Maine Ocean and Coastal Acidification Partnership

Updates to the Goals and Recommendations of the
Maine Ocean and Coastal Acidification Commission Report

October 2016

Prepared by:

Aaron Strong, Cayla Calderwood, Parker Gassett, Jennifer Leech, Nick Battista, Ivy Frignoca, Susie Arnold and Esperanza Stancioff with support from the University of Maine.

2016 Ocean and Coastal Acidification Symposium: Updates to the 2015 Commission's Goals

Below is a summary of the information presented at the June 29, 2016 *Maine Ocean and Coastal Acidification Symposium* (the Symposium). The symposium was organized by the **Maine Ocean and Coastal Acidification Partnership** (MOCA) and attended by over 100 academic scientists, aquaculture growers, fishermen, lawmakers, state and federal agency officials, and concerned citizens. The Symposium convened this broad set of expertise on acidification in Maine with two primary objectives.

The objectives of the Symposium were:

(1) to present and consolidate important updates to the six (6) primary goals and recommendations outlined in the *Maine Ocean and Coastal Acidification Study Commission Report* (The Commission Report); and

(2) to identify future needs and opportunities in relation to achieving those goals and recommendations.

This summary presents information for each goal in three sub-sections:

(1) current action(s) being taken to achieve the goal;

(2) new information learned since the Commission Report; and

(3) key future needs

The intent of the summary is to provide a quick informational guide to the current state of OA science and management in Maine. More detailed information on the content of what was presented at the Symposium as well as researcher and presenter information is supplied in the **Appendix.**

What does the MOCA Partnership do?

The Commission Report was produced by the legislative study commission on ocean acidification authorized by the 126th Maine State legislature. A primary recommendation of the Commission Report was the creation of an on-going state council to maintain a coordinated focus on OA. In March 2015, Island Institute and Friends of Casco Bay, in conjunction with UMaine Extension/ME Sea Grant, and other stakeholders, formed the Maine Ocean and Coastal Acidification Partnership to keep the Commission report momentum moving forward. In March 2016, the Maine Legislature recognized that as an informal body which included state agency staff, members of the legislature, scientists, fishermen, aquaculturists, and community activists, MOCA was the right vehicle to maintain the focus on the threats of acidification to Maine's coastal resources and to advance and coordinate research, education and outreach on acidification in Maine. The volunteer partnership, which has included and will continue to include the participation of state agency staff, has two primary goals:

(1) MOCA works to implement recommendations of the Ocean Acidification Study Commission, as set forth in the Commission Report;

(2) MOCA works to coordinate the work of governmental agencies, private organizations and citizens who are studying and implementing means to reduce the impacts of, or help adapt to, ocean and coastal acidification.

More details on the work of the MOCA partnership can be found on the Maine Sea Grant website: http://www.seagrant.umaine.edu/extension/maine-ocean-and-coastal-acidification-partnership

Summary of Overall Progress Toward Achieving OA Commission Goals

Key Areas of Progress

1) Numerous researchers are investigating many aspects of coastal and ocean acidification in Maine, especially in southern and mid-coast Maine, and the extent and range of citizen science, non-profit, and academic scientific monitoring in the nearshore and Gulf of Maine has increased.
2) Numerous experiments focused on impacts on commercial species and the potential for OA remediation are under way, the results of which will meaningfully inform future resource management and remediation plans.
3) A unique and robust grassroots network of scientists, non-profit organizations, aquaculturists, fishermen and policy-makers focused on ocean acidification exists in Maine.

Key Needs and Future Directions

1) Coordination of information about *research and monitoring plans* and sharing and dissemination of *results*.
2) Additional biogeochemical and biological monitoring data are needed to further our understanding of the impacts of acidification, and especially to identify potential ways to slow or remediate those impacts, and inform necessary policy and changes. In particular, a coast-wide assessment of aragonite saturation state is desired.
3) There is a need to develop nitrogen criteria or a model that can be used to impose nitrogen limits in to reduce point and nonpoint source nutrient loading into coastal waters.
4) In alignment with discussions currently underway on the west coast, there is a need to investigate the potential for developing and using OA-specific criteria in waste discharge permits.
4) Better coordination regionally and nationally with groups in other states facing similar issues is needed. Through the federal NOAA OA Program and the regional Northeast Coastal Acidification Network, MOCA can facilitate information exchange to Maine can learn from other organizations facing similar issues around the country, including the west coast.
5) Funding for the MOCA Partnership is needed in order for the Partnership to continue to play a primary role in coordinating and sharing information within the state.

Summary by Goal

Goal 1: *Invest in Maine's Capacity to Monitor and Investigate Effects of Ocean Acidification and Determine Impacts of Ocean Acidification on Commercially Important Species and Mechanisms behind Impacts.*

Several organizations are running monitoring programs in the mid-coast region and in Casco Bay. Monitoring is taking place through a combination of large-scale, federally sponsored research projects, citizen-science initiatives, and the work of non-profit organizations. Some results of research show that mean pH is declining, especially near freshwater sources, while others show strong control of pH by deep-water intrusion of oceanic water. Furthermore, daily respiration cycles, CDOM (colored dissolved organic matter) and photosynthesis in estuaries can strongly shape pH and aragonite saturation.
Key future monitoring needs:

- Expand and coordinate existing programs.
- Studies that focus specifically on coastal aragonite saturation and on the impact of deep-water intrusion events.

In addition to these programs, studies have been conducted on the responses of clam, oyster and lobster larvae to ocean acidification. A recent study has shown that warmer temperatures increase lobster larvae mortality, while elevated pCO_2 had complex influences on lobster larvae feeding and swimming behavior, the effects of which require further study. Oyster larvae grown in Maine appear to respond poorly to low aragonite saturation states associated in particular with greater freshwater discharge. However, this problem can potentially be combatted in oyster hatcheries through operational adaptations.
Key future research needs:

- Expand research to study multiple stressors (temperature and low aragonite saturation state) and conduct modeling/experimental work/observational studies to assess the potential impacts on population dynamics outside of the laboratory in the Gulf of Maine ecosystems.
- Investigate realistic temporal and biogeographic impacts of ocean acidification.

Goal 2: *Reduce Emissions of Carbon Dioxide*

The state of Maine is a member of the Northeast's Regional Greenhouse Gas Initiative (RGGI). Maine's current emission reduction plan fits into the RGGI plan as well as into the USA's Intended Nationally Determined Contributions (INDC) goal: Reduction of 26-28% of 2005 levels by 2025. The Natural Resources Council of Maine is leading an effort to urge Maine DEP to strengthen RGGI as it goes through a review and update process to extend from 2020 to 2030. However, there are still several key needs in this area:

- Make current emission reduction plan more stringent; as is, it will still lead to dangerous interference in the climate system.
- Extend RGGI cap from 2020 through 2030.
- Engage more coastal resource stakeholders in climate policy discussions.

Goal 3: *Identify and Reduce Local Land-Based Nutrient Loading and Organic Carbon Contributions to Ocean Acidification and Freshwater Runoff by Strengthening and Augmenting Existing Pollution Reduction Efforts and Making Groundwater Recharge a Land Use Priority.*

Attempts are being made by various state agencies and several organizations to understand and identify sources of local land based nutrients and organic carbon. However, the runoff system is both complicated and understudied (in many watersheds, the total flow of water is not known). Friends of Casco Bay have estimated that Casco Bay absorbs 1 million kg of nitrogen (N) annually. Maine's Waste Water Treatment Plants are willing to work on reducing this nutrient runoff, but many plants would need expensive upgrades in order to handle nitrogen removal. One critical update to this goal is that the DEP has decided to look into using reasonable potential modeling rather than setting numeric nutrient criteria under EPA direction.

In part because point sources are not the only sources of nutrient runoff, managing nutrients poses many difficulties and achieving this goal may require the most work in the future.
Key future needs include:

- Substantial expansion and improvement to data gathering and analysis.
- Improve education and community infrastructure to reduce non-point sources.
- Analyze the reasonable potential model as a replacement for numeric criteria, and what it means for the dynamics of coastal acidification.

Goal 4: *Increase Maine's Capacity to Mitigate, Remediate and Adapt to the Impacts of Ocean Acidification*

This goal has generated a great deal of interest, especially among coastal communities and stakeholders, the news media and the general public. It represents a key area of research that can engage the public. Two recent pilot studies were highlighted. One involved spreading un-ground clam shells over mudflats. The study found this had no apparent effect on either pH or the settlement of clam larvae. However, it was pointed out that previous buffering efforts have been successful using fine, *ground* clam shells over mudflats. The second study has shown promising results. Preliminary data suggests a sugar kelp farm in Casco Bay locally raises pH, lowers pCO_2 and elevates aragonite saturation state as compared to a control site outside of the farm.

Key future needs include:

- Studies investigating the efficacy of using different sizes and placement of clam shells.
- Peer-reviewed studies on various mitigation and remediation efforts.
- Identifying social and ecological hotspots of vulnerability to acidification to help target remediation and mitigation practices.

Goal 5/6: *Inform Stakeholders, Public and Decision Makers about Ocean Acidification in Maine and Empower Them to Take Action / Create an Ongoing Ocean Acidification Council*

Since its formation in March 2016, the MOCA Partnership has become the established forum for informing the public and stakeholders and for maintaining a sustained focus on ocean and coastal acidification in Maine. Currently MOCA has no active funding source and is being run as a volunteer grassroots science synthesis organization through Friends of Casco Bay and the Island Institute, with support from the University of Maine. Regionally, the Northeast Coastal Acidification Network (NECAN) has played a key role in stakeholder engagement, education, outreach and information sharing on ocean acidification throughout the northeast region. Composed of federal agency representatives, non-profit leaders, and academic researchers, NECAN and MOCA are working closely together to advance societal responses to OA in Maine and the region.

Key future needs include:

- In June 2017, a $45 bond package will go before voters in a referendum Maine. Part of this bond could be used for funding ocean acidification monitoring and research that would benefit Maine aquaculturists and fishermen, to "preserve jobs for Maine people." Support for this bond initiative is a critical way to engage ongoing state support for needed OA monitoring.
- Funding and continued support for MOCA Partnership to coordinate future information sharing and symposia on ocean acidification around the state.
- Sharing information on Maine's progress on achieving OA science and management goals with regional and national collaborators through engagement with NECAN and NOAA Ocean Acidification Program.

Appendix:
Detailed Notes from the Symposium

This appendix comprises notes, organized by goal, summarizing each of the presentations at the MOCA Symposium. The Symposium presenters and their affiliations are listed below. Please note that the contents of this Appendix are solely intended to provide notes that reflect the content of the presentations at the Symposium and may discuss claims and reports of initial findings from scientific research that is on-going, un-published and has not yet been subject to peer review. All discussions of results should be considered "draft" and may be subject to revision. **Please do not cite these notes as scientific evidence.**

Introduction

Libby Jewett, Director of NOAA Ocean Acidification Program
Updates from NOAA: Connecting stakeholders, expanding research and monitoring, and assessing vulnerability and potential for adaptation

Joe Salisbury, University of New Hampshire
Updates on the Gulf of Maine

Commission Goal 1, Part 1: Invest in Maine's Capacity to Monitor and Investigate the Effects of Ocean Acidification

Facilitator: **Damian Brady**, University of Maine and Maine Sea Grant

Mike Doan, Friends of Casco Bay
Monitoring acidification in Casco Bay

Larry Mayer, Darling Marine Center, University of Maine
Maine Coastal Observing Alliance: Capacity-building and early results for mid-coast estuaries

Matt Gray, Darling Marine Center, University of Maine
Ocean acidification research and monitoring at the Darling Marine Center

10:15-10:45 Q&A and Discussion of Future Actions

Commission Goal 1, Part 2: Determine the Impacts of Ocean Acidification on Commercially-Important Species & the Mechanisms Behind Those Impacts

Facilitator: **Meredith White**, Bigelow Laboratory for Ocean Sciences

Jes Waller, Darling Marine Center, University of Maine
Effects of ocean acidification and warming on the larval development of the American lobster (*Homarus americanus*).

Rick Wahle, Darling Marine Center, University of Maine
Future directions of OA research on Maine lobster populations

Bill Mook, Mook Sea Farms
The Mission: Supporting Maine's fisheries and aquaculture through monitoring, research, and innovation

Commission Goal 2: Reduce Emissions of Carbon Dioxide

Aaron Strong, Marine Policy, University of Maine
CO_2 reductions: the future of the Regional Greenhouse Gas Initiative

Commission Goal 3: Identify and Reduce Local Land-Based Nutrient Loading and Organic Carbon Contributions to Ocean Acidification and Freshwater Runoff by Strengthening and Augmenting Existing Pollution Reduction Efforts and Making Groundwater Recharge a Land Use Priority

Facilitator: **Ivy Frignoca**, Friends of Casco Bay

Curtis Bohlen, Casco Bay Estuary Partnership
Nutrients in Casco Bay

Angie Brewer, Maine Department of Environmental Protection
Using "Reasonable Potential" as a tool for prioritizing nutrient reductions

Scott Firmin, Maine Water Environment Association
Wastewater treatment -A perspective on nutrients

Commission Goal 4: Increase Maine's Capacity to Mitigate, Remediate and Adapt to the Impacts of Ocean Acidification

Facilitator: **Nick Battista**, Island Institute

Brian Beal, University of Maine-Machias
Remediation in clamflats

Susie Arnold, Island Institute
Remediation using seaweed: Experimental results and future directions

Commission Goals 5/6: Inform Stakeholders, the Public and Decision-Makers about Ocean Acidification in Maine and Empower Them to Take Action and Maintain a Sustained and Coordinated Focus on Ocean

Esperanza Stancioff, UMaine Cooperative Extension
Public outreach and education in midcoast Maine

Aaron Strong, Marine Policy, University of Maine
What actions can decision-makers take?

Goal 1, Part 1: Invest in Maine's Capacity to Monitor and Investigate Effects of Ocean Acidification and Determine Impacts of Ocean Acidification on Commercially Important Species and Mechanisms behind Impacts.

What Is Being Done?
The monitoring of coastal acidification in Maine's waters is currently being undertaken by a several organizations:

- **Mike Doan, Friends of Casco Bay** currently have two monitoring programs:
  - **Citizen Steward Program:** Citizen science sampling for pH and oxygen with calibrated meters trained with EPA-approved techniques at locations throughout Casco Bay
  - **Staff program by Boat:** Same program as above but more comprehensive coverage by FOCB staff at locations throughout Casco Bay (More information:
- **Larry Mayer, Darling Marine Center,** The **Maine Coastal Observing Alliance (MCOA)** – An alliance group composed of 9 watershed conservation organizations based in mid-coast rivers and estuaries. MCOA organizations share technical expertise to aid organizational volunteers in citizen science sampling. Currently, MCOA affiliated organizations are conducting sampling across mid-coast Maine estuaries using a citizen science program that is heavily dependent on volunteers.
  - They are prioritizing their sampling in months with highest expected eutrophication impacts. They are looking at: salinity, pH, temperature, and HDO% saturation.
- **Matt Gray, UMaine Researcher at the Darling Marine Center** is currently working with the NSF-funded EPSCoR project Sustainable Ecological Aquaculture Network (SEANET) that includes pH and carbonate chemistry monitoring in the Damariscotta
  - Monitoring is being done by two LOBO buoys deployed in Saco Bay (monitored by UNE) and two deployed in the Damariscotta. Damariscotta buoy data are available here: http://maine.loboviz.com. The buoys are tracking nutrient concentrations, pH, O_2, CDOM temperature and salinity.

Beyond the mid-coast and Casco Bay regions, there is no comprehensive monitoring of coastal pH or aragonite saturation state that we are aware of.

What Do We Know?
The above monitoring programs have already begun to produce invaluable insights into the situation along the coast of Maine.

- **Key Casco Bay Findings**: The overall trend in pH is declining. Friends of Casco Bay data have shown that lower mean pH is associated with freshwater sources, though data shown by Joe Salisbury showed an association farther offshore where lower pH is also associated with high salinity and deep ocean intrusions. Monitoring data have confirmed that daily cycles have a strong impact on pH – photosynthesis during the day decreases pCO_2 and increases pH in the water, then respiration during the night acidifies it.

- **Key MCOA Findings:** Based on limited sampling and available data, lower pH values appears to be coming from outside estuaries. The greatest penetration of ocean water -and thus low pH- is happening in deeper estuaries as the intrusion depends on the depth of the channel. Higher pH values exist inside the estuary where plants use CO_2 and raise pH. pH values farther up the estuary are lower, suggesting that in situ production/respiration dynamics strongly affect estuarine pH. Note: *Data were not shown from all estuaries MCOA samples, only example data were shown.*
- **Knowledge from DMC**: Again, pH is low in ocean water and low in river water and highest in between. Colored dissolved organic matter (CDOM) appears to be affecting the net balance of respiration and photosynthesis and thus merits monitoring associated with acidification impacts. Numerous hatcheries in Damariscotta River are below the critical threshold of aragonite saturation state, which can be problematic for oyster larval development.

Key Future Needs

- The goal of monitoring should be to determine aragonite saturation state along the coast and the relative contribution of different drivers of variability.
- The existing monitoring projects discussed should continue to collect data.
- Desired expansions of the existing monitoring programs, which requires support:
    - Friends of Casco Bay wants to begin a third monitoring program with SMCC Pier Continuous Data- it would collect hourly data at 1-3 sites around Casco Bay to create a long-term data series. This program would include monitoring of a wide range of water characteristics.
    - Darling Marine Center: Wants to begin periodic profiling with pCO2 sensors and monitors and increase research of commercially important species. Wants to maintain a more permanent buoy with nutrient, chlorophyll, pH, etc.
- Monitoring programs should be developed for sections of Maine's coast that are not currently being monitored.
- Calibration of equipment used to monitor pH within each organization and between the different organizations is need.
- Calibration of water monitoring kits that are used across citizen science monitoring programs is needed. Note: NOAA OAP Director Jewett highlighted that this is a topic with nationwide interest.
- Understand the variability of the ocean intrusion driver of low pH is a major research need. In specific: Oceanography and physics research is required at the boundary between estuaries and the ocean to better understand intrusion of low pH waters. The area below 30 meters is of specific interest.
- More water quality data collection is needed near Casco Bay's wastewater treatment plants.
- More information sharing across monitoring efforts is needed:
    - Current researchers should have access to Friends of Casco Bay's historic research.
    - FOCB's training program for citizen scientists should be made available, especially to MCOA.

Goal 1, Part 2: Invest in Maine's Capacity to Monitor and Investigate Effects of Ocean Acidification and Determine Impacts of Ocean Acidification on Commercially Important Species and Mechanisms Behind Impacts.

What Is Being Done?

Since the Commission Report, additional experimental and observation work has been done to study the effects of ocean acidification on lobsters, oysters and clams, and further work is planned.

- Lobster: Within **Rick Wahle's** research group, work is being done at the Darling Marine Center (DMC) on the impacts of high CO_2 and elevated temperatures on the growth and mortality of lobster larvae. This work, conducted by **Jes Waller** with the support of Maine Sea Grant, was recently covered in the Maine press including Maine Public Broadcasting.
- Oysters: The **Mook Sea Farm** is implementing changes in hatchery practices to adapt to low saturation states that are monitored at their site on the Damariscotta River.
- Clams: **Friends of Casco Bay** have been observing changes in recruitment of larval clams under different pH conditions in Casco Bay clamflats.

What Do We Know?

- Lobster: Experiments thus far have shown that temperature has negative effects on lobster larval growth (when lobster larvae are fully fed). High pCO_2, when combined with warmer temperatures had complex influences on lobster larvae feeding and swimming behavior, the effects of which require further study.
- Oysters: The Mook Sea Farm observed negative larval responses due to low aragonite saturation states. They also found that many of the oysters in the hatchery were spending a lot of time below the saturation state due to influences from freshwater and high pCO2. They discovered that they are largely able to overcome these problems through adaptation.
- Clams: Friends of Casco Bay have observed that larval clams have trouble settling in areas with low sediment pH.

Key Future Needs?

- Lobster:
  - Look at multiple stressors and assess variability of responses across subpopulations.
  - Investigate long term, carryover and intergenerational effects.
  - Look at NextGen genomics to assess mechanisms of stress.
  - Move outside of the experimental box where lobsters are provided with full-food and oxygen and look at impacts of lobster larvae in more natural environments. Note: Sea Grant has provided funding to do this.
- Oysters:

    - Try to discover previous saturation states.
    - Research how and where the natural recruitment of commercially important bivalves is and isn't impacted by coastal acidification.
    - Determine role of CDOM in ocean acidification and reduced phytoplankton production.
    - Investigate the carbon source for oyster growth.
    - Establish Omega threshold for calcite (not just aragonite).
    - Increase education and awareness.
- Clams:
    - Continue current monitoring efforts and improve on them as outlined in above section.
- Continue and expand research into other species' responses to increasing pCO2.
- Expand research to study the effects of ocean acidification on full ecosystems.

Studies are required on species or subgroups shown to be more resistant to pCO2.

Goal 2: Reduce emissions of Carbon Dioxide

What Is Being Done?

Maine's current target for emissions reductions is to reach 10% below 1990 levels by 2020 and then in the long term to reduce emissions between 75% and 80% below 2003 levels. Maine is on target to reach the 2020 goal, in part because the state of Maine is a member of the Northeast's Regional Greenhouse Gas Initiative (RGGI), a region-wide utility-sector cap and trade program that has reduced GHG emissions. RGGI has successfully reduced power-sector emissions through the northeast region. RGGI power sector emissions have declined 40% since 2005, while the economy has grown 8%. Auctions of emissions permits have generated $2.5 billion that has been reinvested in energy efficiency.

What Do We Know?

Maine's emissions reductions from currently existing policies are likely to align with US Intended Nationally Determined Contributions (INDC) goal: Reductions of 26-28% of 2005 levels by 2025. Maine is achieving this through energy efficiency and expanded renewable energy deployment. RGGI has been successful in leveraging funds for energy efficiency improvements that have made the program more politically palatable. RGGI is seen as a success, in part due to its energy efficiency funds, and is aligned with other climate change policies, though it may not put Maine on a trajectory to avoid dangerous anthropogenic interference in the climate system.

Key Future Needs?

- Extend the RGGI cap through 2030: Currently, the RGGI cap only extends through 2020. This needs to be extended through 2030.
- The current emission reduction plan (the cap has reduced at 2.5% per year from 2015-2020) should be made even more stringent, given that RGGI is a well functioning policy system.
- Support necessary research topics for the state of Maine:

- More research must be done on the role of global CO2 in driving ocean acidification variability. This work is especially needed in Maine.
- More research needed on how motivation to take action on OA is linked with motivation to take action on climate.

Goal 3: Identify and Reduce Local Land-Based Nutrient Loading and Organic Carbon Contributions to Ocean Acidification and Freshwater Runoff by Strengthening and Augmenting Existing Pollution Reduction Efforts and Making Groundwater Recharge a Land Use Priority.

What is Being Done?

Nutrient loading Currently attempts are being made by the state of Maine and several organizations to identify the sources of local land-based nutrient loading.

- **Curtis Bohlen, Casco Bay Estuary Partnership's** main strategic goals is to reduce nutrient loading to Casco Bay. They currently support monitoring programs that examine nutrient loading and have information, education and outreach programs designed to target sources of nutrient loads.
- **Angela Brewer, Maine Department of Environmental Protection:** DEP has adopted a "reasonable potential modeling" approach to source attribution for marine nutrient management, rather than the development of marine nutrient criteria
- **Scott Firmin, Maine Water Environment Association:** WWTPs receive permits from the state for their discharges. The flows are closely monitored and they report to the DEP regularly. They have a role to play in OA management to the extent that OA is related to nutrient inputs. DEP point source permitting processes under the authority of the Clean Water Act currently apply.

What Do We Know?

We currently do not know the relative amounts or the sources of nutrients that are entering the Casco Bay ecosystem. However, despite significant information gaps, monitoring has provided some information about Casco Bay:

- The yield of nutrients from different types of watersheds goes from least to largest as follows: range, forest, pasture, crops, urban.
- Approximately 23kg N ha^{-1} enters Casco Bay.
- There are several nitrogen hotspots in Casco Bay which often correspond to areas of low pH.
- WWTP point sources are NOT the only sources of nutrient loading to Casco Bay. Septic systems, agriculture, lawn fertilizer, and other nonpoint runoff add to nutrient loading.
- WWTPs are designed exclusively for conventional pollution. Therefore, some have tertiary treatment to remove nitrogen through microbial decomposition, but others cannot be operated to remove nitrogen without expensive changes.

Key Future Needs

- Work must be done on identifying and then answering basic questions on which future research will depend, i.e.: What is the nutrient loading budget to Casco Bay?
- Additional monitoring data are needed for better modeling; in particular presenters highlighted the following needs:
    - Determine the budget of nitrogen inputs into the coastal ocean and how it varies over space and in time.
    - Identify the relative contribution of marine nitrogen to Casco Bay nitrogen.
    - Improve on river discharge data and quantify nutrient contributions in tributaries. Local data will be needed to calibrate these models.
- Assess the application of the reasonable potential, how it will work and how not having criteria will affect regulation relevant to ocean acidification.
- Work on creating a fully functioning biogeochemical model for Casco Bay.
- Work on identifying/creating nutrient criteria and thresholds.
- Discuss the potential for ocean acidification-specific water quality criteria.
- Research the extent of the association on nutrient loading with low pH outside of the Casco Bay region (currently generally assumed to be low, but is unknown in many regions.)
- Additionally CBEP's work seeks to do the following:
    - Support WWTP upgrades
    - Improve storm-water infrastructure
    - Reduce Combined Sewer Overflows
    - Repair and replace septic systems and tanks
    - Reduce lawn fertilizer usage
    - Minimize agricultural runoff
    - Increase education about nutrients
    - Enforce the current regulations, permits, standards including implementing non-point source as well as point source standards through a TMDL under the Clean Water Act

Goal 4: Increase Maine's Capacity to Mitigate, Remediate and Adapt to the Impacts of Ocean Acidification

What Is Being Done?

Out of all six of the goals identified in the commission report, this goal has generated some of the most public interest. There has been substantial media coverage and stakeholder interest in Maine's ability to lessen the effects of ocean acidification at a local level.

There have been two significant experiments on remediation that MOCA is aware of that have been undertaken since the commission report on remediation and mitigation. Both took place near or in Casco Bay:

- **Brian Beal** from UMaine Machias is doing experimental work on clamshell remediation of clam flat pH in northern Casco Bay. They designed a study to compare the effects of scattered clam shells on clamflats vs the effects of protective netting to exclude green crab predation. They wanted to test if the benefits of clam shells were due to a change in pH, or if the shells were simply acting as a predation deterrent. They used large shell fragments brought straight from the dealer and scattered them on the surface of the mud.
- **Susie Arnold** from the Island Institute and **Nichole Price** from Bigelow are conducting experimental work on mussel aquaculture combined with kelp aquaculture to evaluate the role that kelp can play in preserving aragonite saturation state around the mussels. They are working with a kelp farm in Casco Bay. They used two monitoring systems within their experimental design, one in the middle of the experiment site and another one in a control site nearby. Both measured pH, O_2, salinity, temperature, depth and CO_2. They also took discrete water samples every two weeks.

What Do We Know?

- Clam Shell Experiment: The experiment found that large shell fragments scattered on the surface of the clam flat did not have a significant impact on pH or on the number of clams present. However, other researchers present at the meeting suggested that this may have been due to the large size of the shell fragments and that ground shell would have yielded improvements in pH and thus clam growth/number.
- Kelp Farm Experiment: The results so far have been promising, which show that pCO2 has been consistently higher outside the farm and pH has been lower outside the farm. Furthermore, there has consistently been a higher aragonite saturation state within the kelp forest- something which has increased along with the growth of the kelp.

Key Future Needs?

Both of the above experiments have created the need for additional research, highlighted at the Symposium:

- The effects of different sizes and placement of shell fragments should be studied.
- Different locations of pH measurements to assess mudflats should be tested.
- The variability of the size of the halo effect around the kelp must be understood.
- Research on if pairing mussels with kelp will impact mussel shell growth.
- More pairs like kelp/mussels should be studied i.e: clams and eelgrass, rockweed (Ascophyllum) and oyster.

In addition to the continuations of the above experiments, there are other key future needs:

- There is substantial need for peer-reviewed scientific data on restoration experiments.
- Areas of elevated vulnerability should be identified so that they can be focused on for remediation and mitigation efforts.

- Additional research into Carbonate Restoration and Carbonate Preservation.
- It is necessary that research be done on the comparative impact of local vs. global remediation and subsequently that the different mitigation and remediation approaches are organized as either local or global.
- The primary actors in mitigation and remediation practices need to be engaged early on and involved in conversations. These will primarily be towns and aquaculturists.

Goals 5/6: Inform Stakeholders, Public and Decision Makers about Ocean Acidification in Maine and Empower Them to Take Action. / Create an Ongoing Ocean Acidification Council.

What Is Being Done?

Esperanza Stancioff and Aaron Strong: While no government council was formed to oversee Maine's efforts regarding ocean acidification, much has been done since the commission report. Most of this effort has coalesced around the MOCA partnership, which has become a focal point for the grassroots effort to battle ocean acidification in the state of Maine:

- Since its formation, the MOCA Partnership has become the established forum for informing stakeholders and the public and for maintaining a sustained focus on ocean and coastal acidification in Maine.
- Currently MOCA has no active funding source and is being run as a volunteer grassroots science and outreach partnership formed by Friends of Casco Bay and the Island Institute and partnership with UMaine Extension/ME Sea Grant and UMaine.
- The Northeast Coastal Acidification Network (NECAN) has maintained an active role in bringing together scientists, stakeholders, and decision-makers throughout the northeast region to discuss what we know about OA impacts and its effects. The partnership and relationship between MOCA and NECAN is strong: members of the MOCA Steering Committee also serve on NECAN Working Groups, several members of the original Maine Ocean Acidification Commission are NECAN Steering Committee members, as well as having a liaison from NECAN steering committee on the MOCA Steering Committee.

What Do We Know?

While the capacity of MOCA to pursue new initiatives and maintain the focus of the state on OA is limited due to its volunteer status, there are many potential actions that MOCA can take to help Maine continue to make progress on the goals outlined by the Commission Report. Based on the conversation at the Symposium and a follow-up survey with participants, there is strong support for:

- MOCA to play a convening and information sharing role, providing information about ocean acidification to stakeholders by convening targeted workshops/symposia on specific subjects. ***MOCA is pursuing this strategy currently through its next workshop on November 15th***.

- MOCA to act as a boundary-spanning organization (potentially conducting targeted research)
- MOCA to act as an education and outreach organization.
- MOCA, potentially, to act in support of new state legislative initiatives to continue furthering the Commission's goals.

Key Future Needs?

- Support for the on-going work of the MOCA Partnership is necessary.
- In June 2017, a $45 million dollar research and development bond package will be going before Maine voters for approval. Part of this bond allocates funds to "preserve jobs for Maine people," which could be used to justify funding for ocean acidification monitoring and research equipment focused on aquaculture. There is a key need to support this bond package as an avenue for state support for maintaining work on OA.
- Online data and information sharing through shared platforms, both within the state and between MOCA and other state councils and regional organizations is needed. Both NOAA OAP and NECAN have mentioned their interest, initiative and willingness