

Hydroacoustic pinging as a diver tool for underwater navigation in surveying Puget
Sound Eelgrass (*Zostera marina*) densities.

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Abstract:

Advances in technology have led to a change from data limited, direct observations to much numerous, more remote data. Despite this trend direct observations are still an important source of information and invaluable means of ground truthing remote data collection. In oceanography the direct collection of data is much more difficult and is accomplished primarily using SCUBA. This study focused on the design and build of a low cost hydrophone-pinger system to aid in SCUBA navigation to fixed locations within two eelgrass (*Zostera marina*) beds off of San Juan Island, Washington. Study beds were different in size and shoot density was measured at each fixed location to examine the effects of bed size on density and subsequent colonization patterns. Three diver navigation methodologies to markers were timed and compared: the Hydrophone-pinger build, underwater compass navigation, and memory (dead reckoning). ANOVA results showed that the smaller bed had higher shoot density than the larger bed with a p value of 0.04, suggesting that beds colonized from a central radiating location rather than filling in patches. The piezo transducer element from the hydrophone-pinger ultimately led to a failure in the distance of sensitivity parameter objective.

Introduction:

Recent remote sensing accomplishments make it an exciting time to be a scientist and an oceanographer especially. As we continue to engineer new and creative ways to collect data we can start to tackle more complex problems that historically needed a person onsite. Marine biodiversity estimates, for example, usually require a human actually diving to the ecosystem in question or looking at visual data from an ROV

(Kenyon et al. 2006). Newer methods are developing to remotely detect organism assemblages to a finer scale than in the past using remote sensing (Turner et al. 2003). While we start to shift into these more remote methods of data collection it becomes increasingly important to ground truth these data to ensure the accuracy and lack of bias in these measurements.

SCUBA is an invaluable way to gather in situ data and ground truth various forms of remote sensing data to prevent inaccurate interpretations. SCUBA use in scientific papers has increased exponentially since the 70's along with technology (diving and remote sensing) (Witman et al. 2013). Research using SCUBA has led to an increased understanding of coral reefs (Macintyre and Aronson n.d., Vollmer et al. 2013), pelagic ecosystems (Madin et al. 2013), and sub ice marine ecosystems in the polar caps (Willason 1981). Behavioral research may also prove unfit for remote data, where in situ observations of animals are required (Eggleston et al. 2013).

This study is focused on the enhancement of SCUBA data collection methodologies and ground truthing applications of Eelgrass Surveys. Eelgrass (*Zostera marina*) is an extremely important component of temperate marine ecosystems that provides a large amount of primary productivity and complex habitat for commercially important fish such as salmon (Kenworthy et al. 2007, Semmens 2008). Human disturbance, mostly in the form of activities that alter water quality (e.g. pollution), has been shown to negatively impact these critical ecosystem around the world (Short and Wyllie-Echeverria 1996). As a result *Z. marina* is now protected and there is a large effort to monitor eelgrass to prevent further decline.

Two common methods of monitoring eelgrass include video footage taken from boats, and manual diver transects. Video footage has been shown to be more viable for larger, site and regional scales, rather than finer transect scales (McDonald et al. 2006). Diving using SCUBA is chosen for smaller, coastal surveys and the WA Fish and Wildlife has standardized methods for diver transects (“Eelgrass/Macroalgae Habitat Interim Survey Guidelines” 2008). My research explored the relationship between underwater navigation and SCUBA data collection through studying *Z. marina* beds. I specifically looked at how memory (called “dead reckoning”), underwater compass headings, and a built hydrophone-diver ping system affected diver time in finding fixed eelgrass beds. Once at the beds I measured the density of 2 differently sized beds to see if eelgrass bed density correlates with bed size. These data explored colonization patterns of *Z. marina*, which could have important implications to local Puget Sound fishing industries.

Methods:

Site Criteria

Eelgrass sampling sites were chosen based on size, depth, substrate type, and bathymetry. Sites varied in the size of eelgrass beds to test bed size effects on density. Sites were separate to prevent diver navigation bias. Both eelgrass sites were within a short surface swim of Friday Harbor Labs dock off of San Juan Island, WA in Puget Sound (Figure 1).

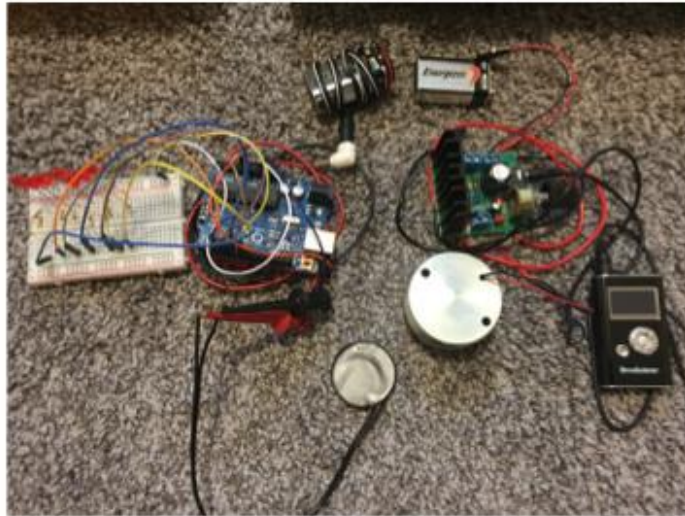


Figure 1: Eelgrass sampling beds at Friday Harbor labs and rough marker locations

Hydrophone-Pinger Build Design

The first method of underwater navigation was the proposed low cost hydrophone-pinger dive setup to aid in diver underwater navigation. The build consisted of two major parts: an underwater pinger and a portable hydrophone. The pinger was to be dropped with the surface maker and send out an audio signal at specific intervals. This signal was to be picked up by a portable, waterproof hydrophone, which relayed decibel intensity to the diver visually via LED's. Signal intensity was supposed to increase as the diver approached the marker pinger, allowing it to be used as a

navigational tool (Figure 2).



Hydrophone (Rx)

- Arduino
 - Internal LED lights with sound
 - Power 15min on 9V supply
- External LED
 - Can connect to Arduino
 - High vol causes more to light up
- Potted Piezo Element
 - Increased pressure lights up ext LED
 - 10m detection of 740Hz tone

Pinger (Tx)

- Tone Generator
 - Meets frequency requirement
 - Power for 15 min
- 12 V Amplifier
 - Tone for 15 min on 9V supply
- Transducer
 - Plays music via amp
 - Music detected via commercial Hydrophone
- Surface for Transducer
 - Transmit sound via transducer

Figure 2: Design- build picture with objectives for each major component

The pinger prototype consisted of a Brookstone MP3 player connected to a DROK TDA7297 amplifier, which then sent the signal to a Spark Fun COM-10975 surface transducer. The transducer produced sound when pressed against a rigid surface. Plexiglass, PVC plastic, and rubber were tested for their viability as surfaces to transmit the signal using a free Volume Unit (VU) meter mobile application. Signal frequency was also tested at 140Hz, 440Hz, and 740Hz using the VU meter to determine which frequency traveled the furthest. The pinger was powered with a portable 9V battery and housed in 2" PVC.

The hydrophone consisted of a plastic potted Piezo element connected to an Arduino UNO board. LED's were connected to the Arduino to serve as visual aid. The Arduino was programmed to light up more LED's as the pinged signal intensity, and therefore proximity to the marker, increases. The hydrophone was encased in waterproof Pelican housing. A 9V battery also powered the hydrophone.

Eelgrass Sampling

Divers went down using SCUBA to 2 fixed locations and surveyed eelgrass shoot counts along the bottom of the seafloor. Within bed sampling sites were standardized with a 0-5m depth range. Quarter meter quadrats were used in sampling eelgrass shoots. Quadrats were laid out 1m from the marker at right angles for the first sampling of the marker site, and 2m for the second sampling (Figure 3). Each site had two markers to replicate bed counts with 8 quadrats per marker. This sampling method strayed from traditional methods of long transects along depth contours to optimize diver air time

while gathering both eelgrass data, and diver navigation times.

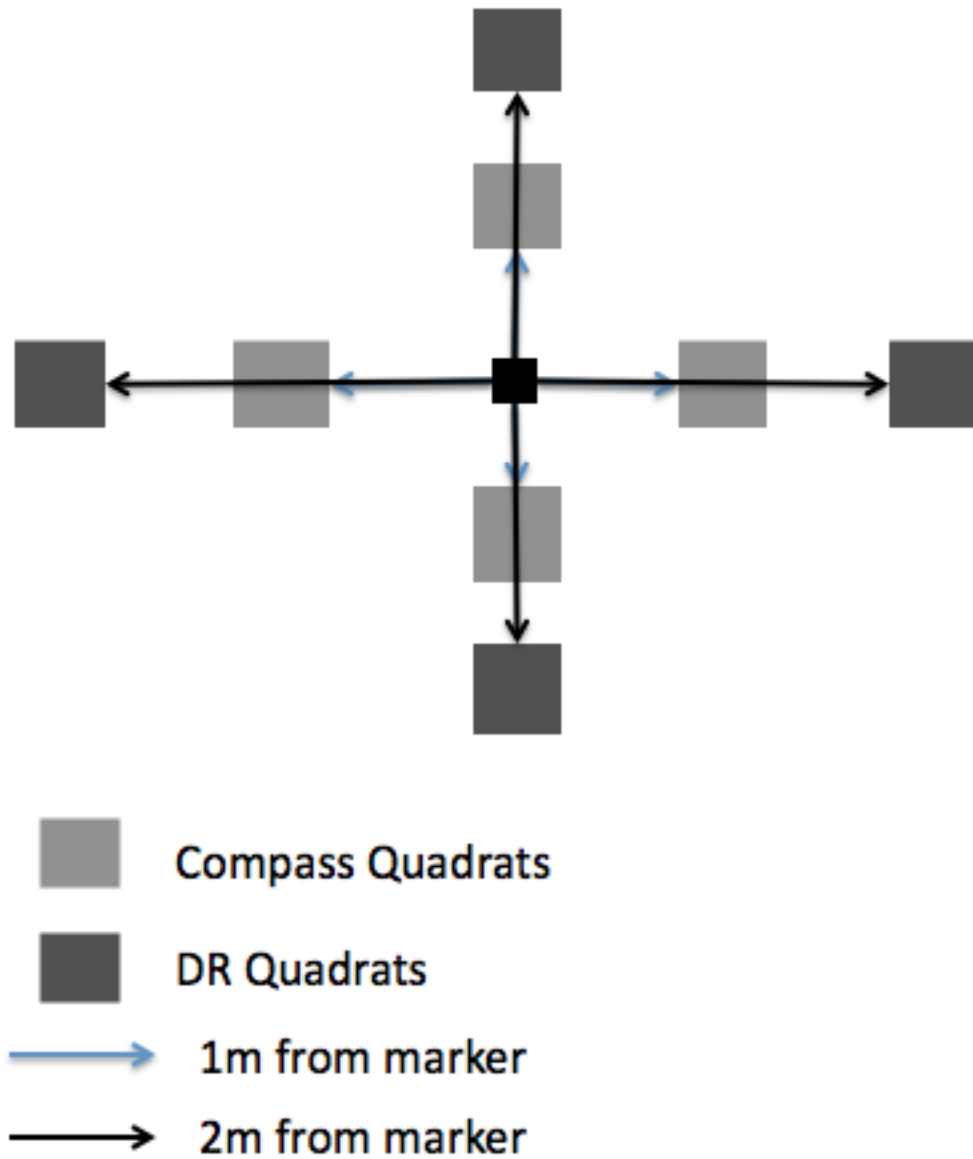


Figure 3: Diagram of sampling methodologies surrounding the fixed marker (small black square). The first round of compass navigation data collection (light grey squares) was 1m from the central marker. The second round of dead reckoning data collection (dark grey squares) was 2m from the marker.

In addition to the sampling of eelgrass patches, divers relocated the transect markers using 2 separate navigational approaches: simple surface markers plus memory acting as the control and underwater compass headings. The start point was the same for

both treatments. Time from initial descent and the finding of the marker was compared between the 2 navigational methodologies.

Compass navigation involved compasses especially used for SCUBA. Divers took a marker heading by rotating the bezel upon initial transect setup and followed the compass heading for subsequent sample dives. Proper compass navigation included holding it level in line with the center of the body. Wrist mounted setups bent the compass bearing arm at the elbow, touching the outstretched arm of the opposite hand. Console mounted compasses were held in front with both hands cupped in a triangle.

The diver navigation control was simply divers using surface markers to roughly mark the spot where they deemed the marker to be. Once underwater, memory was the only resource they used to navigate to the marker. Control navigation runs were done after successful compass runs so that the diver could familiarize with the site.

Data Analysis

Eelgrass densities were compared using R Statistical Software. One-way ANOVAs were conducted between sites as well as within site repetitions. ANOVA tests were also done on navigation times among the three methods for underwater location. These results were used to determine the viability of using hydrophone technology underwater to significantly reduce navigation time.

Results:

Diver Navigation

The pinger met all initial design parameters. The hydrophone met all design parameters up to water tests of visual response to signal pick up. The piezo sensor was found to be extremely sensitive to changes less than 1 cm away from the source signal,

but was ultimately unable to pick up the signal at further distances (Figure 4).

Hydrohone(Rx)

- Arduino
 - Internal LED lights with sound ✓
 - Power 15min on 9V supply ✓
- External LED
 - Can connect to Arduino ✓
 - High vol causes more to light up ✓
- Potted Piezo Element
 - Increased pressure lights up ext LED ✓
 - 5cm detection of 740Hz tone ✘
 - Retest with increased sensitivity ✘
 - Retest with different pinger surfaces ✘

Pinger(Tx)

- Tone Generator
 - Meets frequency requirement ✓
 - Power for 15 min ✓
- 12 V Amplifier
 - Tone for 15 min on 9V supply ✓
- Transducer
 - Plays music via amp ✓
 - Music detected via commercial Hydrophone ✓
- Surface for Transducer
 - Transmit sound via transducer ✓

Figure 4: Hydrohone-pinger design and build parameter objectives pass/fail

Time comparisons of compass and dead reckoning navigational methods were found to be insignificantly different from each other. Compass navigation was shown to have a much smaller variation in average time than the dead reckoning methods (Figure 5).

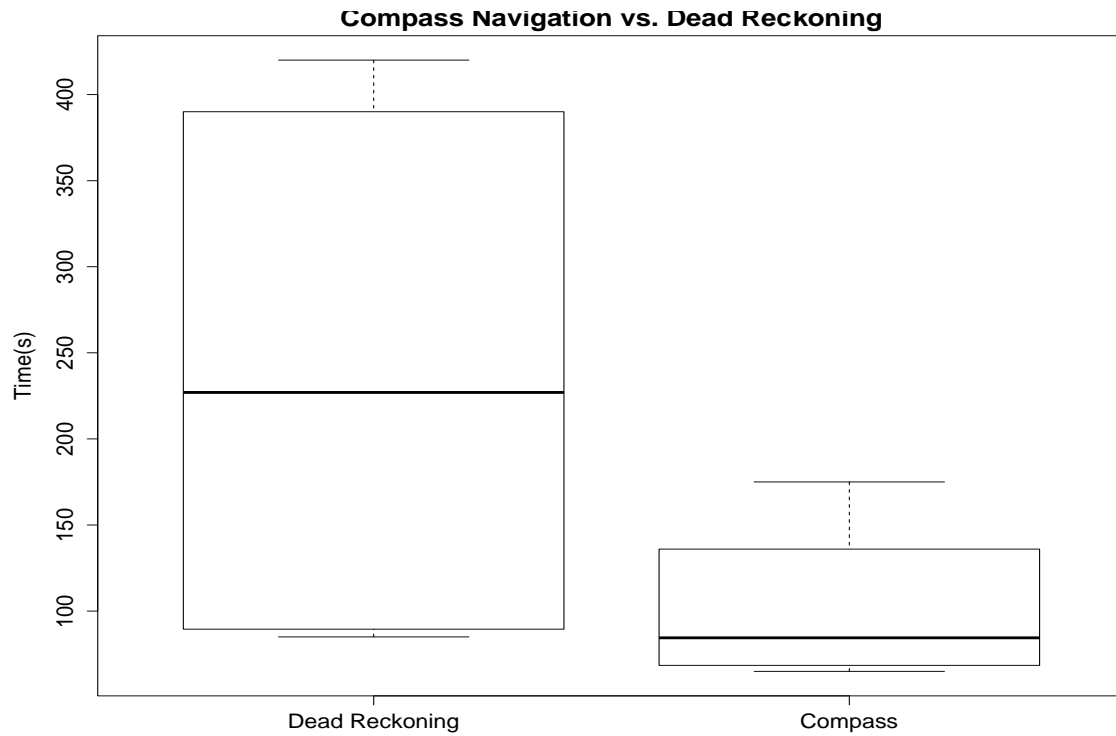


Figure 5: Average time in seconds the diver took to navigate from a fixed start point to a marker. Navigation methods were compass headings, and memory (dead reckoning). Paired sample t-test yielded insignificant results ($p = 0.2654$). General ANOVA analysis also yielded insignificant results ($p = 0.182$).

Shoot density was found to be significantly different between bed size with an ANOVA test yielding a p values of 0.04. The small bed had a higher number of shoots on average than the large bed (Figure 6).

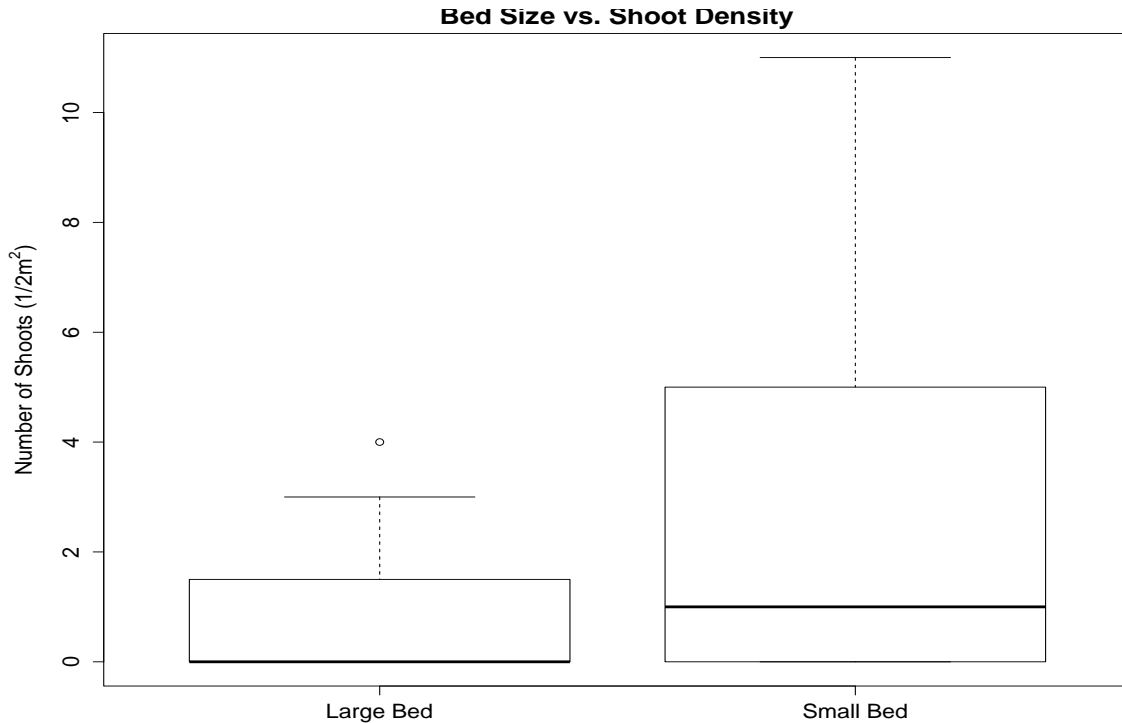


Figure 6: Average number of shoots counted per $\frac{1}{2} \text{ m}^2$ between large and small eelgrass beds. ANOVA analysis showed that small beds had a significantly higher number of shoots ($p = 0.0451$).

Discussion:

The low cost hydrophone-pinger ultimately failed to be a useful navigational tool due to proximity constraints between the signal transducer and the receiver. The hydrophone detected changes in pressure from direct contact and LED response increased when pressure increased, however, the hydrophone was not sensitive enough to detect the pinger signal underwater. The piezo element, a common component of many commercial hydrophones, was found to be only sensitive in extremely close distances. This may be due to its free-floating design of the piezo element. An Alternative hydrophone build would involve the element being anchored against a rigid material. The next step would be to test different mounting methods to different materials (metal, pvc, plexiglass) to see

which material would lead to picking up a constant signal at the greatest distance underwater.

The other two forms of diver navigation were found to be insignificantly different, although the dead reckoning/memory treatment had a much wider amount of time variation from the start point to the marker than the compass navigation. This suggests that the compass navigation was much more consistent across trials. Both divers found that the compass navigation was much more effective and the lack of statistical can be purely due to small sample size.

The eelgrass densities between the two beds were found to be statistically significant with the smaller bed having a higher number of shoots on average. Based on the assumption that a more dense bed is more established, this suggests that eelgrass beds tend to first reach a certain density before radiating outwards from a center point. This supports previous research that has shown that mortality decreases with increasing bed size due to improved anchoring, mutual physical protection, and shoot integration (Olesen and Sand-Jensen 1994). These findings could have important consequences for a variety of industries that rely on exploiting natural resources around these areas by allowing them to predict future areas of eelgrass bed growth based on patch size and density. Future research looking at more eelgrass beds as well as changes in density throughout the year is recommended for more in depth and robust pattern analysis.

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