Developing a Statewide New Jersey Ocean Acidification Monitoring Network – Workshop Summary

Hosted by New Jersey Department of Environmental Protection's Coastal Management Program and Rutgers University
November 19, 2021
Virtual via Zoom Meetings

Workshop Summary prepared by:
Brooke Schwartzman and Grace Saba (Rutgers University)

This report was made possible with financial assistance from the Coastal Zone Management Act of 1972, as amended, as administered by the Office of Coastal Management, National Oceanic and Atmospheric Administration (NOAA) Program through the New Jersey Department of Environmental Protection, Coastal Management Program. These environmental data and related items of information have not been formally disseminated by NOAA and do not represent and should not be construed to represent any agency determination, view or policy. This project was undertaken through a grant with the New Jersey Department of Environmental Protection (NJDEP), Coastal Management Program. The views expressed in this report are the authors' own and do not reflect the official policies or positions of the New Jersey Department of Environmental Protection (NJDEP) Coastal Management Program, or Rutgers University.

Contents

Workshop Overview

Background Information

On June 30, 2020, the New Jersey Department of Environmental Protection (NJDEP) published the 2020 New Jersey Scientific Report on Climate Change. This document states that "New Jersey is at increased risk to the effects of ocean acidification due to its economic dependence on shellfish harvests, with southern New Jersey counties ranking second in the United States in economic dependence on shelled mollusks. […] [While it is predicted that] New Jersey will not see unfavorable acidification conditions for shellfish until 2100, given the State's dependence on shellfish resources, there will be high social and economic impacts." As a result of this concern, NJDEP's Coastal Management Program (NJCMP) engaged a team of experts at Rutgers, The State University of New Jersey ("Rutgers University"). The Rutgers University Team was charged with offering insights regarding potential approaches that the Coastal Management Program (CMP) could undertake to initiate a focused OA effort in New Jersey.

In 2020, the Rutgers University Team supplied the CMP with: 1) an assessment of the current scientific understanding of OA impacts in New Jersey; 2) an assessment of gaps in OA scientific knowledge in New Jersey and opportunities to address those gaps; 3) an analysis of other coastal states' focused OA efforts to inform the content and approach of a possible OA initiative in New Jersey; 4) an outline of key elements that might be appropriate for a New Jersey OA Action Plan; 5) an educational infographic for outreach and education with New Jersey residents; and 6) a database of stakeholders the CMP could utilize for outreach and education efforts. These findings were detailed in the Rutgers University Team's report titled, "Opportunities to Address Ocean Acidification Impacts in New Jersey: An Outline of Options for the New Jersey Coastal Management Program".

The current acidification monitoring efforts in New Jersey are a mosaic of individual projects without cohesiveness. Recent investigations have identified locations of OA monitoring in the state and the larger Mid-Atlantic region. There exists an opportunity to strategically link these efforts and develop a comprehensive statewide OA monitoring network. This network would facilitate efforts through a coordinated membership that can cohesively identify observation gaps, coordinate observation efforts to maximize temporal and spatial coverage, and expand observing capabilities within the network. Furthermore, engaging stakeholders is essential to advancing a coordinated OA initiative. This engagement can come in many forms, such as allowing for public commentary on proposed policy, and conducting educational outreach regarding the potential economic impacts of OA. New Jersey does not currently have such a forum with which to begin a science-informed dialogue among stakeholders. Based on the experiences in other states, results from scientific monitoring have been critical to initial engagement of fishery and shellfish industry actors.

Meeting Objectives and Outcomes

On November 19th, 2021 Rutgers University and the NJCMP OA team jointly composed and facilitated a virtual workshop via Zoom Meetings. Workshop attendees were invited to participate based on previous efforts that identified entities collecting OA data and entities whose partnership will be essential in building a strong monitoring network. Those invited included industry (e.g., commercial shellfisheries, commercial and recreational fin fisheries, hatcheries, aquaculture facilities, nurseries), offshore wind developers, state executive branch agencies, federal researchers, academic institutions, and non-profit organizations.

The objectives of the workshop were as follows:

- Review the existing acidification monitoring in New Jersey state waters and the current observation gaps
- Collectively summarize locations, time periods, and potential approaches to optimize and expand monitoring in New Jersey
- Discuss required costs, logistics, and next steps needed to develop, coordinate, and maintain a statewide acidification monitoring network
- Discuss strategies for communication, engagement, and partnerships with industry stakeholders

The outcomes to be produced from this workshop were as follows:

- Workshop summary report that includes a summary of the workshop discussions pertaining to the four workshop aims described above (this document).
- Recommendations for Developing and Maintaining a New Jersey Statewide Monitoring Network document which would integrate recommendations and guidance derived during the workshop for NJCMP consideration.

Theme 1: Why an OA Monitoring Network?

Presentation 1: Why an OA Monitoring Network?

Megan Rutkowski (NJDEP)

Megan is an Environmental Scientist with the New Jersey Department of Environmental Protection (NJDEP) and has worked under several coastal offices and bureaus since 2004, most recent of which is the Bureau of Climate Resilience Planning. Her area of focus is the science behind resilience planning, particularly in regard to ocean issues. She leads the OA team at DEP's Coastal Management Team and also serves as a Steering Committee member for the Mid-Atlantic Coastal Acidification Network (MACAN) and also leads the MACAN Policy Working Group. She received her Bachelor in Environmental Science at Stockton University and her Master's in Earth Sciences at the University of Pennsylvania.

Presentation Summary

New Jersey's climate change and ocean acidification efforts were advanced by Executive Order 89 which was signed into law by Governor Murphy in 2019. It created the Chief Resilience Officer position, the Bureau of Climate Resilience Planning, and the Interagency Council on Climate Resilience. EO 89 also directed NJDEP to write the first Scientific Report on Climate Change, and the Statewide Climate Change Resiliency Strategy with a Coastal Resilience Plan.

From the Scientific Report on Climate Change, which contains a chapter dedicated solely to OA, it was discovered that New Jersey is at high risk of economic harm caused by OA impacts. Southern NJ counties rank 2nd in the nation in terms of their economic dependence on shellfish, which are known to suffer from increased ocean acidity. Coastal ecosystems will also be harmed by local amplifiers including eutrophication (excessive levels of nutrients and algal growth in water), freshwater runoff, and upwelling (rising of deep-level sea water to the ocean's surface). The chapter concluded with an analysis of gaps in the data surrounding OA. One issue is that the ecological impacts of ocean acidification on Mid-Atlantic marine life and ecosystems are not fully understood yet. The other primary concern is that the ocean acidification sampling technology and methodology needs to be more consistent in order to improve data accuracy.

The Bureau of Climate Resilience and Bureau of Marine Water Monitoring combined efforts to create the OA Team. The team then engaged Rutgers University's NJ Climate Change Resource Center to fill knowledge gaps in science, learn about OA Action Planning from other coastal states, and outline elements to be used in New Jersey's eventual OA Action Plan. Since its inception, the OA Team has expanded to include partners across the NJ Coastal Management Program. In 2021, New Jersey joined The OA Alliance, an international organization dedicated to bringing governments together in a concerted effort to combat ocean acidification.

The OA Team and Rutgers University are partnering again to build out an ocean acidification monitoring network for New Jersey. It was determined in the Scientific Report on Climate Change that NJ would benefit from a comprehensive monitoring network to address observation needs. The OA Monitoring Network Workshop is a first step in achieving this goal. The OA Team and Rutgers are also working to fill regional and biological research gaps, and expand stakeholder engagement. This work will all culminate into an OA Action Plan for the state. OA action plans should include strategies for reducing carbon and land-based pollution, strengthening monitoring near shore, partnering with industry, and sharing information.

The presentation concluded with Megan sharing her email address (Megan.Rutkowski@dep.nj.gov) for any who may have additional questions.

Presentation 2: Current Monitoring Efforts and Gaps in NJ Waters and How Best to Gap Fill

Dr. Grace Saba (Rutgers University)

Grace Saba is an Assistant Professor in the Department of Marine and Coastal Sciences at Rutgers University. Her broad research interests are in the fields of coastal marine organismal ecology and physiology, with emphasis on how organisms interact with their environment and other organisms, how physiological processes impact biogeochemistry), and how climate change impacts these processes. She conducts experimental laboratory and field studies, and utilizes ocean technology to monitor physical, biological, and chemical properties in habitats of commercially and recreationally important species. She co-founded the Mid-Atlantic Coastal Acidification Network (MACAN), and currently serves on the MACAN Steering Committee and Science Working Group.

Presentation Summary

Dr. Grace Saba began with an overview of ocean and coastal acidification and the potential impact on marine organisms. Atmospheric carbon dioxide (CO_2) has increased over 40% since the 1800's.[1] There has been a corresponding drop of 0.1 pH units, causing a 28% increase in ocean acidity – a rate of change 10x faster than anything experienced over the past 50 million years.[2] Ocean acidification is now a global-scale issue. Projections from the Intergovernmental Panel on Climate Change (IPCC) estimate that CO_2 emissions will double by 2100 and with that a corresponding drop of 0.2 to 0.3 pH units; this is equivalent to a 100% to 150% surge in ocean acidity.[2]

In studying the effects of OA on organisms, it was found that acidification has strong, negative impacts on survival and calcification, and milder, but still negative, impacts on growth, development, and reproduction[3]. More recently, data were collected from a series of ocean acidification studies on 18 species economically important to the Mid-Atlantic.[4] After looking at several response variables, it was determined that 65% of these species had a negative response to OA, 5% had a positive response to OA, and 30% had no measured response to OA[4]. Another study found that because of a

[1] Dlugokencky & Tans (2020) Trends in atmospheric carbon dioxide. NOAA Earth System Research Laboratory.

[2] Intergovernmental Panel on Climate Change [IPCC] (2019) Summary for Policymakers. *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*.

[3] Kroeker et al. (2013) Impacts of ocean acidification on marine organisms: quantifying sensitivities and interaction with warming. *Glob Chang Biol* 19(6): 1884-1896.

[4] Saba et al. (2019) Recommended priorities for research on ecological impacts of ocean and coastal acidification in the U.S. Mid-Atlantic. *Estuar Coast Shelf Sci* 225.

combination of New Jersey's economic dependence on vulnerable commercial species and the presence of OA drivers in the area, southern New Jersey was determined to be one of the most socially vulnerable regions to OA effects[5].

There are four carbonate chemistry-related variables that can be measured:

- pH: This variable measures how acidic or basic water is based on the amount of H^+ present. It can be measured in the field using an electrode or solid state ion-sensitive field effect transistor (ISFET)-based sensor or in a laboratory on discrete water samples using spectrophotometry
- Dissolved CO_2 (pCO_2): This variable measures the concentration of CO_2 dissolved in the water. It can be measured with a range of sensor types.
- Total alkalinity (TA): This variable is a measure of seawater buffering capacity. Specifically, this variable measures charged ions in the water. It is typically assessed in a lab through titration but vessel-based sensors with a flow-through seawater application are now available.
- Dissolved Inorganic Carbon (DIC): This variable measures the sum of the dissolved carbon species. It is typically assessed in a lab through a coulometer but in-field spectrophotometric-based sensors are becoming available

At least two of these variables must be measured in order to calculate the other parameters of the carbonate system, including carbonate saturation state, Ω. The two most common variables measured in the field are pH and pCO_2. Additional measurements like temperature, salinity, and pressure are required too.

There are three platforms available for collecting data *in situ*:

- Vessels: This is the most traditional method and vessels provide the ability to collect detailed water column profile data. Vessels are expensive to operate, however, leading to limitations in the ability to collect data over large time and/or spatial scales.
- Buoys/Moorings: This method provides high resolution data over time but is limited to collecting data in a singular location and typically measures surface-only parameters. Depth-profiling platforms are commonly being operated in deeper, offshore waters but are not typical in shallow, coastal systems.
- Autonomous Underwater Vehicles (AUVs): This platform includes underwater gliders. It is the newest of the three platforms and is able to collect high resolution data over time and space. It is also a more cost-effective platform compared to vessels. However, these platforms, and the sensors developed for these platforms, are currently limited to measuring pH only.

Several entities are performing ocean water monitoring off of the coast of New Jersey. The water quality sampling being performed by NJDEP and NYSDEC include a combination of vessel-based and moored platforms. NOAA is performing vessel-based

[5]Ekstrom et al. (2015) Vulnerability and adaptation of US shellfisheries to ocean acidification. *Nature Climate Change* 5(3): 207-214.

monitoring including East Coast Ocean Acidification (ECOA) surveys every 3-4 years (Ocean Acidification Program) and seasonal Ecosystem Monitoring surveys (Northeast Fisheries Science Center). Academic groups, including Rutgers University and Stony Brook University, utilize gliders among other methods. Additional organizations like JC NEER and BBP are using moored platforms for measurements of pH and/or pCO_2. Data tracked from the early 80's until now shows that Mid-Atlantic waters have increased in acidity over time with increases in pCO_2.[6] The impacts on Ω are less clear. New Jersey sits at a point where lower saturation state northern waters mix with higher saturation state southern waters[7], thereby causing large variability in the saturation states of NJ coastal waters. Seasonal changes have been found to impact the level, or intensity, of acidification.[8] During summer months, bottom "Cold Pool' waters on the NJ shelf are isolated from surface waters, resulting in lower pH and Ω. However, surface to bottom mixing caused from increased winds and storms in the fall alleviate the low pH/ Ω in bottom waters.[8]

While the data collected so far has been extremely valuable in understanding event-based and seasonal dynamics, there are data gaps that need to be filled in order not only to establish a baseline climatology for carbonate chemistry to determine long-term changes, but also to better pinpoint times and/or locations where acidification is already an issue in important organism habitats. Specifically, the state requires higher sampling frequency, measurements of multiple carbonate chemistry parameters, higher resolution bottom water measurements, monitoring across the salinity gradient, and co-located biological response monitoring[9]. In response to these needs, New Jersey would benefit from establishing a statewide OA monitoring network. Four initial strategies for filling the data gaps were offered by the Rutgers team. These include efforts to:

- Synthesize data and develop data products from the repository of previous and ongoing OA monitoring efforts.
- Coordinate with partner agencies to add carbonate chemistry parameters to existing monitoring stations.
- Optimize existing glider-based observation programs.
- Partner with industry groups to begin monitoring at economic sites of interest.

The presentation concluded with Grace sharing her email address (saba@marine.rutgers.edu) for any who may have additional questions.

Group Discussion on Optimizing Network

[6] Xu et al. (2020) Long-Term Changes of Carbonate Chemistry Variables Along the North American East Coast. *J Geophys Res: Oceans* 125(7).

[7] Wanninkhof et al. (2015) Ocean acidification along the Gulf Coast and East Coast of the USA. *Continental Shelf Res* 98: 54-71.

[8] Wright-Fairbanks et al. (2020) Autonomous observation of seasonal carbonate chemistry dynamics in the Mid-Atlantic Bight. *J Geophys Res: Oceans* 125(11): e2020JC0165052020.

[9] Goldsmith et al. (2019) Scientific Considerations for Acidification Monitoring in the U.S. Mid-Atlantic Region. *Estuar Coast Shelf Sci* 225: 106189.

Group discussions on this topic organically fell into three major themes: 1) Gaps in Monitoring, 2) Partnerships for Monitoring, and 3) Lab Capacity for Sample Analysis. These are discussed in detail below.

Gaps in Monitoring

Most information we have pertaining to the response of marine organisms to OA is from controlled laboratory experiments; as a result, there has been much recent discussion on if these responses hold true under natural conditions *in situ*. Therefore, the co-location of biological monitoring alongside oceanic water quality monitoring is critical in better understanding the impacts that OA has on economically vital species. One source of biological data are the ECOA cruises which travel between the Gulf Coast and Maine every 3-4 years. These cruises cover several transects, two of which are in NJ coastal waters. The cruises collect measurements of all four carbonate chemistry parameters (pH, TA, pCO_2, DIC) and biological parameters, including net primary production (the rate at which phytoplankton produce biomass) and community respiration (total amount of CO_2 produced by an individual organism). There were suggestions of adding additional biological samples to these cruises (i.e., zooplankton sampling, fish acoustics), if funding and logistics allow. A new project in coordination with the EcoMon cruises is adding a pteropod bioindicator component to their surveys. There was group consensus that additional efforts need to be carried out to create a comprehensive picture of the impacts of OA on economically vital species.

Several attendees representing a range of water quality monitoring organizations indicated interest in getting involved with sampling. In order to do this, however, there was consensus that the community adopt similar protocols and data quality assurance and quality control procedures. NJDEP's data collection standards, methodology for collecting samples, along with guidance on the appropriate equipment for collecting such data, would be necessary. A cohesive list of the exact parameters that DEP needs measured and the level of importance for each would be helpful as well.

Certain natural processes are not fully understood in terms of how they influence OA. Monitoring can be structured in such a way that it fills these gaps. There is a preliminary understanding that OA impacts coastal marshes and is simultaneously influenced by inputs from terrestrial and freshwater bodies, but current monitoring does not focus on these interactions yet. Benthic flux monitoring has not been considered in the OA plan so far but may prove to be insightful as interactions with sediments are likely an important factor for benthic dwelling organisms. Naturally acidic Pineland waters impact background concentrations which then directly affect oceanic pH, yet there is little monitoring on the relationship between Pineland waters and OA. On a statewide level, more information is needed on background concentrations in general. In order to determine boundaries between background concentration measurement areas, the salinity information from DO gliders could be used to locate boundaries of freshwater influence along the coast. This effort can be bolstered with the eutrophication models being developed by Long Island Sound and Rutgers' tide prediction modeling. Gliders are also able to capture these relationships because they measure chlorophyll. An additional process to be monitored further is how freshwater determines saltwater's buffering capacity in the areas where they converge. There are difficulties in choosing indicators for these regions because of extreme fluctuations in the water's chemistry, but one option would be using exoskeletons and shells from invertebrates living in the area.

In making decisions about how and where to monitor, there first needs to be an understanding about if and where spatial and temporal variability exist. From there, the state can better plan where high-density sampling is needed. Due to the labor and time costs inherent to collecting samples, a case can be made for favoring the usage of sensors instead. So far, there is known variability in spatial and temporal data along the north to south shelf of NJ, although there is room to study these variations in further detail. Before any of this planning is done, it would be beneficial to answer larger questions around who the monitoring is done for and what the data will ultimately be used for. Data collection cannot be based purely off of academic interests, but needs to incorporate actionable concerns as well. An additional data gap exists around the level of resolution to measure parameters at; however, it is difficult to know the resolution needed for any given parameter until after it has been measured.

Key Takeaways:

- Increase the co-location of biological monitoring and carbonate system monitoring
- Create standard protocols, methods, data QA/QC materials for the on-ramping of new monitoring partners
- Be intentional in locating sensors where they can unearth additional information on OA processes not fully understood including freshwater inputs and background concentrations.
- Strategically fill data gaps so that they solve actionable problems rather than gather data for the sake of gathering data.

Partnerships for Monitoring

There have been brief discussions with offshore wind developers about adding sensors to their platforms, although no concrete partnerships are in place yet. These conversations are ongoing and occurring at a statewide and regional level. The ideas pulled from this workshop will be used to guide decisions about where to collect additional data. There is also a survey being developed to determine preferences for data sampling methods from offshore wind partners.

The AmeriCorps Watershed Ambassadors program is made up of individuals who spend 10 months working under NJDEP to improve watershed quality. Each ambassador is assigned to a specific area within NJ and is responsible for collecting samples and monitoring water quality in said location. Not all ambassadors oversee water bodies that are relevant to the study of OA, but for those who are closer to estuaries and coastal regions, they could collect additional data. For safety reasons, the ambassadors are likely unable to use boats, but could still monitor oceanic changes from piers or docks. More recently, ambassadors have been assigned to estuaries and bays which are very much relevant to the study of OA.

Partnerships with commercial and recreational fisherman would produce samples from both nearshore and offshore waters and these measurements would be co-located with biology (e.g., presence/absence, abundance, biomass). Other commercial actors, like hatcheries, could engage in OA monitoring as well. These sites may not always be located in the exact area of interest, but because of how seriously the aquaculture industry could potentially be impacted by OA, there may exist a fruitful funding opportunity by partnering with such groups. If partnerships with commercial industry are pursued, further thought will need to be given on who exactly would perform sample analysis and how to ensure quality in data collection.

Key Takeaways:

- Pursue partnerships with offshore wind developers, AmeriCorps Watershed Ambassadors, and commercial and recreational fisherman while being intentional in addressing the unique challenges associated with each.

Lab Capacity for Monitoring Samples

Collecting samples is the first hurdle to overcome for gap filling observations, but the second hurdle is having access to a certified laboratory to analyze discrete water samples using community-accepted quality control standards. NJDEP operates a laboratory to process samples collected by NJDEP, but there is currently no statewide lab that can be contracted to analyze water samples collected by other entities. There are also a few academic institutions and academic working groups with the ability to analyze samples. As of now, however, there is not a clear understanding of the total lab capacity available, nor is there a formalized network of labs that a monitoring group can easily access and use to find laboratory partnerships. Due to the dearth of available labs, monitoring opportunities are limited. Another effect of this is that research efforts are siloed to studying very specific attributes as labs do not have the capacity to take on samples from more exploratory research. Before planning a network of labs, there needs to be an established future usage for the data. Data collected for regulatory purposes must be approved by EPA, DEP, or USGS. Regulatory usage data must also be analyzed in a certified lab. Some labs may be certified for only a few of the total parameters that are to be tested.

Key Takeaways:

- Compile a list of certified labs with the ability to analyze carbonate chemistry samples for those collecting samples to form partnerships with.
- Create and distribute best practices to ensure data quality and standardization.

Theme 2: Coordinating an OA Network

Presentation 3: Planning and Improving the West Coast OAH Monitoring Network: Roads Traveled and Lessons Learned

Presenter Dr. Caren Braby (Oregon Department of Fish and Wildlife)

Dr. Caren Braby is the Manager of the Marine Resources Program Manager for the Oregon Department of Fish and Wildlife, providing strategic leadership on all things 'ocean' within the state of Oregon and across the West Coast. Caren and her staff build partnerships with industry, academic researchers, tribal governments, federal & state agencies, stakeholders, and elected officials to collaboratively define, and achieve, both economic and ecosystem resilience. Her work is grounded in both fishery and ecosystem stewardship, with particular focus on changing ocean conditions (including ocean acidification and hypoxia). As Co-Chair of Oregon's legislatively-created Ocean Acidification and Hypoxia Coordinating Council and a Council member on the Pacific Fisheries Management Council, Caren is helping West Coast communities and fisheries develop successful strategies to adapt to and mitigate ocean change. She received her Doctorate from Stanford University's Hopkins Marine Station and has conducted scientific research from estuaries out to deep sea hydrothermal vents of the Pacific Ocean. Caren's career began by exploring West Coast tidepools, from the time she could first walk.

Presentation Summary

The first step in strengthening research of OA is to decide for whom the data is being collected and how said data should be collected. Connecting with an audience is critical because there needs to be an understanding of what matters to them in order to encourage engagement. For example, if data are collected for the public, they need to be shown ecosystem changes in the locales and within the species they care about. This can be measured via trends. If data are collected for political appointees, they need to be made aware of the issue and demonstrate the urgency for policy-based action. This can also be provided through trends. If data are collected for scientists, they need measurements that can be analyzed in such a way that they are generalizable to a region. This requires specific and rigorous monitoring of parameters. If data are collected for managers, they need information that can guide their policy, budgeting, staffing, and research decisions. How to measure this depends on what exactly managers need to know most.

In 2016, the West Coast Ocean Acidification and Hypoxia Science Panel (WCOAH-SP) looked into the key attributes needed for developing an OAH monitoring network. Several were identified, the most important being that the monitoring network supports the needs of decision-makers. Representatives from the United States federal government, British Columbia and Alaska then formed an Inventory Task Force. Based on the previous work done by WCOAH-SP, the Task Force understood that creating a network is expensive, so the building of one must be strategic. The inventory is a catalog of monitoring projects (data for the inventory are the projects themselves, and information about what data the project is collecting). The first step is to understand what monitoring already exists and from there perform a formal gaps analysis in the monitoring network. Gaps can then be filled with additional monitoring sites (or by adding sensors/metrics to an existing site), but in a strategic way realizing that not every gap is automatically a hindrance to the overall information being delivered by the monitoring network. With this process in mind, the Inventory Task Force met for two years. The team included policy and science leadership plus significant staff support from Knauss & Sea Grant Fellows. Before creating the inventory, the Task Force designed the inventory template, so that data providers were asked for the same level of detailed information, generally characterized by the following questions:

- Who is monitoring? Do they have the capacity to continue to monitor?
- Where and when are measurements taken? Is there spatio-temporal coverage?
- What metrics are being used? Are there measurements of physical, biological, and chemical indicators?
- What are the long-term data sets in existence? Which of these are at risk of losing capacity?
- What sites are providing little value now but could easily be augmented to provide lots of value?

By answering these questions, the Task Force envisioned creating a catalog of monitoring projects that could be used to make future monitoring investments – strategically, to maximize spatio-temporal and discipline (metric) coverage. The inventory (access here) took about 3 years to complete. It includes 247 projects and 4,103 assets, which in combination describe the OA and hypoxia monitoring network (sampling sites) on the West Coast. Several lessons were learned from this venture:

- In some cases, the inventory was more detailed than necessary. It became difficult to paint a picture of what the network looked like because of the number of unique metrics included.
- Inventory updating and maintenance was not built into the inventory design, and as of now is difficult due to limited funding and workforce; there would be great benefit in establishing a simpler data submission process and portal design.
- Regional gaps were harder to identify than expected, even after the inventory had been completed because it is not yet clear how to optimize information at the

regional scale. There were also geographical gaps in data collection identified that lack on-the-ground capacity to support the monitoring effort.

So far, the inventory has proven to be useful. Oregon actively uses it to communicate needs in its grant proposals, build foundations for collaborations, and approve direct investments in specific bodies of water. As other states look to create similar OA monitoring networks, there are several lessons to keep in mind: 1) the network should be inclusive in terms of its geographic scope and partners, 2) the network must be sustainable in terms of developing personal connections between local communities and the data, focusing on the metrics that will inspire continued support, and being easily updated, 3) the network's desired outcomes should be established ahead of time.

The presentation concluded with Caren sharing her email address (Caren.E.Braby@ODFW.Oregon.gov) for any who may have additional questions.

Presentation 4: A Gaps Analysis to Enhance California's OA Monitoring Network

Presenter Dr. Stephen Weisberg (Southern California Coastal Water Research Project Authority)

Stephen Weisberg is Executive Director of the Southern California Coastal Water Research Project Authority, a research institute formed by 14 California water quality agencies to create a solid scientific foundation for their management activities. Dr. Weisberg received his undergraduate degree from the University of Michigan and his doctorate from the University of Delaware. Dr. Weisberg's research emphasis is in developing molecular tools to support coastal aquatic monitoring programs. Beyond his research, Dr. Weisberg focuses on helping connect scientists with the water quality management community. He serves on numerous advisory committees, the most relevant here is that he Chairs California's Ocean Acidification and Hypoxia Task Force.

Presentation Summary

For the state of California, managing ocean acidification is a top priority. In response to the increasing severity of OA on the West Coast, California established their OAH Task Force. The group produced an action plan, a monitoring inventory, and then a gaps analysis on said inventory (access here). The OAH Task force was comprised of leaders from inside and outside of California in order to tackle the problem from a multi-state level. When it came time to perform the gaps analysis, the task force looked at several forms in which insufficient data could appear:

- Spatial: Is monitoring occurring in the right places, especially in relation to upcoast versus downcoast monitoring, cross-shelf monitoring and monitoring vertically within the water column?

- Temporal: Is monitoring taking place at the right times?
- Parameters: Are the right indicators being monitored?
- Data quality: Are parameters being monitored well, particularly in terms of consistency and high-accuracy equipment[10]?
- Data availability: Is the collected monitoring data easily accessible?

Filling gaps should be prioritized based on how relevant each gap is to management needs. Investments in the additional monitoring necessary to fill gaps should provide a return on investment in the form of providing the state actionable information. A gaps analysis follows a three-step process: 1) identify the OA Action plan decisions that are dependent on monitoring data, 2) assess how well existing data collection systems provide actionable data for those decisions, and 3) determine the future investments that will most improve the state's ability to manage. Because founding new monitoring initiatives are prohibitively expensive, first try leveraging existing data collection programs. Following the gaps analysis in California's monitoring efforts, the task force offered three core recommendations:

- Better connect chemical and biological monitoring: Of the three recommendations, this was deemed most important. The state makes management decisions primarily around protecting biota, yet most OA monitoring is focused on chemistry. There needs to be a connection forged between changes in chemistry and the impacts OA has on marine life, which can be accomplished with synchronized biological and chemical testing. Laboratory-based studies are helpful in determining initial water quality thresholds, but field studies are needed to confirm those results and must cover a wide array of OA exposure conditions. Two approaches were recommended for improving the biological information needed for management. One is to standardize, advance, and incorporate biological measurements of OA effects into pre-existing regional chemistry monitoring programs. The other is to add OA related chemistry parameters to pre-existing biological monitoring programs. The task force ultimately decided to focus more heavily on the first approach. This method offered better quality control and was more effective at registering early warning signs of OA impacts than the second approach.
- Assess and improve OA models: Most key management decisions are made based on models. Models are used to define the areas most and least vulnerable to OA change, assess the likely effectiveness of reducing local nutrient and carbon inputs, and then decide where the best locations for mitigation are. Confidence in these models is therefore critical. In order to assess model performance, higher quality data and more thorough data must be input first.
- Ensure continuity of long-term OA monitoring programs: Many monitoring programs that provide essential information have uncertain financial support.

[10][10]McLaughlin et al. (2017) An evaluation of potentiometric pH sensors in coastal monitoring applications. *Limnol Oceanogr: Methods* 15: 679-689.

Sometimes these programs need additional funding support, but often just the endorsement of government is enough to prioritize their longevity.

The task force also imparted recommendations on OA research efforts. Most importantly, research should create a roadmap for the socioeconomic effects of OA over time. It should also quantify key species sensitivity and adaptations to OA changes. Finally, research must assess how OA effects extend from individual species to entire ecosystems.

Group Discussion on Network Coordination

Data Collection

Before the more technical process of planning an OA monitoring network begins, there first needs to be a consensus on which questions the network is designed to answer. In order to narrow down the list of possible questions, there are two pieces of information needed at the outset. One is a description spatially, of what locations are presently at risk of low pH impacts, and the other is temporal trends, if OA is worsening over time. Once this information is established, managers must consider what authority they have to act on the data, what species most need to be protected, and which communities are at most risk. Because behavioral change is an outcome past OA networks have sought to achieve, one question for New Jersey to contemplate may be how to inspire local behavioral change.

The exact process for collecting data depends heavily on the questions the network is designed to answer. For instance, the depth of the water column that measurements are taken can tell very different stories. Surface waters with sufficient light to support photosynthesis can be characterized by higher pH and Ω, whereas bottom waters in coastal systems can seasonally be cut off from the surface, accumulate CO2 via biological respiration, and lower pH and Ω. The exact place to measure, then, should be decided based on what is most interesting from a management perspective and what could best address the public concern. The type of equipment used to monitor also centers around the questions the network is trying to answer. High quality sensors are most accurate for climate-grade applications, but that accuracy comes with a larger price tag. A possible solution is to establish a few anchor sites with high quality sensors and then several peripheral sites with lower cost sensors to complement the anchor site data. In regard to water samples, having a singular established lab that all samples run through aids in data quality and consistency.

As covered in prior presentations, monitoring chemical indicators is not enough. There must be co-location of biological parameters as well. California decided to select their biological parameters to create three classes of data collection: exposure measurements (evidence that the animal has been exposed to acidification), physiological measurements (evidence that the animal's functioning is negatively impacted), and presence/absence measurements (acidification conditions at which the species is no longer present). The variables that California is considering to measure these parameters are damaged bodily structures, oxidative stress, and eDNA respectively.

Key Takeaways:

- Narrow down the list of questions that New Jersey's OA network will be designed to answer by establishing a base understanding of where New Jersey is most vulnerable and what authority NJDEP has to act on this.
- Use the truncated list of questions to make data collection decisions on measurement depth, sensor accuracy, and biological parameters.

Data Management

The monitoring inventory needs a pre-established portal to reside. Oregon structured their inventory as a spreadsheet of projects and assets. It is GIS enabled so the locations of data providers can be mapped online easily. The inventory must be granted a dedicated project manager to update and maintain, otherwise it will quickly fall out of date. One option for New Jersey is to house their inventory in the MARCO (Mid-Atlantic Regional Council on the Ocean) Mid-Atlantic Ocean Data Portal[11] or the MARACOOS (Mid-Atlantic Regional Association Coastal Ocean Observing System) OceansMap[12] which already have respective teams dedicated to its maintenance.

After the process of creating a monitoring inventory has been completed, work on assembling and integrating the monitoring data itself can begin. These data need a pre-established database to live within once it has been collected. If NJDEP does not host its own database, one possibility is to integrate the state OA data into those at a regional-scale (e.g., MARACOOS). There are already academic partners moving glider and buoy data into this destination. MARACOOS also partners with MARCO, making potential collaboration on the inventory easier. However, data input should be standardized to ensure ease of accessibility, updating and maintenance, and translation. Furthermore, a data product that requires the manual translation of information is unsustainable. Funding for both the monitoring data and monitoring network should be collaborative at the regional and state levels.

Key Takeaways:

- Establish a portal for the monitoring inventory to live within and a dedicated project manager to oversee its maintenance

[11] https://portal.midatlanticocean.org

[12] https://oceansmap.maracoos.org

- Establish a database for the monitoring data to live within that allows for the easy accessibility by a diverse range of users as well as movement of information between systems

Theme 3: Strategies for Stakeholder Engagement and Network Participation

Presentation 5: Working with Industry to Fortify Aquaculture in a Future Ocean

Presenter Nichole Price (Bigelow Laboratory for Ocean Sciences)

Nichole Price is a Senior Research Scientist and the Seafood Solutions CVR Director at Bigelow Laboratory for Ocean Sciences. She also holds an additional joint title of Professor of Environmental Studies at Colby College. She is a benthic marine ecologist with interest in how global change phenomena, like ocean acidification and warming, can alter bottom-dwelling species interactions, community dynamics, and ecosystem function in shallow coastal regimes. Her work focuses primarily on the eco-physiology of seaweeds and calcifying invertebrates and their current and future role in dissolved inorganic carbon and nutrient cycling. Nichole utilizes state-of-the-art analytical tools in field campaigns, develops custom experimental aquaria in the lab, and utilizes modeling to extrapolate results to regional and global scales. Nichole also applies her expertise to explore mitigation strategies for coastal acidification and climate.

Presentation Summary

Maine constructed a statewide coastal acidification commission to develop a comprehensive report on the condition of ocean acidification in the state. Six goals and several recommendations were ultimately proposed to address OA impacts. Bigelow Laboratory used these recommendations to guide their research and their partnerships with industry actors. Through the work done alongside industry interests, a pattern in their concerns appeared. The main question from them was whether changes in water chemistry would affect their business in the next five years, and if so, at what dollar amount of OA mitigation would the benefits outweigh the costs.

One form of OA remediation is to co-locate the growing of shellfish species with primary producers. The hypothesis is that through primary production, enough CO_2 is absorbed by photosynthesis that the pH of the surrounding water is raised, and consequently, organisms are relieved of the stress from acidification. An additional benefit of this phytoremediation is the release of oxygen into the water, which combats potential hypoxia conditions. For Bigelow Laboratory's study, two sets of instrument packages were placed in Casco Bay. One was located in a sugar kelp farming area, and the other was located upstream in a hydrodynamically similar region. Parameters, including pH, pCO_2, salinity, water temperature, depth, TA, DIC, and kelp biomass were measured using a combination of SAMI pCO_2 sensors, SeapHOx sensors, and discrete water samples. After three years of research funded by the NOAA Saltonstall Kennedy program, it was found that the pH levels inside of the kelp farm were 13% higher than the control site outside of the kelp farm, and that held true for the full three-year timeframe. In the second and third year of research, a pCO_2 system was attached to the back of a vessel and driven in concentric circles around the kelp farm to understand how far reaching this "halo effect" spanned. They found that the shape of halo moves around the kelp farm with the tides and tends to stretch further in the downstream direction. In the third year of research, four sets of predator exclusion cages containing blue mussels were placed 0 meters, 125 meters, 180 meters and 395 meters away from the kelp farm and in the direction of the control site, to measure pH effects on mussel physiology. They found that mussels grown inside the seaweed farm not only had thicker and denser shells, but also were more resistant to crushing. This outcome is of importance to industry partners because during mussel harvest and shell sorting, a certain number of mussels are lost to fracturing.

Bigelow Laboratories is now pursuing several next steps to build on this research:

- Determine the underlying mechanism behind co-culture benefits
- Measure whether carbon sequestration is happening in the sediment below the farm
- Test phytoremediation at sites with different hydrodynamics
- Advise on operational design of co-cultured kelp and mussels to maximize mussel resilience to OA and improve mussel yield
- Establish nitrogen bio extraction best practices and technoeconomic analysis

Thus far, the results from the study are part of four separate manuscripts being prepared for publication. There are also early adopter aquaculturists in Maine using the results to inform their lease site co-cultivation design. Bigelow Laboratory's work is also contributing to the design of the Blue Carbon strategy for Maine, which seeks to improve carbon sequestration and the reduction of ocean acidification – an adaptation strategy recently identified by the Maine Climate Council. There is significant market potential for seaweed in Maine, furthering the viability of seaweed co-location practices.

Presentation 6: What's Up with the Carbonate Chemistry? A Commercial Shellfish Aquaculture Perspective

Presenter Mike Congrove (Oyster Seed Holdings)

Mike Congrove is the President of Oyster Seed Holdings, a large-scale commercial shellfish hatchery in Virginia. OSH has been in operation since 2009 and has sold nearly one billion oyster seed and billions of eyed larvae since its inception. In the last few years OSH has increasingly focused on R&D efforts to better understand water quality as it pertains to hatchery culture and to increase the resiliency of shellfish hatchery culture through tech-forward innovation.

Presentation Summary

Hatchery functions include growing the feed that will be provided to oysters, conditioning adult oysters to spawn, cultivating larvae, and assisting larvae through metamorphosis until they are large enough to be relocated to farms. Therefore, the quality of water entering hatcheries plays a vital role in the business's success. At Oyster Seed Holdings, located in VA on the coast of the Chesapeake Bay, they have seen changes over time in water chemistry such as decreased salinity, decreased pH, and increased water temperature. These alterations have been observed at several depths in the water column. While increases in acidity cause carbonate to become less available, this is not the primary biochemical process hurting industry. Shellfish are capable of buffering some acidity on their own. The bigger issue is that they exert so much energy buffering acidity impacts that they have less energy available for shell creation, growth, and reproduction.

Starting in 2011, Virginia industry leaders joined together to research OA impacts. The most recent project ran from 2015 to 2018 and was funded by the NOAA Saltonstall-Kennedy Grant Program. It allowed for pCO_2 monitoring of three shellfish hatcheries over two years. Unlike the relationships observed on the West Coast, these data did not draw strong correlations between saturation states and larval survival. This suggests that OA may not exclusively be negatively impacting marine life, but instead, demonstrates that there are several compounding stressors harming the shellfish. The complexity of the environment makes it difficult to tease out the relative amount of influence each environmental condition has on survival. Hatcheries on the Chesapeake Bay face very different environmental conditions than those on the West Coast, which likely explains the difference in research outcomes. The Delaware Bay's watershed is similar in size to the Chesapeake Bay's watershed; this may indicate an overlap in OA experiences between New Jersey and Virginia, at least in the context of Delaware Bay waters. Other stressors impacting marine life include harmful algal blooms, freshwater inputs decreasing salinity, toxins, and bacterial blooms. OA by itself or paired with one another stressor may be manageable, but the combination of several stressors may overwhelm local marine life.

Industry actors would like to see spatially relevant monitoring, especially in high culture areas. Partnerships with industry to locate monitoring near, or at, sensitive culture facilities would also be helpful. Many hatcheries are already measuring the water inside of their facility but do not have the money to measure ambient water. Publicly funded ambient water monitoring could resolve the issue. Lastly, industry would like to see supportive research that couples biological performance data with chemistry.

Group Discussion on Stakeholder Engagement and Participation

Seagrass and Seaweed Mitigation

There are multiple options available to industry for buffering their waters. Oyster Seed Holdings for example artificially supplements their incoming water with carbonate additives when pH is particularly low. It is not a foolproof solution, however, as the addition of carbonate past a certain point seems to offer little improvement in larval survival. There have been attempts to utilize sugar kelp remediation practices in the Chesapeake Bay, but those were unsuccessful as the waters were too warm for the plant to thrive. Maine also struggled with sugar kelp because of its short growing season and subsequent short buffering capacity. The benefits of sugar kelp are that it grows 2-3 meters in just a few months and has low associated capital and operating costs. Microalgae could theoretically produce the same effects as kelp, but it cannot be grown in the ocean and would therefore be limited to aquaculture usage. Even in a controlled environment it is difficult to balance the biomass of algae. If an algal bloom were to occur, it would initially buffer OA impacts and then worsen acidification as the algae dies and is converted into CO_2, typically in bottom waters.

New Jersey has seen some initial interest in growing seagrasses for aquaculture usage but this movement is still in its early stages. The NJ Department of Agriculture would likely need to get involved for seagrass usage to reach larger scales. Rutgers University has engaged in some seagrass monitoring and small-scale pilot seagrass restoration studies. No studies as of yet have been conducted at an industrial scale. More recent work by researchers at Stockton University has found success with seedbanks and seed distribution method experimentation.

Key Takeaways:

- The buffering capacity of sugar kelp is promising, but for New Jersey's climate there may be another species of seaweed or seagrass that is better suited
- More studies are needed on the benefits of industrial scale seagrass operations in New Jersey

Connecting with Industry Partners

One of the most prominent hurdles facing New Jersey's OA plan is establishing industry partnerships. Bigelow Laboratories had a fairly easy time with this element because the local seaweed grower they partnered with had already been fielding questions about phytoremediation, and by consequence, was eager to participate in their research. For Oyster Seed Holdings, they were brought into the fold of research by Virginia Sea Grant, which connected them with a leader on pCO_2 monitoring when they began to struggle with water quality in their hatchery. Virginia Sea Grant overall is responsive in connecting industry partners with resources and acting as a source of support as issues arise for farmers. Maine's seaweed and shellfish councils have also been helpful in establishing relationships between industry and research. Because New Jersey Sea Grant performs similar work with industry, they could act as a conduit for partnerships in New Jersey. The state is also home to two shellfish councils and an aquaculture advisory council, all of which have the potential to provide industry connections. Another possible route for establishing industry partnerships is through the annual Northeast Aquaculture Conference and Exposition (NACE) which applies science-heavy topics practically towards aquaculture.

Participants' experiences in their own work with stakeholder engagement have found a pattern of stakeholders being skeptical about the consequences of OA, but nevertheless eager to learn more about OA and even participate in research. This depends heavily, however, on the finances of monitoring. Oyster Seed Holdings, for example, had been participating in monitoring ambient water, but eventually stopped because of the associated expenses. However, further development of cost-efficient sensor technology may prove to be an acceptable replacement for the more costly monitoring equipment in use today. While these sensors are easier to operate than current high-quality sensors, they still need to be calibrated frequently by trained laboratory technicians. The funding of sensors used at industry facilities must be shouldered by the state of New Jersey, or by some other entity. A strong benefit to monitoring in these areas is that there is easy access for co-location of chemical and biological monitoring. It is still too early in the planning phase for NJDEP to definitively fund equipment, but a likely end result would be Sea Grant or an academic institution setting up monitoring sites, and then the maintenance being handed off to the state.

Key Takeaways:

- Use New Jersey Sea Grant, NJ-based shellfish councils, the Department of Agriculture's Aquaculture Advisory Council, and NACE to establish industry partnerships
- Fund the usage of sensors so that there are lower barriers to participation in research for stakeholders

Appendix

A recording of the workshop is accessible here. Below is a table of the video's contents.

Video Section	Timestamp
Presentation 1	3:30
Presentation 2	16:00
Discussion 1	54:00
Presentation 3	2:05:50
Presentation 4	2:30:45
Discussion 2	2:45:00
Presentation 5	3:19:05
Presentation 6	3:31:45
Discussion 3	3:51:30