Long-Term Coastal Acidification Monitoring in National Estuary Program (NEP) Sites

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What is Ocean and Coastal Acidification?

Oceans absorb carbon dioxide from the atmosphere, creating carbonic acid in the waters.

Carbonic acid “steals” carbonate needed by some marine organisms for their shells.

The shells of some marine organisms are made up of calcium carbonate (CaCO₃).
Monitoring Ocean and Coastal Acidification

Carbonate Chemistry Parameters:

• $p\text{CO}_2$ (dissolved carbon dioxide)
• pH
• Total alkalinity
• Dissolved Inorganic Carbon

Calcium carbonate saturation rates ($\Omega$ (omega)) is calculated to compare how easy or difficult it is for organisms to build their calcium carbonate shells and skeletons. Aragonite is one of the crystalline forms.

$\Omega < 1$, conditions are undersaturated

Credit: https://westcoastoa.wordpress.com/2016/05/28/the-beginnings-of-ocean-acidification-studies-in-mexican-waters. Illustration: Katie Douglas
Contributions to Coastal Acidification

Multiple natural and anthropogenic drivers make carbonate chemistry highly variable in coastal areas.

- Nutrients inputs
  - increased primary production; respiration increases hypoxia and acidity
- Freshwater inputs
  - alkalinity of riverine sources based on the geology of the watershed
- Shallow systems
  - benthic-pelagic coupling
  - temperature variability
- Upwelling from ocean
- Tidal Influence

National Estuary Program (NEP)

Non-regulatory program established by Congress and authorized by CWA 320 in 1987

- Priorities are defined by local, city, state, federal, private and non-profit stakeholders
- EPA HQ and the Regions provide oversight and management of the NEPs.
At 9 NEPs, EPA funded continuous monitoring sensors for pCO2 and pH in 2015-2016. NEPs face different stressors, coastal water dynamics and economic interests; using varying methods for long-term monitoring. Partnerships are critical to accomplish the monitoring.
Drivers: Impact of Acidification on Shellfish Industry

Casco Bay Estuary Partnership

Partners:
- University of New Hampshire
- Southern Maine Community College
- Friends of Casco Bay – historic nutrient data

Massachusetts Bays National Estuary Program

Partners:
- University of Massachusetts- Boston
- Watershed Associations
- EPA Narragansett Lab
Drivers: Role of Land-based Nutrients Inputs

Nutrient Inputs in Urbanized Watersheds

Long Island Sound Study

Barnegat Bay Partnership

Partners: Long Island Sound Study; University of Connecticut, NERACOOS

Partners: NOAA, New Jersey Department of Environmental Protection

Nutrient Inputs in Rural Watershed

Tillamook Estuaries Partnership

Partners: EPA Region 10 & Newport, OR ORD laboratory; Oregon Dept of Ag; USGS-Menlo Park; US Navy Research Lab

Dairy

Wastewater Plant

Timber Farms
Drivers: Influence of freshwater inflow / ocean upwelling

Coastal Bend Bays and Estuaries Program

Partners:
- Texas A&M University Corpus Christi
- Mission, Aransas National Estuarine Research Reserve

San Francisco Estuary Partnership

Partners:
- San Francisco State University
- University of California, Davis
- CeNCOOS

Santa Monica Bay Restoration Foundation

Partners:
- Sanitation Districts of Los Angeles County
- California Current Acidification Network
- Santa Monica Bay Restoration Commission
- Southern CA Coastal Water Research Project
Drivers: Role of Seagrass in Buffering Acidification

Seagrass beds can locally elevate pH and aragonite saturation, but can also decrease both parameters.

• Exploring the balance bay-wide.
• Understand influence of freshwater flows vs. oceanic sources to carbonate chemistry.

Partners:
• USGS
• NOAA

Tampa Bay Estuary Program
Deployment Methods: Buoys/Moorings

Tampa Bay Estuary Program

- OCSv2 system
  - Solar panel
  - Rechargeable battery
  - LOBOViz telemetry
  - Seabird 5p water
  - SeapHOx (pH, CTD, DO)
  - ECOPAR sensor
  - CO2pro (pcO2)
  - Stor-x data logger

- Mid-water column, 2.5 m depth
  - Total water depth ~5 m
  - Hourly sampling
  - Discrete validation ~3wk schedule
  - TA-DIC-pH

Bernoulli’s Revenge!? (used for image 3)

San Francisco Estuary Partnership

- Bay Ocean Buoy (BOB) - SeaFET @ 1m

Marine Acidification Research Inquiry (MARI)
- SeapHOx @ 60 ft

Santa Monica Bay Restoration Foundation

- Sea-Bird SeapHOx & SunBurst SAMI @ 15 m below surface (Year 1)

- SunBurst SAMI pCO₂ & Satlantic SeaFET pH

Long Island Sound Study

- Sea-Bird SeapHOx & SunBurst SAMI @ 14 m
- @ 23 m
Deployment Methods: Piers/Docks/Bulkheads

Barnegat Bay Partnership
Pro-Oceanus CO2 Pro-CV & Satlantic SeaFET
Vertical pipe attached to a bulkhead, 0.6 m from bottom

Casco Bay Estuary Partnership
Sunburst SAMI pCO2 & Satlantic SeaFET pH
Pier – 1-5 m depth depending on tide.
Cage on bottom, sensors 0.5 m of bottom

Tillamook Estuaries Partnership
Mounted under dock

Wastewater Treatment Outfall
Lessons Learned: Biofouling

Santa Monica Bay Restoration Foundation

Long Island Sound Study

Barnegat Bay Partnership
SAMICO$_2$ and SeaFet are deployed inside a cooler with surface water pumped directly from the ship channel at ~1 m depth.

Flow-through design includes Sunburst CO$_2$ and Sunburst pH sensors located ex situ.
Data Storage

• Santa Monica- Archived at SCCWRP and in house, Possible future SCCOOS
• San Francisco- CeNCOOS
• Tampa Bay- Archived at USGS weekly, Satlantic hourly
• LIS- Archived at UCONN, NERACOOS, NOAA http://lisicos.uconn.edu/
• Barnegat Bay- Archived at NJDEP and in-house
• Coastal Bend Bays- Archived in-house
• Casco Bay- Archived in-house
• Mass Bays- Archived at Umass Boston

Real-time data available online

http://tampabay.loboviz.com/
Lessons Learned: Difficulties – but has advanced the equipment

Calibration & Maintenance
• Factory calibration- several months
• Annual maintenance- several months
• Reagent depletion (LIS, SM)

Equipment failures
• pH membrane failures (LIS)
• Sensor malfunctions (BB)
• Casing failure > sensor damage (TB)
• Periodic pump failure (CBB)

User Error
• Field cleaning introduced moisture (BB)
• Bundling equipment not ideal (TK)

Environmental
• Icing concerns (BB)
• Hurricane considerations (CBB)
Lessons Learned: Successes

Partnerships
• Forged relationships with federal, state, academic, and local partners.

Maintenance
• Biofouling work arounds
• Modified casings working well

Data
• Logical trends (Tampa Bay)
• Santa Monica had 87% good data return over 11 mo. for SAMI pCO2, and 98% over 10 mo. For Sea-Bird
• Currents impacted sampling - Tampa Bay continuously improved validation over 4 checks-need to coordinate with flat tides

Graphs Courtesy of Kim Yates
Physical controls on CO₂ & pH

Evidence for tidal control on daily time scale

Evidence for temperature control over weekly to monthly time scale

3 month record
Preliminary Results: San Francisco Estuary Partnership

Ocean and watershed sources of low pCO2; ocean source for low DO
Preliminary Results: Casco Bay Estuary Partnership

pCO2 and DO inversely correlated showing influence of primary production on carbonate chemistry

Periods of low pH show higher pCO2
TA/DIC data not yet available for calculation of saturation

Courtesy of Matt Liebman
In 2015 we saw a potential influence of end of spring bloom on aragonite saturation

Omega dropped below the threshold of 1.6 during substantial periods of the deployment in July (shown here) and in October as well.

The lowest omega values coincided with a significant precipitation event in October (not shown), when omega-a and omega-c reached near-zero values.
Next Steps

• Continue deployments and analyze the data!

• NEP Coastal Acidification Progress Report – complete Spring/Summer 2019

• Inter-NEP results comparison and synthesis -2019
  • Can we compare the results given different methods, time frames, and systems?

Questions?
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