 8dB less than the peak intensity of site A, site B was generally a much quieter site during the dawn chorus and got even quieter at its minimum of 23dB in mid August. Inspecting the spectrograms for this quiet period, it is possible that the dawn chorus has disappeared completely and that the averages that we were reading are close to the ambient at night (see Fig. 3.4). Despite having significantly lower peak intensity levels than site A, site B has an even greater difference between the maximum and minimum five-day

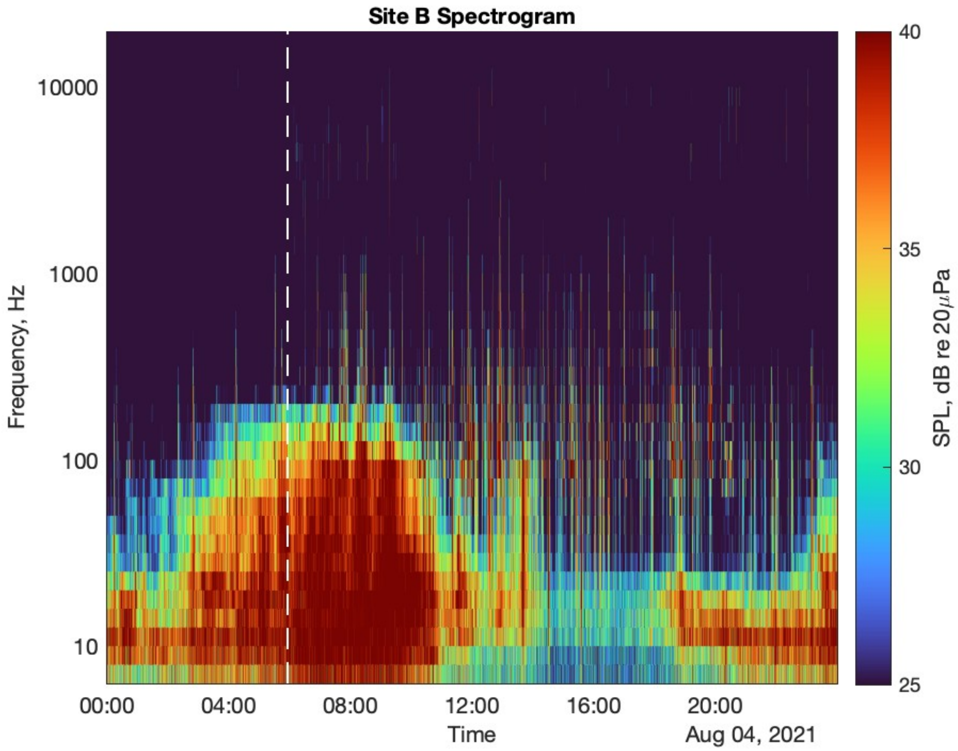

Figure 3.4 A spectrogram from Site B on August 4th. Note that the dawn chorus does not seem to be present at all in this spectrogram.

averages of 24dB. This minimum intensity correlates very well with times that we know the unit north of the microphone is completely dry.

Site C had a peak five-day average intensity that was more comparable to site A of 52dB. It also, however, had a minimum five-day average intensity of 29dB, which is closer to that of site B than site A. This minimum for site C happened around July 20th, and inspection of spectrograms around this time show that the dawn chorus is indistinguishable from night (see Fig. 3.5). The dawn chorus does return at the beginning of August for a short period of time then disappear again (see Fig. 3.6). This minimum intensity correlates with the time that we know the unit to the north of site C is completely dry, and the reappearance of the dawn chorus also correlates with the time that we know water is being returned to the unit by management from our water data. In short, these

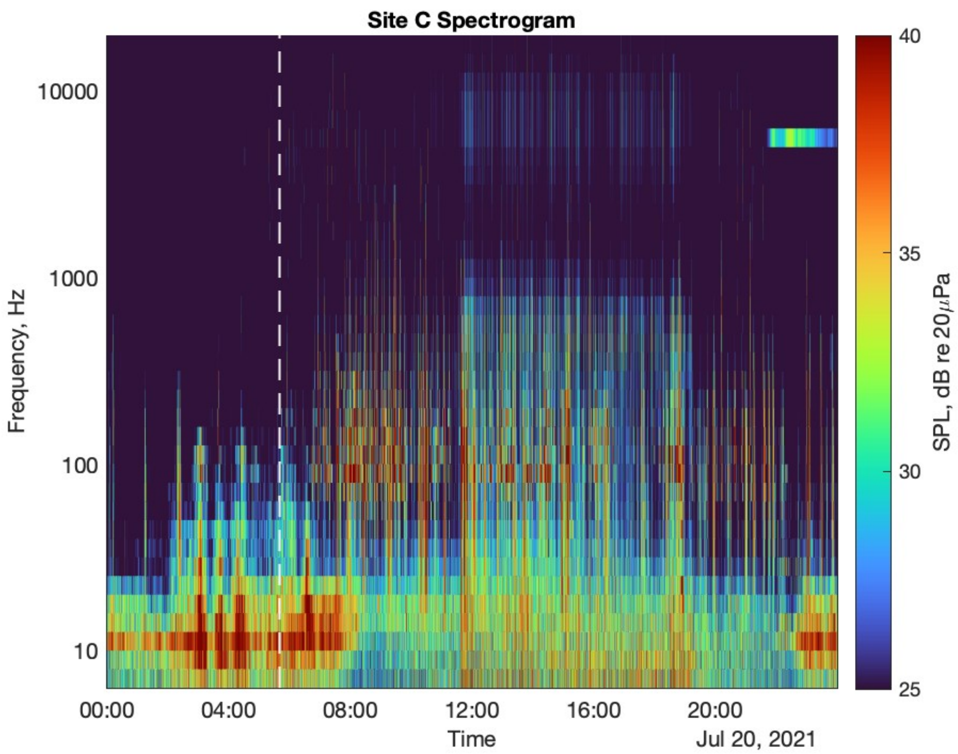

Figure 3.5 A spectrogram from Site C on July 20th. Notice that there is no distinguishable dawn chorus around civil twilight in the frequency range of 500Hz-10kHz.

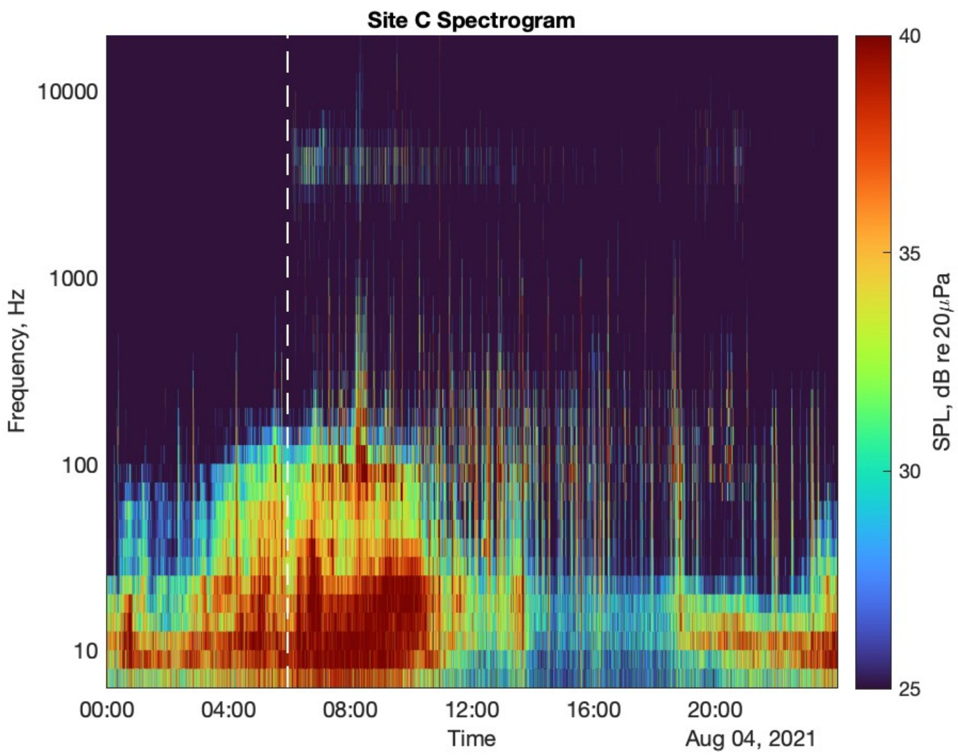

Figure 3.6 A spectrogram from Site C on August 4th. Note the dawn chorus taking place starting around civil twilight with significantly reduced intensity and spectral content.

changes of intensity suggest that standing water levels at BRMBR have a strong influence on the acoustics of the dawn chorus.

3.2 Rates of change

Another indication that water levels have an influence on the acoustics of the dawn chorus is the relative rate at which the average intensity of the dawn chorus at different sites changed over the season. Between June 1st and July 15th, sites A and B had changes of -13dB and -3dB respectively while site C had a change of -19dB. Between June 1st and July 15th is also when we know site C went from wet to dry. Similarly, between July 15th and August 15th site A changed -3dB while site B change -20dB. We know that in this time period site B went dry. This change for site B is a drop of 2dB every 3 days suggesting a very rapid change in the habits of the vocal avian population in this area.

The intensity of the dawn chorus can be correlated with the amount of standing water in a given location at a wetland bird refuge. These changes in sound levels can be interpreted in several ways. The decrease in SPL could be due to four different changes in the sound sources: the number of birds could decrease, the location of birds could move farther from the microphone, the intensity of individual birds could be weaker, or the frequency at which birds call could be lower. Biological insights can point us to what the most likely scenario is, while physical acoustics can help to determine to what extent these changes have taken place. If all changes in SPL were solely attributed to a decrease in the number of birds present, and all other factors remained constant, a change of -3dB would indicate that half of the bird population has left the area. This is particularly noteworthy in the case of site B, which experienced changes of -20dB within a month, suggesting that 99% of the bird population had left the area if the decrease in bird population was the only reason for the decrease in SPL.

Chapter 4

Conclusion

This study shows that the intensity of the dawn chorus at BRMBR is strongly correlated with the presence of water in the wetland units there. Lower amounts of water lead to significantly less acoustic intensity in the dawn chorus. The exact behavioral cause for this change in intensity would take other types of data such as actual recordings and populations counts; however, it is significant that the methods we employed were able to determine that there was a distinct behavioral change in the birds that we could correlate with water levels.

The method of using sound level meter data and analyzing only a small temporal range situated at the beginning of the dawn chorus has proven to be a viable method of documenting general trends in avian behavior in an area.

4.1 Future Work

This procedure has the potential to be more robust in its conclusions with additional data and analysis methods. For instance, conducting in-depth spectral analysis of the dawn chorus samples can provide valuable insights into the participating species. Using recordings during the dawn chorus instead of relying solely on sound level meter data would also allow for bird identification using audio programs like BirdNet, developed by Cornell Lab of Ornithology. Additionally, collecting meteorological data could help explain the other variations found in the dawn chorus, making the analysis of the acoustic data more meaningful.

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