The Changing Tides of Action to Address Ocean Acidification in Maine

by Ivy L. Frignoca and Heather R. Kenyon

INTRODUCTION

Summers in Maine evoke images of eating lobsters and steamers drizzled in butter, feasting upon oysters, slurping quahog chowder, or supping on steamed mussels drenched in savory broth. Imagine if Maine had no shellfish, or if the health of those shellfish was threatened by changes to the cold, salty waters in which they live. Unfortunately, those changes are happening, are projected to continue, and are known as ocean and coastal acidification. Here, we outline how Maine's communities, policymakers, and scientists are tackling this problem to preserve this facet of life in Maine.

OCEAN ACIDIFICATION

Since the start of the industrial revolution, the concentration of atmospheric greenhouse gases (including carbon dioxide) has exponentially increased. Between 1970 and 2010, carbon dioxide emissions from fossil fuel combustion and industrial processes contributed about 78 percent of the total increase in greenhouse gas emissions (IPCC 2014). While news stories often focus on the extreme temperatures and intense storms that result from these increased emissions, the ocean also suffers. It absorbs about 30 percent of all carbon dioxide released into the atmosphere (Gruber et al. 2019), and when the carbon dioxide combines with seawater, a series of chemical reactions occur that make the ocean more acidic. As seawater becomes more acidic, calcium carbonate, which is typically available in abundance, becomes less available for marine organisms to build shells and skeletons. Under conditions of severe acidification, shells may even dissolve.

The Pacific Northwest was the first region to suffer the detrimental effects of ocean acidification. In 2007 and 2008, the Whiskey Creek Shellfish Hatchery experienced unprecedented mortality rate of young oysters and identified the acidified seawater flowing into the hatchery as the cause (Barton et al. 2015). By 2010, the Pacific Coastal Shellfish Growers Association established a full monitoring program funded by the National Oceanic Atmospheric Administration (NOAA). The state of Washington then formed an official panel to address the issue (WSBRP 2012) and funded it with support from the Washington Shellfish Initiative, a regional partnership established to implement NOAA's National Shellfish Initiative. The panel was charged with laying the groundwork for addressing the causes and consequences of ocean acidification and established a framework for ongoing funding and work to address ocean acidification in the state and region.

Meanwhile, a marine scientist in Maine wondered if wild bivalves also suffered from acidified conditions and designed an extensive experiment to determine the answer (Green et al. 2009). The results indicated that conditions in mudflats may be corrosive enough to dissolve certain-sized juvenile clams that had settled in the mud. The authors note that changes in ocean chemistry have the potential to cause those conditions, citing oceanic carbon dioxide absorption and coastal eutrophication (which can be caused by nutrient runoff from land) as reasons for changed conditions.

In 2009, a Maine hatchery, Mook Sea Farms, began documenting a drop in pH (an increase in acidity) of the water they draw into the hatchery to rear oyster larvae (Arnold 2020). This drop in pH occurred after storms, as water ran off the landscape into the salty Damariscotta River. It correlated with longer larval phases, larval deformities, and sometimes complete losses of cohorts.[1] Other Maine researchers then began to wonder what impact acidification had on lobster, Maine's most lucrative crustacean (Niemisto et al. 2021). Although more research remains to be done, it appears that ocean acidification combined with rising ocean temperatures affects post-larval lobsters on a genetic scale.

Ocean acidification was not just a West Coast problem; the facts showed it clearly harmed Maine's iconic farmed and wild shellfish too. If Maine did not act, it could lose these fisheries, and a crucial element of our economy, tourism, cuisine, and way of life.

CREATING POLICY

With the problem identified at the most basic level, the question became how Maine could address ocean and coastal acidification when we had limited understanding and data regarding the problem. The answer was, and is, that science and policy must advance in

lockstep, from recognizing the problem, to collecting the best available science to inform management and policy, and to filling data gaps, which will increase understanding and lead to adaptations in policy and management.

Ocean Acidification Study Commission

In 2014, Maine became the first East Coast state to recognize and address ocean acidification by passing a resolve to create an Ocean Acidification Study Commission (Chapter 110, Resolve 2014). The resolve focused on the detrimental effects of acidification to commercial shellfish rather than on the causes of acidification. It was strategically written this way because climate change was (and in some arenas still is) a divisive topic, while protecting Maine's valuable fisheries unites us and rises above politics.

With this framing, the bill garnered strong and diverse support including from Maine's environmental community, fishermen and aquaculturists, shellfish managers, and state officials (Public Hearing Testimony 2014).[2] The resolve created a six-month study commission that included legislators, scientists, resource managers, commercial fishermen, aquaculturists, and representatives from nonprofits dedicated to protecting Maine's ocean and fisheries. Both the composition of the commission and its mandate ensured that Maine identified the best available data to inform management and policy. At its conclusion, the commission submitted its report to the legislature (MOAC 2015).

The report addressed the factors contributing to ocean and coastal acidification; how to mitigate it; critical scientific data and knowledge gaps pertaining to our understanding of this acidification and its effects; steps to strengthen existing scientific monitoring, research, and analysis; and included recommendations to the legislature regarding next steps and ways to increase public awareness. It also contained six goals:

1. invest in monitoring ocean acidification and its impacts on commercially important species;
2. reduce carbon emissions;
3. reduce land-based sources of nutrients and organic carbon that cause coastal acidification;
4. increase Maine's capacity to mitigate, remediate and adapt to the impacts of ocean acidification;
5. inform stakeholders, the public and decision-makers about ocean acidification and empower them to act; and
6. maintain a sustained and coordinated focus on ocean acidification.

The report further included detailed recommendations to achieve those goals. Lastly, the study commission drafted proposed legislation to create and fund an on-going council to carry out the recommendations.

The Pivot: Maine Ocean and Coastal Acidification Partnership

At this point, Maine hit a road block. Then Governor LePage opposed creating an ongoing council, citing lack of staff and funding. Maine, therefore, could not follow the path taken by Washington State, which did establish and fund an on-going commission. Nonetheless, Maine stakeholders agreed to informally address ocean and coastal acidification without state-sanctioned policy. Those who worked together to pass the resolve now had to envision another path forward.

In 2015, those stakeholders held a series of meetings to explore creating a voluntary partnership to advance the study commission's recommendations. By 2016, they created the Maine Ocean and Coastal Acidification (MOCA) partnership. MOCA quickly grew to over 200 members including hatchery owners, oyster farmers, state and local officials, scientists, ocean advocates, state legislators, and others. MOCA formed a steering committee, set up a web page,[3] and established its purposes: to implement the study commission's recommendations, to coordinate advancements in research, and to effectuate the means to reduce the impacts of ocean and coastal acidification.

MOCA remained active from 2016 to 2019 and drew together a statewide network of scientists and policymakers. During the field season, scientists compared instruments and methodology while they were out in the field. In the off season, MOCA hosted meetings that typically drew audiences of over 100 participants. The meetings provided a means for scientists to share their data, spark collaborative review, and advance techniques and methodologies. For example, different instruments can be used to measure the acidity of seawater.[4] Additionally, the meetings served as a forum for advancing federal, state, and local policy and shellfish management. Management updates included actions taken by shellfish hatcheries and farmers to adjust operations to minimize the effects of acidification, and studies of the impacts of ocean and coastal acidification on wild populations, especially Maine's soft-shelled clams. Policy updates included discussions of nutrient criteria and setting nitrogen monitoring requirements and discharge limits in Clean Water Act pollution discharge permits; the federal Environmental Protection Agency's recognition that ocean acidification qualifies as a water quality impairment;[5] along with contemplating changes

to the state's current water quality standards. Finally, MOCA created an email distribution list to send newsletters and updates and to foster further conversation among stakeholders on science, management, and policy.

Although this wholly voluntary partnership belonged to no entity, had no independent funding, and no formal staffing, it drew regional and national attention as an effective way to advance science and policy until such time as a state had the staffing, funding, and mandate to assume leadership. During its three-year tenure, MOCA facilitated a coastwide collaboration and culture in which people willingly worked together to share equipment, knowledge, and ideas. The immense benefits of this approach carry through to the present.

Formal Leadership: Maine Creates a Climate Council

In 2019, Maine elected Janet Mills as governor. Shortly after she became governor, Mills worked with the legislature to create the bipartisan Maine Climate Council. The council included a Science and Technical Subcommittee to gather and analyze the best available data, and six expert working groups to recommend policy based on that science. The council was tasked with creating a state climate action plan, to be updated every four years (38 MRS § 577(1)).

The bill that created the council advanced ocean and coastal acidification policy in two significant ways: it clearly identified climate change as the cause of acidification, and it mandated that the state address ocean and coastal acidification in its climate action plan (38 MRS § 577-A(6)(D) and A(8)). With these advancements and formal state leadership, the question became how to transition the knowledge gained from MOCA to the Maine Climate Council, which wished to build upon existing efforts (See 38 MRS § 577-A(8)(D)).[6]

To effectuate the transition, MOCA took two actions. First, its steering committee asked MOCA's most active members to complete templates listing what they had accomplished since 2015 and what they planned to do in the future to meet the recommendations identified by Maine's Ocean Acidification Study Commission. Second, MOCA hosted three stakeholder discussions on the topics of research and monitoring, policy and law, and resiliency and adaptation. Twenty to twenty-five people attended each meeting, and representatives of the Mills' administration attended all three meetings. The research and monitoring meeting drew renowned researchers whose work had advanced Maine's understanding of ocean acidification and climate change. The policy and law meeting drew staff from Congresswomen Pingree and Senator Collins' offices, members of the Maine Legislature's Joint Standing Committees on Environment and Natural Resources and Marine Resources, and noted professors and marine advocates. The resiliency and adaptation meeting commingled several areas of expertise, including people who were experimenting with mitigation, remediation, and adaptive strategies. MOCA synthesized the recommendations from these meetings into a report that it presented to the council (MOCA 2019). In addition, most MOCA steering committee members were appointed roles on the MCC, the Science and Technical Subcommittee, the Coastal and Marine Working Group, and the Community Resilience Working Group.

MOCA's science informed the Science and Technical Subcommittee's 2020 report (MCC STS 2020), and its recommendations evolved into detailed actions developed by the Coastal and Marine Working Group (MCC CMWG 2020). Both were captured in the Maine Won't Wait Climate Action Plan (MCC 2020). The plan acknowledges that rising greenhouse gases will cause rapid ocean acidification, continue to affect marine organisms that need calcium carbonate to build shells, and continue to harm both wild and farmed shellfish. It also identified the need to start a coordinated, comprehensive monitoring system that includes acidification parameters by 2024. Ultimately, the climate action plan formalized the need for standardized, uniform monitoring germinated by Maine's 2014 Ocean Acidification Study Commission and fledged through MOCA.

Maine Ocean Climate Collaborative

Although uniform monitoring sounds easy, it is quite the opposite. Diverse Maine entities (including public and private universities and colleges, federal and state agencies, nonprofits, and marine science institutes), measure and collect data on ocean and coastal acidification. These entities have vastly different equipment, budgets, and funding mechanisms. In addition, as scientists study ocean and coastal acidification, questions and discoveries continually arise. These include concerns regarding which instruments produce the most accurate data, how best to calculate precise methods for translating data into real-world effects, and how to address challenges posed during the pandemic such as supply chain issues and discontinued equipment.

By 2021, a smaller group of scientists, some from MOCA and some new, banded together to create the monitoring program contemplated by the climate action plan. This partnership is known as the Maine Ocean Climate Collaborative (MOCC). Like MOCA, it is a public-private collaboration facilitated by a nongovernmental entity. Unlike MOCA,

the state participates in this monitoring program as a way to fulfill a state climate action goal and funds acidification research carried out by state scientists. The MOCC has accomplished three important tasks thus far.

First, the full MOCC has met at least twice year since its inception, discussing in depth the suite of instruments available to monitor ocean acidification. Second, MOCC members created a shared drive where they post updates regarding the equipment they are using, how well it works and the problems they encounter. Third, a subset of MOCC scientists received a two-year grant to test equipment and protocols, using the University of New Hampshire's Coastal Marine Lab as a hub for analysis. With input from the full MOCC, this subgroup will create a report that details recommended technology, methods, and quality assurance protocols. This report will be useful for creating the uniform monitoring network contemplated by the state's climate action plan. The Northeast Coastal Acidification Network (NECAN)[7] also plans to use the report as a model for other states. Finally, the report will be used to assist the state as it begins drafting its next four-year climate action plan, due December 2024.

In concert with this evolution in monitoring, ocean and coastal acidification policy continues to take big steps. The climate action plan includes ambitious goals to reduce carbon emissions, and many municipalities have adopted climate action plans that further reduce emissions. In certain wastewater permits, the state has required nitrogen testing and optimization of operations to reduce the amount of nitrogen in effluent. The state also has begun drafting nitrogen criteria that will establish limits for future permitted nitrogen discharges. Additionally, coastal municipalities are adopting fertilizer ordinances to reduce nonpoint source nitrogen loading to nearshore waters.[8] On the management side, pilot programs are colocating seaweed farms with shellfish to buffer against acidification (BLOS 2021) and research is being conducted to better understand the effects of acidic mud on wild clam populations (Czaja et al. 2023).

CONCLUSION

Maine's approach of relying on public-private collaboration to tackle the issue of ocean acidification serves as a model in at least two ways. First, it shows the strength of collaborative policy efforts that adapt to suit the realities of the times. If Maine decided in 2014 it could not address ocean and coastal acidification because it did not have the funds or ability to establish a panel like the one in Washington State, our valuable and beloved shellfish and economy would suffer the harm. Second, it illustrates adaptive policy. During these times of climate change, conditions are ever evolving and our understanding of the consequences caused by excess carbon emissions continues to progress. Therefore, we will never have a past set of data that alone can inform forward-thinking actions. We must have sound data from which we can project evolving conditions and experiment with actions that reduce the causes of acidification and make our shellfish more resilient to acidifying conditions. Maine's approach could be used in other states facing similar challenges. In summary, in these divisive times, Maine's way of addressing ocean and coastal acidification illustrates the benefits of working together toward a common goal–protecting our valuable shellfish–without regard to politics or social divides.

NOTES

1 Just two such extended larval phases means the loss of an entire spawn, or over $100,000 in lost seed sales.

2 Maine's Environmental Priorities Coalition (EPC) represents 37 organizations with over 120,000 members. The EPC collaborates to set a common agenda for each legislative session. The 2014 priority agenda included the Ocean Acidification Study Commission Resolve. https://protectmaine.org/epc/priorities/2014. Also see the public hearing testimony: https://legislature.maine.gov/bills/display_ps.asp?snum=126&paper=HP1174PID=1456.

3 https://seagrant.umaine.edu/extension/maine-ocean-and-coastal-acidification-partnership-moca

4 MOCA scientists co-deployed various instruments and compared results to determine how to affordably collect the most accurate data. They also worked together to best determine the amount of carbon dioxide in sea water.

5 The federal Clean Water Act prohibits the discharge of pollutants from a point source into a water of the United States unless the discharger has a permit. Relevant to acidification, a wastewater treatment facility must have a permit to discharge effluent into marine waters. Because excess nitrogen causes nuisance algal blooms that can contribute to coastal eutrophication, the state has begun to require testing and reducing nitrogen loads in effluent where necessary. Federal water quality standards are regulatory provisions that describe the desired condition of a water body and the means by which that condition will be protected or achieved. Every state has water quality standards, and EPA requires the state to review its water bodies to determine if they are meeting the standards assigned to that water body. If a water body is not meeting its standard, the state must submit a report to EPA and list that water body as impaired. EPA has issued guidance affirming that a state may consider acidification as a water quality impairment. https://www.epa.gov/tmdl/epa-issues-november-15-2010-memorandum-integrated-reporting-and-listing-decisions-related

6 Most of this happened as a result of conversations between the administration and MOCA steering committee members.

7 NECAN is the leading group in the region for the synthesis and dissemination of

ocean and coastal acidification information. Established in 2013, under the Northeastern Regional Association of Coastal Ocean Observing Systems (NERACOOS), NECAN is a partnership among government agencies, industry members, and the scientific community. NECAN serves as a conduit through which decision makers and stakeholders can provide guidance for regional research and monitoring. The NECAN region encompasses the coastal ocean from the high-water line out to the shelf-break from Long Island Sound to Nova Scotia.

8 For example, the cities of Portland and South Portland worked together to create a unique-to-them climate action and adaptation plan for achieving a low-carbon, thriving, and inclusive future (https://www.oneclimatefuture.org/). Additionally, Portland and South Portland have also implemented land care management ordinances that restrict the use of synthetic pesticides and fertilizers on all public and private properties. The ordinances further restrict the use of all pesticides and fertilizers within 75 feet of a waterbody or wetland, including ponds, rivers, streams, tidal areas, and coastal or freshwater wetlands (https://www.southportland.org/files/1016/0738/0873/CH_32_-_Pesticides.pdf; https://content.civicplus.com/api/assets/cbe6782e-55ca-469e-9aea-69f6102f154c?cache=1800).

REFERENCES

Arnold, Susie. 2020. "For Mook Sea Farm, 'Problems Are the Raw Material for Innovation.'" *Island Institute,* June 9, 2020. https://www.islandinstitute.org/2020/06/09/for-mook-sea-farm-problems-are-the-raw-material-for-innovation/.

Barton, Alan, George G. Waldbusser, Richard A. Feely, Stephen B. Weisberg, Jan A. Newton, Burke Hales, Sue Cudd, et al. 2015. "Impacts of Coastal Acidification on the Pacific Northwest Shellfish Industry and Adaptation Strategies Implemented in Response." *Oceanography* 28(2): 146–159. https://doi.org/10.5670/oceanog.2015.38.

BLOS (Bigelow Laboratory for Ocean Sciences). 2021. "New Research to Explore Seaweed for Ocean, Economic Health." News release, February 2, 2021. https://www.bigelow.org/news/articles/2021-02-02.html.

Czaja, Raymond, Robert Holmberg, Emmanuelle Pales Espinosa, Daniel Hennen, Robert Cerrato, Kamazima Lwiza, Jennifer O'Dwyer, et al. 2023. "Behavioral and Physiological Effects of Ocean Acidification and Warming on Larvae of a Continental Shelf Bivalve." *Marine Pollution Bulletin* 192:115048. https://doi.org/10.1016/j.marpolbul.2023.115048 .

Green, Mark A., George G. Waldbusser, Shannon L. Reilly, Karla Emerson, and Scott O'Donnell. 2009. "Death by Dissolution: Sediment Saturation State as a Mortality Factor for Juvenile Bivalves." *Limnology and Oceanography* 54(4): 1037–1047. https://doi.org/10.4319/lo.2009.54.4.1037.

Gruber, Nicolas, Dominic Clement, Brendan R. Carter, Richard A. Feely, Steven van Heuven, Mario Hoppema, Masao Ishii, et al. 2019. "The Oceanic Sink for Anthropogenic CO2 from 1994 to 2007." *Science* 363(6432): 1193–1199. https://doi.org/10.1126/science.aau5153.

IPPC (Intergovernmental Panel on Climate Change). 2014. "Climate Change 2014: Mitigation of Climate Change." *Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_full.pdf.

MCC (Maine Climate Council). 2020. *Maine Won't Wait, A Four-Year Plan for Climate Action.* https://www.maine.gov/future/initiatives/climate/climate-council/reports.

MCC CMWG (Maine Climate Council Coastal & Marine Working Group). 2020. *A Report from the Coastal & Marine Working Group of the Maine Climate Council.* https://www.maine.gov/future/initiatives/climate/climate-council/reports.

MCC STS (Maine Climate Council Scientific and Technical Subcommittee). 2020. *Scientific Assessment of Climate Change and Its Effects in Maine.* A Report by the Scientific and Technical Subcommittee of the Maine Climate Council. https://www.maine.gov/future/initiatives/climate/climate-council/reports.

MOAC (Maine Ocean Acidification Commission). 2015. *Report of the Commission to Study the Effects of Coastal and Ocean Acidification and its Existing and Potential Effects on Species that are Commercially Harvested and Grown Along the Maine Coast.* Augusta: Maine Office of Policy and Legal Analysis.

MOCA (Maine Ocean and Coastal Acidification Partnership). 2019. *An Action Plan to Address and Adapt to Ocean Climate Change in Maine.* Official Report to the Maine Climate Council. https://seagrant.umaine.edu/extension/maine-ocean-and-coastal-acidification-partnership-moca/moca-planning-report-2019/.

Niemisto, Maura, David M. Fields, K. Fraser Clark, Jesica D. Waller, Spencer J. Greenwood, and Richard A. Wahle. 2021. "American Lobster Postlarvae Alter Gene Regulation in Response to Ocean Warming and Acidification." *Ecology and Evolution 11:806–819.* https://doi.org/10.1002/ece3.7083.

WSBRP (Washington State Blue Ribbon Panel on Ocean Acidification). 2012. *Ocean Acidification: From Knowledge to Action, Washington State's Strategic Response,* edited by Hedia Adelsman and Laura Whitely Binder. Olympia, WA: Washington Department of Ecology.

Ivy Frignoca is the Casco baykeeper with Friends of Casco Bay. She has helped shape and implement Maine's response to ocean acidification beginning with leading efforts to pass the OA Study Commission bill to coordinating the current collaborative of scientists working to advance OA monitoring. Frignoca loves water, especially the ocean.

Heather Kenyon is the science and advocacy associate with Friends of Casco Bay. She focuses on combining the worlds of water quality science and policy to advocate for a healthy Casco Bay. Kenyon works to ensure future generations can enjoy the ocean as much as she does.