Earth’s Natural “Greenhouse Effect”
Earth’s Enhanced “Greenhouse Effect”
Ocean Acidification

Driven by the ocean’s absorption of increasing atmospheric carbon dioxide ($CO_2$)
Increase in seawater CO$_2$:

- Increase in seawater carbonic acid, H$_2$CO$_3$
The chemistry of OA: carbonate chemistry

Increase in seawater CO$_2$:

• Increase in seawater carbonic acid, H$_2$CO$_3$
• Release of hydrogen, H$^+$, ions into the seawater
• Decrease pH = increase ocean acidity

$\uparrow$ CO$_2$, $\downarrow$ pH
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- Decrease in CO$_3^{2-}$ ions (buffering process)

\[
\text{Ca}^{2+} + \text{CO}_3^{2-} \rightleftharpoons \text{CaCO}_3 \quad (\Omega < 1) \quad \text{CaCO}_3 \quad (\Omega > 1)
\]
Increase in seawater CO$_2$:

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- Release of hydrogen, H$^+$, ions into the seawater
- Decrease pH = increase ocean acidity
- Decrease in CO$_3^{2-}$ ions (buffering process)
- Can impact calcification in organisms

The chemistry of OA: carbonate chemistry

$$\text{Ca}^{2+} + \text{CO}_3^{2-} \rightleftharpoons \text{CaCO}_3$$

(dissolution) \hspace{1cm} (calcification)

($\Omega < 1$) \hspace{1cm} ($\Omega > 1$)
August 09, 2020

Last CO₂ reading: 413.05


http://keelingcurve.ucsd.edu/
Anthropogenic Change

August 09, 2020


Last CO₂ reading: 413.05

http://keelingcurve.ucsd.edu/
Ocean acidification: The “Other” CO₂ Problem

- Atmospheric CO₂ has increased 40% since the 1800s
  - Drop of 0.1 pH unit
  - 28% increase in ocean acidity
  - 10x faster than anything experienced over past 50 million years

- CO₂ is projected to double by 2100 (IPCC)
  - Additional drop of 0.2-0.3 pH units
  - Equivalent to 100-150% increase in ocean acidity
Ocean Acidification Drivers in Mid-Atlantic

Wanninkhof et al. 2015
Ocean Acidification Drivers in Mid-Atlantic

GOMEC2
July 21- August 13, 2012
Aragonite Sat at 10 dB =10 m

Warm, salty, well buffered Gulf Stream

Cold, higher CO₂, weakly buffered Labrador Sea Slope Water

Wanninkhof et al. 2015
Drivers of Coastal Acidification

High variability and extremes in high CO$_2$/low pH due to a combination of natural and anthropogenic (human-caused) biogeochemical and physical processes.
**NJ Observations - Gliders**

- Understand the baseline/climatology of OA conditions
- What are the seasonal conditions in known shellfish habitats?

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**Seasonal glider-derived pH on New Jersey Shelf**

- **Winter**
- **Spring**
- **Summer**
- **Fall**

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Atlantic Surfclam
*Spisula solidissima*

Atlantic Sea Scallop
*Placopecten magellanicus*

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*Saba et al., 2019*

*Wright-Fairbanks et al., in revision*
Acidification Impacts on Organisms

Kroeker et al. 2013
Acidification Impacts on Organisms

- Reproduction
- Olfactory
- Behavior
- Swimming ability

AND......

- Biotic interactions
- Biodiversity
- Ecosystem
- Acclimation???
- Adaptation???

Kroeker et al. 2013
Data compiled from a review of acidification and multi-stressor studies conducted on economically important groups and species in the Mid-Atlantic:

- 18 species comprising of crustaceans, mollusks, finfish and elasmobranchs (from 59 studies)
- Species managed by MAFMC, ASMFC, NEFMC, NOAA and/or States
- Wide range of response variables
Learning by Example: Shellfish Growers in the Pacific Northwest

Upwelling of acidic water

Feely et al. 2008
Learning by Example: Shellfish Growers in the Pacific Northwest

Affected growers
- Taylor Shellfish Farms
- Dabob Bay Hatchery
- Goose Point Oyster Co.
- Whiskey Creek Hatchery

80% decrease in oyster production in 2007/2008 linked to ocean acidification
Learning by Example: Shellfish Growers in the Pacific Northwest

80% decrease in oyster production in 2007/2008 linked to ocean acidification
Learning by Example: Shellfish Growers in the Pacific Northwest

Panic/Adaptation

- Ramped up research and monitoring at hatcheries
- Expanded larvae production capacity at Kona, Hawaii
- Treating hatchery rearing water
- Breeding OA resistant oysters

*Slide by Bill Dewey, Taylor Shellfish Farms*
Industry Need Leads to Policy Actions

Ocean Acidification Blue Ribbon Panel

A panel of science and policy experts to address the effects of OA on WA’s shellfish resources

In March, Gov. Chris Gregoire convened an Ocean Acidification Blue Ribbon Panel, the first of its kind in the nation.

- Convened in 2012

- Identified 42 actions toward increasing “capacity to understand, reduce, remediate, and where possible adapt to the consequences of ocean acidification” – First state OA Action Plan

- Region-wide impact led to multi-state Pacific Coast Collaborative
Several other U.S. States Follow Suit

State Department of Environmental Conservation Releases Final Ocean Action Plan for New York
Plan introduces integrated, adaptive approach to managing, restoring, and protecting state's ocean resources

New Law Creating Ocean Acidification Task Force Leads The Nation

- Many states join OA Alliance (International Alliance to Combat OA)
- Bipartisan support for 4 OA bills currently in House committee
- Regional Acidification Networks established (e.g., MACAN)

U.S. Member States in the International OA Alliance

- California
- Hawaii
- Maine
- Maryland
- New York
- Oregon
- Virginia
- Washington
“New Jersey is at increased risk to the effects of ocean acidification due to its economic dependence on shellfish harvests, with southern New Jersey counties ranking second in the United States in economic dependence on shelled mollusks. While it is predicted that New Jersey will not see unfavorable acidification conditions for shellfish until 2100, given the State’s dependence on shellfish resources, there will be high social and economic impacts.”

-NJDEP 2020, Science Report on Climate Change
High Regional Social Vulnerability

Ekstrom et al. 2015
Associated Economic Risks in NJ

• Marine resources in New Jersey have ecological, economical, social, and cultural significance

• New Jersey’s commercial fishing industry is the fifth largest in the United States and provides more than 50,000 jobs

• The fishing and aquaculture industries contribute more than $1 billion annually to state’s economy

• The most commercially important shellfish species in New Jersey include the Atlantic sea scallop, Ocean quahog, Atlantic surfclam, blue crabs, and the eastern oyster. Commercially and recreationally important finfish in NJ include Atlantic mackerel, summer flounder, black sea bass and squid.
Significant Research Gaps

Of the 35 managed species in our region, 69% (24 species) have not yet been investigated for acidification impacts.

Saba et al., 2019

Estuarine, Coastal and Shelf Science
Significant Research Needs

Additional and new studies focused on these important species are needed to investigate their responses to acidification and specifically include:

• The potential impacts to various life stages
• Acclimation and adaptation potential
• Potential thresholds of acidification
• Impacts on the food web, populations dynamics, and community structure

Continue and expand research on shellfish genetics to breed OA resilient species for aquaculture industry

Investigate mitigation strategies for aquaculture facilities, hatcheries, nurseries, and impacted waterways

Connect organism and ecosystem responses to ecosystem services and the economy
Observation Needs

- High sampling frequency
- Measurements of multiple carbonate chemistry parameters
- High-resolution depth-profiling measurements
- Monitor across a salinity gradient
- Observe OA with other stressors
- Co-located biological response monitoring

see Goldsmith et al., 2019
Observation Needs

- High sampling frequency
- Measurements of multiple carbonate chemistry parameters
- High-resolution depth-profiling measurements
- Monitor across a salinity gradient
- Observe OA with other stressors
- Co-located biological response monitoring

NJ would benefit from a comprehensive statewide monitoring network that can cohesively act to address observation needs

see Goldsmith et al., 2019
Thanks!
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