Restorative Acoustics

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Abstract

Coastal reefs are important ecosystems that provide a buffer to storm surges, prevent coastal erosion, and provide a habitat for important commercial fish species. Due to anthropogenic activity and the effects of climate change, these reefs are becoming increasingly damaged. The recruitment and eventual settling of different species is essential to maintaining a healthy reef (Gordon, 2019). Olfactory cues are subject to currents and tides, but auditory cues can disperse independent of flow conditions and travel for hundreds of meters to several kilometers (Williams, 2021). The goal of the project is to capitalize on the restorative effects of acoustic playback through autonomous playback for prolonged periods of time on an underwater speaker. The speaker would have a power source and playback system completely independent from surface interaction with playback optimized at 12-hour intervals. The system is composed of rechargeable batteries, an amplifier, and microchip controller contained within a watertight container capable of significant heat transfer and future modification. The speaker and housing will be deployed in Great Bay, NH, either fully submerged or with surface buoyancy along mooring lines. A speaker system with this level of independence and extended playback time can provide the restorative means to counteract the damage inflicted by mass change in climate on the world’s oceans.

Tables of Contents

Introduction, Background, & Justification 4

Objectives 5

Approach & Methods 6

Results 8

Discussion & Interpretation 9

Next Steps 10

Acknowledgements 11

References 12

Introduction, Background, & Justification

Coastal reefs are important ecosystems that provide a buffer to storm surges, prevent coastal erosion, and provide a habitat for important commercial fish species. Due to anthropogenic activity and the effects of climate change, these reefs are becoming increasingly damaged. It has been hypothesized that sensory cues, such as sound and smell, play an important role in the recruitment of larval fish to reefs. The recruitment and eventual settling of different species is essential to maintaining a healthy reef (Gordon, 2019). Olfactory cues are subject to currents and tides, but auditory cues can disperse independent of flow conditions and travel for hundreds of meters to several kilometers (Williams, 2021). This makes acoustic signals an attractive option to help mitigate and reverse reef degradation. Recent research has explored the effects of acoustic playback of healthy reef soundscapes on the recruitment of larval stage marine organisms.

In 2013, a study was published on the settlement of larval oyster cultures in both laboratory and field experiments (Lillis, 2013). Sub-tropical and temperate coastal areas provide critical habitat for commercially and ecologically important species. Oyster reefs, salt marshes, sea grass beds, and soft sediment bottoms all likely produce differing soundscapes within these habitats (Lillis, 2013). To see if these differing soundscapes acted as a settlement cue for larval oysters, laboratory tests were done using playback of pre-recorded oyster reef sounds and soft sediment bottom sounds. A control group with no acoustic manipulation was also observed. In the two experiments carried out, significantly higher larval settlement was observed when exposed to the reef sound treatment with no significant difference in the mean larval settlement of the soft sediment sound and no sound treatments (Lillis, 2013). Four trials were completed in the field by suspending replicate larval housings 1 meter above the sea floor at oyster reef sites and off-reef sites. The housing was then exposed to the ambient sound in the chosen locations for 2-5 days. The field experiments showed similar results, with the reef sites showing significantly higher larval settlement (Lillis, 2013).

A similar study was also conducted at the Great Barrier Reef in 2017 (Gordon, 2019). In this study, the effect of acoustic playback of healthy reef soundscapes on the recruitment of larval damselfish was observed. Prior to the experiment being conducted, the coral reef in this area had experienced a mass bleaching event and had resulted in a mortality rate of over 60 percent (Gordon, 2019). Recordings of healthy reef ambient noise were taken at the deepest experimental site. Tests were conducted over the course of 40 days with ambient noise played through UW30 underwater loudspeakers overnight. Control groups were either installed with a dummy loudspeaker (no playback) or no loudspeaker at all. The results showed twice as many juvenile damselfishes on the loudspeaker reefs as both control groups (Gordon, 2019). After 40 days, it was also noted that there were increased populations in all trophic levels at the test sites when compared to the control sites.

Both above studies show that there is significant evidence for the efficacy of acoustic manipulation of both larval and adult marine organisms across all trophic zones. Auditory cues help orient organisms to suitable habitats for settlement, reproduction, and feeding. While still relatively new, this method could show to be useful in both mitigating reef degradation and helping to restore already damaged areas.

Objectives

The goals of the project were centered around the construction of the speaker system in the appropriate housing to be deployed in Great Bay, NH for the recruitment of larval oyster species. Among the electrical connections, the speaker needed to be connected to a power source and an amplifier to conform the desired auditory signals. At the other end of the amplifier would be the playback sound source, ideally one with controllable parameters in order to maintain consistent playback intervals that have demonstrated success in similar previous research. Between all wired connections, fuses were to be used to control electrical flow among the components. The housing unit was to be designed to be watertight in up to 10ft under the surface. In addition, the housing needed to be resistant to overheating, either with an internal cooling system or be constructed of a material conductive enough to put off the heat produced by the components, especially the amplifier. The system was to be completed for which there would be no need for maintenance for up to days at a time with complete functionality, to reduce the amount of human presence in the area and improve the restoration of the environment. To allow for this, and allow an adequate power supply, the design will have DC-DC connections prepared for the addition of solar panels in future modifications of the unit. The final component would be the connection of a microchip controller capable of playback at the set intervals desired for the study.

Approach & Methods

The electronics of our system consist of a Bogen CC4021 CC Series amplifier, a UW30 underwater loudspeaker, two 12-volt batteries and an iPad. The case that all of this (except the speaker) sits in is a 50 L aluminum case from Atlantic British Ltd. with foam inserts. The two 12 V batteries are connected in series to create 24 V that are connected to the amplifier to power the amplifier and speaker. The positive wire of the speaker is connected to the COM output. The negative wire connects to the 25 V output but requires a 25 Ω 20 W resistor and 1.5 A fast-blowing fuse connected in parallel to prevent speaker overload. This configuration is in series with the speaker. The iPad is connected to the RCA inputs via an AUX to RCA cable. Below is a wiring schematic to visualize the electronics (figure 1).

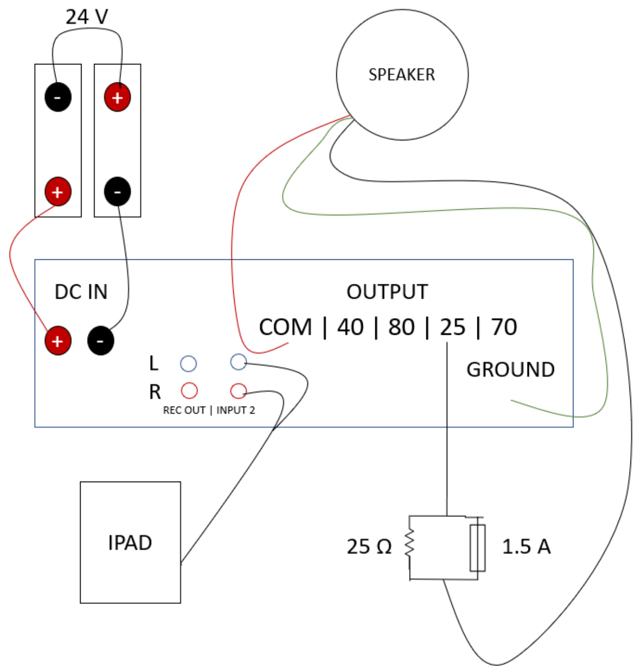

Figure 1: Wiring Schematic

The iPad is currently kept charged via a portable charger power bank that the iPad is plugged into inside of the case.

The plan for the mooring and deployment of this system consists of the case floating on a buoy at the top of the water. It is attached to a deadweight anchor with a mooring line that runs alongside the audio cable. There is also a neutrally buoyant line attached to this anchor and the mooring line. Audio cable is then run across the ground from the anchor to the speaker which is suspended at a designated level a distance away. A mooring schematic can be found below (figure 2).

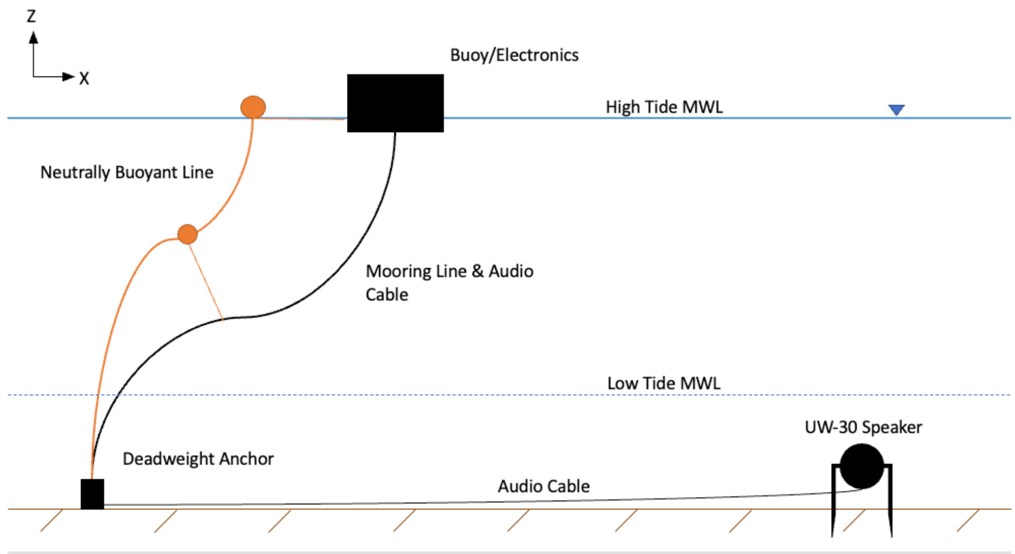

Figure 2: Mooring Schematic

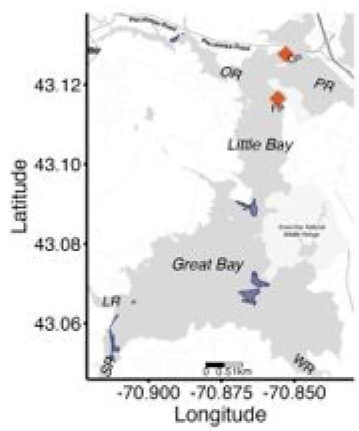

Figure 3: Deployment locations

Results

The device itself works very well. The speaker reaches the frequencies we need it to hit and there have been no electrical issues. The batteries last for well over 12 hours and there have not been any issues with the amplifier overheating on its own. Using the DC IN on the amplifier does cause the batteries to bypass the power switch, meaning batteries are always connected as though the device is on. This is easily rectified and will be discussed in Next Steps. The case is not waterproof. Due to the way the bottom is riveted on, water leaks through the bottom and floods the case. This can easily be resolved with some sealant along the seams and riveted sections.

Discussion & Interpretation

The design was meant to be cost efficient and easily replicable for future restoration efforts. The system is not yet perfected, but the results were satisfying to the original objectives. Among the electrical connections, there were not many complications and electrical flow was not disrupted on any end. The constant flow out of the batteries upon connection exposed the need for a switch control to mitigate the power flow to the system. The amplifier was a great means to control the volume of playback in demonstrations, showing great usefulness for the deployment of the system. The UW-30 speaker shows identical functionality to those used in previous studies although the exact range of the playback sounds when deployed in Great Bay are something that can be investigated to identify optimal deployment location or number of deployments. The iPad being used for playback sound storage currently can satisfy the needs of testing and demonstration of speaker capabilities, however the need for human interaction and power needs reveals the need for programmed control. The ideal system in completion will have playback maintained by a microchip controller, likely a Raspberry Pi. The housing unit provided the most difficulty in locating, as there were extremely limited options for units that were capable of keeping the internal components completely waterproof at our deployment depth and large enough to house the entirety of the system's components. Another concern was the likely overheating from the amplifier, without open air exposure for circulation. The solution of an alternative surface deployment allowed for a broader range of housing options. The selected casing is large enough to hold all components along with foam liners and the aluminum material is highly conductive and eliminates the risk of overheating. The unit was not totally designed for waterproof deployment and will need sealing of all seams and replacement of the O-ring. This gives the opportunity to ensure the unit is waterproof up to the standards of the project. The overall efforts of creating a system prepared for the deployment of an underwater speaker, with playback capabilities for the purpose of oyster recruitment in Great Bay, provided successful results. Short of waterproofing the housing unit and adding a microchip controller for playback control, the system is prepared for testing and sample deployments.

Next Steps

We'll start with the easiest steps. The simplest next step is to install a switch on the batteries which will allow the device to be turned on and off as needed without disconnecting and reconnecting the batteries, improving the battery life and safety of the device. As discussed in the results, the case needs to be waterproofed. A sealant will be put along seams and riveted sections of the case before it is tested again. The current connections in the wiring will either have new wire nuts put in that fit better or will, most likely, be soldered fully together. Also, the cable for the extension will have to be spliced with more cable to reach the length necessary for the mooring setup in our tentative deployment plan. The installation of a Seacon connector is also required to feel this cable through the box, and this installation site would need to be sealed.

For larger steps, the installation of a microcontroller to replace the iPad would be ideal. This microcontroller would be programmed to play our audio files at set intervals. For example, it could play a file once every hour or once every 10 minutes depending on what is ideal for the location. Another improvement would be the installation of a DC-to-DC charger and solar panels. This would allow the rechargeable batteries to be charged while the device is deployed, extending the battery life, and allowing for longer deployments. Steps can also be taken towards the deployment set up, getting together supplies for it and testing it.

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