Results in Engineering 5 (2020) 100087

Contents lists available at ScienceDirect

Results in Engineering

journal homepage: www.editorialmanager.com/rineng/Default.aspx

Equipping smart coasts with marine water quality IoT sensors

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ARTICLE INFO

Keywords:
Water quality
Internet of things
Ocean acidification
Aquaculture

ABSTRACT

Ocean acidification, the decrease in seawater pH as a result of increasing carbon dioxide, has been shown to be an important driver of oyster mortality in West Coast shellfisheries [1]. Yet carbon chemistry is only sparsely measured, especially relative to its high variability in coastal ecosystems, due to the complexity and cost of appropriate sensors and their maintenance. Worse, data are rarely communicated in real time to water quality or aquacultural managers. In the Agua Hedionda Lagoon (AHL) in Carlsbad, CA, researchers from Scripps Institution of Oceanography and industry representatives from the Carlsbad Aquafarm have come together through a NOAA-facilitated project to alleviate this data shortage using a combination of cutting-edge research technology alongside off-the-shelf and easy-to-implement IoT communications packages.

1. Methods

1.1. Technology overview

The project team deployed a SeapHOx with a cellular-enabled surface mooring for real-time communications from AHL (Fig. 1). The SeapHOx is a multiparameter oceanographic sensor package measuring pH, dissolved oxygen, salinity, temperature, and water depth [2,3]. The surface buoy contains a Particle Electron 3G (https://www.particle.io/), cell antenna, and rechargeable battery, as well as UART–RS232 converter. Underwater connectors/cables provide a communication link between the SeapHOx and Electron. The Electron polls the SeapHOx and sends the resulting water quality data to a Google Sheet at hourly intervals; data are also logged internally in the SeapHOx for added redundancy. The Southern California Coastal Ocean Observing System (SCCOOS) data integration script subsequently extracts quality-controlled data from the Google Sheet and uploads them in a publicly available data repository used by oceanographers and environmental scientists worldwide (named ERDDAP: the Environmental Research Division's Data Access Program): http://erddap.sccoos.org/erddap/tabledap/pH-AHL.html. The Particle Electron's code and instructions for populating a Google Sheet through Particle Integrations is available at https://github.com/SUPScientist/Equipping-Smart-Coasts.

1.2. Chemical measurements and their importance

While pH is the carbon chemistry term most commonly associated with the phenomenon of ocean acidification, it is hypothesized that a related variable, saturation state of calcium carbonate as aragonite mineral, is more directly related to shellfish and other marine shell-forming organism health [1,4,5]. Saturation state of aragonite ($\Omega_{Ar} = \frac{[Ca^{2+}][CO_3^{2-}]}{K_{sp}}$, where $[Ca^{2+}]$ and $[CO_3^{2-}]$ are the dissolved calcium and carbonate ion concentrations, respectively, and K_{sp} is the solubility product of calcium carbonate as aragonite) decreases as a direct and measurable result of ocean acidification. As excess anthropogenic CO_2 is absorbed by seawater, it predominantly reacts with water and carbonate ions to form bicarbonate, thereby decreasing carbonate and increasing bicarbonate concentrations in seawater. Ω_{Ar} is estimated through thermodynamic relationships using the R programming language [6,7] (RStudio version February 1, 1335, R version 3.5.3, and seacarb version 3.2.12) from sensor pH and an average total alkalinity (from sparse discrete samples) and, along with the parameters measured by the SeapHOx, is reported in ERDDAP and on http://sccoos.org/ocean-acidification/.

Low Ω_{Ar} has been shown to have dramatic, deleterious effects on shellfish growth and survival, especially at the larval stage [8]. Carbon chemistry monitoring allows for the creation of biogeochemical models

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https://doi.org/10.1016/j.rineng.2019.100087
Received 27 November 2019; Received in revised form 7 December 2019; Accepted 7 December 2019

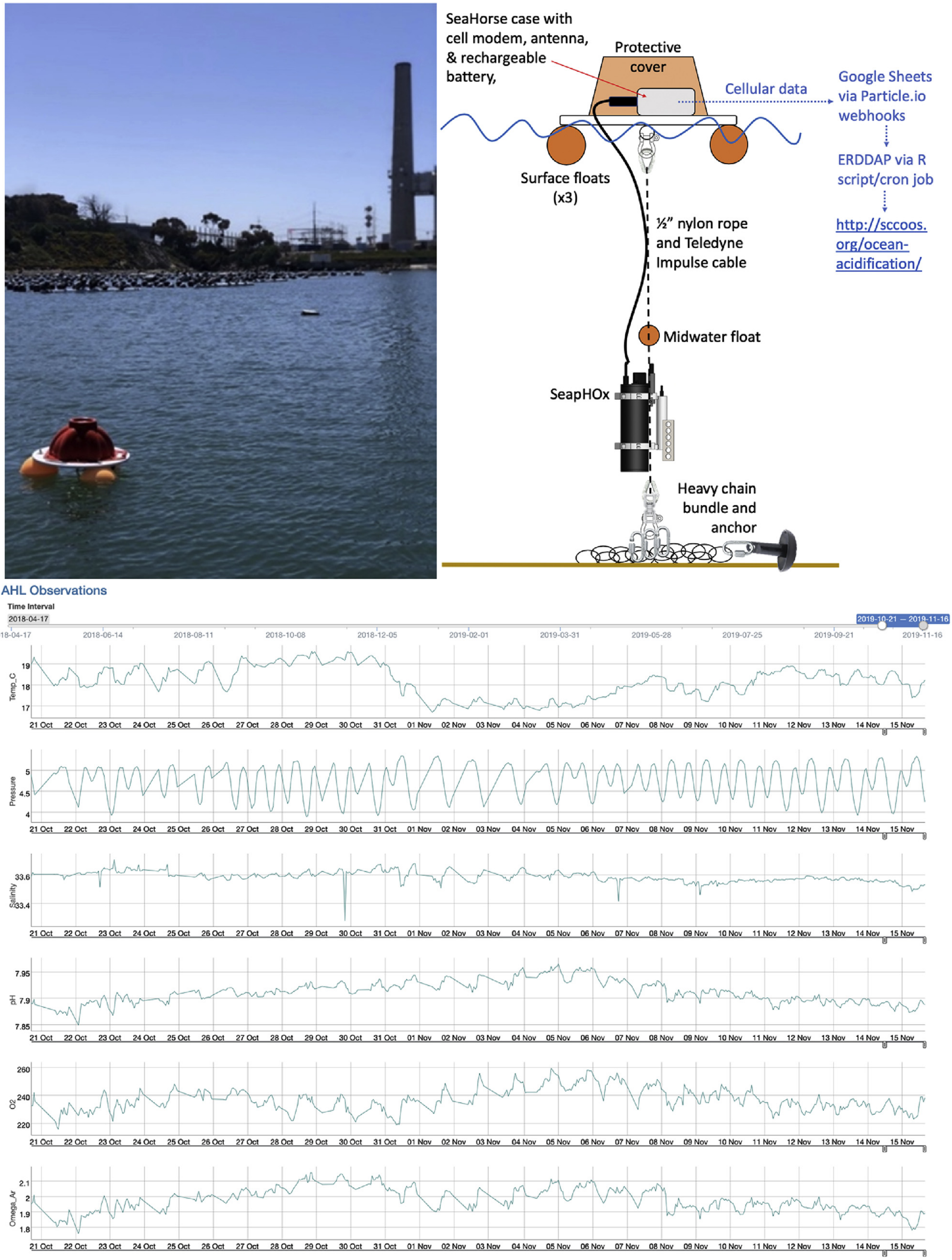

Fig. 1. (Top Left) the closed surface buoy deployed in Agua Hedionda Lagoon, (Top Right) schematic depicting the positioning and functions of equipment during deployments as well as the data pipeline in blue, and (Bottom) screenshot of real-time data feed on http://sccoos.org/ocean-acidification/.

which can be used to improve the timing of shellfish breeding and releases into ambient seawater. Adding real-time data availability greatly enhances managers' ability to adapt on-the-fly to changing conditions. In the most proactive approach, managers at the Whiskey Creek Shellfishery in Netarts Bay, OR, actively buffer incoming seawater when Ω_{Ar} begins to dip below potentially threatening thresholds [1]. It should be noted, however, that the topic of ascribing specific thresholds in carbonate parameters to survival models is still an open field of scientific research: the effects of neither magnitude nor duration nor timing relative to life stage are well known for most carbonate shell–forming organisms [9].

2. Conclusion

"Smart Coastlines" are not always included in Smart Cities conversations and city planning efforts. Yet, with ever-increasing populations relying on the coast for food, housing, and recreation, it is critical that we work to bring the Internet of Things into the sea. Smart water quality monitoring is not a novel concept (e.g. Refs. [10,11]) but the ease of use of hardware and software in this project will make additional coastal IoT deployments much more prevalent. Furthermore, the researchers in this project have benefitted greatly from this collaboration through the Carlsbad Aquafarm's assistance with sensor siting and deployment/recovery, auxiliary data feeds, and access to a protected test bed for novel sensor packages. We believe that this collaboration serves as a useful case study for other university/industry collaborations and that the cellular mooring developed for this AHL deployment could be easily and inexpensively replicated to add real-time capabilities to other sites as well.

Acknowledgments

The authors wish to thank Megan Hepner-Medina and Vipulkumar Lakhani for code improvements as well as Matt Steinke, Wiley Wolfe, and Garrett Schmid for fieldwork assistance. This project was supported by NOAA Grant numbers NA14NOSO120151 and NA16NOSO120022 and a donation from the Lost Bird Project.

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Update

Results in Engineering
Volume 8, Issue , December 2020, Page

DOI: https://doi.org/10.1016/j.rineng.2020.100178

Results in Engineering 8 (2020) 100178

Contents lists available at ScienceDirect

Results in Engineering

journal homepage: www.editorialmanager.com/rineng/Default.aspx

Erratum regarding missing Declaration of Competing Interest statements in previously published articles

Declaration of Competing Interest statements were not included in the published version of the following articles that appeared in previous volumes of *Results in Engineering*.

The appropriate Declaration/Competing Interest statements, provided by the Authors, are included below.

"Analysis of solar PV glare in airport environment: Potential solutions" Results in Engineering, 5(2020), 100079. https://doi.org/10.1016/j.rineng.2019.100079.

"The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper."

"Influence of catalyst, exhaust systems and ECU configurations on the motorcycle pollutant emissions" Results in Engineering, 5(2020), 100080. https://doi.org/10.1016/j.rineng.2019.100080.

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"Thermodynamic screening of alternative refrigerants for R290 and R600a" Results in Engineering 5(2020), 100081. https://doi.org/10.1016/j.rineng.2019.100081.

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"Stresses distributions of sand piles on rough rigid plate" Results in Engineering, 5(2020), 100084. https://doi.org/10.1016/j.rineng.2019.100084.

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"Equipping smart coasts with marine water quality IoT sensors" Results in Engineering, 5(2020), 100087. https://doi.org/10.1016/j.rineng.2019.100087.

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"Energy saving based lighting system optimization and smart control solutions for rail transportation: Evidence from China" Results in Engineering, 5(2020), 100096. https://doi.org/10.1016/j.rineng.2020.100096.

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"Pre-stressed thin tubular composite energy absorbers for improved impact energy absorption" Results in Engineering, 5(2020), 100102. https://doi.org/10.1016/j.rineng.2020.100102.

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"Experimental study of quenching agents on Al6061–Al2O3 composite: Effects of quenching treatment to microstructure and hardness characteristics" Results in Engineering, 6(2020), 100105. https://doi.org/10.1016/j.rineng.2020.100105.

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DOIs of original article: https://doi.org/10.1016/j.rineng.2019.100087, https://doi.org/10.1016/j.rineng.2020.100096, https://doi.org/10.1016/j.rineng.2019.100091, https://doi.org/10.1016/j.rineng.2019.100081, https://doi.org/10.1016/j.rineng.2020.100110, https://doi.org/10.1016/j.rineng.2020.100118, https://doi.org/10.1016/j.rineng.2020.100121, https://doi.org/10.1016/j.rineng.2019.100079, https://doi.org/10.1016/j.rineng.2020.100105, https://doi.org/10.1016/j.rineng.2020.100106, https://doi.org/10.1016/j.rineng.2020.100135, https://doi.org/10.1016/j.rineng.2019.100084, https://doi.org/10.1016/j.rineng.2020.100102, https://doi.org/10.1016/j.rineng.2020.100122, https://doi.org/10.1016/j.rineng.2019.100080, https://doi.org/10.1016/j.rineng.2020.100104.

https://doi.org/10.1016/j.rineng.2020.100178

Engineering, 6(2020), 100106. https://doi.org/10.1016/j.rineng.2020.100106.

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"The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper."

"Performance investigation of high-proportion Saudi-fly-ash-based concrete" Results in Engineering, 6(2020), 100118. https://doi.org/10.1016/j.rineng.2020.100118.

"The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper."

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"Effective extrusion-based 3D printing system design for cementitious-based materials: Results in Engineering, 6(2020), 100135. https://doi.org/10.1016/j.rineng.2020.100135.

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"Flexural behavior of preflex sfrc-encased steel joist composite beams" Results in Engineering, 7(2020), 100122. https://doi.org/10.1016/j.rineng.2020.100122.

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