Opportunities to Address Ocean Acidification Impacts in New Jersey

An Outline of Options for the New Jersey Coastal Management Program

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I. Background

Carbon dioxide (CO_2) gas dissolves rapidly in seawater, and approximately up to one-third of human-caused CO_2 emissions is sequestered by the ocean. Ocean acidification (OA) is the process by which the addition of CO_2 acts to increase seawater acidity and lower pH. This change in seawater chemistry reduces the concentration of carbonate ions, and as a result the carbonate saturation state (Ω), in the ocean which are needed by many marine organisms to develop protective shells and skeletons. While increased ocean exposure to atmospheric CO_2 is the primary driver of ocean acidification in ocean waters globally, several drivers in nearshore coastal shelves and estuaries are attributed to 'coastal acidification' and include inputs of nutrients from fertilizers, wastewater treatment effluents, and pollutants from developed land use patterns. Increased nutrient inputs cause eutrophication, a process that fuels additional growth of algae in the surface ocean during spring and summer seasons. The algae ultimately sink and are respired by bacteria in subsurface or bottom waters, resulting in elevated CO^2, decreased pH, and low dissolved oxygen, known as *hypoxia*.[1] Inputs of freshwater with limited capacity to buffer changes in pH and episodic upwelling events that bring deeper, corrosive seawater to the nearshore surface are additional sources of acidification in coastal systems. Furthermore, OA can be exacerbated by or co-occur with other climate-related stressors affecting coastal and marine ecosystems, including warmer water, low dissolved oxygen, harmful algal blooms (HABs), coastal erosion, and rising sea levels.

Changes in seawater chemistry, and their interactions with other stressors, have been found to have significant local and global impacts. OA can directly impact an organisms' ability to make carbonate structures (calcification), but it also can disrupt several other processes (e.g., development, reproduction, metabolism) in many calcifying and non-calcifying marine species. Coping with environmental stress requires organisms to expend energy, therefore leaving less available for other processes (e.g., reproduction) or causing them to be more susceptible to other dangers (e.g., disease, predation). OA can interact with other environmental stressors to cause interactive effects (additive, synergistic, antagonistic). OA impacts may reduce the ability

[1] The Mid-Atlantic Ocean Acidification Network. Available at: https://midacan.org/

of species to recover from climate-related impacts such as with corals that may be more vulnerable to disease in warming water and, with less available calcium carbonate, corals may be less able to return to health.

U.S. Member States in the International OA Alliance

California
Hawaii
Maine
Maryland
New York
Oregon
Virginia
Washington

Notable impacts from ocean acidification on industry and the economy have been documented in the United States and globally. In 2007 and 2008, Washington State experienced large-scale oyster hatchery losses linked to ocean acidification provoking the collaborative establishment of the Pacific Coast Collaborative among California, Oregon, Washington and the Canadian province of British Columbia. Since that time, many coastal states have focused attention on developing action plans and policy to aid in OA monitoring, experimental research and modeling, assessing and addressing impacts of OA, and mitigation. Eight U.S. states have joined the International Ocean Acidification Alliance[2] a non-profit, jurisdictional member-based organization that promotes understanding of and actions to address OA. OA members agree to develop an OA Action Plan for their jurisdiction and to work together to:

- Improve the scientific understanding of OA impacts globally;
- Reduce causes of OA;
- Implement actions to promote adaptation of ecosystems and ocean-dependent communities and industries to OA;
- Expand public awareness of OA and the need for action to address OA; and
- Build international support for actions to address OA.

In the Mid-Atlantic, impacts of OA on industry have been less pronounced and, as a result, there has been less of a call for action among fishery and shellfish industry leaders than in the west coast. Given the significant contribution of the seafood industry to New Jersey's economy, the state Coastal Management Program is considering a proactive initiative to address potential OA impacts in the Garden State. New Jersey's commercial fishing industry is the fifth largest in the United States and provides more than 50,000 jobs (2016; NOAA NMFS). The fishing and aquaculture industries contribute more than $1 billion annually to the state's economy. The most commercially important shellfish species in New Jersey include the Atlantic sea scallop, Ocean quahog, Atlantic surfclam, blue crabs, and the eastern oyster. Sea scallops are the state's most valuable fishery, and NJ is the leading supplier for ocean quahog. The state also supplies significant amounts of commercially and recreationally important finfish (e.g., Atlantic mackerel, summer flounder, black sea bass and squid. Out of these listed studies, the eastern oyster is the most studied in terms of responses to ocean acidification (Saba et al. 2019a). However, OA-specific studies on other important species are severely lacking. Farm-raised fish and shellfish growing in New Jersey (aquaculture) is a growing industry that is receiving incentives for further expansion by the state Department of Agriculture.[3] The NJDEP Science Report on Climate Change that was issued by the agency in July 2020 pursuant to

[2] International Ocean Acidification Alliance. Available at: https://www.oaalliance.org/

[3] https://www.jerseyseafood.nj.gov/AquacultureBrochure.pdf

Executive Order 89 points out 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."* (NJDEP 2020)

As such, the New Jersey Coastal Management Program (CMP) engaged a team at Rutgers University to offer insights as potential approaches that the CMP could undertake to initiate a focused OA effort in New Jersey. This effort reflects the contribution from the New Jersey Climate Change Resource Center housed at Rutgers University. Established by statute in 2020 (P.L. 2019, c. 442), the **New Jersey Climate Change Resource Center** is directed to collaborate with other academic institutions to carry out collaborative outreach, analysis, and research activities that will help New Jersey adapt, mitigate, and prepare for climate change. The statutory mission of the Center is to advance government, public, private and nongovernmental sector efforts to adapt to, and mitigate, a changing climate.

In particular, the Rutgers team was asked to:

- Assess the current scientific understanding of OA impacts in New Jersey including identifying gaps in scientific knowledge and opportunities to address those gaps;
- Assess the experiences in other coastal states with regard to management of focused OA efforts that can inform both the content and approach of a possible focused OA initiative in New Jersey;
- Create an educational infographic that can be used for outreach and education purposes in New Jersey;
- Outline elements that might be included in an OA Action Plan in New Jersey; and
- Develop a database of stakeholders that could be used by the CMP as part of outreach and education efforts.

This report provides a summary of the outcome of those efforts and includes the following four sections:

II. Insights and observations about OA opportunities and policies in New Jersey;
III. A Summary Table of 11 States' Ocean Acidification Efforts;
IV. Groundwork Toward Developing a New Jersey OA Observation and Research Plan;
V. Outline of a Potential OA Plan for New Jersey based on best practices in other states.

II. Insights and Observations about OA Opportunities and Policies in New Jersey

- ***Observations***

As part of this project, the Rutgers Team reviewed OA information and materials in 11 coastal states and conducted webinar-based interviews with OA program leads in those states. Eight of the 11 states reviewed are the members of the International OA Alliance and the three other states studied, Delaware, Massachusetts, and South Carolina, were chosen given their level of developing OA activity. Additionally, the Team conducted interviews with the Project Coordinator of the International OA Alliance. One of the members of the Rutgers Team serves on the Steering Committee and Science Working Group of the Mid-Atlantic Coastal Acidification Network (MACAN), one of several regional acidification networks across the country and is extensively familiar with the work of MACAN and its participating states. MACAN is coordinated jointly by the Mid-Atlantic Regional Association Coastal Ocean Observing System (MARACOOS) and the Mid-Atlantic Regional Council on the Ocean (MARCO). Monitoring and science efforts in other regional OA networks were also reviewed.

As outlined in the summary of state efforts in Appendix A, the Rutgers Team found a diverse range of OA programs and policies underway in states across the country. For example, some of the other state efforts are very mature while others are at early stages. Despite this variety, the Rutgers Team identified ten consistent themes based on the states' experiences:

1. ***Coordinated OA initiatives serve to spur needed multi-jurisdictional policies, research, monitoring and actions.*** In general, OA initiatives in other states do much more than serve as an organizing framework for existing state climate change, coastal and ocean initiatives. Rather, structured OA initiatives serve to facilitate multi-agency and multi-sector collaboration, identify gaps in science and monitoring, and inform development of risk-based policy. In California, the development of a statewide OA Plan prompted individual executive branch agencies to develop their own action plans to document strategies that contribute to the OA Plan goals and objectives. One state program director said that having an OA Action Plan ensures that all agencies with jurisdiction for water quality, oceans protection, coastal and fisheries management, fisheries and policy, are all "rowing in the same direction" and, in doing so ensures efficient use of public resources. Several states also indicated that having an organized OA initiative serves to directly connect conservation and coastal protection efforts with economic development goals in the form of promoting the needs of fisheries, shellfisheries, and aquaculture industries.

2. ***State-based OA initiatives benefit from and complement regional (multi-state) initiatives.*** All of the states interviewed for this project both lead state-based OA initiatives as well as participate in regional acidification networks. States' indicate that launching a state OA initiative does not present an "either/or" with regard to their participation in a regional network. Rather, the states' experience is that individual state OA efforts and regional efforts are mutually supportive given the pace in which OA research and scientific

understanding of OA impacts is emerging. States also shared that, in most cases, the impacts of OA on fisheries and shellfisheries expand beyond state borders. Participation in regional initiatives provide individual states with valuable data from monitoring efforts in other states. As one state representative said, "the ocean does not stop at our state border," meaning that use of monitoring data from other states provides an efficient mechanism for any state to increase its science and monitoring capacity.

3. ***Partnerships with the research community are critical to support state-based OA initiatives.*** Every state interviewed for this project has established collaborative efforts with the science and research community including in the academic and nongovernmental sectors as well as federal agency scientists (i.e., NOAA) and Sea Grant. In general, state OA efforts are driven by assessment of individual species and ecosystem risks informed by scientific monitoring results. The states' collaborative efforts with scientists and researchers take multiple forms, including establishment of science advisory panels such as California's O*cean Acidification and Hypoxia Science Task Force* and its non-for-profit Ocean Science Trust, both of which were statutorily established. Many of the state executive branch agencies have collaborative relationships with their state Sea Grant programs, estuarine research reserves and academic scientists. In several states, state Councils, Commissions and/or Task Forces include participation and membership by scientists and researchers such as Maryland's Climate Council's Adaptation and Resilience Task Force, a special legislative Commission established in Massachusetts, New York's Ocean Acidification Task Force, New Hampshire's Coastal Marine Natural Resources and Environmental Commission and the multi-state West Coast Science Panel that was formed after the 2007 hatchery failure in Washington. States reported involvement of university-based researchers on such Councils, Commissions or Task Forces had the added benefit of building relations and personal connections between executive branch agencies and the research community that fostered collaborative research, monitoring efforts and more efficient integration of science into development of policy decisions. Additionally, several state representatives discussed the complexity and expense of monitoring systems for OA, indicating that it is more amenable to research-based, rather than regulatory compliance, monitoring and the necessity of collaboration with researchers to maximize data collection. With the exception of California, the states interviewed for this project indicated that they needed to enhance their effort to identify science and research needs and to proactively reach out to scientists and researchers to "match-make" available resources to ensure that priority research and science is conducted to support state policy efforts.

4. ***Development of a comprehensive, statewide monitoring network is an essential foundation to a state OA initiative.*** Given the nature of state OA initiatives that rely on risk assessments informed by scientific monitoring results, the development of a statewide monitoring network is a "first order" action within the more mature state OA programs. The states interviewed for this project generally develop a collaborative monitoring network that rely on data from multiple partners including water quality monitoring by state executive branch agencies, academic institutions, National Estuarine Research Reserve System entities, Sea Grant, federal agencies, and non-profit organizations. One

state representative commented that coordination and facilitation of partners was a bigger challenge to developing a collaborative monitoring network than availability of resources. Ensuring consistent monitoring protocols and data quality assurance standards, conducting assimilated assessment of data from multiple partners, and facilitating openly accessible, timely and accurate delivery of monitoring data involves considerable facilitation. At least one state explained that, given limitations of resources, it was unable to develop a fully comprehensive statewide monitoring network and, as such, needed to collaborate with the science community to set priorities for enhancement of monitoring sites/locations that can act as "sentinels" to track OA trends.

5. ***Engaging stakeholders is essential to advancing a coordinated OA initiative.*** Almost all of the states interviewed for this project include extensive and substantial stakeholder engagement as part of their OA initiatives. In some states, stakeholder engagement is in the form of Commissions, Task Forces or Councils established by Governor's Executive Orders, legislative action or initiation by an Executive branch cabinet memo. In these cases, participation by fisheries and shellfisheries industry representatives is the dominant engagement of stakeholders such as Washington's Blue Ribbon Commission which issued its recommendations report in 2012. Other engagement includes collaboration with educational institutions such as Oregon's partnership with the Oregon Coast Aquarium focused on outreach and education to the general public. Several states, such as New York, allow for public comments on reports containing public policy recommendations designed to address OA. States interviewed for this project recognize the importance of engaging secondary industries that will be affected by OA (e.g. tourism, restaurants, direct buyers of fish and shellfish, etc.) but indicated that their efforts to do so have not been very effective. The primary engagement of public stakeholders is generally with coastal conservation organizations and fish and shellfish industry representatives for which research and monitoring has shown the great impacts or potential impacts from OA. States' reported that engagement of industry stakeholders led to important support for development of policy options and identifying support for science and monitoring.

6. ***States' OA efforts benefit from resources available through authoritative sources, including the International OA Alliance, NOAA, Sea Grant and regional networks.*** The highly emerging nature of science and global understanding of impacts of OA to species and ecosystems adds to the complexity of state-based OA initiatives. States interviewed for this project strongly endorsed the scientific, educational, communication and planning resources that are available through several key sources that are regarded as authoritative, reliable and of high integrity including the International OA Alliance, NOAA's Ocean Acidification program, Sea Grant programs and regional OA networks. In particular, states pointed to these sources as "go to" resources for state-based public communication and outreach efforts, development of policy options, science and research and monitoring data. The recently developed "Toolkit" generated by the International OA Alliance was identified by several states as especially helpful in planning development of an OA Action Plan.

7. ***Precipitating actions drive public attention to OA.*** The 2007 and 2008 hatchery losses in Washington sounded an alarm for Oregon, Hawaii and California as well as other states on the east coast including Maine, New Hampshire and New York. In some cases, state efforts were strongly advanced by fisheries and shellfisheries industry representatives, such as by Maine's lobster industry representatives. In other states, OA efforts were launched by legislators expressing concern about the potential economic impact of OA on coastal resources, such as in Massachusetts, New Hampshire and New York. OA efforts in other states were initiated by executive branch agencies where efforts were focused on being proactive to put monitoring systems in place to assess potential impacts to coastal resources. For states, such as those on the east coast where OA impacts have not been significantly realized, precipitating actions include public reporting of research and monitoring results pointing to changes in seawater chemistry as well as a growing awareness of the cumulative burdens facing the states' fisheries and shellfisheries leading to concern about coastal resources reaching a "tipping point." In some states, such as California, Maryland and New York, precipitating actions that drive OA efforts are tied to accounting for impacts from climate change to support policy initiatives.

8. ***States take care to deliberately frame messages to inform OA outreach and education efforts.*** It was clear that most of the states interviewed for this project gave focused attention to how messages associated with the issue of OA was framed as part of communication, outreach, and stakeholder efforts. In some states, such as New Hampshire, Oregon and Washington, the focus of OA framing was on economic impacts to a critical industry in the state, avoiding connections to climate change. States reports that such framing was deliberative and intended to ease engagement of industry representatives that might not otherwise support climate change policy. In other states, such as New York, Maine, Delaware and California, OA messages were clearly tied to the state's climate change initiatives – both climate change adaptation and mitigation strategies. These states also report that such framing was deliberative given broad support for climate policy in the state. They note that communicating OA's connection to climate change is an opportunity to bring a new set of stakeholders, fisheries and shellfisheries, to advancing state climate policy. Other important framing issues that were used in states include:
   - Actions – States' communications distinguish ocean upwelling causes of OA in ocean waters from land-based causes of OA on coastal and estuarine ecosystems to point to a host of actions that are needed to address OA including reducing CO_2 emissions, regulating nutrient and wastewater loadings, controlling land use patterns, use of natural systems, such as seagrass, to sequester CO_2 in the water column and protect nearby. All states have focused optimistic messages that convey concepts that there are cost-effective and realistic actions that can be taken to address OA.
   - Vulnerable populations – California's Geography of Stress project, funded by the Pew Charitable Trust, is an effort to map the most potentially affected fishing and shellfishing industries with affected populations to document impacts to communities and lower income populations.

- Cultural impacts - Some states, such as Washington, focused on the cultural contributions that fisheries and shellfisheries contribute to the state's history, including impacts to Tribal communities.
- Secondary impacts – States are working to expand their framing of OA issues to also communicate impacts to other economies, including tourism and the food industry.

9. ***States attempt to focus content of OA Action Plans to ensure feasibility.*** Many of the states that we talked to referred to their efforts to ensure that the commitments in their OA Action Plans are feasible given resources, authority, stakeholder interest, and level of coordination needed among multiple agencies. One state said that "if everything is a priority, then nothing is a priority," referring to its efforts to not only set specific, actionable priorities but to also align an implementation plan with timelines and responsibilities to each priority. In California, the Ocean Protection Council developed its Ocean Acidification Action Plan, in consultation with its Ocean Acidification and Hypoxia Science Task Force, in 2018. Now the Ocean Protection Council is developing a strategic action plan to identify specific priorities within the Action Plan for implementation purposes based on resources and which will include assignment of responsibilities and timelines. In Maryland, the state Department of Environmental Protection is currently developing an interagency strategy to facilitate implementation of the state's OA Action Plan. Several states also discussed the critical need for measurable indicators of OA trends as well as transparent reporting of trends and agency progress towards implementing agency strategies. Several states maintain ongoing advisory bodies to provide oversight, transparency and to ensure accountability. At least one state discussed that one limitation of a statewide, networked monitoring system is that each monitoring partner takes responsibility for analyzing its own monitoring results but identifying a single entity to aggregate and assimilate statewide results to identify and communicate overall trends and impacts can be a challenge.

10. ***Some states find benefits in integrating efforts to address OA along with other cumulative burdens.*** Many of the states discussed the value of integrating its efforts to address OA as part of a more comprehensive effort to address other climate-related stressors facing ocean and coastal waters that have the potential to affect fisheries and shellfisheries. California's initiatives formally link OA with Hypoxia. Especially for states in the Mid-Atlantic where ocean upwelling does not significantly occur, some states find that addressing OA along with other climate-related impacts to coastal and estuarine resources and fisheries offers the ability to efficiently deploy networked monitoring systems for multiple purposes, engage stakeholders on multiple, cumulative issues, and identify actions that can address multiple challenges, such as efforts to address nutrients and wastewater pollutants.

- ***OA Observation and Research Plan***

Section IV of this report lays the groundwork for development of an OA Observation and Research plan for NJ. Development of a comprehensive statewide OA Observation and Research Plan would need to be developed with the benefit of input and involvement of a wider group of experts during a formal OA Action Planning process. Should New Jersey decide

to pursue development of such a plan, Section IV may serve to inform and begin a planning process of experts. More specifically, Section IV of this report outlines current monitoring efforts in New Jersey and current ecological research in New Jersey, current gaps in monitoring for OA as well as specific opportunities to build upon current monitoring efforts to develop a statewide, coordinated OA monitoring network. Section IV also outlines ongoing ecological research in New Jersey with a discussion of current ecological research, gaps in current research on OA ecological impacts, and a discussion on opportunities to build upon current ecological research to better understand and assess OA impacts and risks to specific species.

- ***Opportunities for New Jersey Action***

While New Jersey has not tangibly realized the potential impact of OA on its coastal resources, OA is an emerging threat for the state's commercial fisheries and shellfisheries industries and its growing aquaculture sector. Given the general level of concern regarding climate change among state residents[4,5] and the fact that other climate-related cumulative impacts are being felt by coastal communities throughout the state, the identification of the potentially serious economic impacts of OA as a finding in NJDEP's July 2020 Science Report on Climate Change appears to provide an opportunity for the state to benefit from the experiences of other coastal states that have already advanced concerted OA initiatives. In particular, several opportunities, based on the experiences of other states, that appear to present themselves include:

Stakeholder engagement	Based on the experiences in other states, results from scientific monitoring have been critical to initial engagement of fisheries and shellfish stakeholders to conduct outreach and education regarding the potential economic impacts of OA and other climate-related coastal stressors. Most of the states with comprehensive OA initiatives identified very strong benefits of diverse Commissions, Task Forces, or Councils that elevated understanding about the potential serious impacts of OA as well as to drive dialogue about potential actions needed to address OA. In some states, such engagement was in the form of a "Climate Commission"-type group, while other states administered OA-specific groups with diverse participation. The New Jersey Coastal Management Program can also consider the extent to which other stakeholders, including those involved in issues such as tourism, food and restaurant, natural, historic and cultural resources, have the interest to be engaged. New Jersey does not currently have such a forum with which to begin a science-informed dialogue about potential OA impacts and opportunities for action.
Intersection of OA with other climate-related stressors affecting coastal communities and industries	Given the multiple climate-related stressors affecting New Jersey's coastal fisheries and shellfisheries now and into the future, a multi-sector effort would provide New Jersey with the benefit of coordinating monitoring for different indicators, engaging stakeholders to efficiently receive input on multiple stressors facing their communities and industries, and developing actionable strategies that can address multiple impacts.
Collaboration with other states and jurisdictions regionally, nationally, and globally	Ongoing involvement in the Mid-Atlantic Coastal Acidification Network (MACAN), the Mid-Atlantic Regional Council on the Ocean (MARCO), and the Mid-Atlantic Coastal Ocean Observing System (MARACOOS) provides New Jersey with the opportunity to continue to learn about OA impacts and actions from partners throughout the region.

[4] https://climatecommunication.yale.edu/visualizations-data/ycom-us/

[5] http://eac.rutgers.edu/wp-content/uploads/Eagleton-NJCCA-NJ-Climate-Poll-report_04-25-19.pdf

	Additionally, participation in the International OA Alliance has proven to be a tremendously helpful resource to other states as they develop comprehensive OA initiatives. The Alliance is hosting a virtual meeting during New York City Climate Week (September 21-27, 2020) which may be an opportunity for New Jersey to highlight its OA commitments.
Partnerships with the science and research community	It is clear from the experiences in other states that efficient and effective comprehensive state efforts on OA involve close partnerships with the science and research community including academic institutions, estuarine research reserves, Sea Grant among others. These partners not only serve to expand the reach of a networked monitoring system, but they also allow for the assessment of risks to specific species and ecosystems based on monitoring results and modeling about future impacts. Additionally, these partnerships have proven critical to states' development of science-informed strategies that, increasingly, are focused on assessing outcomes of certain actions (e.g. reduction in nutrients) on coastal processes. Several New Jersey-based academic and federal researchers, the state's Department of Environmental Protection and estuarine research reserve, and New Jersey Sea Grant are actively involved in monitoring, science and research that can inform development of a comprehensive OA initiative for NJ. One insight from other states' efforts is that NJ would benefit from having a lead point of contact on science, research and data to ensure the greatest amount of coordination to ensure efficient leveraging of resources. The Coastal Management Program can also explore the extent to which it can work through existing science-based partnerships such as the estuarine research reserves, Sea Grant, the New Jersey Cooperative Extension Service and the New Jersey Climate Change Resource Center.
Multi-agency coordination	OA presents challenges to New Jersey that, based on experiences of other states, will involve action on the part of multiple state programs including those involved in water quality monitoring, ocean and coastal protection, fisheries and shellfisheries, economic development, and science and research. Several other states commented on the value of a coordinated Action Plan as serving to ensure that all programs and agencies are operating towards clear, transparent and shared goals. Additionally, other states pointed to the value of a single program that is identified as the lead or coordinating state entity on OA issues. Based on the experiences of other states, the nature of that program may vary and, in other states, examples included programs that are responsible for water quality monitoring, science and research, coastal zone management, oceans protection, climate change, and/or fish and wildlife.
Development of a coordinated, statewide monitoring network	The current observation efforts in the state are a mosaic of individual projects without cohesiveness. A monitoring network with a coordinated vision and directed state funds supporting implementation of actionable efforts to expand or improve observations has proven to be successful in states like New York and California. This coordination and funding model would prove successful for New Jersey in enhancing the state's OA monitoring capabilities.

In general, the lessons from experiences in other states as well as the status of developing a comprehensive monitoring network in New Jersey point to the value of a coordinated response to OA. While New Jersey has not yet experienced direct impacts from OA, the science points to future impacts that will affect coastal ecosystems, vibrant industries and the communities that depend on sustainable ocean and coastal resources.

III. A Summary Table of 11 States' Ocean Acidification Efforts

California							
Impetus for State Efforts	**Stakeholder Engagement**	**Authority**	**Organization**	**Science and Risk Assessment**	**Messaging and Communications**	**Accomplishments and Policy**	**Limitations and Challenges**
International OA Alliance member The devastating failure of oyster hatcheries in the Pacific Northwest between 2006 and 2009 signaled the first OA-related warning sign in the region. In collaboration with Oregon, Washington, and British Columbia, CA spearheaded formation of the West Coast Ocean Acidification and Hypoxia Science Panel – a multi-disciplinary regional effort to synthesize the state of knowledge and identify potential management options. In April 2016,	West Coast OAH Science Panel offered 8 recommendations divided among three themes: ● Address local factors that can reduce OAH exposure; ● Enhance the ability of biota to cope with OAH stress; and, ● Expand and integrate knowledge about OAH. The 2018 OPC *State of California Ocean Acidification Action Plan (Action Plan)* was produced by the California Ocean Protection Council in	The State Ocean Protection Council (OPC) was established by law in 2004. Following release of the 2016 Panel report, the CA legislature passed two related bills: ● AB 2139 - Authorizes the OPC to develop an O*cean Acidification and Hypoxia Science Task Force* to ensure that council decision making is supported by the best available science. Requires the OPC to take specified actions to address OA and hypoxia and	The Ocean Protection Council office is the lead agency on OAH. It is located within the Natural Resource Agency. The OAP is more of a planning agency than a regulatory one and serves as a planning office for the Governor's office on ocean-related issues. OPC is funded through the state license plate fund and Proposition 68 (authorizes funds for water infrastructure projects).	As part of its strategic plan, OPC narrowed the focus to several areas: ● Monitoring – Creating an inventorying of monitoring assets to determine how to strategically enhance and link them to form a comprehensive statewide monitoring program. The current network is a mosaic of individual projects without cohesiveness. ● Modeling – Identification of specific questions that need to be answered through modeling to inform risk assessment. One	Findings of 2016 West Coast OAH Science Panel: 1. OAH will have severe environmental, ecological and economic consequences for the West Coast, and requires a concerted regional management focus. 2. Global emissions are the dominant cause of OA. 3. There are actions we can take to lessen exposures to OA. 4. We can enhance the ability of	In 2016, West Coast OAH Science Panel offered 8 recommendations divided among three themes: ● Address local factors that can reduce OAH exposure; ● Enhance the ability of biota to cope with OAH stress; and, ● Expand and integrate knowledge about OAH. CA Ocean Action Plan Recommendations: 1. Prepare for a full range of OA risk and impacts	The West Coast OAH Science Panel and the state Ocean Action Plan offered very ambitious and comprehensive actions to address OAH: the challenge become that, when everything is a priority, nothing is a priority. As a result, the OPC adopted a 5-year strategic plan in February 2020 that is specific, realistic and aligned with funding availability. Challenges associated with research and monitoring are: ● Coordination of research and

the Panel issued its report: West Coast Acidification and Hypoxia Science Panel Report: Major Findings, Recommendations and Actions.	cooperation with the California Ocean Science Trust. Development of the *Action Plan* involved broad consultation with policy-makers, managers, experts, and interested parties across California AB 2139 created an Ocean Acidification and hypoxia Science Task Force that provided scientific and technical input and reviewed the draft plan for scientific feasibility. The plan also underwent a 30-day public comment period. Action Plan Recommendations: 1. Prepare for a full range of OA risk and impacts • Conduct a statewide vulnerability assessment • Make targeted investments in	adopt recommendations for further actions that may be taken. ● SB 1363 - Establishes the Ocean Protection Council (OPC) and requires it, in consultation with the State Coastal Conservancy and other relevant entities, to establish and administer the Ocean Acidification and Hypoxia Reduction Program, and proposes authorization of funding for grants or loans for projects or activities that further public purposes consistent with the Ocean Acidification and Hypoxia Reduction Program. In October 2018, the CA OPC issued the state OA Action Plan in cooperation with the California Ocean		of the main findings of the CA OAH Science Task Force was to better connect the biological and chemical monitoring in the field to be able to use current conditions to predict biological impact. A current focus is on near shore model improvements; ● Living systems – research, monitoring and information synthesis on living systems, with a big focus on SAV and wetlands as habitats with goals of expanding acreage of wetlands and seagrasses. ● Spatial management – Potential expansion of marine protected areas ● Water quality - Advancing development of water quality management	ecosystems and organisms to cope with OA. 5. Accelerating OA science will expand the management options available. 6. Inaction now will reduce options and impose higher costs later. Addressing this threat requires a sustained, multi-pronged approach to both mitigate acidification at a local and statewide scale and manage the resulting disruptions. State OA Action Plan messages: ● Some actions in the Action Plan address OA as a stand-alone issue and others address OA within the context of other environmental drivers and changes, as	• Conduct a statewide vulnerability assessment • Make targeted investments in monitoring to inform decision making 2. Activate responsible elements of state government ● Integrate OA into state policies, planning and operations ● Reduce the pollution that causes OA ● Identify and reduce local water-borne and airborne pollution that exacerbates OA ● Develop technical tools 3. Deploy living systems to slow OA and store carbon ● Restore and enhance seagrass meadows, kelp forests and salt marshes	monitoring is a bigger challenge than resources. Goal is to build a coordinated statewide monitoring effort that links individual efforts of different researchers and agencies but that requires a tremendous amount of time and energy on the part of OPC. ● Few agencies or researchers want to be involved in coordinated assimilation and analyses of monitoring results – most are focused on their own individual monitoring outcomes. OPC is exploring options such as the OOS or the west coast ocean data portal.

	monitoring to inform decision making 2. Activate responsible elements of state government ● Integrate OA into state policies, planning and operations ● Reduce the pollution that causes OA ● Identify and reduce local water-borne and airborne pollution that exacerbates OA ● Develop technical tools 3. Deploy living systems to slow OA and store carbon ● Restore and enhance seagrass meadows, kelp forests and salt marshes ● Evaluate and advance aquaculture approaches that can help	Science Trust. The California Ocean Acidification and Hypoxia Science Task Force, convened per Assembly Bill 2139, provided scientific and technical input and reviewed the draft plan for scientific feasibility. The Plan sets a 10-year vision for addressing ocean acidification and identifies a set of actions to work towards that vision.		thresholds. Just approved a $1m plan with UCLA and others to use a state of the art model oceanic and biogeochemical model to simulate different scenarios of impacts from different loadings of runoff and wastewater.	appropriate to the policy or management circumstances. ● The major drivers of OA originate largely from land-based activities, while impacts manifest in ocean and coastal regions. It is recognized that long-term, comprehensive actions to mitigate OA must therefore span the land-sea interface. ● Scientific understanding of OA is rapidly evolving, as is experience worldwide in identifying and implementing strategies to mitigate and adapt to OA. Periodic assessment of progress on the Action Plan and revisions to update and refine it should be undertaken at a minimum of every 5 years to incorporate	● Evaluate and advance aquaculture approaches that can help 4. Build resilience of affected communities, industries and interests ● Establish a statewide advisory group ● Advance resilience of shellfish aquaculture industry and fisheries industry 5. Engage beyond state borders Import lessons from other geographies to speed and improve California's OA efforts. Early OPC progress included investments in OA monitoring in seagrass beds and convening of an OPC Science Advisory Working Group to explore the use of seagrass as an ocean acidification management tool	

	4. Build resilience of affected communities, industries and interests ● Establish a statewide advisory group ● Advance resilience of shellfish aquaculture industry and fisheries industry 5. Engage beyond state borders Import lessons from other geographies to speed and improve California's OA efforts The OAH Science Task Force includes an appointed interdisciplinary team of scientists from California, Oregon, Washington and beyond were assembled to provide scientific advice, guidance, and recommendations to the Ocean Protection Council. Appointments are until 2021.				what has been learned from California's experience and the experiences of others. ● The ongoing and future changes in ocean acidity will have important effects on marine animals and plants that can translate into impacts on coastal and marine fisheries and ecosystems, and the benefits they deliver to society. ● OA is just one of many significant environmental changes now occurring along the CA coast, and it will act in combination with these other processes. Climate change is altering temperature and precipitation patterns and oceanographic processes. Larger and more intense	(http://westcoastoah.org/ resources/California/). Geography of stress project is looking at socioeconomic impacts of OA, especially on lower-income fisheries "communities at sea." Funded by Pew.	

	The OPC includes three cabinet members, two legislators and two public members. The CA Ocean Science Trust is a 501(c)3 non-profit organization, with support from the state, academic institutions, federal government, philanthropy and private industry created by the California Ocean Resources Stewardship Act in 2000. The law directs the Trust to advise state agencies to encourage coordinated, multiagency, multi-institution approaches to ocean resource science. The Trust has professional staff and a Board with three appointees from state cabinet agencies, public members and 7 members appointed by				regions of low oxygen (hypoxia) are occurring in some areas. Sea-level is rising and coastal communities are responding by relocating and protecting infrastructure. Human uses and inputs to the oceans also are shifting, driven by population and land use change, shifting fisheries, and new uses of the oceans for food, energy, recreation, and habitation. CA is taking an integrated approach to address OA: ● Ocean Stewardship ● Mitigation of GHG Emissions ● Water quality of marine waters ● Climate Change Adaptation		

	the Natural Resources Secretary representing academic institutions, ocean and coastal interest groups.				● Adaptation to Sea level rise CA makes a concerted effort to connect its OAH efforts to its climate change initiatives.		
Delaware							
Impetus for State Efforts	**Stakeholder Engagement**	**Authority**	**Organization**	**Science and Risk Assessment**	**Messaging and Communications**	**Accomplishments and Policy**	**Limitations and Challenges**
Not an OA Alliance Member. Delaware's OA focus was initiated by the senior management in the Department of Natural Resources and Environmental Control's Administrator who encouraged MARCO to view OA as a cross-state ocean priority. This work is led by the Coastal Zone Management Program (CZM). There was also a 2015 graduate student report "Delaware and	Delaware has no formal commitments regarding stakeholder engagement. However, the Delaware CZM does engage the shellfish industry (most connections are made through MACAN). Current engagement efforts have consisted of two stakeholder calls with the industry. Through these efforts the CZM has learned the shellfish aquaculture community is interested in adding pCO2 monitoring to	Delaware has no official authority and no councils or commissions that are ocean-related nor has a dedicated OA Commission or Council been established.	OA in Delaware is centered in the NERRs and CZM in Delaware's DNREC. This integration has proved helpful and provided helpful synergies. While their internal staff is small regarding OA efforts, Delaware collaborates with other states to inform the expansion of their monitoring network. • They consult with west coast on expanding platforms (pCO2 sensors used in Pacific Northwest	"Delaware and Ocean Acidification: Preparing for a Changing Ocean" (2015) was the state's first report regarding OA. The report was completed by a student of an academic researcher whose work focused on OA science. The report highlights the economic importance of protecting the Delaware coastal environment from climate change and OA. In addition to the report, The National Estuarine Research	While DNREC has no official messaging or communication policy regarding OA, DNREC recognizes there is a possible tie in of OA to DE's Climate Action Plan. DE Climate Action Plan is the current focus of the agency and OA is not part of that initiative. The Climate Action Plan will be completed by the end of the year. There has been some talk as to whether the state CZM would	Delaware has no formal recommendations regarding OA. Delaware's efforts are focused on creating a good monitoring system, partnering with NERRs, and starting to collect data and science that is needed to support future decisions. The state does have two funding attempts in the works right now: one with MARACOOS and one with NOAA's acidification program (internal call for	Delaware is one of the first states trying to form a robust OA monitoring network. A limitation is not having guidance from other states' experiences. A lot of reserves and researchers are looking to DE to see how they handle this process. Like other states, limited resources (*i.e.* money and time) take their toll. The technology of OA is difficult and CZM shared that incorporating these

Ocean Acidification: Preparing for a Changing Ocean" which was the state's first dip into the OA world as Delaware Department of Natural Resources and Environmental Control had little expertise at the time.	their farms, but the stakeholders are more interested in the general water quality data (*e.g.* dissolved oxygen) that would come with pCO2 measurements. This is because harmful algal blooms have been a problem for these farmers in the past. The CZM is also created a multi-state research working group with other NERRs OA specialists (and are welcoming new members). Target audience for regular workgroup presentations are research coordinators in the NERRs or other researchers in the NERRs network.		have been shown to be too labor intensive to run) • Also engaged with New England NERRs monitoring updates and learning from their deployments (*e.g.,* a pCO2 sensor will be deployed next to a YSI). All funding is coming through federal CZM dollars.	Reserves (NERRs) in DE has a system wide monitoring system with ideal platforms to add sondes for OA. DNREC is obligated to maintain current monitoring efforts, but funding for OA expansion could come through the NERR via its CZM section 213. Unlike other states, Delaware has no restoration efforts for sea grasses and oysters. But seagrasses are not common in the state due to local turbidity.	pursue an Ocean Action Plan after this. The tone of any future Ocean Action Plan will largely be dictated by how the Governor receives the Climate Action Plan.	proposals). The latter will be a regional effort between Delaware and New England (New England interest is from folks who don't have a pCO2 sensor yet or want one so they can have a comparison site).	tools would add work to a staffer that is already overloaded. West coast efforts concluded that any state implementing this technology would need a new staff person just to maintain the sensors. In addition, Delaware has a full range of marine habitats to monitor and therefore finds it challenging to decide on the best sensors for each environment. The affiliation of NERRs also has an impact: DE reports that its NERRs' affiliation with the state limits access to literature/scientific papers. CZM noted that state driven monitoring may erode trust from the aquaculture industry

							Farmers are worried that if there is a monitoring station near their site the could be penalized for it. For example, if something bad happens to their equipment during the year, could they be held liable?
Hawaii							
Impetus for State Efforts	**Stakeholder Engagement**	**Authority**	**Organization**	**Science and Risk Assessment**	**Messaging and Communications**	**Accomplishments and Policy**	**Limitations and Challenges**
OA Alliance member. Interest in OA started in HI when WA sent spat to hatchery in HI. Chair of the Department of Land and Natural Resources initiated letter of participation to the International OA Alliance with HI's participation being announced at the Conference of the Parties (COP24) to the U.N. Framework Convention on Climate	Aquaculture industry has been engaged. Fisheries industry representatives have not expressed much interest. Big focus will be on engaging the tourism industry. Pacific Coast Shellfish Growers Association (PCSGA) represents growers in Alaska, Washington, Oregon, California. Work over the past year has focused on		Lead is by Sea Grant fellow in Department of Land and Natural Resources. State Department of Health is responsible for all water monitoring (including beaches and coastal) so there is a strong focus on health-based indicators (e.g. fecal).	Rely on partnerships with research institutions: ● UH has an NSF-funded time series monitoring program that has been in place for more than 30 years of tracking pH and pCO2. Now named the Coastal Ocean Hawaii Acidification Monitoring Network or COHAMN). ● Sea Grant is a strong partner and so is the	Learning to tell the story of local impacts to educate stakeholders about a global issue. Expect that recent research pointing to potential bioerosion of corals will be one of the biggest factors influencing stakeholders.	OA effort is collaborating with the State's Climate Commission as well as the City and County of Honolulu's Climate Commission. Also collaborating with the Office of Planning's Coastal Zone Management Program which is responsible for state efforts in coastal waters.	Access to key information that can be used in HI effort can be a challenge given limited staff dedicated to the OA effort. The NOAA OA exchange and the International OA Alliance have been tremendously helpful. More inter-departmental coordination needed.

Change (UNFCCC) in December 2018. OA Action Plan is currently under development. Unlike WA, OR, CA, OA impacts not are yet being seen in HI and industry is not pressing for HI action. HI's effort is more in support of pressures being felt by other states.	stakeholder engagement: September-March 2020 was almost exclusively focused on stakeholder engagement. In March, a series of webinars were hosted to communicate OA impacts, actions in other states. One set of webinars was for other programs in her agency to build support for Action Plan development. The second set of webinars included about 60 participants (NOAA, PACIOOS, TNC, cultural groups, industry, other agencies (e.g. Agriculture, Health).			Pacific Islands Ocean Observing System. ● NOAA is a strong partner – NOAA Pacific Islands Fisheries Science Center is monitoring throughout the pacific islands with a focus on bioerosion. Results are alarming: detecting erosion of the reefs south of Oahu and the Cutter Coast which are high priority sites for corals. University of Hawaii time series monitoring indicates that coastal reefs of Oahu are net annual sources of carbon dioxide to the atmosphere, as opposed to the open ocean, which is largely a sink of carbon dioxide, but the strength of the signal is seasonal and evidence to date exists suggests that fringing reef sites			

				are slowly changing to become additional sinks of this greenhouse gas.			
Maine							
Impetus for State Efforts	**Stakeholder Engagement**	**Authority**	**Organization**	**Science and Risk Assessment**	**Messaging and Communications**	**Accomplishments and Policy**	**Limitations and Challenges**
International OA Alliance member Strong fishing industry (lobster industry) led call for action leading to 2014 law. Aquaculture industry leaders expressed strong concerns. The 2014-2015 Commission included some legislators who are lobstermen.	After the Legislative Ocean and Coastal Acidification Commission issued its report in 2015, legislation was introduced to establish a standing Commission but was not passed nor supported by the Governor. A voluntary network was formed, Maine Ocean and Coastal Acidification Partnership, with industry, educators, legislators, academics, nonprofit Baykeeper, and Cooperative Extension. The partnership's focus was to keep OA in the public eye. Partnership released its Action Plan in 2019 which focused on tangible actions to	2014 – Legislative Ocean and Coastal Acidification Commission was formed. Very short-term effort – convened in August with a report to legislature in January. Six goals: ● Increase capacity to monitor and investigate; ● Reduce CO2 emissions; ● Reduce nutrient loadings; ● Plan for adaptation ● Increase public awareness ● Create a sustained focus on OA	Lead on OA is in the Maine Department of Environmental Protection Environmental Assessment Program which oversees water monitoring.		How to frame the OA issue was an important consideration given the previous administration's conservative policies on climate change. That framing shifted when a new Governor came into office and the OA issue is now framed with climate issues which has not upset fishing industry.		Maine does not have a robust monitoring network. No sustainable dollars are dedicated to OA.

	prompt a legislative response. Action Plan called for: ● More systematic monitoring; ● Assistance to communities (e.g. nutrient loadings); ● Identification of ways in which fisheries can adapt; ● Identification of resources to support efforts; ● Exploration potential regulatory action to address causes and impacts of OA. Maine Climate Council includes multi-sector state agency and authority representatives, legislators, conservation groups, various industry representatives, tribes, subject matter experts, local government, etc.	Commission sunsets in 2015 and issues its final report. In January 2015, the Commission ends and issues its final report. Law passed in 2019 creating the Maine Climate Council. Council assembled in September 2019. Council is charged with updating the state's climate action plan by December 2020. Because of COVID, Council has focused its work on work through six subcommittees including one focused on coastal impacts of climate change, including OA.					

Maryland							
Impetus for State Efforts	**Stakeholder Engagement**	**Authority**	**Organization**	**Science and Risk Assessment**	**Messaging and Communications**	**Accomplishments and Policy**	**Limitations and Challenges**
2014 law created a Maryland Ocean Acidification Task Force directed to issue a report. Spearheaded by two legislators especially focused on OA. The Secretary of Environment, in consultation with Secretary of Natural Resources, directed MDE to coordinate development of an Interagency Action Plan that is due in August/September 2020. MDE has also consulted with academic institutions. The Action Plan is expected to point to specific regulatory, monitoring, planning and other actions that the two agencies will commit to undertake.	Maryland Climate Commission includes cabinet members, legislators, local governments, academics, industries, labor, etc. Adaptation and Resilience workgroup includes Sea Grant, land conservancies, etc. Science and Technical Workgroup includes academic institutions.	2014 law to create Maryland Ocean Acidification Task Force; directed to: ● Analyze best available science regarding OA and potential effects on ecology of state waters and fisheries. ● Make recommendations regarding potential strategies to mitigation effect of OA on state waters and fisheries. Task Force members include: aquarium, legislators, academia, industry, Chesapeake Bay foundation, executive branch agencies. Task Force met monthly and issued final report in 2015.	Coastal Management Program (CMP) is responsible for policy-related issues. CMP has always had a role in staffing the adaptation and resilience task force of the Climate Commission and OA is included as one of those impacts. In the Commission's initial work, OA was not included. Historically, the CMP 2 has been able to advance overall coastal impacts as part of the climate conversation, including, for example, in the CMP annual workplan and 309 priorities. CMP has the leverage to frame the coastal adaptation and resilience issues for the Commission and to highlight where additional work is needed.	MD state agencies have been working with MACAN, MARCO and IOOS to assemble better information to assess what additional data is needed along the Atlantic coast. On the bayside, the focus has been on climate resilience in partnership with the state climate work to better understand impact on oysters, etc. Maryland is unique given that the bay is an estuary with very dynamic interaction with the land and other carbon sources, wetlands and coastal processes. Different impacts will be realized at different depths. Bay organisms are very sensitive to any small change. OA effort is	● Much is known about the ocean becoming more acidic from increased introduction of CO_2 in the atmosphere, and the importance of upwelling events in the coastal ocean off of Washington State that have impacted the success of shellfish aquaculture facilities. ● Much less is known about the more complex acidification processes in shallow estuarine environments like Maryland's Chesapeake and Coastal Bays, which are highly sensitive to terrestrial inputs, and the potential impacts that may be posed to the aquaculture industry and important fisheries	Task Force issued its final report in 2015. Key findings focus on calling for MD to: ● Enhance monitoring of State waters to quantify scale, patterns, and trends of ocean acidification. ● Establish additional research priorities in estuarine and coastal waters ● Improve coordination with other states and federal resource managers ● Focus on impacts to key species and associated activities ● Provide direct support to affected industries ● Pursue legislative activities	Impact of OA on local species is indefinite.

			Climate Commission is currently focused on developing a statewide "report card" for adaptation, recognizing that climate mitigation efforts are well measured and it is likely that there will be an OA indicator. Maryland Department of the Environment oversees statewide water monitoring efforts and its Resource Assessment Services is leading OA monitoring efforts. NOAA Chesapeake Bay program: https://oceanacidification.noaa.gov/CurrentProjects/Southeast.aspx Sea Grant - https://oceanacidification.noaa.gov/CurrentProjects/Southeast.aspx	very separate for bay than for Atlantic coast. Currently, there is insufficient science to understand if/how OA will affect local Maryland species.	such as oysters, crabs, striped bass, and other aquatic resources. ● Ocean acidification could pose big risks to oysters, clams, and other organisms that live in the Chesapeake Bay. But scientists still don't know enough about how this global phenomenon will affect life in the estuary.	● Improve communications and outreach State OA effort on the Atlantic coast is mostly focused on tracking monitoring and raising awareness; do not expect any major policy developments. With regard to state OA efforts associated with the Bay, there is a much closer alignment with the work of the state Climate Commission with regard to climate adaptation in the bay. OA efforts in the bay will be featured in the MD Climate Action Plan.	

Massachusetts							
Impetus for State Efforts	**Stakeholder Engagement**	**Authority**	**Organization**	**Science and Risk Assessment**	**Messaging and Communications**	**Accomplishments and Policy**	**Limitations and Challenges**
Not an OA Alliance Member. Late-2018, Massachusetts Legislature passed an Ocean Acidification Bill. This Bill created a Special Legislative Commission to address OA. The bill is an amendment to the Environmental Bond Bill which was signed by the Governor August 2018. The legislative impetus is not clear but state staff expect that OA was elevated by the shellfish industry because the Bill's sponsors were from coastal state representatives.	Massachusetts' CZM (located in the Executive Office of Energy and Environmental Affairs) engages and coordinates with Sea Grant and NERRs for funding and outreach which CZM find pivotal to the state's OA efforts. The CZM has also attempted to engage regional players like the Gulf of Maine Council, NONOC to become partners and also influence funding mechanisms. But overall, a good amount of engagement comes from the representation of many stakeholder groups in the Special Legislative Commission itself.	The Environmental Bond Bill (Bill H.4835) calls for the creation of a Special Legislative Commission to make an investigation and study relative to ocean acidification. According to the bill, the commission will: • Identify the actual and potential effects of coastal and ocean acidification on commercially-valuable marine species • Identify the scientific data and knowledge gaps that may hinder the commonwealth's ability to craft policy and other responses to coastal and ocean acidification; and	The Special Legislative Commission has a broad cross section of legislators and agencies, marine fisheries, environmental protection, Coastal Zone Management Program, community groups, NGOs, a rep from the Massachusetts Bay National Estuaries, commercial and non-commercial shellfish industry representatives. CZM leads planning of the Commission including identification of potential The makeup of the commission is quite structured. It has two legislators that chair the Commission.	Massachusetts is in the beginning stages of getting this information organized. For example, the goal of first Special Legislative Commission meeting (held Fall 2019) was to understand the science of OA as a group and to get input from people on the ground about monitoring needs and suggestions they may have. Now, because of COVID, the Commission has transitioned into something more and with a greater sense of urgency: 4 workgroups working to identify policy options. • Industry (shellfish) • Monitoring and barrier beaches (CZM and MADEP) • Understanding the state of the science • Policy and outreach	Massachusetts key messages will be forthcoming with the report generated by the Special Legislative Commission. In addition, the state does not make a strong connection between OA and the state's aggressive climate work. MA is working on 2050 Road Map to identify significantly reducing carbon emissions by 2050 (Governor Baker wants net zero by 2050). This report would be completed by end of year. CZM has been involved in conversations about the report, but they are looking at mitigation so there could be a connection to OA but it's not directly made.	Massachusetts has not made big OA strides yet but is working on it. The Commission's will make informal recommendations as the Special Legislative Commission by the end of the summer 2020 and official recommendations by end of 2020 to legislature. The recommendations are expected to trigger legislative action and may provide general direction such as pointing to the need for regulatory changes, development of a monitoring program, etc. The Commission expects the final OA plan will be a combination of new policies and pulling together ongoing efforts. The CZM sees	CZM mentioned that without a formal policy or regulation about monitoring for OA, there is minimal impetus for moving the OA cause forward. There is no current funding promised for additional monitoring efforts. The Special Legislative Commission is charged with assessing priorities with regard to monitoring and identifying funding needs.

		• Prioritize the strategies for filling those gaps to provide policies and tools to respond to the adverse effects of coastal and ocean acidification on commercially-important fisheries and the commonwealth's shellfish aquaculture industry. The bill also specifies who shall be on the commission and requires all appointments to be made not later than 30 days after the effective date of the bill. Meeting requirements are also outlined in the bill which requires: • The commission to meet at least 4 times to review existing scientific literature and data	Furthermore, the commission is made up of four workgroups: (1) industry focused (primarily shellfish, lobster), (2) monitoring and barrier beaches, (3) understanding the state of the science, and (4) policy and outreach • The monitoring workgroup has CZM, MADEP, and a rep from the National Estuary Program. CZM is a good hub for ongoing projects from partner organizations and has their finger on what monitoring is happening and where. Has geospatial capabilities in house to communicate that information. This workgroup also plans to plug in with the industry workgroup to gain local knowledge, see what they	The expectation is that the policy recommendations would point to legislative action rather than executive. There is a good amount of existing monitoring in the state, but the CZM program admits there are benefits to an improved statewide plan. A starting point for the state is with University of Massachusetts which is doing a lot of good monitoring work.	As the state works to develop their own OA messaging, of note is that the Commission's work is not directly linked with an existing document, the Massachusetts Ocean Plan. • CZM facilitates the Ocean Plan with the Ocean Advisory Commission and the Science Advisory Council. The 2015 version of the Plan referred to OA. MA is required to update the Plan every five years and they expect to include a discussion on OA, but the Ocean Plan isn't expected to address this specifically. The review of the 2015 plan will be completed before the end of the year and may inform the Special Legislative Commission's	an OA Plan as a way to strengthen some existing policies and regulations surrounding OA in different offices/programs, but also adding in new monitoring plans to supplement existing monitoring efforts.	

		on coastal and ocean acidification and how it has affected or potentially will affect commercially-harvested and grown species and shall address: (i) the factors contributing to coastal and ocean acidification; (ii) how to mitigate coastal and ocean acidification; (iii) critical scientific data and knowledge gaps pertaining to coastal and ocean acidification as well as critical scientific data and knowledge gaps, (iv) steps to strengthen existing scientific monitoring, research and analysis regarding OA; and (v) steps to take to provide recommendations	understand about sensitive areas, and then prioritize where monitoring should be added along the coast. To keep the Commission to its deadlines, a fellow from Harvard has been hired by the Chairs. Fellow is staffed to each working group, sets up meetings, and does bulk of work. Acts as eyes and ears for legislator Chairs. Funding for the Commission's work comes from the mitigation fee revenue being placed in the Ocean Fees and Waterways Trust. This means, if there is a project that has unavoidable impacts to the sea floor while following the Ocean		report, but not a big deal. • For context, the Ocean Plan has two parts: (1) surrounds management (*e.g.,* are there allowable uses that we need to start thinking about in sensitive areas) and (2) surrounds a baseline assessment that will inform management framework. • For additional context, of note is that the Ocean Advisory Commission and Science Advisory Council were both set up in 2008.		

		to the general court and to increase public awareness of coastal and ocean acidification. Public engagement is requirements are also highlighted.	Management Plan, then a fee is applied.				
New Hampshire							
Impetus for State Efforts	**Stakeholder Engagement**	**Authority**	**Organization**	**Science and Risk Assessment**	**Messaging and Communications**	**Accomplishments and Policy**	**Limitations and Challenges**
Impacts to other states (WA, ME) prompted action in NH. EPA made funds available to enhance monitoring efforts. One NH state senator is active in the National Caucus of Environmental Legislators which provided education on OA, including bringing a WA state senator to		In 2016, New Hampshire (SB.375) enacted legislation to study the impacts of OA on the state's economy and crated the Coastal Marine Natural Resources and Environmental Commission which is directed to: ● Investigate, monitor, and propose prevention and mitigation strategies for emerging environmental threats in coastal and	CMP is lead agency but Fish and Wildlife and the NERR are directly involved. The CMP serves as the policy lead; Sea Grant chairs the Commission. Some resources have come from state operating dollars for purchase of equipment. There was also a onetime appropriation from the general fund capital budget.	In the Gulf of Maine, there are multiple interacting processes that tend to obscure the effects of ocean acidification, including a large amount of freshwater that enters into and is retained within the GOM, resulting in the system that is poorly buffered against acidity. Other contributing factors include large shifts in temperature and productivity. Variability of OA in the Great Bay	2017 Commission report found that: ● OA is believed to be responsible for significant economic losses in Washington State oyster hatcheries and degradation of key members of marine ecosystems that are important for supporting salmon populations. Locally, an oyster hatchery in the Damariscotta River, Maine observed oyster	Three Northeast Regional Association of Coastal and Ocean Observing Systems (NERACOOS) buoys that are collecting CO2 data within the GOM. The NERR put a monitoring device in the Great Bay which will continue into the future. For the NH state fiscal year 2017, the state	Constrained resources. NERACOOS and NECAN have been very helpful. Difficulty of building a comprehensive monitoring network when day-to-day crisis demand attention. NH determined that, given its size, a meaningful OA initiative needs to work regionally.

NH to discuss impacts there. One particular researcher at UNH was also very influential.		Great Bay waters, including but not limited to warming of waters, ocean acidification, sedimentation, and nutrient loading, which impact fish, shellfish, and the food chain, etc. ● Identify gaps and recommend improvements in water quality monitoring, including monitoring pH and evaluating its impact on the impaired waters designation of waterbodies. ● Recommend strategies for enhancing capacities for improving water quality. ● Examine the Blue Carbon credit program for sea grass promotion and oyster bed restoration. ● Report annually to the chairpersons of the NH House and Senate committees with jurisdiction over		and Hampton-Seabrook estuaries is potentially more hyperactive than the GOM because they are more affected by freshwater inputs and high nutrient loading. Within these two estuaries, the main drivers of OA are increased precipitation, the resulting runoff from those precipitation events and subsequent nutrient loading within the water bodies. Greater precipitation delivers more runoff of acidifying compounds and nutrients. Greater frequency and intensity of storms storm also shortcuts the natural infiltration and filtering processes of these acidifying compounds and nutrients. The surge of freshwater during storm events decreases salinity within the estuary, thus further increasing the vulnerability of the	larvae development failure as a result of low egg conversion and larval feeding failure were associated with large storm events. Although pH was not measured during these events, the hatchery attributed the larval failures to reduced pH in the water and have since buffered their systems to be able to produce oyster larvae, spat and seed. ● Although NH does not have a sufficient time series of measurements within the Great Bay Estuary, a decade of measurements at the Isles of Shoals point to seasonally low pH values that approach critical thresholds for larval growth of certain shellfish. ● If OA gets to a critical level in our nearshore waters it has the potential to	made a $260,000 capital investment in monitoring and assessment of coastal waters, including $25,000 that was specifically allocated for OA monitoring in Great Bay. 2017 Commission report findings: OA may already be impacting NH coastal resources although there was not any specific evidence to definitely point to current effects. Recommends: NH should develop a monitoring plan and research agenda and also explore potential mitigation strategies to the effects of OA on important biological processes.	

		issues affecting coastal marine resources and the environment, the President of the Senate, the Speaker of the House of Representatives, and the NH Governor. Commission members include: Sea Grant, industry representatives, academics, several elected state representatives, several conservation organizations, NH Port Authority, state natural resource agencies (including coastal program acting as secretary). The Commission's 2017 annual report focused on OA. The commission met 6 times over 2016-2017 and all meetings were primarily focused on educating the Commission about the potential effects of OA		system to the effects of OA.	negatively affect calcifying organisms such as oysters, clams, scallops and lobsters, species that are economically valuable to our local communities. Ocean Acidification mitigating processes within the estuary include carbon storage or sequestration due to growth of eelgrass beds, macro algae, and oyster reefs.	EPA region 1 issued guidance re: OA monitoring. Currently, NERACOOS and Sea Grant have a citizen science water monitoring effort underway that will contribute to the development of a volunteer monitoring program in the bays.	

		on NH coastal and marine resources with a series of guest speakers. Following its 2017 report, the Commission shifted its focus to nutrient loadings for its 2018 report.					
New York							
Impetus for State Efforts	**Stakeholder Engagement**	**Authority**	**Organization**	**Science and Risk Assessment**	**Messaging and Communications**	**Accomplishments and Policy**	**Limitations and Challenges**
2016 Legislation for an Ocean Acidification Task force and, a few years later, joining the OA Alliance were the impetus for state efforts. Motivation for these actions came from: NY's long-standing commitment to climate change, particularly due to economic impacts. There is also considerable legislative interest. State representatives from Long Island raised OA issues which resulted in	NY's Department of Environmental Conservation (NYSDEC) is required to hold four public meetings during the development of an OA Report. They have held three meetings already with the last meeting to kick off a public comment period on the draft OA Report. To create a draft report, NYSDEC contracted work from Stony Brook University School of Marine and Atmospheric Sciences (SMAS).	In November 2016, a bill to create the Ocean Acidification Task Force was signed (Bill Number A10264). In 2019, the bill was amended to extend the existence of the Task Force from 2019 to 2023 (Bill Number S02411). The Task Force was charged with identifying "the causes and factors contributing to ocean acidification and evaluating ways to addressing the	The OA Task Force members, as outlined in the 2016 Bill, identifies the 14 positions to be filled in the Task Force. The NYSDEC Commissioner, or their designee, serves as the chairperson for the Task Force. The Task Force is split into specific working groups to address the five tasks outlined in the legislation: • a literature and data review of its	Most of the current OA funding comes through support for the Ocean Action Plan. In the Ocean Action Plan, the following is identified as a goal, "Monitor Ocean Acidification and investigate the impacts of ocean acidification on shellfish and crustaceans" with specific milestones outlined for a two- and five-year lookout. NYSDEC has funding for a SUNY project as part of an ocean monitoring project for the bite. This research is tied to	Internally, NYSDEC has an Ocean Coordinator to ensure pieces of the Ocean Action Plan are pulled into the OA Action Plan. Externally, public meetings are held to foster stakeholder engagement. NYSDEC was able to go into contract with Stony Brook SMAS to run meetings, to collect information from members and to create a smaller report.	The OA Task Force's Report is due to the legislature December 31, 2022. But the goal is to have a final plan published and ready to be implemented by summer 2021. It will contain: • Collection of OA science • Application of the science to NY state waters to even see if there was an OA problem here that industry folks are experiencing to their shellfish aquaculture	It took a long time to get all Task Force members appointed necessitating an extension of the Task Force's work. NY also warned that a change in majority party in the senate or assembly would alter who sits on the Task Force. The elections line up such that a change in administration would not preclude the Action Plan's timely completion, but it's important to keep this

the 2016 OA Task Force. The Governor's office decided to join the OA Alliance. This action shifted the tone of the OA Task Force to create a Report more like an OA Action Plan than just a report back to the legislature. This has encouraged NYSDEC to include more robust recommendations in the Report than would have been included in a typical report for the legislators. In a separate effort, a "New York Ocean Action Plan 2017-2027" was created in 2017 to "focus the state's efforts to ensure the long-term health of the ocean and to promote stewardship and sustainable use." NYSDEC underscored that the Ocean Action	NYSDEC has decided that industry (fishermen and shellfishermen) will be fully pulled in after the Legislature decides what actions they will take from the OA Report (*e.g.,* NY Shellfish Advisory Council).	problem by applying the best available science as to ocean acidification and its anticipated impacts." The legislation also required a final Report to be provided to the governor by a certain deadline. The way the legislation is written, the Report will be a product of the state, not NYSDEC. Legislation expects the Report to, at a minimum provide: (a) an assessment of the anticipated impacts related to ocean acidification; (b) recommendations related to mechanisms New York could establish to provide stronger, more protective standards, and the implementation and enforcement of such standards in the context of ocean acidification; (c)	effects on commercially harvested species; • adaptive measures, including identifying and monitoring early effects of ocean acidification on marine life, animals, plants, and natural communities; • integrating mitigation and adaptation strategies into state environmental plans; • state and local regulatory and/or statutory alterations to respond to the impacts of ocean acidification; and • increasing public awareness of ocean acidification. Working groups were originally divided geographically on east	developing a suite of indicators for the full geographic scope of the Ocean Action Plan. One related climate change effort being studied is creating a suitability model for sea scallops in the mid-Atlantic bite with respect to climate change (not specifically OA). This was a collaboration with University of Maine. Of note is that NY has a lot of information on estuaries, but not a lot on the mid-Atlantic bite or open ocean.	To hold public meetings advertisements were posted via NYSDEC listservs, newsletters, social media, old school flyers at universities and libraries. Attendees typically included NGOs (ranging from The Nature Conservancy to NGOs that partnered with NYSDEC on the Ocean Action Plan and members of that extended circle), and folks from shellfish industry. NYDEC also communicates with the state's Shellfish Advisory Council. NYDEC found it helpful to engaging with plugged-in stakeholders. For example, NYDEC has learned a lot about the Billion Oyster Project through this group. As	industry (see Section 2 subdivision 11). The OA Task Force has also been able link to other ongoing state initiatives, such as working with a climate council formed by the 2019 Climate Leadership and Community Protection Act. This relationship has added OA into the climate council's plans. The Task Force is also interested and support Regional coordination on the smaller scale. Smaller scale refers to coordination between a few states rather than the entire east coast: the latter would represent far too many stakeholder interests for any real progress to be made. NYSDEC hopes to coordinate with CT and NJ specifically because of shared geographic boundaries.	timing in mind in other states. When developing an Action Plan, or any plan, it is important to clearly decide with partner states if shared water bodies will be monitored/protected at the Regional level or by individual states. That way no water body is ignored.

Plan is different than the efforts of the OA Task Force: the former identified actions the state should take to protect local industries, while the Task Force is on an OA specific fact-finding mission.		recommendations regarding adaptive measures including measures to: (i) identify and monitor early effects of ocean acidification on marine life, animals, plants and natural communities; and (ii) integrate ocean acidification mitigation and adaptation strategies into state environmental plans; (d) recommendations on state and local regulatory and/or statutory alterations; (e) review existing scientific literature and data on ocean acidification and how it has directly or indirectly affected or may potentially affect commercially harvested and grown species along the coast; (f) identify and monitor the factors contributing to ocean acidification; and (g) recommendations to increase public	and west side of NYC for ease of travel, but COVID may have shifted the structure to be more topical rather than geographic. NYDEC entered a contract with SMAS who have been able to prepare out the Report with more specific suggestions to mitigate OA in NY waters. To maintain ocean work in the state, the Governor's office tripled the 2016 budget to support implementing some of the priority actions in the 2017 Ocean Action Plan. But this funding doesn't just go to new projects, like those that NYDEC may outline in their final Report. There are long term environmental projects that this money will		such, the Council has been integral in communicating between the OA Task Force and other industry folks. Communication with other agencies within the government has also been meaningful for NYDEC. The state found that it was important to share messaging and goals with sister agencies so other reports can be consistent with regard to OA (*e.g.,* the Climate Council). This benefit goes two ways. For example, the OA Task Force has communicated/coordinated with the authors of a Long Island Nitrogen Action Plan which has been able to plug in some of their eutrophication related solutions that can be		

		awareness of ocean acidification.	fund and is earmarked for. Funding allotments for the 2017 Ocean Action Plan money are decided by the OA program manager along with the head of the Division of Marine Resources. Decisions are also informed by recommendations of a separate estuary committee. The State Environmental Protection Fund is where the Ocean Action Plan draws other state funding from. This is under the NY Ocean and Great Lakes Conservation Act line of money. Nothing from NOAA or from other grants.		inserted into the OA Task Force's Report.		
Oregon							
Impetus for State Efforts	**Stakeholder Engagement**	**Authority**	**Organization**	**Science and Risk Assessment**	**Messaging and Communications**	**Accomplishments and Policy**	**Limitations and Challenges**

OA Alliance member. Oregon suffered a triggering OA event that turned OA into an important issue. In 2007, there was a failure of an Oregon oyster hatchery. This event had a big impact of the west coast shellfish industry because most oyster farmers in the region rely on spat from Oregon. University of Oregon was called in to find the cause of the problem and found the water was too acidic to grow spat. After this event, the shellfish industry, academia, and state agencies were intimately aware that this was a problem that needed a response. In addition to this event, Governor Brown joined the International OA	Oregon has extensive stakeholder engagement. During the state's initial response to the 2007 catastrophic event, the West Coast Science Panel was formed. Panelists consisted of oceanographers along the west coast. The goal of this panel was to generate big questions surrounding the OA problem (*e.g.,* what other species are impacted, what is the influence of physical oceanography here). This panel found science existed that indicated species other than oysters were vulnerable to OA issues in OR: salmon, Dungeness crabs, and any other organism requiring calcium carbonate to create shells during young life stages	In 2017, the Oregon legislature passed Oregon Senate Bill 1039 to create the Oregon Coordinating Council on Ocean Acidification and Hypoxia (OAH Coordinating Council). The OAH Coordinating Council was charged with providing recommendations and guidance for the State of Oregon on how to respond to the OA issue. This Bill was encouraged by the Global Acidification Network which recommended each western state create state actions and develop a coordinating council. The state has the authority to coordinate coastal and ocean management via the CMP which is housed in Oregon's Department of Land Use Planning.	Oregon's response to OA is highly organized both within the state and the West Coast. The two most mature councils in the state are the OAH Coordinating Council and the Ocean Policy Advisory Council (OPAC) and they collaborate to some degree. The OAH Coordinating Council (formed in 2017) is what brings many state agencies together on the issue of OA and hypoxia. The OAH Coordinating Council has 13 members and includes ODFW, CMP, Department of Environmental Quality, and Department of Agriculture. Outside of state agencies, the OAH Coordinating Council also engages NGOs, conservation groups, tribes, industry	Oregon's research priorities have been made public through a "Research Needs" document which was released as part of Oregon's OAH Action Plan in 2019. The document highlights three top research actions that could make a difference in the state: • Advance scientific understanding of OAH • Reduce excess CO2 and OAH stressors • Create Resilience. The agency relies on interested researchers to find their own dollars do conduct research in these topic areas. There are no state funds for this work. Academics would find out about these research needs through their own channels. But academics do sit on the OAH Coordination	Looking forward, CZM is hoping to generate OAH material and communication strategies for different groups and the impact of OA on those economies. In general, the OA conversation has been separated from the climate conversation in Oregon. This is because tying anything with the term "climate change" invokes polarization of political parties. For example, when Oregon's Senate Bill 1039 passed, there were only three no's in both chambers because the bill didn't pull in climate change issues. But the climate agenda found in the 2018 Senate Bill was more polarized. The inclusion of hypoxia in OA messaging/policy was a	The following are documents generated with "Oregon OAH Action Plan 2019-2025": • Funding and Timeline • Carbon and Climate Proxies • Action Plan Development Process • Build Sustained Support • Species Spotlights on: Olympic and Pacific Oysters, Salmon, Dungeness Crab • Take Action • Research Needs • Executive Summary • OAH Backgrounder • 1 pager on OAH on the West Coast (Providing Decision Makers with Scientific Guidance on Changing Ocean Chemistry) • Overview of Relevant Parties in OAH Policy Development	Funding has been challenging for Oregon even with the abundance of public support for OA issues. Even though the Governor is supportive of climate actions, OAH Coordinating Council's money comes from the legislature and is dependent on the Governor's budget. Resources may be slimmer now with COVID. Current funding is a mix of traditional funding mechanisms (appropriations), Sea Grant research competitions, and national collaborative research proposals. The funding would be distributed to a small number of folks so they patchwork funding wherever they can. -Funding is sufficient to staff employees and to start little projects.

Alliance in December of 2016 and committed to making an Action Plan. This is consistent with the Governor's support for climate change mitigation as she has issued several executive orders on the subject. While a triggering event can be helpful in creating impetus for OA action, the following is advice from Oregon's Department of Land Conservation and Development (DLCD) on how to still generate public support for mitigating OA: • Identify the marine economic sources that would be helpful in telling NJ's story. • Capitalize on the multi-driver system that is exacerbating OA issues: east coast	Later, the Oregon Coordinating Council on Ocean Acidification and Hypoxia (formed in 2017 and discussed in next column) was formed and is a public group. Another key group DLDC engages with are Tribal Communities. Oregon has over 100 federally and non-federally recognized tribes that they try to bring into conversations as much as possible. DLDC has also found it helpful to engage stakeholders beyond primary industries. OR participates in a good amount of direct buyer engagement. But this is attributed to many seafood restaurants being owned by retired, young		representatives (shellfish and fisheries), academics, Sea Grant folks. The Governor's Office is also a member of the OAH Coordinating Council. This is great because it provides a direct opportunity for the Governor's office to be educated on OAH. Narrowing in on two of the aforementioned groups: • The CMP is responsible for coordination between the Ocean Advisory Policy Council and the Oregon State Science Trust. • The Oregon Department of Fish and Wildlife (ODFW is responsible for coordination with the Ocean Acidification and Hypoxia Council and the OA	Council. These individuals are key in spreading the research needs around their academic networks. Additional science opportunities come from OAH Coordinating Council's engagement of the ocean monitoring network (about 50 individuals). This helps to facilitate collaborative opportunities and helps the Council better understand what everyone is working on and potential grants that may be available. Another gateway to scientific information is The Oregon Ocean Monitoring Group. This group is not housed institutionally anywhere. It is an ad-hoc group that exists because there is strong support for it. However, information generated from this	conscious decision to help pull in the fishing industry. This is because hypoxia was common to talk about before OA was established as a threat in Oregon waters. Fishermen had been seeing the effects of hypoxia during El Nino years and the direct negative impacts of those algal blooms on their fishing efforts. The OAH Coordinating Council also seeks out opportunities to spread awareness of OAH issues. For example, they have added language to state's efforts in redoing 2012 Climate Adaptation Framework. (A different program in the Department of Land Conservation and Development is responsible for this effort and has asked the CMP to translate what CMP has done so	• Five Things We Know About OAH in Oregon • Oregon Agency Responses- OAH Panel Science Information Needs Before these products were created, the first big accomplishment came from the OAH Coordinating Council 2018 Report. This was the result of the OAH Coordinating Council being required by legislation to provide a report to legislature every two years, so another report is coming in 2020. The 2018 Report indicated 45 recommendations over five broad topic areas. The OAH Coordinating Council took those recommendations and created an action plan that it will aim to meet over a 3-5-year period	-Attempt to make OA research a recipient of blue carbon funding during the 2019-2020 Climate Bill, but the bill did not pass. The political polarization of climate change in the state has also been a challenge. The bill that was supposed to fund the first year of the OA Action Plan's implementation was caught up in the term during which Republican legislators left the state so they wouldn't have to take action on climate change. Finally, time has been a challenge. There is a growing need to get more creative in terms of adaptation and mitigation strategies. Once the OAH Action Plan expires in 2025, and as more

has upwelled water, DO and OA. Look into how Chesapeake tells their story because NJ environmental factors will likely be equally complex. Oregon's story is simpler and cleaner. Easier to tell a collective story that pulls in all the factors to create a more inclusive conversation about OA. • Use personal stories • Engage your entire state (coastal and inland) to get buy-in.	fishermen. Another non-primary industry the state works with is the Oregon Coast Aquarium. The OAH Coordinating Council also has a communication working group within it which includes the Pacific Shellfish Grower's Association. DLDC is excited about engaging with them because they will be helpful in refining Oregon's OA message. DLDC is also Interested in engaging the Dungeness crab industry due to a recent scientific paper saying the species is susceptible to OA and holds great economic value in the state. ODFW provides outreach and communication		monitoring group. ODFW also participates in the Pacific Coast Collaborative Ocean Acidification subgroup. Collaboration with non-Oregon entities: • The Pacific Coast Collaborative- An agreement between CA, OR, WA, and BC via a Governor's agreement that has been renewed by each Governor. The group is a high level legislature fueled effort to understand where everyone has investments so they can collectively be smart about new investments. • Collaborates with the West Coast Ocean Alliance- This is the west coast version of	Group has no direct line anywhere.	far into a broader climate perspective so it can be added to the Framework.) OAH Coordinating Council has also extended the scope of Oregon OA communication via involvement with West Coast Ocean Data Portal (co-chaired by CMP). The Portal group seeks to coordinate data and to visualize information from across the west coast. Recently an east coast contact asked the group to create a template for an ocean index score card, and the Portal group put OAH as a top priority on the score card. This has led to a collaborative west coast effort to generate a matrix of indicators of water quality to easily understand what water bodies are healthy or	OAH Coordinating Council is also responsible for generating 2019-2025 OAH Action Plan. The Council used the 2018 report to create the OAH Action Plan. The OAH Action Plan requires each state agency (eight) to write a document about how they will implement actions in the OAH Action Plan (*i.e.,* how they will enhance regulatory action or create new regulations on OA). This is Component 2 of Action 5. The OAH Action Plan has been helpful justification for being awarded grants. In addition to these achievements, the OAH Coordinating Council helped to revise the state's Territorial Sea Plan's chapter on managing rocky shores along the coast. The TSP is administered by	stakeholders are engaged over time, there needs to be more flexibility and creativity in finding solutions.

	including engagement with state legislature. Sea Grant Office as a member of the OAH Coordination Council was key in generating the different Species Spotlight documents etc. as part of the OAH Action Plan.		MARCO post Obama and includes, WA, OR and CA. • CMP staffer oversees their version of the MARCO Data Portal (called the West Coast Ocean Data Portal)		not healthy. Scientists as well as federal, state, and tribal governments are involved in this effort. Oregon offered the following advice to NJ: Seek out potentially impacted stakeholders and try to get them to be invested in this issue. Sell the multi-stressor complexity of east coast water quality (OA, temp, hypoxia, HABs/eutrophication).	the coastal programs that oversee the Land Conservation Development Commission that works with the OPAC. This chapter was last revised in 1994. The more recent revisions included a new policy for submerged aquatic vegetation as that is a top priority for the state. This is driven largely because SAV can mitigate OA. And because the state thinks the nearshore area is particularly trampled, so it was good to put in writing that the state had concerns about OAH in these systems Future policy efforts will be dictated by when the 2019-2025 Oregon OAH Action Plan expires. Right now, focus is on reviewing project proposals for ecosystem stress responses (kelp, urchin,	

						abalone ecosystems) which will rely on external funding but have been identified as priorities in the OAH Action Plan. When OAH Plan expires in 2025, the goal is for the document to be living such that the state can continue to identify priority actions.	
South Carolina							
Impetus for State Efforts	**Stakeholder Engagement**	**Authority**	**Organization**	**Science and Risk Assessment**	**Messaging and Communications**	**Accomplishments and Policy**	**Limitations and Challenges**
Most OA efforts are occurring at the Regional level rather than state by state in the southeast. There is no known interest from legislators to pursue the OA issue. As such, the only way SC can get engaged in an OA effort would be as a Region. There's been a little bit of a concern for shellfish, but nothing major. SOCAN and SCDNR	There is minimal engagement on OA with any stakeholder group at this time, including industry. SCDNR attributes this to not having a triggering event where the impacts of OA are clearly seen by the industry. SCDNR recognizes the most awareness is in Pacific Northwest where their aquaculture industry is seeing the impacts of	The two relevant agencies are: (1) the SC Department of Natural Resources (SCDNR) and (2) the larger SC Department of Health and Environmental Control (SCDHEC). The CZM sits in SCDHEC. Primarily the CZM tries to manage coastal resources via dock permits and things of that sort rather than SCDNR	Biggest player in state right now is a regional group: The Southeast Ocean and Coastal Acidification Network (SOCAN). SOCAN hasn't discussed how to encourage states to pursue individual OA actions, yet. SOCAN recently developed a state by state summary of OA work, but haven't	Minimal scientific data exists concerning the impacts of OA in state waters. SCDNR expressed that technology is not available to them to test for OA and pH in SC's marine ecosystems, particularly because their coast has a lot of estuaries that have huge swings in pH daily so "it would be hard to discern changes to pH	Climate change is not a priority in the state. In the early 2010s SCDNR created a climate report to understand climate impacts. That didn't take off and didn't instigate many changes in the state. SCDNR recognizes the need to gain a better understanding of what the needs are in the southeast. • Current question is whether it is a need	While the state has no current policies in place regarding OA, there is generally regional driven focus/interest in better understanding OA issues (not achieved via state efforts). SOCAN is being reinvigorated and have hired 2 new employees as stakeholder/communications coordinators to handle the mid-east. New hires have OA	More pressing state priorities are a limitation to making OA progress. The lack of local evidence or a single "event" of OA has caused a challenge. This has led to a lack of concern from industry folks and, thus, a lack of state action.

recognize they need to keep track of what is happening in the Pacific Northwest with their hatcheries. Furthermore, the shellfish industry is not speaking up about any problems related to OA. This can be attributed to there not being a lot of shellfish hatcheries in the southeast. So the region isn't seeing impacts of OA on their industry. No impetus for a state in this Region to go down the OA route alone.	OA today and changing the way they work. Most stakeholder engagement is occurring at a regional level. For example, SOCAN is undergoing OA Reinvigoration Efforts. The goal is to engage more stakeholders and researchers, but state agencies not really involved. SCDNR acknowledged it would be great for SECOORA to do stakeholder workshops. It is helpful to hear from fishermen what their biggest concern is and it's been a couple years since that happened. SCDNR is hopeful this component will come back with the reinvigoration.	managing those resources.	talked specifically state-by-state. The following are some ongoing efforts related to OA: • Bureau of Water has confirmed they aren't doing any OA work, as has the Fisheries Manager in DNR. There were some workshops in 2015/2016 where OA presentations were given by SCDNR, but nothing more. • SCDNR keeps the National Estuarine Research Reserve System engaged in knowing what data we've collected, but Eric Smith (North Inlet Bay NERR) has been pushing this effort forward. Funding for these efforts, and other OA work, comes from	as a result of OA" under these conditions. The main science concern in the region is HABs in estuaries (but in SC HAB problems are more common in stormwater ponds which can be connected tidally to saltwater sources), coastal erosion (both beaches and estuarine shorelines), offshore energy (if that happens). Biggest problem affecting fisheries is species distribution from climate change The following is the extent of known research related OA work: • Research at the two NERRs in the state: Ace Basin is managed by SCDNR and the	for research (and monitoring) or a need to reach out to stakeholders to help them understand OA issues. • Voluntary networks previously involved in OA eb and flow, so SC recognizes the need to know where they are now before moving forward in the next one or two years. • SCDNR recently wrote a proposal with EPA and NOAA's National Marine Sanctuaries folks, as well as aquaculture industry partners and fisheries managers. They could be pulled in this reinvigoration initiative.	background which will be helpful. A town hall will occur in the next couple weeks (mid to late July) to kick off the reinvigoration. It seems like all of the CANs are reinvigorating now as well. SOCAN in the past has been focused on proposal development, sharing cruise updates, and some monitoring efforts. SC's policies are more focused on the most commercially valuable species in SC and are not related to OA work. These include the shrimp fishery (whites and browns mostly, but some pinks) and oysters. Recreationally	

			NOAA through SOCAN for $20,000 a year via a cooperative agreement. SC has submitted proposal elsewhere for grant money and has experienced minimal luck.	North Inlet Bay. Some pH work has been going on at the latter, but if you want to do OA work you need to collect more than just pH. • A SCDNR staffer affiliated with the College of Charleston does crustacean research and works with oysters, blue crab, shrimp, horseshoe crab (medical) and crawfish. But none of that work is necessarily OA related. • Climate research is a priority for the researchers who work for the state. - Researchers go after climate change grants and the like. But, this doesn't align with state priorities because the state has so many other issues that rise to the top of the pile.		red drum and sea trout are big.	

				Lastly, SC has intertidal oysters and used to have subtidal oysters (no one knows if these latter populations still exist).			
Washington							
Impetus for State Efforts	**Stakeholder Engagement**	**Authority**	**Organization**	**Science and Risk Assessment**	**Messaging and Communications**	**Accomplishments and Policy**	**Limitations and Challenges**
Founding member of International OA Alliance Between 2005 and 2009, disastrous production failures at Pacific Northwest oyster hatcheries signaled a shift in ocean chemistry that had profound implications for Washington's marine environment. Billions of oyster larvae were dying at the hatcheries. Recognizing the risks of ocean acidification to Washington, Governor Christine Gregoire created the	Governor's 2012 Blue Ribbon Commission includes high level representatives of government, conservation groups, academia, tribes, fisheries. 2012 - Outgoing Governor Christine Gregoire announced $3.3 million to implement 2012 report recommendations and issued an Executive Order directing agencies to do so. In 2017, the legislature created a Governor-appointed board,	Original Blue Ribbon Commission was created by the Governor through Executive Order. Legislative Action led to establishment of the Marine Resource Advisory Commission with 27 appointees (RCW 43.06.338) and the UW Washington Ocean Acidification Center.	Governor's 2012 Commission is staffed by Washington State Department of Ecology, University of Washington and Washington Sea Grant. 2012 Report funded by: EPA, NOAA, philanthropies, academic institutions, fisheries partnership. The MRAC is a Governor's council and advises the Governor on the implementation of the state's plan. The Governor is actually a member of the council The CMP has a	Much of the focus has been on assessing vulnerability of specific species. Considerable investment has gone into improving forecasting of water quality conditions on biological impacts using improved modeling. Research has clearing pointed to diminished capacity of buffering conditions and the science community does not think the state can "buy time" and must act more aggressively.	Strong focus on historic, economic and cultural importance of fisheries industries. Washington is particularly vulnerable to ocean acidification because of regional factors that exacerbate the acidifying effects of global carbon dioxide emissions. One of the most important regional factors is coastal upwelling, which brings offshore water that is rich in carbon dioxide and low in pH up from the deep ocean and onto the continental shelf.	Governor's Blue Ribbon Commission issued a 2012 report, Ocean Acidification: From Knowledge to Action, Washington State's Strategic Response. Report is accompanied by a science report. The 2012 report recommended 42 actions in 6 areas: ● Reduce CO2 emissions; ● Reduce local land-based OA contributions; ● Increase ability to adapt to OA; ● Invest in WA's monitoring efforts; ● Inform, educate and engage stakeholders,	Few people reside on the coast and do not understand its importance; forming a regional partnership with other states was critical. The state pointed to the need for greater interagency coordination. The state would like to enhance involvement of secondary industries (restaurants, tourism, etc.)

Washington State Blue Ribbon Panel on Ocean Acidification to chart a course for addressing the causes and consequences of acidification. The Panel, convened in February 2012, was assembled under the auspices of the Washington Shellfish Initiative, a regional partnership established to implement the NOAA's National Shellfish Initiative. The Governor charged the Panel to: Review and summarize the current state of scientific knowledge of ocean acidification; Identify the research and monitoring needed to increase scientific understanding and improve resource management; Develop recommendations to respond to ocean acidification and reduce its harmful causes and effects; and Identify opportunities	Marine Resources Advisory Council (MRAC) which convenes scientists, state agencies, public members, industry representatives, conservation community representatives to issue updates to the state's OA Action Plan and evaluate the state's progress towards meeting the objectives of the plan. MRAC issued a 2017 update to the original Blue Ribbon Commission 2012 report.		representative on the Council. The Environmental Assessment group in the state Department of Ecology is a science group leading the monitoring and risk assessment efforts. The Secretary of the Natural Resource Agency is independently elected and not an appointee of the Governor. MRAC identifies where resources are needed and priorities for resources. MRAC plays a critical role of ensuring that the science community is communicating with policy-makers and to ensure coordination among different state agencies for consistent policy action.	Efforts focused on being more precise with using models to predict impacts to specific species temporally and spatially will directly inform efforts to bring more industry representatives into the discussions.	Ocean Acidification is a risk to Washington's Marine Species and Ecosystems. Many life processes, including photosynthesis, growth, respiration, recruitment, reproduction, and behavior are sensitive to carbon dioxide and pH. As a result, ocean acidification has the potential to affect a wide range of organisms, from seagrasses to fish, in many different ways. More than 30 percent of Puget Sound's marine species are vulnerable to ocean acidification by virtue of their dependency on the mineral calcium carbonate to make shells, skeletons, and other hard body parts.	the public and decision-makers; ● Maintain a coordinated focus on OA in all levels of government. 18 of the 42 actions were identified as "Key Early Actions." In 2017, the MRAC saw a need to re-evaluate the 2012 strategy given scientific advances. It issued a 2017 addendum to the 2012 report. WA climate policies designed to dramatically reduce the state's carbon dioxide emissions, including mandating 100% clean electricity by 2045, improving efficiency of buildings, and advancing electrification of the transportation sector from cars to ferries.	Need to now take the science that has been developed to advance better policy. The issue is still new enough that there is a need for a lot of education of legislators. These issues are controversial from a policy perspective because Puget Sound is development quickly.

to improve coordination and partnerships and to enhance public awareness and understanding of ocean acidification and how to address it. Commission members included: farm bureau, scientists, fisheries industry leaders, etc. Local NOAA scientist was also influential in advancing action.					Ocean Acidification is a Risk to Washington's Marine Economy and Tribes. Washington is the country's top provider of farmed oysters, clams, and mussels. Annual sales of farmed shellfish from Washington account for almost 85 percent of U.S. West Coast sales (including Alaska). The estimated total annual economic impact of shellfish aquaculture is $270 million, with shellfish growers directly and indirectly employing more than 3,200 people. Shellfish are also an integral part of Washington's commercial wild fisheries, generating over two-thirds of the harvest value of these fisheries. The economic benefits of Washington's wild and hatchery-based seafood harvests extend well beyond the value of the	WA established the Washington Ocean Acidification Center at the University of Washington to coordinate scientific investigations and the Marine Resources Advisory Council to oversee plan implementation. Research focused on improving the state's understanding of the role of seagrass and kelp in ameliorating local ocean acidification conditions through a variety of research activities and pilot projects. WA launched a conservation hatchery that serves as a hub for research on ocean acidification and restoration of shellfish, kelp, and other species.	

					harvest when it arrives on shore. For example, licensing for recreational shellfish harvesting generates $3 million annually in state revenue and recreational oyster and clam harvesters contribute more than $27 million annually to coastal economies. Overall, Washington's seafood industry generates over 42,000 jobs in Washington and contributes at least $1.7 billion to gross state product through profits and employment at neighborhood seafood restaurants, distributors, and retailers. Ocean acidification also has important cultural implications. To Washington's tribal communities, ocean acidification is a natural resource issue and a significant challenge to	Initiating enhanced and wide scale monitoring –with real-time sharing through the Northwest Association of Networked Ocean Observing Systems (NANOOS) –to collect data and support shellfish hatchery adaptation practices. Developed and enhanced oceanographic models that predict ocean acidification conditions through short-term forecasts and that aid evaluation of how much local land-based sources contribute to exacerbating acidification. Improved scientific capacity of state agencies to evaluate ocean acidification as it relates to their authorities and	

					their continued identity and cultural survival. With salmon at just a fraction of their former abundance, tribal fishers are depending more on shellfish to support their families; almost all of the commercial wild clam fisheries in Puget Sound are tribal. The tribes also harvest wild shellfish for ceremonial and subsistence purposes. Washington State will need to respond vigorously to ocean acidification if we are going to avoid significant and possibly irreversible losses to our marine environment and all it supports, including shellfish farming and wild harvest of shellfish and other commercially and culturally important marine species. Public	management of resources. Created K-12 curricula, garnering local and national media attention, and aiding development programs and exhibits by aquariums on ocean acidification to increase awareness and literacy among the public. Co-founding the International Alliance to Combat Ocean Acidification. Department of Ecology has instituted a general permit for retrofits to wastewater treatment plants mostly to address violations related to dissolved oxygen.	

					investment by the state is needed, as are public-private partnerships that promote innovative solutions to acidify-cation. Additionally, the Panel calls on Congress, the White House, NOAA, and other federal agencies to support our efforts to address acidification and, in particular, to take a leading role in the recommended research agenda so the nature of the problem facing Washington and the majority of other coastal states can be better understood and more effectively addressed.		

IV. Groundwork Toward Developing a New Jersey OA Observation and Research Plan

The purpose of Section IV of this report is to outline current monitoring efforts in New Jersey and current ecological research in New Jersey. With regard to monitoring, Section IV identifies current gaps in monitoring for OA as well as opportunities to build upon current monitoring efforts to develop a statewide, coordinated OA monitoring network. With regard to ecological research, Section IV outlines ongoing ecological research in New Jersey with a discussion of current ecological research, gaps in current research on OA ecological impacts, and a discussion on opportunities to build upon current ecological research to better understand and assess OA impacts and risks to specific species. Development of a comprehensive statewide OA Observation and Research Plan would need to be developed with the benefit of input and involvement of a wider group of experts during a formal OA Action Planning process. The discussion included in Section IV of this report serves to provide a point of departure for undertaking a more comprehensive OA monitoring and research plan.

Observations and Monitoring

Existing observations in NJ Waters:

Currently, there are 67 static stations in NJ waters that measure at least pH (Fig. 1a; a list of these stations is also included at the end of Section IV as *Table 1*). A majority of these static stations in New Jersey are monitored by NJDEP, but some are also Delaware River Basin Commission (DRBC), Barnegat Bay Partnership (BBP), Jacques Cousteau National Estuarine Research Reserve (JCNERR), and Rutgers Haskin Shellfish Research Laboratory (HSRL). The efforts include surface pH measurements but are driven primarily by larger-scale water quality observation objectives and can include several other parameters including temperature, salinity, dissolved oxygen (DO), and nutrients, but typically no other measurements of the carbonate chemistry (e.g. pCO_2, total alkalinity or TA, dissolve inorganic carbon or DIC). Over time, as entities identified acidification as an emerging threat, some efforts were made to add the sampling of a second carbonate chemistry

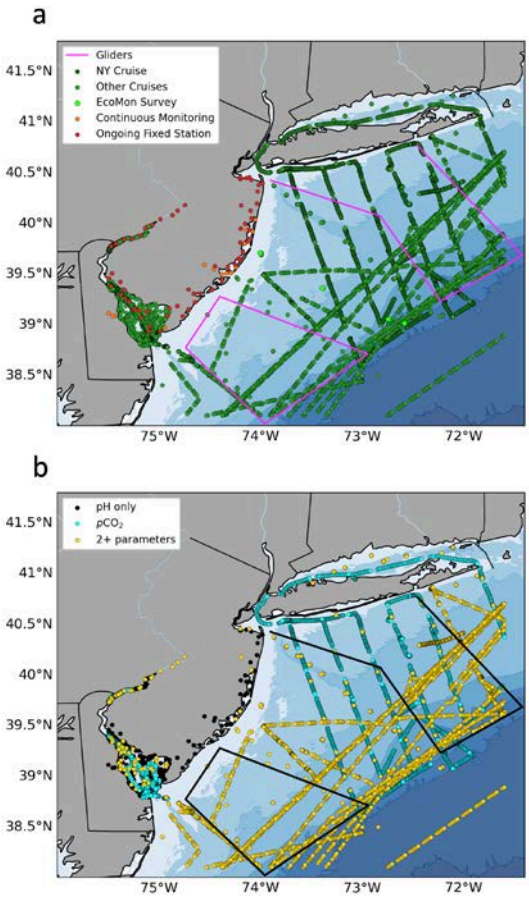

Fig 1. Current and ongoing observations in New Jersey Waters measuring at least one aspect of the carbonate system (a) and separated into type or number of carbonate chemistry parameter measured (b).

parameter to select stations in order to fully characterize the carbonate system and hence acidification, including the derivation of carbonate saturation state (Ω) which is a measure and proxy for calcifying conditions. Currently, 14 of these stations include one other carbonate chemistry parameter (13 stations with TA and 1 station with pCO_2).

Additionally, there are four ongoing efforts that include or solely focus on NJ marine shelf waters, and some are dedicated specifically to ocean acidification research (Fig. 1a). NOAA cruises that include or are specifically focused on carbonate chemistry measurements occur, on average, only once every four years (Ocean Margins Program or OMP: 1993-1996; Gulf of Mexico Ecosystems and Carbon Cruise or GOMECC: 2007, 2012; East Coast Ocean Acidification or ECOA: 2015, 2018). Cruises for NOAA Northeast Fisheries Science Center Ecosystem Monitoring (EcoMon) surveys have collected carbonate chemistry data (pH, TA, DIC) every Spring and Fall since about 2012. Seasonal cruises (2018-2028) supported by the New York State Department of Environmental Conservation (NYSDEC) measure surface pH and pCO_2 (continuous) and discrete pH, TA, DIC at depth in the New York Bight (north NJ shelf: Montauk to Hudson Canyon). Finally, Rutgers University (since 2018) and, starting in 2020, Stony Brook University use autonomous underwater gliders equipped with novel pH sensors to measure pH and derive TA seasonally in NJ coastal waters (Fig. 1a).

<u>Identified gaps in observations:</u>

Several gaps in observations were recently outlined for the Mid-Atlantic region in Goldsmith et al. (2019) and are relevant to those in NJ waters. These include:

- *Need for high sampling frequency*: With the exception of a few fixed autonomous stations (e.g., buoys), the sampling frequency is too low to adequately capture short-term episodic events that could have immediate impacts to industries and managed ecosystems.
- *Need for measurements of multiple carbonate chemistry parameters*: As described above, few current monitoring efforts combine frequent monitoring with an adequate number of carbonate system parameters for monitoring the status of acidification (Fig. 1b). Two or more parameters are needed to fully characterize carbonate chemistry and define the status of acidification.
- *Need for high-resolution depth-profiling measurements*: Most current sampling is done in surface waters, but subsurface waters are typically more acidic due to the biological remineralization of sinking particulate organic surface material. This has been observed in NJ coastal shelf waters (Saba et al. 2019b). Furthermore, this is not only a multi-stressor issue but also one of the most important gaps to address for coastal acidification due to subsurface or bottom waters becoming increasingly or episodically more acidic in response to eutrophication, simultaneously with decreasing dissolved oxygen (see below).
- *Need to observe OA with other stressors*: Other stressors such as temperature, pollutants (namely excess nutrients that result in eutrophication), algal blooms (both benign and harmful species), and hypoxia may also interact with the acidification of local inshore and nearshore waters.

- *Need for co-located biological response monitoring*: Because most of what we know about organism response is a result of single-species laboratory studies and may not capture realistic, natural conditions or variability, simultaneous measurements of biological response indicators (e.g., survival, development, productivity, growth) need to be co-located with carbonate chemistry observations.
- *Monitor across a salinity gradient*: It is important to monitor different habitats across different salinity gradients as well as major sources of inputs, such as rivers, wetlands, and upstream of source waters to understand the spectrum of impacts to the region. These efforts would account for the complexity of estuary, coastal and ocean environments and further identify potential areas of enhanced vulnerability.

<u>Recommended approaches to enhance and coordinate observations and monitoring</u>

Here we describe several specific actionable recommendations for addressing observation gaps outlined above and to facilitate coordination efforts for optimizing observations efficiently. A list of additional recommendations is provided at the end of Section IV in *Table 2.*

- *Develop a robust, coordinated acidification monitoring network*: MACAN has done the work in identifying locations of OA monitoring in the Mid-Atlantic, and we provide the description of those specific to NJ in Fig. 1a and *Table 1*. This information provides the opportunity to strategically link these efforts to develop a comprehensive statewide monitoring network that can cohesively act to identify observation gaps, coordinate observation efforts to maximize temporal and spatial coverage, and expand observing capabilities within the network cost-effectively by leveraging partners' stations through sensor and equipment augmentation. This network should also include a data synthesis component that regularly integrates statewide datasets that can be used to develop products for a range of industry and policy stakeholders such as reports indicating OA status and trends and creating an OA "report card".
- *Add a carbonate chemistry parameter in Rivers/Estuaries*: Several programs are currently monitoring a variety of water quality and other parameters for inshore and nearshore waters in New Jersey. The United States Geological Survey (USGS), JCNERR, NJDEP, the Barnegat Bay Partnership, NJ Fish & Wildlife, and a number of New Jersey educational and research institutions (Rutgers University, Stockton University, Monmouth University) operate water monitoring equipment at fixed stations within areas of importance (Fig. 2). In some cases, augmenting sampling efforts or upgrading established hardware with additional sensors would maximize the return on investment. Existing water quality stations that

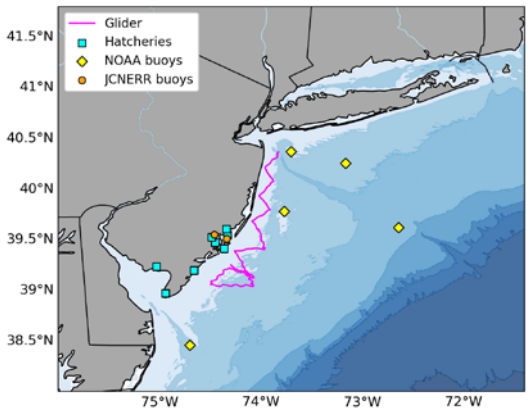

Fig. 2. A subset of existing platforms that could be optimized with sensors for carbonate chemistry observations and locations of New Jersey hatcheries that could partner with academic, state, or federal institutions to enable real-time monitoring capabilities.

are already observing temperature, specific conductivity, DO, and pH could be leveraged for acidification monitoring by either deploying a pCO_2 sensor or adding some discrete bottle sampling (pH, TA, and/or DIC) for quality assurance checks and calibration of the sensors.

- *Add a carbonate chemistry parameter in NJ shelf waters by leveraging existing buoy platforms*: There are several existing buoys in prime surfclam and sea scallop habitats operated by the National Data Buoy Center and U.S. Army Corp of Engineers that range between 20 and 200 km offshore on the NJ shelf where additional sensors could be incorporated to measure pH and pCO_2 along with temperature and salinity (Fig. 2). This would not only allow for including two or more carbonate chemistry sensors to fully characterize OA, but would also greatly enhance temporal resolution in these important habitats to capture episodic events (e.g., upwelling, big seasonal bloom) and seasonal cycles.
- *Add nearshore coastal glider-based monitoring*: NJDEP supports glider-based program for monitoring of dissolved oxygen near-shore (Fig. 2). The addition of a new glider-based pH sensor on these glider missions would add high spatial (horizontal and vertical) resolution sampling of pH in the nearshore system that is prone to coastal acidification driven by freshwater inputs and high biological activity.
- *Partnerships with industry for monitoring (hatcheries, aquaculture facilities, nurseries)*: One of the fastest growing global food sectors is the aquaculture industry, and New Jersey is primed for aquaculture growth. Monitoring upstream and downstream of oyster hatcheries would provide an opportunity to understand both upstream drivers (such as rain events) and downstream drivers (such as upwelling) (Fig. 2). This will require partnerships between the aquaculture industry and the scientific community to implement adequate monitoring, such as those successfully established on the West Coast.

Ecological Research

Summary of Existing Research:

Coastal and ocean acidification challenges the ability of calcifying organisms to deposit shell and have also been observed to affect hatching success, larval development, metabolic processes, immune response, organ development, acid-base regulation, and olfaction in both calcifying and non-calcifying organisms. Data compiled from a review of acidification and multi-stressor studies conducted on economically important groups and species in the Mid-Atlantic (Saba et al. 2019a), revealed that a majority of responses of organisms to OA conditions were negative (Fig. 3). However, this recent research has demonstrated highly variable responses of marine life to acidification and suggests the occurrence of species-specific differences, high phenotypic plasticity, and/or the potential for acclimation or adaptation that may lead to relative “winners” and “losers” in a future, more acidified ocean. And, generally, compared to adults, younger life stages (e.g. larvae) of animals tend to be more sensitive to increases in pCO_2, decreases in pH, and changes in Ω, in part due to effects on reduced calcification rates, increased dissolution rates, reduced growth, impaired development, acid-base disturbances, and/or changes in energy allocation.

Research gaps on NJ species:

New Jersey's commercial fishing industry is the fifth largest in the United States and provides over 50,000 jobs (2016; NOAA NMFS). The fishing and aquaculture industries contribute more than $1 billion annually to state's economy. The most commercially important shellfish species in New Jersey include the Atlantic sea scallop (*Placopecten magellanicus*), Ocean quahog (*Arctica islandica*), Atlantic surfclam (*Spisula solidissima*), blue crabs (*Callinectes sapidus*), and the eastern oyster (*Crassostrea virginica*). Sea scallops are the state's most valuable fishery, and NJ is the leading supplier for ocean quahog. The state also supplies significant amounts of commercially and recreationally important finfish (e.g., Atlantic mackerel [*Scomber scombrus*], summer flounder [*Paralichthys dentatus*], black sea bass [*Centropristis striata*]) and squid. Out of these listed studies, the eastern oyster is the most studies in terms of responses to ocean acidification (Saba et al. 2019a). However, OA-specific studies on other important species are severely lacking. Only one laboratory study has been focused on sea scallops, and only two OA-specific studies have focused on each of the following species: ocean quahog, blue crabs, summer flounder, and longfin squid (Saba et al. 2019a). Furthermore, of the 35 managed species in the Mid-Atlantic region, 69% (24 species) have not yet been investigated for acidification impacts (Saba et al. 2019a). This list includes several important to NJ fishing industry including, but not limited to, Atlantic surfclams, Atlantic mackerel, Atlantic menhaden, black sea bass, bluefish, butterfish, Illex squid, and horseshoe crabs (Saba et al. 2019a). Additional and new studies focused on these important species are needed to investigate their responses to acidification and specifically include:

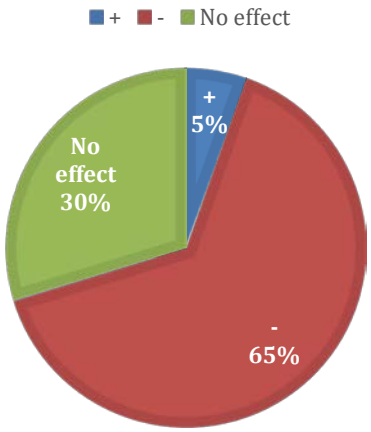

Fig. 3. Proportion of response directions (+ = positive, - = negative, no effect) of various processes of Mid-Atlantic studied organisms in response to ocean acidification conditions. Responses included one or more of these parameters: Survival, calcification rate, growth rate, development, fertilization success, hatching success, behavior, otolith formation, swimming ability, and swimming activity, and feeding. For the few species that showed an OA-related positive trend in one process (i.e., growth), the negative responses observed in other processes for that same species (hatching success, survival, etc.) greatly outnumbered those positive responses.

- The potential impacts to various life stages
- Acclimation and adaptation potential of species and transgenerational responses,
- Potential thresholds of acidification (either pH/saturation state values or extremes) for if and when a species may be lost due to ongoing acidification.
- How altered acidification-induced changes in biotic interactions will impact the food web, populations dynamics, and community structure

Approaches to enhance knowledge of organism and ecosystem response:

Here we outline several specific recommendations for research to not only improve our knowledge of how organisms and ecosystems respond to acidification, in addition to other stressors, but also to better understand acidification impacts on NJ economy and prepare for this emerging threat.

- *Connect observations with organism responses in the field*: Wild-caught species (sea scallops, surf clams, flounder, black sea bass, etc.) require a combination of field studies and observational efforts to better understand their natural range of conditions, how seasonality of conditions is timed with life histories (e.g., spawning), and *in situ* responses to low pH and Ω conditions (e.g., survival, development, growth, feeding, energy partitioning, predation rates).
- *Improve experimental approaches*: Laboratory experiments should incorporate realistic environmental variability and gradients, include interactions with other environmental stressors, and increase transferability to other systems or organisms.
- *Develop ecosystem and forecast models*: These models can move beyond single-species impacts of acidification and incorporate predator-prey, food web, and multi-stressor interactions to better inform large-scale ecosystem responses and enable realistic projections of OA impacts.
- *Continue and expand research on shellfish genetics to breed OA resilient species for aquaculture industry*: In addition to supporting this research in NJ aquaculture facilities, NJ benefits from some of its organisms thriving in naturally low pH waters (e.g., central and southern watershed in Pinelands area), and thus could utilize these unique habitats for experimental and genetic research.
- *Investigate mitigation strategies for aquaculture facilities, hatcheries, nurseries, and impacted waterways*: NJ can learn from mitigation techniques (e.g., buffering incoming seawater) currently being used in oyster facilities in the Pacific Northwest and in Maine for potential modification and adoption to proactively prepare for emerging acidification impacts. Additionally, SAV restoration for natural OA mitigation could be a conceivable approach in certain locations like Barnegat Bay.
- *Connect organism and ecosystem responses to ecosystem services and the economy*: This will provide improved predictions of economic scenario analyses and vulnerability assessments.

Table 1. ***Current and ongoing observations in New Jersey Waters measuring at least one aspect of the carbonate system.***

Site name	Location	Type	Entity	Parameters	Sampling type	Timestamp	Water type	Depth
R53 Keyport Harbor	Raritan watershed	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Freshwater	Surface
R65 Waackaack Creek	Raritan watershed	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Freshwater	Surface
R67 Compton Creek	Raritan watershed	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Freshwater	Surface
RB_01	Raritan Bay	ongoing fixed station/continuous	NJDEP	pH, TA	buoy	15 minute intervals	Estuarine	Surface
RB_02	Raritan Bay	ongoing fixed station/continuous	NJDEP	pH, TA	buoy	15 minute intervals	Estuarine	Surface
900B Shrewsbury River	Raritan watershed	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Freshwater	Surface
1013G Navesink River	Raritan watershed	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Freshwater	Surface
R59 Oceanport Creek	Raritan watershed	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Freshwater	Surface
1217A Shark River	Outlet to coast	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Freshwater	Surface
BFBM000258	Inland	ongoing fixed station/continuous	NJDEP	pH, TA	buoy	15 minute intervals	Freshwater	Surface
R07 Manasquan River	Outlet to coast	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Freshwater	Surface
MR-01	Barnegat Bay watershed	ongoing fixed station/continuous	NJDEP	pH, TA	buoy	15 minute intervals	Freshwater	Surface
Mantoloking Yacht Club	Barnegat Bay	Continuous	BBP	pH	buoy	15 minute intervals	Estuarine	Surface
R10 Silver Bay	Barnegat Bay watershed	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Freshwater	Surface
R11 Toms River	Barnegat Bay watershed	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Freshwater	Surface
1632B Barnegat Bay	Barnegat Bay	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Estuarine	Surface
BB04a: Buoy	Barnegat Bay	Continuous	NJDEP	pH	buoy	15 minute intervals	Estuarine	Surface
Seaside Park Yacht Club	Barnegat Bay	Continuous	BBP	pH	buoy	15 minute intervals	Estuarine	Surface
1651D Barnegat Bay	Barnegat Bay	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Estuarine	Surface
1661D Barnegat Bay	Barnegat Bay	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Estuarine	Surface
BB07a: Buoy	Barnegat Bay	Continuous	NJDEP	pH	buoy	15 minute intervals	Estuarine	Surface
R14A Oyster Creek	Barnegat Bay watershed	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Freshwater	Surface
1675 Gunning River	Barnegat Bay watershed	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Freshwater	Surface
BB10: Buoy	Barnegat Bay	Continuous	NJDEP	pH	buoy	15 minute intervals	Estuarine	Surface
1706 Mill Creek	Barnegat Bay watershed	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Freshwater	Surface
MB_01	Barnegat Bay	ongoing fixed station/continuous	NJDEP	pH, TA	discrete water samples	quarterly to monthly	Estuarine	Surface
1800B Little Egg Harbor	Barnegat Bay	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Estuarine	Surface
1818D Little Egg Harbor	Barnegat Bay	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Estuarine	Surface
Beach Haven	Barnegat Bay	Continuous	BBP	pH, pCO2	buoy	15 minute intervals	Estuarine	Surface
Buoy 115	Barnegat Bay	Continuous	JCNERR	pH	buoy	15 minute intervals	Estuarine	Surface
BB14: Buoy	Barnegat Bay	Continuous	NJDEP	pH	buoy	15 minute intervals	Estuarine	Surface
Buoy 126	Great Bay	Continuous	JCNERR	pH	buoy	15 minute intervals	Estuarine	Surface
Buoy 139	Great Bay	Continuous	JCNERR	pH	buoy	15 minute intervals	Estuarine	Surface
Chestnut Neck	Great Bay	Continuous	JCNERR	pH	buoy	15 minute intervals	Freshwater	Surface
Lower Bank	Great Bay	Continuous	JCNERR	pH	buoy	15 minute intervals	Freshwater	Surface
R25 Bass River	Great Bay watershed	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Freshwater	Surface
2106A Brigantine Channel	Brigantine Channel	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Estuarine	Surface
2536 Inside Thorofare	coast	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Estuarine	Surface
2712 Great Egg Harbor Bay	Great Egg Harbor Bay	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Estuarine	Surface
2900 Great Egg Harbor River	Great Egg Harbor watershed	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Freshwater	Surface
2812 Great Egg Harbor River	Great Egg Harbor watershed	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Freshwater	Surface
3101A Weakfish Creek	coast	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Freshwater	Surface
3201 Ludlam Thorofare	coast	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Freshwater	Surface
3312 Gull Island Thorofare	coast	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Freshwater	Surface
Aquaculture Innovation Center	Cape May Inlet	Continuous	Rutgers HSRL	pH	buoy	15 minute intervals	Estuarine	Surface
R38 Dennis Creek	Delaware Bay watershed	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Freshwater	Surface
3826A Delaware Bay	Delaware Bay	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Estuarine	Surface
3827 Delaware Bay	Delaware Bay	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Estuarine	Surface
South Brown Shoal (RM 6.5)	Delaware Bay	Ongoing fixed station	DRBC	pH, TA	discrete water samples	once per month, Apr-Oct	Estuarine	Surface
3895E Delaware Bay	Delaware Bay	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Estuarine	Surface
3888I Delaware Bay	Delaware Bay	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Estuarine	Surface
South Joe Flogger Shoal (RM 16.5)	Delaware Bay	Ongoing fixed station	DRBC	pH, TA	discrete water samples	once per month, Apr-Oct	Estuarine	Surface
3845P Delaware Bay	Delaware Bay	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Estuarine	Surface
3849B Delaware Bay	Delaware Bay	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Estuarine	Surface
3868 Delaware Bay	Delaware Bay	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Estuarine	Surface
Elbow of Crossledge Shoal (RM 22.75)	Delaware Bay	Ongoing fixed station	DRBC	pH, TA	discrete water samples	once per month, Apr-Oct	Estuarine	Surface
Mahon River (RM 31.0)	Delaware Bay	Ongoing fixed station	DRBC	pH, TA	discrete water samples	once per month, Apr-Oct	Estuarine	Surface
3800 Delaware Bay	Delaware Bay	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Estuarine	Surface
4101G Cohansey Cove	Delaware Bay	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Estuarine	Surface
Ship John Light (RM 36.6)	Delaware Bay	Ongoing fixed station	DRBC	pH, TA	discrete water samples	once per month, Apr-Oct	Estuarine	Surface
Smyrna River (RM 44.0)	Delaware River	Ongoing fixed station	DRBC	pH, TA	discrete water samples	once per month, Apr-Oct	Freshwater	Surface
R51 Stow Creek	Delaware Bay watershed	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Freshwater	Surface
3826A Delaware Bay	Delaware River	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Freshwater	Surface
R55 Hope Creek	Delaware Bay watershed	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Freshwater	Surface
Liston Point (RM 48.2)	Delaware River	Ongoing fixed station	DRBC	pH, TA	discrete water samples	once per month, Apr-Oct	Freshwater	Surface
Reedy Island (RM 54.9)	Delaware River	Ongoing fixed station	DRBC	pH, TA	discrete water samples	once per month, Apr-Oct	Freshwater	Surface
R56 Alloway Creek	Delaware River	Ongoing fixed station	NJDEP	pH	discrete water samples	quarterly to monthly	Freshwater	Surface
OMP/GOMEC/ECOA	NJ Shelf	Cruise	NOAA	pH, DIC, TA, pCO2	discrete water samples, continuous (pCO2)	about every 4 years	Marine	3-6 depths in water column
EcoMon	NJ Shelf	Cruise	NOAA	pH, DIC, TA, pCO2	discrete water samples, continuous (pCO2, TA [after 2016])	fall, spring	Marine	Surface, mid, 10m from bottom
NYSDEC cruises	NJ shelf	Cruise	NYSDEC	pH, DIC, TA		seasonal	Marine	3-6 depths in water column
Glider	NJ Shelf	Autonomous platform	Rutgers/SBU	pH, TA	continuous	seasonal	Marine	full water column

Table 2. ***Actionable recommendations for filling observation gaps and building and optimizing carbonate chemistry observations in New Jersey.***

Water Body Type	Actionable Recommendation	Observational Gap to Fill	Notes
Rivers/Estuaries/Shelf	Add total alkalinity to all or select stations with pH data	Need for measurements of multiple carbonate chemistry parameters, Need to observe OA with other stressors	"select" criteria: those with high FW contributions, range to capture various soil/rock types to see weathering impacts on TA
Rivers/Estuaries	Data synthesis of carb chem variability and long-term change	Characterize variability, identify hot spots, determine if/rate of long-term change in NJ waters	
Rivers/Estuaries	Add sampling stations in Hudson-Raritan estuary	Monitor across a salinity gradient, add spatial resolution to our understanding of acidification in the region	
Estuaries (main stem of bays)	At select stations, add discrete sampling at depth (minimum effort : mid-depth [see Cai et al. 2017 - CB] and few meters above bottom)	Need for high-resolution depth-profiling measurements, Need to observe OA with other stressors	"select" criteria: deeper stations (greater than 15-20m)
Estuaries/Shelf	Development or refinement of ecosystem and biogeochemical models	Inform potential ecosystem responses to OA and other stressors	
Estuaries/Shelf	Short-term, long-term model projections	Predict variability and trajectory of low pH and carbonate concentrations	
Estuaries/Shelf	Data synthesis of carb chemistry with biological observations (e.g., primary productivity, fisheries distribution and recruitment)	Need for co-located biological response monitoring, Inform potential ecosystem responses to OA and other stressors, identify hot spots or vulnerable species/habitats/communities	
Shelf	Support continuation of existing seasonal (at minimum) monitoring	Need for high sampling frequency, Need for high-resolution depth-profiling measurements, Need for co-located biological response monitoring	
Shelf	Increase temporal resolution by adding buoy systems in shelf waters (e.g., Cold Pool, surf clam and sea scallop habitat)	Need for high sampling frequency, Need for high-resolution depth-profiling measurements, Need for co-located biological response monitoring, conduct or continue monitoring in specific ecological regions that may have enhanced vulnerability	
Shelf	Add nearshore coastal glider- or ship-based monitoring	Need to observe OA with other stressors (low DO, warmer, eutrophication, OA); current data showing low pH/saturation state with freshwater inputs	

V. Potential Outline of an OA Plan for New Jersey and Approaches to its Development

Eight states reviewed for this report have joined the International OA Alliance as government members. Joining the OA Alliance involves government members endorsing the Alliance's "Call to Action" (https://www.oaalliance.org/call-to-action/) and making public commitments to broadly support five goals within the Call and develop statewide OA Action Plans that include components addressing the five goals:

1. **Advance Scientific Understanding:** Improve the understanding of OA globally and within the members' regions, including support for research and OA observations within their region.
2. **Reduce Causes of OA:** Implement actions that will prevent or slow OA through reducing atmospheric emissions of CO_2, reducing inputs of land-based pollutants, and other measures.
3. **Build Adaptation and Resiliency:** Implement actions to assist ocean-dependent communities and industries, and marine ecosystems to adapt to increasing acidity in marine waters.
4. **Expand Public Awareness:** Engage policy makers, scientists and the public on the growing threat posed by OA, as well as local actions that may be taken to address OA.
5. **Build Sustained International Support:** Secure sustained funding, nationally and regionally, for ongoing, enhanced, and coordinated research and OA observation systems, to continue to inform governments and others about the increasing impacts of OA.

States that were interviewed for this report indicate receiving support for their individual OA efforts by the Alliance. In particular, states pointed to the benefit provided by participating in the OA through exchange of information on the most recent and relevant science and best practices. Recently, the OA Alliance issued a "toolkit" that guides members through the potential content of and approach to developing an OA Action Plan. (https://www.oaalliance.org/). Alliance members participate in member webinars, calls, and organize periodic convening of members at international oceans and climate-related meetings.

There is also no monetary cost to join the Alliance. The Alliance explains that their aim, "is to bring in diverse members at all stages of investment and understanding. [The Alliance is] looking for consistent engagement and commitments that demonstrate strong support for advancing Alliance goals. Individual member commitments are made completely in keeping with their own determined ability to meet goals set forth in a unique OA Action Plan. Over time, and in keeping with the Alliance's jointly developed work plan, there may be opportunities for interested members to commit resources that help advance specific projects, priority issues or support Alliance events, if desired." Joining the Alliance imposes no legally binding requirements or obligations enforceable in any court of law or other tribunal of any sort. Similarly, joining the Alliance also does not create any funding expectation on New Jersey or any other member governments.

Elements of an OA Action Plan:

In general, OA Action Plans describe real, tangible actions that members are taking—or will take—to better understand and respond to the threat of ocean acidification and other climate-ocean stressors and impacts. According to the OA Alliance, "OA Action plans will not all have the same framework or structure, for example some members may choose to write a stand-alone plan, while others may decide to address ocean acidification mitigation, adaptation and resiliency within existing Climate Action Plans, Ocean Action Plans, Nationally Determined Contributions pursuant to the Paris Climate Agreement, or decide to integrate actions across ecosystem management tools. The Alliances encourages Affiliate members to create OA Action Plans that describe how they can use their capacity to support and encourage actions that mitigate, adapt and build resiliency to OA and serve a critical role in education, outreach, data gathering, information sharing."

Steps to Creating a New Jersey OA Action Plan:

In general, the following approach would be consistent with the elements for an OA Action Plan outlined in the Alliance Toolkit:

1. Review experiences of other states. The summary of efforts, and insights from reviewing those efforts, outlined in Sections II and III of this report provides a sound basis for such an effort.
2. Assess the current state of science, research and monitoring on OA in the state. The summary of research and monitoring efforts included in this report provides a sound basis for such an effort. Further engagement with the research community and organizations that host monitoring stations is critically needed.
3. Identify state priorities and any actions already being taken to address OA to identify what Alliance Action goal(s) may be most relevant to New Jersey. For example, New Jersey may want to consider whether an OA effort become an extension of its climate resilience efforts and/or if a distinct multi-stressor initiative would be most effective.
4. New Jersey would also need to give consideration to an effective process to advance an OA Action Plan, including involvement of other state agencies, stakeholders, and the research community.
5. Development of an OA Action Plan is also an opportunity for New Jersey to highlight what is already underway in the state and how it aligns with the Alliance *Call to Action* goals.

Outline of Possible OA Action Plan:

The following is an overview of the potential sections New Jersey could consider including in their OA Action Plan. The sections are largely informed by the OA Action Plans developed in California, Oregon, and Washington. Interspersed are elements from other states' OA efforts that may be of interest to New Jersey, including the New York Ocean Action Plan 2017-2027.

1. Letter from Governor endorsing the OA Action Plan.
2. Executive Summary
    a. This section could be a place to provide an overview of what OA is, what the impacts of OA are to New Jersey (ecologically, economically, socially to vulnerable populations, etc.), the Call to Action goal(s) New Jersey is addressing, and an overview of the actions

New Jersey will take to adapt to and mitigate OA impacts outlined in more detail in the body of the Action Plan.

b. Washington State included a sub-section called, "Time to Act" in their summary. This section serves to energize and gives urgency to the issue.

3. Part 1: Introduction
   a. Summarize the current scientific understanding of the causes and consequences of OA in New Jersey waters.
      i. Identify OA Causes and Trends
      ii. Highlight Contributing Processes and Regional Distinctions to New Jersey OA
      iii. Call out species and ecosystem responses to OA
   b. Provide a background of New Jersey efforts to address OA.
   c. Describe stakeholder engagement process implemented in the development of the OA Action Plan
      i. California included a timeline of key steps in developing their OA Action Plan and color coded who was involved in that individual step (*e.g.* west coast individuals, federal partners, California agencies, and international engagement efforts). See page 9 in the State of California Ocean Acidification Action Plan. Scientists and other stakeholders (*e.g.* industry groups) may be helpful to highlight in a figure like this to highlight the collaborative nature of the OA Action Plan.
   d. Outline the scope of New Jersey's OA Action Plan to set the stage for remainder of the document.
      i. Identify how this effort aligns with other ongoing New Jersey climate actions/groups and how that relationship will be maintained into the future.
      ii. Identify how this effort aligns with other priorities, such as efforts to address multiple stressors of coastal resources, including fishing and shellfishing industries.
4. Part 2: Vision and Strategies for Action on Ocean Acidification
   a. This section is where New Jersey could identify priority Call to Action goal(s).
      i. For each goal, California explained the underlying rationale for wanting to address that goal, provides a 5-year plan to achieve that goal, and identify a set of specific tractable actions that will need to be translated into operational steps by state agencies.
      ii. Washington State provided a table to outline each goal it intended to address, up to four strategies to accomplish each goal, and identified specific actions to achieve each strategy. Each goal was then addressed in its own subsection.
      iii. Oregon's OA Action Plan was less detailed but effective. For each goal, Oregon identified their vision of what they wanted to accomplish, spelled out specific steps to reach that vision, and a timeline for each step.
   b. California, Oregon, and Washington highlight strategies to ensure effective and efficient multi-agency coordination and collaboration.
   c. If any of New Jersey's strategies for OA Action cover multiple Call to Action goals, it could be helpful to highlight that integration.
      i. California created a helpful table to clearly demonstrate visually how each strategy aligned with the five Call to Action goals. See page 47 of Appendix 1 in the State of California Ocean Acidification Action Plan.

d. If New Jersey is interested in pursuing a regional effort, it could consider consulting with New York's Ocean Acidification Task Force when developing these strategies. New York's OA Action Plan is expected to be published December 2022. It could be helpful to have similar language/commitments in each Action Plan to ensure any regional coordination efforts have a strong Action Plan foundation to turn to.
e. Alternatively, New Jersey may also want to consider making separate sections for each of their strategies to improve the flow of their OA Action Plan.

5. Part 3: Conclusion and Plans for Moving Forward
   a. This section of state OA Plans is generally a place to offer implementation strategies.
   b. An Evaluation sub-section may also be helpful here.
      i. How will OA Action Plan progress be tracked and evaluated? This could be an important component for stakeholders and members of the public who want transparency in how goals are achieved.
      ii. Oregon identified the following success measures: timely completion of identified actions in OA Action Plan, successful implementation of actions at achieving the vision and goals in the OA Action Plan, achievement of criteria or benchmarks developed on a per action basis as each action is implemented, and updating research priorities as they are identified.
6. Appendices
   a. This section can vary in length and purpose depending on the needs of New Jersey.
      i. Oregon created many two-page appendices that could be helpful in communicating with stakeholders about OA issues in the state (*e.g.,* an overview of research needs, a species spotlight on salmon).
      ii. California and Washington's appendices are aimed more at providing additional details and context for what is highlighted in the body of their OA Action Plan.
      iii. New York's Ocean Action Plan includes an appendix on Management Authority (see page 83) and Priority Projects (see page 95) that provide additional context and impetus for specific ocean actions moving forward. A similar structure could be helpful to New Jersey.

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