Monterey Bay Aquarium Research Institute

Designing a Deep-Sea Device to Determine if Feeding Sounds Attract Scavenging Organisms

Katharine Tinsman, CSUMB

Mentors: Dr. Crissy Huffard & Dr. Ken Smith

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ABSTRACT

The deep ocean is relatively unexplored due to lack of access and technology. To combat this issue, more deep-ocean instruments need to be designed to address some of the many questions that we still have regarding deep sea ecology, carbon transport, food chains, and more. Sound is one way we can look at communities, since sounds plays an important role in communication, predator/prey detection, and habitat locating for many marine organisms. Scavenging plays an important role in the deep ocean due to a lack of primary productivity at these depths, and therefore this proposal focused on whether scavengers use sound for food detection. The hypotheses were that scavengers detected sounds below 20kHz and that these group of organisms would respond to feeding sounds played back through a transducer. This study combined engineering and science to propose a device that could be used to answer these questions.

BACKGROUND

Despite all the research that has been done on the ocean and its inhabitants, there are still many mysteries that have yet to be uncovered. The ocean is a difficult place to conduct research, due to both its sheer size and the physical limitations of many surveying methods that are used in terrestrial ecosystems. Even common research methods such as scuba diving have time and pressure constraints that make it difficult to study past a certain depth. These facts leave the deep ocean much less explored than surface waters, as research done in these locations is often expensive, time consuming, or technologically demanding. Only in relatively recent scientific history have we been able to broaden our understanding of what lies beneath the waves through the use of technology. The development of instruments such as ROVs, satellite imagery, live video, and acoustic devices are currently being used to answer some of our questions.

Of particular importance in the ocean is how marine organisms are affected by sound. In water, sound travels much more effectively than light or scent, and therefore plays a more important role in sensing compared to terrestrial environments. Marine mammals, for example, use both passive listening and echolocation for navigation and communication (Ketten 1992, Richardson et al. 1995). This reliance on sound has led to concerns regarding the effects of anthropogenic noise in the ocean on marine species, and studies have shown that there are negative impacts on marine mammals when it comes to increased shipping noise (Slabberkoorn et al. 2010). But mammals are not the only organisms using sound to navigate their environment; in fact, studies have shown that many species of fish also use sound. For example, reef fish larvae have been shown to use reef noises to find suitable habitat (Tolimieri et al. 2000). As long as we have the equipment to study it, this use of sound by marine organisms gives us valuable knowledge about their lifestyles.

Numerous instruments have been developed that can study animal sounds or even mimic the way animals use it. Techniques such as SONAR use sound similar to how marine mammals use echolocation, allowing ships to chart the sea floor or find shipwrecks. Other instruments, such as hydrophones, are microphones that are meant to listen to underwater acoustics. Hydrophones take the changes in pressure caused by sound waves and convert them into electrical voltage, which is then analyzed or saved for later research. Since depth is a major design constraint, these devices are not used as commonly in deeper water, so studies often focus on more shallow marine water communities. This lack of accessibility and technological constraint have largely prevented science from studying the deep ocean soundscape comparatively. Though the deep ocean is less studied, that by no means makes it less important, and hydrophones do exist that can go to greater depths.

The deep ocean lacks the primary producers commonly found near the surface, and as such feeding behaviors such as scavenging play a vital role in bathyal food webs (Britton et al. 1994, Fleury et al. 2013). Deep sea organisms rely on surface productivity as a primary food source, and therefore the amount of falling organic matter, or "marine snow", that sinks in a region can determine the abundance of organisms present there (Turley 2002). The absence of light also guides feeding behavior, since organisms need to rely on non-visual cues to find food and avoid predators. The use of olfaction by scavengers to locate food is well documented (Premke et al. 2003, Sainte-Marie 1992), but less is known about the extent to which sound plays a role in deep sea scavenging.

RESEARCH QUESTION & HYPOTHESIS

This study aims to contribute to understanding the roles that sound play in food detection for bathyal scavengers. The aim of this experiment is to design a device that can answer the questions below by recording the feeding noises of scavengers around a bait source, then removing the bait and reproducing these noises while monitoring scavenger responses. The following predictions will be made based on these questions:

Question 1: What noises do deep sea scavengers make?

Alternate hypothesis: Deep sea scavengers make sounds that are below 20kHz.

Null hypothesis: Deep sea scavengers do not make sounds that are below 20kHz.

Question 2: Do feeding noises by themselves attract any deep sea scavengers?

Alternate hypothesis: The sounds played by the transducer will attract deep sea scavengers.

Null hypothesis: Scavengers will not respond to feeding noises played by the transducer when no bait is present.

PROPOSED INSTRUMENTATION

CONSIDERATIONS

To test these hypotheses, a device will need to be built, which can both record and play scavenger noises. In addition, the device will need some way of monitoring scavenger presence in the study area. When piecing the system together, it is important to take certain considerations in mind:

- *Sound Frequency:* Frequency is how often a sound wave repeats itself. In the context of hydrophone building, it is important to consider the frequency made by scavengers, since it will determine how audio is received and sent back out.

- *Depth (pressure and temperature):* Several physical factors are affected by depth, including pressure and temperature. Pressure increases with depth, so deep-sea technology needs to be built to withstand that force or risk being crushed. Temperature decreases with depth, and these lower temperatures also cause the speed of sound to increase. While deep ocean temperatures are relatively stable, the difference in sound speed compared to shallow water or air needs to be considered when recording the soundscape of the deep ocean.

- *Power requirements:* The hydrophone requires power to monitor, record, play, and store information. Data will be collected continuously over a three-day period, so the device needs to have enough power to last for the study duration.

- *Sampling interval:* The amount of data collected over a year needs to be coordinated with both the data storage limitations and the available power. Calculating how to ration these limits over a year will determine how frequently samples can be taken.

- *Lighting:* Since there is no sunlight at the bottom of the ocean, artificial lighting must be used when taking photos with a camera. These lights need time to turn on, so timing considerations need to be made when syncing with the rest of the system.

- *Corrosive nature of seawater:* Seawater has a lot more dissolved ions than freshwater, so more consideration needs to be made regarding the prevention of corrosion.

- *Deployment and recovery from a large ship:* Monitoring devices cannot sit in the ocean forever; they need the ability to be deployed and recovered. Desired location is important to consider when deploying a device, and the ability to recover it for servicing and data collection is essential. Size and weight limits of the ship crane that will deploy/recover the device also need to be considered.

A number of components will be needed for the device to function properly for our hypotheses (figure 1). The device will be designed to record the sounds of scavengers that are attracted by a bait bag. The hydrophone recording needs to be able to receive the sounds of several different species, and therefore a broader range of frequencies will be critical in catching a large amount of scavenger sound. Similarly, the transducer will need to match the specifications of the hydrophone in regards to frequency, so that it can return all the sounds that the hydrophone records. A camera will also need to be attached to the system to determine what species are recorded and if the playback sounds had an effect on the scavengers. Waterproof cable connectors will attach the components to the controller, providing power and transferring information throughout the system. A controller will tell each component how often to take samples, and will be connected to a storage medium. The controller will be connected to a battery. Connections between the components can be seen in Figure 2.

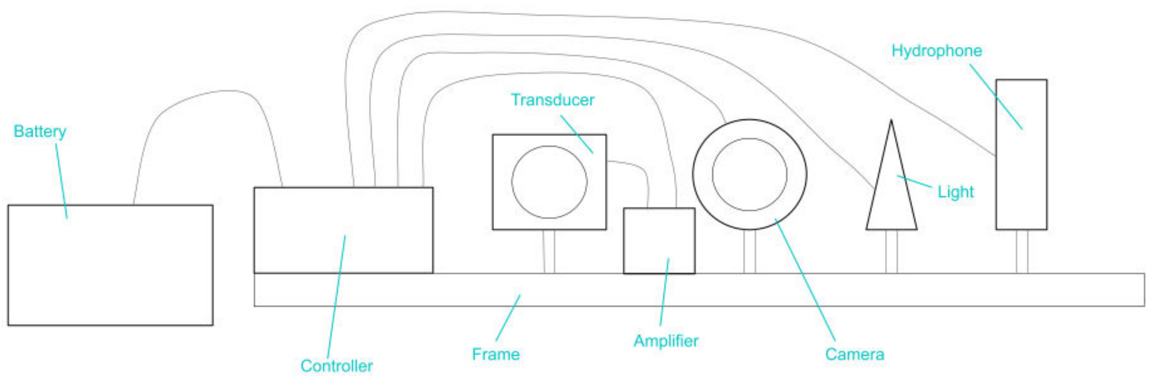

Figure 1. General layout of the device with all the components and how they connect.

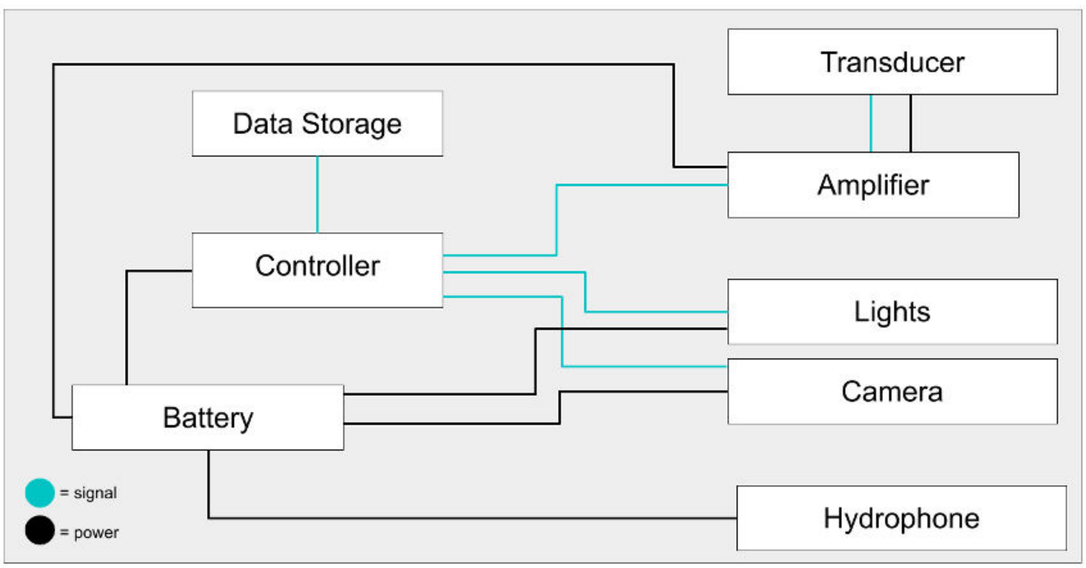

Figure 2. A block diagram that shows the major components of the system and how they are connected.

COMPONENTS

● *Hydrophone:* Many hydrophones convert mechanical sound input into electrical voltage, but the frequencies recorded differ by build. Pre-built hydrophones are made to record specific sound frequencies, and usually come with batteries and storage; each of these specifications will need to be considered when choosing the right component for this project.

● *Microcontroller:* The microcontroller will manage the sampling frequency by controlling the speakers and camera. It will also direct the storage of all information that the instrument generates.

● *Transducer:* A transducer is required to play back scavenger noises that the hydrophone records. The transducer must be waterproof, have the ability to play the frequencies that are being received, and be loud enough to potentially attract scavengers.

● *Camera:* To monitor the effect that the speaker noises have on other scavengers, a camera will capture images of the site. This camera must have a light source since there is no natural light at depth. Considerations for field of view, imagining frequency, and distance light penetrates need to be made.

● *Storage (for sound and images):* The instrument needs to have storage, so that researchers can analyze the data collected over the interval that it was left at MARS. Both image and sound data will need to be stored for long periods of time, and the data will also need to be easily retrieved. The amount of storage required must be measured beforehand to ensure there is enough room for all of the data.

● *Battery:* The battery needs to be strong enough to power the instrument and all active components for both deployments, which spans three days.

● *Watertight housing:* A watertight and pressure-proof housing is required for certain components, including the microcontroller, storage device, camera, and speakers.

● *Cables and connectors:* Cables are needed to send power, commands, and information to different parts of the instrument. The connectors need to be waterproof to prevent damage.

- *Frame:* The frame must be capable of holding all the components in place despite possible strong currents or bottom composition. The frame must be bottom heavy so that it does not tip over, and be made of a material that is resistant to corrosion from seawater.

PROPOSED RESEARCH METHODS

DATA COLLECTION

The purpose of the experiment is to determine whether scavengers respond to scavenger feeding noises. The experiment is intended for a three-day deployment schedule. On the first day, the sounds of scavengers will be recorded using the hydrophone, camera and sealable bait source of the device. The system will be lowered to the seafloor upon arrival at the site, after which the hydrophone will be situated 1m above the bait source, close enough to the seafloor to clearly pick up scavenger sounds at frequencies below 20kHz while limiting bio-abrasion. Sound will be recorded by the hydrophone for the entire deployment, but the presence of bait will change at certain time increments (see figure 3). The bait will be sealed for the first three hours, open for sixteen hours, then closed again for another three hours. The bait-sealed times act as the experimental control. Using flash photography to minimize the effect of light on animal presence, images will be taken in intervals depending on the experimental stage. Coinciding with the bait opening and closing, images will be taken in one minute intervals for the first hour of each stage, and five minute intervals after each of those initial hours. The device will be deployed for one day before being retrieved for the second part of the experiment.

On the second day, the device will be retrieved with acoustic recall upon arriving at the site, then prepped to play back the previously recorded scavenger sounds. The device will then be deployed for another day, this time with the hydrophone, transducer, and camera active. No bait will be present for this portion of the experiment. This deployment will follow a similar time schedule to the first: there will be a three-hour quiet period after placing the device (serving as the control), followed by sixteen hours playing the recorded scavenger sounds, then another three hours of quiet. Flash photography will be taken in the same manner as the first deployment. The device will be retrieved on the third day. This three-day, two deployment schedule will be repeated a total of five times to give a proper number of replicates for the analysis.

DATA ANALYSIS

This experimental design allows for comparisons in scavenger presence when bait and sound are present or absent. The data that are collected using these methods will be analyzed to see if scavenger noises alone attracted other scavengers. The first deployment will provide data on sound and imagery from the site. Sound data will include frequency and duration of sound being recorded, while the camera will take still images that will be used to find time stamps, species and individual counts, and densities. The second deployment will collect still image data, with the same information being recorded as in the first deployment. Classification of the species found in the image data will be done using VARS image annotation (Schlining et al. 2006).

To test whether or not the transmitted sound of feeding had an observed effect on other scavengers, statistical analyses will be done on scavenger presence in the image data for both deployments. Comparisons will be made within and between each deployment, looking at both number of species and number of animals present. Within comparisons will be done by looking at the difference in density and count averages with bait open/closed and sound on/off respectively. Between comparisons will be done by looking at the difference in density and count averages during the bait-open period of the first deployment and the sound-on period of the second deployment. A chi-square test will be considered for this experimental design, since count and density comparisons are being made between independent categorical variables (sound on or off, bait open or closed).

In addition to comparing bait and sound, this study can also tell us about relative species abundance at the site. Time of first arrival is a measure that has been shown to effectively estimate species abundance (Priede & Merrett 1996). This measurement depends on several different physical and biological factors. Current strength and direction, strength of bait odor, smell detection of the species, and speed the organism moves are some of the pieces that give each species its own unique arrival time. Using time of first arrival, we can use the baited cameras in this study to also tell us about relative abundance.

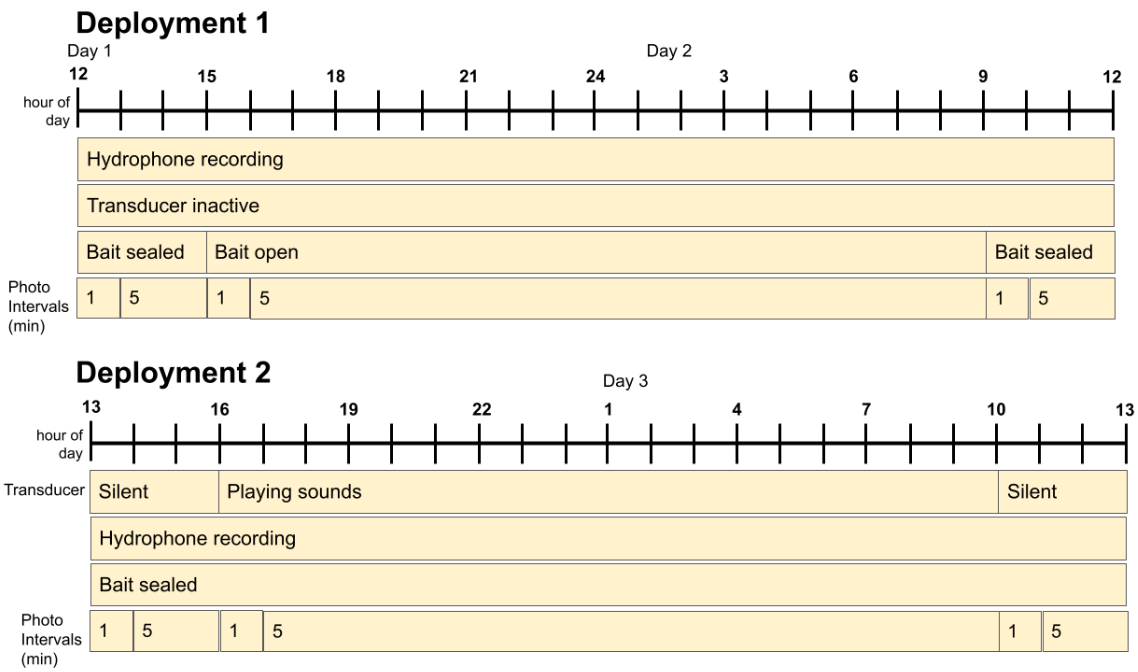

Figure 3. Device schedule, focusing on points in time where certain components turn on/off.

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