The Design and Implementation of Lagrangian Drifter For Shallow Water Coastal Ecosystems

Frank Perez, California State University Monterey Bay

Mentors: Yui Takeshita, Irene Hu

Summer 2022

Keywords: NCP, Lagrangian, Drifters, Data, Fix, GPS, Arduino

ABSTRACT

Net Community Production (NCP) is used to understand the quality of life in aquatic ecosystems. Lagrangian drifters can be used to measure surface water as it flows throughout the ecosystem. The drifters do this with various sensors that gather data during movement. In this project, we made modifications to an existing drifter to get better measurements of NCP. One feature that the previous drifter implementation had was that it lacked accuracy in its location data. Its location data had 2 points, which were a beginning and end. Then a line would be drawn through them and the assumption was that the drifter traveled in a straight line, which was not always the case. A GPS can increase the accuracy of the path taken and can be used to verify if the drifter moved with the current. Our design criteria was to modify the existing drifter's housing, to account for our antenna constantly being underwater, move passively with minimal effect from the wind, and a minimum battery life of 12 hours. We created several drifter prototypes to take multiple tests of our GPS module in combination with an optode module (used for oxygen).

INTRODUCTION

Net Community Production (NCP) is used for understanding the amount of biological activity. The difference between photosynthesis and respiration are important when measuring NCP. Higher levels of oxygen indicate there is more photosynthesis and the ecosystem is healthy. Meanwhile, the ecosystem is unhealthy when there is more respiration, because there are higher levels of carbon dioxide. It is important that the data used in NCP measurements is accurate, so that researchers know where conservation efforts should be made. NCP can be measured with lagrangian drifters, which are designed to float on the surface of watery ecosystems. Lagrangian drifters have modules that passively gather data while moving along with the current. Typically non-shallow drifters will use drogues to gather additional data. Drogues are large devices attached to the bottom of drifters that are submerged further and get more data. The more data, the more accurate an NCP measurement will be.

In our project, we used existing drifter housing that was designed for shallow water ecosystems. The drifter did not have a drogue, because it could have easily gotten stuck in shallow waters. Previously, the path the drifter took in water was assumed to be in a straight line, but not known for certain. We added a GPS module to accurately map out the path our drifter took, instead of assuming it went in a straight line.

MATERIALS AND METHODS

The drifter needed to be designed for deployment in shallow water environments and be easy to reproduce (cost effectiveness was taken into consideration). There was left over housing from a previous drifter that we used to house our drifter, with few modifications needed. One modification being the removal of the durafet (ph sensor). The goal was to have a drifter with a battery life of 12 hours that measured GPS and oxygen. The GPS and oxygen data needed to be stored simultaneously to ensure that the data could be observed simultaneously. The GPS antenna needed to be able to regain a signal (also known as a "fix") after being submerged underwater.

We needed to find a good GPS that could be tested out on an Arduino Uno prototype. We used an Adafruit GPS shield and later swapped it out for the module version. Then we needed to attach an antenna to get a better signal, because the module's default antenna was small and had a harder time retaining a fix. We used a small generic antenna that barely sticks out of water in the final design of the drifter. We tested 2 types of batteries, 9 volts and AA Lithium batteries. Both types of batteries were tested out multiple times in the lab, but the AAs were only tested once in a real deployment. The 9 volts batteries lasted 12 hours when only powering an Arduino Uno and a GPS shield. The AA Lithium Batteries could last 26 hours in a continuous drifter deployment.

RESULTS

This project had 3 prototype drifters based around collecting GPS and oxygen data. The first two were made with an Arduino Uno and were a proof of concept. The first drifter was tested on a cruise onboard the Western Flyer. The second drifter was tested out on a small trip on the Paragon. The third/final prototype drifter was made using a mpHOx board and was programmed in C. The final drifter was tested multiple times on a trip into the Elkhorn Slough.

The first prototype wasn't a complete drifter, because it was designed to test the accuracy of the GPS module with Arduino. It was an Arduino Uno with an Adafruit GPS shield and external antenna inside of tupperware (to prevent water damage). It was tested on the YODA 2022 research cruise onboard the Western Flyer and followed a similar path as the ship's on-board GPS system. It was placed outside on the second floor of the Western Flyer.

The second prototype did function as a primitive drifter. It had the previously mentioned Arduino and GPS module inside of a water resistant housing. The purpose of this prototype was to test out the ability of the antenna to retain a signal. This prototype was onboard the Paragon on a short trip into Monterey Bay. The drifter would briefly be placed into the water and submerged a few times to stimulate being fully underwater. The antenna was able to regain signal quickly after being submerged under water.

The third and final drifter prototype was tested in the Elkhorn Slough and was followed by a small team consisting of people who worked on the drifter. The drifter recorded GPS and oxygen data accurately. The drifter was weighed down by 3 pieces of lead in an upright position. The drifter was almost completely submerged underwater, with the exception of the antenna. The team was able to confirm the accuracy of the drifter's path. The drifter was always on and was deployed 3 separate times. Dr. Hu took the time for each deployment and was able to confirm with the drifter's oxygen level data. The data was parsed in MATLAB and the oxygen data showed spikes whenever the drifter was deployed. This information was used to confirm the deployments to know which GPS coordinates when the drifter was deployed. The results were three recorded paths and three separate oxygen levels recorded for each path.

DISCUSSION

Lagrangian drifters are useful devices for gathering raw data for NCP measurements. They record data by floating in a body of water and there are different kinds of lagrangian drifters developed for various bodies of water. Typical lagrangian drifters consist of an antenna, surface float, a drogue, and multiple sensors. The antenna may be used to transmit and receive data; like where the drifter is located and what information it has gathered. The surface float prevents the drifter from sinking and keeps the drifter floating on the surface. The drogue can perform multiple tasks, ranging from carrying additional sensors to being a weight that submerges the drifter. The sensors gather data, such as the pH or oxygen levels of the ecosystem.

This drifter was designed for shallow water ecosystems, which led to some differences from traditional lagrangian drifters. A key difference is the absence of a drogue, because the drogue could easily get caught on something in a shallow environment. Another difference is the lack of a surface float, because there was no need for one. The final drifter's entire system functions within a cylindrical device. The top of the device has an antenna that is used by the GPS module to have a better signal with the satellites it connects to. The bottom of the device contains the optode, which is used to gather oxygen data. This design was done to reduce costs and to maximize the amount of drifters that could be produced.

Some of the problems we encountered were needing the device to get a fix before deployment and not knowing when the device has a fix. The only way to know if the device has a fix is to connect the mpHOx, which has to be done before it leaves the lab. This is an inconvenience that could be mitigated or removed in the future. Knowing when the device has a fix can be useful, because it's easier for the device to regain a fix after it already had one.

CONCLUSIONS/RECOMMENDATIONS

I would recommend adding sonar, so that it could provide context for the NCP measurement. Sonar could be used to map out the ecosystem's floor. The map of the ecosystem could be used to understand why a portion of the ecosystem has a low level of NCP. The drifter's sonar could be used to show changes in an ecosystem over time, if redeployed in the same ecosystem. For example, sonar images contrasting a coral reef when it's healthy and when it's dying. Another recommendation would be to add a light on top of the drifter to determine whether or not the GPS has a fix. Dr. Hu suggested this, because it is easier for the GPS to regain a fix, after the GPS gets its first fix. Currently the drifter needs to get its fix before being assembled and someone has to manually check if the drifter has its fix by connecting to the mpHOx with a computer. Obviously, this is inefficient and could complicate the process by increasing the odds of a drifter malfunctioning, because it has to constantly be opened and closed. The light could flash red if the fix is lost and green if it has a fix, which would increase the amount of times the drifter could be redeployed. A final recommendation would be to add an on/off switch outside of the drifter, so that it could be turned off after returning from a deployment. The switch would help conserve power by having the drifter turned off whenever it's not deployed. Most of the data the drifter gathered would during its deployment, which would reduce the amount of data cleaning required.

Overall, the project was a success, but could be improved in the future with the aforementioned recommendations. The final drifter successfully measured oxygen and GPS location data in the Elkhorn Slough during three separate deployments. The GPS and oxygen data were in sync and could be used to determine which oxygen levels belonged to which regions of the slough at a given time. I think the switch and light would drastically improve the quality of the data gathered by the drifter.

ACKNOWLEDGEMENTS

The David and Lucile Packard Foundation

Rentschler Family Fund in memory of former MBARI board member Frank Roberts

Maxwell/Hanrahan Foundation

Dean and Helen Witter Family Fund

Yui Takeshita, Irene Hu, Joseph Warren, George Matsumoto, Megan Bassett, and Lyndsey Claassen

REFERENCES

Johnson, D., Stocker, R., Head, R., Imberger, J., & Pattiaratchi, C. (2003). A Compact, Low-Cost GPS Drifter for Use in the Oceanic Nearshore Zone, Lakes, and Estuaries, *Journal of Atmospheric and Oceanic Technology*, *20*(12), 1880-1884. https://journals.ametsoc.org/view/journals/atot/20/12/1520-0426_2003_020_1880_aclgdf_2_0_co_2.xml

Austin, J., & Atkinson, S. (2004). The Design and Testing of Small, Low-Cost GPS-Tracked Surface Drifters. *Estuaries*, *27*(6), 1026–1029. http://www.jstor.org/stable/3526977

Falter, J. L., R. J. Lowe, M. J. Atkinson, S. G. Monismith, and D. W. Schar (2008), Continuous measurements of net
production over a shallow reef community using a modified Eulerian approach, J. Geophys. Res., 113, C07035,
doi:10.1029/2007JC004663.

Ulf Riebesell, Victoria J. Fabry, Lina Hansson, Jean-Pierre Gattuso (2011), Guide to best practices for ocean acidification research and data reporting.

Supreeth Subbaraya, Andreas Breitenmoser, Artem Molchanov, Jorg Muller, Carl Oberg, David A. Caron, Gaurav S. Sukhatme (2016), Circling the seas Design of lagrangian drifters for ocean monitoring.