

GOALS & RECOMMENDATIONS SECTION ONLY -DRAFT

**STATE OF MAINE
126th LEGISLATURE
SECOND REGULAR SESSION**

**Final Report
of the**

**COMMISSION TO STUDY THE EFFECTS OF COASTAL AND OCEAN
ACIDIFICATION AND ITS EXISTING AND POTENTIAL EFFECTS ON
SPECIES THAT ARE COMMERCIALY HARVESTED AND GROWN ALONG
THE MAINE COAST**

December 2014

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IV. Goals and Recommendations¹

Maine must make hard decisions to effectively address the rapidly increasing rate of acidification of its marine environments. Ocean acidification and its effects are not readily observable by the general public, underscoring the importance of education and outreach efforts to illuminate the seriousness of this issue and its importance among other issues that capture the public's attention. Maine decision-makers are often faced with competing economic and political issues but share a deep commitment to, and understanding of, the economic and cultural importance of the State's fisheries. The gravitas of ocean acidification must be understood by both Maine's leaders and the public to ensure the long-term stability of its commercially-harvested species, which are vital to the State's economy.

The commission's unanimous support for its goals and recommendations are the culmination of four months of in depth discussions, involving the review and analysis of highly technical scientific data, federal and state ocean acidification studies and programs and policy considerations. For Maine and its commercial fisheries, addressing ocean acidification has become an urgent matter and the commission emphatically supports the immediate implementation of its recommendations. The goals and recommendations in this report represent a starting point for efforts that this commission believes will put Maine on a path to identify, mitigate and remediate the impacts of ocean acidification and to take advantage of the opportunities it may afford us. While the commission understands that some of its recommendations have significant financial and time implications, preliminary actions can still be taken towards fulfilling those recommendations.

As used in this section, "shellfish" means the American lobster, crabs, oysters, mussels, clams, scallops, sea urchins, northern shrimp and periwinkles unless otherwise indicated by the context.

Goal 1: Invest in Maine's Capacity to Monitor and Investigate the Effects of Ocean Acidification and Determine the Impacts of Ocean Acidification on Commercially-Important Species and the Mechanisms Behind Those Impacts

To date, most experiments have focused on single-species responses to ocean acidification in laboratory settings. Given the current rate of acidification, we must move beyond a single-species approach and consider how ocean acidification impacts the structure of marine ecosystems as a whole and over time. Filling this knowledge gap will require the expansion of monitoring and multispecies experiments that bring a small part of the natural environment under controlled conditions for study. Multispecies food-web

¹ The commission's recommendations dovetail with many of the recommendations from the 2012 report of the Washington State Blue Ribbon Panel on Ocean Acidification. The Washington State report can be found at <http://www.ecy.wa.gov/water/marine/oceanacidification.html>.

models should be developed to obtain a better understanding of the direct and indirect impacts acidification is having on our commercial species.

Recommendations

1.1. Enhance monitoring and create a database sufficient to support the development of regulatory and non-regulatory approaches to reduce and limit nutrients and organic carbon from sources that are contributing significantly to the acidification of Maine's marine waters. Enhanced monitoring should begin in one or more pilot estuaries where impacts are presently occurring.

To support new or strengthened pollution reduction efforts, Maine industries, landowners and policy makers need to understand if and how public and private investment in pollution controls will deliver the desired reduction in nutrients and the acidification they may cause in coastal waters. Inputs from land-based sources (wastewater treatment plants, industrial point sources, urban runoff and agricultural and silvicultural practices) need to be better understood in the state. Maine does not currently monitor nitrogen production or its biological impact.

We recommend instituting pilot projects that involve monitoring key estuaries around Maine to learn more about how specific pollutants and freshwater runoff conditions are contributing to ocean acidification. While much work has been done in Casco Bay, more data is needed in that location as well as in other important locations along Maine's coast to better understand acidification processes in those areas.

1.2. Expand monitoring of ocean acidification to establish its natural variability and to detect trends in water chemistry and related biological responses.

There is a dearth of information on the impact of acidification on Maine's commercial species, especially under environmental conditions found in Maine. We also lack high-resolution data on the present state of the carbonate system of coastal waters in Maine, making it difficult to know what conditions commercial species currently experience and how those conditions are expected to change in coming years. The commission recommends that the following research and monitoring activities be priorities for the state:

1. Monitor/sample watershed fluxes of materials affecting pH and the carbonate system. These materials include carbon compounds and nutrients such as nitrogen;
2. Resolve the acidification attributable to nitrogen and phosphorus fluxes;
3. Monitor the carbonate system of inshore and offshore water column and benthic habitats;

4. In conjunction with water quality/carbonate chemistry data collection, monitor larval abundance and recruitment success for commercially important shellfish species;
5. Conduct modeling and laboratory based efforts to understand how or if ocean acidification affects our most important species (lobsters, Jonah crabs, spider crabs and rock crabs, sea scallops, elvers and other finfish, sandworms and blood worms);
6. Conduct more in-depth experiments including multi-stressors, multiple life stages/multiple generations or predator-prey interaction studies;
7. Research mitigation, specifically regarding sediment buffering, algal growth and harvest (phytoremediation techniques to better understand the mitigation potential provided by upland and marine vegetation) and animal rearing; and
8. Conduct experiments to provide a better mechanistic understanding of how ocean acidification impacts marine organisms.

It is difficult to adapt to or mitigate acidification if it cannot be detected. Maine requires more “eyes” on its coastal waters to see where and when acidification occurs. These eyes will likely include fixed measurement platforms, research cruises and citizen monitoring efforts to measure more extensive areas. Time series using reproducible methods will be vital to find trends associated with ocean acidification.

Measurements of both water quality and biological indications of acidification are technical and, at present, expensive. More extensive measurements need to be made by less expensive means. Five strategies to extend these measurements include:

1. Expand monitoring capabilities within the context of the Northeastern Regional Association of Coastal and Ocean Observing Systems (NERACOOS) and the National Oceanic and Atmospheric Administration’s Ocean Acidification Program;
2. Empower and assist citizens, singly such as individuals on fishing vessels or in organized groups, such as environmental monitoring groups (e.g., Maine Coastal Observation Alliance) to make measurements as extensive as possible. Reliability of data should be ensured via practices such as training in and adoption of Quality Assurance Project Plans overseen by the Environmental Protection Agency or the Department of Environmental Protection;
3. Support the development and take advantage of rapidly evolving technology such as new sensors to bring down the costs of direct or indirect measures of acidification (or proxies; see Recommendation 1.3) of waters or sediments;

4. Take advantage of existing platforms such as hatcheries, shore side laboratories and moorings to deploy sensors; and
5. Continue the Department of Environmental Protection's work with regulated entities to obtain additional monitoring data regarding nutrient loading, specifically phosphorus, nitrogen and fixed nitrogen.

Detection of biological impacts from acidification is difficult because there are many stressors that may account for biological problems. Considerable research will be needed to develop indices of stress that are attributable to acidification.

Monitoring efforts will need to be coordinated and data compared between places and times. Central data-gathering groups, such as NERACOOS, coalition groups of citizen monitors (e.g., Maine Coastal Observation Alliance) and state agencies with water quality databases will all be vital to this networking. It is important that scientific data on ocean acidification from various sources be centralized and made readily available to all researchers.

1.3. Develop new tools with which to assess and understand acidification and its impacts in Maine waters.

The science and technology of assessing acidification impacts are developing rapidly. Maine needs to both keep up with this rate of evolution as well as develop tools appropriate to its local waters and species. Maine is in a position to be a leader in the development of new technologies related to ocean acidification and to realize the economic opportunities presented by burgeoning technologies.

Water quality and biological indicators of acidification need to be enhanced. Expensive chemical measurements of acidification will need to be supplemented by less expensive ways of measuring the same properties (e.g., pH). Similarly, impacts on organisms will be increasingly measured by automated methods such as genetic and image recognition technologies.

New tools will be developed by the assessment of chemical or biological proxies that signal the onset of acidification, such as dissolved oxygen or indicator bacteria. Such indicators need development not only for present and future conditions, but also to allow us to reach into the past so that we can understand how changing water quality has affected commercial species in prior times. Basic oceanographic sensing will enable detection of water masses that set the stage for acidification, whether it is salinity sensors inside estuaries or offshore buoys/glider systems that sense different water masses entering the Gulf of Maine.

Models are needed that connect the atmosphere, water masses and their chemistry, impacts on organisms, and linkages to socio-economic processes. This modeling extends the results of data gathering into times and places not measured. Modeling should proceed first at the level of individual components and later in linked forms as the

components are proven. As understanding improves from experiments, field studies and models, sensing systems will need expansion or reorganization to detect acidification effects in the actual ocean.

1.4. Determine the causes and relative importance of acidification in the waters and sediments of Maine.

The commission recognizes three primary sources of acidification in Maine waters: (1) enrichment of atmospheric CO₂ via fossil fuel combustion; (2) eutrophication via nutrient additions; and (3) increased inputs of low-pH freshwater. The importance of these sources will vary with place and time. For example, freshwater inputs will likely be most important where rivers lower the salinity of marine waters, and nutrient controls will be strongest near sources of nutrients. The separate and combined roles of each, including relative contributions, should be assessed for a more complete understanding of the acidification budget.

Acidification of patterns of pelagic (open ocean) waters may be different from acidification patterns at the benthic boundary (water located directly above the bottom). Sediments will experience a suite of different processes, such as those mediated via biologic activity over a wide range of oxygen concentrations.

While ocean acidification is occurring very rapidly on a geologic time scale, detectable acidification caused by increasing atmospheric CO₂, as experienced by Maine's commercially important marine species, will continue to take place over decades. It is very likely that this will lower pH to levels potentially harmful to Maine's commercial species. Careful time series of appropriate measurements should be enhanced, as well as explorations of past conditions via proxy measurements. Modeling can and should be used as it will be fairly successful since the physics and chemistry are relatively well understood.

Nutrient-derived acidification will be more variable, and increased acidification via this pathway will require studies of nutrient-driven cycles, such as photosynthesis and subsequent respiration. Nitrogen is likely to be the principal nutrient of concern, but the role of other nutrients, such as phosphorous, should also be assessed. The contributions of various sources of these nutrients to the inshore waters, including atmospheric, sewage, land use, river, oceanic source waters and others sources should be determined to plan future adaptive and remediation actions. Changing patterns of freshwater inputs into marine waters should be monitored and evaluated.

1.5. Identify the impacts of acidified waters and sediments on Maine's commercial species.

Maine must develop better information on the impacts of acidification on wild and cultured commercial species using Maine's environmental conditions. Because acidification is one of many environmental challenges faced by Maine's commercial species, its impacts should be considered both separately and in conjunction with other

stressors, such as warming, disease, invasive species and fishing pressure. Differences between water and sediment ecosystems mean that acidification of water inputs to hatchery bivalves may differ considerably from acidification affecting natural sets of bivalves in adjacent coves.

These impacts may occur in direct and indirect ways. Direct impacts on species should be studied in well-controlled experimental systems capable of evaluating the combined effects of climate change parameters, such as dissolved oxygen and temperature. These studies should include impacts on both physiology and behavior and should assess the ability of various species to adapt to changing conditions. Acidification may also affect ecosystems in ways that indirectly affect commercially important species. For example, plankton that serve as food may change in quality or quantity, or disease-causing organisms may become prevalent. Studies of overall impacts of acidification on commercial species must remain sensitive to these possibilities.

Studies should address whether the impacts found in experiments appear in organisms in the field, and should also address the success of larval recruitment to natural populations, especially in conjunction with water quality measurements. Researchers should develop markers of acidification impact that can be used in subsequent field monitoring.

Goal 2: Reduce Emissions of Carbon Dioxide

While the acidification of the Gulf of Maine is the result of several processes, the increased atmospheric input of CO₂ can explain the observed multidecadal change in acidity of the seawater. The Gulf of Maine is colder than most coastal areas in the United States and CO₂ is more soluble in colder water, thereby facilitating a higher rate of CO₂ uptake causing an accelerated rate of acidification. Furthermore, Gulf of Maine waters are less buffered than other regions, resulting in a greater increase in acidity from the same uptake of carbon dioxide (see State of the Science Subcommittee report, Appendix C). Reducing global atmospheric carbon dioxide levels should be an immediate priority. While ocean acidification from atmospheric carbon dioxide is largely recognized as a result of global activities (of which Maine has a small proportional impact), Maine can still have a discernable impact in reducing atmospheric carbon dioxide by implementing the following recommendations.

Recommendations

2.1. Strengthen coordination and continue participation with existing national, state and regional initiatives regarding the reduction of atmospheric CO₂ levels.

In recent years, emphasis has been placed on climate change, resulting in resolutions pertaining to energy, alternative fueled vehicles, transportation and climate change.

Maine is currently involved with several initiatives to help reduce atmospheric CO₂ levels and other greenhouse gases² at both the regional and state level. At the regional level, Maine is a member of the Regional Greenhouse Gas Initiative (RGGI). This initiative is the first market-based regulatory program in the United States designed to reduce greenhouse gas emissions and is a cooperative effort among the states of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island and Vermont to cap and reduce CO₂ emissions from the power sector. It is critically important for Maine to continue its efforts as part of this regional group approach to ensure that RGGI is effective.

Maine is also a member of the Transportation and Climate Initiative of Northeastern and Mid-Atlantic States. Its mission is to develop the clean energy economy and reduce greenhouse gas emissions in the transportation sector. Since 1973, Maine has participated in the partnership and annual conferences of the six New England Governors and the five Eastern Canadian Premiers (NEGECP). This partnership is meant to encourage cooperation by focusing on developing networks and relationships, taking collective action, engaging in regional projects and endorsing projects by others, undertaking research and increasing public awareness of shared interests. Additionally, the NEGECP adopted a 2013 Climate Action Plan at its 37th conference and has since developed a work plan for 2014 and 2015.

In 2013, Maine established the Environmental and Energy Resources Working Group whose purpose is to ensure effective cross-coordination and integration of programming among Maine's agencies regarding reduction of greenhouse gases, as well as adaptive measures taken to mitigate environmental or climate changes. The results of this group have been released and call for efficient mechanisms for collaborating to reduce redundancies and duplication of efforts among state and local agencies. The report, "Monitoring, Mapping, Modeling, Mitigation and Messaging: Maine Prepares for Climate Change" is available at <http://www.maine.gov/dep/sustainability/climate/Working%20Group%20maine%20prepares.pdf>. Efforts to work on reducing greenhouse gases as part of an ocean acidification mitigation strategy should be coordinated with the results of the Environmental and Energy Resources Working Group.

As outlined in the report referenced above, a number of Maine's state agencies are working on ways to reduce greenhouse gases. Many of these efforts started as a result of the 2004 Climate Action Plan and the 2010 Climate Adaptation Plan. These efforts include but are not limited to: the monitoring and reporting of greenhouse gas emissions, regulating greenhouse gas emissions at permitted facilities, encouraging both energy efficiency and investments into renewable energy, managing a "cleaner" fleet of state cars and promoting new technologies to capture greenhouse gas emissions. State agencies that are involved include the Department of Environmental Protection, the Public Utilities Commission, the Department of Transportation, the Efficiency Maine Trust and the Governor's Energy Office. Results of these programs include several

² The term "greenhouse gases" includes CO₂, as well as methane (CH₄), nitrous oxide (N₂O), hydroflouorocarbons (HFCs), perflouorocarbons (PFCs) and sulfur hexafluoride (SF₆).

recurring reports that are delivered to the Legislature, for example, The Fifth Biennial Report on Progress toward Greenhouse Gas Reduction Goals (available at <http://www.maine.gov/tools/whatsnew/attach.php?id=611577&an=1>) and the 2014 Regional Greenhouse Gas Initiative Annual Report (available at <http://www.maine.gov/tools/whatsnew/attach.php?id=616525&an=1>).

Other organizations and academic institutions throughout Maine are also focusing on the reduction of atmospheric CO₂ levels and may also serve as useful resources in determining additional strategies. An example of such an institution is the University of Maine Climate Change Institute.

Moving forward and in coordination with the existing initiatives outlined above, Maine should continue to work with federal and state agencies, other coastal states, Eastern Canadian Premieres and other international governments as applicable to promote effective strategies and comprehensive approaches to reduce atmospheric levels of CO₂ by:

1. Sharing knowledge, data, scientific expertise and establishing potential policy initiatives with partners;
2. Participating in joint actions to protect oceans and other marine waters from acidification;
3. Pursuing agreements with other partners to cooperate in scientific initiatives that will better define the impacts of atmospheric CO₂ on marine fisheries, seafood supplies and water quality; and
4. Building public awareness by using intergovernmental compacts and joint outreach and education efforts.

2.2. Encourage key leaders and policymakers to synchronize in establishing a comprehensive and unified strategy to reduce carbon dioxide emissions.

Since Maine is already actively taking a variety of steps and engaging in multiple initiatives to reduce atmospheric CO₂ levels, it is critically important that Maine's legislators, congressional delegation, Governor, community stakeholders and academic and business leaders come together with state agencies to establish a comprehensive path forward on the best approaches and strategies for reduction. Better coordination of these efforts is important to avoid duplication, to ensure entities are not acting at cross purposes, and to ensure that Maine's leaders can effectively serve as ambassadors to promote the reduction of CO₂ levels with a unified voice. To effectively carryout this recommendation, elected officials and other key leaders should be periodically briefed on ocean acidification issues to stay current on CO₂ levels and trends, ocean acidification science and impacts relevant to Maine's commercial fisheries.

2.3. Expand actions at the state and local level that may help in reducing CO₂ emissions.

Although Maine acting individually or alone will lessen only a small proportion of the overall levels of atmospheric carbon dioxide (as compared to the global contribution), Maine can still help to increase public awareness and set a good example by supporting regional or national initiatives. A considerable amount of work has been conducted on the reduction of greenhouse gases and the commission strongly recommends that this work be drawn upon and integrated with other related ongoing efforts, including the state's Comprehensive Energy Plan. An integrated approach may allow Maine to take the following actions at the state and local levels:

1. Provide additional funding to existing state air quality emissions, monitoring and climate change mitigation and adaptation programs;
2. Continue support for existing air quality programs pertaining to transportation fuel efficiency, including:
 - Requiring the use of cleaner-burning fuels;
 - Implementing motor-vehicle emission standards (meeting the California Low Emission Vehicle standards); and
 - Administering the Maine Clean Diesel Program and the Maine Clean Marine Engine Program;
3. Continue support for existing programs pertaining to point of use energy generation;
4. Create additional incentive programs to encourage energy conservation and efficiency and the use of renewable energy sources as well as clean technologies;
5. Set policies and establish programs that will encourage the creation and expansion of new technologies and innovations to reduce greenhouse gas emissions;
6. Provide educational and outreach materials to demonstrate the benefits of reducing greenhouse gases; and
7. Expand local energy conservation boards.

Collaborating with other state to take the actions listed above will increase their potential impact.

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

Maine's numerous rivers and streams provide an influx of freshwater that typically has a lower pH than ocean waters and are also a possible source of excess nitrogen and phosphorus, both of which can be contributors to ocean acidification. While the proportion of impact or relative contribution by these sources is unknown, the influx of additional nutrients and lower pH waters are generally understood to adversely impact commercially valuable species, especially in estuaries.

An increase in nutrients boosts biological productivity but in larger amounts may lead to oxygen depleted waters, toxic algae blooms and the acidification of marine waters. An increase in the frequency and severity of storms and anticipated trends in precipitation are likely to result in lower pH water entering rivers and streams and ultimately estuaries. While it is recognized that both of these factors contribute to ocean acidification, it is not understood to what extent marine species are stressed by acidification alone as compared to other competing factors, including, but not limited to, invasive species (green crabs), other water quality parameters (temperature), low levels of dissolved oxygen and overfishing.

Recommendations

3.1. Identify and reduce nutrient loading and organic carbon from point source and nonpoint discharges determined to cause or contribute to ocean acidification.

Nutrient and organic carbon originating from a variety of point sources (including municipal wastewater treatment facilities or publicly owned treatment works (POTWs));³ industrial point source discharges; industrial, municipal, agricultural or construction storm water discharges; and on-site sewage discharges,⁴ such as overboard discharges and septic failures as well as nonpoint source discharges (runoff) likely account for the majority of local nutrient inputs into Maine's marine waters. Discharges from most point sources are regulated by individual or general permits issued by the Department of Environmental Protection under the Maine Pollutant Discharge Elimination System program.

³ When properly designed and installed, POTWs provide a high level of treatment for bacteria and other pollutants including pH. The allowable limits of pH in wastewater discharges are governed by statute and legislation would be required to change those limits. Nutrients like nitrogen are not removed unless nitrogen-reducing technologies are used. Because POTWs are considered to be permanent infrastructure, they are costly to construct, maintain and operate. Reducing nitrogen from these sources will require technology that must be tailored to location conditions and the actual facility design to work properly. The cost of the advanced treatment of nutrients will generally fall on individuals as POTWs are managed and funded at the municipal level. If it is shown to be effective and reliable, nitrogen-removal technologies ought to be considered as an option in areas where it is determined that nutrients from POTWs are contributing significantly to ocean acidification.

⁴ In addition to POTWs, other smaller on-site sewage systems are in operation around the state. Continued efforts to improve technologies and mitigate these localized sources where opportunities are available is still worthwhile. These include residential sewage and septic systems. Provided that funding is available, Maine offers several programs to assist qualifying homeowners with replacement of failing on-site septic systems and overboard discharge systems.

Point source permits typically impose specific effluent limits, monitoring and reporting requirements and other conditions on permitted discharges. At this time, however, specific nutrient criteria (i.e., nitrogen and phosphorus) are typically not included in permits as these criteria are not yet developed in Maine.⁵ In addition, the extent of the relative contribution of impacts on estuaries from specific point sources is not well understood.

As compared to point sources, nonpoint source discharges are typically not licensed, but the Department of Environmental Protection and the Department of Agriculture, Conservation and Forestry have programs to help landowners with reducing runoff and restoring impacted areas to improved environmental health. Several programs to help with planning and implementing best management practices are already in place.

The commission recommends additional research and monitoring to determine the extent to which point sources of nutrients and organic carbon cause significant acidification. Using that research, the commission recommends that more clarity be provided on nutrient criteria and how they might be incorporated into both regulations and the permitting process. Concurrently, sources that significantly contribute to nutrient loading should be required to reduce their contributions when feasible by instituting new technologies.

Additionally, state agencies should enhance their efforts to remediate sources of pollution, especially in the watersheds of shellfish growing areas and in pilot ocean acidification watersheds, emulating successful efforts such as the Department of Agriculture, Conservation and Forestry and the Department of Environmental Protection memorandum of agreement that outlines the responsibilities of both agencies to assist with agricultural runoff.

3.2. Assess the need for additional water quality criteria⁶ relevant to ocean acidification.

⁵ Numeric nutrient criteria provide the basis for regulations to reduce nutrient loading to water bodies from licensed (or permitted) point source discharges. In 2004, the Environmental Protection Agency directed states to develop numeric nutrient criteria for nitrogen and phosphorus to protect aquaculture, shellfish harvesting/propagation and habitats for aquatic marine life. For marine waters, Resolve 2007, chapter 49, required the Department of Environmental Protection to create a work plan and timeline leading to approved nutrient standards and a report on technological innovations to (total nitrogen) nutrient reduction/wastewater treatment. Significant point and non-point sources of nutrients flowing into Casco Bay were subsequently inventoried. The Department's June 2008 report is available at http://www.maine.gov/dep/water/nutrient-criteria/nutrient_criteria_report_2008.pdf. The Department's deadline for completing this work is currently 2015 (extended from 2012 by the Legislature).

⁶ Water quality criteria under Goal 3 refers to regulatory criteria or standards set to guide the regulated community regarding their discharge limits and what is allowable under their licenses. This is different from the criteria and information outlined in Goal 1 that will help in understanding more generally the chemical and biological indicators of ocean acidification.

The commission recommends that the Environmental Protection Agency and other federal agencies, in conjunction with the Department of Environmental Protection, take the lead on evaluating existing standards and the need for new standards (e.g., pH, oxygen, temperature and conductivity) to address ocean acidification. Cost effectiveness of the standards should be considered. If it is determined that existing standards are insufficient to control the impacts of local sources, the Environmental Protection Agency should evaluate the applicability of pH and other water quality criteria identified by recent research or recommended by scientific experts in the fields of ocean acidification and water quality. Recent scientific research suggests that other ocean chemistry parameters such as dissolved oxygen and biological indicators may be relevant to local acidification.

Currently, pH is the only water quality criteria that can be readily associated with ocean acidification. It is conceivable that changing existing regulatory limits may have an effect on pH in the near coastal waters depending on the volume of effluent being discharged and the diluting characteristics of the receiving water. The allowable limits of pH in wastewater discharges are governed by statute and legislation would be required to change those limits.

The commission encourages the Department of Environmental Protection to meet its June 2015 deadline for establishing numeric nutrient criteria (see footnote 10).

3.3. Ensure that state staff and other practitioners are working with the best information and most effective technology.

To ensure that the people of Maine are getting access to the most effective technologies, the commission recommends continuing and enhancing current best management practices (BMPs) workshops and training sessions on storm water runoff, erosion control and sedimentation. These workshops and training sessions should continue to provide information about the most effective existing and emerging tools that remove or reduce nutrients, organic carbon and help minimize land use changes that increase freshwater dilution of seawater.

There is a critical need for better technologies to address nutrient loading, especially from nonpoint sources such as new septic system technologies that more effectively treat nutrients. Where demonstrated to have an impact (based on the understanding of relative contributions of nutrients), the State should seek to establish private partnerships to identify, promote and support new and improved technologies that remove or reduce nitrogen and organic carbon from both point and nonpoint sources.

Maine should also continue to enforce BMPs written into licensed entities' permits to ensure the BMPs are followed and required technologies are installed and effective in achieving demonstrated reductions in nutrient loading. For those entities that are not required to be licensed, Maine can enhance public education and outreach on the importance of BMPs and how to voluntarily implement them.

3.4. Investigate incentive programs for pollution and freshwater runoff reduction.

The design of best management practices is often site-specific, and existing financial incentives are often insufficient to warrant landowner participation. Maine should investigate the use of effective incentives for landowners to participate in activities that will contribute toward water quality improvements.

3.5. Support and reinforce current planning efforts and programs that address the impacts of nutrients and organic carbon and freshwater runoff into coastal waters.

Local, state and federal programs are already working collaboratively to protect and improve water quality through storm water management, land use planning and land conservation. Land conservation programs conserve forests, marshes and agricultural lands, all of which all can function as natural filters to remove nutrients and sequester carbon and help minimize fluctuations in seawater dilution (lowers pH levels) from freshwater runoff in estuaries.

Land use planning that encourages the use of “green infrastructure” practices reduces the amount of impervious surface and assists in groundwater recharge.⁷ State and local government should advance the use of incentives and continue efforts to working with other non-regulatory tools to promote and conserve forest and agricultural land uses, promote reduction in impervious surfaces and encourage use of green infrastructure and other sustainable practices.

Maine state agencies, county soil and water conservation districts, watershed groups and other qualified organizations should continue existing planning, technical, and financial assistance programs to help rural and urban landowners, farmers and others properly manage nutrients and reduce organic carbon.

3.6. Enhance education and outreach programs that provide landowners with information about best practices for reduction of nutrient pollution.

While the relative contributions of nitrogen loading from the use of fertilizers are not certain, they are believed to have an impact. In some watersheds, the impact may be more than in others depending on the specific characteristics of the coastal watershed.

The commission recommends that outreach and education programs be instituted in areas where it is demonstrated that commercial and residential fertilizers are impacting the nutrient levels coming out of coastal watersheds into estuaries. Based on the characteristics of individual coastal watersheds, the impact of nutrient pollution from fertilizer use on residential and commercial properties may be noteworthy. Other states have led successful outreach and education programs encouraging home and business

⁷ Per the Environmental Protection Agency, at the lot or neighborhood level, “green infrastructure” refers to storm water management systems that mimic nature by soaking up and storing water. At the municipal or regional scale, green infrastructure refers to the patchwork of natural areas that collectively provide habitat, flood protection, cleaner air and cleaner water.

owners to make optimal choices about the types and quantities of fertilizers needed. In the aggregate, the possibility of communities and individuals lessening their use of certain fertilizers and pesticides may help reduce nutrient loading in their watersheds.

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

Ocean acidification is occurring in our ocean and coastal waters. Scientific data suggest that the rate of acidification will continue to increase and further alter ocean chemistry. The rate of change to ocean chemistry represents the most stressful impact of ocean acidification on marine species. In light of these data, the commission makes the following recommendations to mitigate the current effects of ocean acidification and to begin to research mechanisms and methods that may enhance the adaptability of commercial species and those industries that depend upon them, thereby improving their resilience to changes in ocean chemistry.

Recommendations

4.1. Preserve, enhance and manage a sustainable harvest of kelp, rockweed and native algae and preserve and enhance eelgrass beds.

Because plants absorb carbon dioxide through photosynthesis, they have the potential to locally remediate acidification by drawing down carbon dioxide in the surrounding seawater, a process known as “phytoremediation.” Acquisition of CO₂ by marine macrophytes (sea grass, seaweeds) represents an important sink for anthropogenic CO₂ emissions. The remediation benefits are likely to be more apparent in areas of slower circulation. Growing and harvesting macroalgae could play a considerable role in carbon sequestration. Determining the benefits of co-culturing macroalgae, such as kelp and shellfish, should be a research priority.

Currently, the process for obtaining a permit for new or expanded aquaculture sites can be quite lengthy. The commission recommends that the Department of Marine Resources work to identify ways to streamline the permit and leasing processes to facilitate and promote the development and use of vegetation-based remediation efforts. Eelgrass restoration efforts are already underway and the state can build off of these existing efforts.

4.2. Encourage bivalve production to support healthy marine waters.

Sustaining shellfish production in Maine helps to protect healthy seawater chemistry and marine ecosystems from acidification. Productive shellfish beds provide natural treatment of some water quality conditions. By the very act of feeding, bivalves filter the water, clean and clarify it. Clearer water allows more sunlight to penetrate, which aids in the growth of seagrasses, including eelgrass. Seagrasses, in turn, take up carbon dioxide and sequester it deep in their root systems, reducing carbon dioxide levels in the water. Different mechanisms exist for maintaining and expanding shellfish beds and the

commission recommends that the State promote shellfish production to support healthy marine waters.

4.3. Spread shells or other forms of calcium carbonate (CaCO₃) in bivalve areas to remediate impacts of local acidification.

Re-depositing shell hash (pulverized bivalve shell) or other sources of calcium carbonate on mudflats can effectively buffer mudflats, reducing corrosive conditions and improving chances for shellfish recruitment. The spreading of shell material in intertidal zones requires permits through the Department of Environmental Protection and Department of Marine Resources. If this process is determined to be effective, these departments should adopt rules to provide a streamlined permitting process for such remediation measures.

Currently, tons of shells leftover from the consumption of shellfish in Maine restaurants are disposed of in landfills, but these shells may be useful for ocean acidification mitigation and remediation efforts. In accordance with the Department of Environmental Protection's solid waste rules for appropriate handling, storage, collection, treatment and processing protocols, a shell collection and deposition program could help protect cultivated and native oysters and clams from acidification and engage citizens and businesses in mitigating local impacts of acidification.

The commission strongly encourages the creation and promotion of shell collection programs and best management practices for carrying them out safely and effectively. To properly process shell material, centralized stockpiling locations should be identified (likely in association with shellfish growing operations) to "season" the shells sufficiently to meet state standards for prevention of disease and exotic organisms. Initially, such programs should be carried out on a "pilot study" scale to identify any unforeseen negative impacts of spreading crushed shells on mudflats.

4.4. Increase the capacity of the fishing and aquaculture industries to adapt to ocean acidification.

As acidification intensifies, hatcheries may become refuges where huge quantities of larvae can be raised in a controlled environment. The creation of this capacity would be an economic development opportunity for the private sector. The commission encourages efforts to examine the feasibility of growing species in this controlled environment until the species reach a point at which they are less vulnerable to acidification. To accomplish this, better information about the tolerances of individual species in combination with rigorous monitoring and maintenance of hatchery water is essential. Hatcheries may require technical support for monitoring and buffering methodology. Furthermore, the development of models to forecast future carbonate chemistry scenarios and the sharing of these results with industry will give business owners some predictive capacity when it comes to investing.

4.5. Identify refuges and acidification hotspots to prioritize protection and remediation efforts.

Vulnerability assessments identify species and habitats in the path of disturbance as well as those less likely to be affected and can help develop site specific adaptation strategies within the priority areas. Once locales are identified as being at high risk from increased CO₂ (hotspots), steps can be taken to mitigate the impacts through habitat restoration, phytoremediation or other measures.

To identify refuges (areas at less risk from ocean acidification because of physical features, remoteness to sources of acidification or because of biological activity utilizing CO₂) or acidification hotspots, monitoring of critical locations must be a priority. A set of criteria should be developed with which to rank different areas. The rankings should guide management efforts by providing a framework with which to focus on the most vulnerable regions first.

4.6. Encourage the enhancement and creation of research hatcheries.

Hatcheries with a focus on research can both maintain and improve genome data of commercially valuable shellfish, including crustaceans, mollusks and echinoderms. The development and testing of technology to improve large scale commercial hatchery production should be supported. Exploring the genetic adaptive capacity within these populations and selectively breed for resistance to ocean acidification and maintenance of these selected lines should be a high priority of the hatcheries.

Goal 5: Inform Stakeholders, the Public and Decision-Makers about Ocean Acidification in Maine and Empower Them to Take Action

The effects of acidification on marine organisms have been a topic of scientific inquiry for only a little more than 10 years. Calcifiers (e.g., organisms that produce shells) account for approximately 87% of landing value of Maine's commercial fisheries and research suggests that these marine resources are at risk. Maine's leaders at all levels of government, those whose livelihoods depend on marine species and the general public must have a better understanding of ocean acidification, not only in terms of what is known but also in terms of the gaps in scientific data. Information is a crucial requirement to empower stakeholders to take appropriate action. A sustained and coordinated effort will be necessary to understand the risks and appropriately address the causes and effects of ocean acidification. Given the high stakes associated with the changes in ocean chemistry, stakeholders, managers, water quality monitoring groups, conservation organizations and scientists must work together to develop a roadmap that will guide Maine's efforts to cope with the uncertainties associated with ocean acidification.

Recommendations:

5.1. In addition to providing the commission's report, its key findings should be communicated to the Governor, Maine's legislative leaders, Maine's Congressional delegation, the press and the general public in a series of briefings by commission members.

5.2. Continue efforts to increase the understanding of ocean acidification among key stakeholders, targeted audiences and local communities to help implement the commission's recommendations.

Leadership amongst nongovernmental organizations and community networks, such as the Maine Sea Grant and the Maine Coastal Observing Alliance, should take steps to help meet this goal by building on existing outreach and education efforts (workshops, multi-media tools and informational mailings) and improving educational materials developed in conjunction with stakeholders. Those stakeholders include, but are not limited to, the Maine Lobstermen's Association, the Maine Lobstermen's Union, the Maine Coast Fishermen's Association, the Maine Clammer's Association, the Maine Aquaculture Association, the Maine Soil and Water Conservation Districts, the Maine Farm Bureau, Agricultural Council of Maine, Maine Water Environment Association and Maine Rural Water Association. Information regarding ocean acidification science, remediation and adaptation strategies should be shared at existing conferences, for example: the Maine Fishermen's Forum, the Maine Water and Sustainability Conference, Northeast Coastal Acidification Network's stakeholder workshops and the Northeast Aquaculture Conference and Exposition.

5.3. Enhance the existing communication network of engaged stakeholders, state agency representatives and the research community.

A number of entities in Maine are important stakeholders in disseminating information about marine research in Maine, including ocean acidification information. For example, the Maine Sea Grant offers educational programs and resources for the general public and in schools and sponsors scientific research related to Maine's coastal and marine resources. There is also an online group called the Maine Ocean Acidification Google group. This is a group of over 110 individuals who have collaborated to stay informed about ocean acidification, and the group is currently managed by the Island Institute.

The commission encourages broader and more active participation in these groups to share information about the latest educational opportunities, research findings, mitigation, remediation and adaptation strategies related to ocean acidification. The commission also supports continuing Maine's representation within the Northeast Coastal Acidification Network.

5.4. Develop, adapt and use curricula on ocean acidification in K-12 schools and institutes of higher education and increase interdisciplinary university programs to equip young leaders with the skills to find solutions to complex multidisciplinary problems such as ocean acidification.

Maine educators should be encouraged to include curricula related to ocean acidification in their K-12 classrooms and college level courses. Ocean acidification educational efforts should include hands-on experimentation and exploration at all age levels, making the subject more engaging. Where possible, students should be encouraged to participate

in Maine's volunteer monitoring efforts and to join citizen volunteer groups to learn about this issue first-hand.

There are existing ocean acidification materials available from multiple sources on the Internet. To promote the most efficient and effective uses of these materials they should be compiled into one database that is readily available to teachers who will be able to select materials suitable to their class. Prior to inclusion in the central database, the materials should be evaluated and revised if necessary to make sure they are aligned with the *National Next Generation Science and Common Core Standards*. The easier it is for educators to incorporate ocean acidification materials into their required curricula, the more likely they are to do so.

Educational, research and non-profit organizations around Maine, including but not limited to, the Maine Sea Grant, the Gulf of Maine Research Institute, the Gulf of Maine Marine Education Association, Bigelow Laboratory for Ocean Sciences and the Island Institute could hold symposia for educators to learn more about ocean acidification and how they can incorporate ocean acidification lessons into their curricula. Such events could also serve to connect students directly with researchers. Maine Sea Grant may provide funding to support low-cost, big-impact school and community partnerships. The creation of university programs, such as the University of Maine's School for Marine Sciences Dual Master's Degree program that link marine policy and marine science education should be encouraged.

Goal 6: Maintain a Sustained and Coordinated Focus on Ocean Acidification

The state's effectiveness in addressing the impacts of changing ocean chemistry and acidification on our marine ecosystems and coastal communities requires sustained leadership and support by the Governor and other state officials and an entity to coordinate and facilitate implementation of the commission's recommendations. The commission's recommendations touch on a wide range of ocean and coastal activities involving multiple entities. Coordinating all actions related to ocean health and coastal resources, including collaboration among scientists and decision-makers, should minimize redundancies and inefficiencies.

Recommendation

6.1. Create an ongoing ocean acidification council.

The commission strongly recommends the creation of an on-going ocean acidification council to facilitate its recommendations and to accomplish the following goals:

1. Establish partnerships with state agencies involved with ocean acidification matters;
2. Coordinate the implementation of the commission's recommendations with other ocean and coastal actions;

3. Incorporate refinements and updates to the recommendations according to the latest science on ocean acidification;
4. Bridge ocean acidification related science and policy needs by supporting continued productive interaction between scientists and policymakers;
5. Coordinate with other states and key federal agencies, including the National Oceanographic and Atmospheric Administration, the Environmental Protection Agency and the Department of the Interior and work within the framework of the National Ocean Policy and with the National Ocean Council, the Northeast Regional Planning Body, the Northeast Regional Ocean Council and the Northeast Coastal Acidification Network, while sharing data with the Northeast Ocean Data Portal.⁸ This can be done by developing memoranda of understanding or other mechanisms among partners to support data sharing, collaboration and leveraging and prioritizing of funding;
6. Identify and promote economic development opportunities afforded by ocean acidification through development and commercialization of new technologies and businesses; and
7. Build public awareness, support and engagement to advance public understanding of the importance of a healthy ocean and of the most pressing challenges facing the ocean and to engage citizens and various stakeholders in the development of and support for actions and solutions needed to address those challenges.

⁸ The Northeast Ocean Data Portal is a decision support and information system which provides centralized access to ocean data, interactive maps, tools and other information to a broad range of government and non-government entities, scientists, and other ocean stakeholders. See <http://northeastoceandata.org>.