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The impact of standing water on acoustic characteristics of the dawn chorus in a western bird refuge

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Migratory bird refuge soundscapes are seasonally dynamic due to changes in wildlife populations. Some of the most prominent acoustical events in a bird refuge are the morning and evening avian choruses, particularly during spring and early summer when breeding activity of birds is high. This event is acoustically dynamic, reacting to both biotic and abiotic drivers. One such driver is the presence of standing water. For this study, near-continuous spectral data were collected at the U.S. Federal Fish and Wildlife Services Bear River Migratory Bird Refuge. Although data fidelity can be compromised by wind and rain, changes in the avian chorus characteristics over time are observed. These changes over time are observed to correlate with times management at the refuge drained the wetland area surrounding the recording sites. Recording sites that were close to drained wetland units saw decreases in the average sound pressure level during the dawn chorus, sometimes on the order of 20 dB.

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1. INTRODUCTION

A. DAWN CHORUS

The avian dawn chorus is a phenomenon that has drawn the interest of many for millennia. The dawn chorus occurs around sunrise when birds vocalize with a much higher intensity than they do otherwise throughout the day. Bird vocalizations during this time fill several purposes, such as attracting mates, defending territory, coordinating group movement, and warning of approaching predators. It has been hypothesized that birds vocalize most during this time of day because meteorological conditions allow birdsong to propagate effectively.[1,2] Other hypotheses include social factors and biological clocks.[3] While the cause of the dawn chorus is not certain, the traits of the dawn chorus are readily measurable.

There are several traits that have been used to acoustically characterize dawn choruses, which include intensity, frequency composition, and timing of onset. All these characteristics have been shown to be dynamic: changing with natural abiotic factors such as season, weather, phase of the moon,[4,5] biological competition,[6] and anthropogenic influences.[7,8] The specific influence addressed in this study is that of standing water levels in wetlands. The main characteristic of the dawn chorus we are observing is the vocalization intensity. Vocalization intensity during the dawn chorus, which is easily quantified using overall sound pressure level (OASPL), correlates with bird activity. Using passive acoustic monitoring of the general dawn chorus at an inland migratory bird flyway, we observed the influence of standing water on average OASPL.

B. BEAR RIVER MIGRATORY BIRD REFUGE

Bear River Migratory Bird Refuge (BRMBR) 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 delta 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, which are divided into impoundments and waterways, allowing water quantity and depth to be controlled for specific needs of breeding and feeding birds (Figure 1). Wetlands, like those found at BRMBR, make up only 0.24% of Utah's area, however, 14% of Utah's bird species use this habitat for breeding.[9]

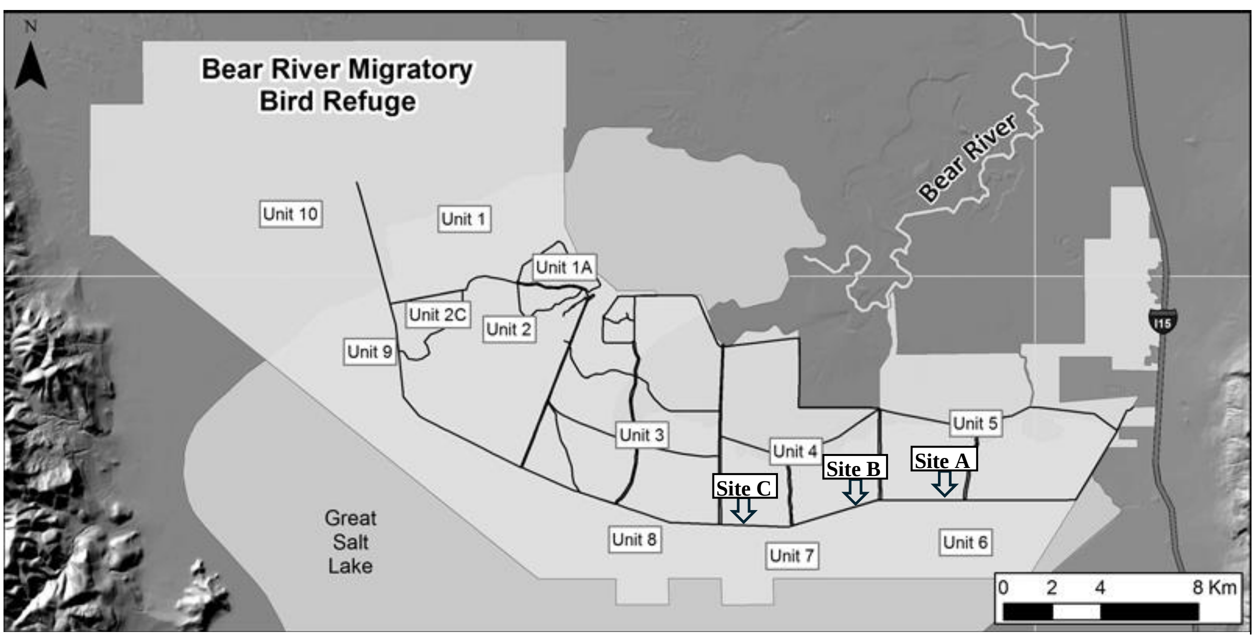

Figure 1: A map of wetland units at BRMBR. Recording sites A, B, and C are included. Lines shown are dikes.

2. MATERIALS AND METHODS

A. ACOUSTIC DATA COLLECTION

We collected acoustic data from three recording sites at Bear River (Figure 2). These sites were located along the dikes running east to west. North and south of the recording sites were wetland impoundment units. The wetland units to the south (6 and 7) had running water and the units (4 and 5) to the north had a few inches of still water when water was present. In the wetland units, vegetation was abundant. Site A was located on the north side of the dike running between units 5 and 6, site B was located on the south side of the dike running between units 4 and 7 and site C was located farther west on the north side of the dike running between units 4 and 7. Habitat characteristics at each recording site were mostly similar, but there were some differences at the beginning of the study. The vegetation south of the measurement sites was fairly consistent, and the vegetation north of the sites varied slightly from site to site (Figure 2). The recording sites were enclosed with fencing to prevent disturbance of the equipment by livestock. The microphone windscreens also had bird spikes on them to deter perching or nesting on the equipment. Site A was characterized by thick vegetation on both the north and south sides (Figure 2). This site never dried up to the extent that the other sites did (Figure 3). Site B also had a substantial amount of vegetation on the north and south borders of the dike (Figure 2). Site C had less vegetation to the north of the dike compared to the other sites (Figure 2).

Figure 2: Clockwise from the top left: recording sites A, B and C.

Each acoustic recording site was equipped with a Larson Davis 831-C SoundAdvisor™ sound level meter (SLM). For the first few days of the study, we deployed all microphones mounted off the ground as seen in the site B photo (Figure 2), however we changed to a ground-based deployment to reduce wind noise[10]. The meters at each site were equipped with solar charging so that they could be continuously deployed for the duration of the study. The SLMs were configured to collect flat-weighted Leq in 1/3rd octave band spectral resolution with 1-second temporal resolution. Data were retrieved from the SLMs 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.

B. RELEVANT METADATA

In addition to the acoustic data collected, we relied on measurements of the water levels in the northern units 4 and 5 (Figure 3). These measurements were taken approximately once every 16 days at each culvert or in the units. Because our site locations were not directly correlated with culverts, 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 and were indicative of when an entire unit was dry.

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 proximity to the Ogden airport. The closest road (US Interstate I-15) was 7 km away from the closest recording site. There was no audible road noise at this distance.

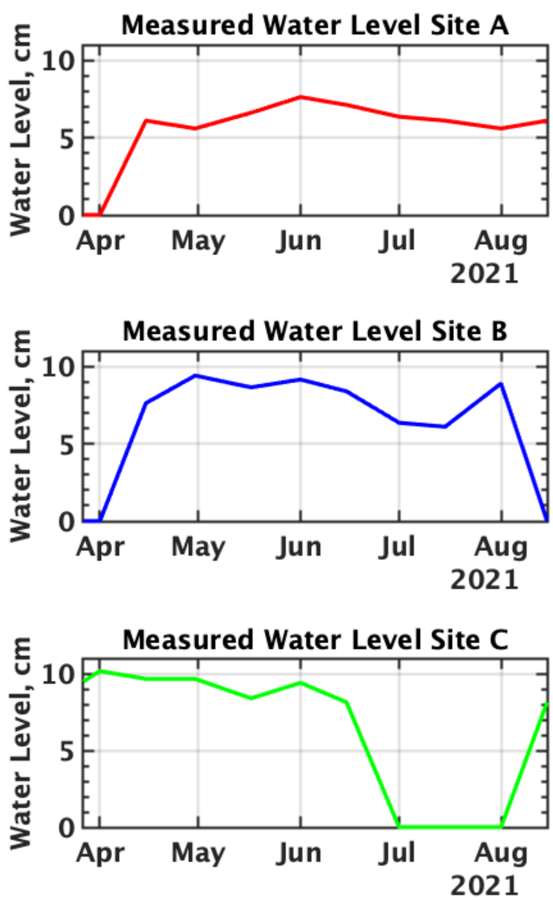

Figure 3: Water level measurements provided by staff at BRMBR labeled with the recordings site that was closest to the measurement location. Site A has consistent water depth through most of the study while sites B and C have dry periods at the end of the study.

C. ANALYSIS

Using the acoustic data collected over the duration of the study, we produced spectrograms representing 24-hour periods (see Figure 4, 7). These spectrograms allowed us to visualize the dawn chorus across the 1/3rd octave spectrum. These dawn choruses 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 500-10000 Hz range[11]. 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 others but they all mainly used the 500-10000 Hz range.

We also found that the dawn chorus correlated very well with civil twilight, as mentioned in the literature.[11] 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 traditionally done on a per-species basis[2] 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 conclude that civil twilight correlated strongly enough with the onset of the dawn chorus for the purposes of this study.

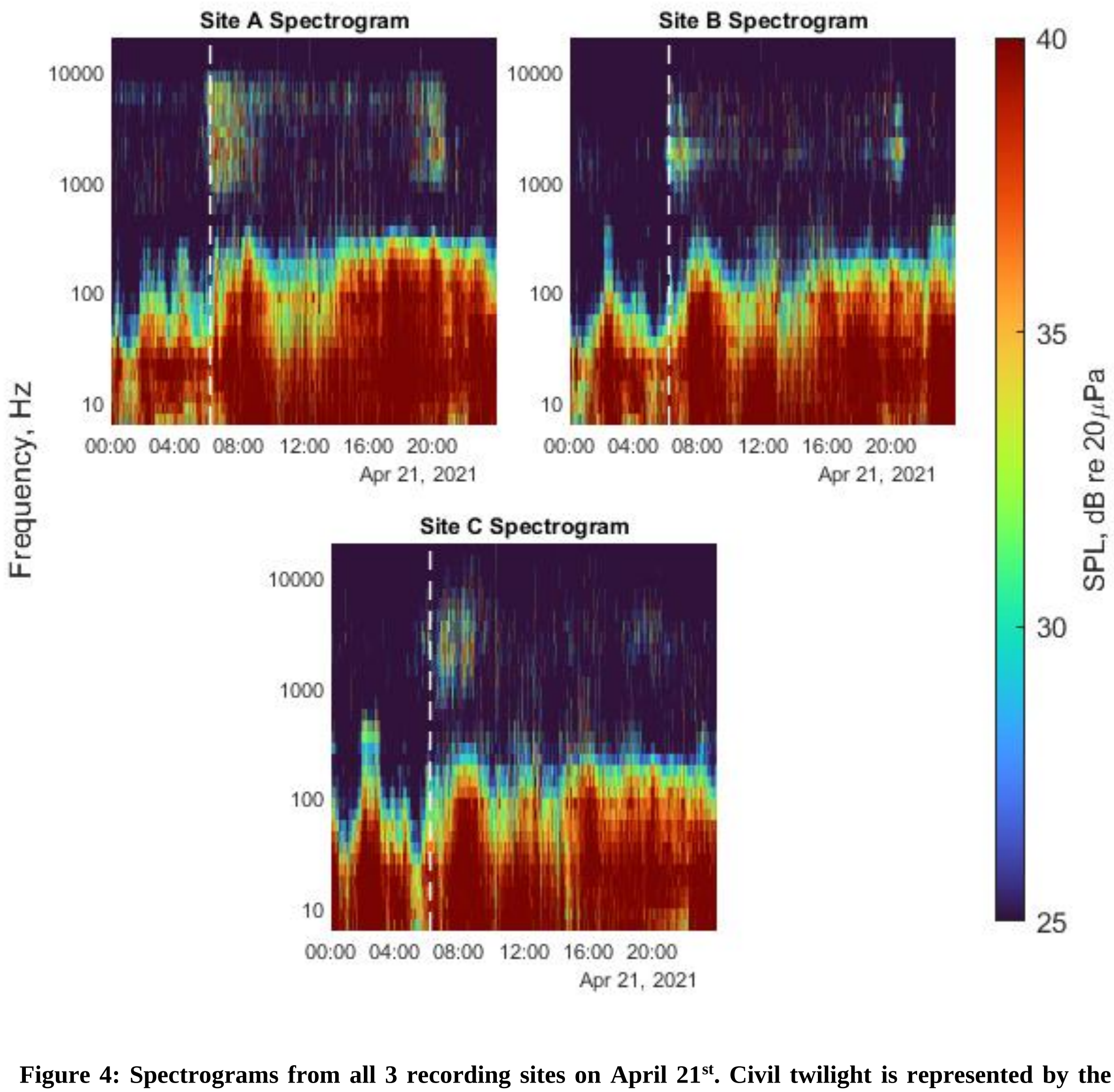

Figure 4: Spectrograms from all 3 recording sites on April 21st. Civil twilight is represented by the dashed white line after which the dawn chorus begins. Site A shows a dawn chorus with a wider frequency range. Site B shows a restricted frequency range. Site C shows a chorus with a later onset.

The spectrograms also show 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 decided also 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.

With a justifiable temporal and spectral range to analyze the dawn chorus for one day established, 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 (Figure 5). Immediately, it is apparent that intensity of the dawn chorus is dependent on the time of year across all sites.

After processing the acoustic data, we plotted the water data that staff at BRMBR provided (Figure 4). 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 notable that site A did not dry up at the end of the study while site B and C both dried up. It is also notable that site C had water returned to it at the end of the study.

To better understand general trends in our acoustic data, we took each site and plotted the 5-day average alongside the water data provided (Figure 6).

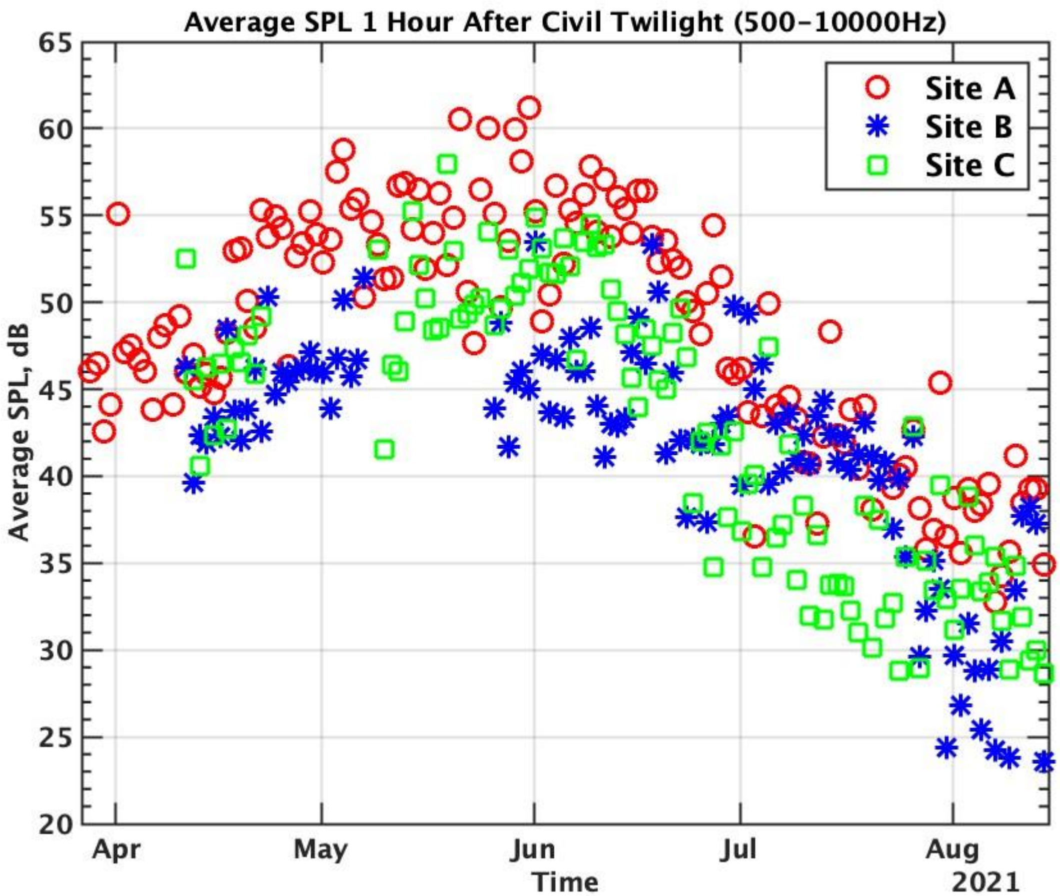

Figure 5: The average SPL for a one-hour duration directly after civil twilight. Long-term deployment of the meters proved to have some initial difficulties with power management and out-of-date firmware. These issues caused data loss at site B in mid-May and site C from the end of April to mid-May.

3. RESULTS

A. MAXIMA AND MINIMA

Every site had dawn choruses that showed general seasonal dependence. Site A had a peak 5-day average level of 55 dB around May 31st with a minimum 5-day average level of 36 dB around August 9th. This change of almost 20 dB means that only 1% of the energy that was present in dawn choruses between May and June remains by mid-August. Despite this large decrease, the spectrogram for August 4th shows there still is some semblance of a dawn chorus at this location (Figure 7).

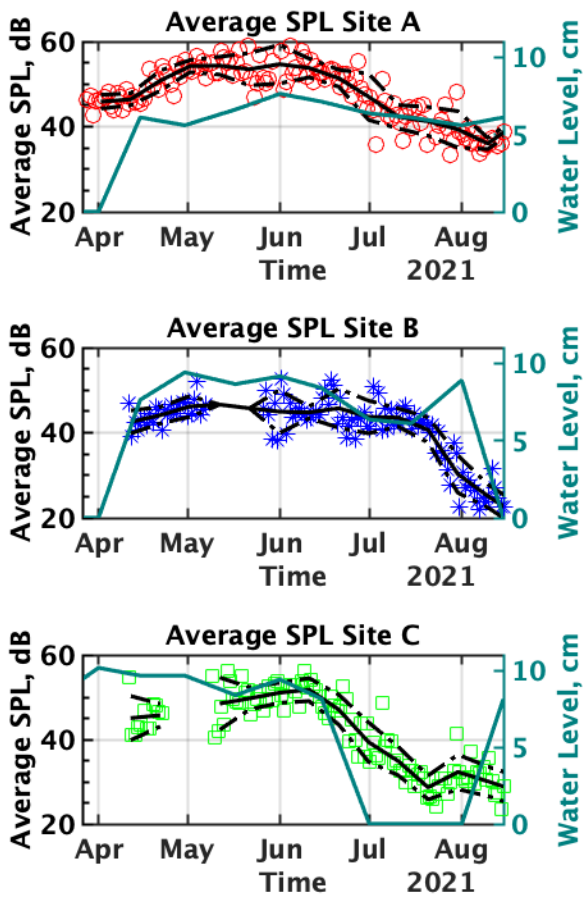

Figure 6: A combination of Figure 4 and 5. The average SPL for each dawn chorus is shown with the standing water trends.

Site B had a peak intensity around mid-May of 47 dB. At 8 dB 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 23 dB 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 (Figure 7). Despite having notably lower peak intensity levels than site A, site B has an even greater difference between the maximum and minimum 5-day averages of 24 dB. This minimum intensity correlates with times that we know the unit north of the microphone is completely dry.

Site C had a peak 5-day average intensity that was more comparable to site A of 52 dB. It also, however, had a minimum 5-day average intensity of 29 dB 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 (Figure 7). The dawn chorus does return at the beginning of August for a short period of time then disappears again (Figure 7). 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 very well with the time that we know water is being returned to the unit by management from our water data.

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

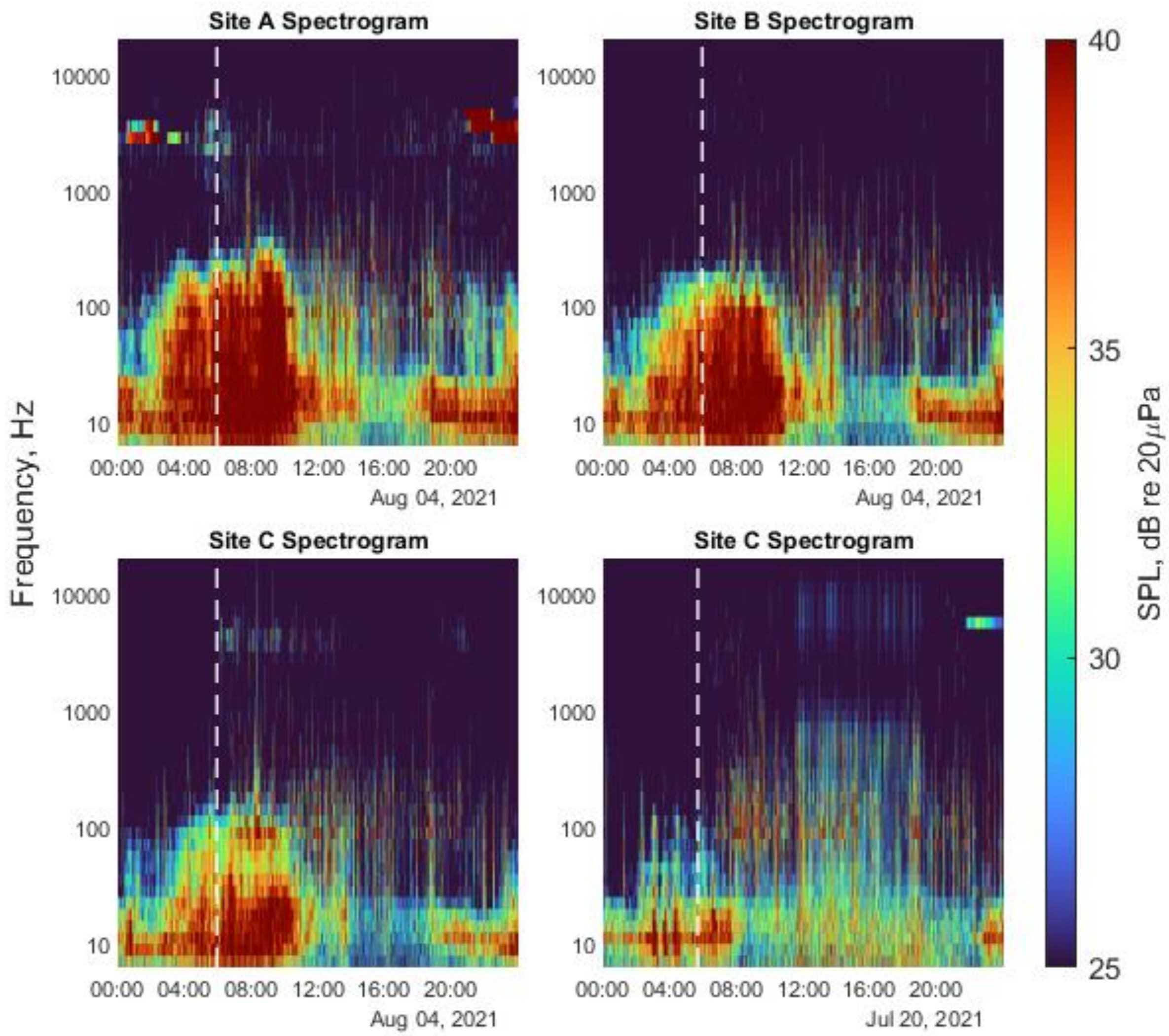

Figure 7: Top left: site A late in the season still exhibiting a weak dawn chorus. Top right: site B late in the season with no dawn chorus. Bottom right: site C late in the season with no visible dawn chorus. Bottom left: a return of a dawn chorus to site C even later in the season.

B. RATES OF CHANGE

Another indication that changing water levels correlate with changing acoustics of the dawn chorus is the relative rate at which the average intensity of the dawn chorus changed at different sites over the season. Between June 1st and July 15th, sites A and B had changes of -13 dB and -3 dB, respectively, while site C had a change of -19 dB. This is the same time period over which we know site C went from wet to dry. Similarly, between July 15th and August 15th site A changed -3 dB while site B changed -20 dB. We know that in this time period site B went dry. This change for site B is a drop of 2 dB every 3 days which means the amount of energy present in the dawn chorus is cut in half every 4.5 days.

4. CONCLUSIONS AND DISCUSSION

A. CONCLUSIONS

The intensity of the dawn chorus is sensitive to the amount of standing water in a given location at a wetland bird refuge. As standing water decreased, so did the intensity of the dawn chorus. We found that areas where standing water dried up had significantly lower-intensity dawn choruses. Possible factors leading to these changes in sound levels include: fewer birds in the area, a greater distance between birds and mic, weaker vocalization intensity, or reduced vocalization frequency. 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. For example, if all changes in sound levels were attributed to decreases in the number of birds present, with all other factors staying the same, a change of -3 dB would mean that half of the bird population has left the area. This is significant when considering site B had changes of -20 dB in one month, meaning that 99% of the dawn chorus participants left that area if birds leaving is the only reason it got quieter.

B. FUTURE WORK

In this study, we established a correlation between dawn chorus sound level and water level. Additional research is needed to establish possible reasons for this. It would be helpful to pair these acoustic data with some observational data, such as changes in insect density, substrate hardness or vegetation cover, to establish contributing factors. The combination of acoustic data and biological surveys could prove to be powerful when monitoring a bird community's general behavior.

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