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

June 5, 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 and NGOs working on issues related to water quality or marine resources in Rhode Island waters. The workshop was held at the Coastal Institute at the University of Rhode Island Graduate School of Oceanography in Narragansett, Rhode Island. This was the third in a series of stakeholder engagement workshops on this topic being organized by NECAN; feedback and lessons learned from these workshops will all be synthesized into an implementation plan. The first workshop was held in Walpole, Maine on December 10, 2014, the second was held in Barnstable, Massachusetts on April 27, 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 of the day:

- There was a broad understanding that ocean and coastal acidification are happening but, we need more research on the impacts that these processes will have on biota.
- There is a need for translation of the science to diverse audiences, which may include a translation of biological impacts into economic impacts.
- With the translation of the science comes the need for a trust factor and an honest broker of the research.
- Research conducted needs to be good, sound science that is dependable, strategic, and done by trusted scientists.
- Coastal acidification is part of a bigger picture, with multiple stressors playing a role in the impacts felt in coastal ecosystems.
- Having strong outreach, education, and translation tools are key factors in sharing our message to various audiences.

[1] This summary was written by Ivy Mlsna (U.S. Environmental Protection Agency), with input from note takers from the workgroups and the oversight of the planning team. People involved in workshop planning included Veronica Berounsky, University of Rhode Island; Chris Gobler, Stony Brook University; Beth Turner and Nathan Rebuck, National Oceanic and Atmospheric Administration; Jason Grear and Matt Liebman, U.S. Environmental Protection Agency; Esperanza Stancioff, University of Maine Cooperative Extension ; Jen Halstead and Cassie Stymiest, NERACOOS. Jeri Weiss of EPA Region 1 facilitated the workshop.

At the start of the meeting, Bruce Corliss, Dean of the URI Graduate School of Oceanography, welcomed participants to the meeting space and gave some insight on the many changes he's seen in New England driven by climate change. He spoke to the importance of ocean and coastal acidification (OCA) research nationally and internationally, particularly in the coastal zone where the organisms most vulnerable (calcium carbonate containing organisms) to OCA reside. Bruce highlighted the particular importance of addressing this issue in New England, as our economy is so dependent on these shellfish species. He spoke to the timeliness and worth of the workshop and his eagerness to hear about its findings and conclusions.

Jeri Weiss, facilitator from the Environmental Protection Agency, gave an overview of the workshop, promising a day of rich conversation involving all participants. See the Appendix for a complete list of workshop participants as well as the agenda.

Cassie Stymiest, Program Manager for the Northeast Regional Association of Coastal Ocean Observing Systems (NERACOOS), the parent organization of NECAN, provided a summary of the formation and goals of 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 waters from Long Island Sound, Georges Bank, the Gulf of Maine and Browns Bank, and Sable Island Bank out to the shelf break. 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 at www.neracoos.org/necan.

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. The group also published an article summarizing the outcomes of the meeting and webinars titled "Ocean and Coastal Acidification off New England and Nova Scotia" in the June special issue of *Oceanography* magazine. 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 and Coastal Acidification?

Ocean Acidification: An Overview for Rhode Island – Nathan Rebuck, National Oceanic and Atmospheric Administration, National Marine Fisheries Service

What is ocean acidification and how are coastal areas different?

OA is the continuous trend of increasing acidity in marine waters resulting from an increase in atmospheric carbon dioxide concentrations. Mauna Loa observatory in Hawaii has measured atmospheric CO_2 concentrations since the late 1950's; there is an upward trend line of this concentration since measuring began. Approximately 10 billion tons of carbon dioxide are emitted by humans each year, and about 26% of this gets absorbed into the oceans. When CO_2 dissolves in water, it converts to a short lived species called carbonic acid which then readily dissociates into hydrogen and bicarbonate. This increase in hydrogen ion concentration is what causes a decrease in pH. This pH change would be much more dramatic were it not for the fact that the ocean is well buffered to such changes, and much of the resultant "extra" hydrogen subsequently reacts with species such as carbonate ion to form more bicarbonate, thereby partly slowing the change in pH. The net result of the reaction is more CO_2, lower pH, fewer carbonate ions, and a lower saturation state for calcite and aragonite. These chemical changes make it more difficult for calcifying organisms to produce shells. The focus of this issue in the media has been widely on the global ocean acidification problem, but acidification can be exacerbated on regional and local levels.

Nitrogen oxides (NO_x) and sulfur oxides (SO_x) emissions from industrial activities can feed acidification regionally. Emissions of nitrate and sulfate gases from power production or other industrial activities are eventually transported out of the atmosphere via rainfall as, essentially, dilute nitric acid and sulfuric acid. Due to these chemicals high reactivity, most emissions generated inland fall back onto land as "acid rain". However, in marine areas immediately downwind of population and industrial centers, such as off the northeast coast of the US, substantial quantities of these chemicals are deposited in coastal and nearshore areas. These emitted chemicals influence the acidity of the water in two ways. First, the direct addition of the acidic compounds reduces the alkalinity of the water and leads to a decrease in pH. Second, many of these chemicals, especially NO^{+3} gas, can serve as phytoplankton fertilizer and augment eutrophication and the subsequent acidifying respiration upon decay.

Eutrophication followed by biological respiration by the phytoplankton and other microbes results in localized acidification effects via a two-step process. The act of cellular respiration results as sugar (produced by phytoplankton during photosynthesis) combines with oxygen to produce carbon dioxide, water, and energy. This resultant carbon dioxide then interacts with the surface water in the same process as previously described to produce hydrogen ions, resulting in a decrease in pH. These effects are most frequently seen in estuaries where industrial and other anthropogenic runoff are swept from upstream sources into the coastal ocean.

Acidification of ocean and coastal waters can be quantified by pH, dissolved inorganic carbon (DIC), pCO_2, and total alkalinity (TA) measurements. With any two of these measurements, one can calculate all four of these components, as well as calcite and aragonite saturation states. Saturation states are often used to express the suite of changes in all carbonate parameters. Pelagic systems are typically at a saturation state of 4 to 6, along the coastal shelf this value is usually 1 to 4. A saturation state of about 1.4 is the "magic number" where shellfish begin to become stressed. So, the addition of carbon dioxide to waters on the coastal shelf can lead to potentially dangerous saturation state levels for shellfish, as those waters are already naturally variable down to 1.

The four parameters of the carbonate system are all measured with different methodologies, with differing levels of ease and accuracy of data. Surprisingly, pH is not the best measurement of acidity, as it is not very easy to get an accurate measurement, however, it is easily continuously monitored. TA measurements entail time consuming titrations and which require discrete samples preserved in the field. TA scales well with salinity, and does not change with increasing atmospheric CO_2. DIC also requires discrete sampling, and gives great data – however, a lot of calibrations are required, and the equipment is expensive. Similar to pH, pCO_2 can be measured autonomously and continuously, but is naturally "noisy" in the marine system. Measuring one or all of these has its drawbacks, but can be done with fair accuracy.

What, and where, are the primary agents of acidification in RI?

The average natural variation of pH in RI waters is about 7.4-8.4, as measured at a few sites in Narragansett Bay. Carbon runoff and other organic inputs from rivers cause much of this high-frequency variability in the near-shore. Freshwater inputs result in a low buffering capacity in estuaries and river mouths. The upper Bay has some very low oxygen areas, which can result in very acidic waters.

The magnitude of OA will be determined by both global increase in carbon dioxide and local carbon inputs and local in-situ alkalinity to buffer those inputs. The ocean biological pump creates some very acidic water layers – as carbon gets absorbed, and the water is not actively respiring with the atmosphere, there is a drop in oxygen and pH levels. It takes a long time for water layers to move from deep to shallow areas, so these acidic water layers will stay in the ocean for a very long time, and may affect RI waters for centuries to come.

What are the potential biological and ecological effects of acidification?
Biological consequences of the effects of acidification have been demonstrated in laboratory studies but are inconsistent and variable depending on the species. Some mechanisms for these consequences are low pH which generates stress on acid/base reactions and ion transport within finfish, typically leading to varying degrees of increased mortality and decreased growth. Low aragonite saturation states demonstrate similarly negative impacts in shellfish. High pCO_2 has been shown to increase photosynthetic uptake.

What is expected in RI in the future?
Along the Atlantic coast, there has been an average pH change of -0.036 over 29 years, or -0.00124/year from 1980-2009. NASA's best model for carbon dioxide/OA response predicts a 50 year change in pH of 0.1-0.15. Over 100 years, pH is expected to decrease by 0.3-0.4, resulting in a drastically different pH environment than today. This model does not even take into account the local environmental changes, so the actual change could be much worse. This would result in dangerously low aragonite saturation states for shellfish in Southern New England and the Gulf of Maine.

Local upstream land usage and nutrient inputs will continue to be the primary determinants of acidification for near-shore coastal regions in RI. Shellfish farms at the mouth of rivers are likely to remain unaffected by global trends in carbon dioxide on the 5-25 year timeframe. Areas of high organic inputs, which make for the optimum shellfish growth conditions, are also especially susceptible to higher increased in acidity and low oxygen. Current eutrophication in many estuaries has acidified many places to a magnitude similar to 50 year projections for the open ocean. Changes in the ecosystem will occur. Acidification is happening in the world's oceans, and will continue to increase in severity.

Participant questions and discussion

- Q: *What is the scale of the effects of pH and carbonate systems here on the east coast as compared to upwelling on the west coast?* A: As water flows around oceans on the west coast, it builds up high amounts of organics that get broken down. As wind blows along shore it forces water offshore, and big upwellings occur, which have been associated with a few hatchery failures on the west coast. Isotopic ratios and temperature/salinity diagrams have identified how much increase in acidity is due to upwelling, atmosphere, and land use. Here on the east coast, there is no old, acidic, carbon-rich deep water, and the water here is typically annually mixed top to bottom. This makes it difficult to use isotopes to measure the origin of acidity. The west coast is light years ahead of us the contributing sources of their acidification problems – however, their need is much more urgent than ours. Upwelling on the east coast is not our main issue. If you are interested in learning more on this issue, take a look at the June special issue of *Oceanography*.
- Q: *The NY/NJ metropolitan area sends a lot of emissions into the upper atmosphere. A lot of shipping emissions may just "sink" into the water column in the busy ports. I'm curious as to whether this has been studied or if these effects may be significant?* A: It has not been studied yet*. There is potential that it could have a local effect, and it might be significant, but we would need the research to really know. *Post-workshop internet searching showed that limited studies

on this topic have occurred [for further information please see “Shipping contributes to ocean acidification” (Hassellov et al., 2013; doi:10.1002/grl.50521, 2013)]. Results indicate most of the effects of shipping on ocean acidification are caused by NO_x and SO_x emissions (process described above in the summary of Rebuck’s presentation) and these effects are spatially non-uniform. More data is needed, particularly in the coastal zone, to fully characterize the effects of these emissions on ocean acidification.

- Q: *What are the timescales around reducing or stopping CO_2 emissions?* A: It would be about 1,000 years until the surface ocean equilibrates with what is already in the atmosphere, if we stopped burning fossil fuels now. It would be approximately 10,000 years until equilibration occurs if you’re considering very acidic bottom waters. We won’t stop burning carbon though, so the clock restarts with every increase in atmospheric pCO2, which occurs constantly throughout the fall and winter, unfortunately.

III. Setting the Local Context

<u>Questioning how acidification will impact shellfish in the Northeast</u> – Robert B. Rheault, Ph.D. Executive Director, East Coast Shellfish Growers Association (ECSGA)

Bob Rheault began his presentation with an “official disclaimer” that the thoughts, questions, and comments presented are his own and probably not shared by anyone else. However, he feels it is his duty to question the conventional thinking before proclaiming shellfish are doomed (as he initially believed when first hearing about ocean acidification science and research). We still don’t yet know how ocean acidification will impact shellfish growth or recruitment, so Bob presented a snapshot of where the current research stands, and presented ideas on how specific biology may be able to combat acidification effects as well as alternative theories on why hatcheries may be experiencing failure.

To panic or not?
Acidification is happening, that cannot be denied. However, we don’t yet know how it will impact shellfish growth or recruitment. We should know more before we say “the sky is falling.”

ECSGA lobbied heavily for the Federal Ocean Acidification Research and Monitoring (FOARAM) Act. A lot of money (an estimated $6 million plus per year) has gone to oceanographic cruises and monitoring, but, frustratingly, with little results regarding effects on shellfisheries.

It does not serve us well to conflate the separate issues of ocean acidification, upwelling of acidic deep-water, and eutrophication induced acidification. These are “three stressors” they all work in the same way, and ultimately cause the same effects. We need to look at these separately as researchers, however, across multiple species.

Pacific Coast Upwelling of Acidified Deepwater
Deepwater has not been in contact with atmospheric oxygen for hundreds of years. Bacterial decay of sinking fecal pellets and dead plankton result in higher levels of carbon dioxide, lower oxygen levels, higher levels of NOx, decreased pH, and decreased saturation states in these deep water layers. Summer northerly winds cause offshore Ekman currents upwelling events of very corrosive and nutrient-rich waters. This has led to hatchery failures on the Pacific Coast. However, keep in mind this corrosive water was not created by an increase in anthropogenic CO_2 inputs.

Eutrophication induced estuarine pCO_2 levels are alarming
Excess nitrogen in water causes blooms of microalgae and macrophytes. Decomposition of this accumulating organic matter leads to hypoxia, high pCO_2, low pH, and acidified muds (eutrophication). Sources of nitrogen include fertilizer from farming, wastewater treatment plants, atmospheric

deposition, and stormwater runoff. Clam larvae coming into acidified muds will not dig in and settle, they would rather be eaten by a crab (so to speak). So, eutrophication is a big problem for shellfisheries.

When you have a dense algal bloom, lots of macrophytes and the sun is shining brightly, the plants will quickly fix the available pCO_2 to form carbohydrates. The pH of the surrounding waters can resultantly go up to over 8.5. At night, these same plants respire, giving off CO_2. By morning, pH may drop to 7. On a daily basis we see a 1.5+ swing in pH. Projections are for OA to cause a pH decline of 0.1-0.2 units in 50-100 years. The natural environment shows a much bigger flux on a daily basis than the average change expected over the next decade, so why is this projection such a big deal? There has been an overall decline in shellfish biomass, but there are still successful sets under these conditions.

Shellfish have already survived a lot of climate change since they appeared about 300 million years ago. In geologic time, global CO_2 levels are now relatively low. There may, therefore, be enough inherited genetic variation that we may find certain shellfish can tolerate low aragonite saturation states. Researchers in Australia have seen oysters "adapt" to high CO_2 levels over just two generations. Adaptation does not usually occur on such a small time scale, so perhaps epigenetics are a better explanation. West Coast researchers have seen "acidification resistant" shellfish species as well. Some studies have shown larvae resilience to acidic effects through use of hemocytic maintenance of internal pH and calcium. Some studies have shown that the carbon isotope ratio of the shell is actually indicative of food availability and consumption, rather than that of ambient CO_2.

Pacific Coast hatchery issues persist even despite their ability to buffer their waters with bicarbonate and keep aragonite saturation states high. Production is still not back to "normal" so maybe there are other issues that we still don't yet understand? This is an obvious identification of a need for more research on how acidification will affect various, economically important, species. What mitigation strategies may help? Will shellfish adapt or will there be mass extinctions? Can they adapt on a time scale of 50-100 years instead of 50,000 to 100,000 years? We know and understand the effects of acidification on the carbonate chemistry of the ocean, and we know that it affects the top layer of the mud in the ocean, but what are the specific implications of these effects?

We know acidification is coming, but we still don't know how OA will impact shellfish growth or recruitment. We do know that many aragonite-based corals are probably headed for extinction, and we cannot, at this point, rule out a collapse of the marine food chain. Nitrate levels and eutrophication represent a clear and present danger to shell-forming species. Acidified muds are already impacting wild infaunal biomass. We need more information in order to correctly predict who the "winners and losers" of ocean acidification will be.

Participant Questions and Discussion:

- Q: *Given that we have insufficient science to guide us in terms of policy or mitigation, should we be preemptive in terms of returning shell into coastal waters to help perhaps offset potential negative impact in coming years*? A: It might work. Localized areas of highly acidified muds not supporting larval recruitment are good test sites to see if crushed shell application would work as a mitigative effort. We could fix the hatcheries on small local scales quite easily. It may be that the future of shellfisheries will rely on hatcheries to get the larvae through the delicate larval stage most vulnerable to acidification.

<u>What are we learning from our water quality monitoring via moored buoys?</u> – Heather Stoffel, University of Rhode Island, Graduate School of Oceanography

Narragansett Bay Fixed Site Monitoring Network

The Narragansett Bay fixed site buoy network was established in 2005 under collaboration between URI/GSO, RIDEM, NBC and NBNERR. Data collected through land based stations are measured year round. Meanwhile, data at buoy stations are collected from May to October, every 15 minutes, using a YSI meter. Indicators measured on the 15 minute intervals include temperature, salinity, DO, pH, depth, and chlorophyll-a.

What we can see in the data
Findings include a decrease in pH variability as you move away from the mouth of the Seekonk River. Freshwater has lower pH compared to saline waters – most upriver stations have the largest variability partly due to freshwater input from rivers entering the bay near the station. The seasons with the largest river flows also have the lowest pH minimums.

The year round surface-water monitoring station at the GSO dock indicates no real (statistically significant) change in pH from 1997-2010. Recent years have seen winter-spring algal blooms, with metabolism influencing changes in pH. Daily data for the Upper Bay and Conimicut Point shows a total range of surface pH values from 7.5-8.9, with an annual average of 8.19. At NBNERR there is no real long term trend in pH change found at this time. More data is available and as it is processed, the lack of pH trend may change. Greenwich Bay has the largest variability in pH on an annual scale. The peaks at this location in late winter and early spring are associated with bloom events, similar to what is seen at the GSO dock.

Multiple Impacts on pH
Multiple time scales impact pH variability, including daily, seasonal, and annual changes. In Narragansett Bay, the changes in pH due to metabolism and freshwater runoff are more than an order of magnitude larger than changes in pH due to anthropogenic forcing. Additionally the sensor is limiting since the global change is equal to the accuracy of the sensor. Thus, detecting a long term trend associated with anthropogenic forcing may be difficult to determine.

Participant Questions and Discussion:

- Q: *Some of the data you showed was from water based stations, while other data was from land based stations; what is the resolution of pH measurements comparatively*? A: YSI instrumentation is used for both land and buoy stations, so the data is comparable.
- Q*: Do you also have temperature and salinity that corresponds to this data? With just pH, results could be due to many things, but using these parameters you can start to tease out specific stressors*. A: Yes we have and use this data, it just was not presented today. This buoy network in the bay was originally established to look at hypoxia in the bay.
- Q: *A few slides of your show deep annual variability of pH – was this variability due to it being a wet year*? A: Yes; we see large variations in wetter years because of the higher volume of incoming freshwater.
- Q: *Those wet years were also bad hypoxia years, looking at the respiration signal, most likely. It is interesting that different parts of the bay look so differently, and that you did not see a bloom this year. We did see a bloom near Ft. Wetherill, so I'm just wondering, in general, if it will be important*? A: That's a good question for the future. We're going to need to look more closely at the long term data for that, I think.
- Q: *Are the impairment status and limitations different for freshwater*? A: The numbers presented today were for saltwater, they may be same for freshwater but I'm not sure, as our data is for the bay, and not upstream sources. [Another participant added that they are different for freshwater]

IV. Participants Observations and Concerns about Ocean and Coastal Acidification

Meeting participants self-selected into breakout groups based broadly on whether their work or interests were more closely related to shellfish or water quality. In this breakout session, discussions across all groups had a few common themes. Most groups expressed concern about our lack of understanding of how acidification will affect biota as well as how acidification will play into the existing variability of ocean ecosystems and whether differing co-stressors or co-benefits will become apparent. Finally, participants expressed concern over how best to communicate acidification science to the public and policy decision-makers, as there is great apprehension over how the local economy will become influenced by acidification issues.

What are your unanswered questions about OCA?

- Threshold-collapse area and where it is relative to a monitoring station?
- Can local NERRS stations help hatcheries? Can the hatcheries use NERRS data to monitor corrosive water events?
- There are multiple stressors affecting marine organisms, can we say it is just OA?
- Would OCA science be captured in eutrophication research/work?
- Are there steps we can take to mitigate or adapt to OA?
- How do we tell this story? What is our main message?
- How can we demonstrate the effects to the public?
- How do we turn green lawns from a badge of good to bad?
- How do we control nitrogen?
- Will spatial variability of OA change? Will it expand?
- What is the time and spatial scale for OA effects?
- What will annual pH changes look like with improvements in nutrient management?
- How do we prepare for the long term?
- How can we use current variability to investigate long-term threats?
- What are the effects of OA beyond shellfish?
- What are the localized OA effects?
- How do we distinguish between coastal and ocean acidification?
- Are more robust monitoring systems necessary to understand which stressors are more important?
- Thinking beyond hatcheries: what about wild clams? Do we need to expand the monitoring network to not just coastal, but offshore shelf break, where we might experience more acidification impacts than just coastal acidification?
- What can we do locally from the monitoring perspective?
- Who is going to do all of this monitoring?
- What species are most sensitive, and at what life stages?
- How do we look at effects on lobster without correlating with just temperature?
- Are we monitoring what needs to be monitored in the Bay?
- Are coastal acidification effects a nutrient or atmospheric problem?
- Do localized increases of CO_2 from shipping vessels correspond to an increase in localized concentrations of CO_2 in the ocean?
- Would tertiary sewage treatment be helpful to mitigate coastal acidification?
- Is the increase in global plankton biomass correlated to the decrease in oceanic pH?

What are you seeing that could be related to OCA?

- Bob Rheault has observed larval settlement issues, as well as large biomass declines in estuaries.

- Heather Stoffel: Narragansett Bay in particular has seen a 50% reduction in nitrogen. This is likely due to the wastewater treatment updates – the largest nitrogen contributors were upgraded in 2014, the rest will be completed by 2017. We need to further look at this, and see if these management changes have had an impact on coastal acidification trends.
- Nathan Rebuck: mudflats that used to be productive have turned to "black mayonnaise" (clam flats that are now hypoxic.)
- A discussion of OCA is occurring among shellfishermen.
- Fewer, smaller bivalves
- Acidified muds
- Loss of scallops in eutrophic areas

<u>What is of most concern to you?</u>

- Finding a common personal connection to try to get attention to the issue.
- Looking at what is contributing to OCA, as OCA itself is not everyone's top priority.
- Hatcheries on the East Coast have expressed increase in more monitoring efforts.
- The need for and the costliness of good quality, higher accuracy measurements and monitors.
- We know this is going to happen, why do we need to measure the rate at which it is going to happen? No more money on expensive cruises to measure what we know is going to happen. More research on biological effects, base of the marine food chain, etc. No question that adding CO_2 will change the saturation state.
- Looking at local, manageable factors.
- Heard clearly that we need to deal with this on a local level.
- Community based solutions, not just individual actions.
- Need a trusted source of information, an honest broker of the research.
- Changes in the land and nutrient inputs.
- Inputs from freshwater sources that are impacting coastal acidification more than anything else.
- The need for good science that we can depend upon, that is strategic, done by trusted scientists, with repeatable methods, that will help this community and effort keep our reputation.
- We need to better define covariants and linkages to improve models.
- Organism's abilities to adapt.
- Shellfish industries' ability to adapt.
- Fisheries ability to adapt.
- What are the food chain effects of OA?
- What is the new normal?

V. Current Research Capacity

<u>What is our capacity for research and what is being done here in RI?</u> - Jason Grear, Ph.D. U.S. Environmental Protection Agency, Atlantic Ecology Division

Food web processes that lead to the consumption of oxygen in bottom waters have been studied for decades by the EPA. These same processes produce CO_2 in the coastal environment and therefor contribute to OCA. The science that underlies the understanding of OCA, including zoology, evolutionary biology, climatology, at the EPA, and across all organizations, has been happening for decades. Researchers in the many fields that contribute to OCA research and science view the issue through a different lens, and have different priorities.

Truth or fantasy: Coastal pH varies a lot, therefore precise measurements are unimportant and coastal organisms are more tolerant and adaptable.

Wouldn't that be nice? The truth is, even though pH has a lot of variation along the coast, precise measurements are still important. We still don't know if coastal organisms are more tolerant and adaptable to the effects of OCA. Therefore, more research is needed to understand the variability itself and its effects on coastal organisms.

Trade-offs
Unfortunately, some trade-offs have to be made between measurement quality and coverage. Buoys are expensive and stationary. They do, however, offer a long time-span of data. It needs to be understood that water is constantly moving across the station as the water exchange occurs naturally in the bay. Another monitoring strategy, boat transects, can get multiple depth measurements along a transect, however this is only a snapshot in time of the transect. Finally, the EPA AED Bay Ecosystem Time Series is once a month measurements of many ecological parameters. While this is useful, it won't show daily, weekly, or tidal variation.

Many studies have been done, and are being done in Rhode Island, at facilities such as URI and through the EPA. While there is a lot going on, continued coordination and communication is key!

<u>What research is being done in our region that may be useful for RI?</u> - Chris Gobler, Ph.D. Stony Brook University

Calcifying Shellfish and their vulnerability to OA
A study of bay scallop and hard clam grown in differing low to high CO_2 concentrations in the water yielded less survival under higher concentrations of CO_2. The organisms were also smaller and had thinner shells. Smaller organisms in the field will be less resilient to predation and acidification.

Another shellfish that has been well-studied for acidification effects is the Eastern oyster. Oysters are the most resistant to acidification as compared to clams and scallops and are typically found in a wider range of saline waters than both clams and scallops. More saline waters generally have lower levels of aragonite saturations so perhaps they are better adapted to increased CO_2 levels.

The larval stage of bivalves appears to be the most impacted by acidification, based on the studies that have been conducted to date. Larval bivalves are more sensitive than juveniles to higher levels of CO_2. Juveniles tend to exhibit a reduction in growth rate, but not in survival rate in high CO_2 conditions. Larval bivalves, however, exhibit a large decrease in both survival and growth rates. The first 48 hours are most critically important to survival.

Ocean Acidification and Fish: one less thing to worry about?
Adult fish are expected to be resistant to acidification, as they are not dependent on calcium carbonate to build shells. However, larval stages of fish have been studied for acidification effects, and were seen to be affected at the same range of CO_2 concentration as larval shellfish. The larvae exhibited reduced growth early in life, as well as reduced survival in some species. This is cause for concern as US fisheries are valued at over $5 billion annually.

Coastal Ocean Acidification: The Other Eutrophication Problem
In coastal zones, it's not just acidification that is a problem – there are multiple stressors causing coastal waters to acidify. Upwelling of corrosive deep-water can eventually make its way into the coastal zone, where the effects of acidification will be further exacerbated by inputs of freshwater, high temperatures, harmful algal blooms and hypoxic events.

In Long Island Sound, acidification and hypoxia appear to be connected problems. Hypoxic events peak in late summer and acidification is happening in the hypoxic areas of the sound. Narragansett Bay, on the other hand, has a co-occurrence of low DO and pH. The intensity of these levels exceeds levels projected for the open ocean in 2100 during the summer months.

Laboratory studies replicating the conditions in Narragansett Bay (low DO and pH) indicate that, of the two, it is DO that affects the size and survival of scallop larvae. However, the additive effect of multiple stressors affect the organism more than DO manipulations alone. Similar results were seen in the same experimental conditions on silversides and hard clams.

In a separate study done on the survival of finfish and shellfish in the Forge River (NY), it was found that pH was the factor depressing the survival of the study species (compared to DO).

What are the effects of algal blooms and low CO_2?
Low CO_2 and algal blooms couple together to form a co-stressor relationship on the coastal environment. When nitrogen is discharged into a coastal zone, that nitrogen stimulates the growth of phytoplankton in the water, which can lead to an algal bloom. As this mat of algae grows in size, the layers of algae on the bottom of the mat will no longer receive the sunlight needed to photosynthesize and continue growth. So, the algae begins to die off, which adds CO_2 to the water as these organisms decay. This leads to a decrease in pH in the water, and impaired survival of finfish and shellfish.

Overall, coastal ecosystems are very complex. We are dealing with multiple stressors, both natural and anthropogenic. Simply put, there's a lot going on.

Participant Questions and Discussion:

- Q: *Is the Shinnecock Inlet break affected by the new break from Sandy? Will it improve conditions to minimize brown tide*? A: In the direct vicinity of the breach, yes, it is affected. On the outside of the vicinity of the inlet, however, the water is more sluggish and more susceptible to brown tide.
- Q: *In lab studies you show pretty significant effects, are there aerial images for these effects (blooms)?* A: The bay scallop is sensitive and does not do well in eutrophic estuaries. We need more analysis to determine how much is pH and how much is due to blooms.

VI. Participants Recommendations for Focusing Research and Monitoring Efforts

Meeting participants returned to their previously self-selected groups for the second break-out session of the day. Most monitoring and research recommendations were focused on increasing monitoring efforts in the "no-man's land" between the coastal and offshore areas where monitoring is already occurring as well as understanding how riverine inputs will affect the coastal system in terms of acidification. Also prominent across group discussions was mention of the high variability of the ocean-coastal carbonate system and the need to characterize which of these variables are most important to monitor.

<u>Are there other monitoring efforts we should be aware of?</u>

- Participants with monitoring efforts that NECAN should be made aware of filled out a sheet with the proper information, so it can be added to an inventory currently being constructed as a resource for future use.

<u>Where do we need to focus our efforts?</u>

- We need to consider a little more about what is happening north of Prudence Island
- We should be looking more closely at riverine inputs.
- We need to pay attention to the rivers coming in from MA, because we don't know what they're allowing into those rivers that ultimately ends up in the bay.

- We should think about monitoring in Salt Ponds, especially since aquaculture is there.
- Where there might be monitoring gaps; we monitor onshore and offshore but nowhere in between.
- We should have an “offshore” monitoring component to further elucidate low oxygen coming from the mouth of the bay.
- We need a regional coordination point for the monitoring efforts (which we recognize NERACOOS/NECAN is working on currently).
- We need a level of committed funding, and to keep the current monitoring maintained and continuing into the future (Let’s not lose what we have).

What do we need to focus our efforts on?

- Outreach and education.
- Community based solutions, not just individual solutions.
- The puzzle of multiple stressors in coastal environments.
- We need to be very strategic about efforts: we should not be replicating monitoring efforts in the same area.
- An effort to get long term data.
- Measurement quality and variability of pH and carbonate systems and how that might be optimized.
- There needs to be a more dedicated effort to characterize what actually needs to be measured in these highly variable environments.
- We need to make a better communication effort between RI and MA due to the fact that two-thirds of the Narragansett Bay Watershed and inputs come from MA.

VII. Communication and Outreach

How do we communicate and share our research results to the general public and to other scientists and managers? - Kate Mulvaney, U.S. Environmental Protection Agency, Oak Ridge Institute for Science and Education (ORISE) Fellow

We CAN better communicate OCA

While it is a challenge to communicate any form of science to people who don’t necessarily understand the large words we use on a regular basis, we can do it. To do so, we need to first listen to and carefully consider the perspectives of our audiences. Second, we should be using words and concepts that humans understand. Finally, we should help people relate to the work we are presenting, as well as its significance.

Listen to and carefully consider the perspective of your audience

Talking about science to a scientist is different than talking about science to your family, or an audience with little science background. To communicate with your audience effectively, you should have an understanding of what they already know. A fool-proof test of if you are communicating effectively is “the mom test;” If she can’t understand it, then who will?

How are you going to say it?

Give consideration to your message, stick to your main message, and only use figures that are easy to understand. Sometimes, you’ll have to use different strategies and figures that work for different audiences. Another key piece of figuring out how to deliver your message is to boil your message down; you should be able to say what you mean and what you need people to take away in one or two sentences.

Use words and concepts that humans understand
OCA terms are not normal, everyday language. Shellfish jargon is not normal, everyday language, either. When you put the two together, you get a web of words that is confusing, messy, and sometimes we don't know what everything means either.

Help people relate to your work and its significance
To communicate effectively, we shouldn't talk about how our results, or our data, only mean that doomsday is coming. A depressed audience has trouble conceptualizing how they can help solve the problem. To avoid this trap, we should present opportunities that the audience can take to do something about the problem, which will avoid doomsday. Moreover, we need to discuss the local relevance of our research. Even though it's easier for people to connect with the coastal zone, versus the offshore environment, it still has challenges. Time scale is another challenge we face when discussing issues. Talking about impacts that may be seen in 2100, 85 years from now, is really hard to digest and conceptualize.

Opportunities for Improvement
As a scientific community, we should publish, translate, share, and collaborate better. Articles need to be published, and also translated. Translation of scientific and shellfish jargon helps us transcend cultural boundaries. This effort of translation allows us to reach out to the general population, as well as policy makers, which are both key groups in our ongoing efforts. Along with this, our collaboration needs to improve. While New England has a strong background in collaboration between fishermen and scientists, we need to develop stronger research designs, data collection, and analysis efforts. Finally, we need to give our audience opportunities to do something concrete

<u>Group discussion on communications and outreach</u> – led by Jeri Weiss, EPA facilitator
Presented with a list of four questions, participants had a discussion focused on what we should do in the future to better communicate our message. The general outcome of the discussion was that we need more collaboration between organizations, to utilize existing communication efforts, and to figure out a better way to communicate uncertainty. These are the questions we used to focus the conversation:

1. How should we reach out and share what we have learned?
2. How will you share this information?
3. What is the best way to communicate with stakeholders? What is the best way for scientists and stakeholders to communicate with each other?
4. What do you need from NECAN to help you share this information?

The following are comments from the group discussion.

- There is a lack of comfort, with general public, when it comes to scientific uncertainty.
    - We think of this in statistical error as opposed to how most people view certainty
        - Scientists get too caught up on statistical significance – we need to get more comfortable moving beyond 95% and 90% statistical significance, and be more confident about making predictions based on GOOD stats, rather than within the 0.05 p value
    - We should save the "we aren't sure" part until the end, instead of starting our message with uncertainty.
- If examples get wrapped up into climate change issues, or other political issues, communication can be blocked. We should focus on the simple issue that industry understands.

- We cannot wait until we are “sure” about something to take action. We need to find a better way to communicate uncertainty, but we also need to find a way to get the general public comfortable with taking action even based on uncertain variables.
- Need to focus less on spewing science, and more on getting people to understand the issue through metaphors. We can focus on what we care about rather than what the science understands the most.
- Need to identify the “they”. Do you want them to do something about it, or do you just want them to learn something?
- Need to create an understanding of what science is, and what it can do. People are comfortable with uncertain rain predictions, why should they not be comfortable with uncertain scientific predictions or models? How do we create the comfort with uncertainty?
- Scientists need more transparency and need to build trust with the public
- NECAN needs more focused newsletters, meetings, focus groups around specific topics
    - Take advantage of existing networks rather than trying to create new ones (NROC, NEERS, NERRS, and NBEP/MBP can cross-pollinate and use their existing communication channels).
    - Listservs
    - State-level climate change coordination committees need resources to understand the issue. These folks can also be used to further disseminate information.
    - NECAN should create a publically available, consistent resource for effective communication (graphics or other types of information for slides presenters could draw on)
        - Other organizations, such as NERRS, could link directly to NECAN for resources.
    - Need a “layman's term” sheet for scientific terms (*NECAN has taken this suggestion and is working on building this resource)*
- Marine Fisheries Institute would love to help communicate the NECAN message. They work directly with the fisherman, who will make them talk to them in a way they understand. A recent meeting indicated a lot of interest on the topic. Also have a listserv they can help disseminate information through as well.

Appendix: Participant List

David Abedon, University of Rhode Island/NRS
Amanda Babson, NPS
Edward Baker, URI GSO
Tom Borden, NBEP
Tyson Bottenus, Sailors for the Sea
James Boyd, RI CRMC
Caitlin Chaffee, RI CRMC
Marty Chintala, EPA
Azure Cygler, URI
Chris Deacutis, RIDEM F&W
Wenley Ferguson, Save The Bay
Chris Gobler, Stony Brook University
Jason Grear, EPA
Jen Halstead, NERACOOS/NECAN
Julia Hogan, URI SURFO Progam
Ralph Johnson, Retired Research Engineer
Hilary Kotoun, Sailors for the Sea
Matthew Liebman, US EPA Region 1
Anna Malek, Commercial Fisheries Research Foundation
Catalina Martinez, NOAA Office of Ocean Exploration & Research
Jen McCann, Rhode Island Sea Grant
Jason McNamee, RI DEM Fish and Wildlife
Kimberly Meneo, Save the Bay Intern
Jeff Mercer, RI Dept of Env Managment Marine Fisheries
Jim Miller, URI
Sabrina Miller, Student Worker at GSO
Ivy Mlsna, EPA
Eivy Monroy, NBEP
Kate Mulvaney, ORISE/EPA
Dennis Nixon, Rhode Island Sea Grant
Peg Parker, Commercial Fisheries Research Foundation
Michael Pilson, URI GSO
Adam Pimenta, EPA
Gopu Potty, URI
Brian Rappoli, EPA
Nathan Rebuck NOAA NMFS
Robert Rheault East Coast Shellfish Growers Association
Christopher Rein, Rein Environmental Science and Consulting
Kenneth Rocha, EPA
Courtney Schmidt, NBEP
Eric Schneider, RI Fish & Wildlife - Marine Fisheries
Rodrigue Spinette, URI
Heather Stoffel, URI GSO
Cassie Stymiest, NERACOOS/NECAN
Meera Subramanian, Freelance Journalist
Heidi Travers, RIDEM
Beth Turner, NOAA National Ocean Service
Veronica Berounsky, URI GSO
Jeri Weiss, EPA
Jen West, Narragansett Bay Research Reserve
William Wise, New York Sea Grant
Meghan Wrenn, Save the Bay