Maine Ocean Acidification Study Commission

First Meeting August 1, 2014

Held at the Darling Marine Center, University of Maine's Marine Laboratory Walpole, Maine

Present: Sen. Johnson, Rep. Devin, Rep. Parry, Richard Nelson, Joe Payne, Larry Mayer, Joseph Salisbury, Jon Lewis, Susanne Miller, Kathleen Leyden, Mark Green, Meredith White, Bill Mook and Susie Arnold.

Absent: Sen. Langley and Rep. Welsh.

Morning Symposium

Damian Brady, Acting Interim Director, welcomed everyone to Darling Marine Center, the U of Maine's Marine Laboratory.

The morning symposium consisted of scientific presentations (latest available relevant Ocean Acidification science). The slides of presentations are posted on the Office of Policy and Legal Analysis at http://www.maine.gov/legis/opla/oceanacidification.htm

1. 1. *Scott Doney, Ph.D., Woods Hole Oceanographic Institution,* provided an overview of ocean acidification (OA).

- Ice core measurements dating to late Pleistocene show atmospheric CO2 historically stable until industrial revolution and modern mechanized agriculture: 40% + increase in CO2 since then. Since the 1960s, atmospheric CO2 has increased from about 320ppm to 400ppm (an anomalous high point, well outside the planet's parameters for prior 600,000 years).
- Human driven carbon emissions (~9.5 billion tons carbon per year) absorbed into atmosphere, land and ocean (26%) "sinks." Sources are fossil fuel burning (oil, natural gas, coal), cement production (minor) and deforestation (including clearing for agriculture) and other changes in land use. Graph shows equal mix of land use change and fossil fuel/cement emissions in 1880s with dominant fossil fuel/cement source post WWII (particularly in the last 54 years).
- CO2 emissions from fossil-fuels will continue to have a steep upward trajectory for the "business as usual" approach. The only real way to stabilize CO2 is to dramatically reduce fossil fuel based emissions. The problem is exacerbated by the existing emission trends, population growth and industrialization and limited energy policies.
- CO2 dissolves in water and converts to "carbonic acid" (hence acidification terminology). Carbonic acid breaks into hydrogen and bicarbonate – this causes pH change. As water becomes more acidic it has less carbonate ion which negatively impacts the ability of many plankton, mollusks and crustaceans to

build calcium carbonate shells and coral to build reefs resulting in less available prey items decreasing biodiversity. One way of expressing the amount of carbonate ion is through the calcium carbonate saturation state, where low values less than 1 reflect undersaturated conditions (un protected calcium carbonate will dissolve).

- Three open ocean sites from 1980s-present reflect evidence of changing seawater chemistry (increasing CO2, decreasing pH, decreasing carbonate ion).
- Presented a flow chart on how increasing atmospheric CO2 enters the ocean via the solubility pump and how carbon is cycled through the natural ocean biological pump, which starts with carbon being absorbed by phytoplankton large and small, transferred through zooplankton and bacteria and some small fraction ultimately deposited in the deep ocean but deep water upwelling brings CO2 back into atmosphere.
- Gulf of Maine OA Mooring site data over the past few years reflect variable pH due to biology, ocean circulation, river runoff, etc.
- East coast data from ME/NH shows presence of relatively acidic water with low calcium carbon saturation state already in deeper parts of Gulf of Maine and along continental shelf. The addition of fossil fuel CO2 may cause undersaturated conditions to spread on to shelf.
- Local acidification sources beyond large scale cycling and fossil fuel – acid rain and nitrogen sources: nutrient/nitrogen runoff, erosion and storm water and fertilizer runoff, upwelling (water from deep ocean).
- Summary of key points: atmospheric CO2 rising due to human emissions (mainly fossil fuels); 25% human CO2 emissions absorbed into ocean, changes seawater chemistry (lower pH = more acidic → calcium carbonate shells more soluble); coastal acidification due to excess nutrients etc.; acidification threat to shellfish.

2. *Barney, Balch, Bigelow Laboratory for Ocean Sciences – Gulf of Maine North Atlantic Time Series (GNATS) project*

- Dr. Balch explained the GNATS project and the status of current OA related measurements for the last 3 years shown against backdrop of regional climate change in Maine. Climatological data for Maine (graphed back to 1890) is well documented and shows a 1.1 degree per century temperature change.
- Rainfall variability: variance in precipitation has doubled since beginning of 20th century so there is more water coming into the Gulf of Maine. Of the 8 wettest years in the last century 4 have occurred since 2005.
- Researchers are measuring: hydrography, chemistry, biogeochemistry, biology (chlorophyll, phytoplankton, coccolithophorids). A NASA funded project that included optical measurements of ocean, 90% of what they see is atmospheric (clouds):
    - Inherent optical properties;
    - Apparent optical properties (above water);
    - Seasonal glider missions. Glider measures variables.

- Radiometers placed on ships to validate satellite overpasses over east-west transect from Portland to Yarmouth (NS); year round since 2006.
- Primary productivity plots (2001-2013) show carbon mg per day logarithmic scale at 3-300. Bottom of the marine food web, all larvae rely on this food for growth and survival. 200-300 range values down to 30-50 in 5-yr. period. Beginning to increase: [primary productivity] inching up to 70 now (after year hiatus). *Not known why*; only 3-yrs of OA variable observations so can't statistically test OA involvement. OA parameters show a gulf-wide response with clear impact of Maine rivers and seasonal temp variation and a low aragonite saturation state in winter.

3. David Fields, Bigelow - What can the 70s teach us about the effects of too much acid?

- Review of Acid rain:
    - Caused by fossil fuel, forests dying, lakes/streams caustic - indirect effect;
    - Phytoplankton diversity decreased but abundance stayed same;
    - Fish mortality.
- The effects of acidification are complicated. The ocean will become less basic, but not fully acidic in contrast to what happens in lakes. There are direct and indirect effects, and interactive effects (temp, eutrophication and metal solubility) to factor in.
- An interdisciplinary approach is needed to tease out changing predator-prey relationships and solubility.
- Atmospheric CO2 sinks into the deep ocean sediments where it is sequestered for long periods of time. Biological mechanisms (marine plants and grazers release CO2 back into the atmosphere). Ciliate deposit CO2 into fecal pellets (produce fecal matter equivalent to 800 billion humans) that sink into and out of the water column having a cumulative effect/impact on CO2 sequestration globally.
- Everything funnels thru zooplankton before making it into the food chain. Small changes in zooplankton have giant implications.
- Indirect effects of OA on biological pump include reduced calcification of plankton in response to increased atmospheric CO2 (300 to 750ppm CO2). Grazing rates increased and pellets are chalkier, affecting sinking rates (the heavier ones with more calcium carbonate sink faster). They will produce more pellets that sink more slowly.
- New Bigelow project looking at juvenile lobster molting rates. Lobster shells are chitin strands toughly interwoven and impregnated with calcium carbonate. When they molt they take that out, ingest and put back into new shell to stabilize. Looking at molting rates, ingestion rates, growth rate, respiration, genetic analysis, and survivorship. Preliminary data indicates reduced respiration rates.

4. Nichole Price, Bigelow – Potential to remediate local acidification using mariculture: creating an OA refuge

- Reducing emissions is best, but at local scale there are other actions that can be taken.
- Ocean acidification refuge:

    - System of resistance, resilient to OA chemical changes
    - Benefit to sensitive organisms
    - Limited in space/time
- Oysters, clam and scallop larvae are at risk.
- Blue mussels may be less vulnerable but the byssus is weakened with acidity – mussels are falling off lines. Mediterranean fishermen are seeing this problem.
- OA refugia process 1: photosynthesis sequesters carbon, releases oxygen into environment, and raises pH (and calcite/aragonite saturation). Examples from:
- Florida Keys: sea grass meadows assist coral reefs; OA refugia process 2: dissolution of carbonate releases alkalinity into environment, and raises pH (and calcite/aragonite saturation). Example from:

    - Chesapeake Bay shell cycling: dead oyster shells act as antacid to buffer seawater for next generation of oysters - being applied in Wash State;

- Gulf of Maine has natural spatial and temporal variability with seaweeds being the primary producers and may be potential mitigators of local OA. Rockweed's response to high CO2 = increase in photosynthesis and production: one of few fisheries positively affected by OA. Could create OA refuge downstream or adjacent to seaweed farms or growth areas.
- Using kelp could be cost effective. Effects of kelp farming show that seaweed farms also absorb nutrient runoff (study of benefit of Ocean Approved farm in Casco Bay). Limitations of kelp are that it is seasonal (grows Nov-Jun), but could match up with shellfish mariculture by diversifying seaweed farm model (multiple species approach).

    - Risks:
        - How leaky are seaweeds – they use carbon differently during photosynthesis, some are inefficient at carbon fixation and release sugars that increase CO2 thru microbial generation and respiration
        - Natural biodegradation of old blades - may be counterproductive
        - Invasive species issue
    - Monitoring focused on chemistry to date- need better system to link biological and chemical feedbacks.
    - Hydrodynamics rarely addressed but there are circulation models for Maine's coastal region.

5. *Bob Steneck, U Maine – OA: Ecosystem Effects and Challenges for Maine*

- Getting beyond a single species to look at the entire marine ecosystems globally.
- Reviewed key variables for studying secondary and tertiary effects of acidification on structure/function of marine ecosystems (structural variables: dominant species, abundance, diversity; function: reproduction, growth, competition, predation – how species interact).
- What's so bad about a little acid? Clear changes to ecosystem structure causes changes to biological functions (reproduction, growth, competition and

predation). Data projections on increasing acidity (decreasing pH) in oceans out to 2100 suggest a decreased in abundance of barnacles, sea urchins, limpets but seaweed does better. Kroecker et al.'s meta study synthesized 146 published studies and found declining growth rate effects of OA across a spectrum of species (from heavily to hardly/not calcified) and secondary and tertiary consequences. It is metabolically expensive to calcify at lower pH levels. This affects predator-prey dynamics. Examples of mussels, oysters, quahogs and periwinkles, which decline in shell strength and thickness increasing vulnerability to predators.

- In Papua New Guinea, they have found behavioral changes in fish resulting from low pH. Behaviors that help them avoid danger are being disrupted so they are gravitating toward predators.
- Ecosystem effects in Alaska and Maine (cold water places) - projecting shift in competitive dominance from coral to seaweed with change from today's 375ppm change to >500ppm by 2050. Corals are less dense and more prone to breakage. This may have a big effect on "grazers" who feed off the reefs. Also, acidification's stress on corals may compromise their immunity: coral disease has increased since 1960s (major diseases). Cold water regions at bigger risk. Density of cell walls and high diversity can be studied to quantify OA effect on architectural strength of dominant reef builder. Local community dynamics matter because local biota can ameliorate effects of OA.
- Maine is at risk ecologically and economically. Many animals on Maine coast use limestone. Fisheries harvested since 1920s: finfish predators were big species harvested, except one invertebrate, (lobster, then only minor) – today monoculture of lobster but shellfish increasingly important. Record lobsters harvests due to various factors but absence of major predators is key; organisms that were formerly prey (many of which have shells) are now base of ecosystem and economy. Seventy-five percent of Maine's marine fisheries value comes from shellfish. Maine has highest lobster population densities in world and is most dependent on the shellfish nationally.
- Lobster population density in Long Island Sound was abundant and increasing until populations crashed due to a shell disease that was likely triggered by numerous stressors. Crustaceans have to work harder to calcify in acidic environments so lobster must spend more metabolic energy as oceans become warm and more acidic. The shell disease is not new but it is of increasing concern for Maine where 6,000 harvesters depend on lobster for their livelihood. Maine and other cold water coastal habitats have always been an environment for shellfish but recent ocean acidification increases stress and may compromise the immune system of lobsters. This along with the hyperabundance of lobster and warming of their coastal habitats puts Maine coastal culture at elevated risk. Lobster population density in Long Island Sound is abundant but devalued by shellfish disease that is triggered by numerous stressors. Crustaceans have to work harder to calcify in acidic environment. Metabolic process more important to lobsters. Rotting shell disease is not new but is of increasing concern for Maine where 6,000 harvesters depend on one species. Maine has always been a difficult shellfish habitat and business climate and OA makes the metabolic process more

stressful/costly for lobsters. The hyperabundance of lobster with warming and OA puts Maine coastal culture at risk.

Note: Dr. Steneck's PowerPoint and an additional slide on the history and evolution of modern corals is available online with the OA study materials. Please contact author for permission to use any information contained in his presentation. It is pending publication.

6. Damian Brady, Darling Marine Center Acting Director - The potential role of water quality modeling in coastal acidification management – whatchya gonna do about it?

- When the scientific community and policymakers determine it is a problem the question becomes how to fix it societally? Currently, there is no model of pH/aragonite saturation/alkalinity/DIC (total maximum daily limit) to inform management decisions.
- Analogs include: degradation of organic matter (lowers dissolved O2); freshwater flow increases acid; eutrophication and hypoxia reduce buffering of estuaries; the relevant "knob" to turn is land derived nutrient and pH loading – this has been done for decades in TX, LA and elsewhere though it is new to Maine.
- A representative of NOAA is in the audience. Congresswoman Rep. Pingree has submitted a federal bill regarding the study of ocean acidification. In a context with multiple stressors, a management driven goal is needed. The recommendation to stop fossil fuels must consider these other stressors. Management models tend to be <u>empirical-deterministic</u> and <u>process based</u> (these should be looked at by commission). They have pros and cons.
- Empirical models assume time series contains all scenarios. Without process level understanding, you can't predict outcomes.
- Process level models are complex and data intensive. They fold in saturation events to determine size, severity and duration of non livable dead zones. Thus they provide more predictive power, ability to test hypotheses from air shed to watershed to water column to sediments.
- Maine's hydrodynamic modeling infrastructure very evolved as there is a large citizen monitoring network tied to DMR Div. of Public Health, NGOs, Universities, and DEP.
- <u>What Maine does not have</u>: biogeochemistry monitoring, watershed modeling, ecosystem-based approaches to dealing with abiotic management issues. These models are needed to really look at things like how hard lobsters have to work to grow shells against acid. Need to scale up Casco Bay Model: with a lot of hydrodynamic data we can track at the species level in a refined way locally. Maine is developing a Cobscook Downeast Model. May also want to consider a nutrient eutrophication model. All states have to come up with a TDL (total daily limit), Maine doesn't have typical nutrient problems because we have macro tide that flushes the area.

- But if we [commission/state/partners] decide OA is a problem, these models are already in place, could be adapted to Maine, beyond recognition of the problem and including a recommendation to stop using fossil fuels.

7. *Nick Batista, Island Institute*

-Reviewed the Jan 2014 OA workshop:
- Scientific updates
- Funders
- Participants
- Local, state, regional strategies, priorities
- Concerns: lack of knowledge about OA, commercial impact, socioeconomic effects, role of runoff, interaction with rising water temps
- Meeting notes are available from Island Institute

-Reviewed other outreach:
- Fishermens forum 2013 – half day workshop
- Fishermens forum 2014
- Google group for OA – email distribution list
- Alaska
- NECAN

-Quickly described what is happening in other states:
- Washington blue ribbon panel - different set of oceanographic conditions but process applicable
- Maryland task to analyze best available science and effects on state waters and develop strategies to mitigate the problem. Potential for east coast strategies/synergies. Reach out to Maryland Task Force to share information and ideas.

-Importance of public awareness/outreach
- OA relatively new issue, outreach important
- Press needs to be expanded from crisis stories

8. *Esperancia Stanzaff – U of Maine Sea Grant and Cooperative Extension*

- Provided overview of Extension/Sea Grant program objectives
- Introduced North East Coastal Acidification Network and described its education/outreach process: webinars, workshop, etc.

9. *Libby Jewett, NOAA OA Program Director – NOAA is Listening*
- Components of NOAA's OAP – federal program structure: Monitoring, Bio- and Ecosystem Response, Data Management, Modeling, Adaptation strategies, Education and Outreach.
- Monitoring:
    - OA Observing: Buoys, Ships, Wave Gliders
    - East Coast Observing cruise – Gulf of Mexico to Scotian shelf (2 parts)

    - Sandy Hook, Northeast Fisheries Science Center
- Federal OA Research and Monitoring (FOARAM) Act of 2009 – multi-agency (NSF, USGS, NASA, USFW, NOAA, EPA, State)
    - Federal funding distribution (2013) ($12-13m research, mainly from NSF, now competing with other fields, specifically CFP for OA discontinued; NOAA has primary responsibility for Monitoring)
    - NOAA OAP role in Northeast: NECAN lead, species impact research, regional observing, modeling and forecasting ocean to economies, coordination (state efforts)
    - Maine process to inform NOAA programming, including RFPs with funding
    - Washington Blue Ribbon Panel report recommendations (6)
    - Tips for Maine: science and policymakers collaborate; scope – don't bite off too much; set priorities for future, this is beginning not end of process; healthy ecosystem and food webs vital to wild-harvested species and most aquaculture operations – consider impacts of OA on whole food web, not just commercial species; leverage other activity around commercial species – how can OA be slotted into existing programs/efforts.

10. Rick Wahle – OA and the Challenges facing the American Lobster Fishery

- Maine perilously dependent on single fishery (lobster): settlement data suggests a coming downturn.
- Surge in lobsters coincides with depletion of large predators (i.e., groundfishery). Landings/values are at historic levels. Economic dependency on single fishery due to depletion of these other fisheries. Lobster is "mid-level" consumer.
- UMO leading lobster research but OA effects are unknown.
- Effects of climate change: time series data show Gulf of Maine warming trend: since 1982: -1degree change every 40 years; since 2004: -1degree every 4 yrs.
- Hot and cold thresholds – physiologic processes: 12 degree-20-degree Celsius – 12 degree slows embryonic development, hatched larvae can't reach settlement before winter; habitat below Cape Cod inhospitable to lobsters, more favorable to North (eastern ME, Fundy). Lobster nurseries receding in southern New England, economic value decimated by shell disease, which is spreading north to New Hampshire and Maine.
- North Atlantic acidifying faster than anywhere else. OA is poorly studied (2 published studies on lobsters and crabs), interactions with other stressors even less known. Data is very species- and life-stage-specific. Seawater surface pH (human driven) from 1700-2000.
- OA research on lobsters and crabs is contradictory: enhances growth/calcification; larval growth/development adversely affected. No data on survival. Same for European lobster.
- Need to forecast – settlement index predicts lobster fishery challenges to promote resilience in the fishery. Need to adapt to changing geography, shell disease, need to minimize fishing costs and maximize value of the end product.
- Scientific Challenges:
    - weighing interactive effects of warming-hypoxia-acidification
    - assessing life stage and species specific responses

- build infrastructure and collaborate for short and long term studies
- support long-term environmental monitoring
- communication/outreach

Link to Rick Wahle and other NECAN webinars on OA:
http://www.neracoos.org/necan_webinars

Commission's afternoon session:

- Senator Johnson reviewed the enabling legislation (Resolve c. 110), focusing on the duties and due date.

-Staff clarified that currently the commission has enough funding to cover 4 meetings and that the last meeting should be limited to the final review of the commission's report.

-The commission discussed possible ways to extend the time needed to deliberate or recommend something that lives on beyond the commission. Funding for additional meetings was also mentioned and a way to front load the first 2 meetings and to bring takeaways back from the first meeting (and complete tasks identified) to the next to make each meeting as productive as possible. The commission discussed keeping the scope feasible to what the commission can actually do/accomplish, and there was a suggestion about focusing on coastal acidification and its impact to commercial species.

-To save time and provide a foil for structure, Susie Arnold presented the following "straw man":

- Why this matters (intro) (can be saved for last, drawn from other pieces as they are completed)
- State of the Science (particularized to the Gulf of Maine)
- Research & Monitoring priorities (gaps identified at the January summit)
- Local mitigation and adaption strategies
- Socioeconomic vulnerability- recent studies have identified Maine as an ocean acidification "hotspot" so its high dependency on a single commercial species puts Maine at a heighted socioeconomic risk.
- Communications & public awareness
- Coordinated focus

-There was consensus on the need to address and tailor to Maine the WA State Blue Ribbon Panel Report Recommendations (also mentioned in Libby Jewett's NOAA presentation) and coming up with a list of recommendations from/for Maine for the federal gov/NOAA so as to inform NOAA and other federal work on OA, including the informational and other resources that Maine may need going forward.

-The State of the Science and Research and Monitoring categories were merged into a single category of focus, and the following subcommittees were formed:

- Subcommittee on Washington State Recommendations. Joe Payne (to be the lead or "chair" to organize meetings and serve as single point of contact for the chairs and staff), Rep. Devin, Kathleen Leyden and Jon Lewis.
- Subcommittee on the State of the Science/Research & Monitoring (this subgroup to bring in NECAN and tap other relevant scientific expertise as needed). Meredith White ("chair" or lead), Rep. Parry, Mark Green, Susie Arnold and Bill Moot. – tentatively scheduled to meet Aug 15 at Bigelow.

-Everyone will bring back ideas for local mitigation strategies – including adaptive opportunities – to the next meeting.

-When the commission is ready, Susanne Arnold offered to pull together a subcommittee for "Coordinated focus."

-Some commission members may attend a vulnerability workshop presented by an outside organization tentatively planned for October 7, 2014 in Maine so that the results of that workshop may be incorporated into the commission's study report to avoid duplication and ensure integration of the state's approach to OA.

- The commission began its strategy session with the following thoughts, questions, comments, suggestions for areas for its focus.

- There needs to be an underlying global process, to show a definitive trend and variability. How to illuminate the complexity of the process with limited data.
- The impact on species needs to be holistic, ecosystem based approach.
- The following topics for focus or metrics were listed:
    - Degree of eutrophication in the water – when/where to measure;
    - Nutrient run-off into watershed. Contribution of land run-off to acidity;
    - Annual seasonal range of acidification;
    - Impact on individual organisms;
    - Range of impact – what is important to whom;
    - Focus on cyclical "hotspots;"
    - Focus on commercial species to the exclusion of other species;
    - What are the influences and data available on influences;
    - Impact on fisheries- primary productivity and impact of rivers vs. total Gulf of Maine;
    - How to define coastal Maine consistently and the species and geography to include as specific foci;
    - Atmospheric CO2 v. nutrient run-off, offshore v. near-shore commercial fisheries;
    - Nutrient is a "knob" to twist;
    - Refugia (kelp, seaweed beds);
    - The new local drivers that have recently been studied/identified; and
    - The legal and financial feasibility to reformulate sewage treatments.
    - Influences to agree on:

- Atmospheric CO2;
- Precipitation variability – pH;
- Nutrient runoff into watershed - management and best practices (i.e., land-use, e.g., agricultural, municipal waste water treatment) is there a metal hypothesis?
- Decline in dissolved O2, eelgrass and macroalgae;
- Focus on quantifiable inputs;
- Upwelling from the Scotian shelf; and

2ppm primary productivity 5-fold.

- What can Maine do about ocean acidification (recommendations from Libby Jewett)?

- Include long-term priorities/strategies in recommendations (including funding, and don't limit to what is politically or fiscally difficult or out of reach).
- Don't oversell the science, be conservative as to the realistic benefits and effectiveness (including cost effectiveness) of mitigation strategies.
- Local decisions are key. How can best practices minimize impacts?

-The purpose of a Legislative report was discussed as well as particulars e.g. regulatory barriers to making changes to sewage treatment.

Meeting adjourned at approximately 3:30. Some members took a tour of the Bigelow facility after adjournment.