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

April 27, 2015

## I. Overview and Context

A daylong workshop was organized by the Northeast Coastal Acidification Network (NECAN) to inform and learn from fishermen, shellfish harvesters, aquaculturists, and representatives from state agencies working on water quality or marine resources. It was held at the Barnstable Village Harborview Conference Room in Barnstable, Massachusetts. This was the second in a series of stakeholder engagement workshops on this topic being organized by NECAN, all of which will be synthesized into an implementation plan. The first workshop was held in Walpole, Maine on December 10, 2014.

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 of the day:

- Ocean and coastal acidification (OCA) is already occurring and its effects are being felt in some regions (e.g., shellfish hatcheries in the Pacific Northwest).
- Although scientists know that the concentration of $CO_2$ in the ocean is changing and that it reduces calcifiers' ability to build exoskeletons and shells, they still do not know the degree to which organisms will be able to adapt over time, or the resilience of ecosystems.
- In the Northeast, short-term coastal acidification events happen now as a result of algae blooms caused by nutrient pollution.
- There is still a great deal of uncertainty about the effects of acidification on fisheries, aquaculture and coastal ecosystems. There is a need to build on existing resources, and the work of groups that are already studying and monitoring OCA.
- There is a desire in the community to know more about OCA, and a need to connect OCA conversations to values that really matter to people.

At the start of the meeting, Ona Ferguson, facilitator from the Consensus Building Institute (CBI), welcomed participants and thanked the many people involved in planning the workshop.[2] See the Appendix for a complete list of workshop participants.

[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.

[2] People involved in workshop planning included Pat Hughes and Owen Nichols, Provincetown Center for Coastal Studies; Diane Murphy, Woods Hole Sea Grant; Julie Simpson, MIT Sea Grant; Matt Liebman, EPA; Todd Callaghan, MA Office of Coastal Zone Management; and Cassie Stymiest, NERACOOS.

Cassie Stymiest, Program Manager for NERACOOS, the parent organization of NECAN, provided 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 and coastal 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 (4) 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 developed in 2015.

## II. What is Ocean Coastal Acidification?

Scott Doney, Senior Scientist and Chair, Department of Marine Chemistry and Geochemistry, at the Woods Hole Oceanographic Institution (WHOI), presented an overview of the science behind ocean and coastal acidification. He began by noting how a collapse of Pacific Northwest Oyster hatcheries starting in 2007, which was caused by a natural upwelling of acidic water in the Pacific Ocean exacerbated by carbon emissions from fossil fuels, has spurred renewed interest in studying ocean and coastal acidification. Scientists are attempting to understand the differences between the Pacific and Atlantic coasts, and what we can learn about global Ocean Acidification ("OA") from the study of coastal regions.

Globally, humans are emitting 10 billion tons of carbon every year, a quarter of which is absorbed in the oceans, and emissions are continuing to rise. When carbon dioxide ($CO_2$) dissolves in water, it releases a hydrogen ion, which makes the water more acidic. The carbon dioxide also drives down the number of carbonate ions in the water.

Different organisms respond to different elements of these chemical changes. For some organisms, the $CO_2$ itself acts as a fertilizer. For others, the important issue is the pH level. For organisms that build their shells out of carbon, like oysters and shellfish, the critical issue is the reduction in carbonate ions. Because these chemical changes occur simultaneously, it is often difficult for scientists to determine which chemical change an organism is responding to, or if it is responding to more than one of them at the same time.

***It is more challenging for scientists to monitor chemical changes in coastal waters than in the open ocean, because more factors affect water chemistry near the coasts. Additional factors include power plant emissions, stormwater runoff, fertilizer, soil erosion, and changes in waters from estuaries and near coastal waters.***

**-Scott Doney, WHOI**

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There is a phenomenon called the "ocean biological pump," in which through a series of processes plankton effectively pull $CO_2$ out of the atmosphere and release it into the water. As a result, there is a seasonal cycle of ocean and coastal acidification associated with plankton productivity. During the productive season, there is a large decrease in oxygen in the water at night along with lower pH. These seasonal variations in oxygen and pH levels are much larger than those resulting from long-term changes in atmospheric $CO_2$. Low oxygen and pH levels can be further exacerbated by local pollution, eutrophication, and runoff.

Organisms that make shells are sensitive to the lower amount of carbonate (the saturation state) in ocean waters associated with acidic conditions. Acidic waters also have a lower saturation state, meaning that minerals dissolve in it more easily, making it harder for organisms to make shells. This has resulted in seasonally corrosive waters in areas like the Gulf of Maine, especially in subsurface waters.

There are regional spatial patterns associated with OCA. Cold water tends to have a lower saturation state, as does freshwater. As a result, the impact of OCA tends to get worse as you move up from Long Island Sound to the Gulf of Maine and Nova Scotia.

There are many unanswered questions about the biological impacts of OCA. For example, it is unclear whether organisms living in colder waters are more adapted to acidic conditions because they have been living with them for longer, or whether they are close to crossing a threshold with respect to OCA that will cause more serious problems.

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Regardless, it is clear that OCA will create winners and losers in the ecosystem. Heightened levels of $CO_2$ will enhance productivity for some kinds of plants and algae, but make it harder for other plants and animals that make shells out of calcium carbonate. For example, in the face of heightened $CO_2$, mollusks show reduced shell size, reduced shell thickness, poorly developed hinge morphology, and elevated mortality, especially in juvenile stages. These impacts have been demonstrated across a range of mollusk species.

Overall, OCA can cause declining growth and decalcification for coral, mollusks, echinoderms, some crustaceans, and others, while there may be positive impacts on fleshy algae. Habitat systems, like cold-water coral, will likely shift. There may be less prey available for organisms that feed on calcifiers, and there will be other effects up the food chain. In addition, there is a growing body of evidence that acidification makes organisms more susceptible to disease and more sensitive to temperature, and that it may affect organism growth and fish behavior.

In order to try to understand what is likely to occur in the future, scientists are studying natural "high $CO_2$ laboratories." For example, in a location off the coast of Papa New Guinea, $CO_2$ bubbles out of the seabed through volcanic vents. The surrounding ecosystem exhibits a loss of coral cover on the ocean floor, with fleshy algae taking its place.

Scott concluded his presentation by emphasizing these summary points:

- The scientific community is interested in understanding the intersection of how changing ocean chemistry will affect organisms, the feedback effects this will have on ecosystems, and the impact of these ecosystem changes on human and economic activities.
- Although scientists know that the concentration of $CO_2$ in the ocean is changing and that it reduces calcifiers' ability to build exoskeletons and shells, they still do not know the degree to which organisms will be able to adapt over time, or the resilience of ecosystems.
- Scientists are eager to know what kind of information stakeholders are interested in learning, so they can provide timely answers.

**Participant questions and discussion**

- *What is the relationship between aragonite and carbonate saturation?* There are different mineral forms of calcium carbonate. Lots of juvenile mollusks start with aragonite and then switch to a different mineral form. That's one reason juveniles might be more sensitive to OCA.
- *Have you looked at the historic conditions of shells to see if there have been changes since the turn of the century?* I have not, but this would be a good project. The only work I have seen along these lines was off the coast of Norway, where researchers studied shell thickness in museum collections. In my work, I have been looking at chemical differences in shells over time to see if we can document changes in pH.
- *The data you showed was mostly water chemistry. Have you looked at sediment composition? Sediment is critical for mollusks.* No, I have not. There is not as much data on sediment. Some people have looked at the sediment-water interface. The general assumption is that the sediment composition is a combination of what is going on in the water above and how much organic matter is being placed into the sediment. In places with more organic matter making their way down into the sediment, the expectation is that the muds will be more acidic.
- *For future research, do you think more emphasis should be placed on mitigation or on adaptation?* The global issue of mitigation is very challenging and is very hard for the scientific community to get much traction on. It is more possible to get traction on mitigation opportunities at the regional and local levels. These include working to reduce nutrient pollution and erosion, increasing the resilience of fisheries through good management, and linking these efforts to water quality issues.

## III. Setting the Local Context

Presentation 1: Fishing Industry Changes

Mo Bancroft from the Cape Cod Commercial Fishermen's Alliance spoke about changes in the fishing industry and the fishermen's perspective on OCA. The Fishermen's Alliance is a community fishery organization representing fishing vessels and families on the Cape. It engages in economic development projects, tries to improve fishing regulations, and engages in community outreach and education.

There are a variety of fisheries on the Cape, including bluefin tuna, haddock, channeled whelk, skate, striped bass, monkfish, and others. Because of the collapse of the cod catch, there is also a strong regional focus on shellfish, including clams, snails, and scallops.

Mo provided background on a number of fisheries, their size, their season, the relevant fishing areas, and the fishing vessels and gear involved. He presented fisheries landing data from NOAA, which included the total pounds and price for each catch, but cautioned that the data were preliminary and incomplete. His presentation discussed mussels (1,145,623 pounds, $1,511,653, fished year-round in

the inshore bays around the Cape and islands), bay scallops (187,543 pounds, $2,484,765, fished November through April in the inshore bays around the Cape and islands), sea scallops (29,277,446 pounds, $334,552,095, fished year-round east of Cape Cod and South of Nantucket), Atlantic surf clams (21,280,486 pounds, $18,013,677, fished year-round offshore in the Nantucket Shoals), conch/channeled whelk (722,796 pounds, $5,605,650, fished April to December in Nantucket Sound, Vineyard Sound and Buzzards Bay), and other fisheries. In total, bivalves account for roughly 70% of fish sales, in dollars, in Massachusetts.

Through the Aquaculture Research Corp (ARC), the Fishermen's Alliance is investing in bivalve shellfish. With respect to the impact of global OA, however, Fishermen's Alliance CEO John Pappalardo has expressed ambivalence about whether it should be a concern for fishermen. He suggested that while everyone assumes negative impacts, there could also be positive impacts.

***It would be very powerful for a group like the Fishermen's Alliance to take a stance on OCA, and to decide whether it would be good or bad for them.***

**-Workshop participant**

**Participant questions and discussion**

- *Do people on Martha's Vineyard qualify for Fishermen's Alliance programs?* Yes.
- The NOAA figure for oysters – $13 million – includes aquaculture and is out of date. The current figure is about twice that amount.
- It would be very powerful for a group like the Fishermen's Alliance to take a stance on OCA, and to decide whether it would be good or bad for them. Mo could link back to his community and spread the message of the impacts OCA will have on shellfish.
- *What are the preconceived notions about impact?* It's mixed. There are some articles claiming positive effects, like that juvenile lobsters fare well under OCA and grew more shell.
    - Scott Doney noted that the study in question was performed at WHOI and showed that some crustaceans grew more shell up to a certain point, but the findings have not been replicated.
    - This underscores the need to target research more to species that have important commercial fisheries.
    - Research should also take into account that you can have a positive impact on a particular species but a negative impact on the ecosystem as a whole that cancels it out.
    - We need to recognize that the industry is in transition from wild harvest to growing shellfish.

<u>Presentation 2: Aquaculture Perspective – Part 1</u>

Chris Sherman from Island Creek Oysters and the Massachusetts Aquaculture Association provided an aquaculture perspective on OCA, discussing what he has learned from running the Aquaculture Association and a shellfish farm and hatchery. He discussed the daunting nature of shellfish farming and the variety of challenges they face from cold winters and hot summer, shellfish disease, and food safety issues, all of which can impact yields and harvests. It is critical that they be able to obtain oyster seed; if they can't, then the whole structure built from that seed collapses.

Chris was on the west coast purchasing shellfish product from a large company called Taylor Shellfish when the upwelling of acidic water from the deeper parts of the Pacific Ocean to the coastal shelf devastated their hatcheries. The industry on the west coast is much larger and more established than it is on the east coast, and the acidic water caused significant problems. Many producers could not get

enough seed to meet demand. However, market production is now back up and a lot of operations have recovered.

***OCA is part of a suite of threats the aquaculture industry is facing, including local runoff, food safety, bacterial growth, oyster disease, and seed access issues.***
**-Chris Sherman, Island Creek Oysters**

Oyster farmers seem concerned about overall changes to the ecosystem, and how changes to the water chemistry will impact nitrogen, dissolved $CO_2$ and other issues. Although aquaculturists have more stability than wild fishermen, they are still consistently challenged by weather and changing environmental conditions. Island Creek Oysters tries to mitigate these risks by finding diverse income channels, such as an open hatchery to hedge against seed production issues.

Chris suggested that OCA should not be looked at in isolation. It is part of a suite of threats the industry is facing, including local runoff, food safety, bacterial growth, oyster disease, and seed access issues. OCA gets a lot of attention because of its association with climate change, but all of these issues are important and represent real threats to the industry. In the past, the industry has proven resilient and has found ways to mitigate risks. Chris maintained that the industry is confident that with help from scientists and regulators, it can once again use its ingenuity to overcome these challenges.

**Participant questions**

- *Besides moving facility locations, what else are businesses doing to address these challenges?* Because the pH varies a lot, one approach is to install better monitoring devices, so when you draw in water for the hatchery, you know from indicators that the water is healthy. Better management techniques have also increased productivity.
- *Has anyone used aeration or additives?* Not that I'm aware of, but I'm not a hatchery expert.

<u>Presentation 3: Aquaculture Perspective – Part 2</u>

Dick Kraus from the Aquaculture Research Corporation (ARC) Hatchery provided an additional aquaculture perspective on OCA. Dick explained that he has worked around shellfish hatcheries since 1973. When he first started at the hatchery, they used intake salt water from the estuary that runs where the hatchery is located. To address issues of acidic water, they timed the water intake around high tides when the pH was higher. At a certain point, they started noticing problems beyond just larval cultures and post-set juveniles — which are the most sensitive to low pH – and started noticing problems with clams. They would go into the hatchery to check on them, and the animals would be there but with no shells. To address the problem, they built a low dam across the property in 1979 that blocked everything but the top 3 feet of Cape Cod bay water at high tide. Immediately everything got better, and they haven't seen those changes since.

They also encounter pH issues in the hatchery, which is a contained system. The $CO_2$ that the animals produce lowers the pH. When it goes down to 7.7, they need to take the animals out and put them back in at a lower density. They haven't seen any major changes in the hatchery, although last year the pH for a batch of hard clam seed went down to 7.4 – a level at which the animals can not keep up with calcification – and they had to revamp their loading system. Last year, something seemed different, almost like the water in Cape Cod Bay was different from how it had been for the last 25 years.

There are definitely changes taking place in the water. The bay used to freeze over, and it doesn't anymore. That said, Dick expressed his belief that the hatcheries can be here forever. It's easy to

moderate the pH of seawater. If you need to, you can pump hydroxides into the tanks to maintain a pH. They used to do that and stopped, but they could always do it again.

Right now, Dick noted that he is conflicted about global OA. He doesn't think OA is a big problem for hatcheries. On the west coast, the danger is upwelling events, but those don't take place in the Atlantic. Neither those monitoring the ocean nor those managing hatcheries are seeing a big change, at least not yet. The bigger issue for this area is runoff events, and concern that all this $CO_2$ is ending up at the bottom of the ocean and will eventually come to the surface. When that happens, Dick suggested the oceans are "history." He cautioned that in 50-100 years he believes we may pass a tipping point, and the ocean will be done; and when the ocean is done, we're done.

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**-Dick Kraus, ARC**

**Participant questions**

- *Have you had any reoccurrences of the problems you noticed in the '70s since installing the dam?* No.
- *Are you still drawing water from the same pools?* Yes, at high tide.
- *Can you say more about why you are conflicted about OA?* It's because everyone is making a big deal about it, but I don't think it's happening now. At the same time, I think it will happen eventually, and it will be serious.
- *What issues with coastal runoff do you experience?* We see eutrophication degrading all our embayments. For example, you used to have scallops in the estuaries every year like clockwork. They're all gone. It doesn't take rocket science to see what we're doing, and we need to fix it. Runoff impacts our ability to grow in many locations. In Wellfleet, in the mid- to late-90s, for example, we starting getting sea lettuce on our nets that would suffocate the shellfish underneath. Weed species are getting into all our estuaries, and it's all due to eutrophication.
- *Hatcheries and oyster farms can mitigate low pH through growing algae. For example, the Taylor Hatchery on the west coast uses a giant tank of kelp with an open top.* We use phytoplankton cultures. When we harvest it and feed it to the seed, the pH is 9.1. But once we feed it, the seed knocks the pH right down.
- *Do we need to ramp up mussel hatcheries, since we still rely on the wild set for mussels?* I hope not. They ruin your equipment because you can't remove the byssal threads.

**Discussion**

*Mussels*

- There used to be a massive wild mussel set in Duxbury Bay, but they haven't taken.
- It's not clear why the mussels are not taking. It doesn't have to do with OCA, unless the sediments are too acidic for them. It is probably more about eutrophication, and the mussels' inability to tolerate the water quality in our estuaries.

*Water quality and eutrophication*

- After the upwelling issue on the west coast brought OCA to national attention, aquaculturalists were emphatic that pH was just one measure in a wildly changing water chemistry and should not be looked at in isolation.
- With respect to eutrophication, there is a population dynamic to the success of shellfish as a species. As the human population increases, the population of shellfish decreases.

- The problems may have to do with the ocean bottoms. We use to have rocky or clean sandy bottoms. Now we have acidic muds. Maybe when animals settle down, their shells are dissolving. Maybe it's a nitrogen issue, or maybe it's an oxygen issue.
- Clam growth has slowed. You used to be able to take seed and within a year and a half it would come up and have beautiful necks. Starting in 2000, this began to take two years. Now we can't use the seed anymore at all. It doesn't grow.
- There used to be a beautiful sand bottom in Wellfleet Harbor, but now it's all turned black.

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

Participants worked in small groups to discuss a set of three questions:

1. What are you seeing related to OCA?
2. What's of most concern to you?
3. Are you measuring pH or other parameters?

The small groups had a mix of participants from different backgrounds. This section synthesizes their comments and ideas, loosely grouping them by theme.

*What are participants seeing related to OCA?*

Participants noted the following observations:

- Many participants have not seen observable signs of global OA to date, but there are significant water quality issues in coastal waters linked to nutrient inputs to estuaries, like phytoplankton and macroalgae blooms and the associated effects on pH, benthic habitat, and eelgrass.
- There may be synergistic effects among OCA, coastal eutrophication, and other variables like anoxic sediments, but it is extremely difficult to identify specific drivers among the many environmental and anthropogenic variables and stressors.
- There have been increasing nutrient outflows, anoxic sediments, and algal mats with black muck underneath where the bottom used to be clean and sandy. Shells can't grow in this "black mayonnaise."
- The amount of plant life activity in the water causes big daily swings in pH in near shore waters.

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>
> **-Workshop participant**

- There have been changes and declines in wild shellfish populations. Different species are doing well while others are suffering. The causes are unknown.
- Nutrients and coastal acidification have affected mussel beds, as well as oyster aquaculture floating systems.
- There has been broad decline in water quality in the Buzzards Bay over 22 years, including an increase in chlorophyll concentration (even absent additional nutrient loading, possibly because there is more organic carbon entering the system), a one degree Celsius increase in surface temperature, light attenuation, seagrass reductions, and increased brown tide blooms.
- In Rhode Island, great improvements have been made in water quality since the passing of the Clean Water Act.

- In Edgartown, there are fewer of *all* species of shellfish (hard and soft clams, bay scallops, and oysters).
- Regionally, there are many fewer steamer clams, and steamer clams have had softer shells at early formation. Hard shell clams are growing a lot more slowly.
- There have been more algae blooms (rust tide) and warmer waters across Nantucket Sound, Buzzards Bay, Cape Cod Bay, and Narragansett Bay.
- Shellfish recruitment and development in Boston Harbor has collapsed since the clean up. The Harbor has also seen a decrease in other fauna, due to the lack of sediment irrigation from clams and clammers. Thirty percent of the clam market came from Boston Harbor fifteen years ago. Now it is less than 1%. This may suggest that changes in sediment composition (e.g. increased bacteria) are a bigger contributor to coastal acidification than previously attributed – i.e., as the bacteria respire, they reduce the oxygen available in the sediments while increasing $CO_2$ levels.
- Lobster larvae are smaller, because of their efforts to fight rusty tide. They may use more energy for that rather than for growth.
- There have been changes in saltwater wedge dynamics in estuaries.
- You can get seed from the same batch from one hatchery, and see differences in shell growth (speed of growth, thickness of shell) depending on the location in which it is grown.
- This past year, it was difficult to get shellfish seed, because hatcheries were not able to produce it. They had multiple sets in which everything died. This type of thing happens about every four years. People are pointing fingers in a lot of directions; they said it was a pH problem, but at least one participant heard people blame a bacterial contamination. Another participant commented that all of the bad sets came from the same shellfish seed provider and suggested that the problem may not be environmental, but rather, related to the provider's seed husbandry methods.

***Participants expressed the greatest concern regarding coastal eutrophication, nutrient pollution and the occurrence of anoxic or acidic sediments and their effects on shellfish habitat.***

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

Participants described the following as their most substantial concerns:

- Most participants expressed the greatest concern regarding coastal eutrophication, nutrient pollution and the occurrence of anoxic or acidic sediments and their effects on shellfish habitat.
- There is a dearth of information on key issues, like pH in sediments, along with gaps in monitoring.
- The spread of anoxic/acidic sediments causes problems because shellfish do not settle on them.
- There is not enough information about how to mitigate the problems we're seeing, like through buffering acidity in sediments. It is difficult to mitigate for issues that we do not fully understand.
- There is a lack of clarity and agreement on the main issue we need to communicate, how to communicate it, and the importance of linking OCA to other coastal problems.
- There may be poorly understood links between the ecosystem changes resulting from eutrophication and Paralytic Shellfish Poisoning (PSP), as well as wasting disease in lobsters. There is also a poor understanding of the potential effects of these issues on finfish.

- We lack understanding of whether there may be other species or strains that are more resilient to changing water chemistry. There has been limited attention to how the marketability of more "resilient" species might be promoted.
- Larval and adult shellfish may be negatively impacted by fluctuating pH (rather than constant exposure).
- A recreational diver expressed concern about coral reefs.
- Seed production is critical. If you can't get seed, you can't grow shellfish, but seed production is the least secure piece of bioproduction and the most vulnerable to OCA issues. There are only a few companies doing it, and if they are lost, the industry will "go off a cliff."

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**-Workshop participant**

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

Participants described the following current efforts to measure different parameters:

- Phytoplankton is being measured at hatcheries.
- There is environmental data in conjunction with *Vibrio* monitoring from the last 2-3 years, including temperature, run by the Massachusetts Division of Marine Fisheries in Duxbury Bay.
- Most small-scale farmers lack capacity to do individual monitoring.
- A good long-term data example of 22 years comes from the Buzzards Bay Coalition's Baywatchers Program.
- Carbonate variables were incorporated very recently in at least some monitoring programs (2013 in the case of Ron Zweig data, 2015 in the Buzzards Bay program).
- There is long-term data (of about 50 years) collected by the Marine Biological Laboratory in Woods Hole that included pH measures, salinity, temperature, and dissolved oxygen; it involves monthly measurements in Great Harbor, near Falmouth.
- The Falmouth aquaculture management program/oyster demonstration project has data available on its web page.
- UMass Dartmouth started measuring $N_2$ liberation in 2013, and added N measurements in 2014.
- Dan McCorkle has monthly data for the last 3 to 4 years in Waquoit Bay; together with Scott Doney, they have ten localities within Buzzard's Bay. They have some loggers for temperature, salinity, and dissolved oxygen. The idea is to add carbonate chemistry variable to the Buzzards Bay Coalition monitoring plan.
- The Cape Cod National Park Service takes measurements.
- Pond Watchers on the Cape work with WBNERR to collect some pond data, which is published in Falmouth Enterprise.
- The Mass. Bays National Estuary Program is an important partner for water quality monitoring in Nantucket and Mashpee. Nantucket, Mashpee and the Barnstable County Cooperative Extension spend significant resources managing these water quality programs.
- For soft shell clams in Boston Harbor, there has been an effort to study historic productive grounds to see if the aragonite state of sediments may have triggered the loss of productivity.
- The YSI sonde stations used by the Cape Cod Cooperative Extension are measuring pH, temperature, dissolved oxygen, conductivity, chlorophyll, and turbidity in Cotuit Bay, Pleasant Bay, Wellfleet Harbor, Duxbury Bay, and Barnstable Harbor.

- There is an advisory group looking at coastal properties, the discharge of carbon into near shore waters, the carbon flux of the estuaries, and how this is affecting acidification.
- Most of the Cape is monitored – most towns have extensive water quality monitoring programs – but few do pH. They focus on nutrients.
- There is some targeted measuring of sediments through the Chatham program and the Buzzard's Bay Alliance.
- The Coalition for Buzzard's Bay has a signature dataset.

## V. Local Monitoring

Josh Reitsma from the Cape Cod Cooperative Extension discussed his involvement with a local near-shore monitoring program funded by Barnstable Country, the Southeastern Massachusetts Aquaculture Center, and Woods Hole Sea Grant. The program monitors five sites – in Barnstable Harbor, Cotuit Bay, Duxbury Bay, Pleasant Bay, and Wellfleet Harbor – with an aim to place the sites near shellfish. For the Pleasant Bay and Wellfleet Harbor sites, they have data going back to 2004.

The program uses YSI sondes to conduct the monitoring, which measure temperature, salinity, pH, depth, DO, chlorophyll, and turbidity, and take data every 15 minutes. They monitor March/April to November/December. It is difficult to maintain the sondes because they get fouled fairly quickly. In addition, the monitors are typically placed a foot above the bottom, which means they can only access the sondes at low tide. The Wellfleet Harbor and Cotuit Bay sites have real time monitoring capabilities.

They have a basic Quality Assurance program, whereby the sondes are usually serviced once a month, especially during warmer months, to address fouling, to upgrade the batteries, and to get data. Sometimes they have to exclude data because something goes wrong with the equipment. They create weekly summaries of the data that are available publicly (http://www.capecodextension.org/).

The data show large daily pH fluctuations. Typically, pH is low in the morning. As photosynthesis kicks in during the day, the pH goes up. Chlorophyll also goes up during the day and down at night, and the pH tracks very well with dissolved oxygen. The height of the peaks and troughs vary day by day. The tide also has an influence. For example, Barnstable has strong tidal influence, resulting in large pH swings. There is also seasonal variation — generally the colder months have less variability and higher pH.

***Variability – especially in near shore waters – may mask the long term trends of OCA.***
**-Josh Reitsma, Cape Cod Cooperative Extension**

The monitoring team has looked at the long-term trends, breaking the data down by season, and has seen no significant trend in any direction. Any trend has been overshadowed by the high amount of variation. The main takeaways are that monitoring pH can be challenging, there is a lot of variability on a daily and seasonal basis, and the variability – especially in near shore waters – may mask the long term trends of OCA.

With respect to coastal eutrophication, algal growth is causing degraded sediments. The black mud on the bottom of the ocean can be acidic. Josh showed one shell from an animal raised in a healthy habitat, and another from an animal raised in a degraded habitat. He demonstrated that the healthy shell was opaque, but it was possible to shine a flashlight through the shell of the animal from the degraded habitat.

**Participant questions and discussion**

- There are new pH probes that have higher resolution and are more reliable.
- *For the chlorophyll that is showing nightly variation, could the sensor be picking up an anomaly?* Yes, it's possible.
- A lot of dinoflagellates will swim down at night into sediments to get nutrients and then go back up into the water during the day. You can have a thick bloom, and then you go back at night and the water is crystal clear. There's also less growth and grazing by zooplankton at night. Some of these small species have the capacity to double three times per day.
- *Have you had any luck with measuring other parameters like alkalinity?* I spoke with YSI, the manufacturer, and I've heard of other pH technologies coming out, but not for the other parameters like alkalinity.
- Almost none of the coastal water quality programs measure pH; most focus on nutrients. It is difficult to operate and maintain a remote pH monitoring program.
- Standard QA/QC protocols developed and used by coastal monitoring programs are key.
- We don't have a whole lot of time allotted to monitoring during today's meeting, but this is really important data. There are few sites like this available for the long term. So many of these measurements are quick snapshots. It's a really valuable dataset. I don't want that to be lost.

## VI. Research, Outreach and Communications

Cassie Stymiest presented on existing capacity for OCA research, and for OCA outreach and communications.

With respect to research, the best measurements for looking at coastal acidification are temperature, salinity, seawater pH, dissolved oxygen, partial pressure of carbon dioxide ($pCO_2$), dissolved inorganic carbon (DIC), and total alkalinity (TA). There are a number of different sites in New England monitoring at least two of these measures (pH, $pCO_2$, DIC, TA). There are ongoing laboratory studies, mostly on shellfish, trying to improve our understanding of the effects of OCA on animals. There are also buoy monitoring systems in the Isles of Shoals and Great Bay, NH that have sensors for looking at OCA. The Isle of Shoals buoy has been monitoring since 2006, and is the only buoy in the region that has been monitoring $pCO_2$ for that length of time. There are also shore stations. At the Mook Sea Farm in Maine, they are measuring temperature, salinity, dissolved oxygen and $pCO_2$, trying to determine whether it is over or under the optimal number for shell growth. They have not yet observed changes in $pCO_2$, but they have been seeing changes in salinity.

> ***The larger picture is that there has not been a lot of research going on but there are few long-term datasets. NECAN wants to know who is measuring what and where, whether we need to do more, and where else we can put buoys and stations so we can start looking at long term trends.***
>
> **-Cassie Stymiest, NERACOOS**

The larger picture is that there has not been a lot of research going on but there are few long-term datasets. NECAN wants to know who is measuring what and where, whether we need to do more, and where else we can put buoys and stations so we can start looking at long term trends.

With respect to communications and outreach, NECAN is interested in communicating the science of OCA. They want to know who they should be reaching out to, and whether there are people who are not

at this meeting but who should have been invited. NECAN communications efforts have included 16 science based webinars and so far 860 Youtube views, and 4,087 Pageviews. NECAN members have created graphical representation of all the connected issues related to ocean and coastal acidification, and the feedback loops involved. Cassie asked for feedback on the draft graphics to be sure that the materials they create are useful.

**Participant questions and discussion**

- *Since NECAN is a part of NERACOOS, is there an interest in putting Josh's monitoring data into the NERACOOS Framework?* Yes, that's our end goal. It's important not just where we monitor, but how we integrate it.
- The Massachusetts Coastal Zone Management office has always advocated for more coastal work from NERACOOS. We would like to see more of this work done close to shore, which is more meaningful for the groups under our umbrella.
- *What are the protocols for quality assurance and control? Do you have any standards for monitoring protocols?* There's a need for that. It's something various NECAN members are interested in working on.
- The Massachusetts Bay National Estuary Program has a QA/QC plan. You could get them from a number of different monitoring programs, and could add them as best practices guides.

**Small group discussions**

In small groups, participants discussed research and outreach. They addressed two sets of questions, the first around research efforts and the second around outreach and communication:

1. Research efforts: Where should we focus our research efforts? What should we study? Who should participate?
2. Outreach and communications: How can we best reach key audiences? Who should we be trying to reach? How can we best reach them? (methods, materials, etc.) Feedback on upcoming stakeholder workshops like this one?

The themes and comments from the small group discussions are captured below.

*<u>Research efforts: Where should we focus our research efforts? What should we study? Who should participate?</u>*

Participants made the following comments about research needs and direction:

- There should be a focus on collaborative research efforts involving long-term coastal monitoring that can show potential impacts and help to better describe the problem. It is important to develop continuous long-term data sets.
- We should focus on expanding monitoring of point sources as well as stormwater inputs to our watersheds.
- Although it is challenging, we need to find ways to get more funding for coastal monitoring. We should take advantage of opportunities to organize citizen science projects.
- We should supplement existing or new programs with standardized protocols to ensure data quality and comparability.
- Priority research topics include the relationship between water-column pH and sediment pH, and the relationship between these factors and shell dissolution. We need a lot more research

> ***We need a lot more research into what is going on in the benthos, and the composition of the anoxic mud we're seeing.***
>
> **-Workshop participant**

into what is going on in the benthos, and the composition of the anoxic mud we're seeing. For example, we could look into whether its composition is similar across areas, or whether it varies.

- We should focus on developing cheaper, more accurate technology for monitoring. In lieu of the development of in-situ equipment (which can be very costly), we should consider challenging researchers to develop other field methodologies for getting the same data.
- We should try to identify the largest impacts to water quality and acidification that we can control, and then control it. However, we need the science/data before we can inform these policy/control decisions.
- There is a need to study the synergistic or cumulative effects of multiple stressors.
- We should focus on developing an understanding of how these stressors affect commercially important species, to inform better regulatory decision-making. This will require more laboratory studies on the effects of these stressors on many life scales over multiple time scales. It also suggests more of a focus on the nearshore and embayment systems.
- Above all, we need to understand more about why seed is failing.
- Although more research is needed everywhere, we should focus on major shellfish growing areas, as well as the microenvironments that these organisms live in (such as sediment and the sediment/water interface).
- We should work to further develop/standardize mitigative methodologies at a local scale, and conduct more research into local adaptation and mitigation strategies, like adding lime to sediments, or adding cultch to the water.
- There should be an investigation into a potential link between the decrease in mussel bed area and the effects of coastal acidification.
- We should study the factors behind successful wild shellfish sets or population declines.
- There should be research into the effect of short-term exposures of low pH on the settlement and growth of shellfish larvae. (One participant is working with researchers on this question already.)
- We need to measure both pH and carbonate chemistry; it is potentially misleading to monitor and report on just the former and not the latter.
- It might be possible to use sentinel sites to monitor acidification in coastal areas.
- We should engage in collaborative research with fishermen, shellfish farmers, and constables.
- We should seek to better understand what positive impacts shellfisheries can have in mitigating the effects of OCA by cleaning carbon and nitrogen out of the water, and what we can do to fully utilize these beds to this effect.
- We need to understand more about how adding shell to the water affects water chemistry; the additional calcium carbonate can be a buffering agent. We could use either live or dead animals to try to maintain the appropriate pH.
- We should study potential positive effects of dredging on the bottom composition of the area being dredged, and whether it could be a short-term loss for a long-term gain. We should use dredging projects to compare benthic ecology pre- and post-dredging to see the effects of removing nutrient loaded eutrophic sediments and how that may better allow shellfish to settle in the benthos post dredging.

***The best way to reach people is through value-based outreach tailored to specific audiences.***
**-Workshop participant**

*Outreach and communications: How can we best reach key audiences? Who should we be trying to reach? How can we best reach them? (methods, materials, etc.) Feedback on upcoming stakeholder workshops like this one?*

Participants made these suggestions about outreach and communication efforts with the public and key stakeholders:

- The best way to reach people is through value-based outreach tailored to specific audiences.
- The goal should be to communicate with the public in a way that causes or inspires them to change behavior and spend money on solutions.
- We should focus on local efforts to address coastal acidification and water quality issues. These will have more positive effects and tangible results. Coastal acidification is critical now, whereas global ocean acidification has a long time horizon and uncertain impacts. OA is an overwhelming global problem that can lead to people "shutting down" rather than deciding to take action.
- We should focus on educating those who are not yet aware of the eutrophication/acidification problem. These efforts should focus on the foods these stakeholders like to eat, and how the collapse of the shellfisheries will very adversely affect the New England economy.
- It is critical to link OCA to other coastal problems, namely increase nutrients and fisheries. We should focus on how these water quality changes are going to affect people economically and at a very local scale.
- Some of this educating may be better done in a setting where people don't know they are being educated (like posting materials/information at an aquarium). It is also very important to reach out to the biggest perpetrators to reduced water quality – we need to educate them on why what they are doing is detrimental and how to reduce their impact.
- The goal should be to reach beyond the core group that always goes to meetings. Other key stakeholders to engage include recreational fishers, shellfish farmers, and special interests like wastewater groups.
- We should also do more outreach among the already existing nets of stakeholders. Mass Audubon, for example, already has a wide network of followers, and they could help us to educate the community on what the problem is and how they could make a difference, without having to put in the effort to bring the group of stakeholders together. There is no reason to distance NECAN from all of these groups; we need to use them to communicate to a wider audience (which already trusts the source of information).
- The fishing industry is a potential ally. Most of their fisheries will be affected by OCA, but fishermen know relatively little about it.
- We can use OCA to bring attention to broader issues because it has shock value. People are bored of hearing about eutrophication.
- The flashlight demonstration that Josh gave showing shell transparency was very effective.
- Another effective way to reach people is through schools – families listen to what their children are learning.
- The infographics that were presented are too complex.
- We need to use different messaging for different groups. For some groups, the climate change message is more resonant than for others.
- We can show the results of experimental studies and projections, like graphics depicting shellfish growth under projected conditions.

***The fishing industry is a potential ally. Most of their fisheries will be affected by OCA, but fishermen know relatively little about it.***

**-Workshop participant**

- We could try various marketing techniques, like getting people to stand in black ooze, or appealing to tradition (e.g. "Bring Back the Scallops").
- We should tie the issue to concrete financial impacts. The lesson from nutrient loading is that people don't pay attention until you tell them how much it will cost on their tax bill.
- The shellfish department in Chatham runs an open house every year, with 7500 visitors, and this could be an effective model. The ARC could have a similar model, run tours, and educate people on what the facility means for the region. When they rebuild the ARC, they should incorporate an educational model.

With respect to the workshop itself, participants made these comments:

- The presentation by Scott Doney was useful.
- It is a difficult time of year for fishermen (a little earlier in spring or in the fall is better), but it is critical to get watermen at these meetings. They often have the most valuable contributions.
- It could be useful to compare the meeting results by geographic area.
- Breakout sessions were especially useful, and more effective than just having speakers.
- This meeting had a good mix of participants from different backgrounds.
- At the next meeting, consider having a presenter who is doing benthos research.

## VII. Final Discussion and Next Steps

At the close of the meeting, participants offered the following broad reflections on what they had heard and learned over the course of the day:

- Some of the experimental research being done could be used for effective communication and outreach. For example, the laboratory research showing the growth of different organisms under different conditions is fairly stark. There's a lot of work being done but not a lot of knowledge of its diversity.
- Neither of the two fishermen's coalitions represented at this meeting had a strong stance on OCA, and they are probably going to be the biggest losers when OCA increases. If we want legislative support and a general consensus around these issues, they are our target audience. If we can convince fishermen that this is going to impact them, we just developed a new lobby.
- There is legislation before the Massachusetts legislature on OCA to establish a commission like what was done in Maine, although it's outcome is unclear.

Ona concluded the meeting by noting these overarching themes:

- There is a need to build on existing resources, and the work of groups that are already doing things.
- There is a need to connect OCA conversations to values that really matter to people. It is important to decide the message before you start going out and trying to deliver it.
- There is a desire to know more about OCA, especially where there are so many confounding factors. There is a desire to tease out answers without waiting thirty years to make sure they are perfect.

Ona thanked the participants and speakers and concluded the meeting.

**Appendix: Participant List**

| Name | Organization |
|---|---|
| Abigail Archer Franklin | WH Sea Grant |
| Michelle Bachman | NEFMC Sea Scallop Habitat Plan |
| Paul Bagnall | MA Shellfish Officers Association |
| Kathryn Baltes | MIT Sea Grant |
| Mo Bancroft | Cape Cod Fishermen's Alliance |
| Carolina Bastidas | MIT Sea Grant |
| Toby Berkman | Consensus Building Institute |
| Emily Bird | NEIWPCC TMDL program |
| Todd Callaghan | MA Office of Coastal Zone Management |
| Jeff Carlson | Nantucket Natural Resources |
| Andrew Cummings | Wash-Ashore Oyster Ranch |
| Scott Doney | WHOI |
| Pine DuBois | Jones River Watershed Association |
| Brian Dudley | MA Estuaries Project, DEP |
| Bob Duncanson | Town of Chatham |
| Ona Ferguson | Consensus Building Institute |
| Renee Gagne | Town of Chatham |
| Chris Gargiulo | Cotuit Oyster Company |
| Les Hemmila | Barnstable Seafarms |
| Pat Hughes | Provincetown Center for Coastal Studies |
| Rick Karney | Martha's Vineyard Shellfish Group |
| Sia Karplus | Consultant for Orleans Wastewater Management Project |
| Steve Kirk | The Nature Conservancy |
| Dick Kraus | ARC Hatchery |
| Matt Liebman | EPA |
| Scott Lindell | Marine Biological Laboratory |
| Alex Mansfield | Jones River Watershed Association |
| Chris Miller | Brewster Dept. of Natural Resources |
| Ivy Mlsna | EPA |
| Diane Murphy | WH Sea Grant |

| | |
|---|---|
| Owen Nichols | Provincetown Center for Coastal Studies |
| Meri Ratzel | Fish Locally Collaborative |
| Josh Reitsma | WHSG/Barnstable County |
| Tara Riley | Nantucket Shellfish Biologist |
| Chris Schillaci | Mass. Marine Division of Marine Fisheries |
| Sarah Schumann | Fish Locally Collaborative |
| Chris Sherman | Mass. Aquaculture Association/Island Creek |
| Julie Simpson | MIT Sea Grant |
| Tom Stone | Woods Hole Research Center |
| Cassie Stymiest | NERACOOS |
| Jennie Rheuban | WHOI |
| Rick York | Mashpee Shellfish Constable |
| Ron Zweig | Coonamessett Farm Foundation |