Regional Impacts of Ocean/Coastal Acidification

Briefing Conducted by the
National Association of Marine Laboratories
www.naml.org

Hosted by the
U.S. Committee on Commerce, Science and Transportation
United States Senate

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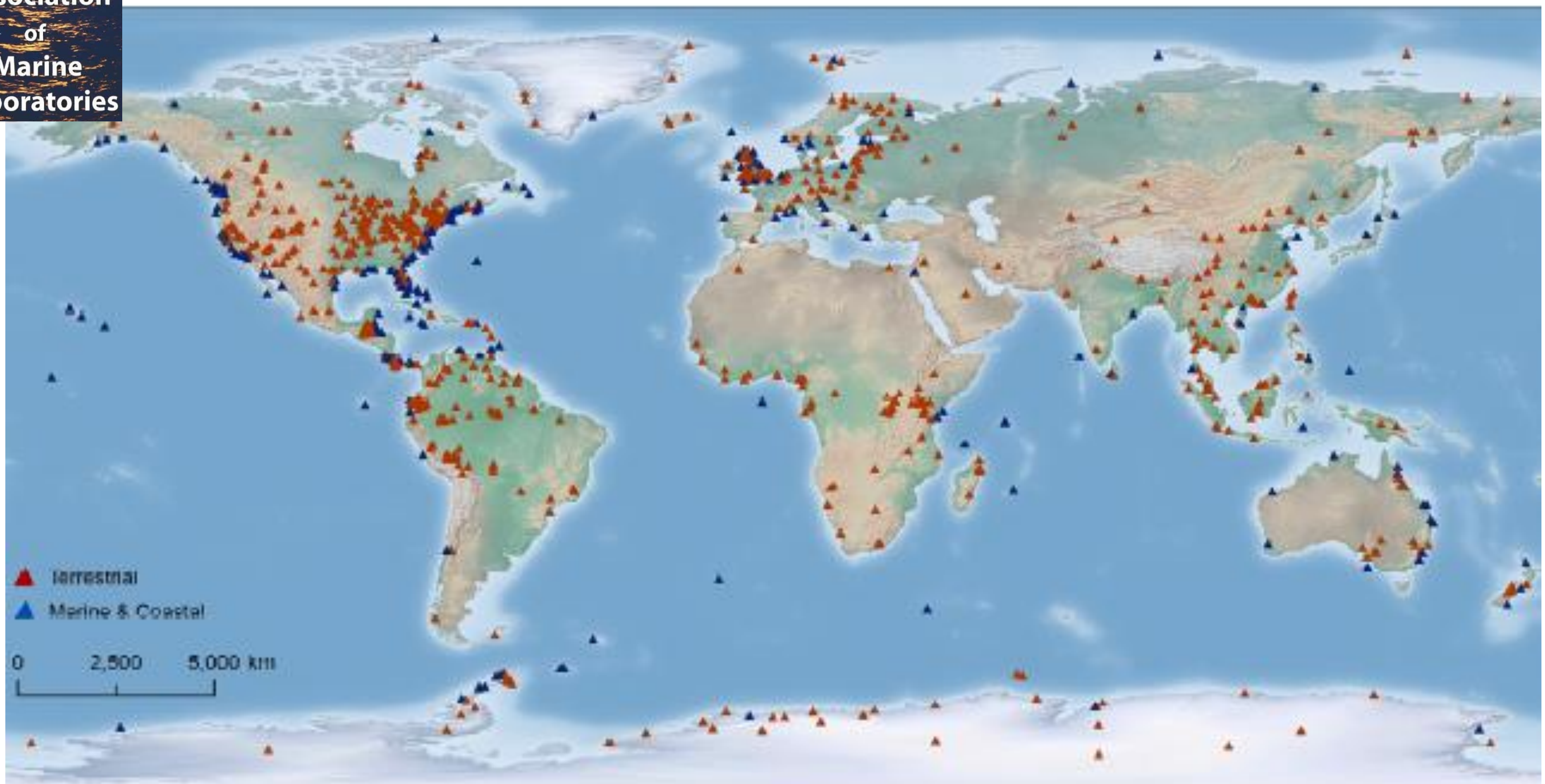
Room SVC 203-02

Map of Biological Field Stations and Marine Laboratories



Speakers

- Mr. Mike DeLuca, Manager, Jacques Cousteau National Estuarine Research Reserve, Director, NJ Aquaculture Innovation Center, Rutgers University;
- Dr. Roberta Marinelli, Director of the USC Wrigley Institute for Environmental Studies, University of Southern California, Los Angeles, California;
- Dr. Daniel McCorkle, Department Chair, Geology and Geophysics, Woods Hole Oceanographic Institution; and
- Dr. Louis Burnett, Professor, College of Charleston, Charleston, South Carolina;
- Mr. Daniel Cohen, President, Atlantic Cape Fisheries, Inc., Cape May, New Jersey

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Ocean and Coastal Acidification: Implications for the West Coast of the United States

Roberta Marinelli

Director, Wrigley Institute for Environmental Studies

University of Southern California

Ocean/Coastal Acidification

What is ocean and/or coastal acidification?

Why is it happening?

Why is this important?

What are the public policy implications of increased levels of ocean acidification?

How and why does the degree and impact of ocean acidification vary from coastal ecosystem to another?

What can marine labs bring to the table to assist policy makers as they grapple with the local, state and regional challenges of ocean acidification?

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Ocean Acidification and the West Coast

Funding from the National Science Foundation is enabling marine labs from Washington State to Oregon to California to create a network to understand how OA will affect coastal regions of the western north America.

What are the OA challenges facing the west coast and why are they different from other coastal areas?

California current, rivers, and nutrient inputs contained within terrestrial run off

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What Does This Mean for the West Coast?

- Many different marine animals, plants, and ecosystems up and down the west coast.   Not to mention the 30 to 40 million people that live, extract their economic livelihood, nourish themselves, and recreate along the west coast.

- If our coastal waters experience water that comes from offshore upwelling, might our coastal organisms already be adapted to OA, i.e. able to cope with ongoing and increasing ocean acidification?

- Or, are important organisms such as coral, bivalves, and other shell-bearing forms, already at their limit, and unable to withstand the stress of increasing acidification?

- We don’t know enough at this point to say one way or the other – but it is a question state, local and regional pubic health, economic development and natural resource managers are asking.

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What is Needed to Understand and Respond to Ocean Acidification?

- Long-term data on ecology and chemistry available though many marine field laboratories and also the ability to make new and more sophisticated measurements and observations to fill knowledge gaps.

- Use of marine labs as a network to provide a more integrated perspective that lets us evaluate how our coastlines and natural resources are changing as the ocean changes.

- Educate and train the next generation to be an informed citizenry so decisions that must be made on made with the appreciation of the complexity of our coastal environments.

- Use of this information by state, local and regional decision makers to make investment and management decisions in infrastructure and technologies to enable them to respond the emerging challenges of OA in their coastal region.

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Acidification in coastal waters – an example from Waquoit Bay, Massachusetts

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Daniel C. McCorkle

Woods Hole Oceanographic Institution

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The basic story:

Rising atmospheric carbon dioxide levels are lowering the pH of the surface ocean globally.
(Ocean Acidification)

The carbon chemistry (e.g., pH) of bays and estuaries can be different from, and more extreme than, the open ocean.

These differences reflect physical and biological processes that vary from site to site, and that help control acidification of coastal waters.

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Sustained measurements in a range of environments (= multiple sites) are needed to understand acidification in coastal waters (and the Great Lakes!)

Today:

Strong seasonal and daily pH cycles in bays and estuaries -

Location-specific natural processes
- Water circulation & residence time
- Biology (photosynthesis & respiration)

Location-specific human processes
- Eutrophication (nutrient pollution), modern and historical.

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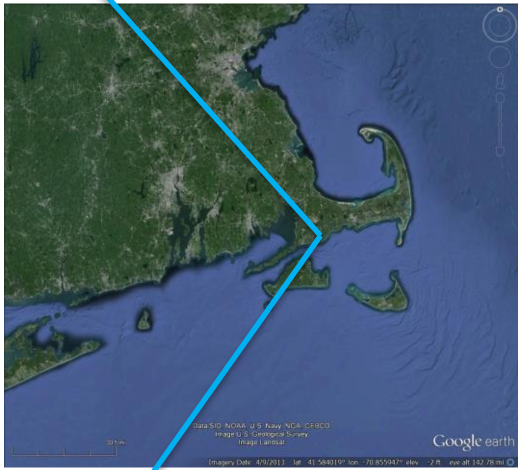
The challenge:

To understand these processes well enough to predict them, and their biological impacts.

Waquoit Bay, MA



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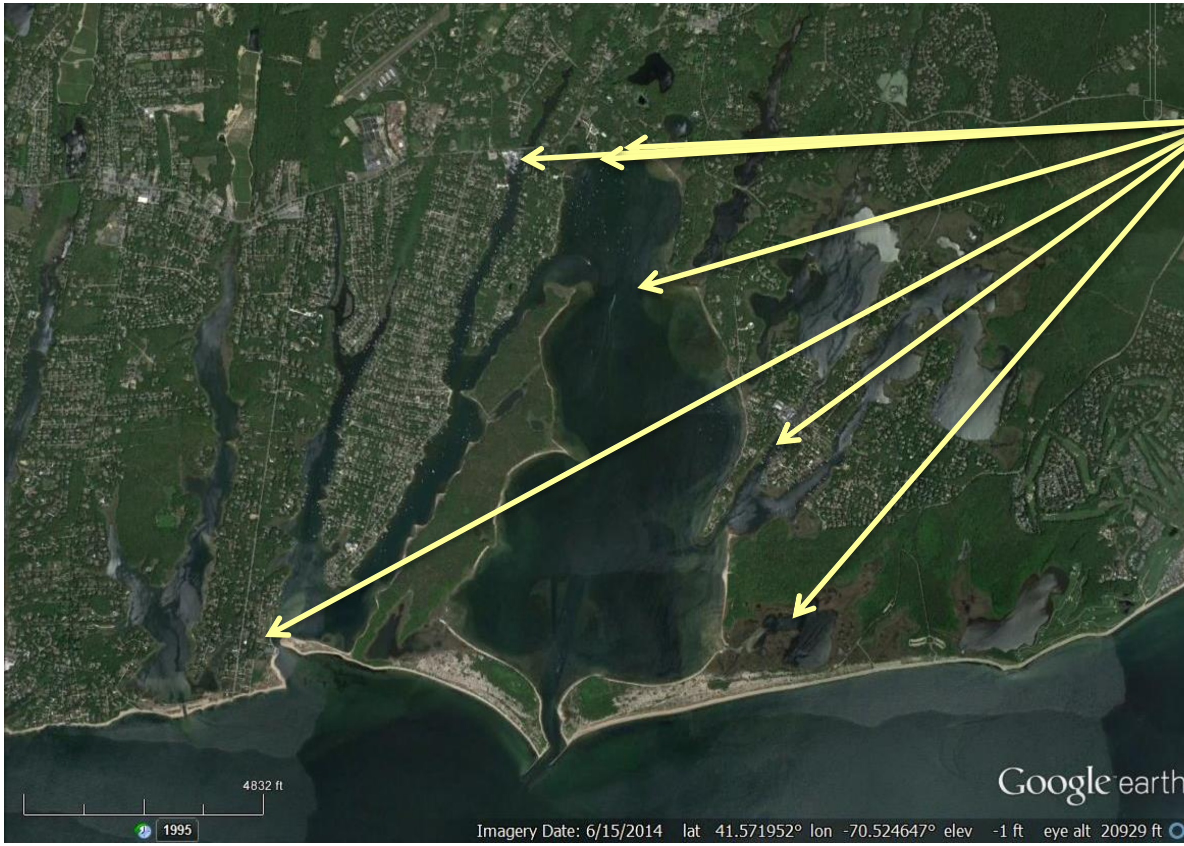
Growing year-around residential occupancy

A range of recreational uses – boating, fishing, shellfishing

Commercial uses include shellfishing and shellfish aquaculture



Waquoit Bay is home to a National Estuarine Research Reserve – one of 28 sites in the nationwide NOAA - NERRS system.

Waquoit Bay National Estuarine Research Reserve

Woods Hole Sea Grant

National Oceanic and Atmospheric Administration NOAA U.S. Department of Commerce

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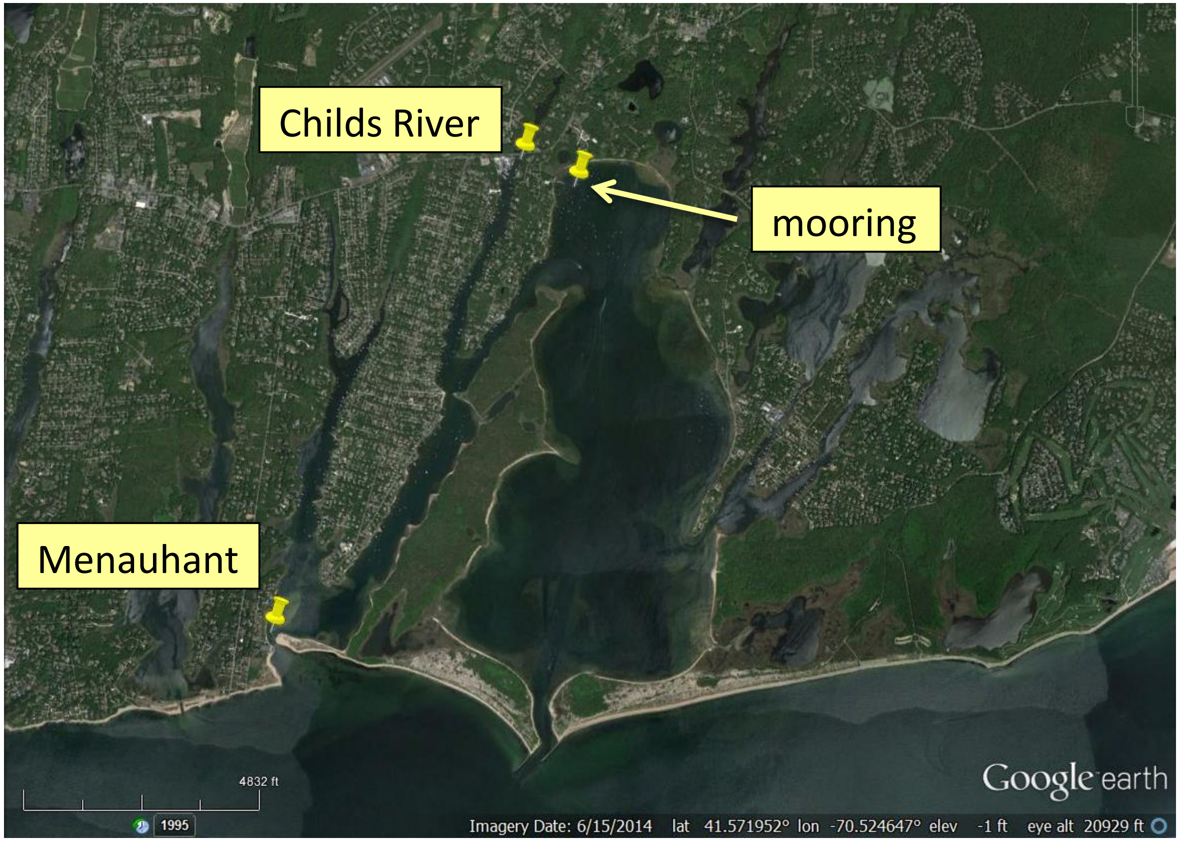
Sustained research at a network of place-based sites is essential to understanding acidification in coastal waters, and its impacts on coastal processes and resources.



Waquoit Bay National Estuarine Research Reserve sample sites.

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Three quick slides:

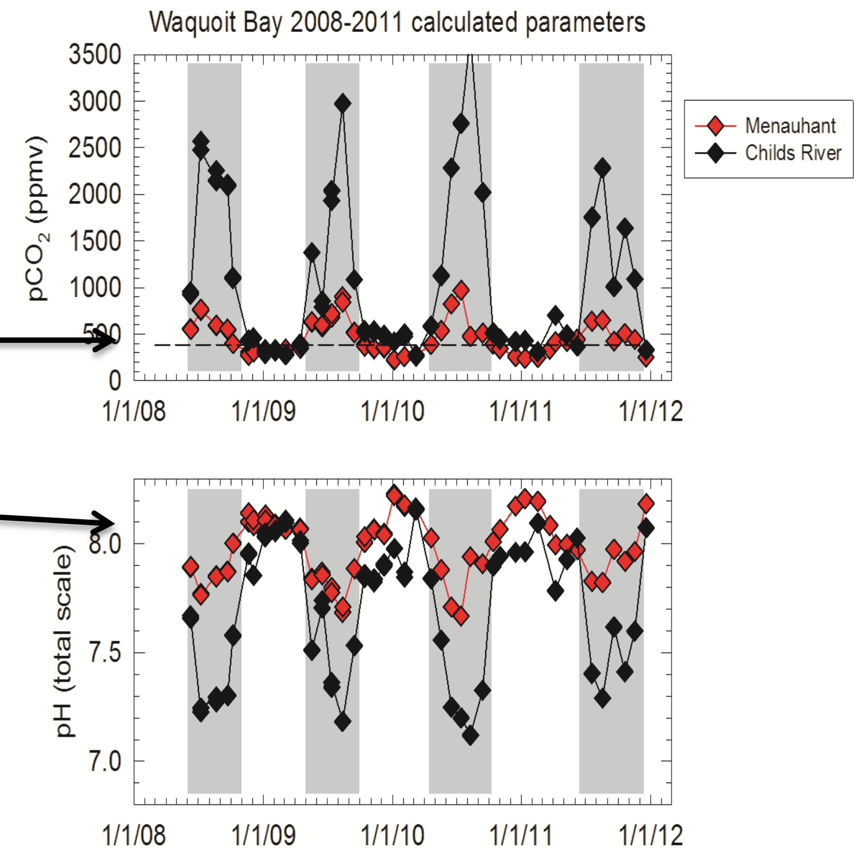
1. Monthly pH and CO_2 data from two NERRS System-Wide Monitoring Program (SWMP) stations - Childs River and Menauhant
2. High-resolution in situ data from mooring station at head of bay
3. Dissolved oxygen data from continuous monitoring sensors at the two SWMP stations

Four-year time series of Waquoit Bay pCO_2 and pH.

Today's atmosphere – 400 ppmv

Typical open-ocean pH ~ 8.1

(these early-morning, low-tide samples catch the lowest pH values of the day)



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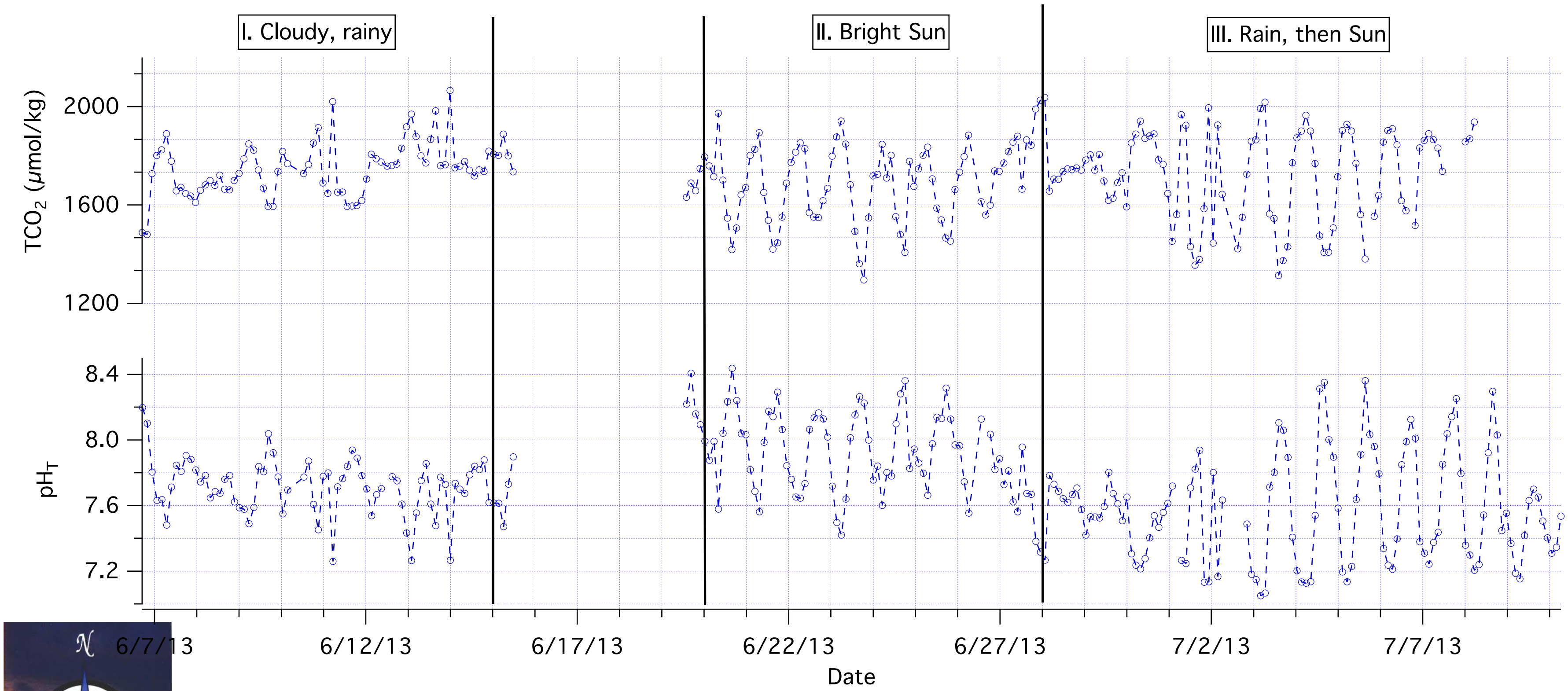
1. We observe dramatic seasonality
   Summer pH and pCO_2 values in Waquoit Bay far-exceed predictions of end-of-century open ocean acidification.

Automated high-frequency *in situ* pH and total carbon analyses show the influence of local biological processes in Waquoit Bay.



2. Photosynthesis and respiration drive strong day/night cycles of pH and CO_2, with high pH during the day, and night-time pH values lower than end-of-century open ocean predictions.

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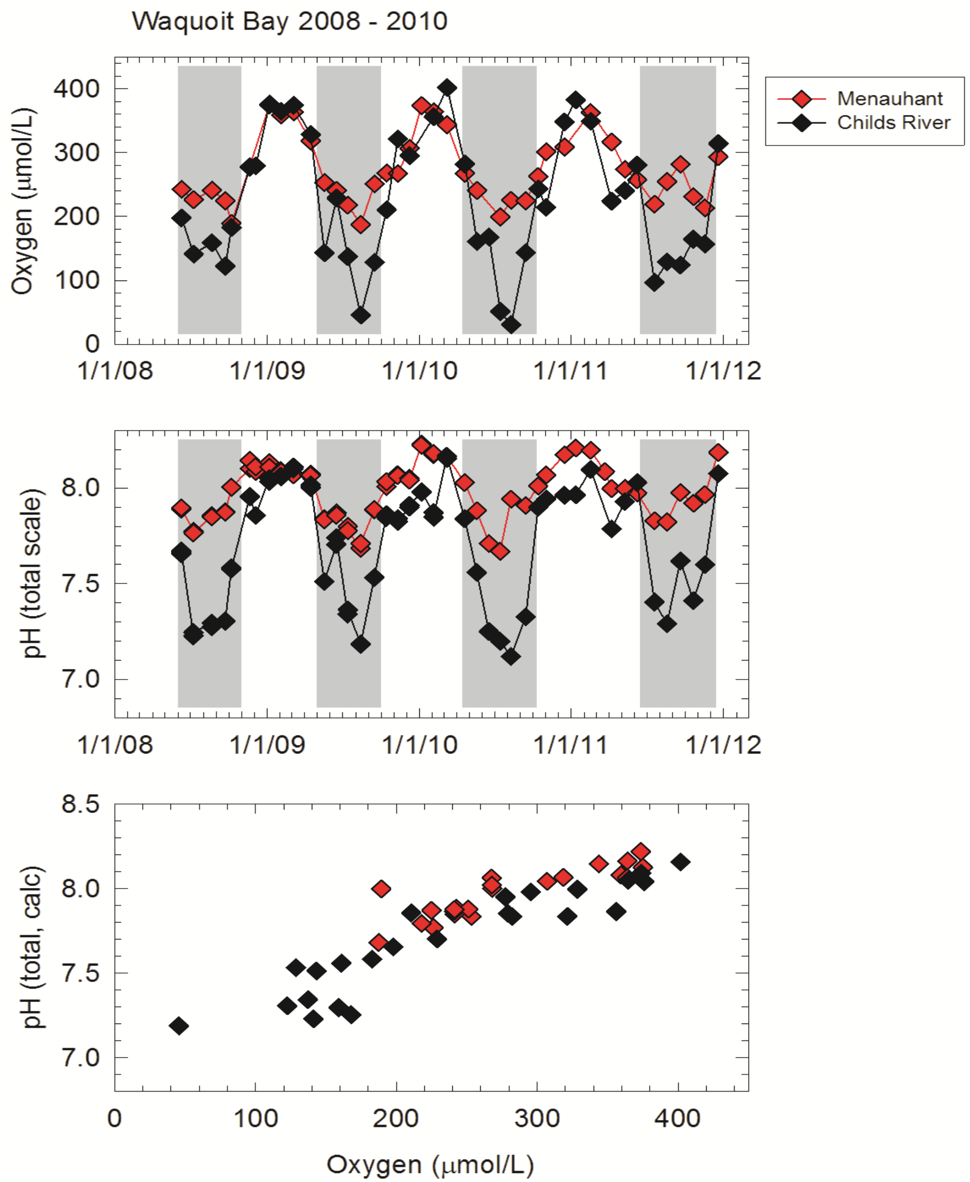
Dissolved oxygen and pH co-vary

3. Nutrient pollution causes algae to "bloom" and sink.
   The decomposition of those algae consumes oxygen and releases CO_2, causing low pH.

Marine life – e.g. larval shellfish – are affected by both stressors: acidification and low oxygen.



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Controls on carbonate system chemistry (e.g. pH) of coastal waters include processes that are variable, and often site-specific:

- Water circulation / “flushing time”
- Natural cycles of
  - Biological uptake and release of carbon dioxide (photosynthesis & respiration/decomposition)
  - Groundwater discharge (fresh and saline) and groundwater chemistry
- Human perturbations to these cycles

These processes can result in local acidification that is much stronger than projected 21st century global ocean acidification.

These processes need to be studied in multiple settings, so that their interactions and relative importance can be compared, and used to develop predictive models.

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Are coastal and estuarine ecosystems pre-adapted to high carbon dioxide, or pre-stressed?

Ocean Acidification in Southeastern Coastal Waters

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Region of the Southern Association of Marine Laboratories (SAML)

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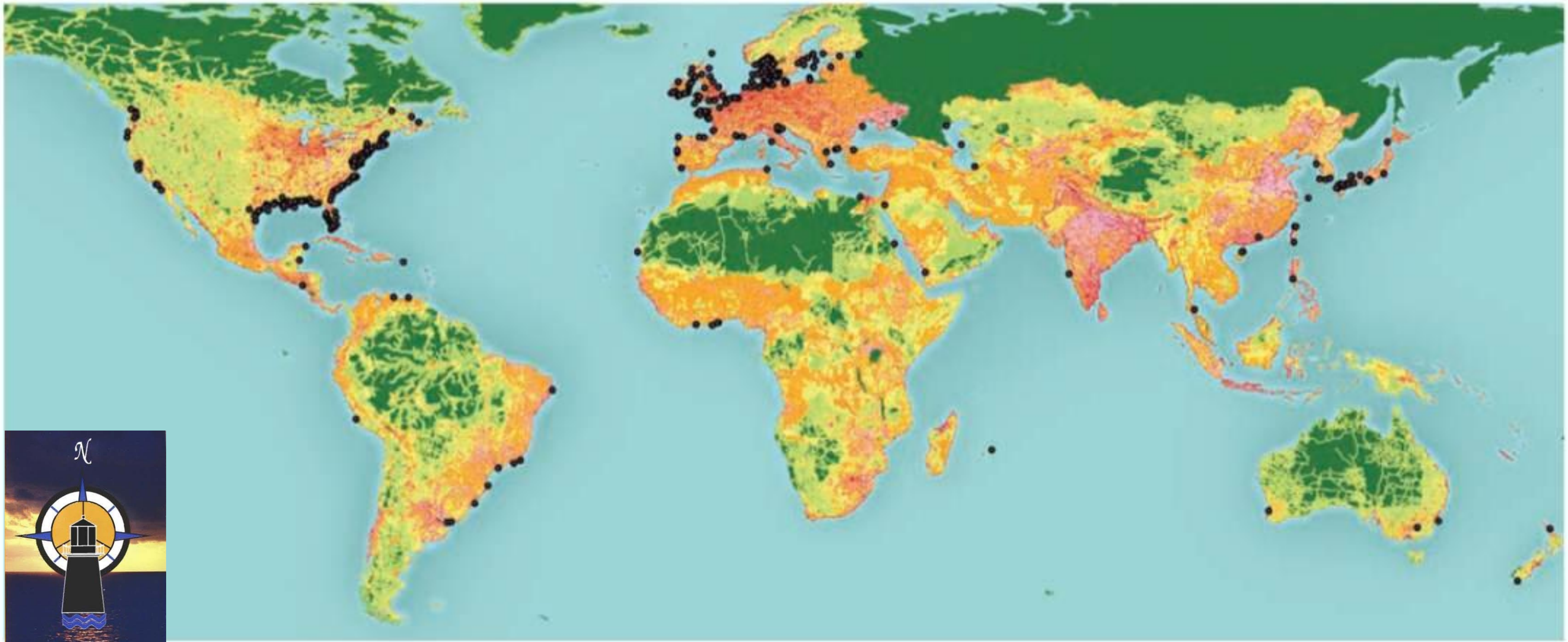
Documented zones of low oxygen



Diaz and Rosenberg, 2008

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Fish Kills

http://www.riverlaw.us/fishkills.html

http://thewatchers.adorraeli.com/

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Jubilees

http://www.wlox.com/story/22730148/jubilee-fish-kill-lures-families-to-beach-for-easy-to-catch-seafood

Low oxygen, the insidious killer……………..

Nearly always accompanied by elevated CO_2.

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Ocean Surface Water

	pH	CO_2 (µatm)
preindustrial	8.2	250
present	8.1	390
2100	7.7 – 7.8	700-1000

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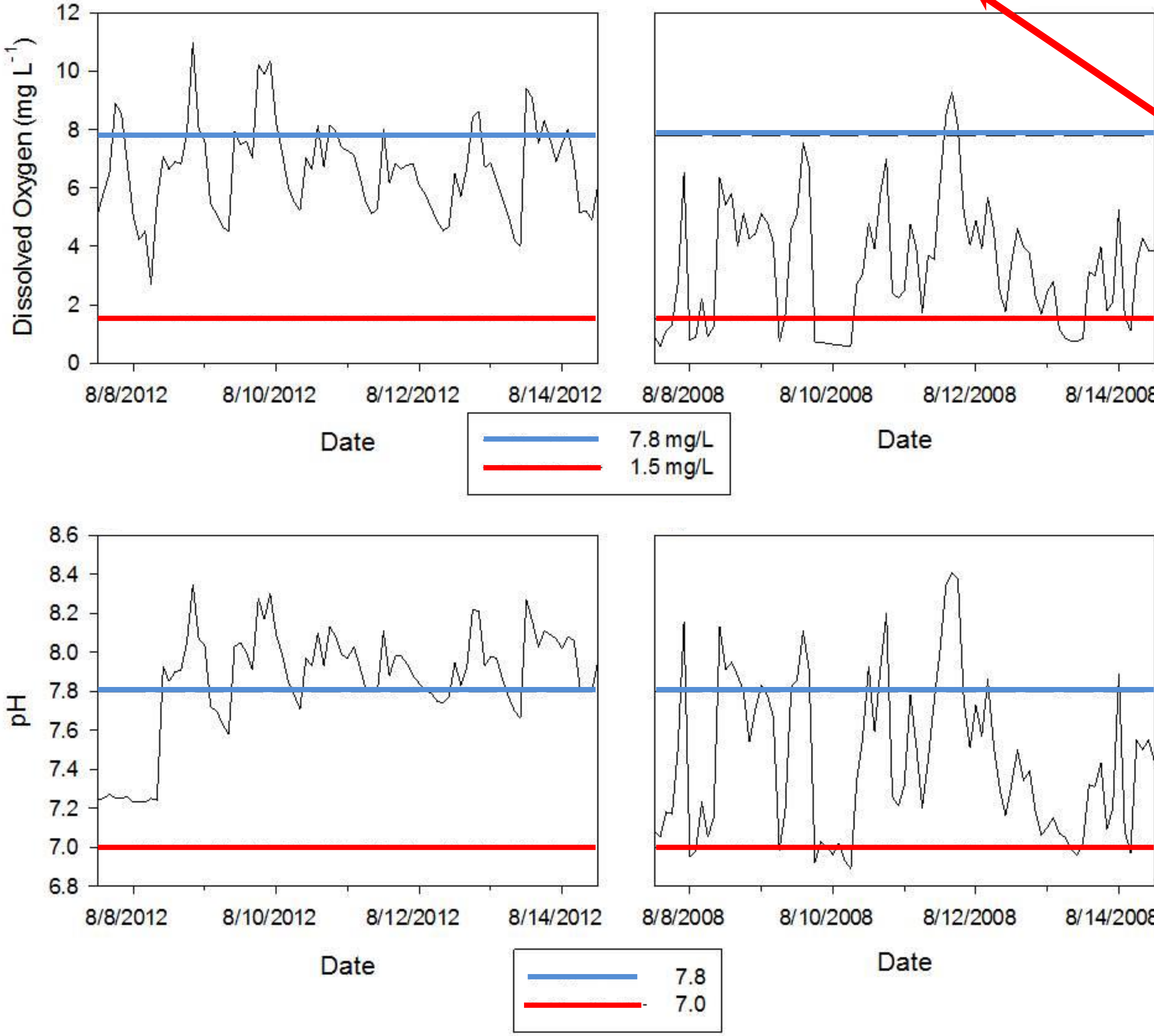
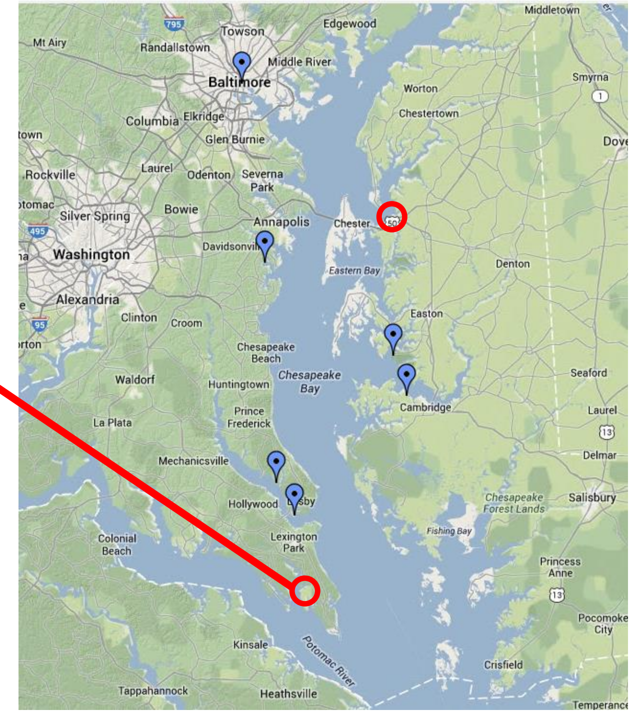
Diel cycling of low oxygen and pH

Possum Point, Corsica River

St Mary's College, St. Mary's River





Data from MD DNR's EyesOnTheBay.net

Slide adapted from Masters Thesis Defense Virginia Clark, U. of Maryland

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Coastal South Carolina Water

for example

	pH	CO_2 (µatm)
preindustrial	8.2	250
present	8.1	390
2100	7.7 – 7.8	700-1000
present	**6.0-8.1**	**300->20,000**

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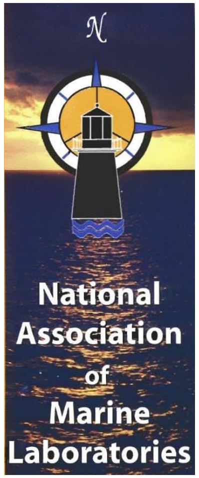
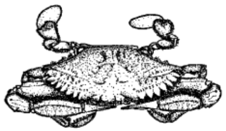
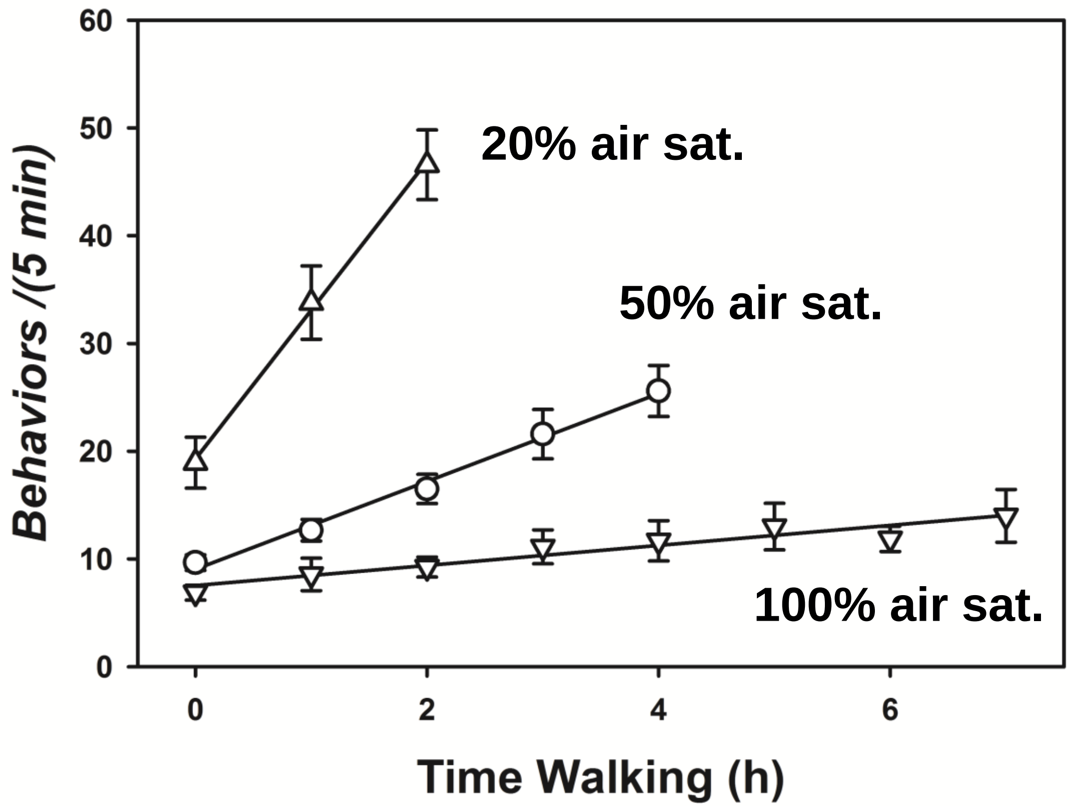
Blue Crab Performance



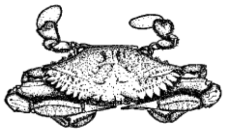
Fatigue Behaviors in Blue Crabs

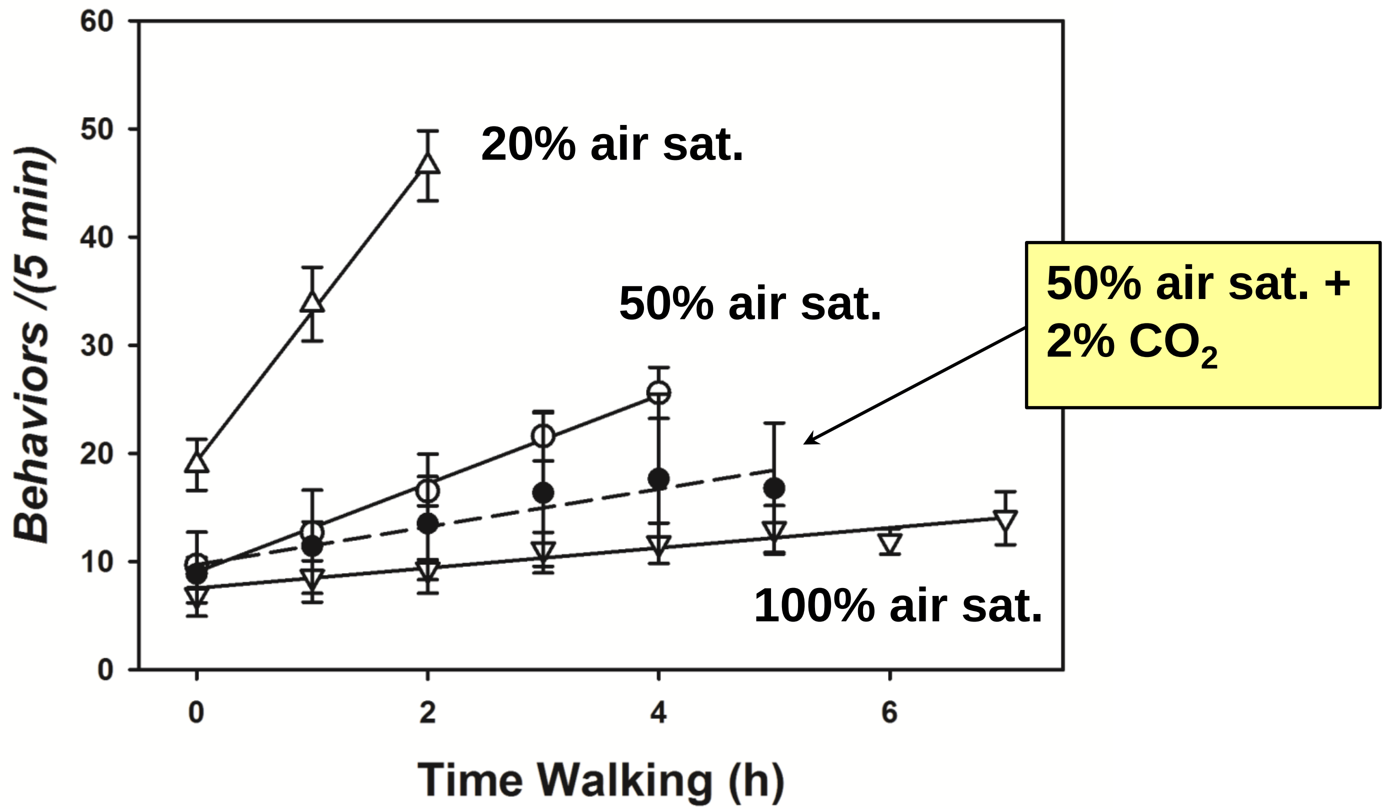




Stover et al. 2013

Fatigue Behaviors in Blue Crabs





Stover et al. 2013

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A BIG Problem

- Many organisms can adapt to low oxygen, even and especially humans.
- BUT this adaptation is muted with elevated CO_2!

Pacific Whiteleg Shrimp
Litopenaeus vannamei

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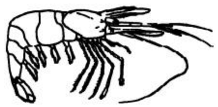
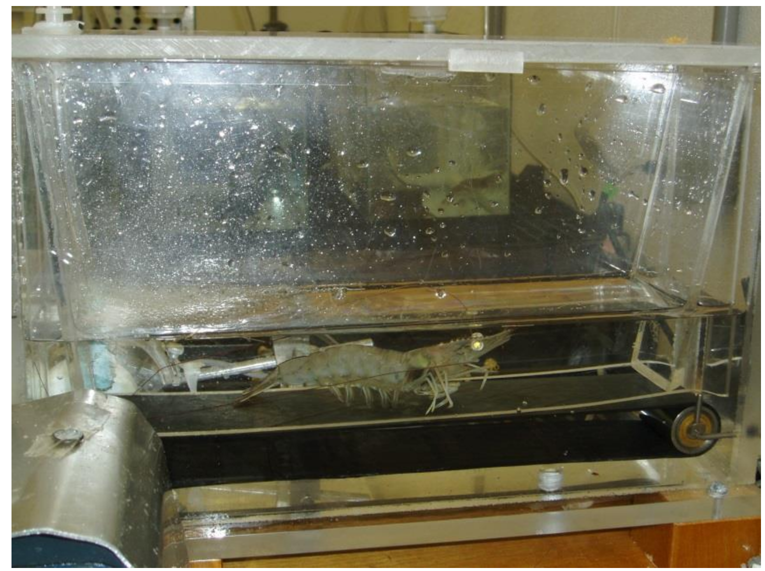
Pacific Whiteleg Shrimp



- Genes to make blue blood are turned on within 24 hours on exposure to low O_2.
- HOWEVER, exposure to CO_2 mutes this response to low O_2 (Rathburn et al., 2013).



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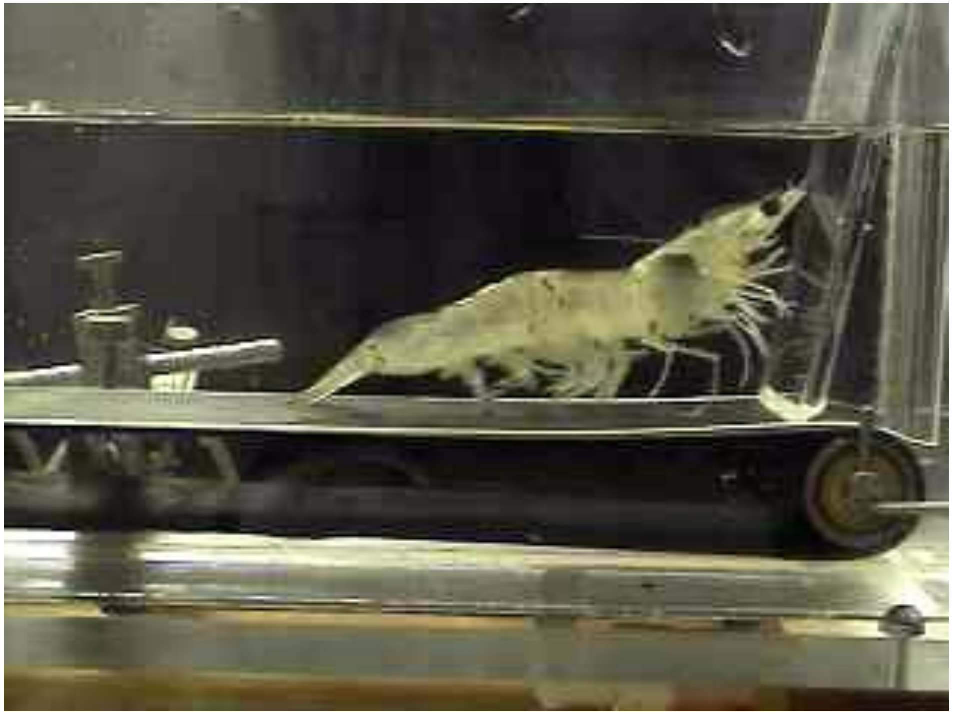

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Impact of Coastal Acidification on Shellfish Farming with Implications for Wild Fisheries

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www.atlanticcapes.com

www.capemaysalts.com

www.islandscallops.com

Impact of Coastal Acidification on Shellfish Farming

- Coastal acidification is already affecting hatchery-produced shellfish.
- Pacific Northwest oyster industry lost at least $110 million due to coastal acidification
- In 2013, 90% mortality was experienced in three year classes of scallops in NA largest scallop farm (2010, 2011, 2012).
- Shellfish larvae and juveniles are particularly susceptible

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Impact of Coastal Acidification on Shellfish Farming

- Shellfish Response to Acidification
  - Decreased fertilization rates
  - Decreased hatching success
  - Decreased larval growth
  - Shell deformities
  - Impacts on shell formation
  - Weakening of shell

Impact of Coastal Acidification on Shellfish Farming

Current Industry experiments in adaptation:

- Hatchery and nursery intake water monitoring and buffering seawater (the “TUMS” approach)
- As volume of water increases in nursery this becomes more challenging
- Buffering the coastal waters for grow-out operations clearly is a different scale challenge

Impact of Coastal Acidification on Shellfish Farming

- Key Steps for Research and Adaption
  - Establishment of standardized monitoring and collection of data in Aquaculture , Coastal waters, and Ocean Waters
    - http://oceanhealth.xprize.org
  - Selective breeding to select for shellfish that can survive in increasingly acidic water
    - Similar to breeding of disease resistance
    - Can now for first time use new genomic tools
  - Capitalize on research networks
    - Coordinate nationally and Internationally
    - Leverage shared problems and collaborate on research
    - Support demonstrations of adaption in the field

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Implications for Wild Fisheries

- Aquaculture hatcheries control the environment and we can see the impact of acidification – immediately at spawning
- Wild fisheries are conducted in open ocean - Spawning events are not observed
- Success of spawning often not known for about 1-2 years until shellfish is large enough to sample in NMFS surveys

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Implications for Wild Fisheries

- There is no existing data base of PCO_2 or pH on the ocean bottom or water column
- Current coastal monitoring shows PCO_2 levels in multiples of atmospheric CO_2
- Ocean modeling needs to consider:
  - Is the World experiencing a combination of atmospheric PCO_2 and climate change
  - Ocean Temperature changes causing changing in ocean currents and upwelling binging up “ancient PCO_2
- Impacts on populations of “carbonate shellfish” can be postulated from aquaculture, but are really unknown in the open ocean
- US shellfisheries have a multi-billion dollar plus impact to the US economy

Implications for Policy

- First: Stop the source of CO_2
  - *Save a Fish: Wear a Condom*
  - Reduce Society's Carbon Footprint
- Second: If we can't stop the source of Ocean Acidification, how can we adapt?
  - Need to monitor to know
  - Need to selectively breed marine species which can thrive in an increasingly acidic environment

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Impact of Coastal Acidification on Shellfish Farming with Implications for Wild Fisheries

QUESTIONS?

Daniel Cohen, President

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