Northeast Coastal Acidification Network (NECAN) Ocean and Coastal Acidification Stakeholder Workshop: Long Island Sound

January 11, 2016

I. Overview and Context

The Northeast Coastal Acidification Network (NECAN) organized this one-day workshop to inform and learn from aquaculturists, shellfish harvesters, and representatives of agencies and organizations working on water quality or marine resources regarding Ocean and Coastal Acidification (OCA). The workshop was held at the Courtyard by Marriott in Shelton, Connecticut, and was the sixth in a series of stakeholder engagement workshops on OCA organized by NECAN. The first workshop was held in Walpole, Maine on December 10, 2014; the second was held in Barnstable, Massachusetts on April 27, 2015; the third was held in Narragansett, Rhode Island on June 5, 2015; the fourth was held in Gloucester, Massachusetts on June 23, 2015; and the fifth was held in Antigonish, Nova Scotia on October 6, 2015.

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

Highlights of the workshop included the following ideas, which emerged from the presentations and group discussions:

- Increasing atmospheric carbon dioxide is causing the surface ocean to become more acidic. As a result, it is becoming more difficult for some marine organisms to make shell material, and the follow on effects through marine ecosystems could be significant.
- Coastal acidification, caused by nutrient runoff and other factors, is already impacting coastal ecosystems. If current trends continue, we can expect increased problems with shellfish hatcheries, and less predictable bivalve larval recruitment.
- For organisms like sea scallops and surf clams, experiments suggest there may be more problems when acidification is combined with a low food environment than with acidification alone. Sea scallops and surf clams are important wild fisheries in

[1] This summary was written by Toby Berkman of the Consensus Building Institute, with input from note takers from the workgroups and the oversight of the planning team. People involved in workshop planning included William Wise, New York Sea Grant; Juliana Barrett and Tessa Getchis, Connecticut Sea Grant; Esperanza Stancioff, Maine Sea Grant; and Cassie Stymiest, NERACOOS/NECAN.

Connecticut and New York, and they rank high, both in their biological sensitivity to acidification and in their climate exposure.

- We should work proactively with industry to try to predict the impacts of OCA. The goal should be for multiple partners to work together to develop more real time, continuous data.
- Participants have observed significant ecosystem changes, but it is difficult to attribute these directly to OCA.
- Ideas like phytoremediation through sugar kelp and macroalgae have promise, but are a long ways from large-scale implementation.

<u>Welcome and Overview of the Workshop</u>

At the start of the workshop, Sylvain De Guise, Director of Connecticut Sea Grant, welcomed participants and noted the impressive number and diversity of the people present and expressing interest in OCA. See Appendix A for a complete list of workshop participants. William Wise, Director of NY Sea Grant stated that NY Sea Grant was happy to be working with NECAN to put the workshop together. Mr. Wise also noted that the Northeast Sea Grant Consortium was working with the NOAA Ocean Acidification Program to fund a research program on ocean acidification in the northeast.

<u>NECAN Vision and Implementation Plan</u>

Cassie Stymiest, the NECAN Coordinator and Program Manager for the Northeastern Regional Association of Coastal Ocean Observing Systems (NERACOOS), the parent organization of NECAN, provided background information on NECAN, how it was formed, and its work to date. NECAN was formed in September of 2013 with members of industry, academia, and government agencies working together on a range of ocean and coastal acidification topics in coastal waters from Long Island Sound to Nova Scotia. NECAN began its work by hosting webinars on OCA roughly once a week focusing on scientific issues. It then hosted a science workshop on OCA, the results of which fed into a highly technical article on OCA published in the journal *Oceanography* in June 2015.

Much of NECAN's current work involves trying to translate science into more accessible formats to get the word out on OCA. Today's workshop represents part of that effort. NECAN is also working on developing an implementation plan, focusing on key questions such as what is needed, what research and monitoring would be most helpful, and what stakeholders believe are the priority areas to focus on.

NECAN has a number of roles, including to:

- Review and assess the most recent scientific, technical and socio-economic information relevant to the economically important marine organisms potentially impacted by OCA;
- Communicate the state of knowledge and critical knowledge gaps identified by stakeholders to relevant state and federal agencies;
- Help to coordinate and set regional priorities for monitoring and research designed to further our understanding of coastal acidification; and
- Respond to user and stakeholder needs.

NECAN's structure includes four working groups: Outreach and Education, Science, Industry, and Policy. Its goals include providing guidance and direction on research and observations, generating information products, organizing workshops and outreach activities, and providing resources for stakeholders. NECAN is policy neutral. Its goal is to provide information on a topic, not to change policy. For more on NECAN, see the NECAN website (www.neracoos.org/necan).

II. An Overview of the Science of Ocean Acidification (OA): Global Implications for Marine Species

Dr. Christopher Gobler, of Stony Brook University School of Marine and Atmospheric Sciences, provided an overview of the science of OA. He began by noting that, globally, OA is a CO_2 issue. Humans emit 10 billion tons of carbon per year, 26% of which is absorbed by the oceans. The "Keeling Curve" charts the concentration of atmospheric carbon dioxide at Mauna Loa Observatory since the 1950s. Last year we hit the benchmark of 400 parts per million. The rate of change in CO_2 levels is rising over time. Ice core data demonstrates a rapid increase in atmospheric CO_2 since the beginning of the industrial era. We have entered an era of CO_2 not seen in 22 million years.

Oceanographers have only been thinking seriously about OA for the past decade or so. Scholars used to think that ocean chemistry would not change significantly due to climate change, because of the ocean's size and buffering capacity. Now they project that pH will drop by up to 0.7 units in the coming decades and centuries.

OA involves a number of chemical reactions. CO_2 enters the water, creating carbonic acid. A hydrogen atom is released (creating the "H" in pH). There is also an interaction with hydrogen ion and carbonate, affecting the ability of animals to create calcium carbonate shells. Carbonate prefers to bind with bicarbonate, and is therefore less available for animals to use in calcification.

The saturation state of carbon or "omega" (Ω) is a measure of the bio-availability of carbonate, for use by animals in making calcium carbonate. For some organisms, if it is below 1, calcium carbonate will dissolve. If it is above 1, it is possible to make calcium carbonate. For biological purposes, it is desirable for omega to be well above 1 [with values above 3 considered best].

Although the ocean buffers CO_2, the current rate of CO_2 going into the ocean is too rapid for the buffering to keep up. As a result, ocean pH and the saturation state of carbon are dropping very rapidly. The International Panel on Climate Change has created various models of projected surface ocean pH. All of them agree that pH will continue to decline. Globally, the calcium carbonate saturation state will also decline.

In the northeast region, bivalves and crustaceans are important species that are vulnerable to OA, because their hard shells are made from calcium carbonate. In New York, four of the top five fisheries are bivalves or crustaceans. In addition, filter-feeding bivalves provide important ecological services, which may be even more valuable than direct landings.

While large adult bivalves may not be especially sensitive to OA, they are more sensitive in earlier life stages. They are most sensitive during the larval stage, when they go from having no calcium carbonate to having much of their weight in calcium carbonate. There are significant visual effects on larval clams and scallops when exposed to higher levels of CO_2 and observed under an electron microgram. The degree of acidification during organisms' first few days of life may be especially important.

There are species-specific differences when it comes to the biological impacts of OA. For example, hard clams are more resistant to OA than are scallops. While species like mollusks are significantly negatively impacted in terms of calcification and growth, seagrasses, some microalgae, and some phytoplankton actually grow better at higher pH levels. The science is less robust on crustaceans, specifically lobsters and crabs.

While some people suspected that the effects of OA on finfish would be minimal, some finfish species are negatively impacted at the embryonic and egg stages. For example, the survival rate of inland silversides decreases with increased CO_2. Inland silversides are forage fish and provide important ecological services, as a prey species for key fishery fish. In addition, some recreational fish such as summer flounder are vulnerable to OA in their larval stages. Overall, US fisheries are valued at more than $5 billion annually.

Chemically, the ocean in the northeast US has the lowest buffering capacity when compared to other regions, and is therefore the most vulnerable to acidification. Survey work has shown a measurable decline in ocean pH in the northeast over the last 30 years. Modeling conducted by NASA suggests pH could decline by 0.4 units in the northeast by the end of the century. Projections suggest that the saturation state in the northeast will be less than 1 in the winter in certain areas by the end of the century, as well.

In coastal zones, especially, ocean pH is highly variable. Although OA is a long-term issue, coastal ocean acidification is a clear and present danger. In estuaries, for example, other processes beyond global OA, such as nutrients, have a large impact. In addition, deep-water upwelling can bring CO_2-rich water right up to the coast. Upwelling has led to serious issues with oyster hatchery production on the west coast. Part of the New York coast may be similarly vulnerable to upwelling. In addition, rivers on the east coast are acidic. Research has shown that high levels of freshwater discharge can severely depress the calcium carbonate saturation state.

In New York and Connecticut, there is significant concern over OCA due to eutrophication. Nutrient discharges into the coastal zone stimulate algal blooms. When the algae decay this results in less oxygen, an increase in CO_2 and a decease in pH—it is essentially acidification via the degradation of organic matter. Studies show a co-occurrence of low oxygen and acidification in Long Island Sound. The amount of acidification in the area exceeds what scientists expect in the ocean overall over next century. In Long Island Sound, acidification is seasonal, but persists longer than hypoxia.

Plant respiration is a significant cause of OCA. The amount of decreased oxygen and increased CO_2 due to respiration versus OA has been studied in the Gulf of Mexico; the amount due to respiration represented roughly two-thirds of the overall change.

A key question for scientists is how acidification and low oxygen effect marine life, since we know that when organisms experience hypoxia they are also experiencing low pH. Studies of larval silversides show decreased survival when they are exposed to both low oxygen and low pH, compared to either of these factors individually. In a study of juvenile hard clams, they actually had higher growth when exposed to either low oxygen or low pH individually, but lower growth when exposed to both combined.

Monitoring of pH and oxygen levels also shows high diurnal variation. Experiments have attempted to mimic these diurnal oscillations, and measure their impact. In one study, the survival of clams and scallops was lower than predicted by mean exposure to low pH and low oxygen when the levels changed on a diurnal basis. This suggests that animals have difficulty adapting to rapid diurnal changes.

Although many organisms are negatively affected by OCA, some benefit. There are still a lot of unanswered questions on species impacts. In one study, researchers investigated the state-by-state vulnerability of US shellfish to OA by considering both social and marine ecosystem vulnerability. They found that Connecticut and New York were among the most vulnerable states. New York and Connecticut both have highly eutrophic estuaries combined with a lower buffering capacity.

In conclusion, Dr. Gobler noted the following summary points:

1. Increasing atmospheric carbon dioxide is causing the surface ocean to become more acidic; ocean pH is changing faster than at any time during the last 50,000,000 years
2. It is becoming more difficult for some marine organisms to make shell material, and the follow on effects through marine ecosystems could be significant.
3. US East Coast estuaries experience hypoxia and acidification during the seasons when early life stage fish and shellfish are spawned and are developing.
4. The levels and patterns of hypoxia and acidification in estuaries can additively and synergistically depress the growth and survival of multiple early life stage forage fish and bivalves.
5. OCA is likely affecting fisheries, and the impacts will increase with time.

III. OCA and Aquaculture: Implications for shellfish farms

Dr. Mark Green, an oyster farmer and researcher at St. Joseph College, presented on the implications of OCA for shellfish aquaculture. Dr. Green noted that about 90% of CO_2 that humans emit into the atmosphere comes from the combustion of fossil fuels. 25% of those emissions dissolve in the ocean. CO_2 is a very soluble gas, and while the ocean has significant buffering capacity, we are putting CO_2 into the ocean at such a high rate that it overwhelms this buffering capacity. In addition, the ocean is stratified. The CO_2 being dissolved in the ocean is going into the surface water, and the rate of mixing between the surface water and deeper water occurs very slowly.

Another source of carbon in the atmosphere comes from deforestation. We are eliminating the equivalent of one football field of forests per second.

The coastal ocean is susceptible to other drivers of acidification besides global carbon emissions, such as coastal eutrophication. We dump a lot of nitrogen into our coastal oceans that cause blooms of carbon, the decomposition of which drives up CO_2.

Dr. Green showed color-coded maps of the globe depicting ocean pH in 1850 versus 2100, suggesting that pH will be significantly lower globally in 2100. He noted that even though OA is one of the biggest looming environmental issues that humans face, the Kardashians receive hundreds of times more news coverage than OA.

Dr. Green reviewed the levels of confidence that scientists have on various scientific issues, based on their level of agreement and the robustness of the evidence, according to the IPCC. He noted that scientists have very high confidence in the following statements:

- OA is caused by CO_2 emissions from human activity to the atmosphere that end up in the ocean
- The legacy of historical fossil fuel emissions on OA will be felt for centuries
- Anthropogenic OA is currently in progress and is measurable
- Reducing CO_2 emissions will slow the progress of OA

In addition, scientists have high confidence in the following statements:

- The ocean is acidifying more rapidly than it has in millions of years
- Mollusks (such as mussels, oysters and pteropods) are one of the groups most sensitive to OA

Finally, scientists have medium confidence in the following:

- Declines in shellfisheries will lead to economic losses (but the extent of the losses is uncertain)

Dr. Green reviewed some of the questions and research regarding the impact of OCA on shellfish. For example, there have been experiments on survivorship, and some shellfish survive low pH environments. This suggests there may be potential for selecting individuals that can tolerate low pH.

It is unclear whether shellfish aquaculture may be able to buffer our loss of commercial wild caught shellfish species. Over the last 30 years, the amount of wild caught shellfish globally has been flat, while aquaculture production has been steadily rising. However, OCA is also impacting aquaculture. For example, there was a seed crisis at the Taylor Shellfish hatchery in Whiskey Creek between 2004 and 2006 due to coastal upwelling of acidic water. Initially, the oyster larvae were not eating and were exhibiting swarming behavior. Instead of 14-15 day larval phases, the larval phases were 20-21 days. Shortly thereafter the hatchery experienced a loss of production. In one year, they lost 95% of their production. They were not sure what was causing the problems, and after almost 100 years in business, the hatchery almost went out of business. Finally, they measured the water chemistry and realized that the pH was low, due to the upwelling.

Upwelling is not a new phenomenon. When the wind blows, water can get pushed offshore and the result is upwelling of high CO_2, low pH, low omega, and low oxygen water to the surface. In studying the impact of pH on oyster larvae, observers noticed that there is a daily variation in pH. In the early afternoon pH is quite high, and during the evening it is quite low. Upwelling exacerbates these differences. During the upwelling period, pH was higher during the day and lower during the night. During the day, you get more nutrients coming up to the surface and spurring production, as CO_2 is taken up by photosynthesis. At night, the CO_2 is released via microbial respiration and the pH goes down.

Now, the Taylor Shellfish hatchery not only treats all its water, but also pumps water into its head tanks only in the afternoon and when there is no upwelling. Dr. Green showed images of pacific oyster larvae spawned in favorable versus unfavorable seawater conditions at the Taylor shellfish hatchery, and the differences were clearly visible. He noted that upwelling has not only created problems in shellfish hatcheries, but in wild populations as well.

At Mook Sea Farms, a hatchery in Maine, there have been similar issues like poor egg conversion and poor early survival, even though there have been no upwelling events. Many of the issues have been correlated with large storm events, which have gone up tremendously in recent years along with an overall increase in average annual precipitation. Freshwater lowers the buffering capacity of the coastal ocean waters and lowers the omega value. The combination of increased runoff and increasing emissions has resulted in a lower aragonite saturation rate at Mook Sea Farms, compared to when the business first opened in the 1980s. Nevertheless, the hatchery has been successful in controlling carbonate chemistry in larval tanks, ensuring normal growth and development.

Another potential impact of OCA relates to the loss of wild mussel populations in Maine. Some areas in Maine have lost up to 90% of their wild mussels. While the losses are due to multiple stressors and are not directly attributable to OCA, OCA appears to be contributing to the problem.

An interesting area to explore involves using "phytoremediation" as an adaptation strategy. This involves growing marine vegetation, such as sugar kelp, rockweed, and eelgrass, to create a "halo" of improved water quality for improved shellfish growth. Use of sugar kelp can boost pH by an order of .1 or .2.

In closing, Dr. Green noted the following predictions for the future:

- Hatcheries in other areas will start seeing larval production problems.
- The window of conditions sufficient for natural bivalve larvae will continue to close: recruitment will become less and less predictable.
- Multi-trophic farms and hatcheries that incorporate seaweeds can mitigate poor water chemistry.
- The slow and relentless increase in atmospheric and surface ocean CO_2 continues. Globally, the only solution is to turn off the "spigot" of carbon emissions.

Participant questions

A participant asked the following question about Dr. Green's presentation. *Dr. Green's response is in italics.*

- Lab studies don't always translate to the field and we should be careful not to over-generalize. Over geological time, mollusks have adapted better than any other group, and they will continue to adapt. Also, the situation on the West Coast involves a very short-term, acute exposure. This is different from the long-term, slow changes due to OA. *OCA is another stressor, and when you couple stressors together it may be a problem for some species. Although there is a difference between long-term OA and short-term acute exposures, there are acute exposures that occur on a daily basis in near-shore estuarine areas. We need to be careful about broad statements, but acidification is an important issue that deserves serious attention.*

IV. OA and Fisheries: OA and wild capture fisheries species

Dr. Lisa Milke from the Northeast Fisheries Science Center presented on the impact of OA on wild capture fisheries species. Dr. Milke noted that a list of managed species is available on the NOAA website and includes species of shellfish, crustaceans, bivalves and finfish (see http://www.greateratlantic.fisheries.noaa.gov/sustainable/ under the "Managed Species" tab in the left-hand menu). Her talk addressed experimental research from the Milford Lab and the Woods Hole Oceanographic Institution, as well as regional projects incorporating OA data.

The first set of experiments she discussed involved surf clams and sea scallops. The experiment measured growth rates at different levels of pCO_2 and two different feeding levels. It found that elevated CO_2 has a significant negative impact on growth (shell length) at both feeding rates, and that feeding rate has a significant positive impact on growth (shell length) at all CO_2 levels. This suggests feeding may compensate for OA impacts, but nutrition does not eliminate the impacts of OA. In addition, although average size decreases as CO_2 increases, even the high-CO_2 treatments include some large individuals. This suggests there is a possibility of selection for CO_2 tolerance.

Another, more recent experiment on surf clams looked at the entire larval stage, including metamorphic success. In this experiment, for some reason the animals that had greatest shell length were in the medium pCO_2 treatment group.

Another experiment on sea scallops also looked at growth under different CO_2 levels and feeding levels. It found a significant CO_2 effect within each food level on both growth and the number of deformities. The data for this study is still preliminary, however.

Overall, the data from these studies have been used in an integrated assessment model paper, to predict what will happen to sea scallops in the face of climate and temperature changes.[2] They have also been used in the Northeast Vulnerability Assessment (NEVA) to identify species at risk, and inform science priorities and management decisions. The NEVA looked at 82 species covering six functional groups, and ranked species with respect to different biological sensitivity attributes. Overall, sea scallops and surf clams rank high both in their biological sensitivity and in their climate exposure.

Within the Northeast Fisheries Science Center, there is a Climate, Ecosystem, Habitat and Assessment Steering Group that is looking at these issues, and coordinating the incorporation of climate and ecosystem issues into stock assessments. In addition, the Northeast Regional Action Plan Work Group (NERAP) is working to establish priority actions related to the National Marine Fisheries Service Climate Science Strategy for the region.

V. Setting the Local Context

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[2] See Sarah R. Cooley, Jennie E. Rheuban, Deborah R. Hart, Victoria Luu, David M. Glover, Jonathan A. Hare, and Scott C. Doney, "An Integrated Assessment Model for Helping the United States Sea Scallop (*Placopecten magellanicus*) Fishery Plan Ahead for Ocean Acidification and Warming," *Plos One* (May 6, 2015).

A set of three panelists each offered some initial observations on OCA, followed by a question and answer session. The panelists included Steve Malinowski of Fishers Island Oyster Farm, Kristen DeRosia-Banick of the Connecticut Department of Agriculture, and Katie O'Brien-Clayton from the Connecticut Department of Energy and Environmental Protection.

An industry perspective: why is environmental monitoring in the context of shellfish farming important?

Steve Malinowski owns Fishers Island Oyster Farm, a hatchery off Block Island Sound. When he first heard about difficulties with the Taylor Shellfish hatchery, initially he thought it was just a West Coast problem. Over the past year, however, his thinking has changed for two reasons. First, Bill Mook at Mook Sea Farms identified acidification as an issue and described how he has made his hatchery function more consistently. Second, Daphne Monroe presented on OCA at a Northeast Aquaculture Conference & Exposition (NACE) conference last winter, and described how a plume of acidic water reached the shoreline after an upwelling off the coast of New Jersey, and was sucked into the hatchery at the Aquaculture Innovation Center at Rutgers.

Mr. Malinowski suggested that we should work to predict what will happen regarding OCA, and act proactively. Monitoring is important, and the shellfish industry can help contribute. Geographically there are four main hatcheries in the northeast, situated in very different bodies of water, and they should each work to set up monitoring systems. The only challenge is the cost and financing. (Bill Mook has suggested that his monitoring system cost $20,000, while the systems on the West Coast may have cost up to $55,000.) If we could set up these systems, we could track OCA changes as they occur, and adapt.

A public health agency perspective: shellfish and human health related monitoring capacity and needs

Kristen De-Rosia Banick noted that part of the work of her agency, the Connecticut Department of Agriculture (CT DoA), involves regulating the safety of shellfish in interstate commerce, including the safety of the commercial and recreational harvest via inspection and licensing. CT DoA looks at the human health impacts of issues like rainfall, runoff, and bacteria. In recent years, they have been seeing more rainfall, and longer closures of shellfish growing areas as a result. There have also been extensive outbreaks of the bacteria *Vibrio* among shellfish populations in the northeast. They have been engaged in large-scale monitoring for *Vibrio*, and working with partners at the University of Connecticut to try to develop economic forecasting for *Vibrio* management.

More real time continuous data — rather than just periodic data — would be helpful both for the Department of Agriculture and for shellfish companies, and the Department of Agriculture would like to see more near-shore monitoring. Currently, they are limited by number of monitoring stations they can put out. Buoys are too far offshore to be useful for monitoring shellfish growing areas, which are generally in coastal areas with a depth of 35 feet or less, and some lack good, consistent, long-term, and continuous datasets.

It may be possible for the CT DoA to partner with NECAN on issues like OCA. CT DoA has a public health role, as well as a resource management role, and will be involved in the conversation on OCA moving forward.

An environmental health perspective: environmental monitoring capacity and needs

Katie O'Brien-Clayton from the Connecticut Department of Energy and Environmental Protection (DEEP) noted that DEEP has conducted sampling in Long Island Sound since 1991 through the Long Island Sound Water Quality Monitoring Program. They have 17 stations, and monitor the extent and duration of hypoxia. During the summer there are an additional 20 stations. Since 2009 they have been monitoring pH. They also conduct biological sampling, including plankton, community biomass and composition, and are developing pilot programs for additional monitoring as well.

There are various other organizations monitoring within Long Island Sound. These include the University of Connecticut, which has buoy systems that monitor surface and bottom but are not yet equipped with pH sensors. Other monitoring organizations include the Interstate Environmental Commission, Clean Up Sound and Harbors (CUSH), Earthplace, Save the Bay, Dominion Power and Energy, NOAA Fisheries Service, the US Geological Survey, and the Connecticut Fund for the Environment.

Participant questions
Participants asked the following questions and made the following statements about the panelist presentations. *Responses from the panelists are in italics.*

- What data is being collected in the DEEP embayment project? Does it include pH? *Ms. O'Brien-Clayton responded that at DEEP, they are looking to expand volunteer monitoring within embayments. They have not yet focused on OCA. Most of their monitoring is for hypoxia, but they could incorporate pH and alkalinity.*
- If you are sampling for nutrients from a boat, you can attach systems to the boat that measure pCO_2 in the water. This measurement then allows you to calculate other parameters as well. This would likely be easier than measuring alkalinity or DIC, which have to be preserved with mercury.
- EPA's estuaries program provided funding to the Long Island Sound Coastal Observing System (LISICOS) at UConn to add pCO_2 sensors to at least one of two buoys.
- NOAA fisheries has found that in an estuary it is difficult to measure alkalinity in the summer due to the influence of biological factors. Living organisms contribute to alkalinity. It is therefore better to measure DIC and pH, or to measure pCO_2 directly.
- Has the Fishers Island Oyster Farm seen differences in spawning successes over last several years? *Mr. Malinowski noted that every hatchery, including Fishers Island Oyster Farm, experience anomalies year-to-year and spawn-to-spawn. While they have experienced some issues, it is hard to say whether they are due to OCA.*
- We have heard about the need for more data from a variety of perspectives. How can we leverage these three perspectives, and find ways to work together to enhance our data collection? *Ms. De-Rosia Banick noted that the CT DoA is currently seeking funding through the Saltonstall-Kennedy Grant Program, approaching the issues from climate change perspective. They are seeking more real time rainfall data, which would have utility for other areas as well, and could be made publicly available. One difficulty is that data are often hidden and not in one central place. They are always looking for partnerships and are intrigued by the idea of using kelp to help buffer intake water, among other ideas. Mr. Malinowski expressed interest in working with the Department on using kelp to buffer intake water.*

- There are currently two commercial growers of sugar kelp in Long Island Sound, and two more are coming online. It is all very new and small-scale at this point, and the potential use kelp for buffering remains to be seen.
- NECAN is working on making more monitoring data available. There is lots of sampling and monitoring occurring in the region. NECAN is compiling an inventory of these efforts.
- To accurately measure the carbonate system, you need two of four parameters among pH, DIC, total alkalinity, and pCO_2. Two of four are needed because pH is hard to measure and often not calibrated correctly.
- NECAN is working on a practical guidance document for monitoring, including guidance on the best sensors to use, monitoring frequency, and other guidance.
- In New York, the most important bivalves are wild caught. There is a burgeoning aquaculture industry but it still accounts for a fraction of the wild caught fisheries. Sea scallops and surf clams are the biggest fisheries. Hard clams, northern quahogs, and bay scallops are also important. In Connecticut, how does the size of the aquaculture industry compare with the size of top wild-caught fisheries? *Ms. De-Rosia Banick noted that she does not have landings data since 2007, and they are working on a better landings collection system. However, they know that eastern oyster is the main commercial species, along with hard clam, and the vast majority is wild caught. Connecticut has very productive natural beds. While the aquaculture industry has been growing in recent years, there is not much hard data on the amount of growth, and there is an overall need to expand hatchery production. Mr. Malinowski suggested that hatchery production will be an important part of the fishery economy in New York for years to come, even if the wild caught fisheries are currently larger. Over the past 30 to 40 years, for example, hard clam production has largely shifted to aquaculture. While aquaculture production has not been growing quickly in Connecticut, this is likely to change.*
- Already, 90% of oysters consumed in New York state are aquaculture.

VI. Breakout Discussions

Participants then worked in small groups to discuss the following questions:

1. What are you seeing that could be related to OCA? What are your observations of changes over time?
2. What species should be a priority for research?
3. What areas should be a priority for monitoring?
4. What do you need for resources to better understand the impacts of OCA?
5. Where do we go from here? What are your recommendations for moving forward?

This section synthesizes participants' comments and ideas, organized by question.

<u>What are you seeing that could be related to OCA? What are your observations of changes over time?</u>

Participants noted a number of species- and water quality-related changes. However, they cautioned that it is difficult to tease out the impacts of OCA on shellfish in Long Island Sound and elsewhere from other impacts such as hurricanes and droughts, especially given the lack of available data in Long Island Sound for OCA. In addition, we have only begun to look into OCA (DEEP began pH monitoring in Long Island sound only in the past five years or so), so there is not a long enough time series to draw useful conclusions. These challenges are augmented by the high seasonal variability in pH in Long Island Sound, which complicates efforts to track long-term trends. Nevertheless, participants highlighted the following observed changes:

- Slipper shell and baby blue mussels are being found in massive quantities, especially around oyster cages.
- There have been changes in blue mussel cycles, and it is unclear whether this is part of a long-term trend.
- Oyster setting was very good in western Long Island Sound in 2015.
- Much more algae are being produced during certain times of year, especially mono-cultures taking over certain areas.
- Decreases in water clarity and quality may be causing decreases in eelgrass, especially in western Long Island Sound.
- Changes in water temperature, as cold water is replaced by warmer water, are causing changes in fish populations. There have been declines in cold-adapted species and an increase in warm-adapted species.
- There has been an increase in blue crabs, an increase in horseshoe crabs, a decrease in lobsters, and a recent decrease in sea stars.
- *Vibrio* is a major issue for this area, and seems to trump other concerns such as OCA because it is perceived as more real and immediate. Industry is voluntarily taking on non-mandatory regulations because they do not want to see people get sick.
- There have been changes in river herring spawning runs.
- In New York there have been catastrophic drops in certain shellfish populations. For example, bay scallops have died off in large numbers due to harmful algal blooms, while hard clams dropped significantly in the 1970s and '80s. Efforts to revive these species by seeding juveniles have met with limited success. It is possible OCA is a factor prohibiting the recovery of these populations.

<u>What species should be a priority for research?</u>

In reflecting on the species that should be a priority for research, participants again cautioned that we should be careful about species changes that we attribute to OCA, given the uniqueness of the Long Island Sound ecosystem and the difficulties in teasing out cause and effect. For example, although our best guess is that the collapse of the lobster industry was mostly attributable to temperature changes, higher temperatures are associated with lower oxygen and pH, so we cannot rule out the impact of OCA. Participants also noted that we lack baseline data for many common species, except for those that are commercially important. There were questions as to how we should collect this data, and whether and how we should work with industry in doing so. Nevertheless, participants suggested the following regarding species priorities:

- Commercially, the most important species in Long Island Sound are oysters and hard clams. We know a lot more about the impact of OCA on these species in hatcheries but not as much about the impact in natural growing areas.
- The main species of importance for aquaculture are hard clams, oysters and scallops.
- Finfish species are also important, especially striped bass, given their recreational importance.

- Other key species include mussels, scallops, snails, and crustaceans.
- Eelgrass is especially important in Long Island Sound.
- Seagrass and macroalgae are important to understand in that they might benefit from increased CO_2 levels.
- If there is evidence that silversides are affected in their larval and juvenile stage, then we should add other species to the list like river herring, because they have their juvenile stage at the beginning of summer and they depend on access to estuaries for mating, where freshwater conditions may create OCA issues. It might be important to look at other finfish species as well, paying particular attention to when the fish spawn because they are most vulnerable at the egg stage, and may have problems if this is during the time of year when OCA is at its worst, like in August. (However, in studies later spawning silversides have been more resistant to OCA, perhaps through some form of trans-generational adaptation or epigenetics.)
- Edible seaweed like sugar kelp should be a priority to help mitigate the effects of OCA. As more kelp growers come online, it will be interesting to study the benefits of adding macroalgae to integrated shellfish growing systems, and see if it impacts shellfish growth and water quality around the farm.
- Horseshoe crabs may be highly vulnerable to OCA, they are used in industry for baitfish, and they also serve an important biological role.

<u>What areas should be a priority for monitoring?</u>

A number of groups focused their discussion on the lack of OCA data in Long Island Sound, and on potential ways forward to get monitoring started. There was an overall consensus that this should be a priority. Participants offered the following specific comments:

- A good first step in establishing OCA monitoring would be to add sensors (pH, pCO_2, DIC, Total Alkalinity) to existing platforms like buoys, ferries, ships of opportunity, or hatcheries. Ferries may be the better option, as biofouling is a concern for the type of sensors needed, and cleaning buoy sensors would be more labor and cost intensive.
- Long Island Sound varies quite a bit in environmental conditions, so monitoring should be established to cover all sides of the sound (including nearshore).
- It is important to have some mechanism to combine all data into a living website or document.
- There are possibilities for engagement with industry, NGOs, citizen science groups and schools for work on OCA. This should be coordinated, and communication between the groups should be facilitated to encourage the best integration between groups. There are already some promising efforts underway (e.g. work by the National Estuary Program), and OCA could be incorporated into these efforts.
- Many in industry see OCA only as a potential problem. They are not seeing the immediate effects, and there is not a monitoring tool that is easy to use and that they can afford. If there were such a tool they would use it, especially if it can gather OCA information along with other water quality parameters.
- It is key to harmonize monitoring methods used by citizen groups, and to translate information in a way that people can understand. A guidance document for monitoring groups will be helpful.
- Non-obvious groups may be collecting data but not sharing it, such as the Connecticut and Long Island chapters of The Nature Conservancy, which are doing research on

nitrogen inputs and supporting conditions for seagrass. Shellfish commissions and local land trusts may also be relevant actors. We should make sure they are collecting and sharing their data in a way that allows it all to be integrated.

- The Connecticut shellfish commissions have a meeting once a year, which could be a good outlet for sharing information. The 2016 meeting is on January 23.
- Overall, we need more data describing diurnal cycles.
- We need more much inshore monitoring rather than just offshore, especially in nearshore embayments.
- The mouth of the Housatonic River is the most critical producing oyster bed in the state of Connecticut. This area could be an indicator for the rest of the Sound in terms of looking at natural beds.
- The Norwalk oyster growing areas should be a priority, especially the Hiller Bloom Hatchery at Norwalk Harbor.
- Niantic Bay is important as a premier scallop growing area; Stonington as well.
- At the Execution Rocks buoy and the Western Sound buoy, they are starting to monitor pH and nutrients with new sensors.
- The East River Narrows in western Long Island Sound are important.
- Much of the shellfish industry in Connecticut uses a hybrid wild/aquaculture model. Two large shellfish companies—the Bloom Brothers companies—get their natural sets by dredging seeds up the Quinnipiac River. They then plant them out. This suggests that the seedbed areas in the Quinnipiac River (and also the Housatonic) are key areas.
- Norm Bloom has a water quality lab, Earthwatch, which could be a natural partner.
- Most of the leased aquaculture grounds in Connecticut are in the Norwalk area. It would be helpful to have more data from this area.
- Natural seedbeds in Connecticut are leased out by individual towns. Many of these towns don't have money for monitoring but some, such as Greenwich, have funding.
- Another issue is the freshwater flow from rivers. The Connecticut River has a large output flow seasonally. Its plume goes almost to Long Island, and with that comes acidification of the water.

What do you need for resources to better understand the impacts of OCA?

In discussing key resources needed to better understand the impacts of OCA, participants highlighted the following items:

- The biggest key to better understanding OCA is attracting more money for research and monitoring. It is especially important to develop long-term and continuous datasets.
- We need a set of best practices, including what techniques we should be using, what types of sensors are needed, and what parameters we should be measuring. The key is to develop a standardized way to measure OCA and provide the training and tools to make it happen.
- Some shellfish commissions (though not all) are very active and have accurate data and records that they would be willing to share, if we find an easy way for them to do so.
- We should think about how to communicate with schools and get some of this information into the STEM curriculum.
- It would be great to get NECAN "blasts" out to even more industry members and others in Connecticut and New York.

- Websites work well for data dissemination, but we should provide regionally or locally specific translational products for different audiences.
- Industry peer groups are a good mechanism for communication. In trying to reach them, we can piggyback off of mandatory state meetings.

Where do we go from here? What are your recommendations for moving forward?

Participants noted the following ideas about where to go next:

- Currently, *Vibrio* seems to trump OCA as an environmental problem because it is seen as more immediate. We need more outreach and education to raise awareness and concern related to OCA.
- There is a need for targeted, localized outreach and education about OCA to stakeholders and the public and about coordination within the research community for more effective efforts and data use.
- There is a close connection between attempts to limit nitrogen additions to coastal water bodies in the fight against eutrophication/hypoxia and what might be done to ameliorate OCA impacts, and they could be explored together.
- We should aggressively pursue public and private funding to establish a network of OCA monitoring and response technologies at the region's shellfish hatcheries and grow-out farms. Under one potential model, commercial participants would get the equipment installed at their site by the program, but would have to commit to an annual maintenance fee to keep the equipment running in good order. (While regional monitoring for pH, pCO_2, dissolved organic carbon and carbonate ion availability is desirable, the spatial patchiness and heterogeneity of these parameters make a measurement taken only a mile away nearly irrelevant to a given hatchery/farm. You need to monitor the water coming in to the facility.)
- We should look more at how we can eliminate fossil fuels on the local level, and provide tangible actions people can relate to.
- We should conduct more research on the kelp concept mentioned earlier, and think about how we can create a market for it in Connecticut.
- We should conduct more research in natural production areas rather than only in hatcheries, and develop a set of key indicators.
- We should get more information on the physiological response of bivalves, crustaceans, seagrasses, and macroalgae to acidification to understand whether or not they are stressed.
- We need to up our communication on the consequences of inaction, including the risks of OCA versus other climate change consequences like temperature, sea level rise, and storms.
- We should prioritize our research needs with respect to monitoring, and work to link citizen science to research findings.
- We should provide practical advice to hatcheries, such as highlighting the importance of taking in larval water when carbonate chemistry is best, and stressing that well-conditioned broodstock will improve larval survival under any conditions.
- We should think about how to get the best bang for the buck in our research, and how to reach most people with the resources we have available.
- The east coast in general needs more localized, relevant monitoring of OCA parameters.

- We need more foundational experimental work on species of concern, as well as a way to make sure this information is available to the groups that need it.
- It would be helpful to have a graphical fact sheet or handout with information to provide industry, including details on who to contact for more information. It could be just one sheet of bullet points. For appealing to industry, it is key to show how OCA directly impacts their business.
- It is also helpful to set up spaces for industry-to-industry communication through storytelling, which is what they will listen to. The message should be, “This is what happened to us and it could happen to you. Here are some simple things you could implement to address the problem.”
- Potential partners include the East Coast Shellfish Growers Association and the new New York Sea Grant work on OCA, which involves meeting with all New York state shellfish hatcheries on these issues, as well as local growers. Hatcheries in Virginia may be doing something similar.
- Regardless of the exact forum, it is key to get industry representatives in the room to have an impact. It is also important, however, to include individuals outside industry who can speak to potential changes in habitat health.

VII. Final Discussion and Next Steps

In closing, Cassie Stymiest from NERACOOS and NECAN provided additional information about the next steps of NECAN. She noted that this summary and summaries of the other workshops would be available on the NECAN website, that NECAN has a listserv that goes out once a month, and that NECAN has a number of workgroups engaged in ongoing conversations. NECAN is also working on a practical guidance document, a technical document, and an implementation plan, and will be hosting a focus group on mitigation options.

Juliana Barrett from Connecticut Sea Grant closed the workshop by thanking the workshop organizers for putting the workshop together, and expressing gratitude to participants for their thoughtful contributions.

Appendix A: Participant List

Name	Organization
Bassem Allam	Stony Brook University
Juliana Barrett	Connecticut Sea Grant
Toby Berkman	Consensus Building Institute
Robert Bilek	Fairfield Shellfish Commission
Walt Blogoslawski	NOAA NMFS Milford Lab
Hannah Blondin	NERACOOS/NECAN
Martin Byrnes	Town of Islip Shellfish Hatchery / Great Atlantic Shellfish Farms
Nikki Cantatore	Harbor Watch
David Carey	CT Bureau of Aquaculture
Sally Cogan	CUSH
Anoushka Concepcion	Connecticut Sea Grant
Josh Cooper	Harbor Watch
Sarah Crosby	Harbor Watch
Sylvain DeGuise	Connecticut Sea Grant
Kristin DeRosia-Banick	CT Bureau of Aquaculture
Peter Fraboni	Harbor Watch
Emily Gamelin	NOAA Ocean Acidification Program
Tessa Getchis	Connecticut Sea Grant
Chris Gobler	Stony Brook University
Mark Green	Oyster Farmer and St Joseph College
Sally Harold	The Nature Conservancy
Dick Harris	Norman Bloom & Son LLC/Harbor Watch
Frances Hoffman	CUSH/Stonington Planning and Zoning Commission
Steve Malinowski	Fishers Island Oyster Farm
Shannon Meseck	NMFS
Lisa Milke	NMFS
David Moore	CUSH
Katie O'Brien-Clayton	CT DEEP OLISP
Michael Pascucilla	East Shore District Health Department
Steve Schmidt	
Sandra Shumway	UConn Avery Point
Esperanza Stancioff	Maine Sea Grant
Sheila Stiles	NOAA NMFS Milford Lab
Cassie Stymiest	NERACOOS/NECAN
Debbie Surabian	NRCS CT
Mark Tedesco	Long Island Sound Study
Gary Wikfors	NMFS
Bill Wise	New York Sea Grant
Ao Yaping	FDA