Scripps Ocean Acidification Real-Time (SOAR) Monitoring Program

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Overview

Ocean Acidification (OA) is caused by the burning of fossil fuels, which releases carbon dioxide (CO_2) into the atmosphere. The released CO_2 dissolves into seawater, making the pH of the ocean more acidic as it equilibrates with the water. The resulting acidification can act like osteoporosis for marine organisms that build shells or have external skeletons (e.g., mussels, oysters, clams, corals, and many others) as availability of the carbonate ion that is used to build calcium carbonate decreases. This acidification can cause shells and skeletons to become more brittle and thus more susceptible to physical damage, predation, and/or death. In order to understand the potential impacts of OA on these coastal marine species, we must monitor pH in coastal ecosystems; unfortunately, most of what we know to date comes from data collected in the open ocean far from human populations or from relatively short-term studies.

There is an urgent need to support long-term monitoring for OA in coastal California and beyond and to pair these measurements with the responses of biological communities to determine the extent and magnitude of OA impacts now and into the future. Given the vast amount of variability that exists in coastal ocean pH, long-term continuous data can be used to detect potential trends over time.

Thanks to the generous support of the Bill and Kathy Scripps Family Foundation, the Smith Lab established the SOAR monitoring program in 2012.

SOAR has already collected near-continuous data for over a decade off of the Scripps Pier, and the Smith Lab hopes to maintain this program into the foreseeable future. We deploy state-of-the-art marine sensors and instrumentation to measure pH, dissolved oxygen, and temperature *in-situ*. The data are transferred from underwater to the cloud in real time, also including shore-based power which eliminates our need for disposable batteries. Our data are now stored on an online server, where they can be accessed anytime from anywhere in the world.

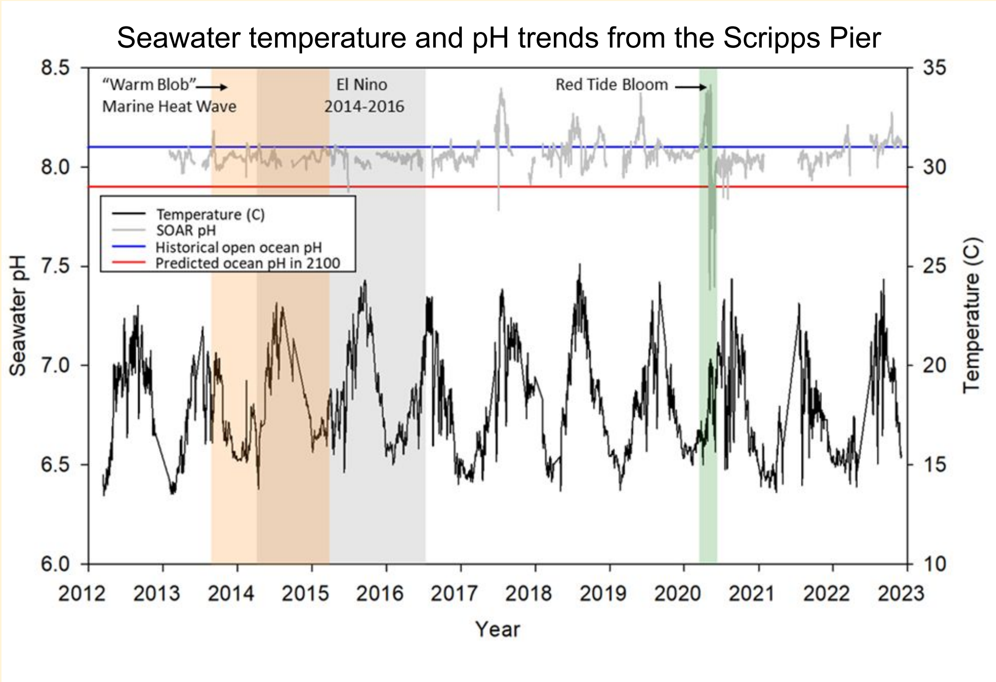

Figure 1: Data collected by the SOAR monitoring program show high variability in both temperature and pH, highlighting a need for long-term monitoring in order to detect potential OA and warming trends over time.

In April of 2020, the SOAR sensors captured high-magnitude changes in pH and DO in the coastal environment during an exceptionally large "red tide event" caused by the dinoflagellate *Lingulodinium polyedra*. Measurements of pH ranged from a high of 8.67 during the peak of the bloom to a low of 7.06 as it began to degrade (Figure 2). The lowest daily mean pH values (< 7.8) and the lowest daily average DO values (< 2.0 mgO_2/l) occurred May 4-7 (Figure 3). While the conservative definition of "hypoxia" is ≤2.0 mgO_2/l, lethal effects have been observed for 90% of coastal marine organisms at values below 4.59 mgO_2/l (2), which were observed daily April 30 - May 8. Oceanographic measurements of events of this magnitude are rarely captured in such detail, and it is only thanks to the long-term and continuous nature of this monitoring program that we were able to capture such a unique and compelling dataset.

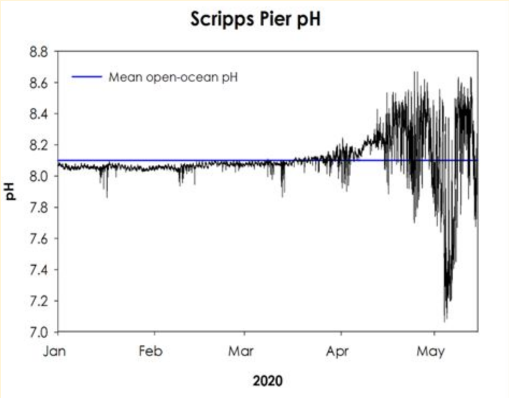

Figure 2: Data from the SOAR SeaFET beneath the Scripps Pier shows anomalous pH variability during the red tide bloom in 2020. Mean open-ocean pH is 8.1.

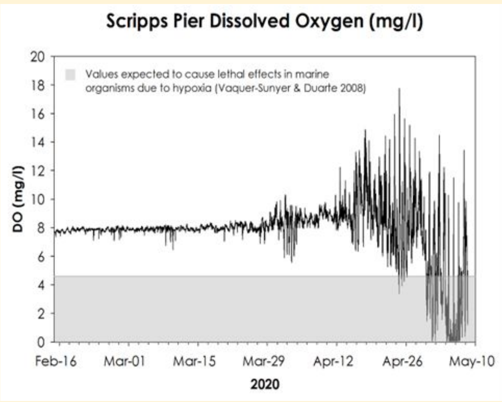

Figure 3: Data from the SOAR miniDOT Oxygen Logger shows values in range expected to cause lethal effects in marine organisms due to hypoxia in late April and early May 2020.

Figure 4: *L. polyedra* bioluminescence can be observed at night in crashing waves during a red tide, pictured here near Scripps Pier.

SOAR Achievements

The SOAR Monitoring Program provides an invaluable and one-of-a-kind coastal OA dataset in both CA and the remote central Pacific. While other researchers have collected similar datasets for short time periods, ours are the first long-term and continuous time series for OA in these regions. This has inspired other groups to start their own respective OA monitoring programs in nearby regions. Because of the rigor of these datasets, they have been in high demand and featured in over 15 published or submitted scientific publications since the program's inception in 2012. These are direct products of the SOAR SIO and Palmyra-specific datasets, and we plan to continue publishing with these invaluable data into the future. We firmly believe that these data will only become more powerful and sought after the longer we are able to maintain them. With any luck these datasets will represent the Keeling Curve(s) of the CA coast and Central Pacific in the future!

The extent of this dataset so far has given us the unique ability to capture record-breaking temperatures (summer 2018) and data spanning the duration of global and local ocean anomalies, such as El Niño Southern Oscillation, the 2014 "warm blob," and the 2020 red tide event. Ultimately, observing and measuring how these anomalous events impact coastal ecosystems can help to inform management and conservation of our marine environment.

Scientific Products

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To learn more about the Smith Lab, please visit our website at https://coralreefecology.ucsd.edu/ or email Dr. Jennifer Smith at smithj@ucsd.edu

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