Ocean and Coastal Acidification in the Mid-Atlantic: the What, the Why, & the Risks

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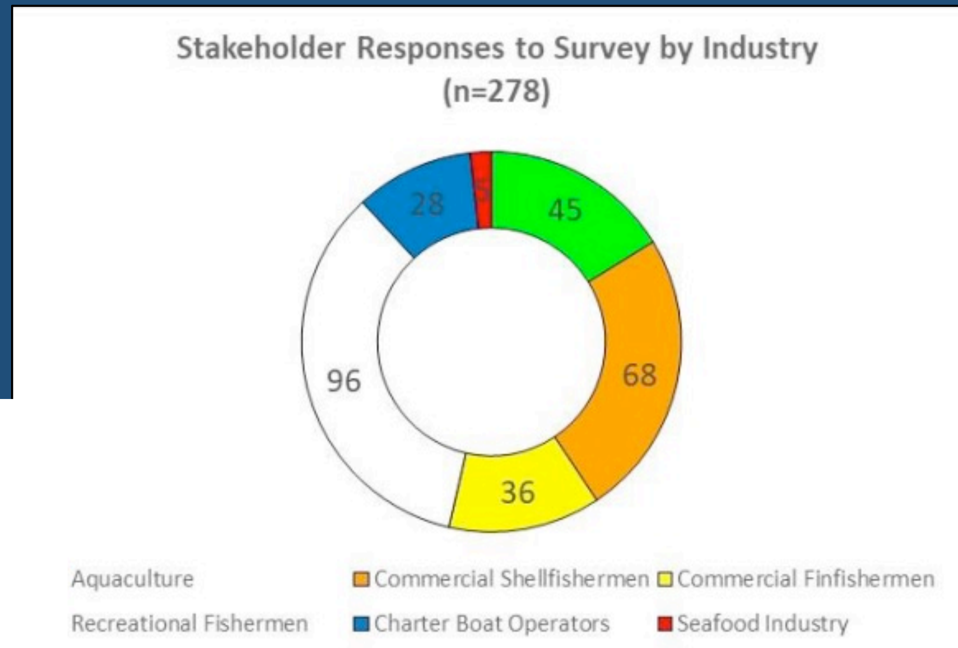
Hooked on Ocean Acidification Mini-Series: February 18, 2021

MACAN Efforts to Address Gaps

- 2019 Stakeholder Survey



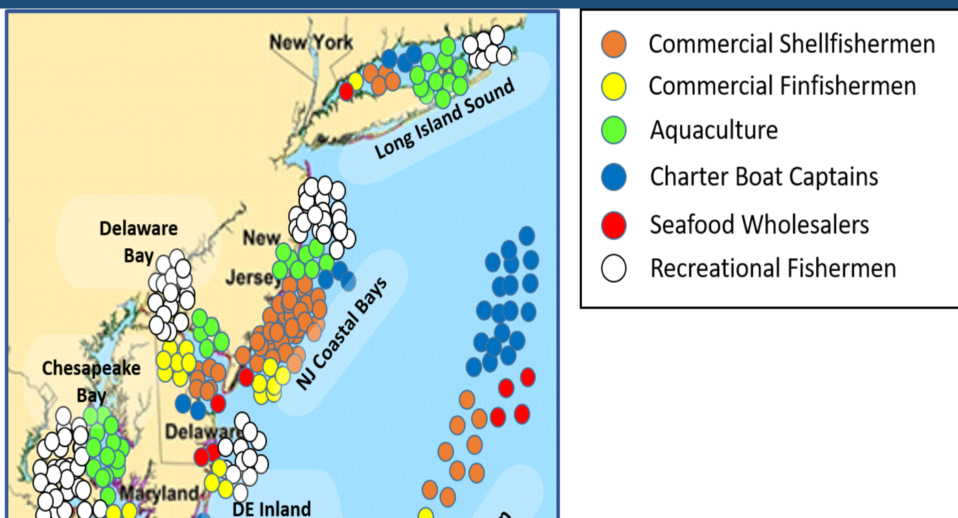


Figure X. Map of locations where stakeholders fish commercially or recreationally, or have aquaculture operations in the Mid-Atlantic region.

MACAN Efforts to Address Gaps

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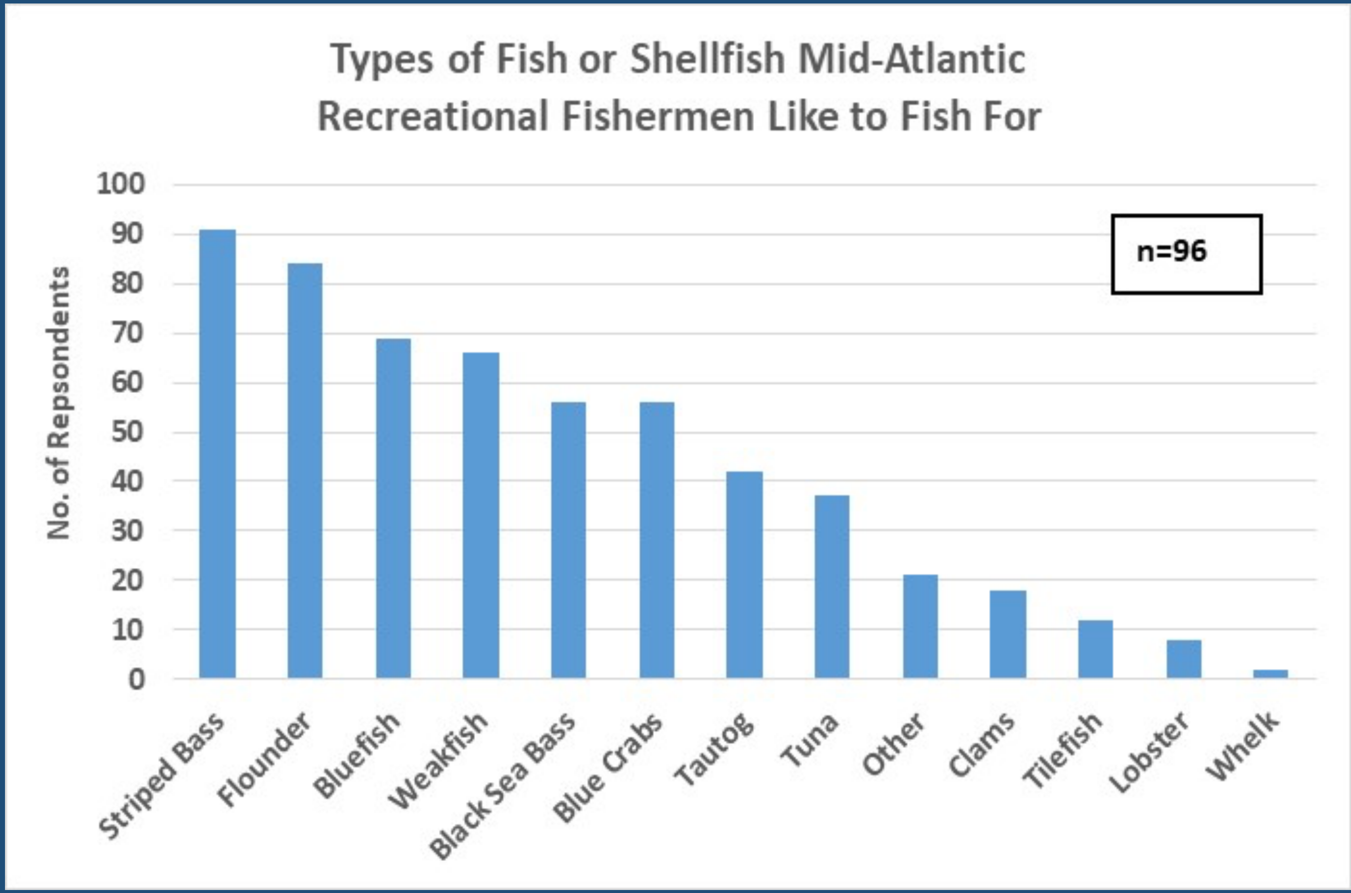

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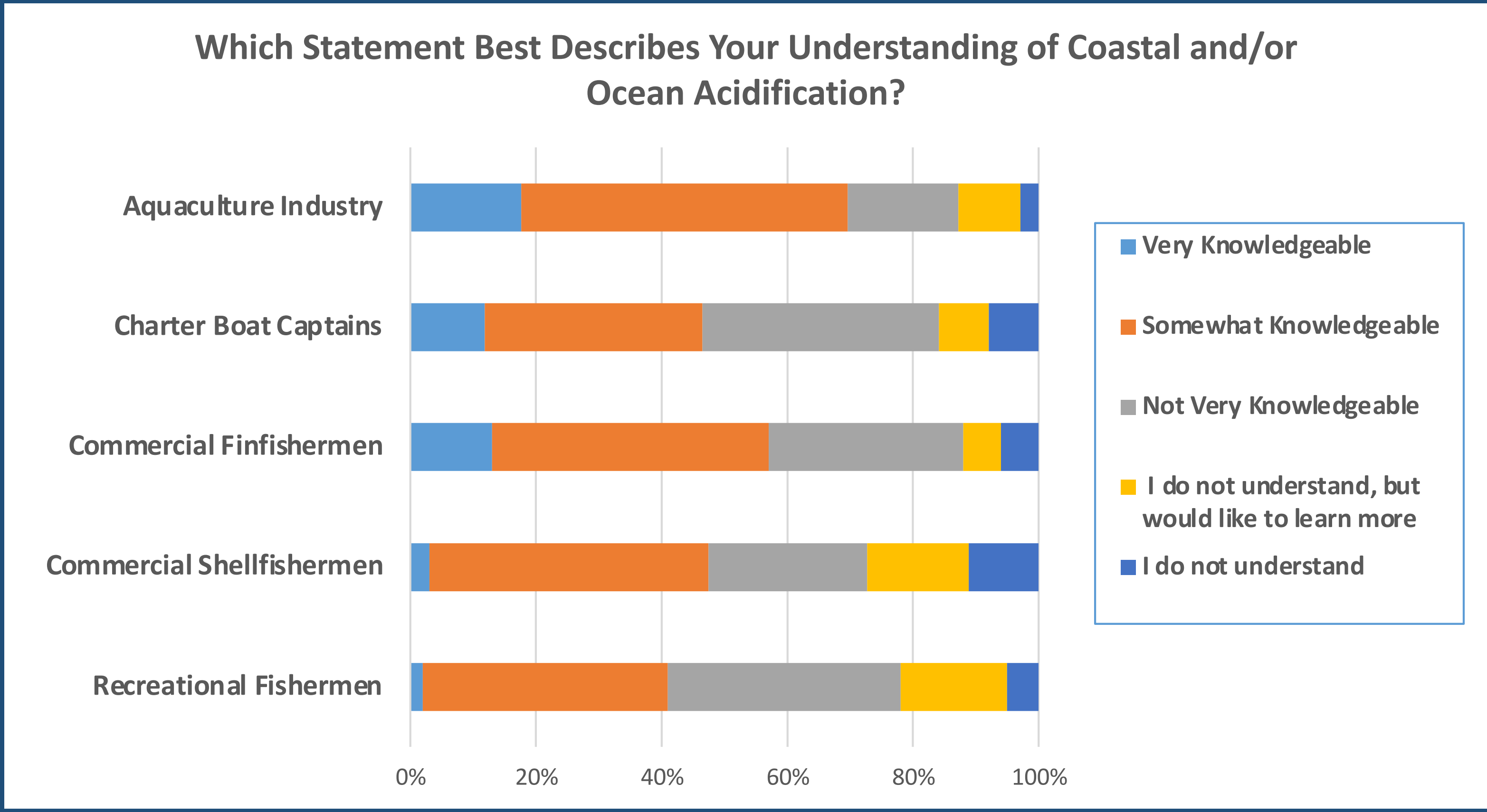


MACAN

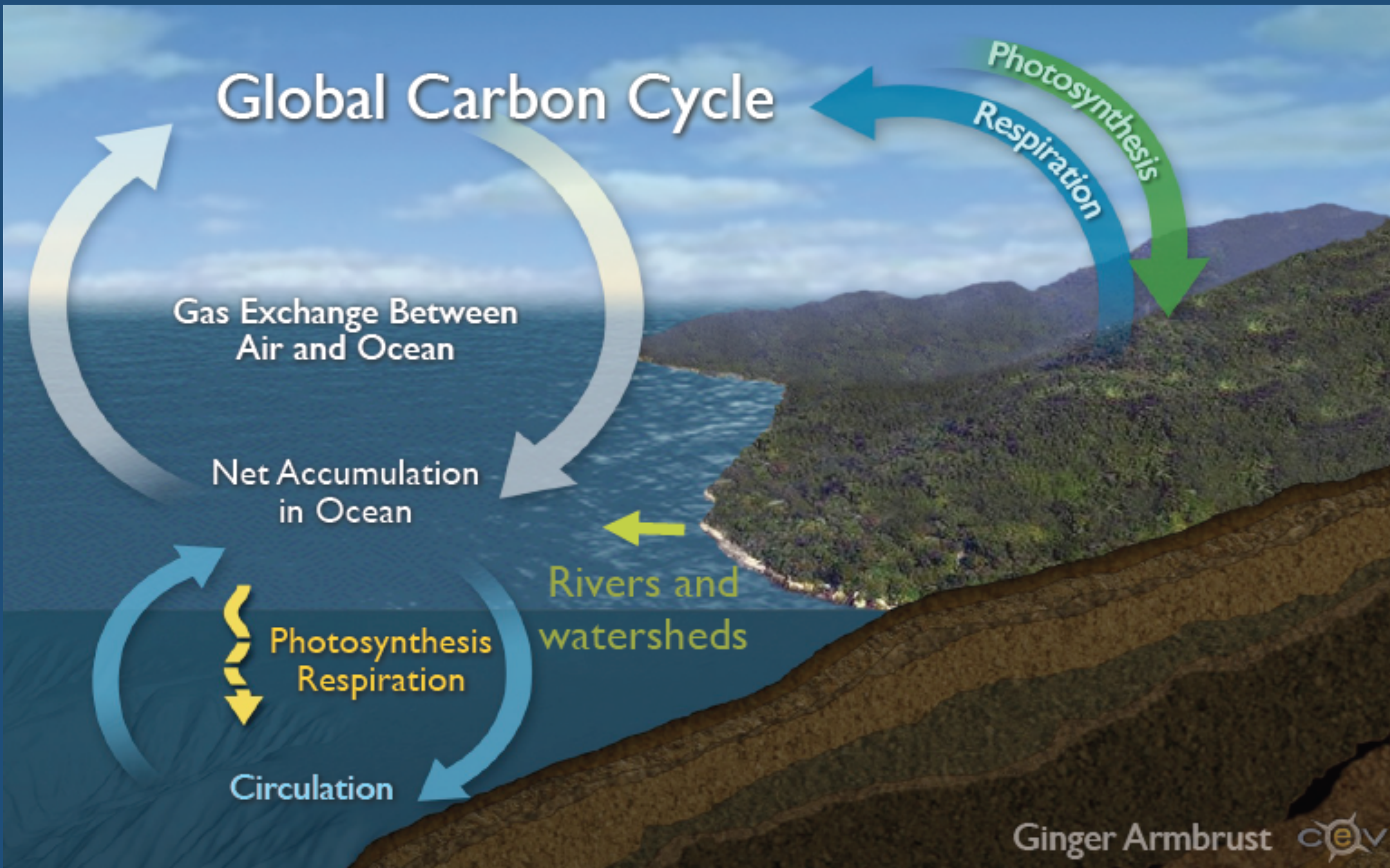
2019 Stakeholder Survey

Questions from Fishermen

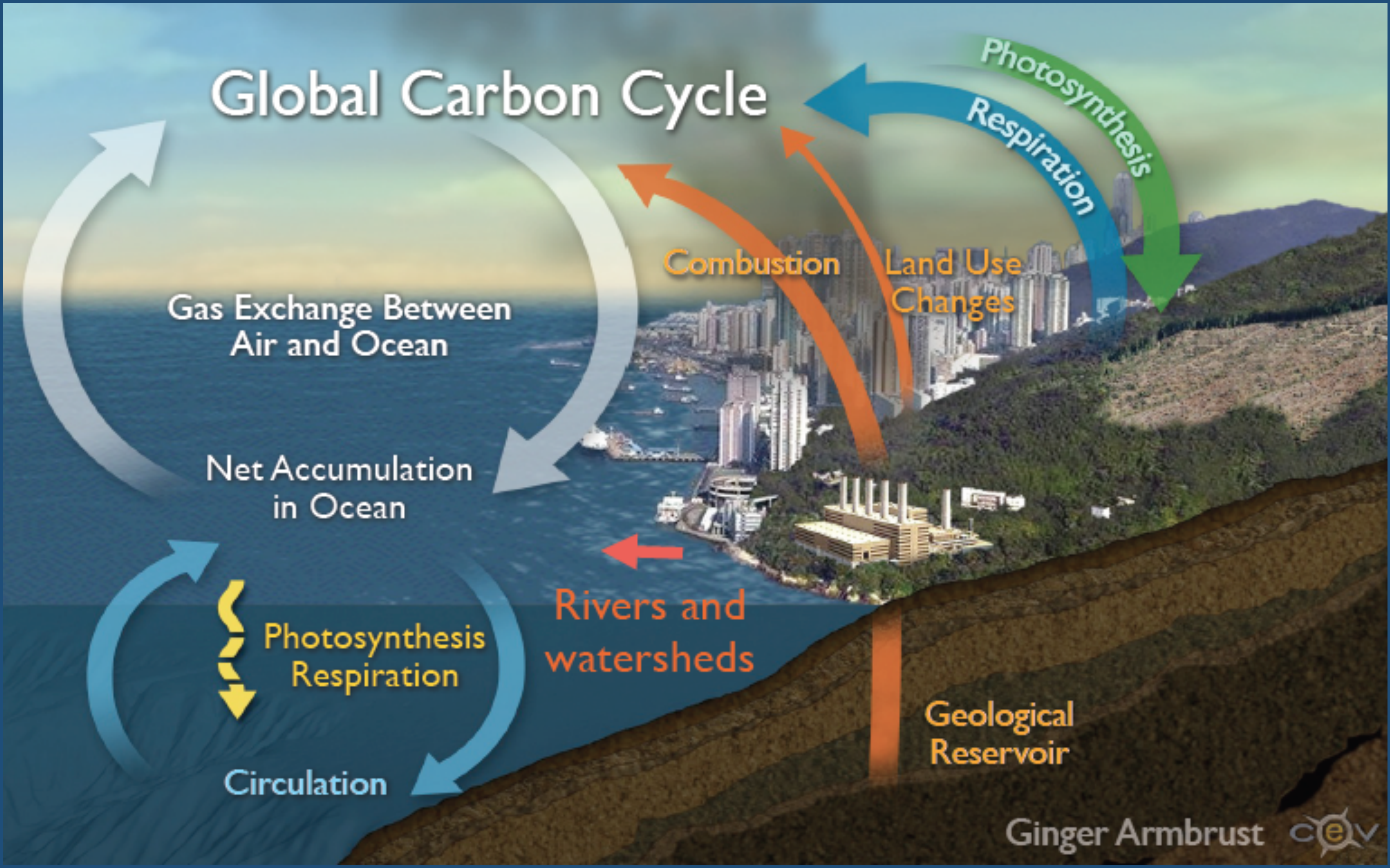
- What are the effects of OA on shellfish? How will that impact the food web?
- What are the effects of OA on fish/fisheries? What's the timeframe?
- Will impacts of OA be more severe in coastal regions vs. ocean waters?

"Does this mean that the ocean and the bay are becoming more acidic? What is the ***baseline*** *for acidity? How do* ***our activities*** *affect the acidity?"*

Earth's Natural "Greenhouse Effect"

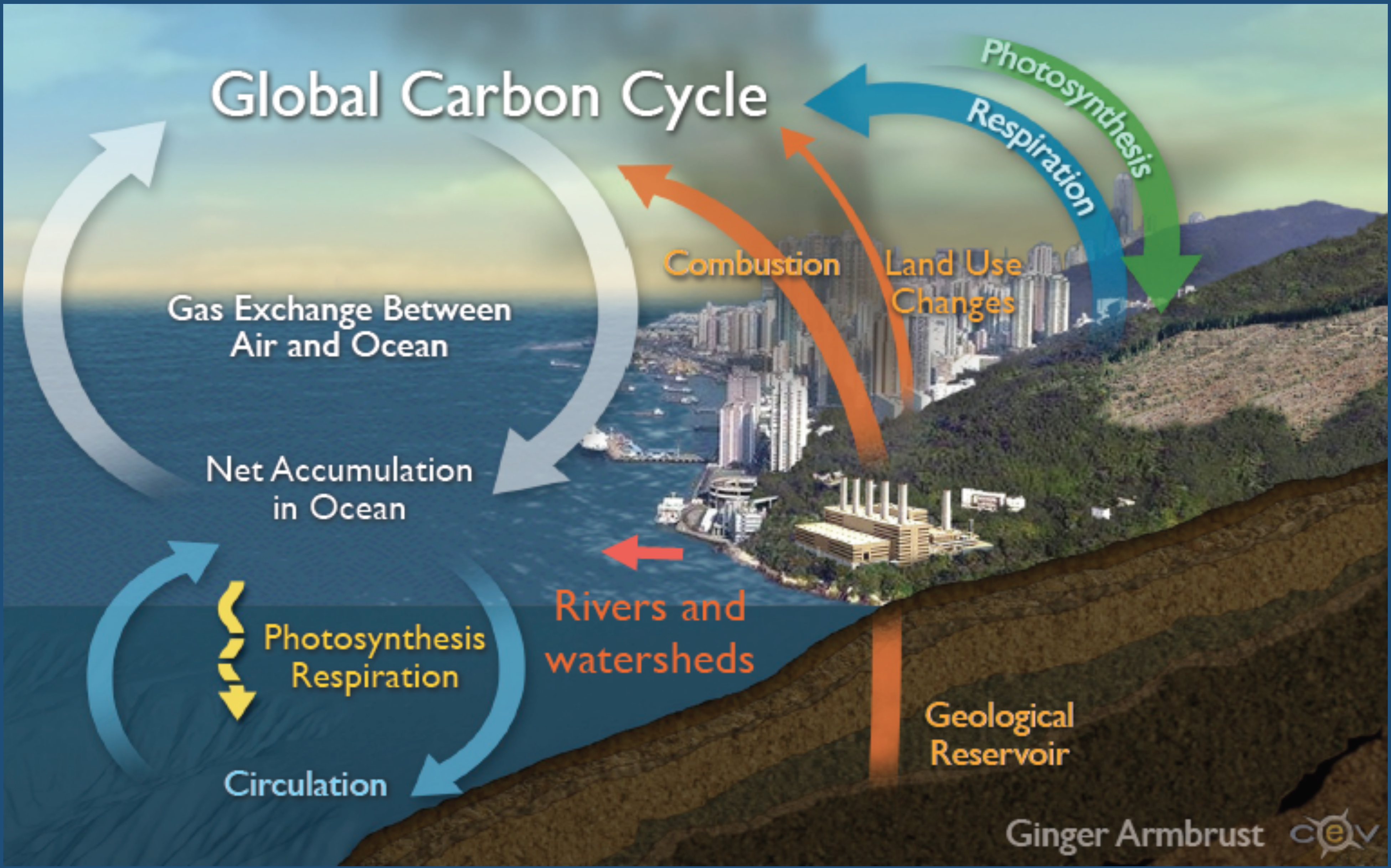


Earth's Enhanced "Greenhouse Effect"

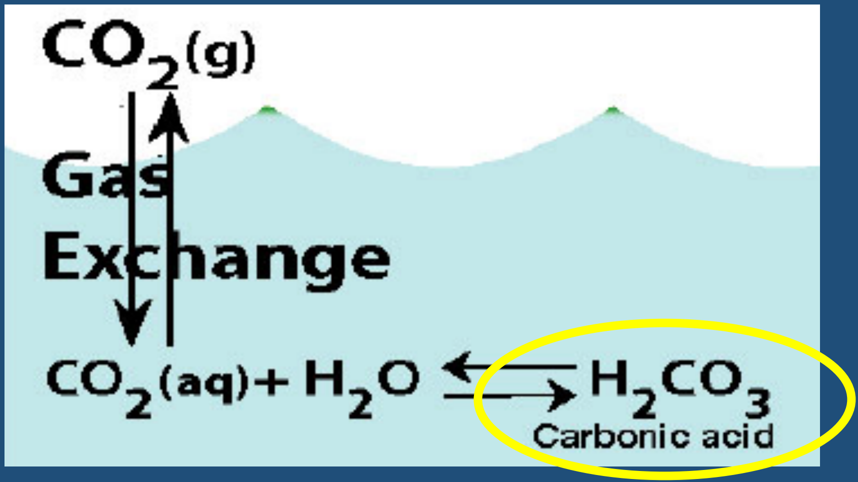


Ocean Acidification

Driven by the ocean's absorption of increasing atmospheric carbon dioxide (CO_2)



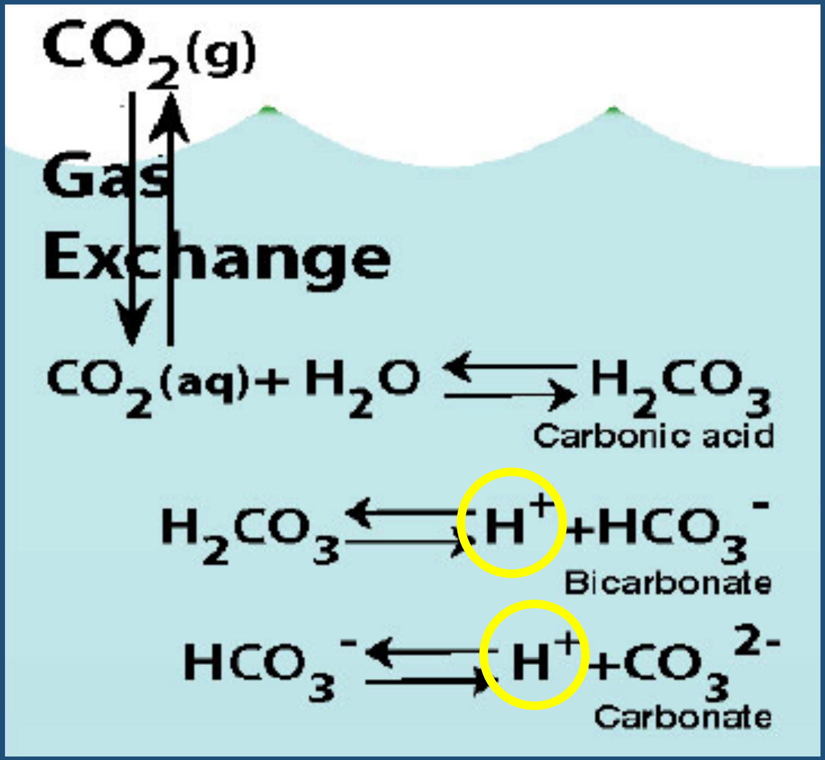
The chemistry of OA: carbonate chemistry



Increase in seawater CO_2:

- Increase in seawater carbonic acid, H_2CO_3

↑ CO_2



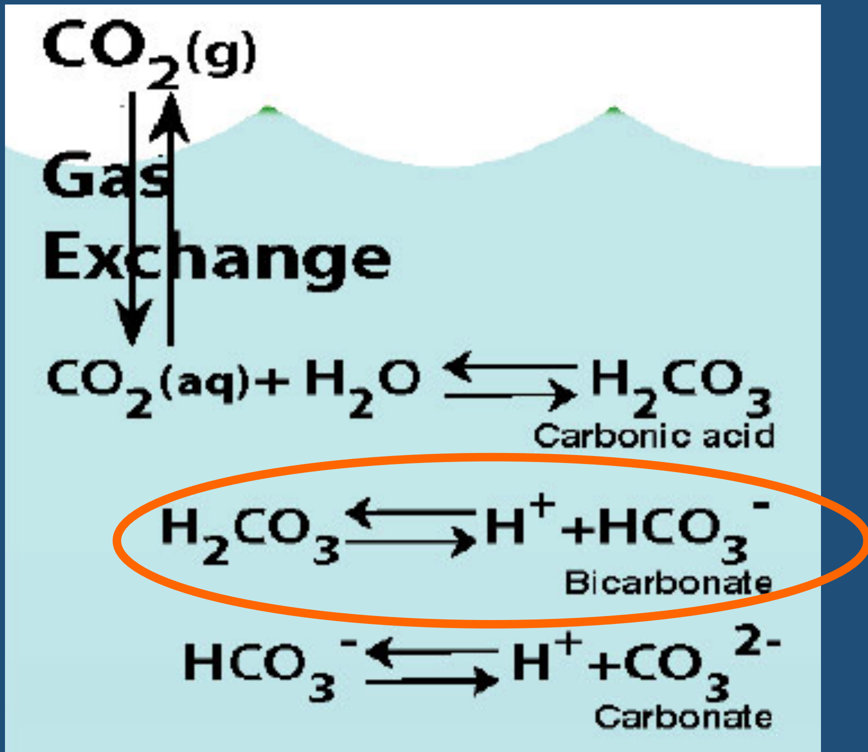
The chemistry of OA: carbonate chemistry

Increase in seawater CO_2:

- Increase in seawater carbonic acid, H_2CO_3
- Release of hydrogen, H^+, ions into the seawater
- Decrease pH = increase ocean acidity

↑ CO_2, ↓ pH

The chemistry of OA: carbonate chemistry



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- Increase in seawater carbonic acid, H_2CO_3
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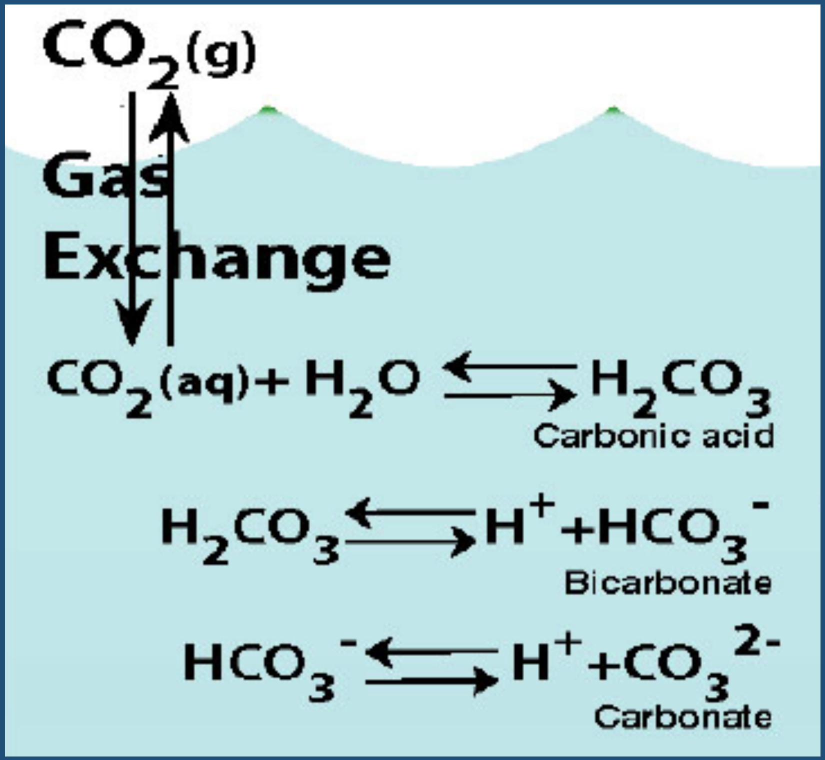
- Decrease pH = increase ocean acidity
- Decrease in CO_3^{2-} ions (buffering process)

↑CO_2, ↓pH



The chemistry of OA: carbonate chemistry

$$Ca^{2+} + CO_3^{2-} \rightleftharpoons CaCO_3$$

(dissolution) (calcification)

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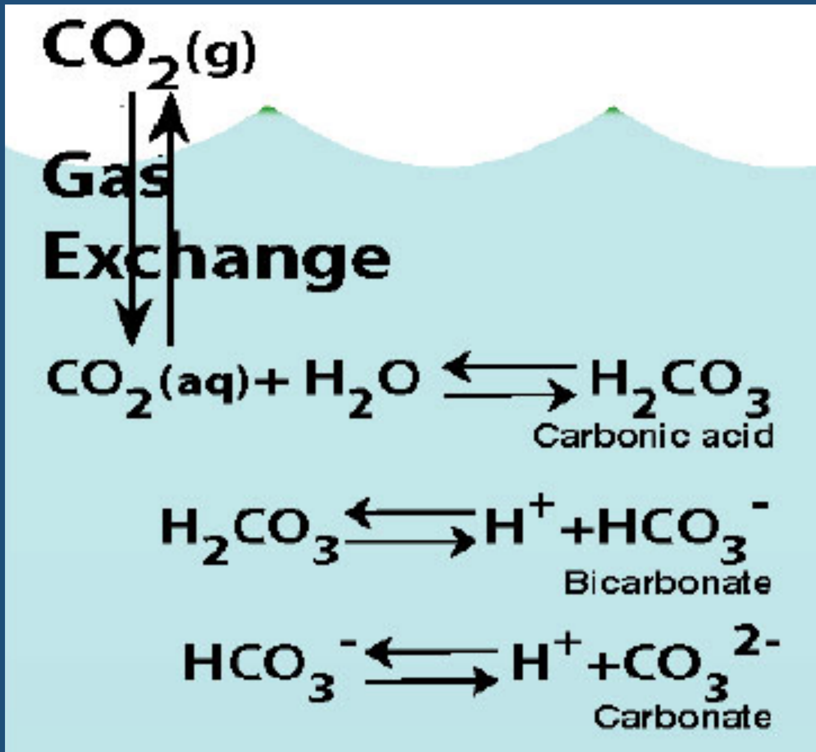

The chemistry of OA: carbonate chemistry

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(Ω < 1) (Ω > 1)

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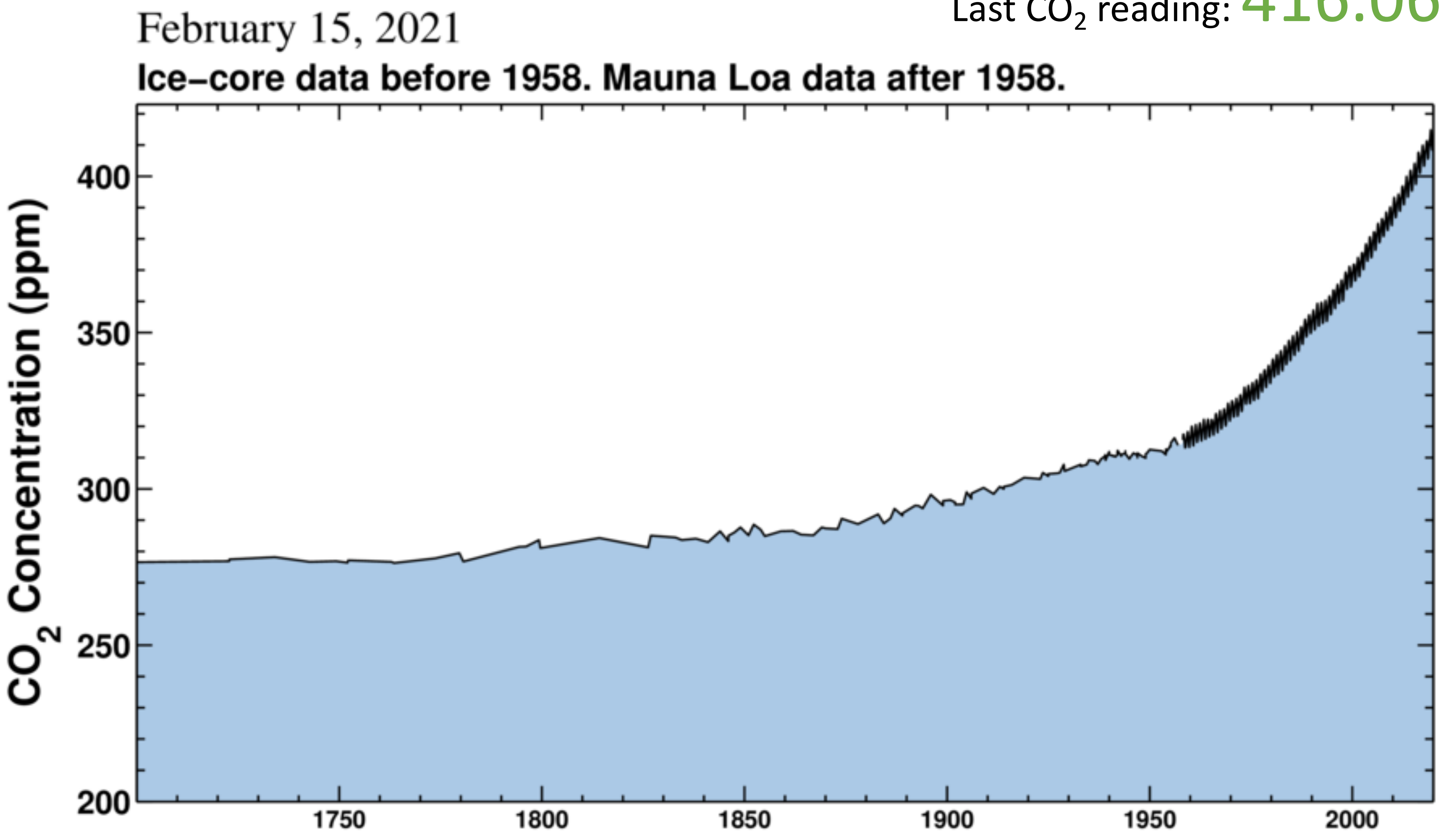
- Increase in seawater carbonic acid, H_2CO_3
- Release of hydrogen, H^+, ions into the seawater
- Decrease pH = increase ocean acidity
- Decrease in CO_3^{2-} ions (buffering process)
- Can impact calcification in organisms

$\uparrow CO_2$, $\downarrow pH$, $\downarrow \Omega$

Human-Driven Change

Last CO_2 reading: 416.06



http://keelingcurve.ucsd.edu/

Human-Driven Change

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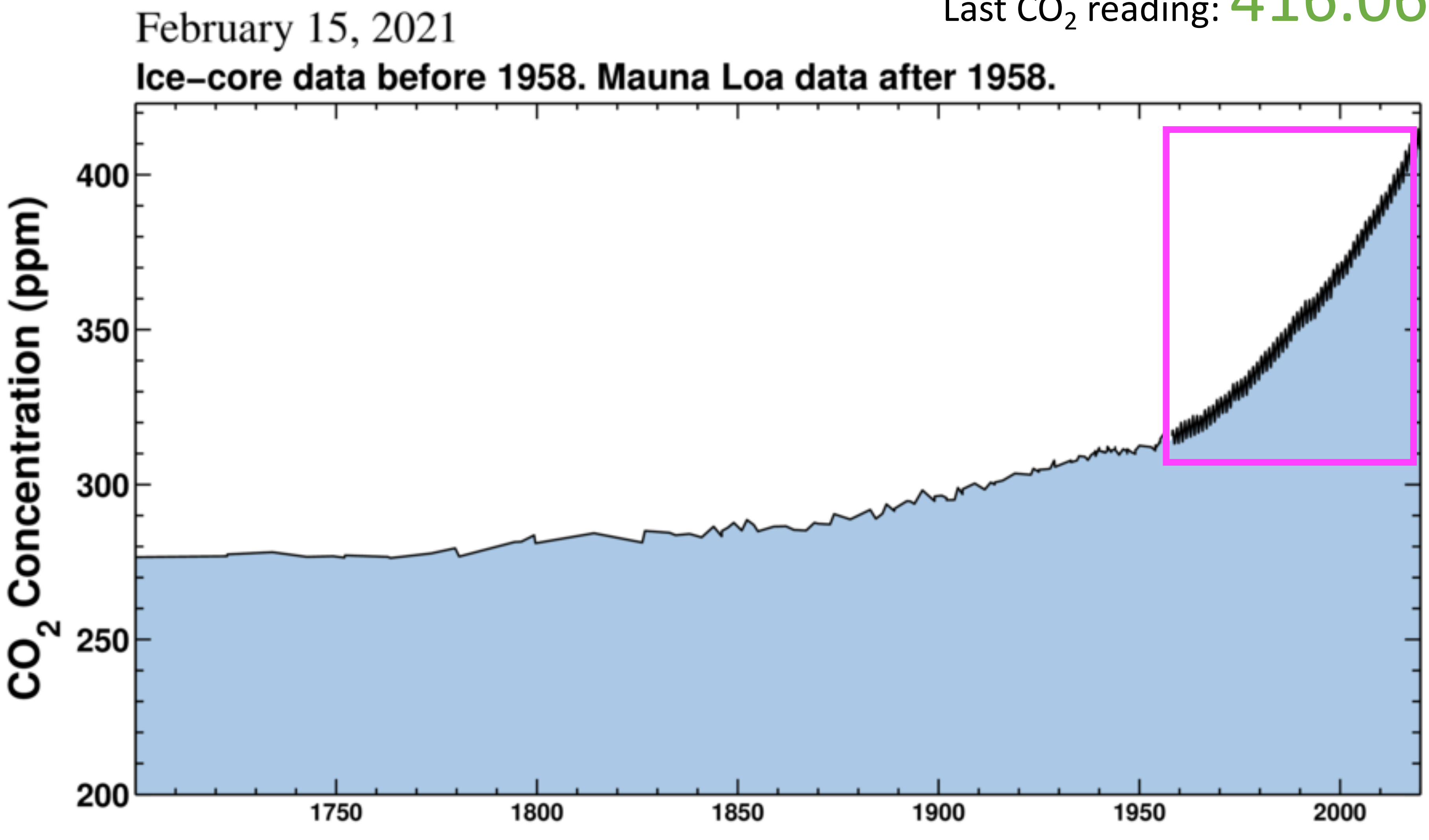
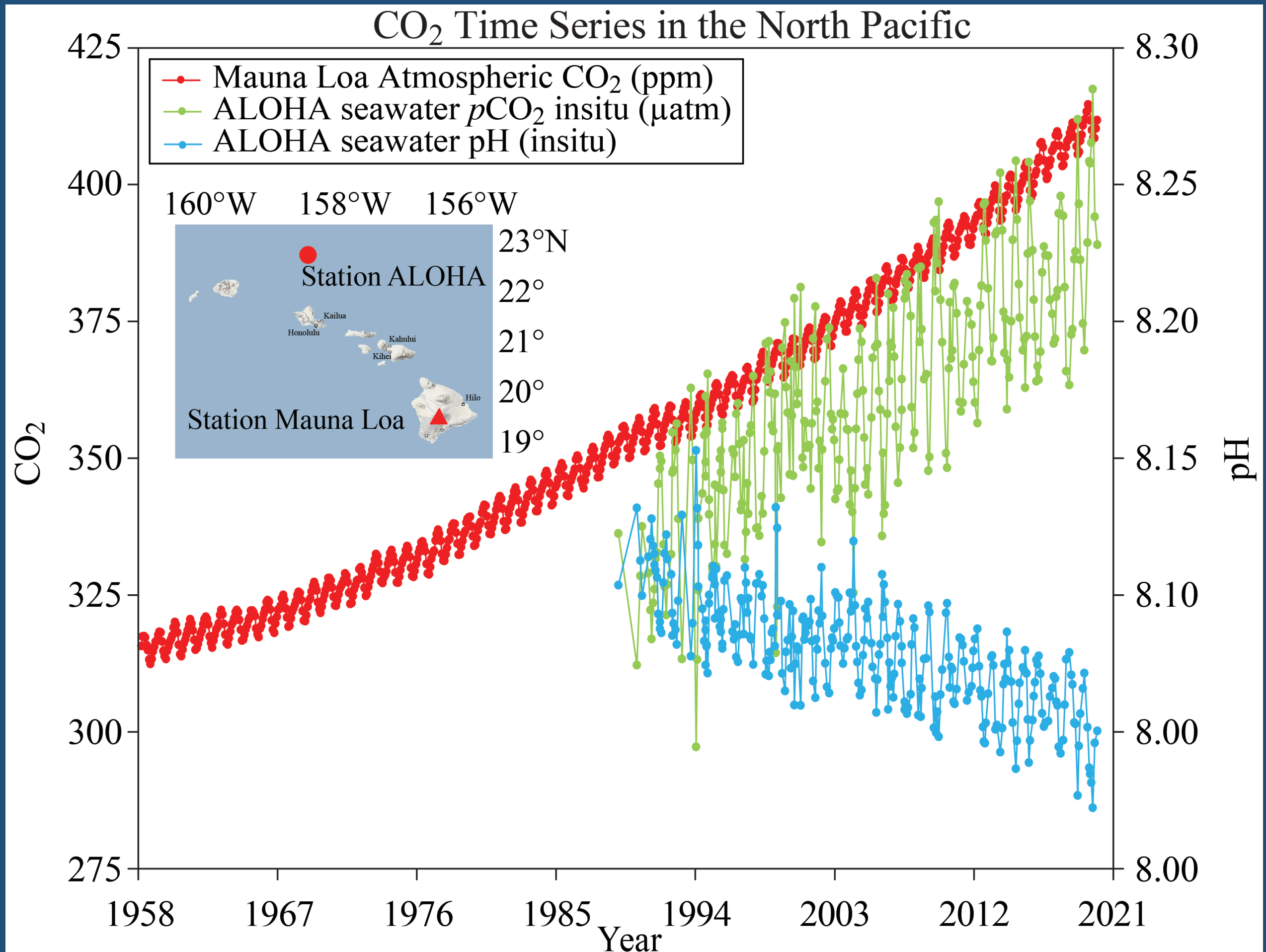


Ocean acidification: The "Other" CO_2 Problem



Data: Mauna Loa (ftp://aftp.cmdl.noaa.gov/products/trends/co2/co2_mm_mlo.txt) ALOHA (http://hahana.soest.hawaii.edu/hot/hot-dogs/bextraction.html)
ALOHA pH & pCO_2 are calculated at in-situ temperature from DIC & TA (measured from samples collected on Hawaii Ocean Times-series (HOT) cruises) using co2sys (Pelletier, v25b06) with constants: Lueker et al. 2000, KSO4: Dickson, Total boron: Lee et al. 2010, & KF: seacarb

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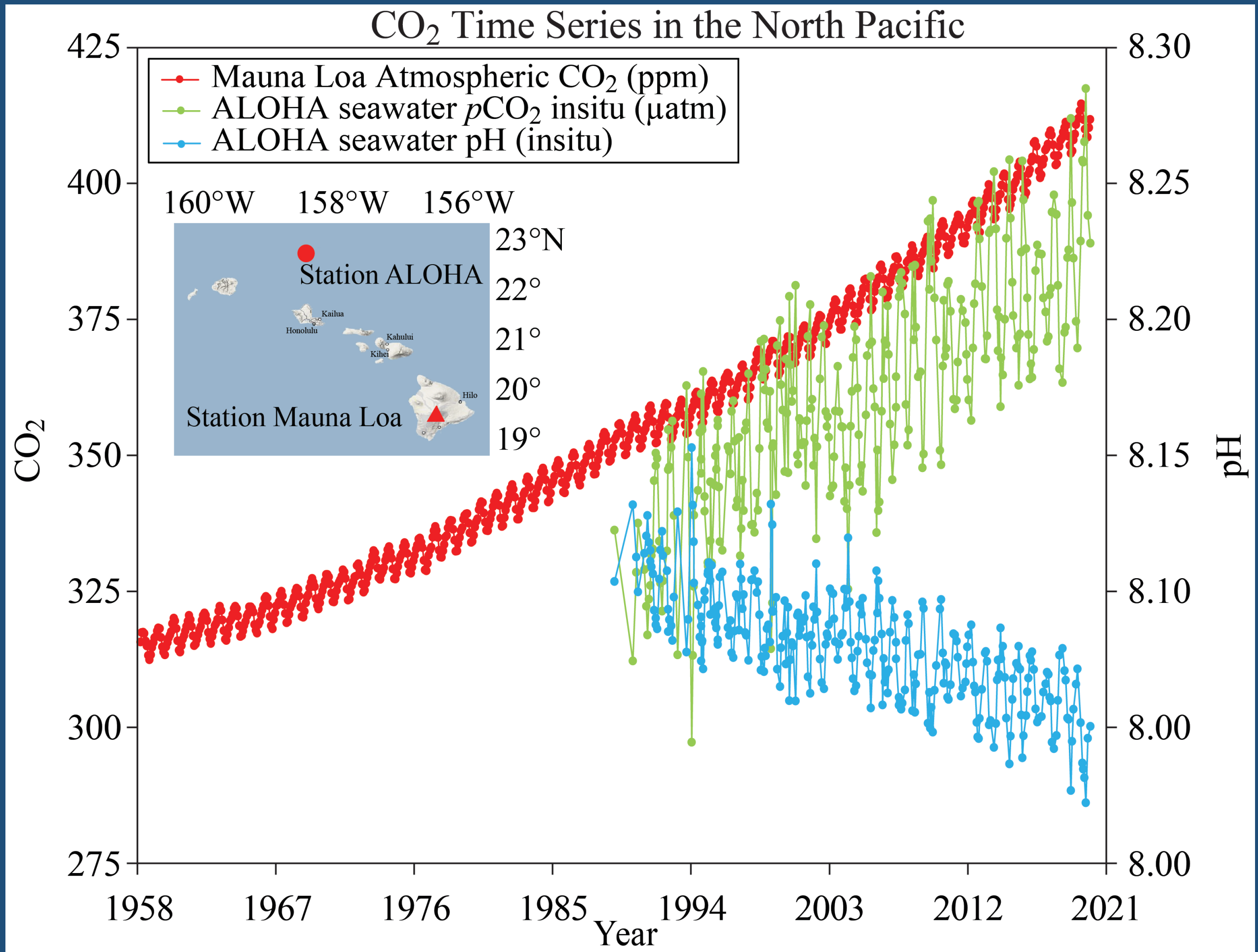

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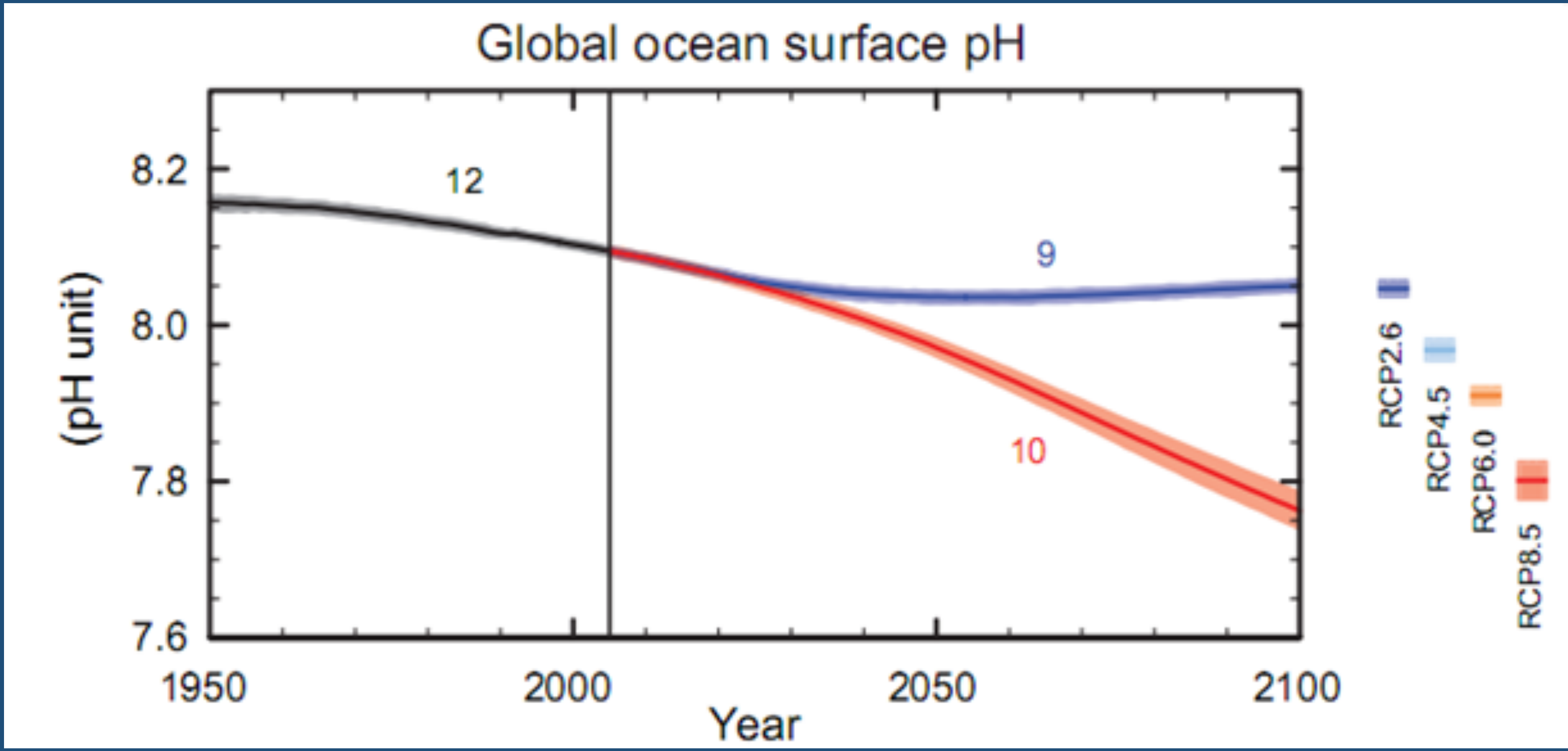
Atmospheric CO_2 has increased 40% since the 1800s

- Drop of 0.1 pH unit = 28% increase in ocean acidity
- Rate of change 10x faster than anything experienced over the past 50 million years
- Occurring globally

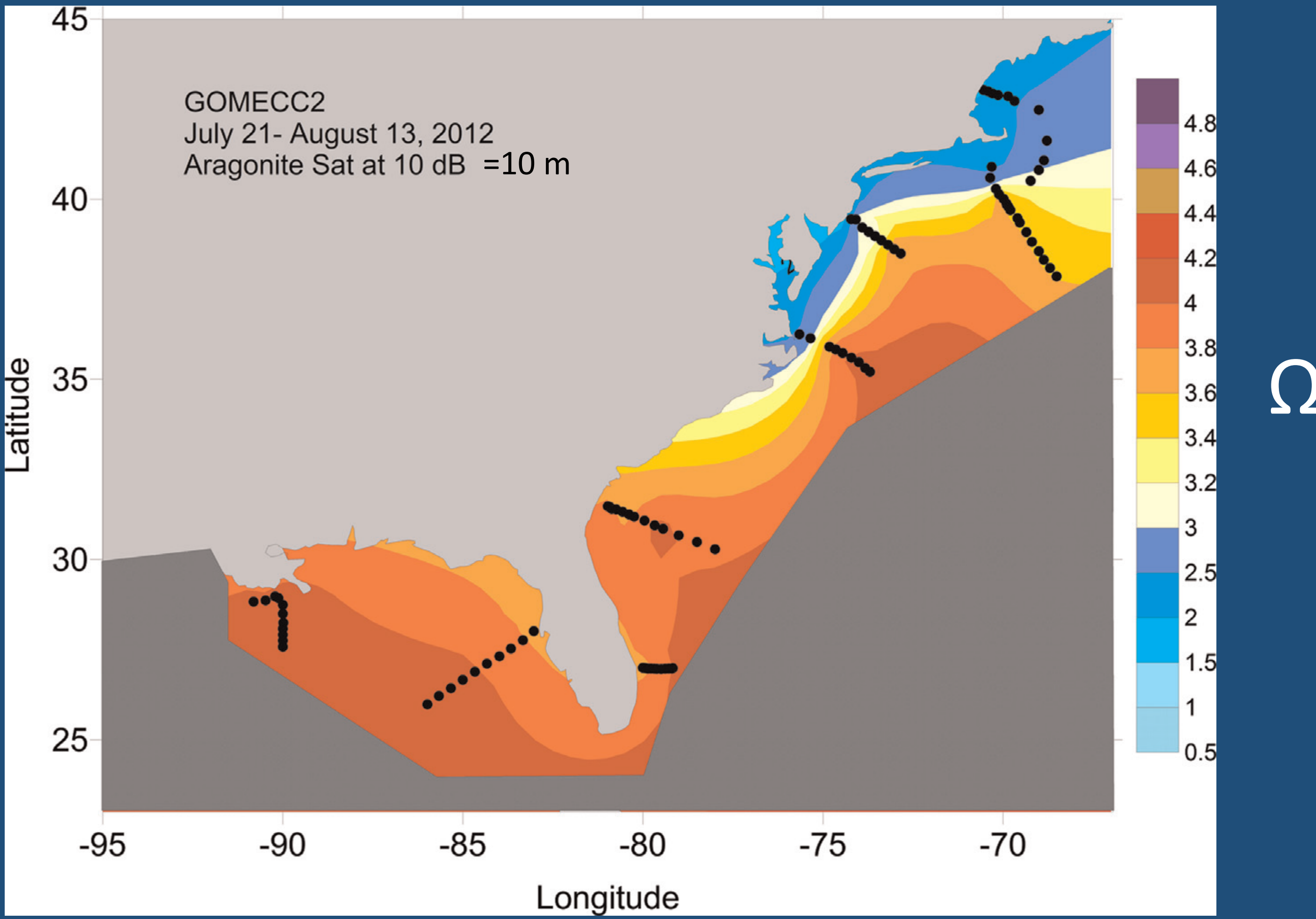
Ocean Acidification - Projections

- CO_2 is projected to double by 2100 (IPCC)
  - Additional drop of 0.2-0.3 pH units
  - Equivalent to 100-150% increase in ocean acidity



2014 IPCC Fifth Assessment Report (AR5)

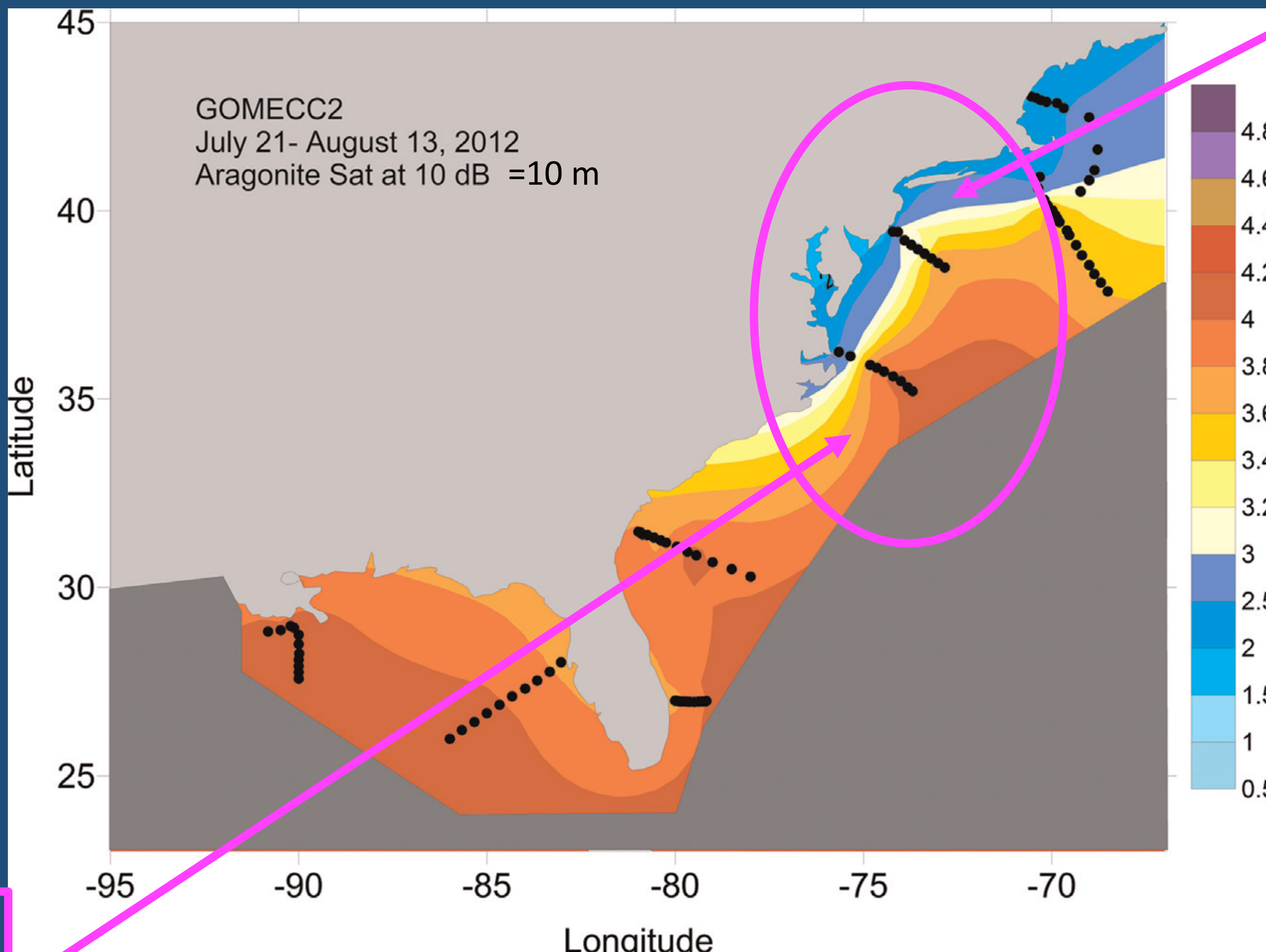
Ocean Acidification Drivers in Mid-Atlantic



Wanninkhof et al. 2015

Ocean Acidification Drivers in Mid-Atlantic

Cold, higher CO_2, weakly buffered Labrador Sea Slope Water



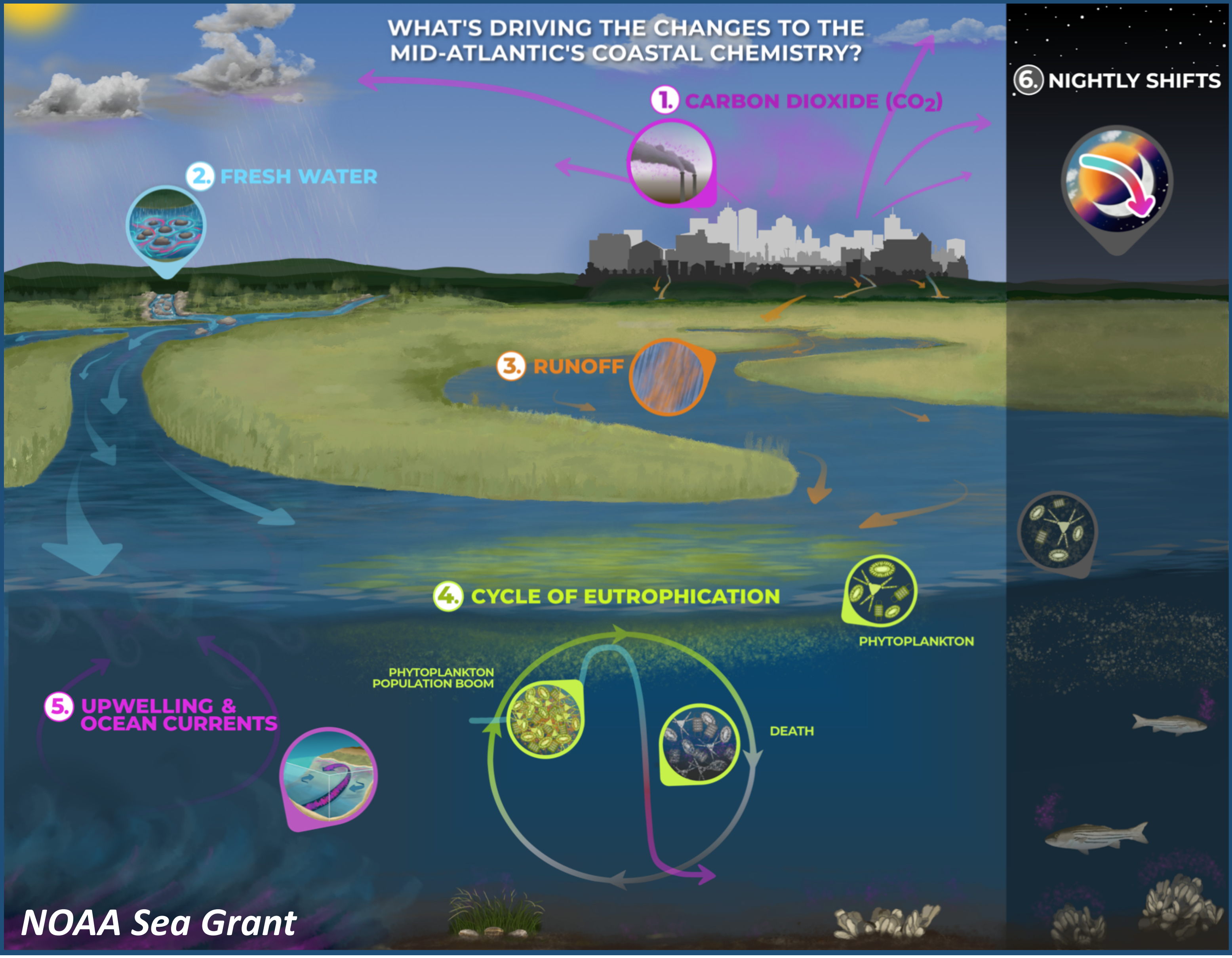
Ω

Warm, salty, well buffered Gulf Stream

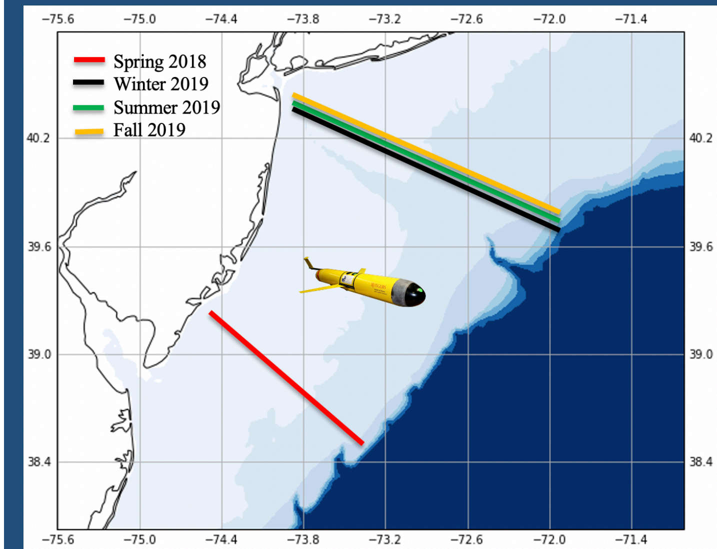
Wanninkhof et al. 2015

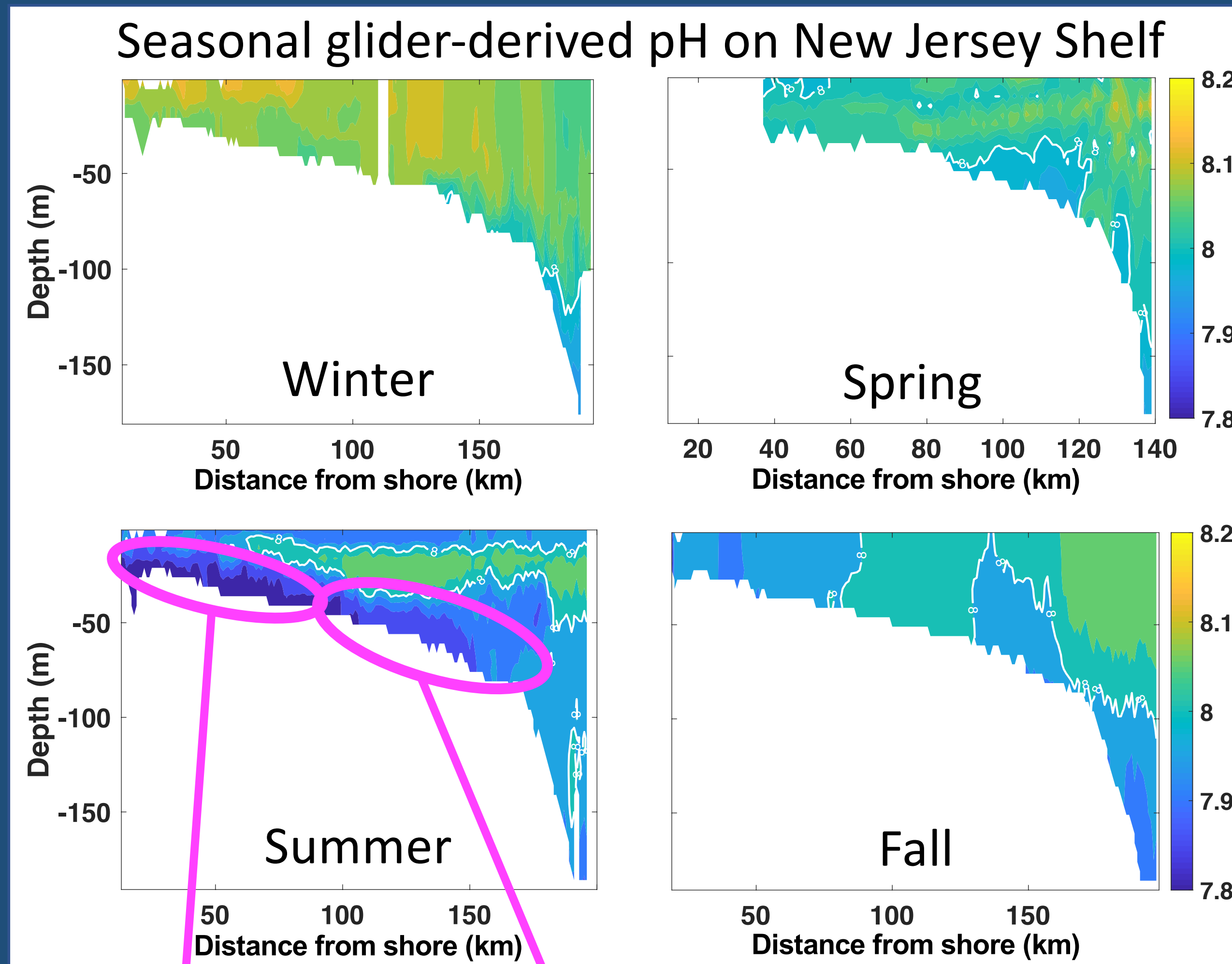
Drivers of Coastal Acidification

High variability and extremes in high CO_2/low pH due to a combination of natural and anthropogenic (human-caused) biogeochemical and physical processes



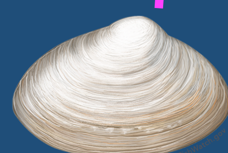
NJ Observations - Gliders



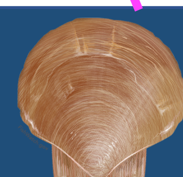


- Understand the baseline/climatology of OA conditions

- What are the seasonal conditions in known fisheries habitats?



Atlantic Surfclam
Spisula solidissima

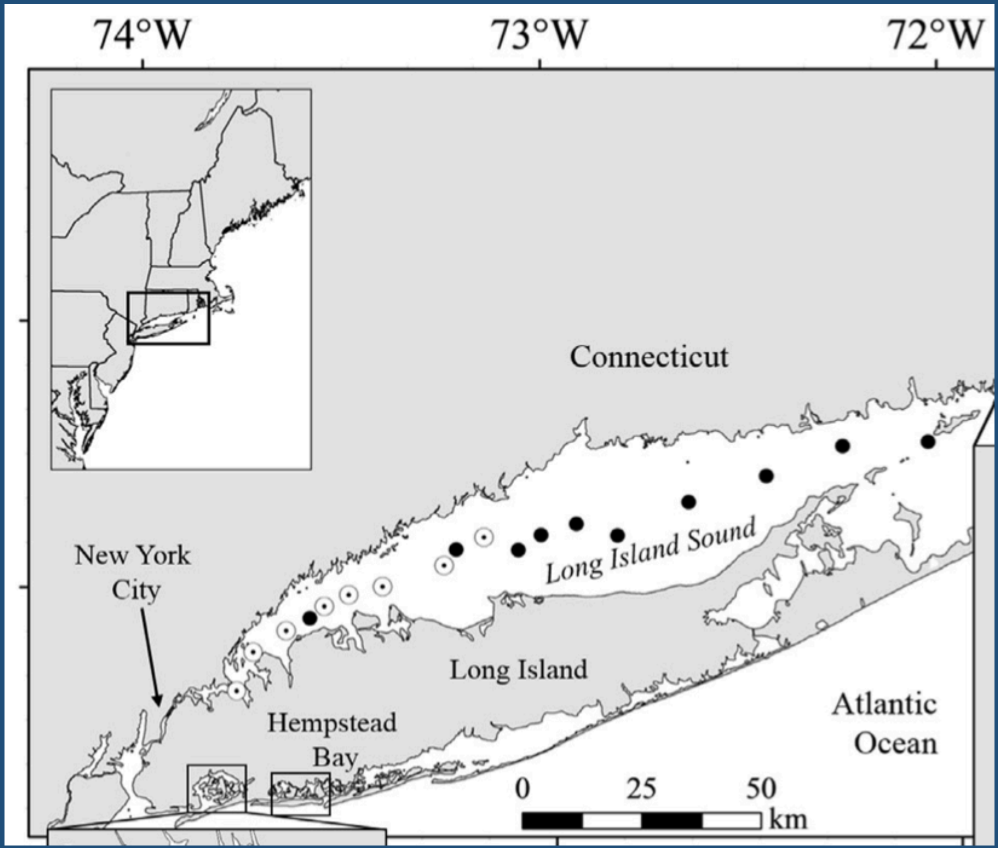


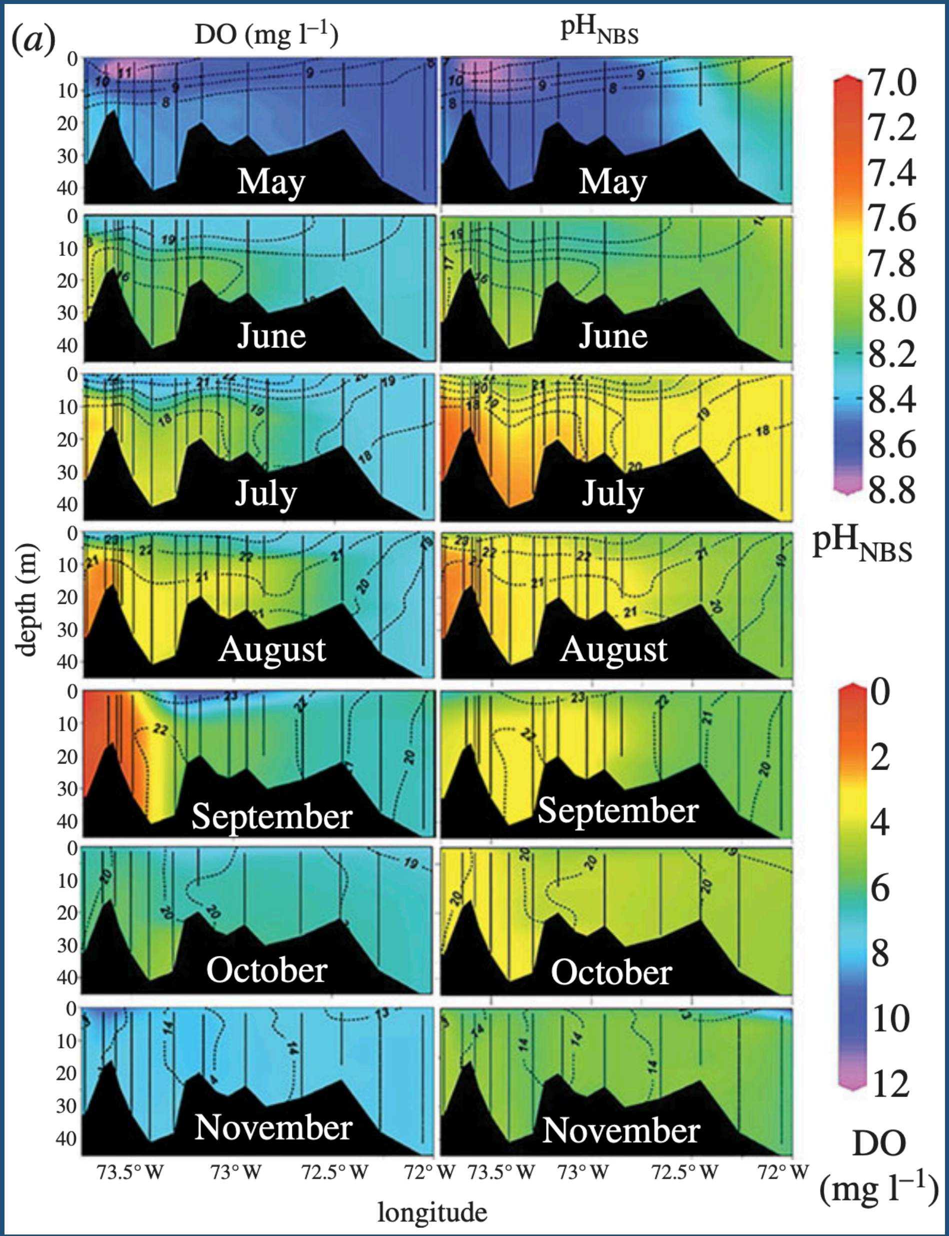
Atlantic Sea Scallop
Placopecten magellanicus

Saba et al. 2019
Wright-Fairbanks et al. 2020

Long Island Sound Observations

L-to-R = West-to-East

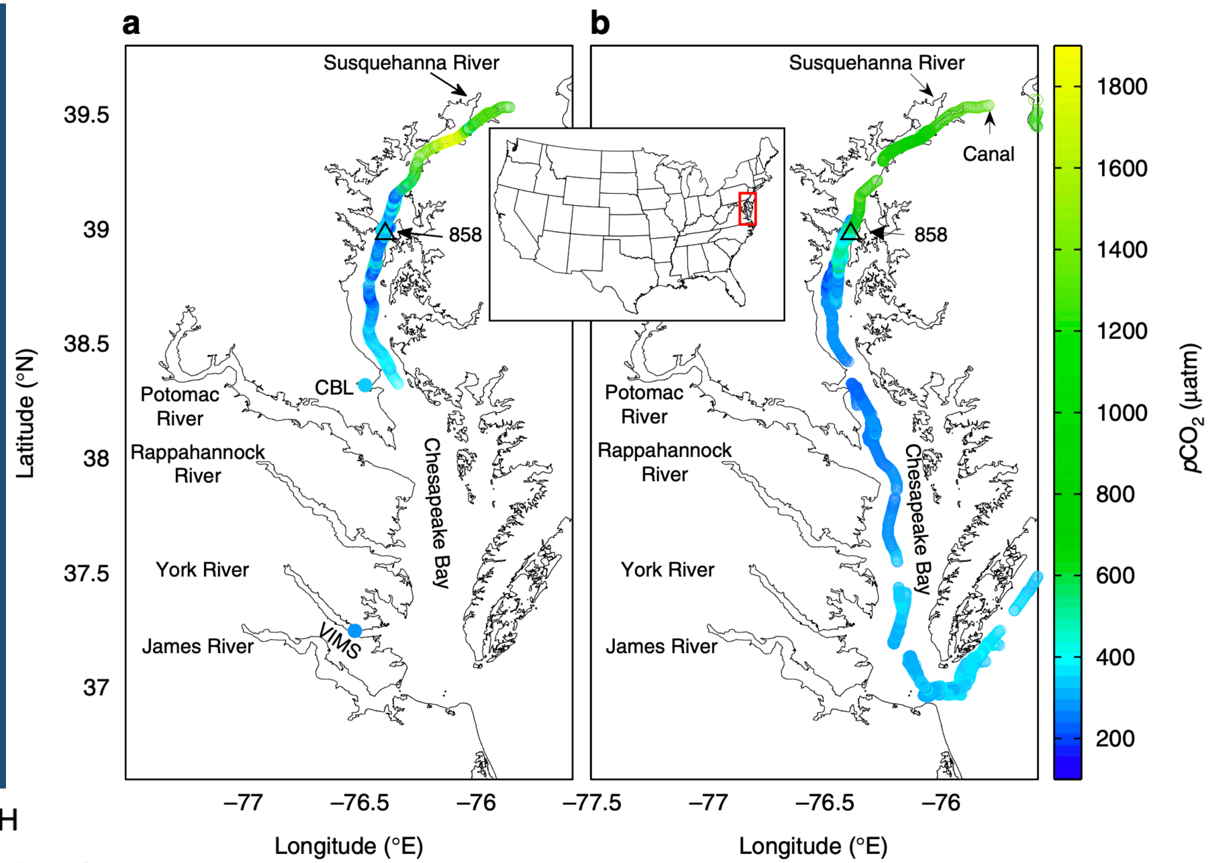


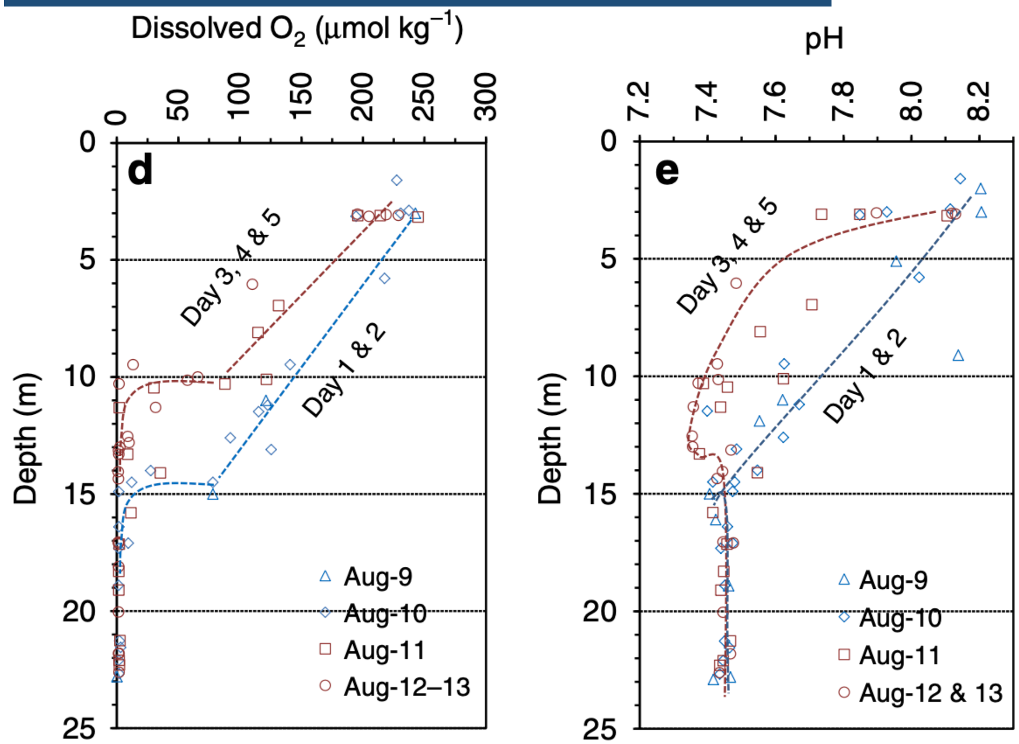


Wallace et al. 2014

Gobler & Baumann 2016

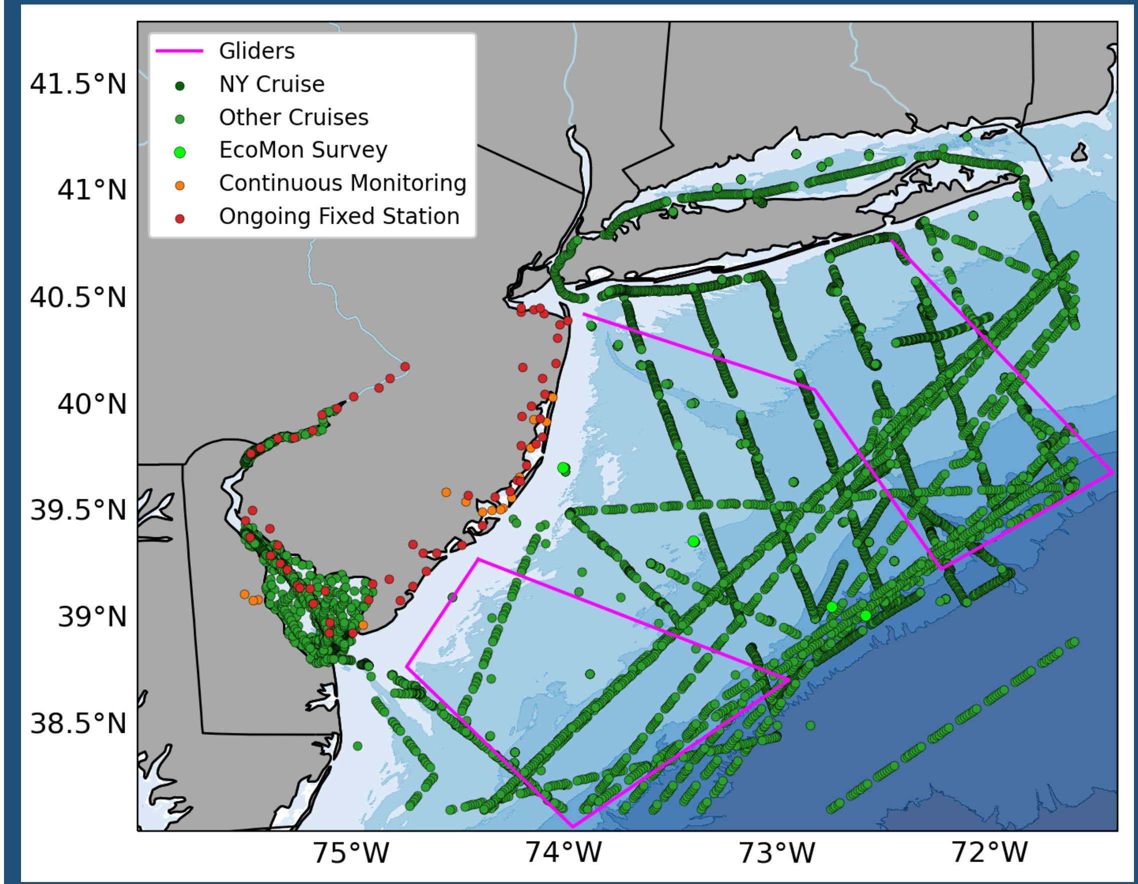
Chesapeake Bay Observations





Cai et al. 2017

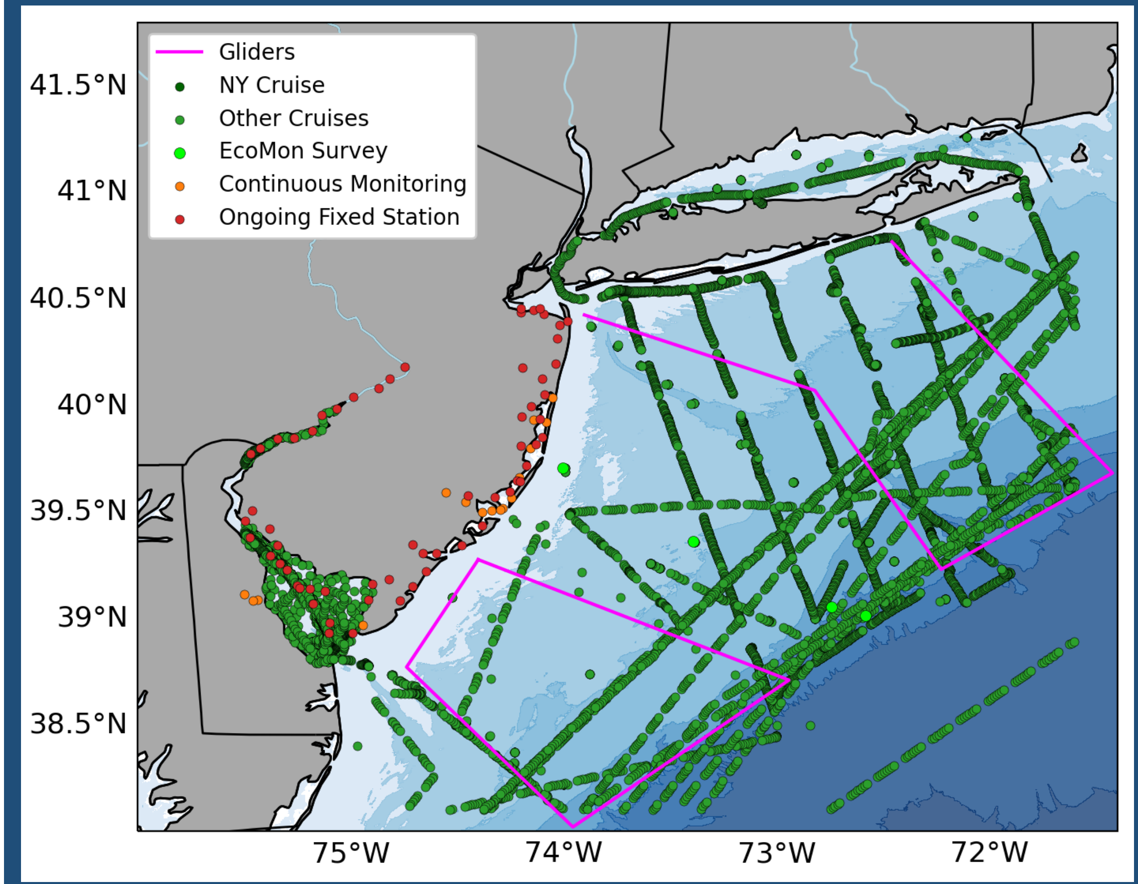
Observation Needs



- 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

Goldsmith et al., 2019

Observation Needs



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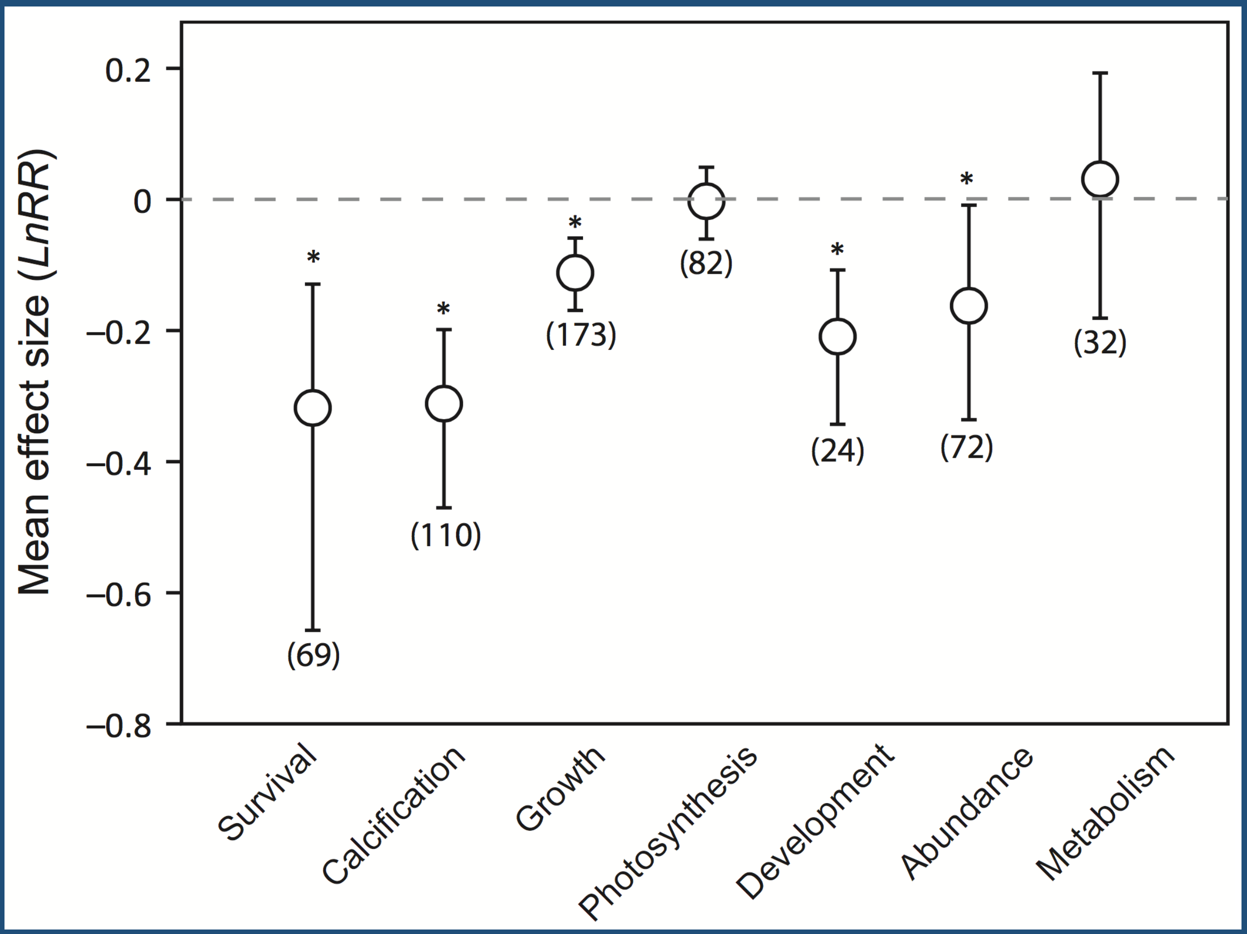
- Measurements of multiple carbonate chemistry parameters
- High-resolution depth-profiling measurements
- Monitor across a salinity gradient
- Observe OA with other stressors
- Co-located biological response monitoring

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

Goldsmith et al., 2019

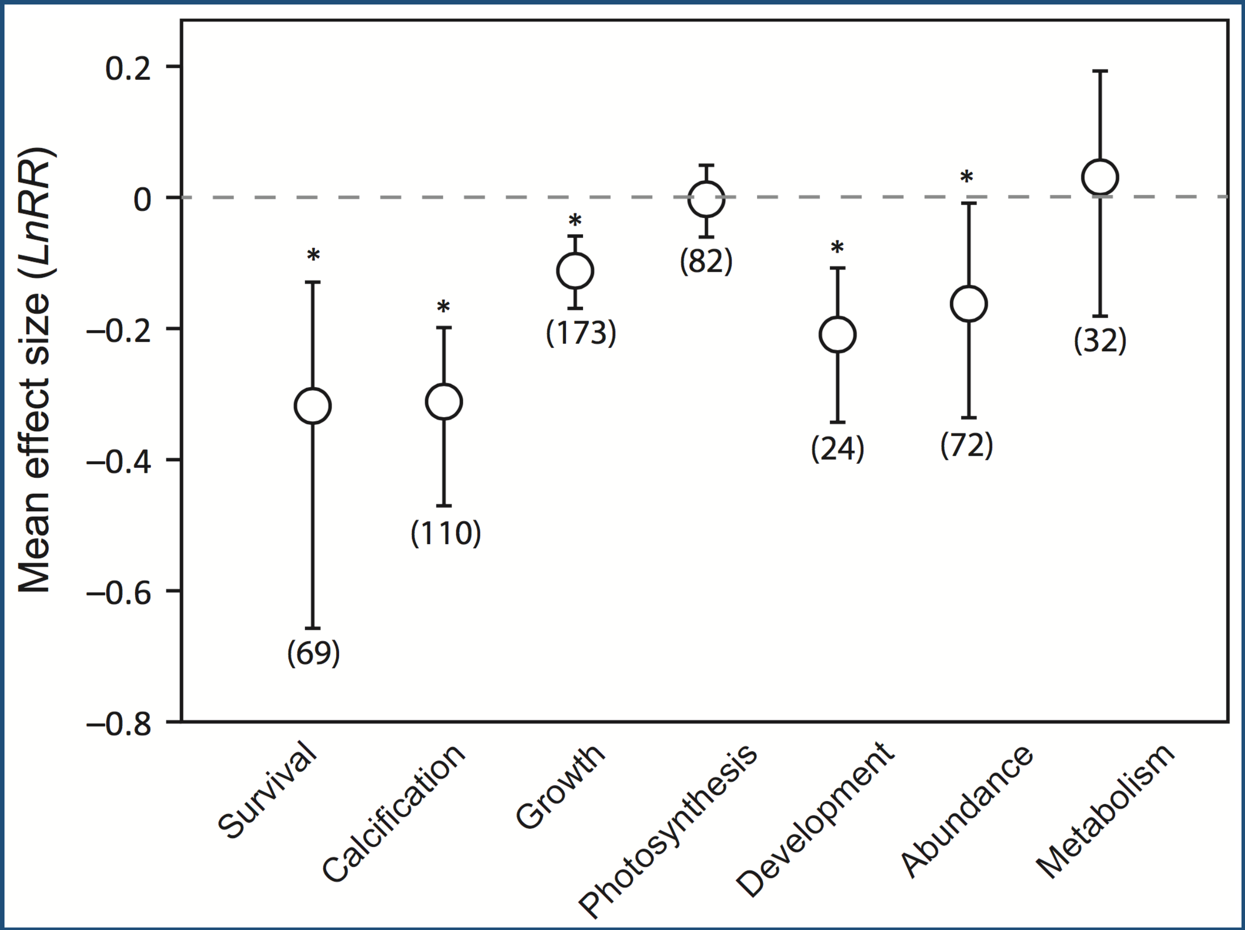
QUESTIONS?

Acidification Impacts on Organisms



Kroeker et al. 2013

Acidification Impacts on Organisms



Kroeker et al. 2013

AND……

- Reproduction
- Olfactory
- Behavior
- Swimming ability
- Susceptibility to disease

➢ Biotic interactions
➢ Biodiversity
➢ Ecosystem
➢ Acclimation???
➢ Adaptation???

Acidification Impacts on Organisms

General Takeaways:

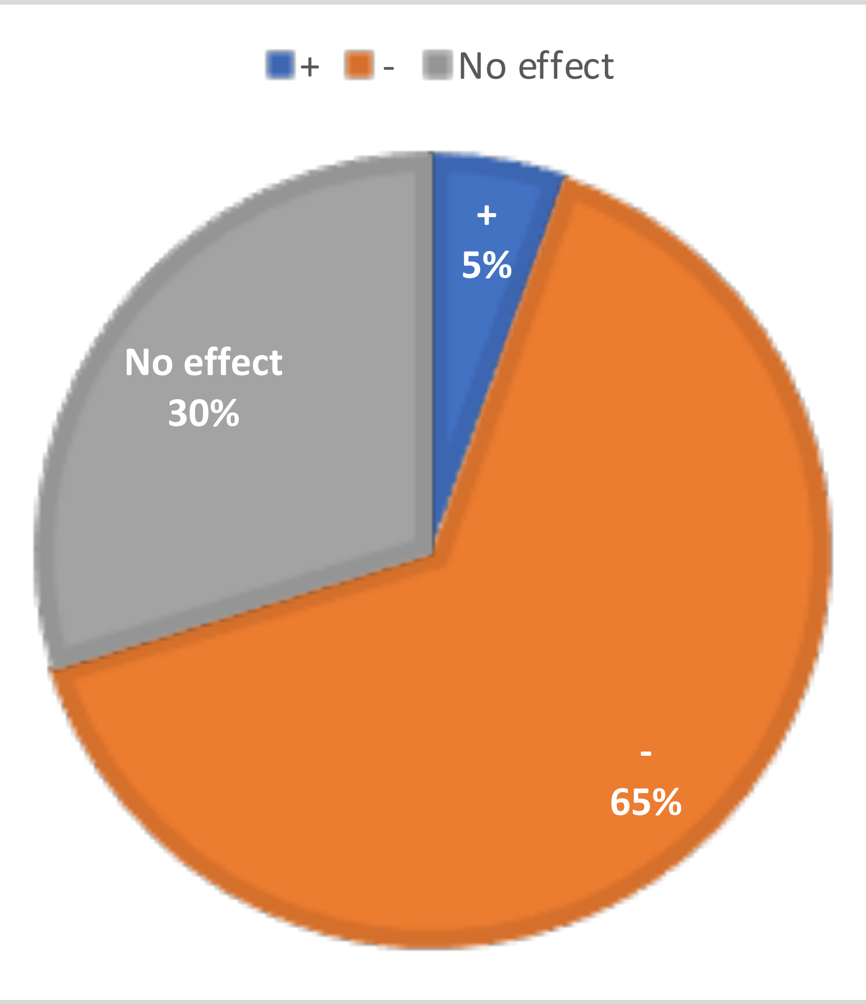
- Highly variable responses between species and even individuals
- Young life stages seem to be most susceptible
- Effects are typically subtle and even indirect
- Ocean acidification interacts with other stressors
- Food availability is very important to potential acclimation

Potential Impacts on Mid-Atlantic Species

Saba et al. 2019: Estuarine, Coastal and Shelf Science

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

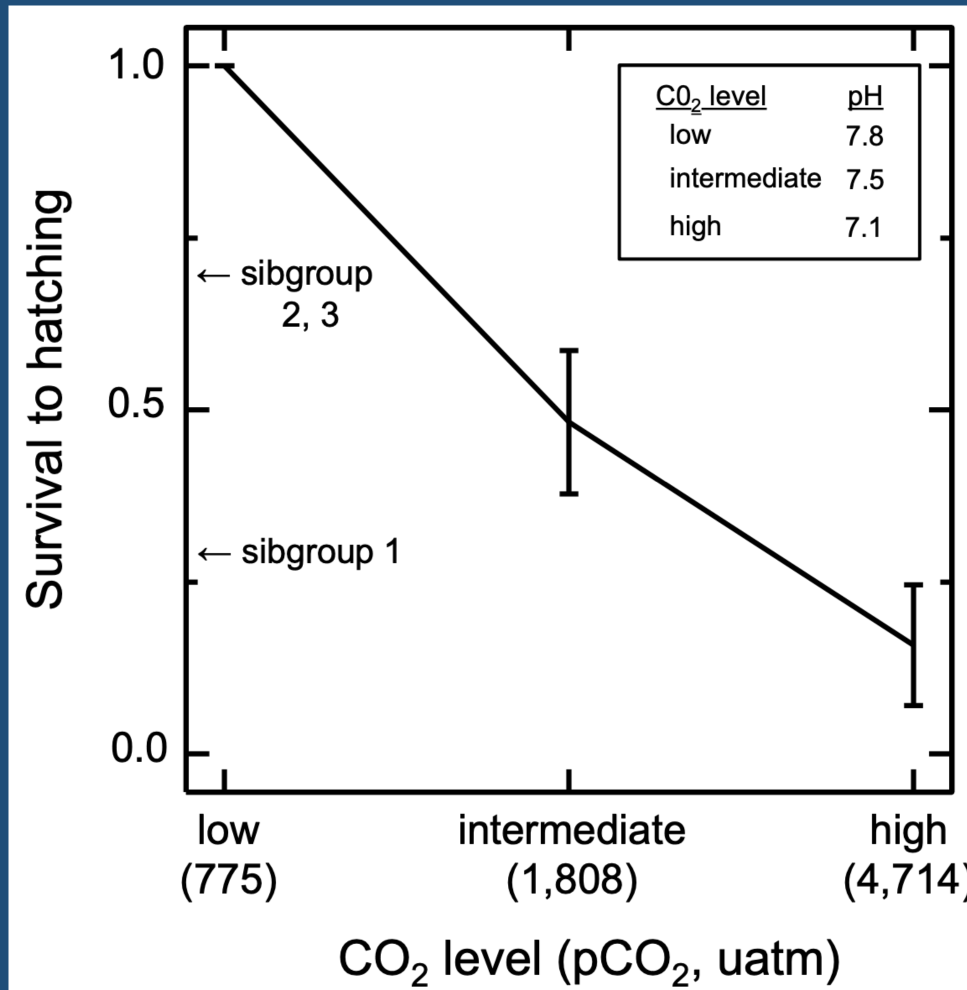
- 18 species comprising of crustaceans, mollusks, finfish and elasmobranchs (from 59 studies)
- Species managed by MAFMC, ASMFC, NEFMC, NOAA and/or States
- Wide range of response variables



Potential Impacts on Summer Flounder Larvae

Chambers et al. 2014

- At high CO_2/low pH:
  - Decreased embryo survival
  - Larvae at hatching were larger but had less energy reserves
  - Higher number and severity of tissue and organ malformations



Potential Impacts on Summer Flounder Juveniles

Davidson et al. 2016

	Normoxic		Moderate DO		Extreme DO	
	Day 0–10	Day 10–20	Day 0–10	Day 10–20	Day 0–10	Day 10–20
Static pH	4.12 (T1) 3.15 (T2) 3.79 (T3)	3.57 (T1) 3.11 (T2) 3.67 (T3)	2.87 (T3)	2.07 (T3)	3.27 (T1)	2.59 (T1)
Moderate pH	3.72 (T1)	3.67 (T1)	3.48 (T2)	3.12 (T2)	2.25 (T1)	2.42 (T1)
Extreme pH	4.04 (T1)	2.97 (T1)	3.11 (T3)	2.09 (T3)	2.04 (T2)	2.26 (T2)

- Mean specific growth rates:
  - Were lower after longer exposure in all treatment conditions
  - Were lowest at extreme DO and pH, but driven more by DO
    - High mortality experienced at longer exposure to these extreme

Potential Impacts on Striped Bass

Acidification effects on larval striped bass, *Morone saxatilis* in Chesapeake Bay tributaries: A review

Lenwood W. Hall Jr.

Water, Air, and Soil Pollution **35**, 87–96(1987) | Cite this article

*Reductions in striped bass populations in the 70s/80s were linked to ***larval*** mortality from acidified conditions in tributaries of the Chesapeake Bay, but other stressors were also likely important.

*No effect of pH on survival of ***juvenile*** striped bass, even at extreme low levels of dissolved oxygen and pH

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Contents lists available at ScienceDirect

Journal of Experimental Marine Biology and Ecology

journal homepage: www.elsevier.com/locate/jembe

Responses of juvenile Atlantic silverside, striped killifish, mummichog, and striped bass to acute hypoxia and acidification: Aquatic surface respiration and survival

Rachel L. Dixon[a,*,1], Paul A. Grecay[b], Timothy E. Targett[a]

Significant Research Gaps

Group	Common name	Scientific name
Molluscs	Atlantic surfclam[a]	*Spisula solidissima*
	Illex squid[a]	*Illex illecebrosus*
Crustaceans	Atlantic deep-sea red crab[c]	*Chaceon quinquedens*
	Horseshoe crab[b]	*Limulus polyphemus*
	Jonah crab[b]	*Cancer borealis*
Finfishes	American eel[b]	*Anguilla rostrata*
	Atlantic croaker[b]	*Micropogonias undulatus*
	Atlantic mackerel[a]	*Scomber scombrus*
	Atlantic menhaden[b]	*Brevoortia tyrannus*
	Atlantic Sturgeon[b]	*Acipenser oxyrinchus*
	Black drum[b]	*Pogonias cromis*
	Black sea bass[a,b]	*Centropristis striata*
	Bluefish[a,b]	*Pomatomus saltatrix*
	Butterfish[a]	*Peprilus triacanthus*
	Monkfish[a]	*Lophius americanus*
	Offshore hake[c]	*Merluccius albidus*
	Red hake[c]	*Urophycis chuss*
	River herring[b]	*Alosa pseudoharengus, Alosa aestivalis*
	Shad[b]	*Alosa sapidissima*
	Silver hake[c]	*Merluccius bilinearis*
	Spanish mackerel[b]	*Scomberomorus maculatus*
	Spot[b]	*Leiostomus xanthurus*
	Spotted seatrout[b]	*Cynoscion nebulosus*
	Tautog[b]	*Tautoga onitis*
	Golden tilefish[a]	*Lopholatilus chamaelonticeps*
	Blueline tilefish[a]	*Caulolatilus microps*
	Winter flounder[b]	*Pseudopleuronectes americanus*
Elasmobranchs	Spiny dogfish[a,b]	*Squalus acanthias*
	Winter skate[c]	*Leucoraja ocellata*

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

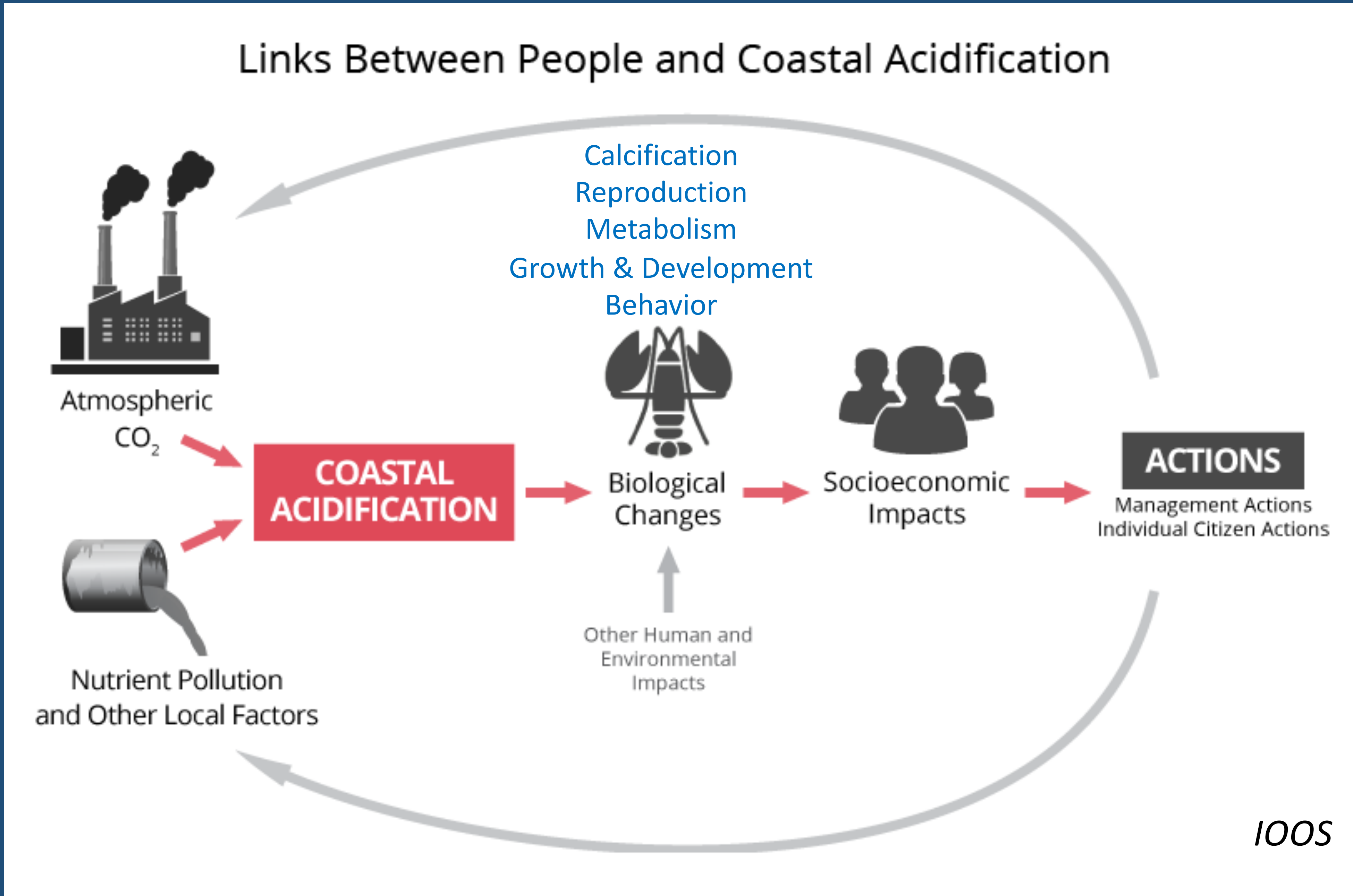
Significant Research Needs

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

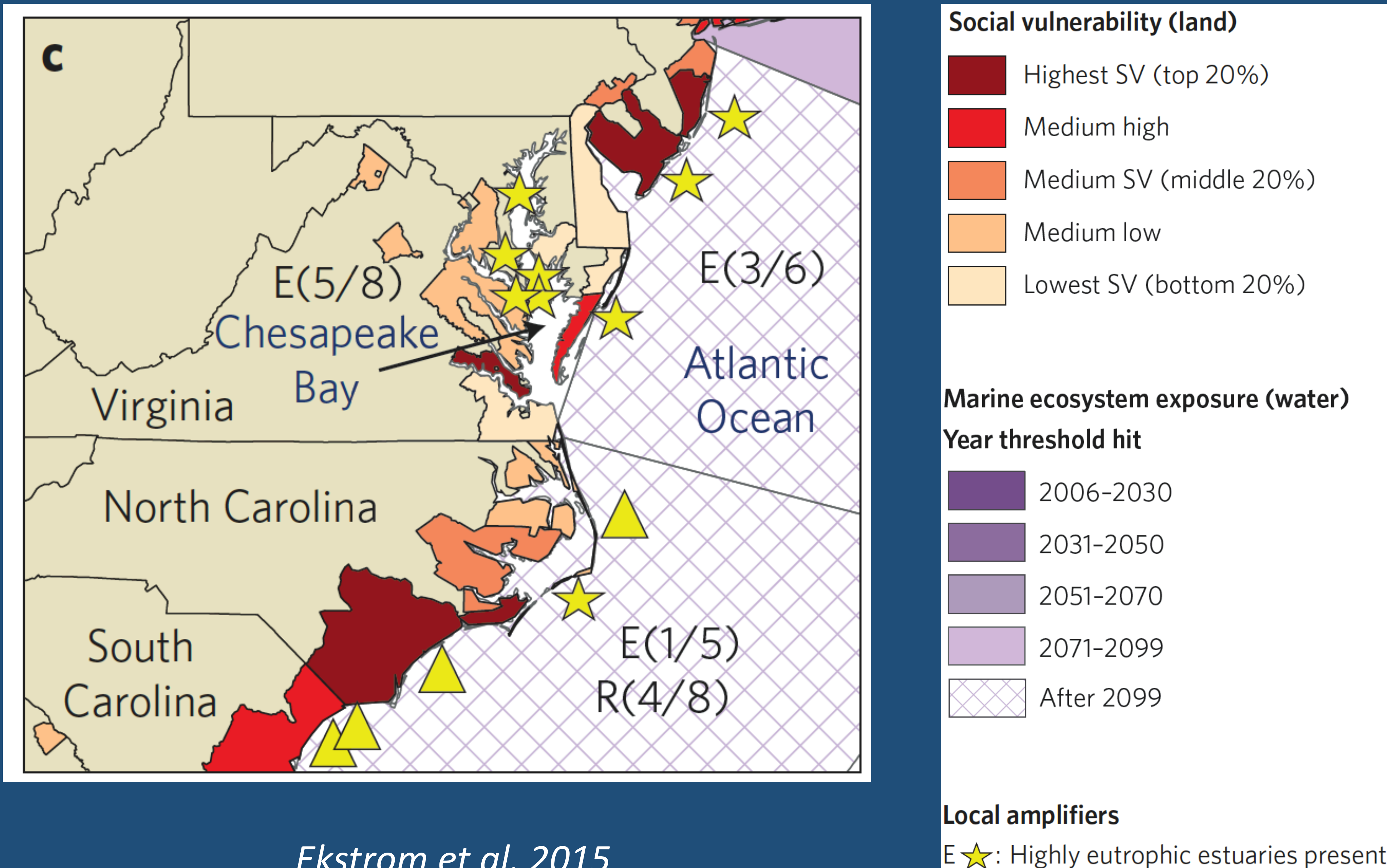
- The potential impacts to various life stages
- Acclimation and adaptation potential
- Potential thresholds of acidification
- Impacts on the food web, populations dynamics, and community structure

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

Connect organism and ecosystem responses to ecosystem services and the economy


Links Between People and Coastal Acidification
Calcification
Reproduction
Metabolism
Growth & Development
Behavior
Atmospheric CO_2
COASTAL ACIDIFICATION
Biological Changes
Socioeconomic Impacts
ACTIONS
Management Actions
Individual Citizen Actions
Nutrient Pollution and Other Local Factors
Other Human and Environmental Impacts
IOOS

High Regional Social Vulnerability



Ekstrom et al. 2015

Associated Economic Risks

- 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.

	2011	2012	2013	2014	2015
Total Revenue	$552,315,000	$510,297,000	$435,977,000	$476,778,000	$512,081,000
Finfish & Other	$119,630,000	$130,357,000	$124,379,000	$119,146,000	$116,461,000
Shellfish	$432,685,000	$379,941,000	$311,598,000	$357,633,000	$395,620,000

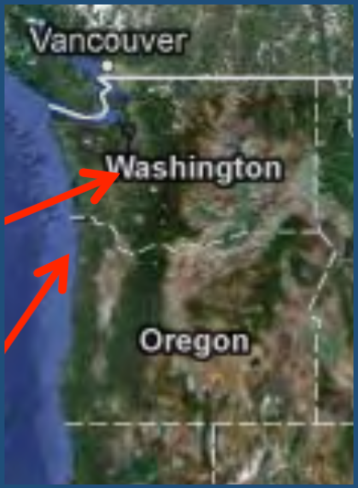
Total Landings Revenue in the Mid-Atlantic (National Marine Fisheries Service 2017)

- Marine resources in the Mid-Atlantic have ecological, economical, social, and cultural significance

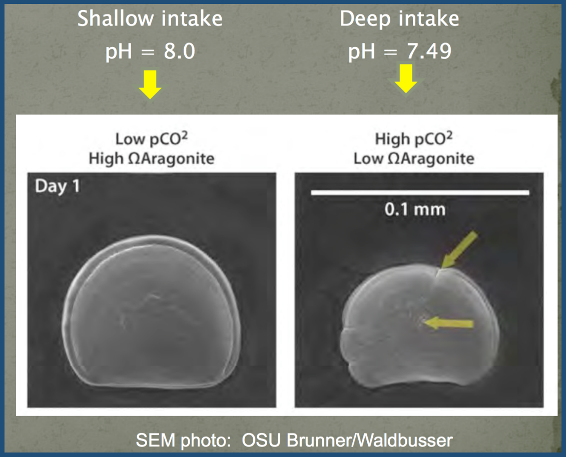
- New Jersey's commercial fishing industry is the fifth largest in the United States and provides more than 50,000 jobs

- Economic scenario analyses and vulnerability assessments starting to include acidification

Industry Need Leads to Policy Actions



80% decrease in oyster production in 2008/2009 linked to ocean acidification



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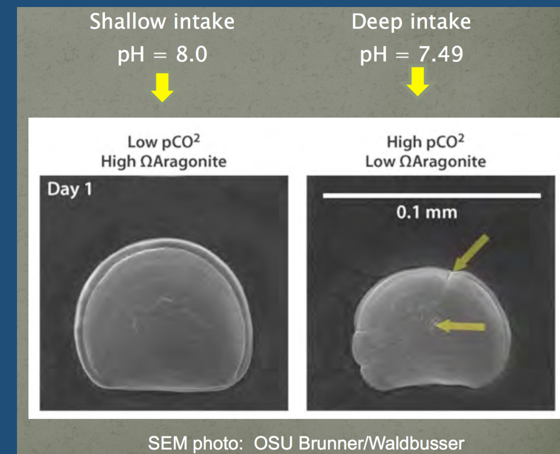


Ocean Acidification Blue Ribbon Panel

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

KENNETH P. LAVALLE December 12, 2016 | ISSUE: CLEAN WATER

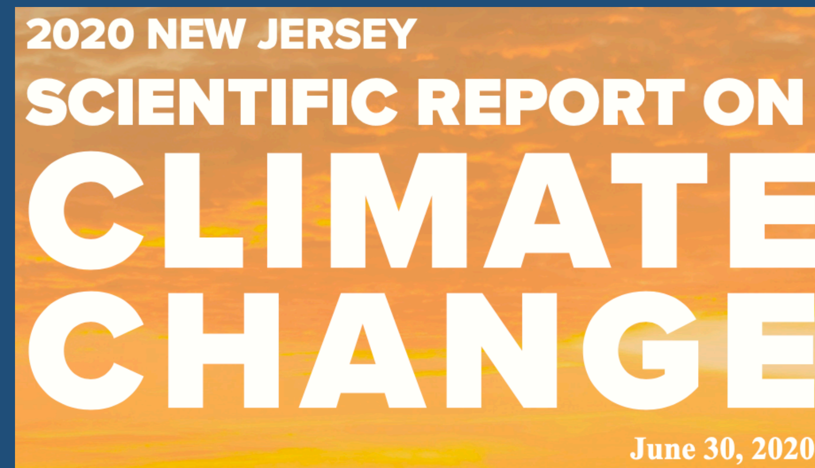
- Many states join OA Alliance (International Alliance to Combat OA)
- Bipartisan support for 4 OA bills currently in House committee
- Regional Acidification Networks established (e.g., MACAN)

U.S. Member States in the International OA Alliance

California
Hawaii
Maine
Maryland
New York
Oregon
Virginia
Washington

NJDEP Recognizes OA Risks

- *Discussion of OA in their 2020 NJ Scientific Report on Climate Change*
- *In response to the 2020 NJ Global Warming Response Act 80x50 Report:*
    - ➢ The New Jersey Office of Policy and Coastal Management in partnership with the Bureau of Climate Resilience Planning and the Bureau of Marine Water Monitoring within NJDEP seeks to plan a broader statewide initiative to incorporate science- informed policies and programs associated with OA nested within the agency's overall climate change efforts.



How Can You Help?

Reduce nutrient runoff by decreasing fertilizer usage on lawns and gardens and adding native vegetative buffers.

Save electricity: Switch to LED light bulbs and use Energy Star devices and appliances.

Talk about it! Teach your friends and family about acidification and how they can help.

Take advantage of mass transit options in your area to decrease emissions.

50
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DEPARTMENT OF ENVIRONMENTAL PROTECTION

NSF

OAP
NOAA OCEAN ACIDIFICATION PROGRAM

MACAN

MARCO
MID-ATLANTIC REGIONAL COUNCIL ON THE OCEAN

IOOS | Integrated Ocean Observing System

MARACOOS
Ocean Information for a Changing World