# Task Force to Study the Impact of Ocean Acidification on State Waters
# September 10, 2014 Meeting Minutes

## Task Force Members

Present:
Bill Ferguson, MD Senate
Eric Schwaab, National Aquarium in Baltimore
Bruce Michael, MD Dept. Natural Resources
Lee Currey, MD Dept. of the Environment
Tom Miller, UMCES Chesapeake Biological Laboratory

Absent:
Eric Luedke, MD Delegate – via phone
Tal Petty, Hollywood Oyster Co.
Robert T. Brown, Maryland Waterman's Association – via phone
Doug Myers, Chesapeake Bay Foundation

Staff:
Marek Topolski, MD Dept. Natural Resources

## Guest Presenter

Whitman Miller, Smithsonian Environmental Research Center – see Appendix A
Denise Breitburg, Smithsonian Environmental Research Center – see Appendix B

## Audience

Matt Stover, MD Dept. of the Environment
Mark Trice, MD Dept. Natural Resources
Ryan Ono, Ocean Conservancy
Zoe Johnson, MD Dept. Natural Resources

## Logistics

- Meeting schedule: 2nd Wednesday of each month
- OA Task Force information is available at http://mddnr.chesapeakebay.net/mdoatf/index.cfm

## Timeline

- Meeting 3: October 15th, 2014 from 9:00 - 12:00

## Discussion (↑ - Increase, ↓ - Decrease, ↨ - Fluctuation)

- Describe the risks of OA in Chesapeake Bay – what strategies can minimize the risks
    - What are the risks to mitigation projects in place, under way, or needed?
        - Are strategies already in place that help address the risks – are they being promoted?
    - Alliance for Coastal Technologies Workshop Proceedings – Chesapeake Bay OA workshop
        - Science Assessment of Chesapeake Bay Acidification: Toward a Research and Monitoring Strategy report (ACT document)
            - 13 recommendations – pp. 13-14 – Task Force should review
        - Workshop identified knowledge gaps and state of the science
    - Next step is for stakeholders to help answer questions about risk
    - Consider a workshop (STAC) to develop a strategy to address unknowns and challenges
        - From a food web and ecosystem services perspective

        - Develop baseline measures to fill data gaps
        - Assess the changes and impacts in the Chesapeake Bay over time
    - Review west coast and Maine actions to incorporate OA affects into management strategies

- Maryland has opportunity to be at forefront of coastal OA research, planning, and management
    - Identify funding/resources to support the science (state, federal) – grants from NOAA OA Task Force
        - There is a growing realization that open ocean and coastal OA are different
            - Coastal OA is more complex than just oceanographic processes
        - NOAA OA Task Force focus has been open ocean OA
            - Are they willing to fund coastal OA research? – i.e. v.3 (see August minutes)
    - Maryland's primary monitoring assets are in Chesapeake Bay and coastal bays.
    - There are a lot of pH data available (recognizing that $pCO_2$ is a better measure than pH)
        - Range of pH data may ameliorate, to some extent, pH probe calibration error
    - Intrusion of deep Chesapeake Bay water into shallow water is analogous to west coast upwelling
        - Water is low in DO but pH is not known
        - Presumably low based on the research of DO/pH relationship
    - Coastal Bays may be a good contrast to Chesapeake Bay
        - Water is more closely oceanic – highly buffered – OA effects may be less extreme
    - Restoring America's Estuaries Summit in November – Emphasis on estuarine effects of OA

- Discussion about the Task Force's report
    - Should people's attention be focused on risks of OA or responses to OA?
        - What are the critical things to focus on?
            - How eutrophication is already affecting the ecosystem
                - Continue nutrient reduction to reduce $CO_2$ input from respiration
            - Where and under what conditions we might need new, different, or more stringent nutrient reduction strategies
            - Identify where existing strategies like DO criteria are not being protected
                - Implement existing strategies where needed but not implemented
            - Adjust regulations that are restrictive to shallow water restoration projects
                - Navigation regulations are restrictive to shallow water (~1m) oyster
            - Continued support for SAV restoration
                - SAV beds/meadows can cause significant $CO_2$ drawdown during day
            - Leverage the advantages of duel/muti-benefit/target restoration strategies
    - Implementation of recommendations should be through the legislative process

- Going forward – Task Force actions
    - Agenda items for meeting 3
        - Focus on other state examples
        - Obtain industry perspectives and issues
        - Develop report framework/outline
            - Report focus is estuarine waters, but will also acknowledge state ocean waters
    - Action items
        - Information is needed about aquaculture and restoration efforts
        - Contact Maine's Task Force to get their perspectives – Bruce and Eric
        - Bring the Oyster Recovery Partnership (ORP) into the stakeholder discussion

  - Contact Tom O'Connell and Mike Naylor (Fisheries) to identify an appropriate ORP contact – Bruce
  - Follow up with ORP – Bruce and Eric
- Task Force should reach out East Coast Shellfish Growers Association (http://www.ecsga.org/index.htm) – it is a secondary industry resource
  - Headed by Bob Rheault

## Appendix A

Presentation: Whitman Miller, Smithsonian Environmental Research Center (SERC)
Topic: Carbonate chemistry and monitoring approaches for Chesapeake Bay

- $CO_2$ distribution: 50% in atmosphere, 25% in ocean, 25% in plants and terrestrial soil
- $CO_2 + H_2O \leftrightarrow$ carbonic acid; reaction direction affected by pH
    - Release of hydrogen ion ($H^+$) from carbonic acid leads to formation of carbonate ion
    - Carbonate ion is necessary for organisms that have/make shells of calcium carbonate
        - Calcium + carbonate ion = calcium carbonate
- ↑ $CO_2$ added to water, the more acidic the water becomes ($CO_2$ acts like an acid)
    - The more acidic the water, the fewer carbonate ions available to organisms
        - $\uparrow CO_2 = \downarrow pH = \uparrow H^+ = \downarrow$ carbonate ion
- Surface ocean water is supersaturated with calcium carbonate
    - Saturation horizon = the depth/temperature point where water becomes undersaturated
        - Calcium carbonate saturation horizon = water is not saturated with calcium carbonate
            - Calcium carbonate shells dissolve below this saturation horizon
- Is OA causing calcium carbonate saturation horizon to move closer to the ocean surface?
    - Is the available water column space for organisms being reducing (squished)?
- What role do coasts have in controlling ocean carbon?
    - NOAA perspective: This is an oceanographic question
        - NOAA buoys monitor the open ocean to detect OA parameter changes
    - Whitman's perspective: This is an estuarine question
        - Coastal chemistry affects biology and biology affects chemistry?
            - Interactions vary by ecological scale and dynamics – where you live
- Estuary characteristics are not constant relative to open ocean
    - Shallow, lower salinity, less buffered against changes to pH as $CO_2$ is added
    - Geology, riverine chemistry, terrestrial inputs, and sediments are important
    - The calcium carbonate saturation horizon varies spatially (not simply vertical)
    - Many more factors that influence carbonate chemistry than in open ocean

Experiments:

- $CO_2$ effects on oyster larvae incubated at different $CO_2$ concentrations (in the water)
    - Pre- & post industrial revolution and 100 year projection (yr100) of $CO_2$ concentration
        - Pre-industrial revolution oysters were larger
        - yr100 oyster had regular growth pattern, but daily growth was slower
        - Oyster settlement is dictated by size of larvae not age
            - Slow growth oyster is in water column longer and exposed to more predation
- SAV beds were enriched with $CO_2$
    - SAV have ↑ growth when water is $CO_2$ enriched
    - Faster growing SAV have lower levels of "defensive" secondary carbon compounds
        - These compounds protect against predation and disease
        - Herbivorous fishes have preference for these fast growing SAV
- Analysis of $pCO_2$ (carbonate) monitoring data
    - Data Types
        - real time chemistry (continuous data)
            - $pCO_2$
            - pH
        - wet chemistry (discrete samples)
            - DIC: dissolved inorganic carbon (carbonate, bicarbonate, and dissolved $CO_2$)

            - T Alk: total alkalinity (buffering capacity)
        - T Alk and $pCO_2$ data are used to calculate pH and DIC
    - Rhode River: SERC pier vs. Marsh – 1 km apart
        - SERC pier
            - Day time $CO_2$ draw down – presumably due to photosynthesis
            - Night time $CO_2$ increase – presumably due to respiration w/o photosynthesis
            - Daily ↨ of $CO_2$ and pH
                - ↓ $CO_2$ corresponds to ↑ pH – inverse relationship
                - pH at the dock varies between 7.5 & 8.0 – fairly constant
            - Daily variability of $pCO_2 \geq$ range of ocean $pCO_2$ levels by up to a factor of ten
            - $pCO_2$ can be below or above ocean's range for extended periods of time
            - Seasonal $pCO_2$ patterns: ↓ cold months and ↑ in warm months
                - Photosynthesis and respiration response rates affected by temperature
                - Temperature driven photosynthesis rates cause daily $CO_2$ ↨ in water
        - Marsh
            - Daily $CO_2$ ↨ from marsh driven by tidal cycle export of decomposing carbon
                - High tide inundation of marsh picks up $CO_2$ from decomposition
                - $CO_2$ is then washed out during low tide
                - pH has greater ↨ ranging between 6.5 & 7.5 – water becomes acidic
                - Positive pH correlation with tide (lower water = lower pH)
            - Marsh biogeochemical processes produce $CO_2$ and T Alk (buffering capacity – resistance to change)
                - Both of these are washed out at low tide
            - Oyster restoration in Rhode River should not be done at mouth of tidal creeks (where marshes are)
        - Heterogeneity of water column $CO_2$ concentration between sites (1 km apart)
            - Water column $CO_2$ at SERC pier is temperature driven
            - Water column $CO_2$ at marsh is tidal driven
            - There are distinct, spatially different habitats between sites
- Can marsh characteristics be used to predict/estimate $CO_2$ and T Alk output to riverine system?
    - Not yet, but that should be possible in the future
    - A marsh is a reflection of the local land/sea interface
        - Different types of shoreline habitats have different land/sea interactions
            - They should have different chemical footprint/signature
    - Should be able to develop localized predictive models, at ecologically relevant scales, for different Chesapeake Bay and coastal habitat types
    - More monitoring data is needed to develop predictive models of $CO_2$ and T Alk for various/specific habitats types
        - Current monitoring is robust – 30 year baseline
        - Very little is known about Chesapeake Bay carbonate chemistry
        - Data is "noisy" requiring a lot of data collection with a lot of spatial coverage
        - Measuring $pCO_2$ and T Alk at existing water quality monitoring stations would give a better understanding of overall system interactions
        - First step – add appropriate monitoring equipment to existing monitoring assets
            - Cost to add $pCO_2$ and T Alk monitoring equipment to existing assets?
            - Oceanographic monitoring device (underway system) is \$80,000 - \$100,000
            - SERC device is ~\$7,500 plus lab costs, data handling etc.
                - Overall is \$10,000 - \$15,000 per device

- Big picture concepts
  - In ocean, when an algal bloom crashes the organics sink to the abyss and lost from system
    - Decomposition is decoupled from surface water
    - In ocean, the chemistry is driving the biology
- In estuary, when an algal bloom crashes the organics sink a few meters and remain in system
  - Chemistry of decomposition remains in system - not decoupled from surface water
  - In coastal systems the biology is driving the chemistry
  - Simple air/water equilibrium model cannot describe coastal OA – way too dynamic
    - Exchanges between sediment (benthos) and surface water are important
      - Benthos has reducing conditions – sulfate reduction generates $CO_2$ and T Alk
      - Shallow systems have extensive muddy bottoms associated with seasonal benthic respiration, strong $CO_2$ inputs, and ↓ pH
    - When algal bloom busts, $CO_2$ spikes and pH drops
- How does nutrient enrichment affect the carbonate chemistry?
  - Nutrient enrichment is not a direct cause of OA
    - Subsequent biogeochemical processes and reactions lead to OA
  - Highly productive systems have year round photosynthesis
    - Can ↓ $CO_2$ below atmospheric concentration
    - ↓ respiration is possibly driven by temperature
    - Can ↑ pH for extended periods
- Measure OA at ecologically relevant scales for organisms – where they live
  - Temporal variability (tidal, day/night, seasonal)
  - Spatial heterogeneity; (land-sea interactions, benthic respiration & photosynthesis)
  - How/when does the ↨ of water chemistry exceed the comfort range of organisms that evolved under the pre-OA conditions?
  - How long are the exposure times faced by organisms?
  - What are the biological responses to prolonged exposure?
  - What were oysters “doing” and dealing with during pre-industrial time?
  - Capacity of oysters to handle current and future $CO_2$ ↨ is being studied
  - Open water Bay buoys provide good data but not at relevant biological/ecological scale
    - Such as evaluating where to site oyster reef or SAV restoration projects
  - Chesapeake Bay has extensive and diverse freshwater input
    - Extensive land/sea interactions – e.g. extensive $CO_2$ input from tidal saltmarshes
      - These inputs affect habitat at local and regional scales
    - Strong diurnal, seasonal, and tidal patterns in $pCO_2$ and pH
    - Salinity gradient is important: ↑ salinity = ↑ buffering capacity = ↓ effect a molecule of $CO_2$ will have on pH
- Need robust/affordable monitoring system leveraged with and expanding on existing monitoring infrastructure
  - e.g. co-locate carbonate chemistry instruments with existing land-, buoy-, and vessel-based observing assets
- Why study Chesapeake Bay?
  - Extensive natural resources, ecosystem services, and commercial fisheries.
  - Extensive scientific understanding of Chesapeake Bay but not carbonate chemistry
  - Extensive research and monitoring activities and assets
    - Piggy-back equipment on existing observing networks - e.g. $pCO_2$, alkalinity, total inorganic carbon

    - see Workshop Proceedings: Science Assessment of Chesapeake Bay Acidification: Toward a Research and Monitoring Strategy

Discussion:

- ↓ buffering capacity in freshwater, urbanized waters
    - Have wild pH swings (~3 units) in a few hours in response to flashy and rapid runoff
        - Example of why storm water control is so important
        - Biological/ecological implications of such rapid stress changes are not known
- Monitoring assets are funded through a state/federal partnership via the Chesapeake Bay Program
    - Addition of monitoring equipment requires funds – no state or federal approval needed
    - Historical pH and T Alk data exists but, pH probes not designed for salinities of 1 – 20 ppt
        - Calibrate probes to a reference salinity for the site – ionic composition
        - Coastal waters do not have a reference salinity because ionic composition is constantly in flux
    - Deployed pH probes have biofouling problem - uncertainty increases as fouling increases
    - $pCO_2$ probe is not in contact with water so there is no fouling - easier to measure
        - Allows for real time monitoring and conversion to pH
- Relative to sea level rise and climate change - Is the marsh carbon flux good or bad for marshes?
    - It is very specific to the marsh and the local biogeochemical conditions
    - Marsh species composition affects the chemistry
    - Changes in community composition will change the chemistry
    - Relative size of marsh to river system will influence the effect of marsh's $CO_2$ and T Alk output (a ratio of marsh:river size effect has not been determined)
    - Marshes and nearby waters are highly enriched with $CO_2$ from the marsh
    - The marsh's response to sea level rise will inform the marshes effect on the land/sea interface
- What are the implications of $CO_2$ & pH patterns on aquaculture, fishing, restoration, etc.
    - Aquaculture & hatcheries
        - Solutions can be engineered since it can be made as a closed system
    - Restoration
        - Include carbonate chemistry in the decision process for where to site restoration projects
        - Carbonate chemistry effect on restoration success/failure is not known
        - Long term – carbonate chemistry will be influenced by indirect management efforts – nutrient reduction for example
        - A baseline for acceptable carbonate chemistry to site restoration is not known - without which the long term implications are not known
        - Need to consider what the TMDL goals really are
            - Reduce nutrients by a certain amount, reduce algal blooms, raise $O_2$?
            - What do we want system to look like in 10, 15 years. Reach goal by 2025
    - Monitoring networks
        - Continuous surface water monitoring would really help capture the carbonate dynamics
            - Caution about misinterpretation between surface water daytime only spot measurements with the continuous measurements
        - MDE monitoring of shellfish harvesting areas – additional platform for adding probes
        - Aquaculture site monitoring

## Appendix B

Presentation: Denise Breitburg, Smithsonian Environmental Research Center (SERC)
Topic: Acidification in Chesapeake Bay: Biological effects in an ecosystem context

- Biological influence on OA within a complex estuarine system like Chesapeake Bay
    - Develop predictable biological/OA interactions in Chesapeake Bay
        - Review existing OA effects in other systems - worldwide
        - What challenges exist for prediction of OA effects?
        - How to manage for a Bay undergoing OA?
        - Examine biological feedback mechanisms and effect on OA
            - Are there co-occuring stessors for biology?
- Dissolved $CO_2$ sources: atmospheric and biological respiration
    - In Chesapeake Bay, $CO_2$ from respiration is the dominant source
        - Algae, aerobic microbes, fish, invertebrates
        - What respiration is and what it does
            - ↓ $O_2$ and ↑ $CO_2$ at same time
            - hypoxia (↓ $O_2$) and acidification co-occurr in systems where respiration drives acidification
        - High nutrient loads stimulate ↑ biomass/production causing ↑ respiration
            - Potential result is ↑ acidification and ↑ hypoxia
        - Acidification and hypoxia must be considered together
        - Daily ↨ of dissolved oxygen (DO) and pH levels at monitoring sites
            - Strong positive correlation between DO and pH conditions
                - Fairly accurate predictions: ↓ DO indicates ↓ pH
        - DO criteria have been established for Chesapeake Bay
            - Can DO criteria be used to set biologically relevant criteria for pH levels?
                - Are DO criteria protective for pH effects since they co-occur?
    - Comparisons with pristine SERC sites (central America) – limited human impact
        - Tidal ponds in mangrove areas, limited circulation patterns, limited nutrient inputs
        - Sites have large daily ↨ of DO and pH
        - Strong correlation between DO and pH - just like Chesapeake Bay
            - Some sites are virtually identical to Chesapeake Bay
            - ↨ in pH (low pH) is natural
    - Challenge - How much of Chesapeake Bay acidification is natural vs. human induced?
        - How much is caused by coastal human activities - i.e. nutrient input?
        - Do changes to food web dynamics play a role in the acidification?
        - Management of the system should not try to undo the natural state of the estuary
        - What are the chemical feed backs in the system? - not fully known.
        - Can respiration $CO_2$ be predicted if environmental parameters (biomass, temperature, DO, etc.) and atmospheric $CO_2$ are known?
        - Is there feedback in the system that ends up making the system worse?
        - Are there limits to the effect on the system if pH reaches a certain amount?
        - Biological and ecological responses to various conditions needs to be studied
            - Responses need to be known to predict the ecological effects from acidification.
            - Combined effect of atmospheric and nutrient derived acidification needs to be known
- Calcification by organisms is directly linked to carbonate chemistry - pH
    - pH affects growth and survival of organisms having calcium carbonate shells or skeletons

    - Larval bivalves are particularly susceptible – more than post-settlement stages
      - Shell’s crystalline structure is affected at a ↓ pH
      - ↓ pH causes ↓ growth rate, ↓ calcification rates, delayed metamorphosis, and ↓ survival (↑ exposure to predators) in oyster and clam
      - Strongest effect on calcification rates were in ↓ salinity areas
        - Problem – these salinity areas are typically refuges from disease
        - Acidification will become a factor when planning restoration strategies
    - When oyster hemocytes (cells that fight disease) are continuously exposed to moderately low pH their activity is reduced by 40%
    - ↑ acidification affects organisms other than shellfish
      - ↓ larval survival and growth of silversides – ↑ vulnerability to predators
      - Summer flounder ↓ larval survival, ↓ energy reserve, metamorphose at ↓ size, and developmental abnormalities – ↑ vulnerability to predators
      - What are the effects on energetics, hormone regulation, genetics, etc.?
      - ↑ otolith size – what is the effect on hearing and movement/orientation/balance?
      - Is there a behavioral effect? – ↑ vulnerability to predators?
      - Fish seem “stupider” (coral reef studies) – settle to reef at wrong time of day/night and wrong behavioral responses to predators - ↑ vulnerability to predators
      - Spiny dogfish and Atlantic shark are less able to detect squid – possibly due to olefactory impairment
      - ↑ in blue crab hardening time
    - The more studies done, the greater the number of species and variety of effects found
    - What are the effects to ecosystem services?
      - ↓ oyster biofouling when ↓pH – the shells are white/clean
        - ↓ oyster reef community abundance, diversity, and ecological processes
- Synergistic effects of hypoxia and acidification
  - ↓ growth rate of hard clam when exposed to both hypoxia and pH than either stressor alone
  - Nutrient level can affect abundance and composition of food for some target species
    - Surf clam exposed to high prey concentration were not affected by acidification
    - The main effect on some organisms may be energetic cost
      - Prey abundance may partially compensate for lowered pH
  - Some species will be more sensitive to acidification than others – cause food web alteration
    - How will fisheries respond as target species are differentially affected by pH?
      - There will be decreased abundance and increased natural mortality
  - Will ↓ harvest mortality be an appropriate management response to compensate for ↓ biomass
  - Few food web models compared to number of nutrient reduction models
- Multiple stressor effects and interactions
  - Temperature stressor
    - Fundamental stressor
    - Chesapeake Bay water temperatures are rising
    - Low pH reduces tolerance to ↨ temperature and ↑ temperatures of red abalone larvae
  - Spatial and temporal patterns
    - Are these stressors coinciding in space and/or occurring in temporal sequence?
    - Are they affecting the same or different physiological processes in species?
  - What is happening when there are large day/night fluctuations of pH and DO

    - Do cycling conditions have fundamentally different effects than constant conditions
      - Is there day or season compensation where conditions are less severe?
      - Is it just the pH minima that are driving the outcome?
  - Variability in the system has a huge effect on the energetic cost
- Organisms expend more energy to maintain appropriate physiology and behavior
  - Experiment: Response of oyster to ↨ conditions (DO and pH) under a day/night cycle
    - Strong effect of hypoxia on prevalence of Dermo in oysters
    - ↓ Dermo presence when ↓ pH and ↨ DO (but observation not statistically significant)
    - Constant conditions reduces hemocyte activity
    - Cycling of conditions stimulates the immune response
    - What are implications of cycling conditions producing different biological responses than constant conditions
    - Different life stages are affected differently under cycling versus constant conditions
- Information needed to develop policy and management positions
  - Identification of how much acidification is anthropogenic
  - How do different sources of $CO_2$ combine in the system – are they additive?
  - Which biological experiments/measurements will be critical for decision making?
  - Policy and management decisions take into account that the system is dynamic - not static
  - Baseline information on biological responses to conditions is needed