Is Ocean Acidification affecting Quahog Abundance in Narragansett Bay?

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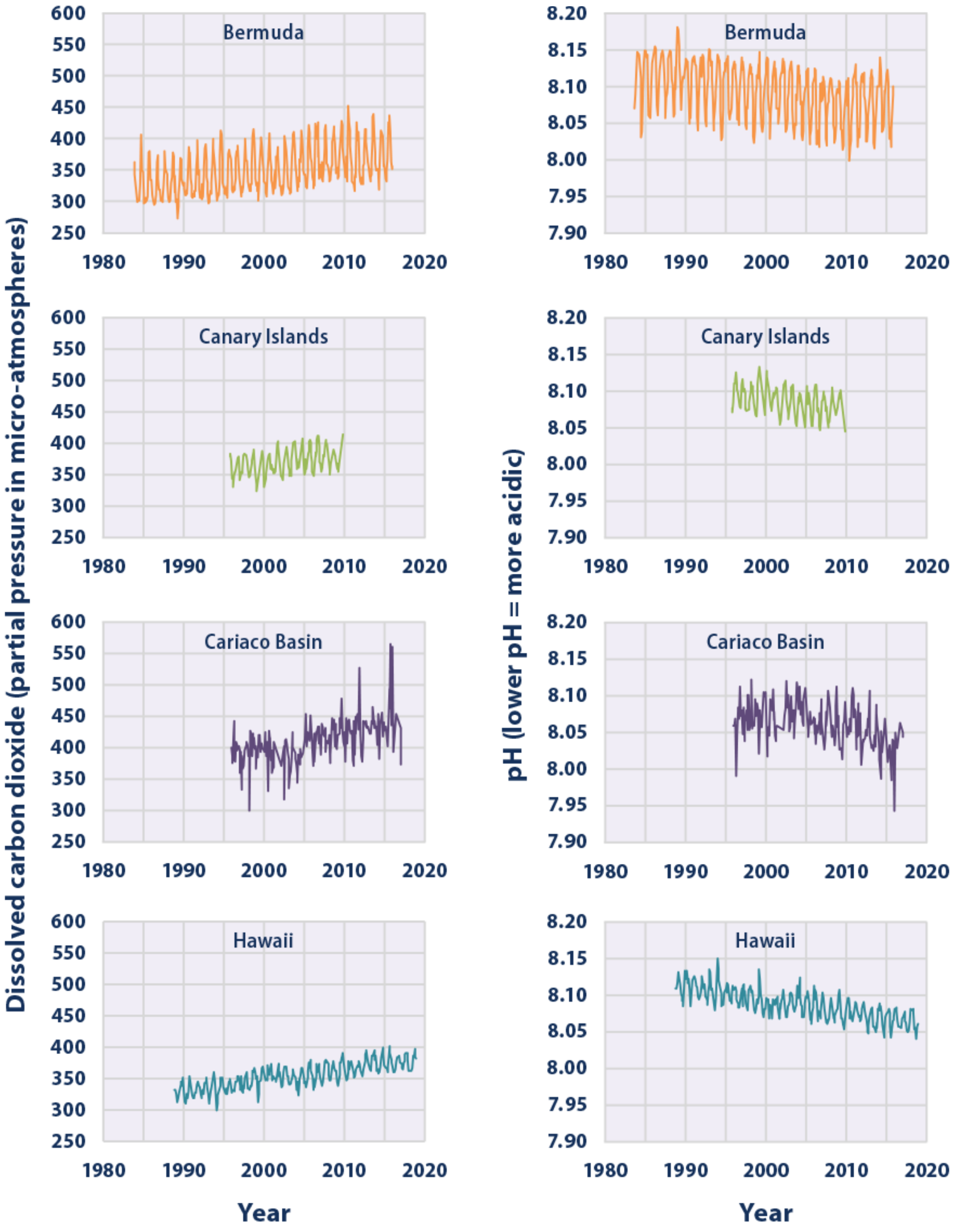
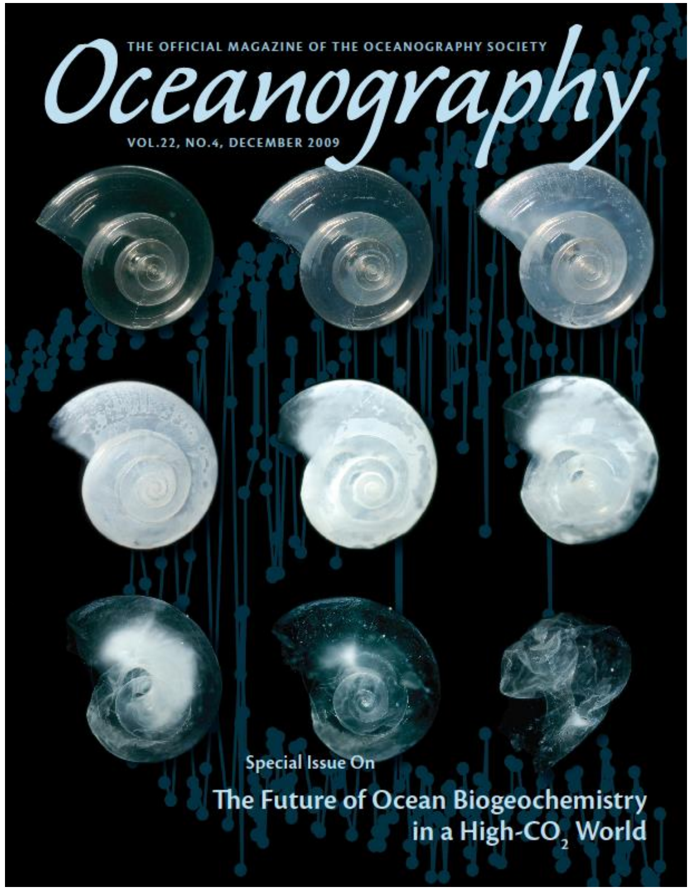
Ocean CO2 | Ocean pH

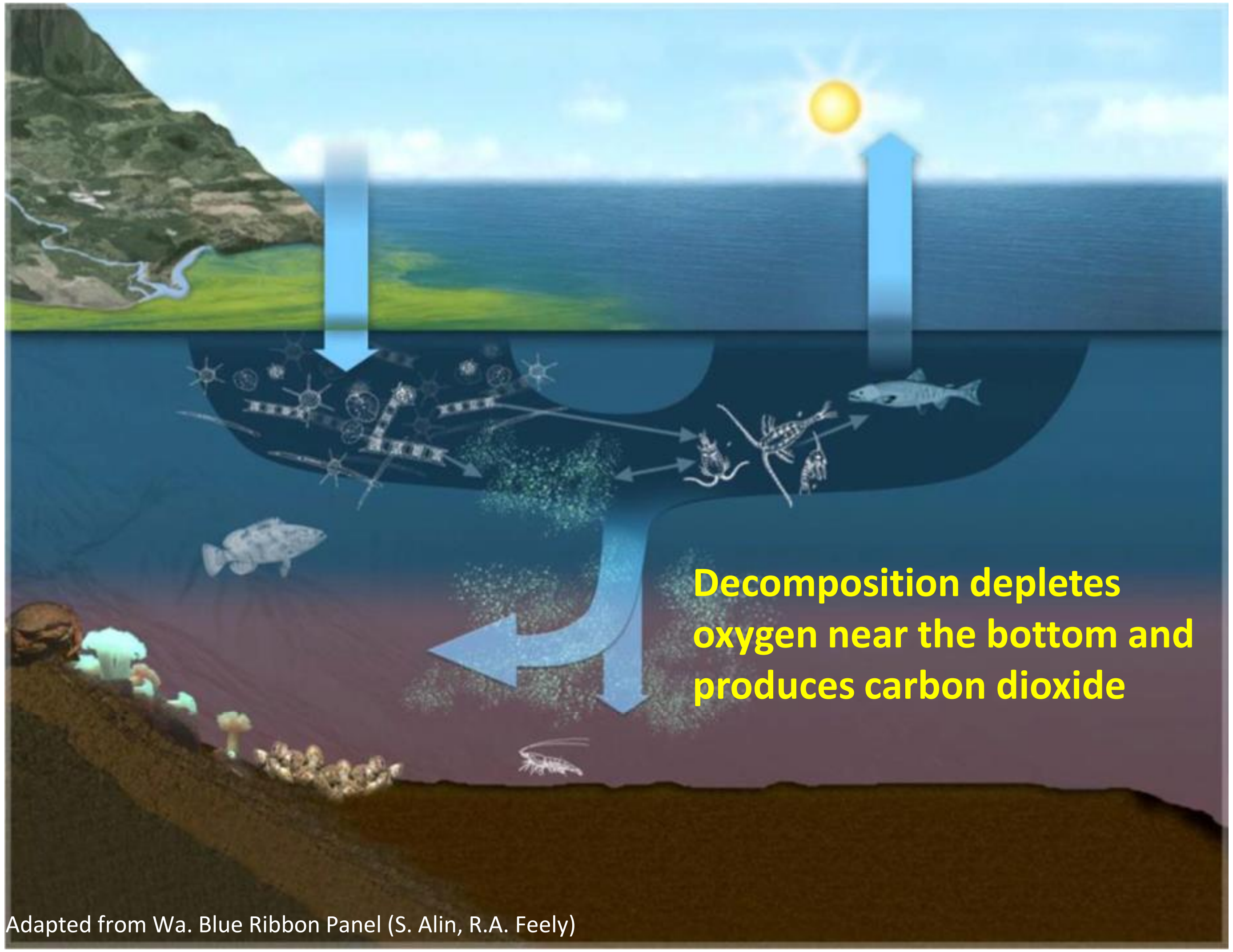


Ocean acidification refers to changes in ocean chemistry, including pH, that occur when carbon dioxide (CO_2) is absorbed by the oceans.



Pelagic snail shell dissolution under carbon dioxide conditions predicted for 2100[1]

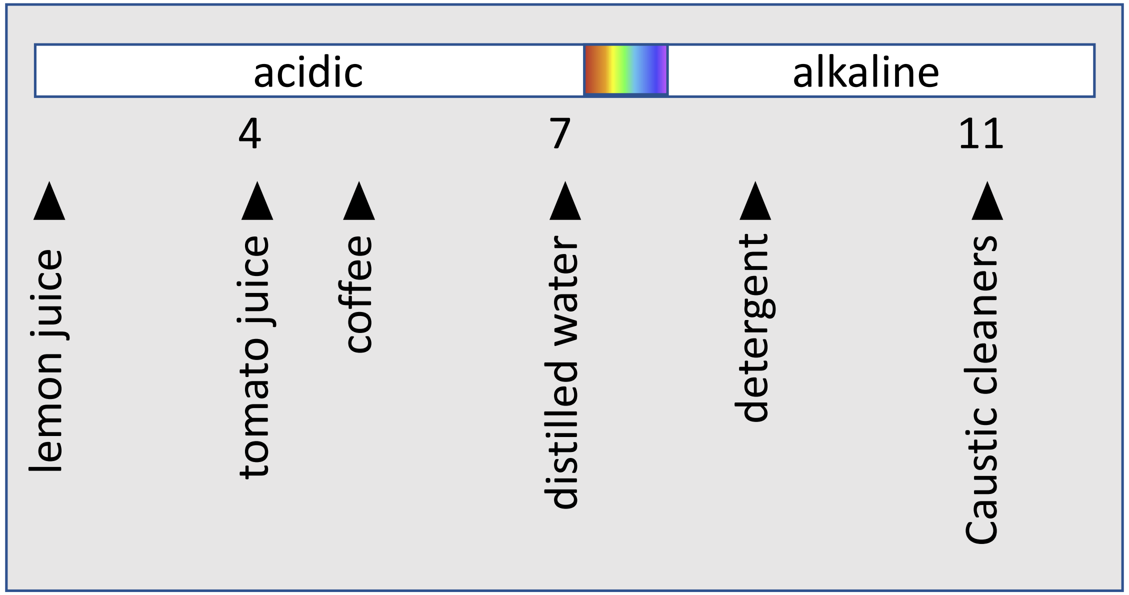
[1]Sources, notes, and credits for each slide are at the end of the presentation



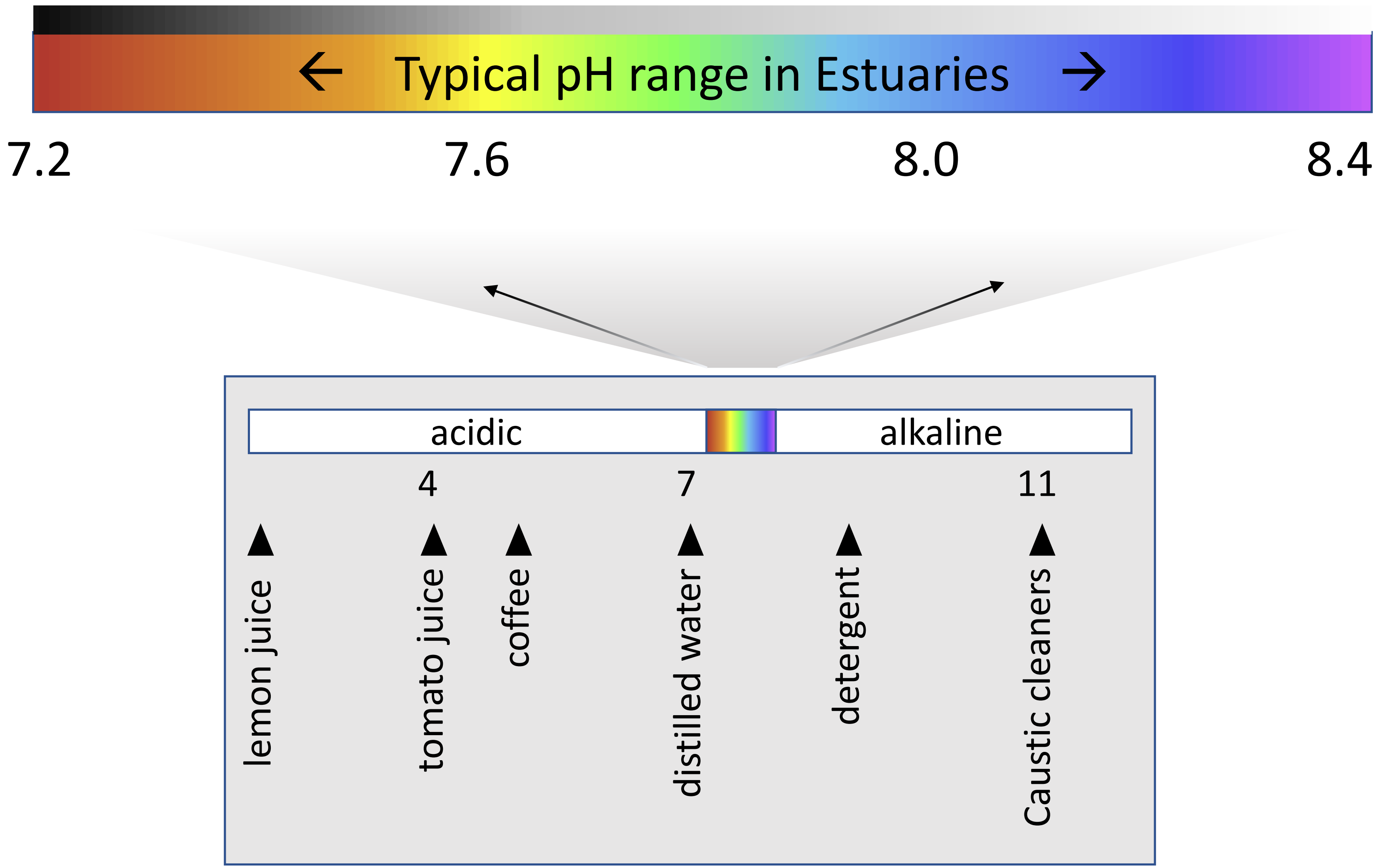
But.....

- In coastal environments, acidification is not just from CO_2 in the atmosphere
- Addition of CO_2 from microbial respiration also causes acidification, so coastal acidification usually co-occurs with hypoxia.
- In our region, local respiratory CO_2 and precipitation make estuaries more sensitive to the influx of CO_2 from the ocean
- Seasonal acidification lasts longer than hypoxia due to the reaction of CO_2 with seawater

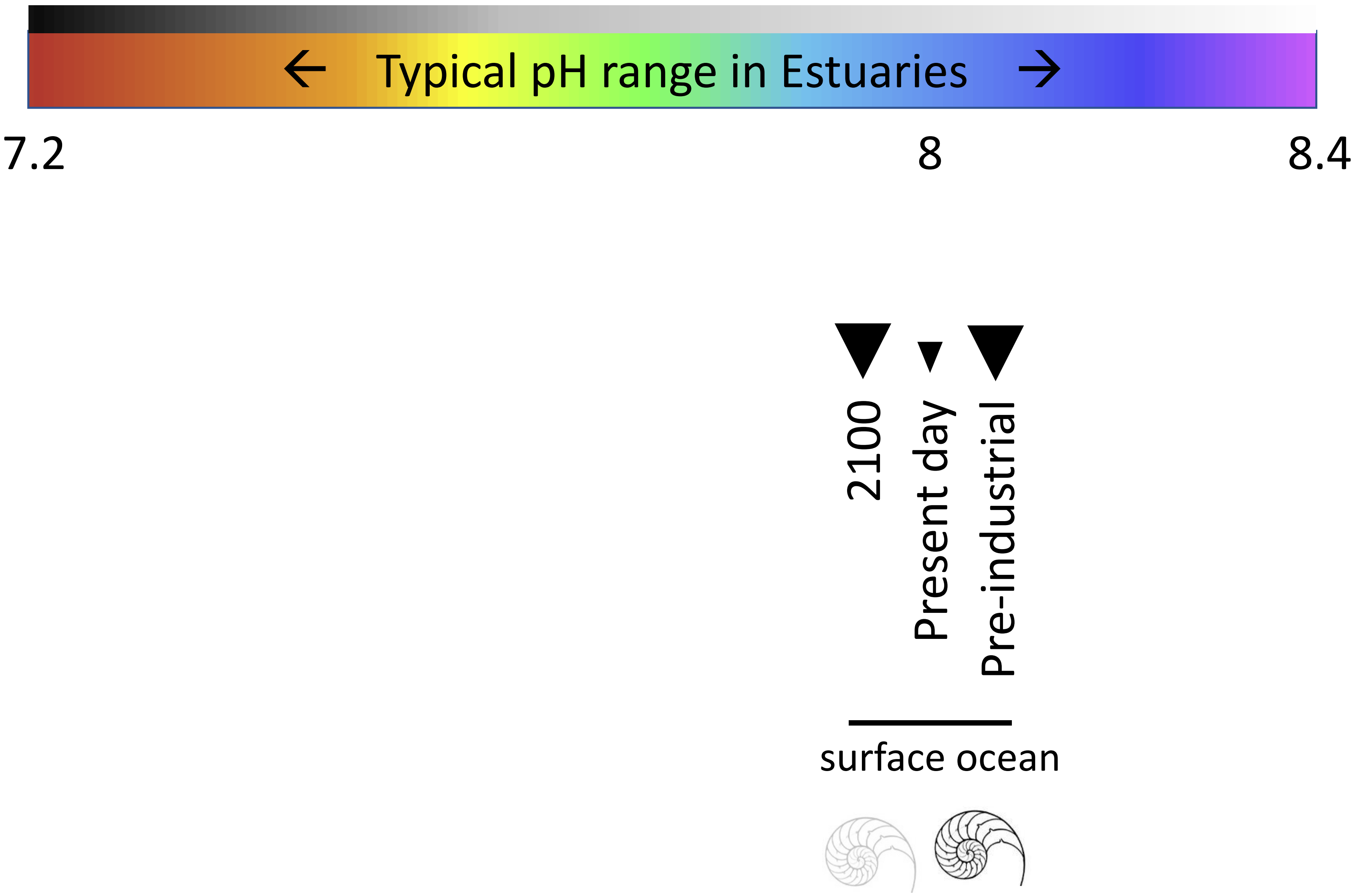
The pH Scale



acidic
alkaline
4
7
11
lemon juice
tomato juice
coffee
distilled water
detergent
Caustic cleaners



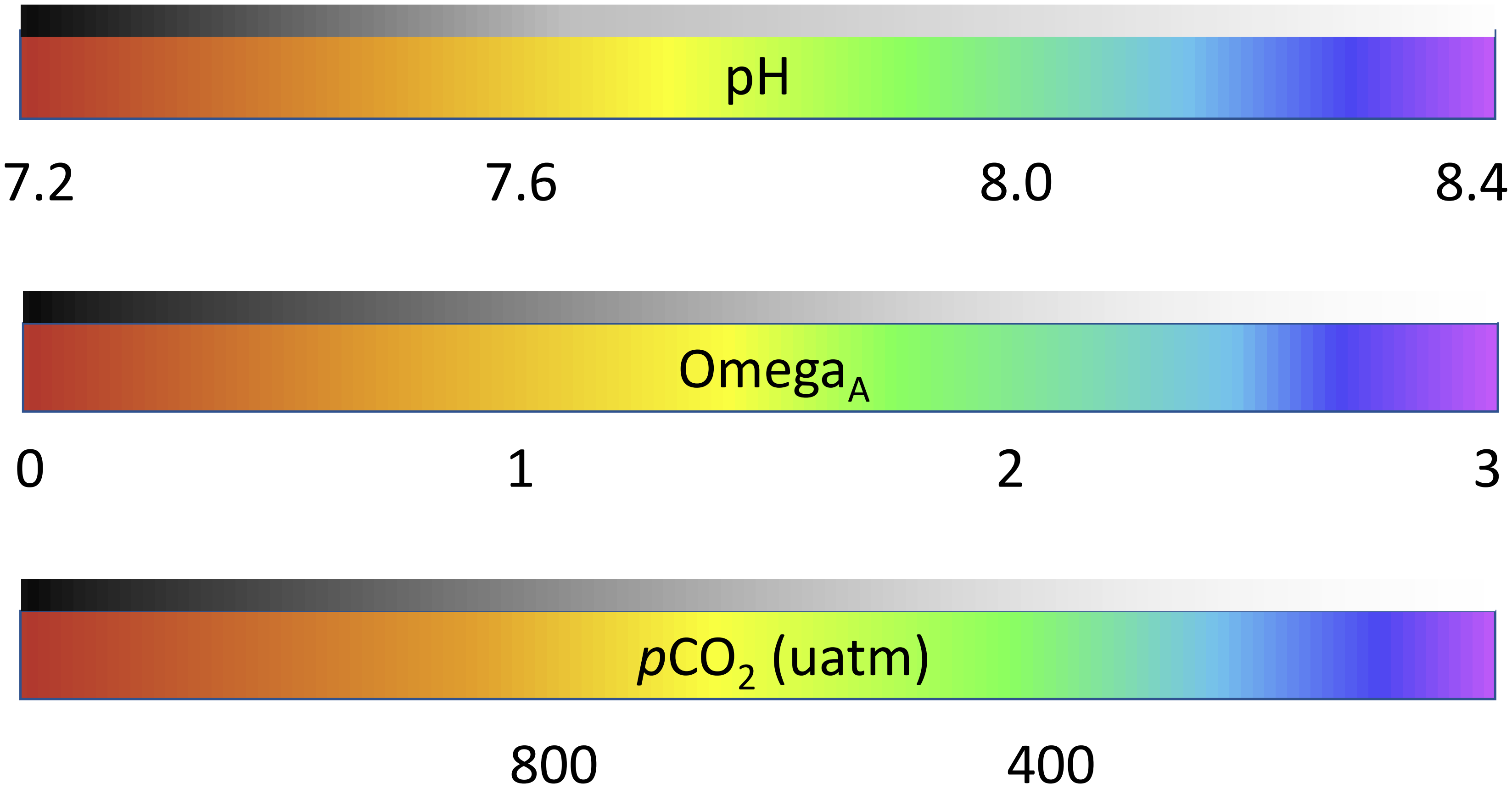
Typical pH range in Estuaries
7.2
7.6
8.0
8.4
acidic
alkaline
4
7
11
lemon juice
tomato juice
coffee
distilled water
detergent
Caustic cleaners



Typical pH range in Estuaries
7.2
8
8.4
2100
Present day
Pre-industrial
surface ocean

Relationships between pH, $Omega_A$, and pCO_2 in Narragansett Bay

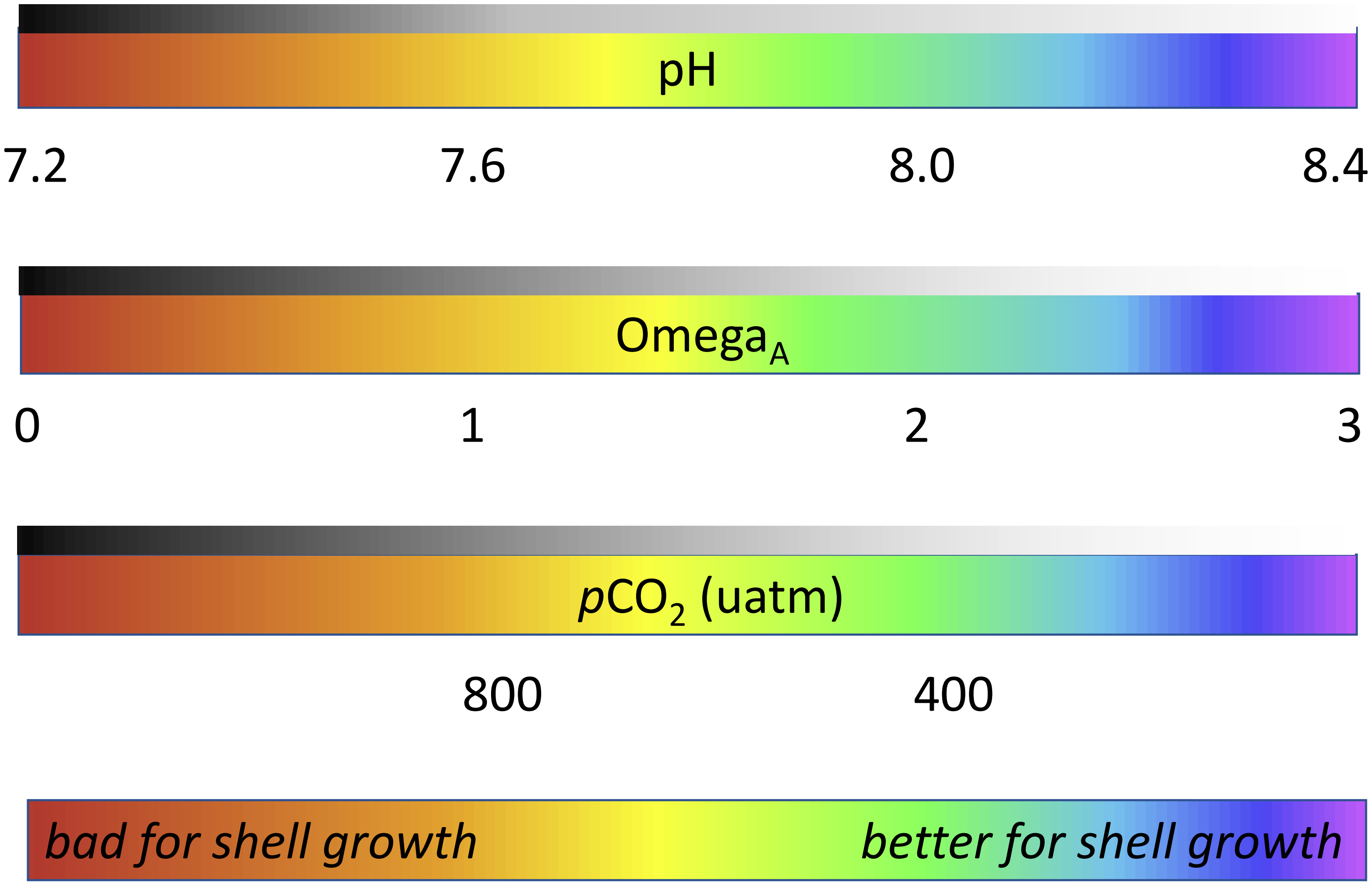
- $Omega_A$ expresses acidification on a scale important for shell formation
- CO_2, regardless of source, reduces pH and $Omega_A$



Color/shading scales are approximate, but helpful for visualizations….

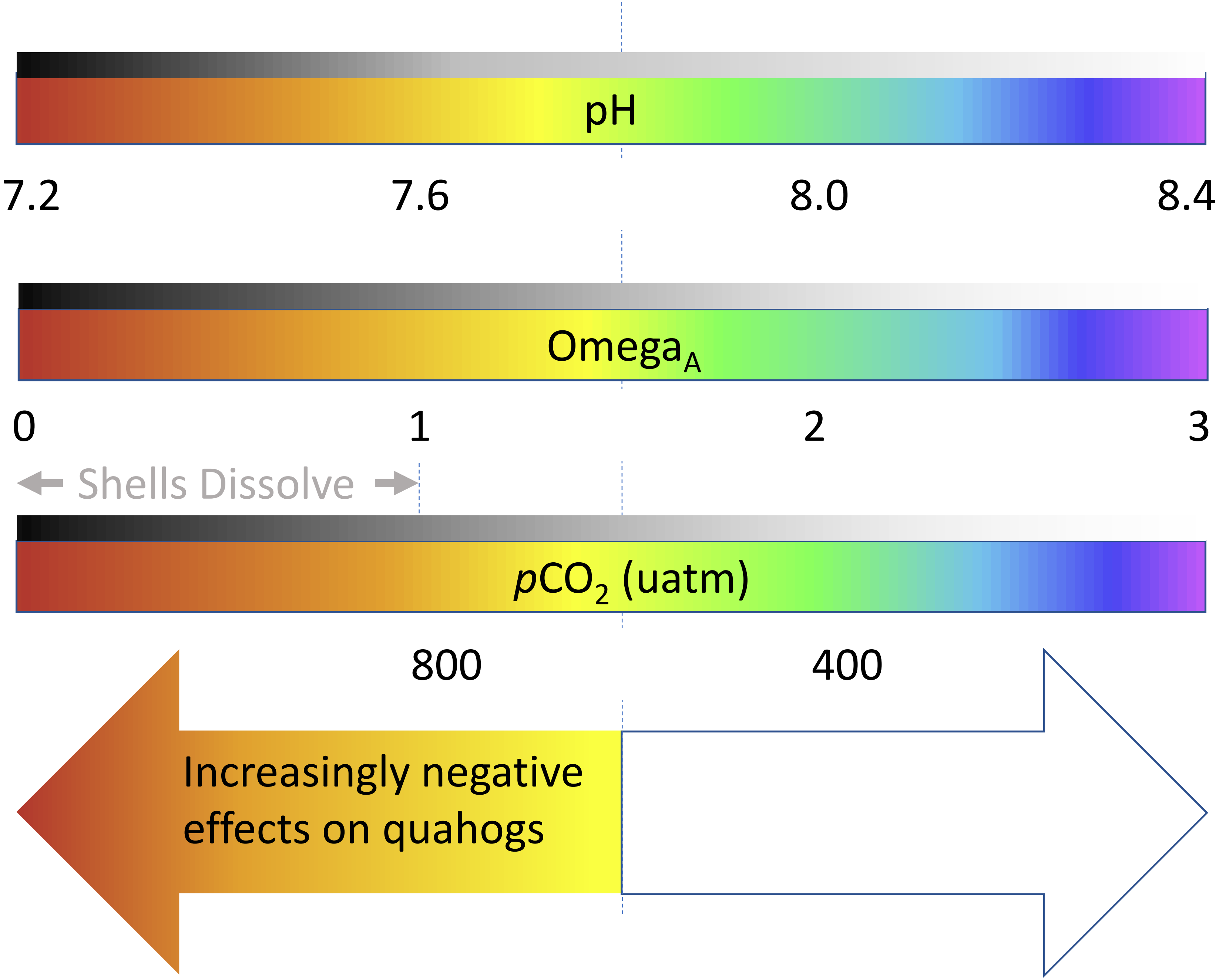
Relationships between pH, $Omega_A$, and pCO_2 in Narragansett Bay

- $Omega_A$ expresses acidification on a scale important for shell formation
- CO_2, regardless of source, reduces pH and $Omega_A$
- At low $Omega_A$, shell formation in larval quahogs can deplete energy in yolk reserves before successful growth to feeding stage

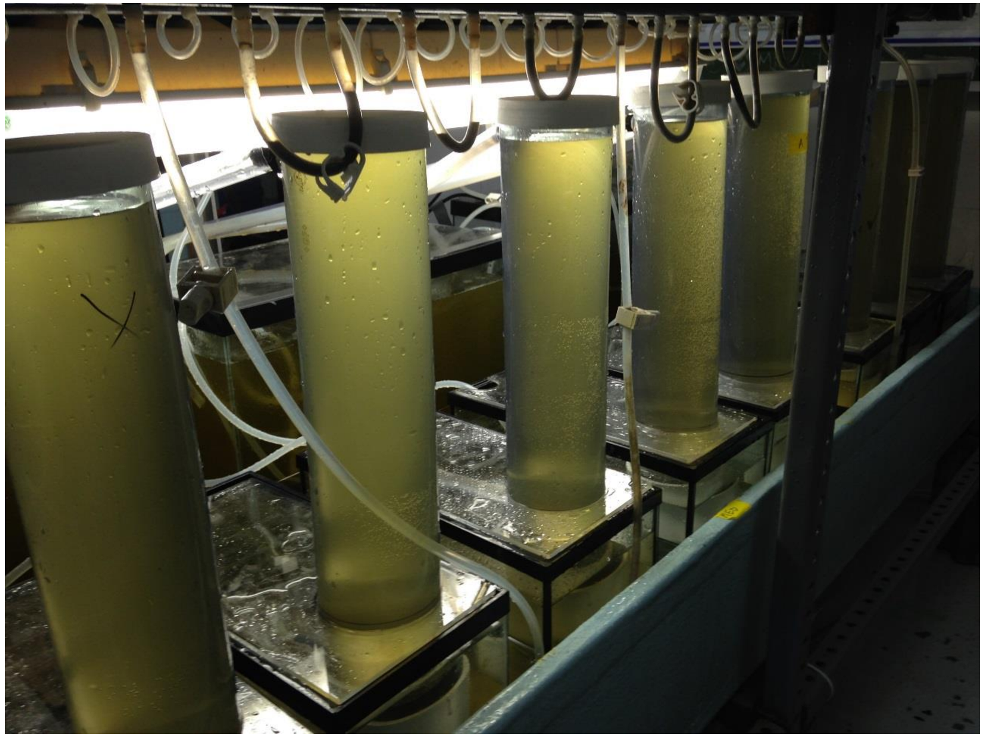


Relationships between pH, $Omega_A$, and pCO_2 in Narragansett Bay

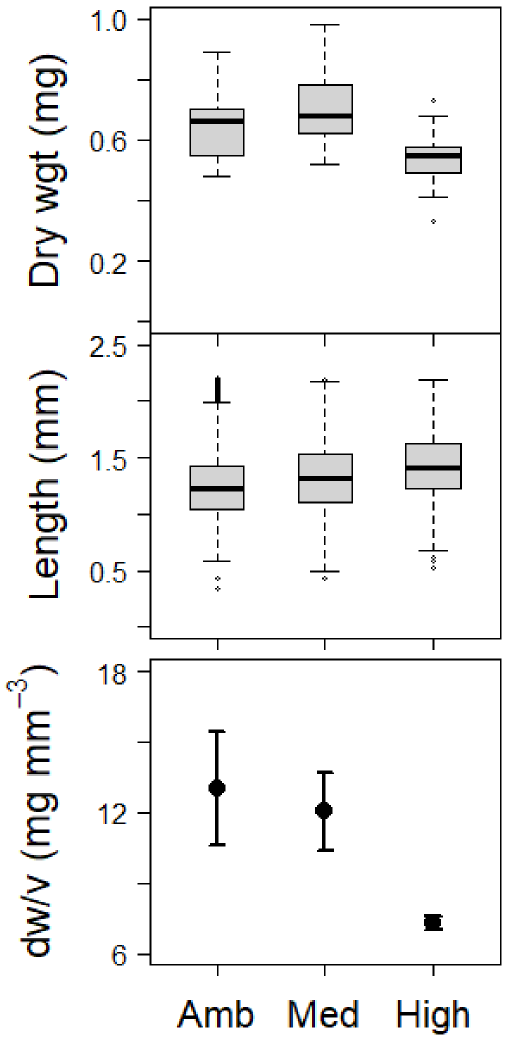
- $Omega_A$ expresses acidification on a scale important for shellfish (availability of ions needed for shell formation)
- CO_2, regardless of source, reduces pH and $Omega_A$
- At low $Omega_A$, shell formation in larval quahogs can deplete energy in yolk reserves before successful growth to feeding stage
- The exact cutoff for $Omega_A$ depends on duration of exposure, but values near 1.5 are commonly cited. In the bay, this occurs at roughly pH 7.8 and pCO_2 600.



Effects on quahog **SHELL INTEGRITY** in laboratory experiments

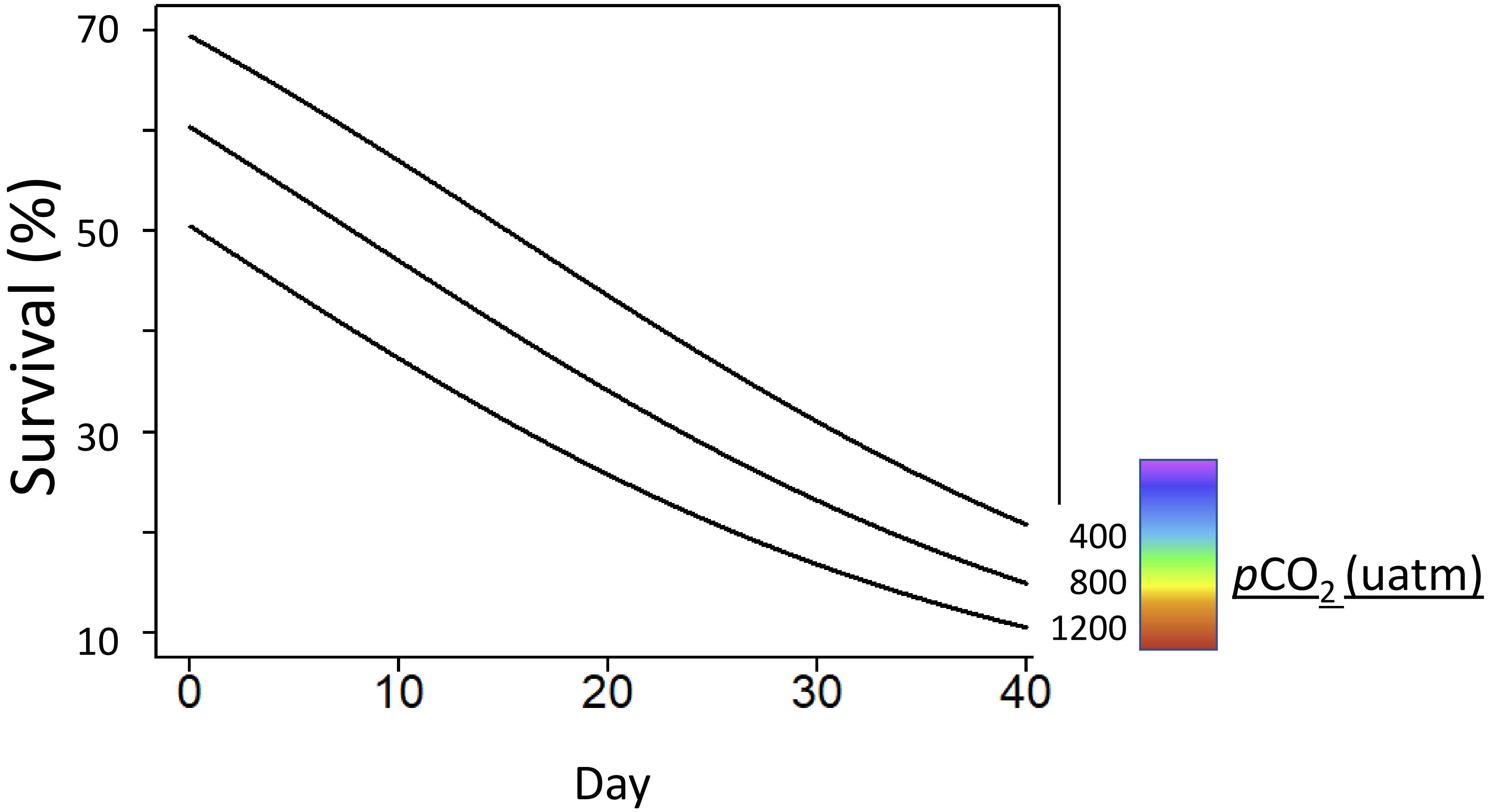


	Ambient	Medium	High
***p*CO_2 (uatm)**	677	1137	1661
pH	7.82	7.62	7.47

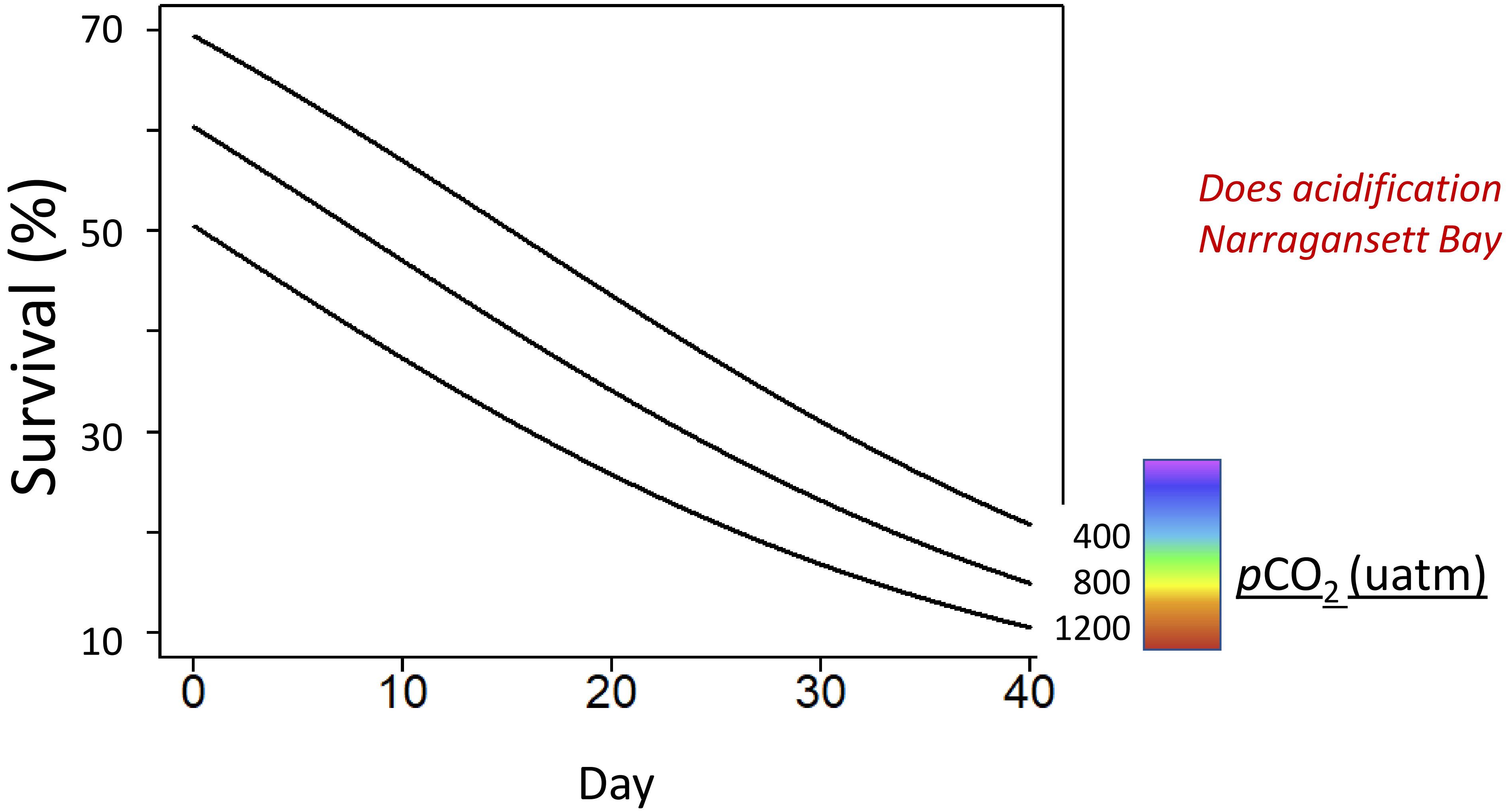


- Length increased under higher acidification but weight did not, which led to lower shell weight per unit volume (dw/v)
- Differences in shell mineral architecture were detectable but variable (more studies needed)
- We also saw hints of effects on digestive tract characteristics

Effects on quahog **EARLY LIFE STAGE SURVIVAL** in laboratory experiments

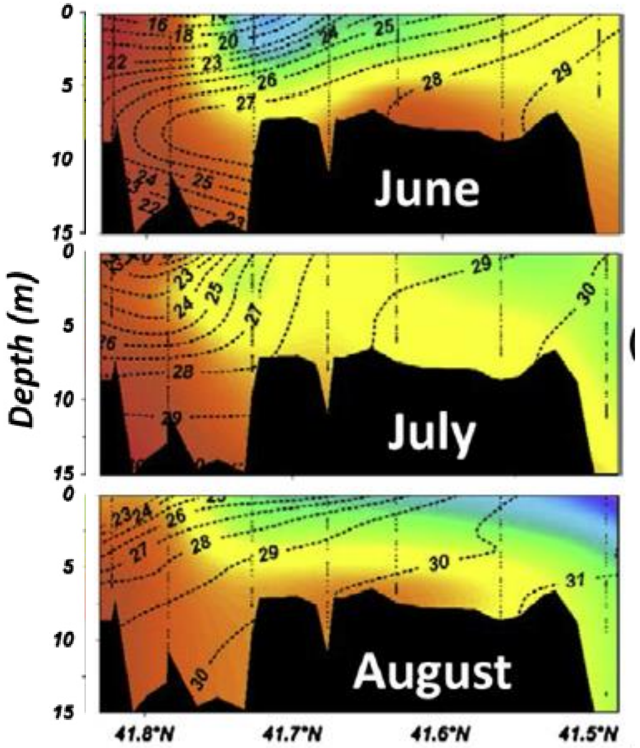


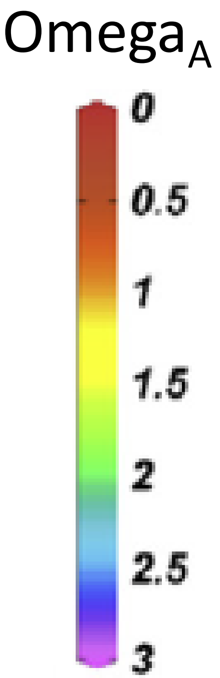
Effects on quahog **EARLY LIFE STAGE SURVIVAL** in laboratory experiments

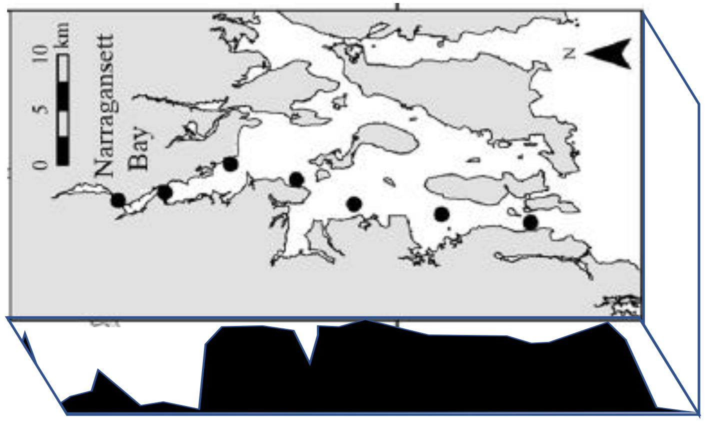


Does acidification occur in Narragansett Bay?

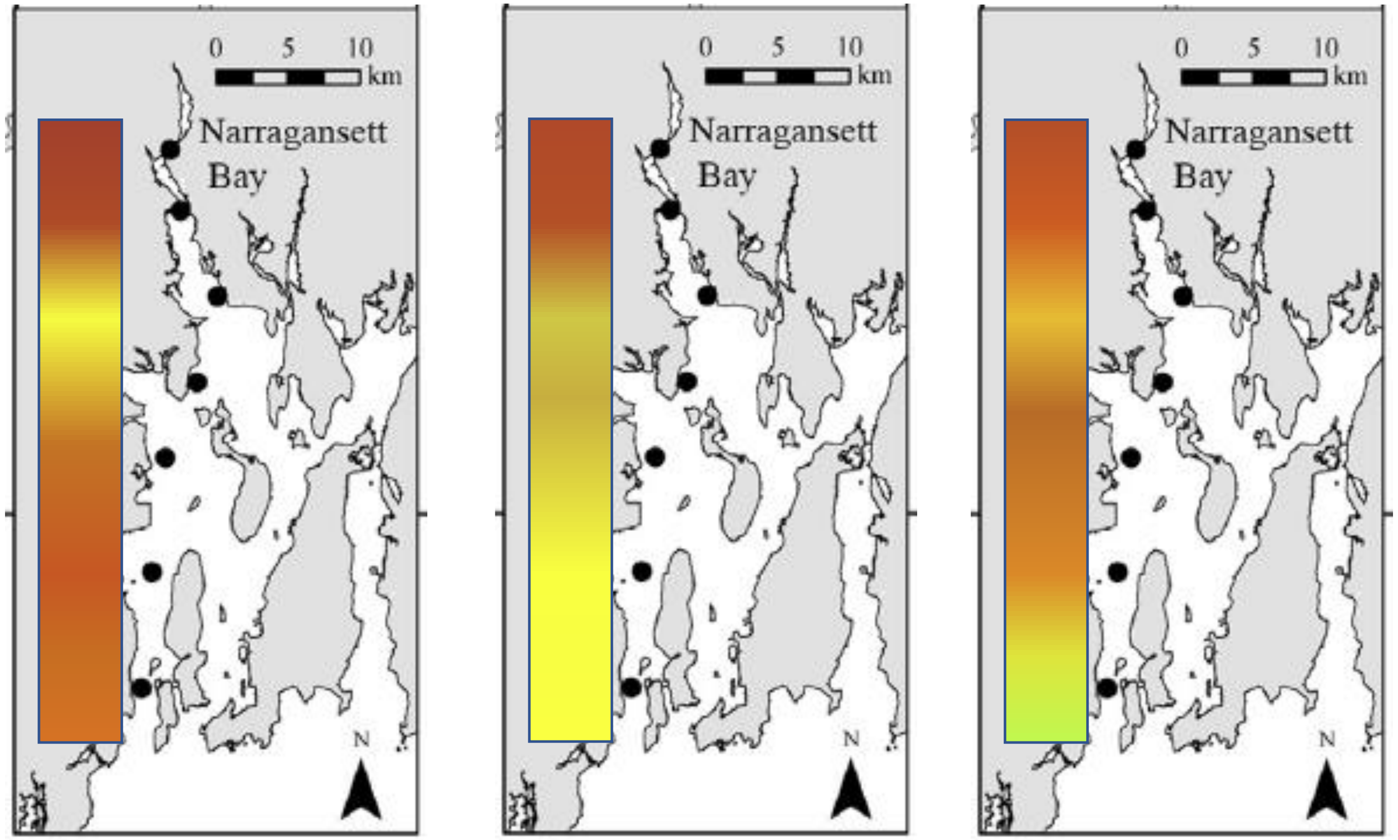
Three surveys in 2013: Poor conditions for LARVAL SURVIVAL and JUVENILE SHELL INTEGRITY







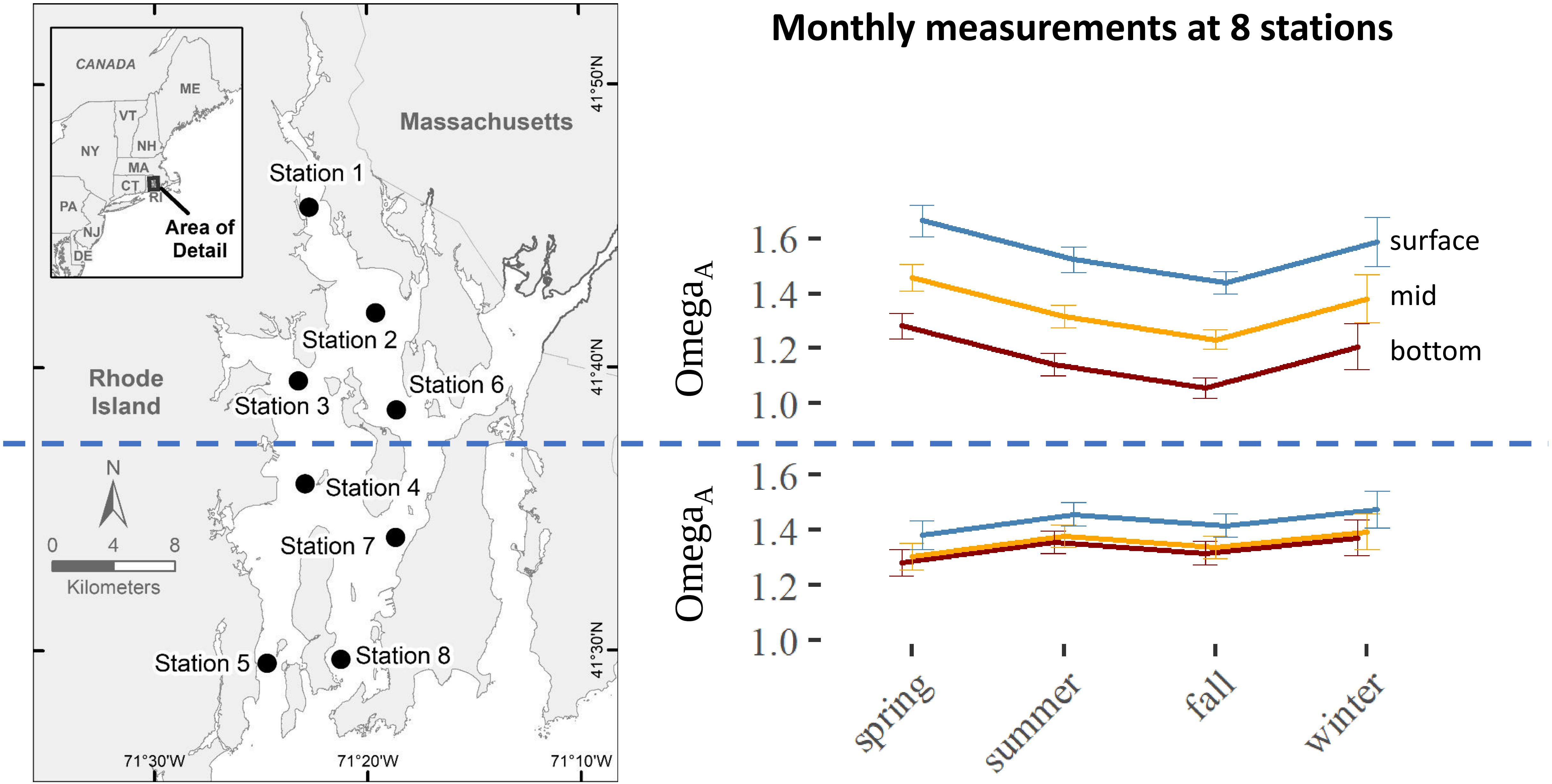
June July August



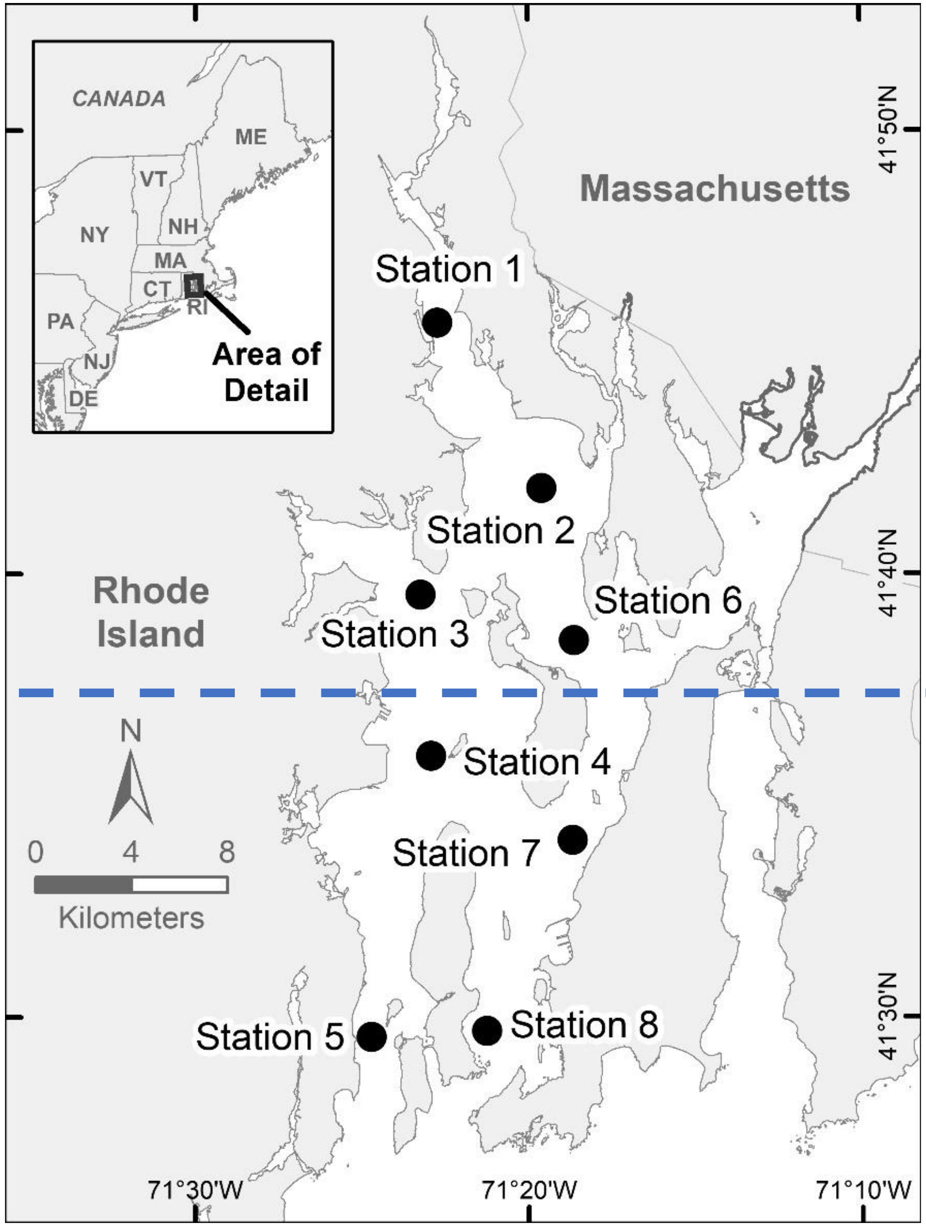
Conditions in bottom waters in 2013

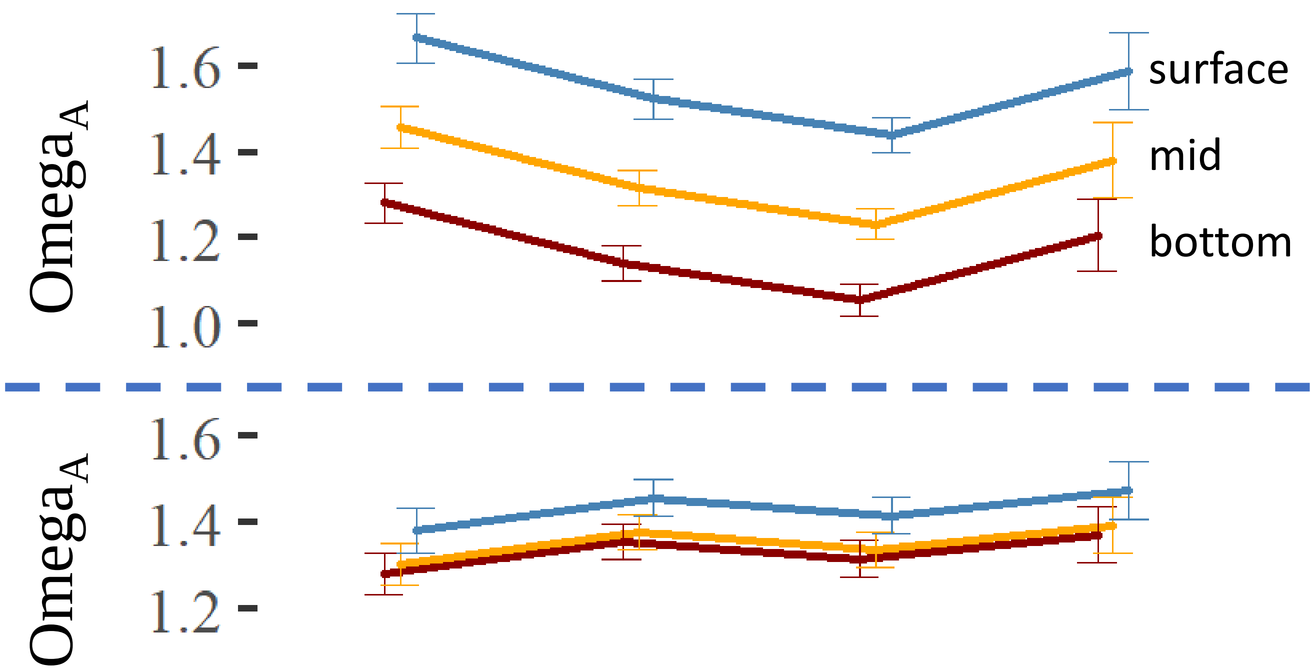
What about other years?

Narragansett Bay 2017-2019
Monthly measurements at 8 stations



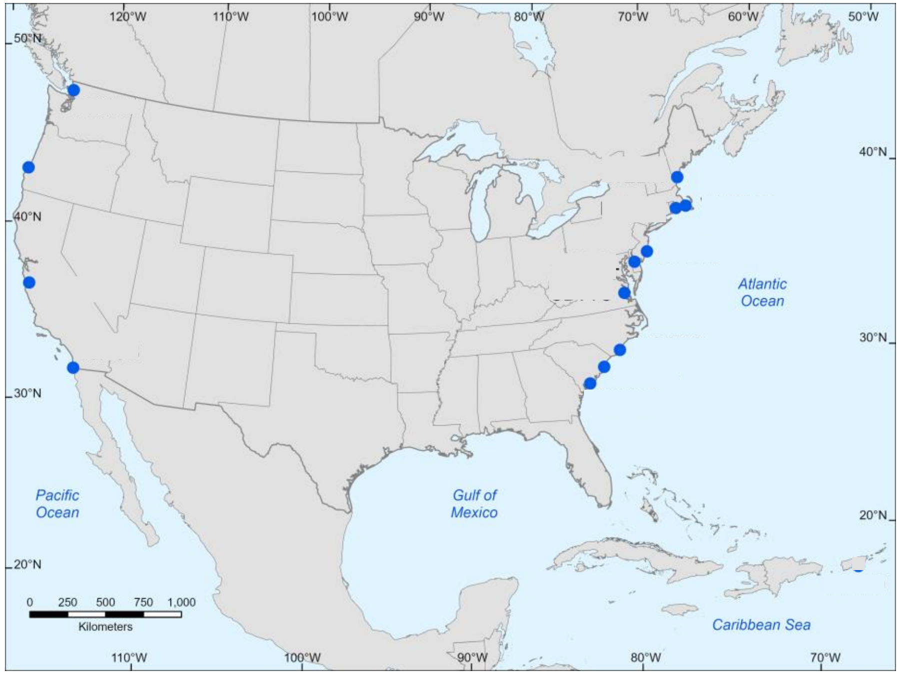
Narragansett Bay 2017-2019
Monthly measurements at 8 stations



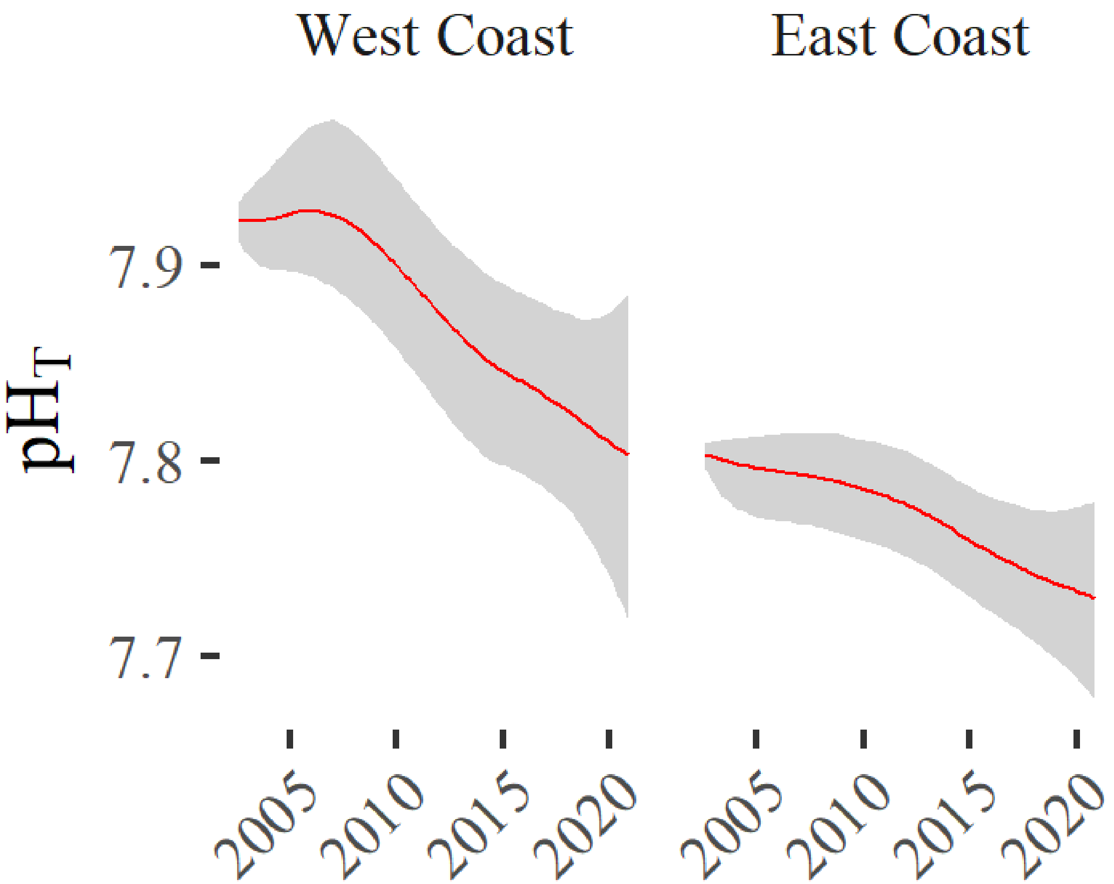


This and the 2013 study are snapshots. Are there longer term trends?

pH is declining in estuaries on West and East coasts of North America

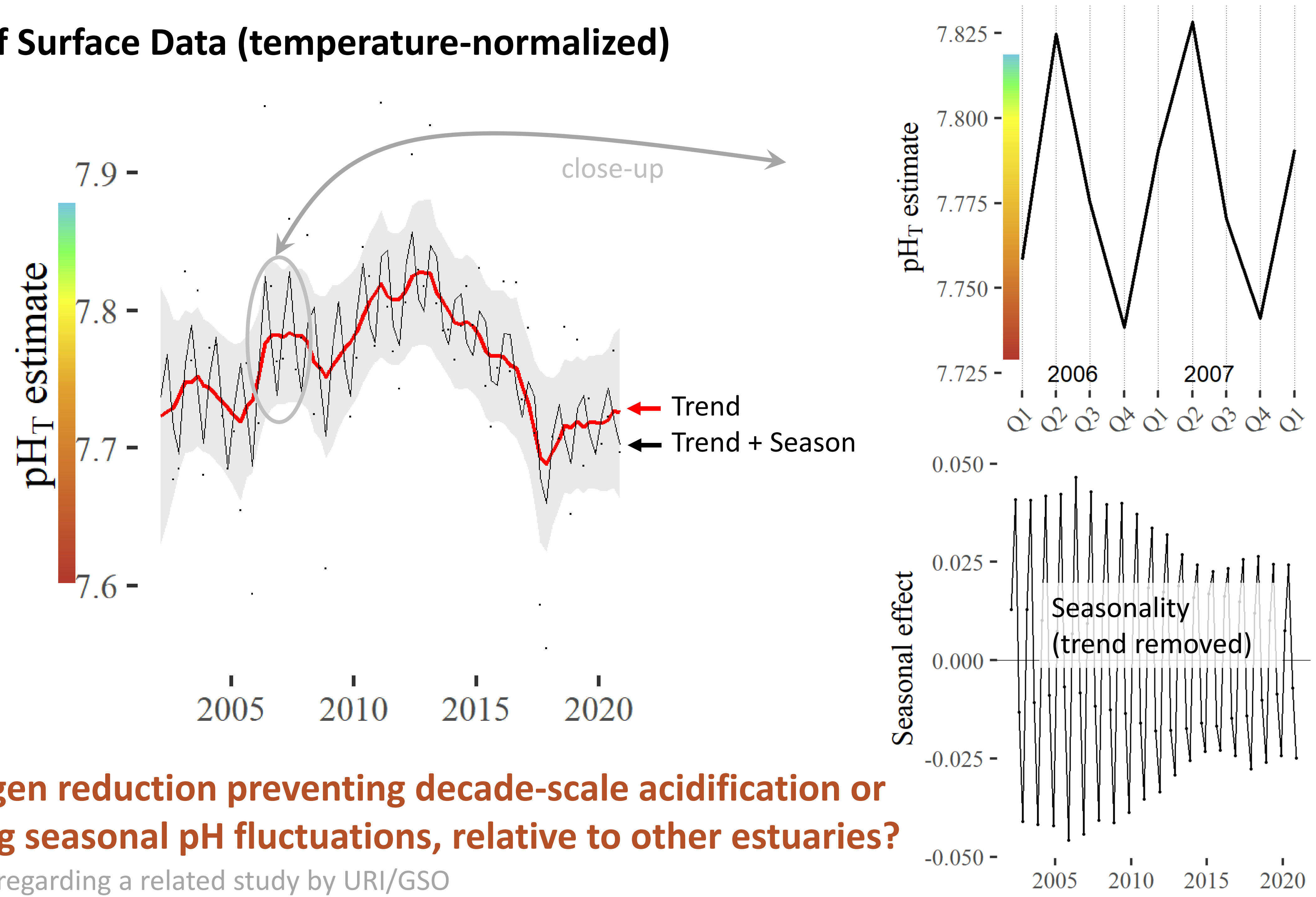


Data were obtained from 13 sites in the National Estuarine Research Reserve system and then temperature normalized



What about Narragansett Bay?

T-Wharf Surface Data (temperature-normalized)



Is nitrogen reduction preventing decade-scale acidification or reducing seasonal pH fluctuations, relative to other estuaries?

See notes regarding a related study by URI/GSO

NOTES, SOURCES, and CREDITS

Slide 1. Quahog picture: https://www.fisheries.noaa.gov/species/northern-quahog

Slide 2. *Notes: It is not totally clear wither the dissolution in the photo was postmortem, but many publications have described shell dissolution in living mollusks. pCO_2 shown on the plot is the partial pressure of carbon dioxide in seawater. It is the concentration of CO2 that the air above the water would have to have in order for ocean uptake to equal off-gassing ((no net change). Plots:* https://www.epa.gov/climate-indicators/climate-change-indicators-ocean-acidity

Image: Oceanography Special Issue: The Future of Ocean Biogeochemistry in a High-CO_2 World. Pteropod Photo credit: David Liittschwager, National Geographic Stock. Background: Changes in atmospheric CO_2, seawater pCO_2, and pH near Hawaii. See Feely et al. on page 36 for details.

Slide 3*. The precipitation effect is mainly due to reduced buffering (lower alkalinity) of freshwater from our granitic landscape. The literature is loaded with relevant peer-reviewed publications on estuarine responses to CO2. See the following for examples*:

Cai, W.-J., X. Hu, W.-J. Huang, M. C. Murrell, J. C. Lehrter, S. E. Lohrenz, W.-C. Chou, W. Zhai, J. T. Hollibaugh, Y. Wang, P. Zhao, X. Guo, K. Gundersen, M. Dai, and G.-C. Gong. 2011. Acidification of subsurface coastal waters enhanced by eutrophication. Nat Geosci 4:766-770.

Feely, R. A., S. R. Alin, J. Newton, C. L. Sabine, M. Warner, A. Devol, C. Krembs, and C. Maloy. 2010. The combined effects of ocean acidification, mixing, and respiration on pH and carbonate saturation in an urbanized estuary. Estuarine Coastal and Shelf Science 88:442-449.

Wallace, R. B., H. Baumann, J. S. Grear, R. C. Aller, and C. J. Gobler. 2014. Coastal ocean acidification: The other eutrophication problem. Estuarine, Coastal and Shelf Science 148:1-13.

Slide 6. *Many peer-reviewed papers describe historic and future conditions, including*

Orr, J. C., V. J. Fabry, O. Aumont, L. Bopp, S. C. Doney, R. A. Feely, and R. M. Key. 2005. Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. Nature 437:681-686.

Caldeira, K., and M. E. Wickett. 2003. Anthropogenic carbon and ocean pH. Nature 425:365.

Slide 8. *Notes: $Omega_A$ is "Aragonite Saturation State" which is the product of the of the concentrations of Ca ions and Carbonate Ions) divided by the product of their saturation concentrations.*

Thomsen, J., K. Haynert, K. M. Wegner, and F. Melzner. 2015. Impact of seawater carbonate chemistry on the calcification of marine bivalves. Biogeosciences 12:4209-4220.

Slide 10. *There are many related papers from other locations and/or for other bivalves. This Narragansett Bay study of quahogs is:*

Grear, J., A. Pimenta, H. Booth, D. B. Horowitz, W. Mendoza, and M. Liebman. 2020. In situ recovery of bivalve shell characteristics after temporary exposure to elevated pCO(2). Limnology and Oceanography 65:2337-2351.

Slide 11. *Notes: Survival curves are from the publication below and are based on many experiments conducted by Chirs Gobler, Stephanie Talmage, and others at Stony Brook University.*

Grear, J. S., C. A. O'Leary, J. A. Nye, S. T. Tettelbach, and C. J. Gobler. 2020. Effects of coastal acidification on North Atlantic bivalves: interpreting laboratory responses in the context of in situ populations. Marine Ecology Progress Series 633:89-104.

Slide 13.

Wallace, R. B., H. Baumann, J. S. Grear, R. C. Aller, and C. J. Gobler. 2014. Coastal ocean acidification: The other eutrophication problem. Estuarine, Coastal and Shelf Science 148:1-13.

Slide 14.

Pimenta, A. R., A. Oczkowski, R. McKinney, and J. Grear. 2023. Geographical and seasonal patterns in the carbonate chemistry of Narragansett Bay, RI. Regional Studies in Marine Science 62:102903.

Slide 16. *Notes: Results from time series analysis using Bayesian dynamic linear model (Grear in prep. for publication)*

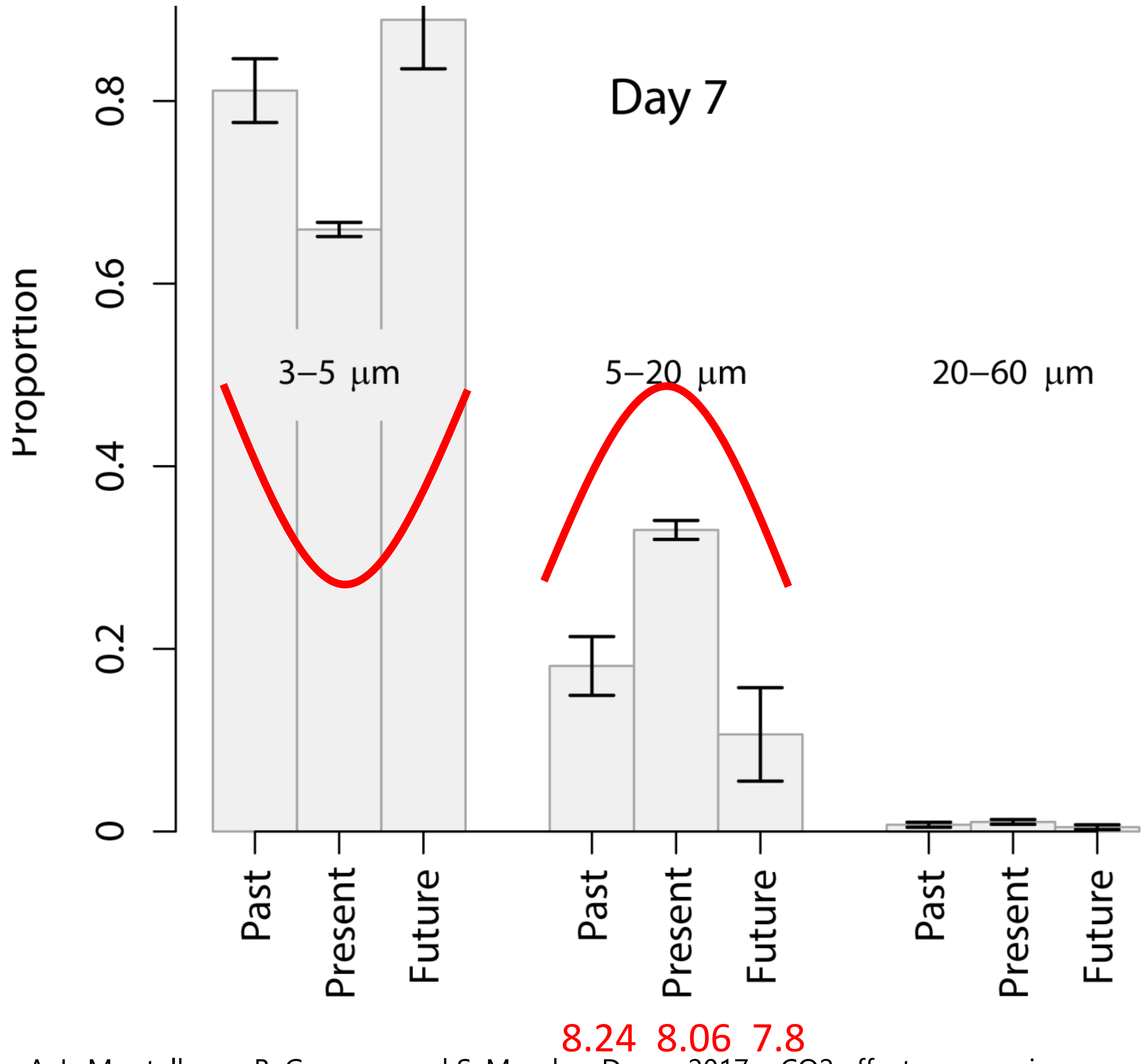
Slide 17. *Notes: Results shown from time series analysis using Bayesian dynamic linear model (Grear in prep. for publication). Data from station, T-wharf (Prudence Island), Nat'l Estuarine Research Reserve. Professor Hongjie Wang (URI/GSO) and other are working on time series analysis of pH data from the Narragansett Bay Fixed Monitoring Station network.*

Also see:

Grear, J. S., T. A. Rynearson, A. L. Montalbano, B. Govenar, and S. Menden-Deuer. 2017. *p*CO_2 effects on species composition and growth of an estuarine phytoplankton community. Estuarine, Coastal and Shelf Science 190:40-49.

Ober1, G. T., C. S. Thornber, and J. S. Grear. 2022. Ocean acidification but not nutrient enrichment reduces grazing and alters diet preference in Littorina littorea. Marine Biology 169:112.

The quantity and quality of phytoplankton are both important ecologically. Is OA or nutrient enrichment reducing the dietary quality of phytoplankton for shellfish?



Grear, J. S., T. A. Rynearson, A. L. Montalbano, B. Govenar, and S. Menden-Deuer. 2017. pCO2 effects on species composition and growth of an estuarine phytoplankton community. Estuarine, Coastal and Shelf Science **190:40-49.**

Phytoplankton incubations of whole seawater for seven days at URI / GSO.

- Counts and measurement of non-spherical phytoplankton is tricky and results were complex, but suggested acidification affects the abundance of certain types.
- Ratios of CO_2, and other nutrients (e.g, C:N:P:Si) are well known to affect phytoplankton growth and the relative abundance of "preferred" types, HABS, etc.
- There may be interactions between OA and harmful algal blooms (HABS).