The following report summarizes the N.H. Coastal Marine Natural Resources and the Environment (CoMNaRE) Commission's activities and findings between November 1, 2016 and November 1, 2017.

1) Summary of Activities:

The CoMNaRE Commission met six times during this time-frame, and all meetings were primarily focused on educating the CoMNaRE Commission about the potential effects of ocean acidification (OA) on N.H. coastal and marine resources. A series of guest speakers were invited to the meetings, including scientific leaders who are studying OA and a Maine oyster farmer who is participating in ocean acidification research. Commission members also reviewed work by similar organizations in other states and regions of the U.S. The CoMNaRE Commission wrapped up its focus on ocean acidification this year, and is now shifting its focus to issues surrounding nutrient loading in coastal habitats. Meeting dates, locations and guest speakers during this reporting year included:

1. January 23, 2017, NH Fish and Game, Durham, NH.
    a. Speaker: Dr. Beth Turner, NOAA Biological Oceanographer, Coastal Ocean Program, Steering Committee for the Northeast Coastal Acidification (NECAN) Network
    b. Talk: NECAN Overview: The Science and Potential Ecosystem Effects in the Gulf of Maine
2. March 20, 2017, NH Fish and Game, Durham, NH
    a. Speaker: Dr. Joe Salisbury, UNH
    b. Talk: Ocean Acidification Knowledge, Risks and Monitoring in the Gulf of Maine
3. May 15, 2017, NH Department of Environmental Services Coastal Program – Pease Industrial Park, Newington, NH
    a. Speaker: Bill Mook, Maine Oyster Farmer
    b. Talk: Coastal Acidification: From an Oyster Hatchery Perspective
4. June 19, 2017, NH Department of Environmental Services Coastal Program, Pease Industrial Park, Newington, NH

    a. Commission Member Presentations and Discussion – Review of Maine, Delaware, Maryland, West Coast, and Washington State assessments and responses to ocean acidification threats
    b. Speaker: Ken Edwardson, NH DES
    c. Talk: Briefing on Great Bay and Atlantic Ocean pH and Nutrient Data
5. Sept 11, 2017, NH Fish and Game, Durham, NH
    a. Commission member presentations and discussion: Review of ocean acidification focus for Commission
    b. Speaker: Kalle Matso, Piscataqua Region Estuaries Partnership
    c. Talk: Nutrients and N.H. estuaries overview
6. October 23, 2017, Dover Wastewater Treatment Facility, Dover, NH.
    a. Commission members: Discussion of summary of ocean acidification topic focus for commission
    b. Tour of Dover Wastewater Treatment Facility: Led by Raymond Vermette, Wastewater Treatment Facility Supervisor

2) Main Findings:

Ocean Acidification (OA), a term that refers to decreasing pH in estuarine and oceanic waters and that is primarily related to increasing atmospheric CO_2. Ocean acidity is further modified by fresh water inputs, increased temperature and higher nutrient loading or dissolved organic matter, and low oxygen levels. Scientists have observed that OA can have negative effects on organisms that produce shells out of calcium carbonate, such as oysters, clams and scallops. The effects for these organisms have been observed in adult stages, but also on larval development and survival. Additional negative effects at observed OA levels for fish species, such as reduced olfactory sensitivity and other behavioral and physiological effects have been observed in laboratory settings. Overall ecosystem effects resulting from ocean acidification are probable, but not well understood.

Ecosystem effects of OA may have important consequences for ecologically and economically valuable marine resources in the U.S. In fact, OA is believed to be responsible for significant economic losses in Washington State oyster hatcheries. It is also thought to be responsible for the degradation of key members of marine ecosystems that are important for supporting salmon populations. Locally, Bill Mook, from Mook Sea Farms, an oyster hatchery in the Damariscotta River, Maine observed oyster larvae development failure. Further investigation at Mook Sea Farms found that low egg conversion and larval feeding failure were associated with large storm events. Although pH was not measured during these events, Mook Sea Farms attributed these larval failures to reduced pH in the water and have since buffered their systems to be able to produce oyster larvae, spat and seed (B. Mook, 2017 personal comms). Although we do not have a sufficient time series of measurements within the Great Bay Estuary, a decade of measurements at the Isles of Shoals point to seasonally low pH values that approach critical thresholds for larval growth of certain shellfish (Sutton et al, 2017). If OA gets to a critical level in our nearshore waters it has the potential to negatively affect calcifying organisms such as oysters, clams, scallops and lobsters, species that are economically valuable to our local communities.

In the Gulf of Maine (GOM), there are multiple interacting processes that tend to obscure the effects of ocean acidification (Salisbury, 2017 personal comms). Among them is the large amount of freshwater that enters into and is retained within the GOM, resulting in the system that is poorly buffered against acidity. Other contributing factors include large shifts in temperature and productivity. The end result is that the GOM is a complicated system with variable temperature, salinity and biological processes all contributing to variability in the potential effects of OA.

Variability of OA in the Great Bay and Hampton-Seabrook estuaries is potentially more hyperactive than the GOM because they are more affected by freshwater inputs and high nutrient loading. Within these two estuaries, the main drivers of OA are increased precipitation, the resulting runoff from those precipitation events and subsequent nutrient loading within the water bodies. Greater precipitation delivers more runoff of acidifying compounds and nutrients. Greater frequency and intensity of storms storm also shortcuts the natural infiltration and filtering processes of these acidifying compounds and nutrients. The surge of freshwater during storm events decreases salinity within the estuary, thus further increasing the vulnerability of the system to the effects of OA. Ocean Acidification mitigating processes within the estuary include carbon storage or sequestration due to growth of eelgrass beds, macroalgae, and oyster reefs.

We currently do not have a clear understanding of the effects of OA within N.H.'s coastal waters. However, research in the coastal Gulf of Maine suggests that lobster, commercial and recreational fisheries, and an emerging oyster farming industry in the Great Bay Estuary are all vulnerable to decreasing pH levels (Gledhill et al, 2015). There are currently three Northeast Regional Association of Coastal and Ocean Observing Systems (NERACOOS) buoys that are collecting CO_2 data within the GOM; including one at the UNH Coastal Marine Laboratory at the mouth of the Piscataqua River and one within Great Bay (Salisbury, 2017 personal comms). For the N.H. state fiscal year 2017, the state made a $260,000 capital investment in monitoring and assessment of our coastal waters, including $25,000 that was specifically allocated for OA monitoring in Great Bay.

Although pH can provide a good general indication of the biological effects of OA, a 'gold standard' for measuring the potential impact of ocean conditions on carbonate chemistry is the aragonite saturation state, Omega (**Ω**). Aragonite saturation state is the most biologically relevant measure of the effects of OA, and when its value is less than 1.5, it indicates conditions under which larval shell development may be compromised. Omega can be derived from measured values of two of the following: pCO_2, pH, total alkalinity and the concentration of dissolved inorganic carbon. Analysis of derived values for Omega indicate broad spatial, diurnal and seasonal variability from the ocean surface to depth. This variability is particularly great in estuarine habitats. This variability is particularly great in estuarine habitats. Data relevant to N.H. waters indicate that the value for Omega can fall below 1 at certain places and times (Figure 1), suggesting vulnerability of biological processes to these conditions. Decreasing Omega conditions resulting from increasing atmospheric CO2, increased nutrient levels, fresher water, warmer temperatures and lower oxygen levels will increase this vulnerability.

As a result of these findings, we believe that it is likely that OA may already be impacting N.H. coastal resources. It should be noted, however, that we did not find any specific evidence to definitely point to current effects. Nevertheless, we recommend developing a monitoring plan and a research agenda, while also exploring potential mitigation strategies to the effects of OA on important biological processes in N.H.

Recommendations:

1) Develop a monitoring plan to improve our understanding of Omega variability in N.H. waters and where these vulnerabilities overlap with biological processes related to ecosystem services such as oyster farming, oyster restoration, and fish biology. Although both state and federal investments have resulted in improvement in our monitoring efforts, further investment to implement an OA monitoring plan will be needed in order to identify trends and potential impacts to our coastal waters.
2) Develop a research agenda that will address gaps in knowledge relevant to N.H. vulnerabilities to the effects of OA. These recommendations are likely to include further research on all life history stages of vulnerable species in N.H. of high economic and ecosystem value.
3) Explore potential mitigation strategies for OA relevant to N.H. waters.

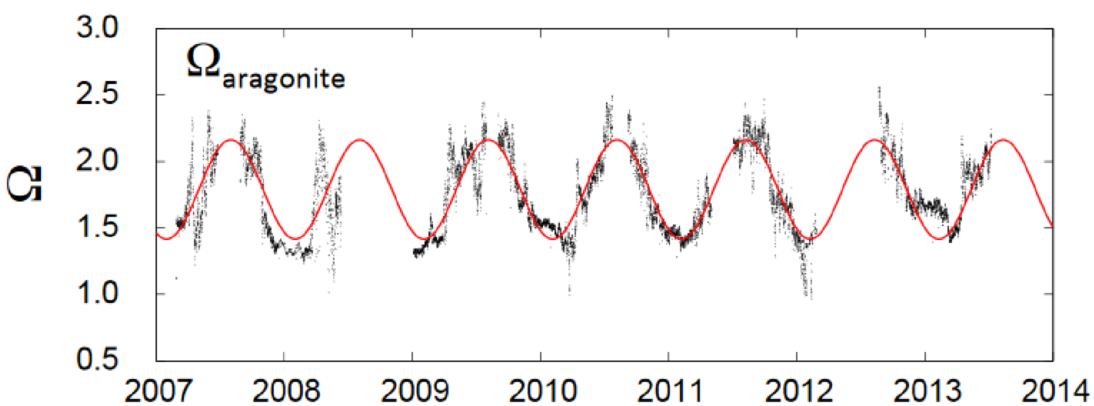

Figure 1. Unpublished data from near Isles of Shoals, N.H. (J. Salisbury)

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