

# Northeast Coastal Acidification Network (NECAN) Ocean and Coastal Acidification Stakeholder Workshop: Maine

December 10, 2014



## I. Overview and Context

A daylong workshop was organized by the Northeast Coastal Acidification Network (NECAN) to inform and learn from fishermen, clam harvesters, aquaculturists, and coastal water quality volunteer programs regarding ocean and coastal acidification (OCA). It was held at the Darling Marine Center in Walpole, Maine on December 10, 2014. This was the first in a series of stakeholder engagement workshops on this topic being organized by NECAN, all of which will be synthesized into an implementation plan.

This summary is designed to capture key themes and topics from the day.<sup>1</sup> Presentation slides from the workshop can be found at the NECAN website ([www.neracoos.org/necan](http://www.neracoos.org/necan)).



Esperanza Stancioff, one of the lead event organizers, welcomed participants and thanked the many people involved in planning the workshop.<sup>2</sup> See the Appendix for a complete list of workshop participants. Esperanza provided an overview of the purpose of the workshop and gave some summary background on NECAN. NECAN was formed in September of 2013 with members of industry, academia, and government agencies working together on a range of ocean acidification topics in coastal waters from the Long Island Sound to Nova Scotia. NECAN's role is to: (1) review and assess the most recent scientific, technical and socio-economic information relevant to the economically important marine organisms potentially impacted by ocean and coastal acidification, (2) communicate critical knowledge gaps identified by stakeholders to relevant state and federal agencies, (3) help to coordinate and set regional priorities for monitoring and research designed to further our understanding of coastal acidification, and (d) respond to user and stakeholder needs. For more on NECAN, see the NECAN website.

Since its formation, NECAN has held 16 science-based webinars led by experts on OCA, which are available on the NECAN website. NECAN hosted a two-day State of the Science Workshop in April 2014. This scientific synthesis and the sub-regional stakeholder engagement workshops are designed to contribute to the development of an implementation plan, to be released in summer 2015.

At the start of the meeting, participants completed a keypad polling exercise to shed light on current knowledge in the room about coastal and ocean acidification, and Ron Beard, facilitator, provided an overview of the day's agenda.

<sup>1</sup> This summary was written by Ona Ferguson of the Consensus Building Institute, with input from note takers from the workgroups and the oversight of the planning team.

<sup>2</sup> Susie Arnold, Island Institute; Tanya Code, EPA; Ona Fields, CBI; Matt Liebman, EPA; Ru Morrison, NERACOOS; Esperanza Stancioff, Maine Sea Grant; Cassie Stymiest, NERACOOS; Elissa Tonkin, EPA; Beth Turner, NOAA National Centers for Coastal Ocean Science

## II. What is Ocean Acidification?

Mark Green, researcher and Professor at St Joseph's College, and oyster farmer in Oyster Bay, presented the science behind ocean acidification as currently known. He discussed carbon dioxide (CO<sub>2</sub>) levels, which are predicted to continue to increase. Our planet is now above 380ppm CO<sub>2</sub>, 100ppm higher than in the last 35 million years. The rate of change is substantially above the background rate of change in last 800,000 years, which Mark said is especially important to note. Mark described causes of CO<sub>2</sub> increase, and showed the current trajectory of CO<sub>2</sub> emissions (i.e. business as usual). The observed average increase in that scenario by 2100 is between 3.2-5.4 degrees Celsius temperature globally.

Increased CO<sub>2</sub> in water makes carbonic acid, which reduces ocean pH levels. It lowers the carbonate ion availability, which are the primary building blocks for shellfish so the lower concentration of carbonate ions makes it harder for organisms to make their shells. Ocean surface pH projections for 2100 show that pH could decrease from about 8.2 to about 7.8. Scientists have a high degree of confidence that reducing CO<sub>2</sub> emissions would slow the progress of ocean acidification and that anthropogenic ocean acidification is currently in progress and is measurable. The ocean is acidifying more rapidly than it has in over 20 million years. It isn't clear that organisms can keep up with this rate of change in their environment.

Mark showed that pH is changing in the ocean. The surface mixed layer (of several hundred feet) seeks equilibrium with CO<sub>2</sub> in the atmosphere. The mixing of the surface mixed layer and the deep ocean occurs on time scales of centuries, so is at too slow a time scale to help absorb CO<sub>2</sub>.

There was one other period when there was a rapid increase of CO<sub>2</sub> in the atmosphere 55 million years ago, but scientists think we're putting CO<sub>2</sub> in the atmosphere about ten times faster now than occurred then. At that time, there was mass extinction, and the fossil record in marine sediments shows a lot of calcium carbonate in the sediments before that period of change.

The effects of acidification on mollusks depend on the saturation state (the ratio of the amount of carbonate in the water to how much should be there at a state of equilibrium). If omega is less than one, then there's not enough carbonate available for shell formation. Ideally omega (the ratio) would be above 1.6 for the wellbeing of marine animals.

Ocean acidification has been happening for many years, it is not just something predicted for the future. At the current rate of decline, coral, which hosts a number of ocean organisms, will be unable to grow by 2050. Another example is pteropods, small snails which are an important element of the food web. Pteropods are dissolving in high latitude oceans, yet they represent half the diet of juvenile pink salmon—where will the salmon make the nutrition up? Decreases in pH disrupt shell formation of phytoplankton.

Acidification may already be having an effect on animals (though that remains to be seen in the Northeast). A lot of what we know about ocean acidification is known from experiments. Mark gave several examples of studies that showing likely survivorship among different species under predicted CO<sub>2</sub> levels. These show thinning of clamshells, for example.

In addition to ocean acidification from absorption of CO<sub>2</sub> from the atmosphere, nutrient loading and freshwater inputs can both have an influence. Nutrient loading as a result of CO<sub>2</sub> produced from the decay of organic matter also alters coastal and ocean pH. It leads to eutrophication. Today there are ~500 dead zones globally, which have decreased acidity. These dead zones are multiplying. They all

have chronic low oxygen and corresponding reductions in pH. For example, Long Island Sound is a nearby dead zone with chronic low oxygen. In these areas, acidification is happening two to three times faster than is occurring in the open ocean because of CO<sub>2</sub> from eutrophication. Adding a lot of fresh water to salt water can also increase ocean acidification. This is one of the sources of coastal acidification in Maine. It is more difficult to determine the sources of coastal acidification than the sources of ocean acidification, as described above. There are many regions in any estuary which have very low pH. There are some studies from Maine showing a strong correlation between low pH mud and reduced harvestable population of clams. Settling clams don't burrow into acidic mud, which can mean they get carried away by tides. If they do settle within the 24 hours required but the soil is acidic, they dissolve and have high levels of mortality.

Most ocean acidification research in the ocean is made of factorial studies to look at many factors, because as CO<sub>2</sub> increases, we're also increasing temperature, oxygen concentration is decreasing, and storm frequency and coastal ecosystem flooding patterns are changing. Ocean acidification is an additional and serious stressor among many. There is significant work being done to show the compounding effect these different elements have on each other.

Mark's conclusions included:

1. Increasing atmospheric carbon dioxide is causing the ocean to become more acidic.
2. There has been a significant increase in acid (decrease in pH) in your lifetime and it is changing faster than at any time during the last 55 million years.
3. The coastal ocean is acidifying even faster than the open ocean and represents a look into the future.
4. It's getting more difficult for some marine organisms to make shell material (and it affects all organisms, not just clams) and the cascade effect through marine ecosystems could be severe.
5. It's all about the rate of change.

#### **Participant questions and discussion**

- *Details about Mark's lab studies.* In a lab study with a tank with five 10cm striations of buffered and five 10cm striations of regular acidic mud from Portland Harbor, hard clam larvae were ten times more likely to settle in the buffered mud than in the unbuffered mud. Mark has seen similar results with hard and soft shell clams in labs and also in nature to a limited extent.
- *How are organisms in acidic waters surviving, and what can we learn from them?* The map of the world showing areas of high acidification (the polar ends) as far back as the 1950s must include organisms that were surviving. How are they surviving? Is it because of slow evolution? Mark responded that yes, organisms were surviving, so the question is the rate of change. Not all marine life dies in very acidic waters. Participants suggested using those animals as root stock in more southern climates.
- *Are localized efforts to buffer the effect of pH on shellfish farms possible?* They might be, by putting in seaweed or kelp upstream. The presence of a lot of dead shells would likely not work in seawater because of the substantial tidal exchange of water. Adding crushed shell to mudflat areas would change the sediment granularity mix and would influence other species, geochemistry and biology, so it isn't clear what overall effect that might have.
- *What species will "win" with ocean acidification?* Research shows that plants, specifically seaweeds, do better with increased CO<sub>2</sub> concentrations. Most of this research is experimental, and the research community needs to figure out how to study ocean acidification in the ocean.

### III. The Local Context, Industry Questions and Experiences

#### Presentation 1: Lobster-Focused Perspective

Dave Cousins, President of Maine Lobstermen's Association, spoke about changes he is seeing in the ocean related to the lobster industry. He's seeing changes in his lifetime that he doesn't think he should be seeing, and he and his Board and members think it is appropriate to be concerned.

He described the need for more research on two topics: (1) what to expect in the future, to the extent that it is possible to know this, and (2) what mitigation measures are possible for the ecosystem and for the industry – especially considering the future of the industry and next generation of people growing up in what are now lobstering communities.

Dave described several examples of changes he is seeing related to climate change that he believes can be traced to warmer waters and some of which might be linked to ocean acidification:

- In 2012, lobsters shed in May, which is a month earlier than normal, and was an industry disaster with no capacity in Maine or Canada to process the shedders and prices dropped significantly. The water temperature had been rising for ten years, with occasional odd occurrences, but nothing as dramatic as 2012.
- The entire 11 million pound lobster fishery in Long Island Sound went through a catastrophic die off and in 2013 the fishery had not yet come back. No one knows why.
- There has been a huge shift from near-shore to offshore in lobstering efforts, with many more lobsters caught 20-40 miles offshore in the last five years. People went from catching 50K lbs. to catching 150K lbs., and no one knows why there is such an increase of lobsters offshore.
- Southern New England lobstermen are seeing shell disease on 70% of lobsters, and they don't know why. Is it something the lobsters can shed out of? More information is needed.
- Finally, they are seeing warmer water species like Black Sea Bass, seahorses, triggerfish, sea horses, and breeding blue crabs in Maine. They don't see shrimp anymore.

Overall, Dave talked about the need to learn more, to be attentive, to be prepared for potentially dramatic changes related to climate and/or ocean acidification. He recommended engaging politicians in discussions about climate and ocean acidification, given the huge economic impact it could have.

#### **Participant questions and discussion**

- *Measurements* – Some lobstermen conduct temperature monitoring from Canada to Rhode Island with Jim Manning (NOAA, NMFS). Some measure salinity as well, but not CO<sub>2</sub>. MLA is interested in increasing the funding for and number of lobster research studies.
- *Lobster responses* – A participant asked if it was possible that lobsters were sometimes lulled into a dormant state if temperature, CO<sub>2</sub> levels and lack of oxygen levels were in a particular combination, after which they'd start to move again after large mixing like a storm. Dave replied that he doesn't know.

#### Presentation 2: Oyster-Farming Perspective

Bill Mook, owner of Mook Sea Farm, an oyster farm on the Damariscotta River, and NECAN Steering Committee member, shared his knowledge. Mook Sea Farms has 40 acres of leases and has been in business for 30 years. Bill told the story of the West Coast oyster industry collapse and lessons New England can take from that story. The west coast oyster industry was a \$270M industry employing 3,200 people. Beginning in 2005, they began to see massive failure of both wild and hatchery larvae sets.

Three years later, production was down 75-80%. Research identified upwelling of acidic water to be the cause of the die off. They set up collaborative monitoring programs, and they have real-time pCO<sub>2</sub> monitoring systems in hatcheries, which improved larval production significantly in 2009-2010. The challenge requires constant adjustment and monitoring. West coast oyster growers came to Maine to share their story in 2009.

At Mook Sea Farm, just prior to the West coast hatchery operators' visit, they started seeing an alarming increase in instances where fertilized eggs failed to develop, or the growth rate of older, healthy larvae would suddenly slow down. For these populations, the larval phase would be protracted, often lasting 21-23 days instead of the normal 14-16 days. Two such episodes in a hatchery season means the loss of an entire spawn that typically yields 12 to 15 million juvenile oysters—a significant financial impact. The problem closely linked to large storm events (2009 was very wet and rainy) with freshwater runoff and reduced salinity.

Assuming that carbonate chemistry was the problem, Bill and his colleagues developed a suite of management and mitigation tactics that they applied to every spawn. In 2014, they applied these tactics systematically to every spawn, and for 16 of 16 spawns, eggs fertilized and the larvae grew normally. Each spawn went through the larval stage and was set in 14 to 16 days – the first time that has happened since the problem arose. Bill's take home message is that through observation, trial and error, they reached the same conclusions reached by controlled, replicated experimentation. It is possible to control the survival of the larvae in a hatchery by insuring optimal carbonate chemistry conditions. Acidification is not a future problem in their hatchery. It is a chronic problem that they have learned to live with, for the time being.

To further their understanding of how acidification is occurring in the Damariscotta River, in April 2014 they deployed one of Joe Salisbury's (UNH) "black boxes" to measure temperature, salinity, dissolved oxygen and the partial pressure of CO<sub>2</sub> in the water, which takes a data point once every 10 seconds and calculates pH and omega (the saturation state for CaCO<sub>3</sub>). The preliminary results indicate that the saturation state for aragonite (a relatively soluble form of CaCO<sub>3</sub> that larval shellfish use make their shells) is below the threshold (1.6) given in multiple published reports as the saturation level below which larval survival is very poor.

Bill also presented evidence suggesting that the decrease in salinity that has occurred over the last 30 years he has been in business may be as important for acidification of the Damariscotta River Estuary as increasing atmospheric CO<sub>2</sub>. Based on observations of larvae in the hatchery and the chronically low omega levels observed in their first efforts at continuously monitoring carbonate chemistry, he expressed great concern about the impact acidification is having and will have on Maine's wild populations of soft shell clams and mussels. Bill emphasized that there are huge gaps in our knowledge and in monitoring.

Bill talked about the State of Maine Commission to Study the Effects of Coastal and Ocean Acidification on Commercially Harvested and Grown Species. Its work was just completed, and the final report<sup>3</sup> includes recommendations to enhance monitoring and research and "maintain a sustained and coordinated focus on OA". He would like the following statement he suggested as a member of the ME OA Commission added to the report before it is finalized: "Perhaps the most effective way for Maine to contribute to global greenhouse gas reduction is through the identification and development of new

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<sup>3</sup> <http://www.maine.gov/legis/opla/Oceanacidificationreport.pdf>

technologies that have global marketability and which would have the added benefit of creating economic opportunities here in Maine.” He believes that regulation of greenhouse gases would not put a drag on the economy but that the Clean Energy Revolution, like the Industrial Revolution and the Information Revolution, represents an opportunity for economic growth and development. [Later addition: this statement was included in the January 2015 Maine report.]

#### Participant questions and discussion

- *Opportunity for Maine* – Participants indicated broad support for the idea Bill is putting forward of the opportunity for Maine to lead on this topic (as described in the quote above).
- *Data* – Participants asked about Dave’s calibration techniques (he is maintaining constant conditions in the water and using a \$300 pH meter as the basis of those decisions) and about whether he and his colleagues differentiate between storm and spring runoff (they measure only during the hatchery season in the first half of every year, but he said they have seen the effect of storms on the pH hold back the larvae).
- *Wild Oysters* – Someone asked about wild oysters in the Damariscotta, and Bill noted that there were a huge number before colonial times. As sea level rose after the last ice age, and waters cooled, it is thought that it became too cold for American oysters to reproduce. With the rise of aquaculture in the Damariscotta River and warming temperatures associated with climate change, there is once again a wild population in the river. Spawning occurs annually, but 2014 was unusually cold. There was a huge spawn of mussels but no oysters.



#### IV. Participants Observations and Concerns about Ocean Acidification

Participants worked in small groups to discuss several questions. The groups were organized around the expertise areas of water quality, lobster, and shellfish/aquaculture. Participants were asked to talk about what they are observing related to coastal and ocean acidification, what issues are of most concern to them, and what they (or others) are measuring related to ocean acidification. This section synthesizes the ideas discussed by these small groups.

##### IV. What are participants seeing related to OCA?

Participants noted observing the following changes:

- An overall downward trend of pH, with increasing variability
- Spatial changes in lobster abundance; fewer lobsters inshore in rivers, a higher abundance offshore
- Increasing sea squirts found fouling mussel farm operations
- More undersized eggings (sub-legal female lobsters with eggs) than ever before
- Odd blooms of salps offshore up to 50 fathoms deep clogging lobster boat engines
- Higher incidences of (lobster) shell disease and immune diseases, without a clear reason
- Examples of no mussels setting after a rain event that led to an omega value of 0.9.
- A general decline in shellfish production in coastal waters
- The presence of tunicates, which have never been seen before
- The disappearance of Eelgrass beds in southern Maine
- Hatcheries are seeing changes in success, possibly linked to seawater pH
- Since the 1980s, traditional patterns in the ecosystem have become entirely unpredictable (e.g. you used to be able to predict when in the year the osprey or herring would arrive)
- Changes in distribution, and a decrease in the abundance of mussels and clams
- Clamshells get thinner as you go upstream near Phippsburg

- An increase in severity and frequency of intense storms, leading to increased runoff and decreased salinity. More, persistent impaired water quality, even with efforts to clean the rivers feeding into coastal zones.
- Ecosystem changes like wet summers and dead mudflats
- An increase in temperature
- Anecdotal reports of effects on finfish, especially in their early life (larval) stages
- Variable horseshoe crab spawning
- Issues with pH changing availability of aluminum metal ions, especially with freshwater runoff

People in a shellfish aquaculture group noted that hatcheries for fin or shellfish are the canary in the coalmine and will see effects of acidification first, while their staff will also be able to control conditions better than will those working in the ocean. People in one of the water quality groups talked about the opportunity that exists to identify local mitigation options to address local drivers.

*What are participants most concerned about related to coastal and ocean acidification?*

Participants described the following as their most substantial concerns:

- Of most concern to the lobster industry are:
  - A new sense that things can change dramatically for the lobster community, making it possible to have a huge economic change in the industry in the course of just a few weeks. The unpredictability of each season is a significant concern.
  - Currently inexplicable observations or occurrences like seeing tunicates and salps.
  - Immune system impacts to lobsters like shell disease.
  - The effects of ocean acidification on lobster larvae.
  - Small, undersized eggers.
  - Observations of shell-formation when larvae are still floating in surface waters.
  - Food web effects and questions about what lobster will eat if their food sources decline.
  - Increased reductions in ocean salinity due to organic nutrient runoff.
  - Lack of awareness about where sewage treatment plants and other human waste is discharged along the coast.
  - Lack of awareness of what each of us can do to improve coastal water quality in our own lives, and lack of political support for making changes to promote ecosystem health.
- Of most concern to those focused on shellfish aquaculture are:
  - The many unknowns around OA, and more specifically the decline in shellfish over time without a clear cause and whether and how acidification will affect organisms in the water, especially mussels' byssal threads.
  - Questions about how wild populations, and thus the fisheries, will be affected.
  - Questions about what policies, mitigation and management options (including climate adaptation strategies) are available in the short and long-term to address ocean acidification, and what the intended and unintended consequences of those options are likely to be. Those making decisions and taking action must think carefully about possible implications or effects, so they don't create new problems.
  - The need for more monitoring (see monitoring section below).
  - Questions about reproductive maturation in adults and how shells will be affected.
  - Questions about when ocean acidification will affect post-settlement of animals.
  - Increased bio-fouling in the last decade or so.
  - Rapid changes in what species are present in a given location, without clear explanations for those changes.

- The economic necessity for harvesters and consumers (markets) to shift their interest to new species. For example, traditional harvesters ignore species like razor clams to get to quahogs. We need to use what is coming out of the ocean in a way that works for us.
- Of most concern to those focused on water quality are:
  - National and international “stuckness” on climate change-related topics. They expressed frustration that there is little effective progress at national and international levels.
  - The many interconnected systems (species, people, ecosystems) and the fact that influencing one aspect of the system affects so many others. This challenge of ocean acidification is extremely complex.
  - The need for large scale monitoring and research. In particular: characterizing the issue and steering research towards data, models, and recommendations useful to the aquaculture and shellfish industry.
  - Changes / disappearance of wild mussel beds, and of the types of surface mussels are attaching to.
  - Storms becoming more severe, causing increased runoff.
  - A decrease in clams.
  - The need for those in the room and others who care about this issue to reducing their own carbon footprints in their daily lives.
  - Too many cooks spoil the soup: concern that disjointed effort in research and community action may bar a cohesive plan.
  - Practical, economic solutions need to be emphasized.

*What is being measured related to coastal and ocean acidification?*

Participants described the following current efforts to measure different parameters:

- The lobster industry is not measuring pH, but is measuring temperature. People in the lobstering community see a great need to get measurements on carbonate chemistry (inshore, offshore, throughout the water column, across a large geographic area).
- Monitoring underway in Maine from spring through fall includes measurements of: dissolved oxygen, temperature, salinity, pH, nitrogen, phosphorous, chlorophyll, transparency, and settlement of clams and mussels on plates. More specifically,
  - The Darling Marine Center collects data once or twice a week.
  - The Town of Harpswell is monitoring pH, overlay land use and shellfish trends.
  - The Town of Brunswick is monitoring pH, tying shell hatch, etc. to try to understand their shellfish trends.
  - Casco Bay has a large volunteer monitoring program. They sample two times a day from April to October for dissolved oxygen, temperature, salinity, chlorophyll and nitrogen. There are 10 near-shore profile sites, sampled at the surface and in the water column. Friends of Casco Bay prepares reports and one-pagers on specific issues, though these are not peer-reviewed or put online.
  - The University of Maine is setting up a program to monitor nutrients in the Gulf of St. Lawrence.
  - Kennebec Estuary Land Trust has volunteer monitoring in the summer, though not as extensive as that of Casco Bay. They take grab samples for nutrients and monitor the extent and percent cover density of eelgrass.
  - Maine DEP does not do long-term monitoring because of resource constraints. Maine data is publicly available, and DEP manages that using EGAD.



- Damariscotta River Association has volunteers monitor seven locations via boat. They have monitored dissolved oxygen, salinity, nitrogen, and fecal chloroform in the past.
- The Alliance Monitoring Project is a partnership of volunteer monitoring networks along the Maine coast that seeks to standardize monitoring, put data in one location and make it available to the public. AMP is just getting started.
- The Maine Healthy Beaches Program monitors temperature, salinity, seaweed rack, bacteria levels and precipitation within 48 hours prior to bacterial monitoring. This is primarily citizen scientist monitoring.
- The Ocean Observing Alliance monitors in estuarine environments and measures numerous parameters. They are interested in normalizing collecting and monitoring for citizen efforts.
- Maine DMR takes water quality measurements, including salinity and fecal coliform.
- Friends of Weskeag does GRTA monitoring for acidification pH meters in the estuary of West Gig.
- The Northeast Regional Ocean Council (NROC) and NERACOOS ISMP group is developing a plan for the region, including ocean acidification. This effort is in parallel, with some cross fertilization, with NECAN.
- Opportunities related to data:
  - Participants see many opportunities for partnerships to do long-term monitoring across various types of groups including research institutions, government agencies, industry and non-profits.
  - Participants noted the need to establish long-term monitoring using consistent, compatible techniques. They asked for guidance on how to monitor, using what technologies, where to do it, and information on who will receive it. They said many are interested in doing monitoring, but are overwhelmed by the many options and the cost.
  - Participants discussed the need to have both widespread access to data and a common repository for data.
  - Some participants asked for guidance specifically on what citizen scientists can do to contribute to research.

## V. Research

Ru Morrison, NECAN member and Executive Director of the Northeastern Regional Association of Coastal Ocean Observing Systems (NERACOOS) gave an overview of the work underway through NECAN, focusing on both research and outreach efforts. Participants then broke into the same small groups to discuss questions related to these two topics.

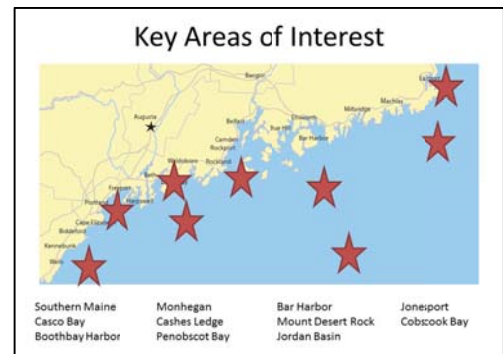
Ru described NECAN's efforts to put together a technical report from a "state of the science in New England" meeting held earlier in the year. This report will be available in the next few months. NECAN affiliates have also submitted an article to the Coastal Oceanography journal condensing the results of the technical report. He described the many places where ocean acidification measurements are being taken and said there is the capacity in New England to do experiments in addition to measurements. Ru's map graphic shows that there's only one buoy that has been taking continuous measurements for as long as a decade, and that is in southern Maine off the Isle of Shoals. A new one was just installed this year in Casco Bay. The map also shows labs capable of doing controlled experiments on organisms. In addition, many places are doing research and analysis. A group at the University of New Hampshire is using data from the long-term buoy to measure ocean acidification. There are two of Joe Salisbury's "black boxes" in New England seeking to constrain carbonate chemistry. NOAA staff are trying to measure different levels of CO<sub>2</sub> and temperature to be able to understand cumulative effects. However,

there are some holes in measurements of ocean acidification, including lobster. There's a desire to identify research priorities so NOAA and others can craft their funding program to meet local needs.

In small groups, participants discussed research. The themes from small group discussions are captured here. Because different groups had independent discussions, some of these ideas contradict each other.

- *What needs to be studied?*
  - Local mitigation options to address local drivers. Local solutions, strategies that people in Maine can undertake themselves (to avoid higher level gridlock).
  - Vulnerable areas like Casco Bay, Cobscook Bay and Pen Bay
  - Critical and sensitive habitats
  - Key estuaries, head and mouth
  - Commercially important areas
  - Representative data from along the coast for statewide fisheries (lobster, clams)
  - The mouths of all major rivers, to track near-shore vulnerability
  - High revenue commercial species should be the first priority: lobster fishery, goal of maintaining diversity for commercial adaptation.
  - Biofouling
  - Different regions – are there different conditions in the eastern and western parts of the state?
  - Mussels byssal threads
  - Selective breeding
  - In order to understand ocean acidification trends in Maine, we need information on how much freshwater is entering the Gulf of Maine (Scotian shelf input). This would require discharge monitoring capabilities.
  - The effects of ocean acidification on lobster.
  - Look for evidence of adaptation in wild populations
  - Positive/Negative effects of co-locating species, aquaculture
  - Temperature, salinity, recruitment, freshwater flow, primary production and shifts in population, chlorophyll, turbidity, atmCO<sub>2</sub>, nutrients, alkalinity, DIC, sediment
  - Why do some organisms survive in acidic waters?
  - Affects of acidification on adults
  - The capacity for shellfish to adapt in the short- to medium-term.
  - Monitoring the ocean shelf would be helpful, as it sets the stage for the rest of the Maine coast.
  - The role hatcheries can play in mitigating some impacts on shellfish industries
  - How freshwater systems affect ocean acidification on the coasts. Comparing large versus small rivers and the effect they have, urban vs. rural runoff and watershed characteristics. Could multiple comparisons help us learn what percentage of ocean acidification is attributable to what conditions? Install gauges in more estuaries and rivers, where freshwater flows are important.
  - BMPs (ideally developed by NECAN) and information about the best, most effective and affordable types of sensors.
  - How does variability in air pCO<sub>2</sub> affect organisms?
  - Comparative studies would be useful, for example, comparing river inputs (freshwater) vs. oceanic inputs (Gulf of Maine)

- *Where geographically should our research efforts be focused?* Participants had a range of ideas related to this question.



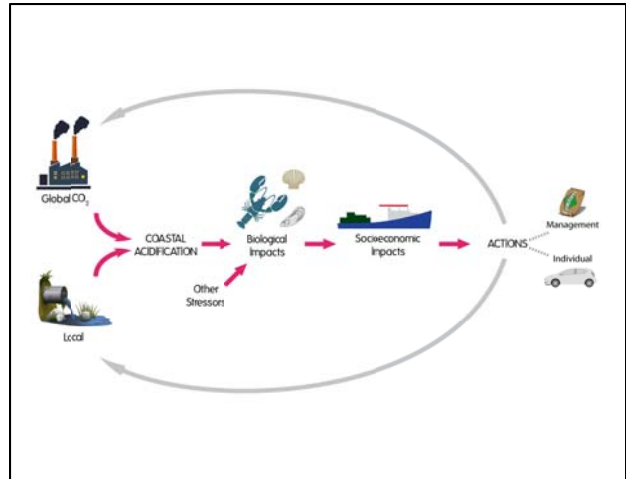
- Areas with existing monitoring buoys (western, central, eastern, Jordan Basin, Cashes, Jonesport) and find corresponding near-shore areas (Casco Bay/lower Harpswell Sound; Penobscot Bay; Isle of Shoals; etc. Need a buoy off Eastport/in Cobscook Bay). Penobscot Bay was mentioned several times.
  - Areas where monitoring infrastructure may already exist: Downeast Institute, Muscongus Bay hatchery, Bigelow lab, Darling Marine Center, Center for Cooperative Aquaculture Research, Bar Harbor/Blue Hill.
  - Southern Maine, Boothbay Harbor, Monhegan, Cashes Ledge, Bar Harbor, Mount Desert Rock.
  - Focusing on where there are multiple commercially important species and where there is significant human involvement would be helpful.
- *Who should participate in research related to ocean acidification?*
    - Cobscook Bay Learning Center
    - EPSCoR effort for aquaculture SEANET
    - NERACOOS - look at permanent monitoring locations
    - Downeast Institute
    - Maine Lobstermen's Association
    - Damariscotta River Association
    - Center for Cooperative Aquaculture Research
    - Mount Desert Island
    - Kennebunk Estuary Partnership
    - Maine Water Environment Association / stormwater /wastewater industry
    - Marine Environmental Research Institute
    - Maine Maritime Academy
    - Friends of Penobscot Bay
    - Island Institute
    - Medomak Land Trust
    - Georges River Tidewater Association
    - Coastal Enterprises, Inc.
    - Camden Partners in Monitoring
    - Spruce Creek Association
    - Maine Healthy Beaches
    - Land trusts
    - Royal River Group
    - Friends of Casco Bay
    - Casco Bay Estuary Partnership
    - University of New England
    - Department of Environmental Protection
    - Bigelow Laboratory
    - Darling Marine Center
    - Mook Sea Farms
    - Pemaquid Oyster Co
    - Muscongus Bay Aquaculture
    - Damariscotta River Association
    - Department of Marine Resources
    - Sheepscot Valley Conservation Association
    - Friends of Merymeeting Bay
    - Bowdoin College
    - Kennebec Estuary Land Trust
    - Wells National Estuarine Research Reserves
    - Maine Coastal Observing Alliance (Sheepscot Valley Conservation Association, Damariscotta River Association, Friends of Casco Bay, Georges River Tidewater Association, Kennebec Estuary Land Trust)
    - NSF funded (\$20 mil) aquaculture center (UME/ UNE EPSCoR)
    - Also, more broadly: banks, businesses, trap builders, lobster dealers, animal-focused groups ("whale people," Human Society, Audubon, etc.), town shellfish committees, schools, citizen scientists

- Coordinate with existing monitoring groups and aquaculture resource groups.
- Look for existing networks and figure out how to augment their activities, for example the Maine Coastal Observing Alliance.
- Focus on collaborative participatory research to enhance buy-in of results.
- *Other points about research:*
  - It is essential to prioritize which species or parameters to measure, to ensure resources are focused on the most important resources in rank order.
  - Need to establish long term monitoring and be able to use that to make decisions in moving forward. Coupled with that, access and a common repository for all is important.
  - It can be difficult to secure the many permits required to do field studies, yet field studies are a real need related to ocean acidification. It is important that there be increased access to permits and recognition of this need, and of the narrow window of time for research (seasonally) that can make timing with permits challenging.
  - Research needed includes: Tank & Bench top experiments, Ocean Monitoring Data, and Field Monitoring of Biological Data (larvae, fouling, adults, settlement, reproduction, condition index, etc.)
  - NECAN could suggest indicator species to study.
  - Following the money to make a difference. Research is important, but adaptation and ingenuity are also important.
  - It is important to keep a high level sense of all issues, not to get too micro-focused on a particular subset of issues.
  - The shellfish/aquaculture industry would like to better understand how biofouling and ocean acidification interact. Are there indirect effects of biofouling and community interactions?
  - If we follow the money, how do we make a real difference? Very important to use money to fund research and also that we not just focus on research, but also focus on how to adapt and innovate and use our resources to stay ahead of the curve of what might be coming.
  - Measurements are often not in the near-shore environment.
  - Not many facilities have even basic monitoring equipment.
  - Monitoring activities will depend on what the aim of the monitoring is – to figure out the effects on various communities?
  - Participants asked for guidance and training on how to monitor to ensure uniformity.
  - There is a lot of habitat restoration work downeast. Downeast salmon federation they replaced culvert with limestone riprap. Doing this had little to no additional economic cost, and has shown to have big impacts on river and freshwater pH. Should we start looking at this for policy in other areas of the state? As freshwater runs off river, it provides buffering capacity.

## VI. Communication and Outreach

Ru Morrison gave a brief overview of NECAN's efforts to develop materials to communicate about ocean acidification and its hopes to assist in outreach on this topic around the region. NECAN is aiming to provide useful resources for those doing outreach about ocean acidification in the region. NECAN is working to produce a graphic of the ocean acidification process, showing causes and effects. The NECAN website has some resources on it, and plan to develop others.

In small groups, participants discussed research and outreach. They then came back together in the large group to continue to discuss some of these key issues. The major points from both of these discussions are captured here.



- Who should we be trying to reach?
  - Fishing organizations
  - Key officials and resource managers at the state and local levels (groups like local planning boards, marine resources committees and the like). Local harvesters will respond to direction from municipal/management level, town officials. Target town officials. They have networks and ability to accommodate change.
  - Wastewater people
  - Lobster dealers
  - Coastal Enterprises, Inc.
  - Those who care about all forms of wildlife, from birds to whales
  - The Humane Society
  - The Maine Restaurant Society
  - Maine Municipal Association
  - Schools
  - Aquaculturists, aiming for broad awareness
  - Landowners, because they will help find or implement solutions
  - Focus on schools and educating children.
  - Find trusted local ambassadors to work with.
  - Look for existing networks that reach a wide number of people, including things like local conservation commissions and code enforcement officers (e.g., plumbing inspectors, shoreline law enforcement)
- How can we best reach these key audiences? What methods and materials should we use? What should we bear in mind?
  - The best communication methods are to share the importance of the topic (horizontal to vertical line in terms of CO<sub>2</sub>), without overwhelming your audience. Focus on how local actions can make a difference.
  - Local level ambassadors are better to communicate the issue and needs to the public, rather than higher level academics or policy makers/enforcers. People respond best to messages they hear from people they know and trust. Academics are not necessarily the best purveyors of information.

- Start at conservation commissions, planning boards, marine resource commissions, etc. They are already tuned to environmental concerns, so get them interested in OA and what's happening. Then let it blossom. Each municipality has different channels for communication. Figure out how to get to someone in each municipality, and these people may not be town officials.
- Some said you get the best response and most interest at the grassroots level – church group, Bailey Island Association, etc. You get the most bang for your buck talking to people that don't know much about it because they will have “aha” moments. Say that CO2 levels are 100 times outside the norm and they will see how serious it is.
- Make video of people in the fishing community discussing how OA affects them. That could be powerful.
- Use Enroll207 is a model for how to get local access to national information.
- Participants looked at a handful of graphic images to give feedback to the NECAN team trying to develop outreach materials. They gave detailed feedback on each document to the team, but shared the following general thoughts:
  - It is very challenging to create effective graphics to represent ocean acidification.
  - Tell the good stories too, or the message is too doom and gloom.
  - The graphic style needs an updated look (to avoid reminding people of text books from 20 years ago).
  - People suggested having a diversity of products that can appeal to the diversity of stakeholders we want to target. There should be a materials toolkit that is both digital and printable, which has different levels of information for different audiences. It should include things like audio voiceovers of slide presentations.
  - Simple graphics which include human actions and the feedback loop are good.
  - Graphics may need additional supporting complementary text.
  - Graphics and other materials should be tailored to be place-based, depicting appropriate species for a given region, for example.
  - Link materials to economic impacts when possible.
  - Geologic timescale depictions are confusing when they depict chemical changes.
  - The list of 20 Ocean Acidification facts was helpful. Make this ME/NE focused.
  - Framing really matters. The problem and solutions are ours, humans are part of the cycle. E.G. Horizontal graphic with the cycle and bag of fertilizer – add a bubble with other positive actions (embrace alternative energy choices, etc.).
- For the fishing community
  - Use social media. Lobstermen don't tend to like paper handouts. Fishermen Supporting a Stronger Industry as a Facebook group- that is very popular.
  - Or bring fishermen from high profile places like Alaska (with its fishing reality shows) for fishermen's exchanges. Those tend to work because they are social.
  - Use the press. 15 second spots on the evening news.
  - Don't make the fishermen look like the bad guy. We (everyone in society) are all the bad guy – OA is the consequence of our actions. Focus on pictures that bring in our own homes and lives and gives us more hope to make a difference.
- For reaching children
  - Get someone in every Maine school to give an OA presentation
  - Build on GMRI program, as they see every 5<sup>th</sup> grader in Maine, get OA in their content.

- The Skippers Program is using marine issues as examples in all 8 (or more?) classrooms. They should use OA for chemistry class.
- Consider a statewide school competition. Competitions engage schools effectively.
- Some participants suggested holding a contest for infographic designers.
- Consider the potential economic impact to segments of the local or regional community to identify audiences that will care about economic viability over the long-term.
- Be sure to offer concrete actions or solutions or people get overwhelmed with sadness and negativity.

## **VII. Final Discussion and Next Steps**

After people had reported out from their small groups, everyone came together for final reflections on the day. They noted that by talking in small groups, the full group generated a broad spectrum of solutions, issues and ideas. No one person could have come up with all the ideas generated over the course of the day. The message that we can all work together to be part of the solution is key. Some noted their dismay that there is not at this time a productive way to talk about climate change and related impacts with leaders in Washington despite the potential impacts to communities, economies and ecosystems. Others talked about where they'd be sharing information from today and their hope that any initiatives around coastal and ocean acidification focus on positive stories of where we can make a difference.

Participants responded to a simple keypad polling exercise at the beginning and end of the day. The results show a highly educated group of participants, with an increase in the percentage of participants who understand that they can do something regarding ocean acidification after the day-long session. There was also an increase in the number of participants who feel they have a good sense of where to turn for additional information, and a better general sense among participants of the numerous factors that contribute to ocean acidification.

Esperanza and Ru thanked the participants for coming together from diverse backgrounds and for working hard. They noted that Maine is leading the region in thinking about how to deal with ocean acidification, and that the success stories here are inspiring. They reiterated that there will be an implementation report developed by NECAN in coming months, which will be shared with participants at this meeting.

## VIII. Appendix: Participant List

**Meeting Facilitator:** Ron Beard, University of Maine Cooperative Extension

### **Lobstermen Group**

Facilitator: Susie Arnold, Island Institute

Participants:

- Catherine Schmidt, Maine Sea Grant
- Esperanza Stancioff, Marine Extension Team/NECAN
- David Cousens, Maine Lobstermen's Association
- Patrice McCarron, Maine Lobstermen's Association
- Richard Nelson, Lobsterman
- Eben Wilson, Lobsterman
- Pat Shepard, Penobscot East Resource Center

### **Water Quality Group 1**

Facilitator: Beth Turner

Participants:

- Tanya Code, EPA
- Peter Milholland, Friends of Casco Bay
- Angela Brewer, ME DEP
- Sarah Gladu, Damariscotta River Association
- Ruth Indrick, Kennebec Estuary Land Trust
- Emily Norton, Maine Coastal Program
- Gretchen Noyes-Hull, UMaine

### **Water Quality Group 2**

Facilitator: Ona Ferguson, Consensus Building Institute

Participants:

- Ivy MIsna, EPA
- Ru Morrison, NERACOOS/NECAN
- Keri Kaczor, Marine Extension Team
- Vivian Newman, Friends of the Weskeag/Sierra Club
- Jon Lewis, DMR

### **Shellfish/Aquaculture Group 1**

Facilitator: Beth Bisson, Maine Sea Grant

Participants:

- Sarah Redmund, Marine Extension Team
- Damian Brady, Marine Extension Team
- Bill Mook, Mook Sea Farm/NECAN
- Christopher Davis, Pemaquid Oyster Co
- Sebastian Belle, Maine Aquaculture Association
- Nellie Brylewski, Muscongus Bay Aquaculture

### **Shellfish/Aquaculture Group 2**

Facilitator: Dana Morse, Marine Extension Team

Participants:

- Cassie Stymiest, NERACOOS/NECAN
- Mike Pietrak, Marine Extension Team
- Matt Moretti, Wild Ocean Aquaculture/Bangs Island Mussels
- Mark Green, St Joseph College
- Darcie Couture, RAI
- Dan Devereaux, Town of Brunswick