Ocean Acidification the in Massachusetts Coastal Zone

June 26, 2019

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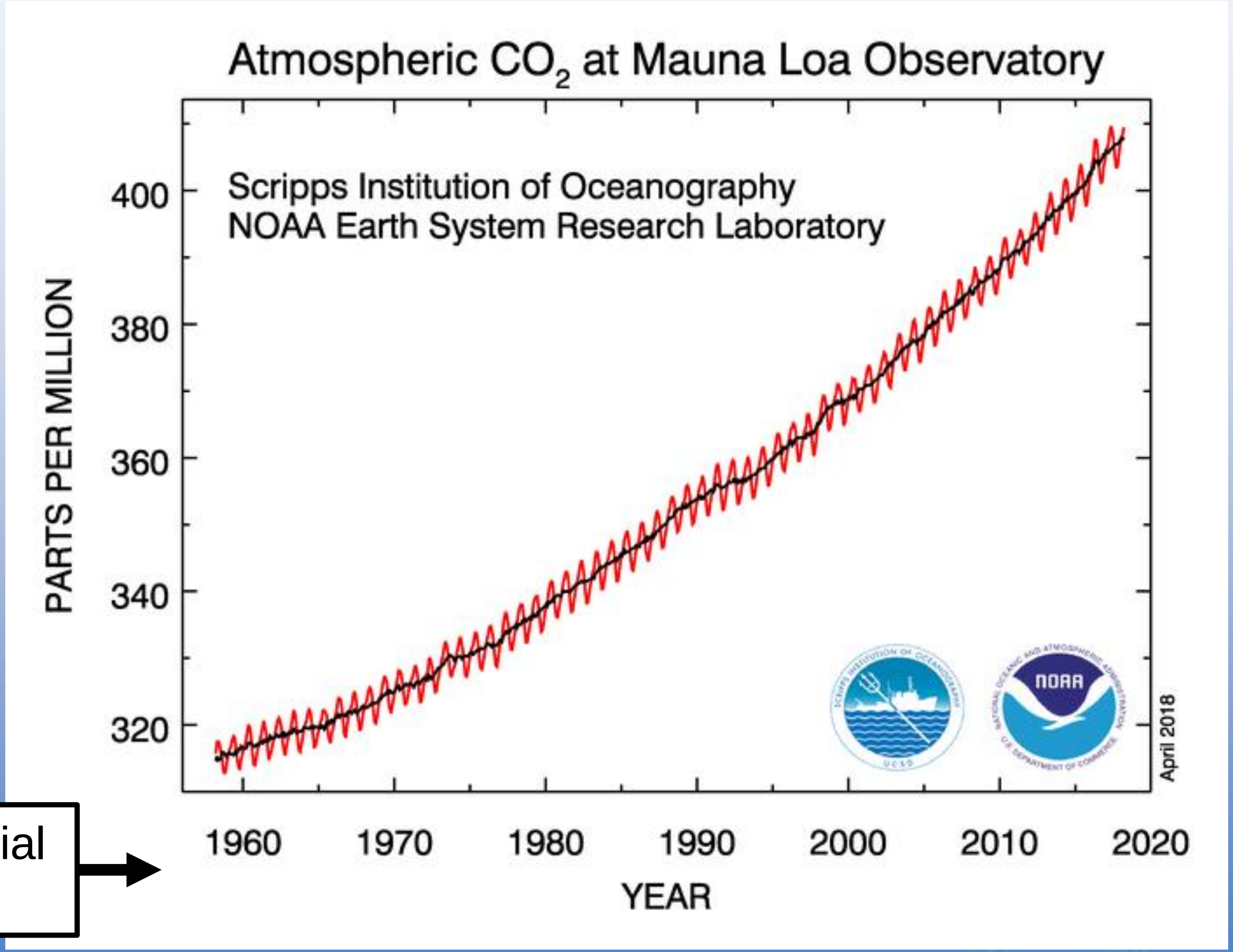
Outline

Background about acidification

Open ocean acidification vs. coastal acidification

Acidification monitoring on Cape Cod

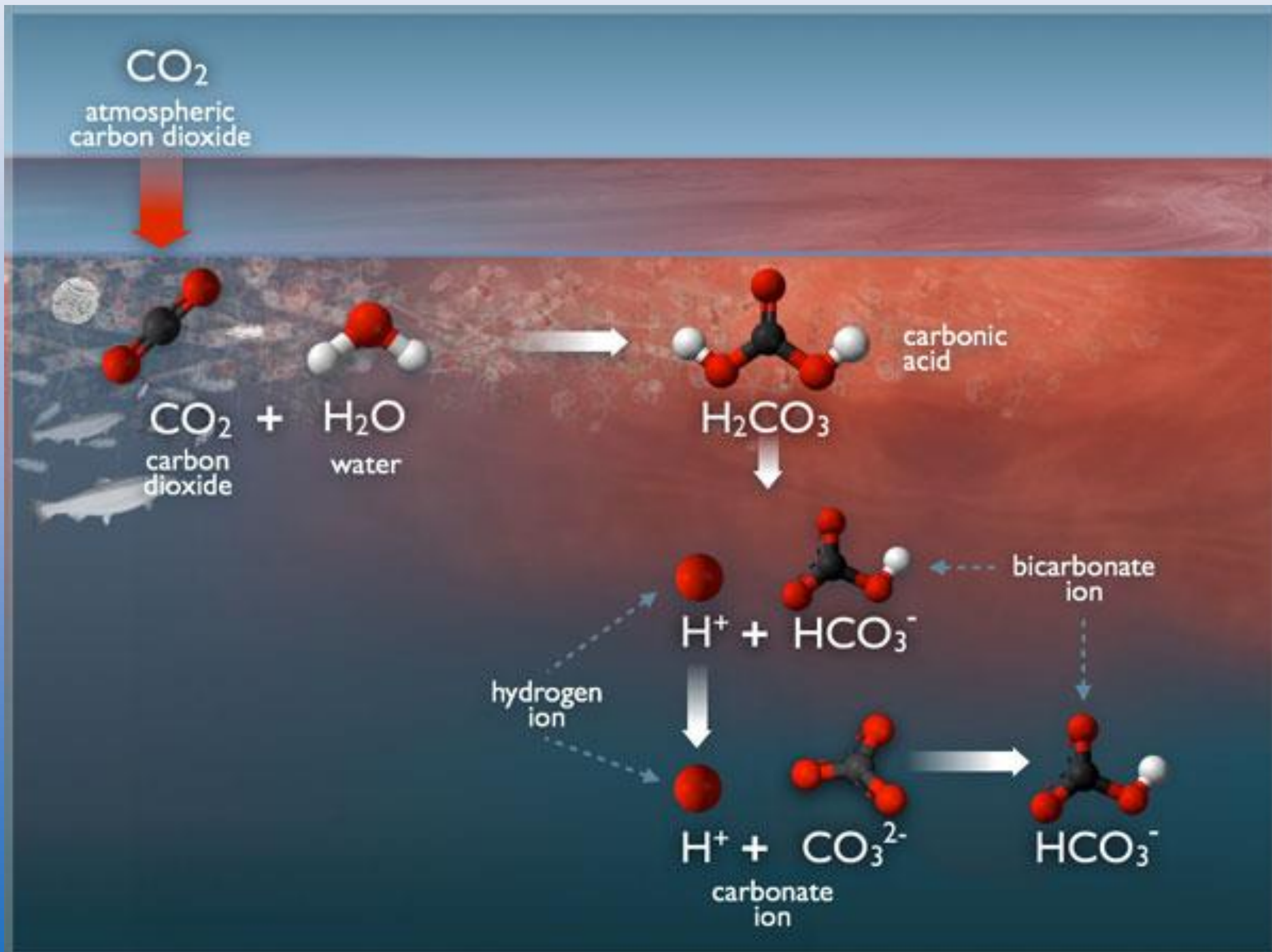


Preindustrial
~280 ppm

What happens when CO_2 increases?

$CO_2 \leftrightarrow CO_3^{2-}$, with $CO_2 \leftrightarrow HCO_3^- \leftrightarrow CO_3^{2-}$

Carbon Dioxide — HCO_3^- Bicarbonate ion — Carbonate ion



CO_2 ↑

HCO_3^- ↑

H^+ ↑

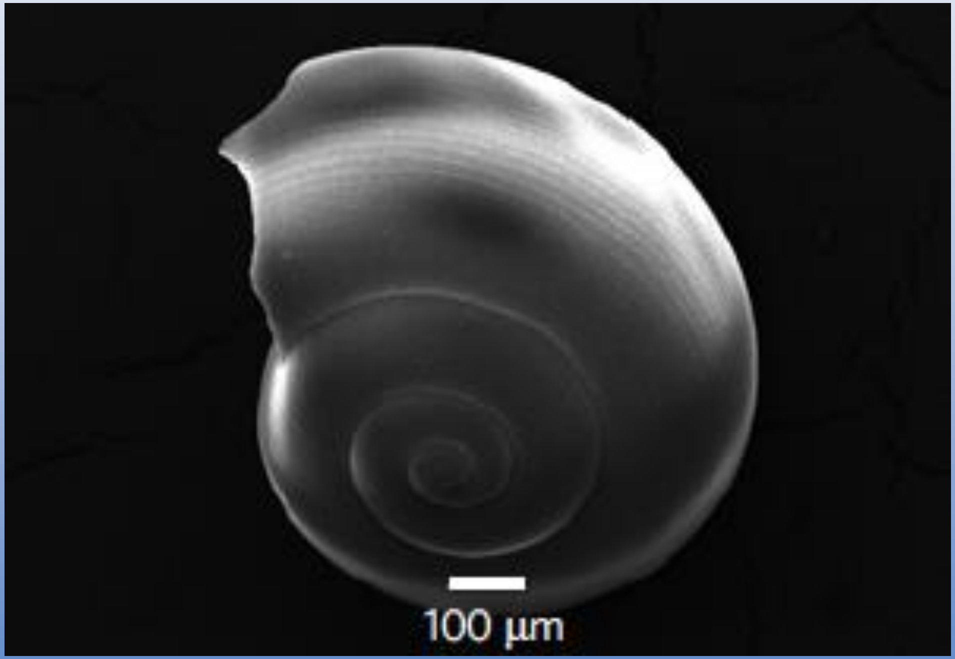
CO_3^{2-} ↓

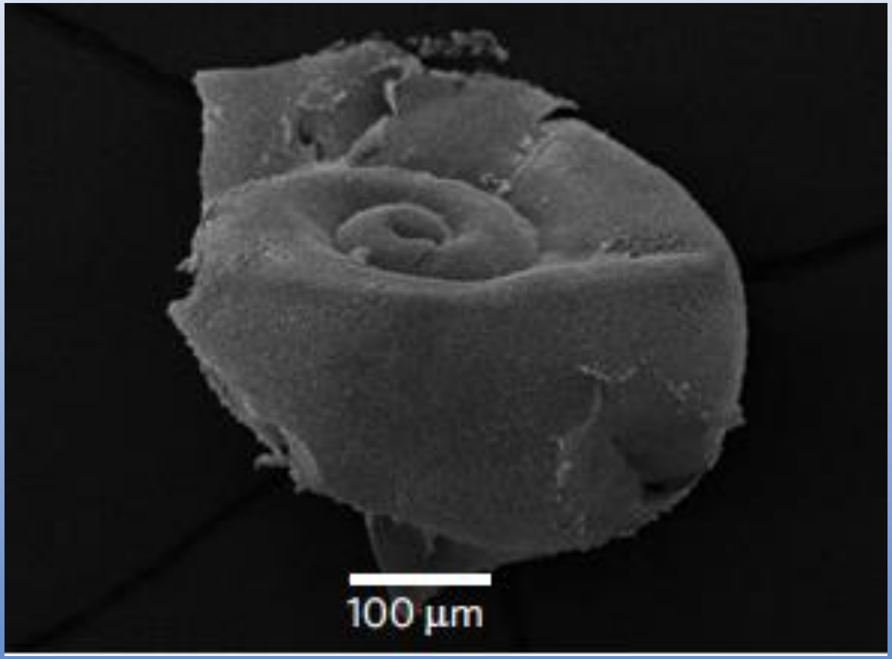
pH ↓

Why do we care about acidification?

Acidification affects the calcification process

$$Ca^{2+} + CO_3^{2-} \longrightarrow CaCO_3 \text{ (solid)}$$



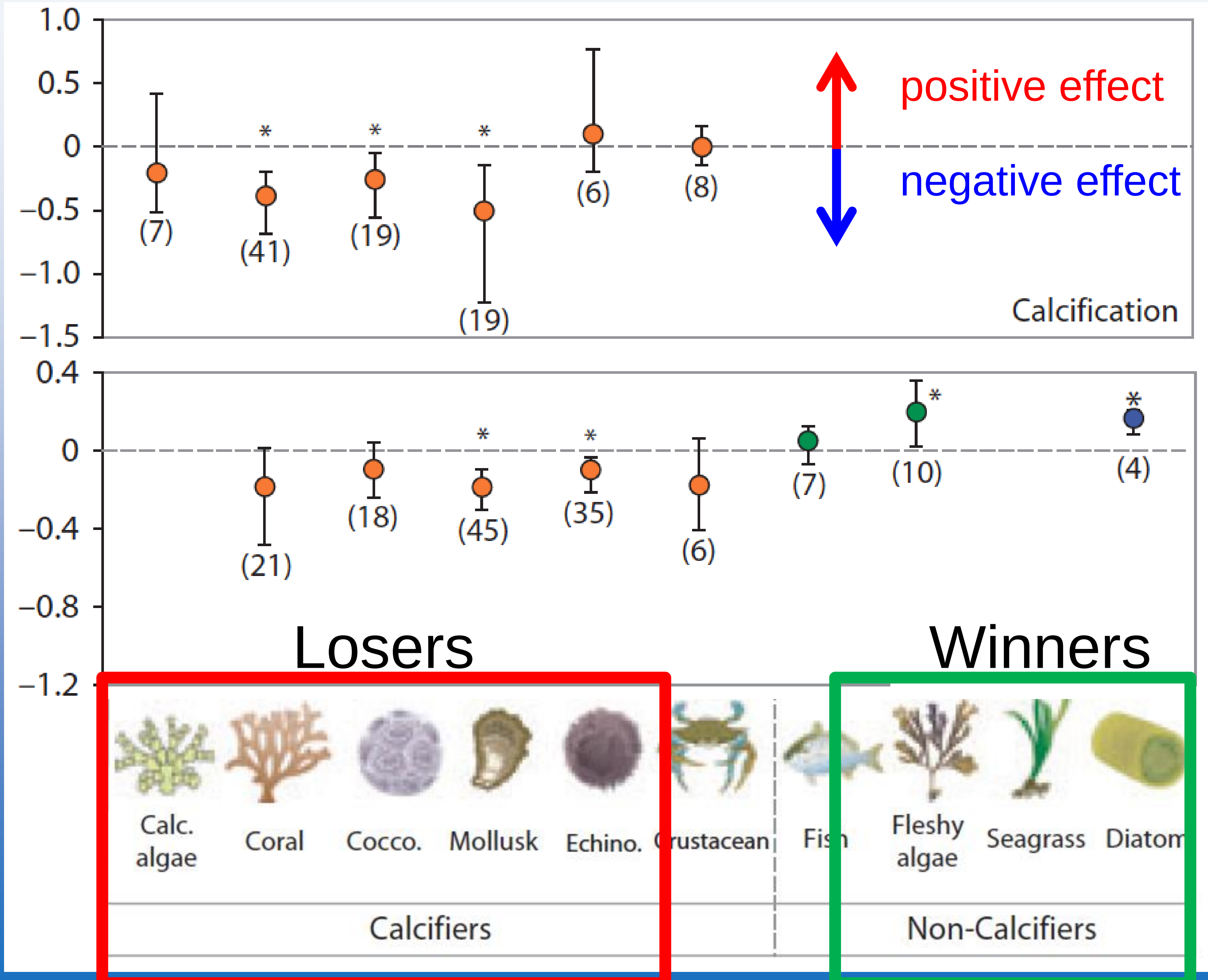


Saturation State: $\Omega = [Ca^{2+}][CO_3^{2-}] / K_{sp}$

$\Omega > 1$ saturated, $\Omega < 1$ undersaturated

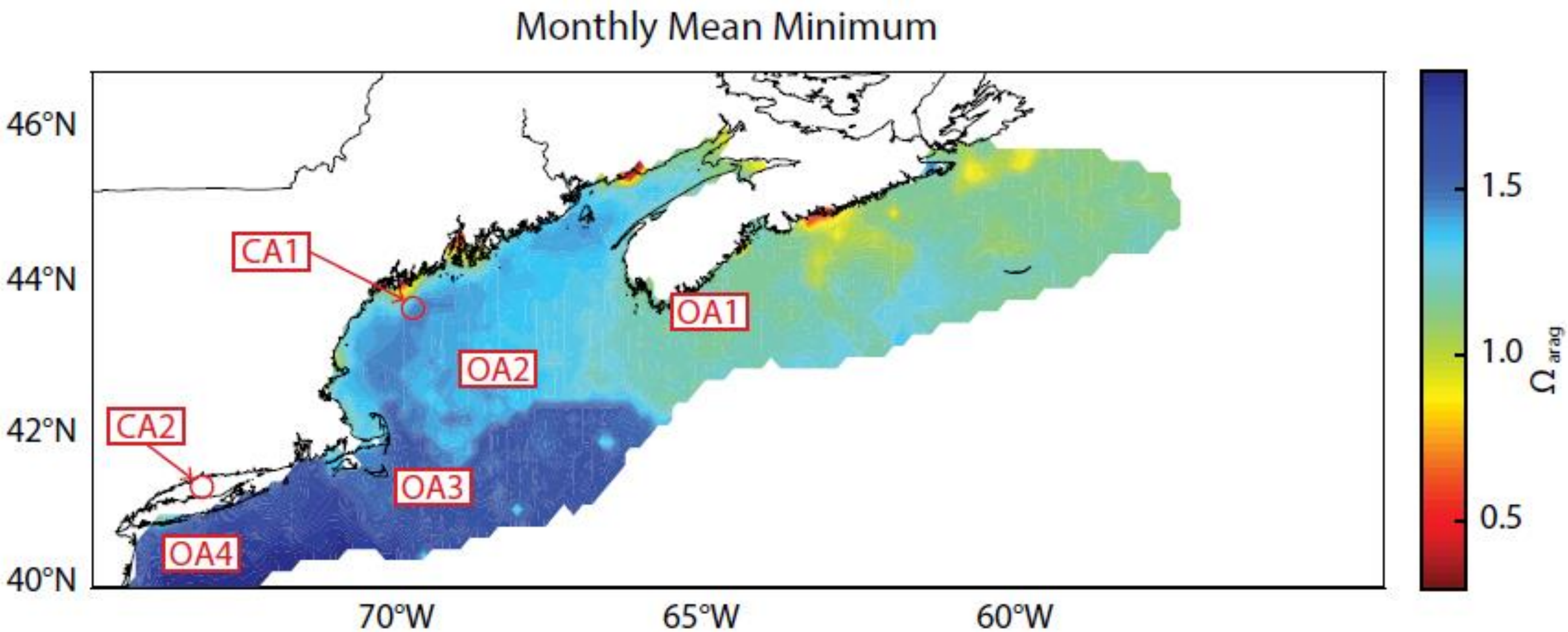
Feely et al. Nature 2005; Bednaršek Nature Geosci. 2012

Who is affected by acidification?



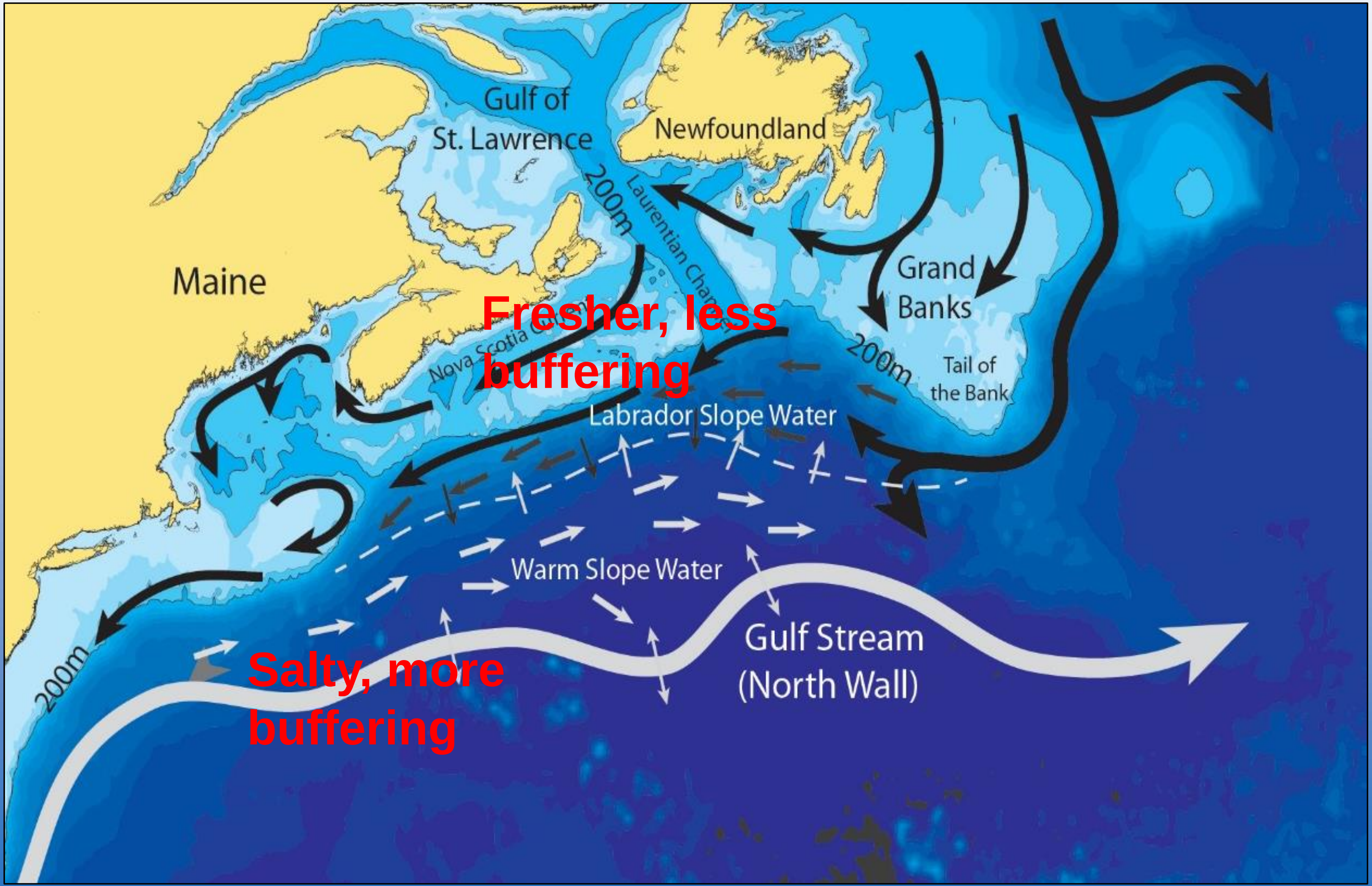
Kroecker et al. Global Change Biology(2013)

New England Shelf omega already fairly low



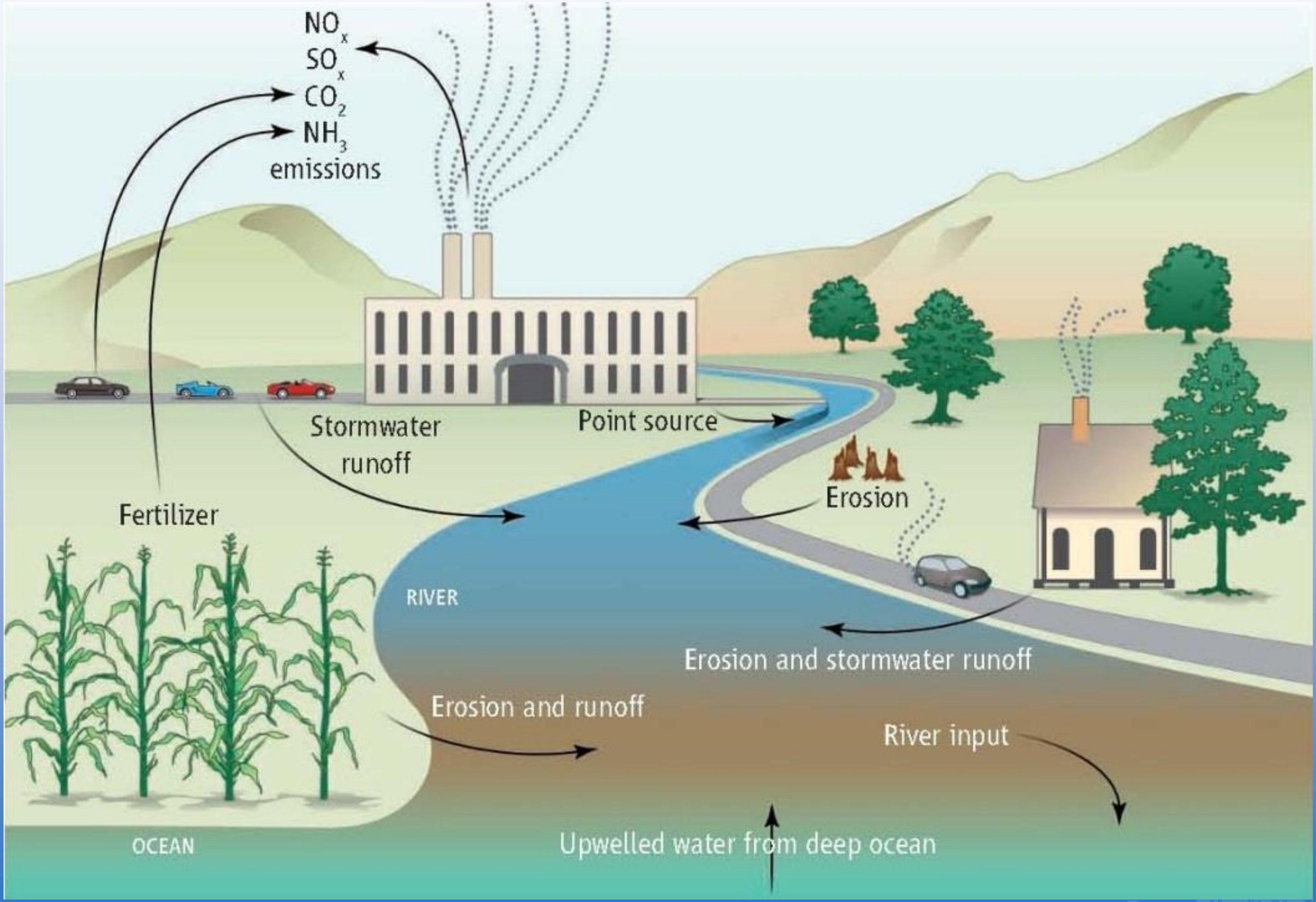
Gledhill et al. 2015, Oceanography

Physical oceanography of the region has a big impact



Townsend et al. 2015, Journal of Marine Research

Coastal systems are more complicated

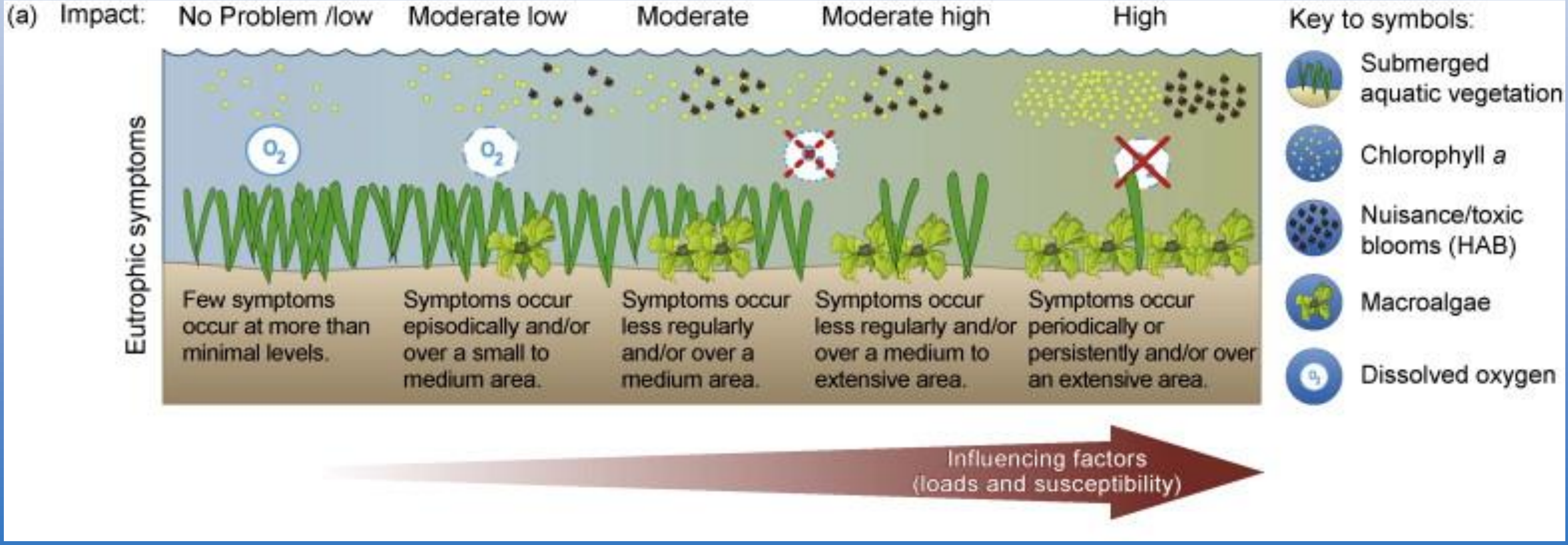


Doney et al. PNAS 2007; Doney Science 2010; Kelly et al. Science 2011

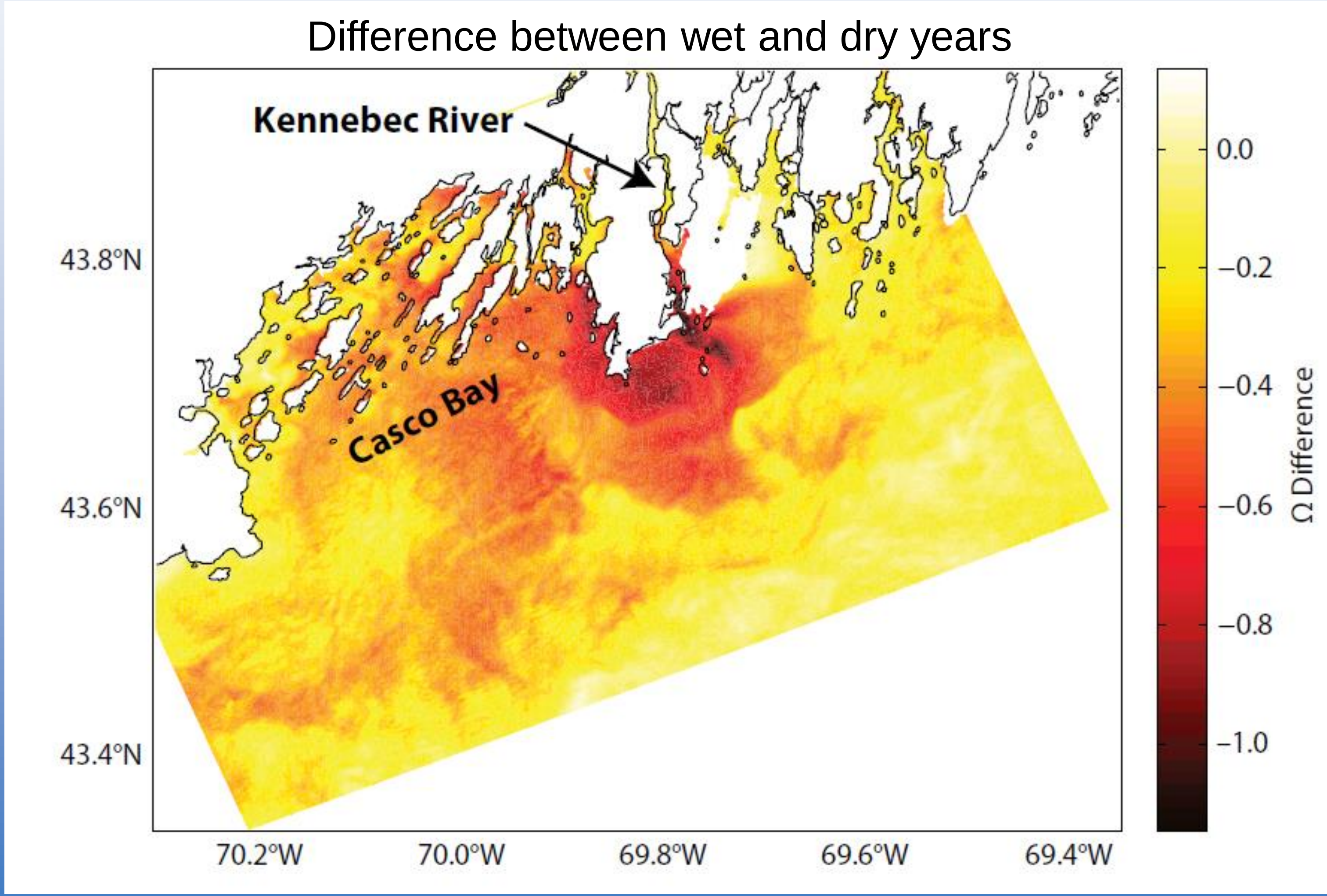
Nutrient pollution leads to acidification

Aerobic respiration:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$



Freshwater sources can also cause low omega



Gledhill et al. 2015, Oceanography

Coastal/Estuarine Acidification

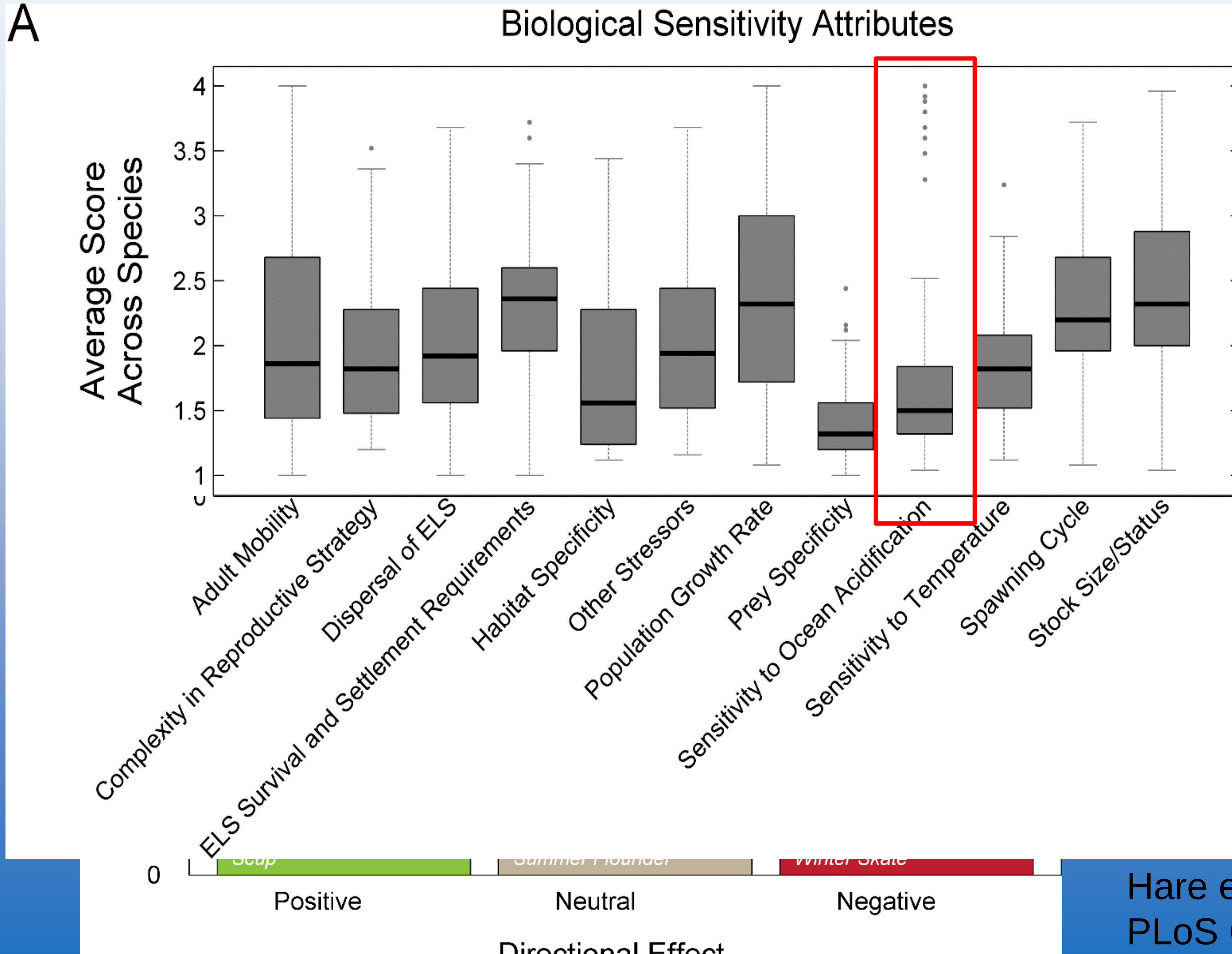
Biologically driven acidification in some cases stronger signal than atmospheric

Biological in this case includes both natural and perturbed conditions because of human excess nutrient inputs

Some "coastal acidification" is natural but we have enhanced those effects

Freshwater inputs important as well – especially if low alkalinity

A lot of New England species are sensitive to climate change

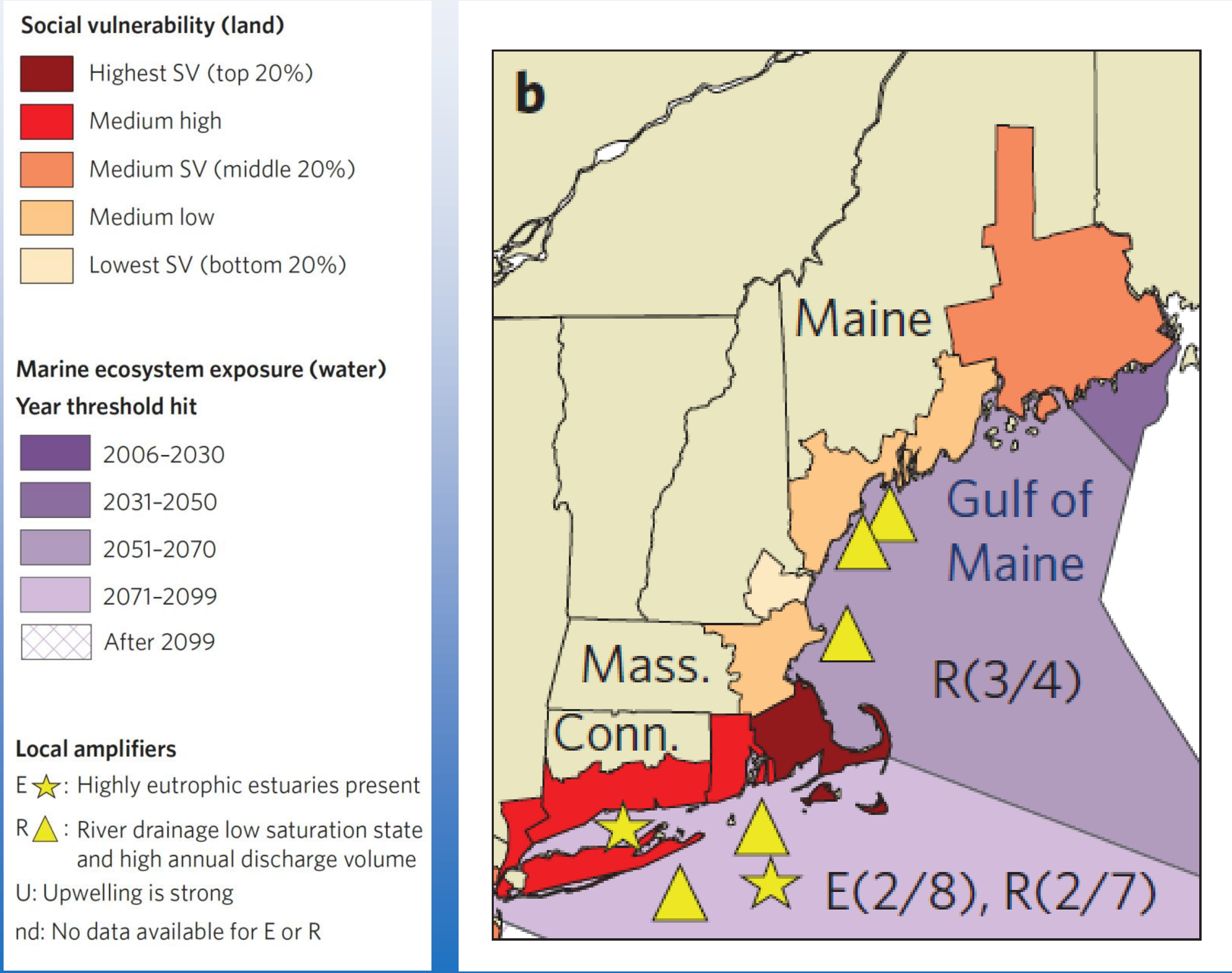


nfidence

ce in

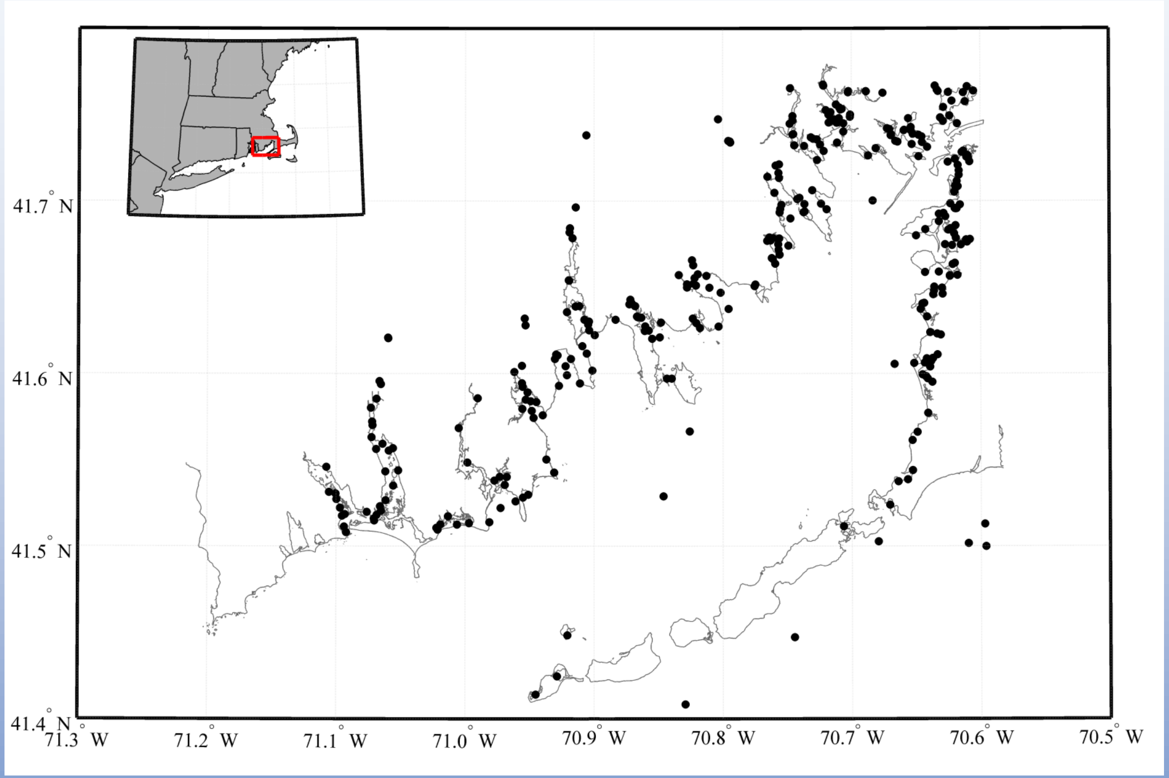
Hare et al. 2016, PLoS One

And MA is particularly vulnerable



Ekstrom et al. 2015, Nature Climate Change

Buzzards Bay



- Site of historical, long-term water quality monitoring by the Buzzards Bay Coalition
- Began in 1992, and more than 200 stations are monitored during summer months by volunteers
- Water quality around Buzzards Bay has been declining

Purpose

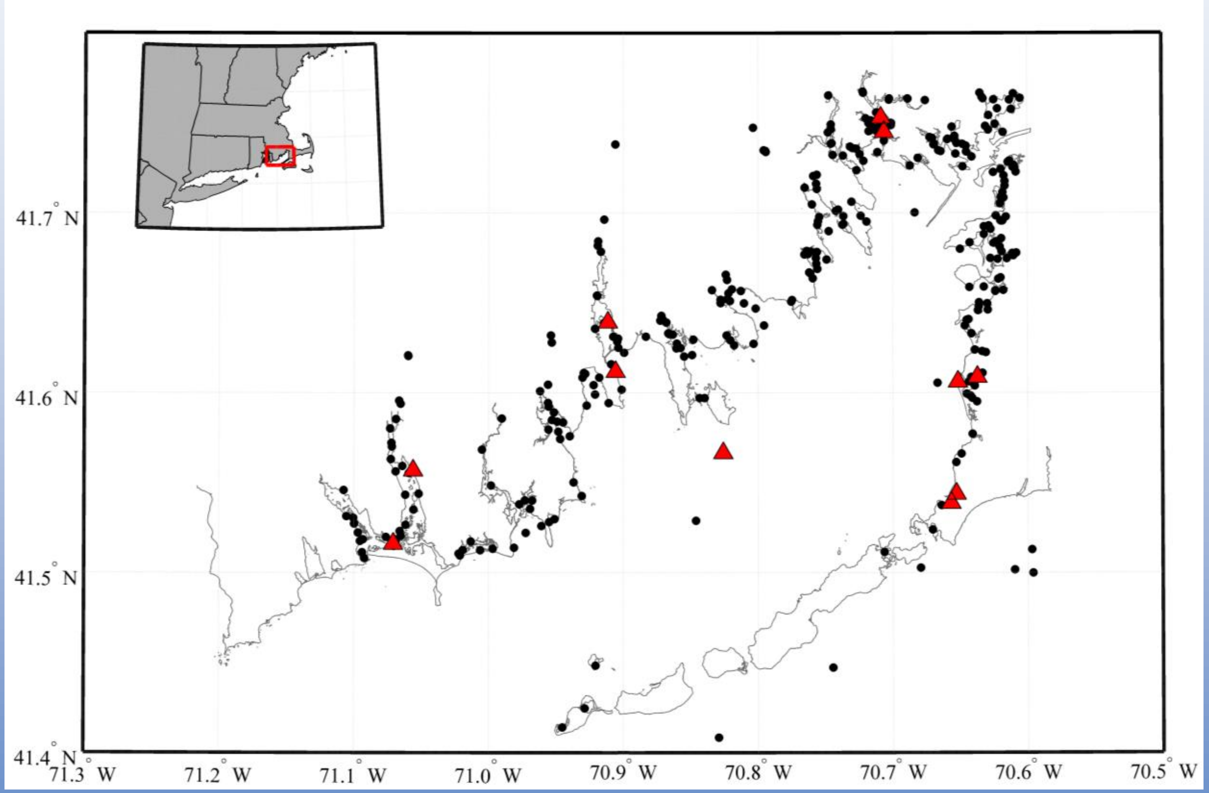
Characterize seasonal and multi-year variations in carbonate chemistry:

- Under critical management conditions - targeting time periods when we might expect peak stress
- Across different estuary types – river vs. groundwater fed
- Across a range of nitrogen loads and impairment
- Within-estuary variation

Can we separate biological variations from mixing and dilution of seawater with freshwater?

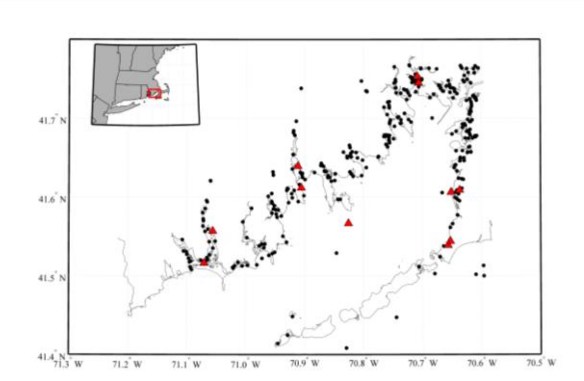
Buzzards Bay

- New sampling added:
    - Carbonate chemistry and nutrients monthly June 2015 – Sept 2017

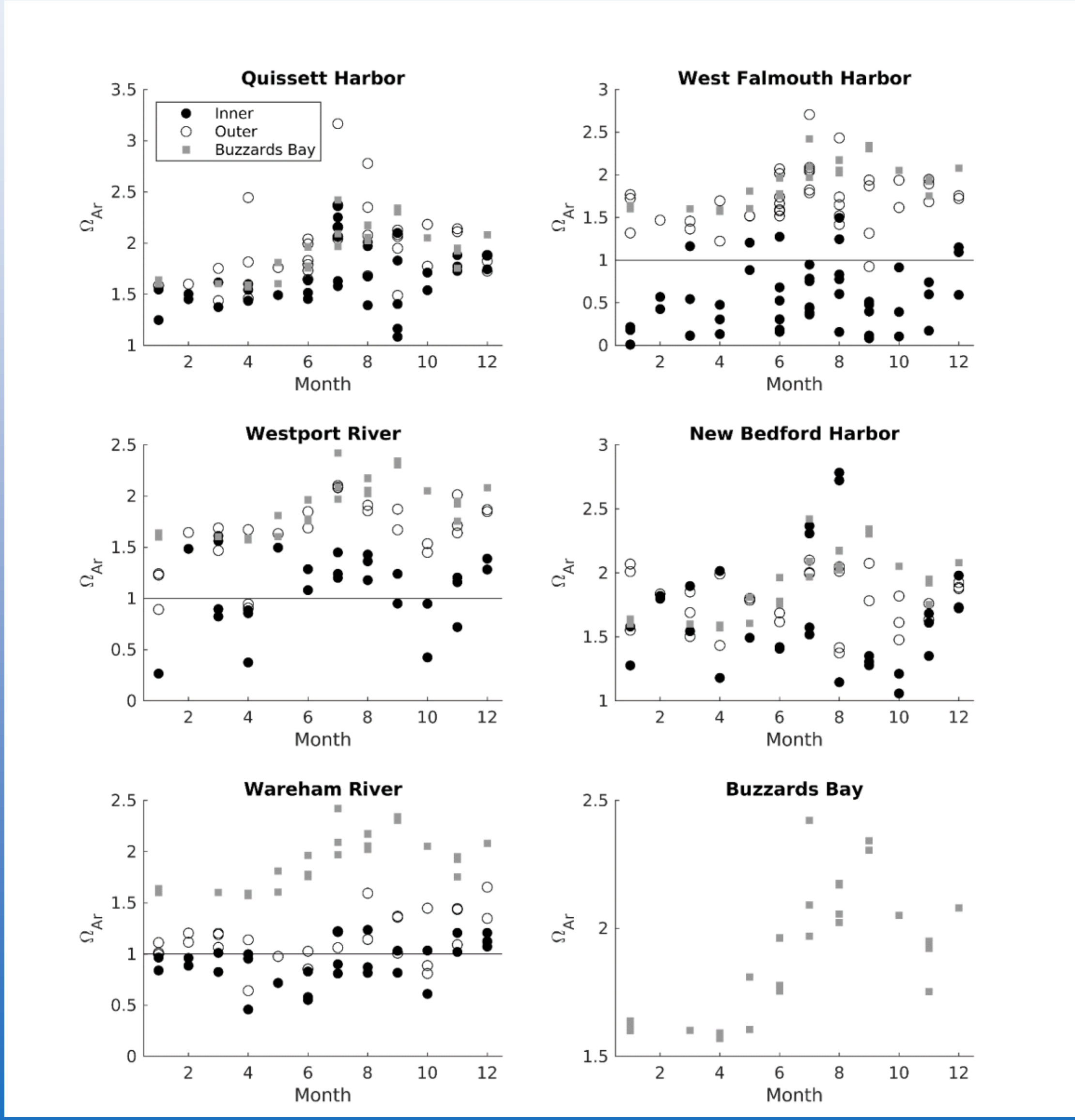


From DIC and ALK bottle measurements, we can calculate pH, pCO2, and saturation state.

Seasonal Patterns



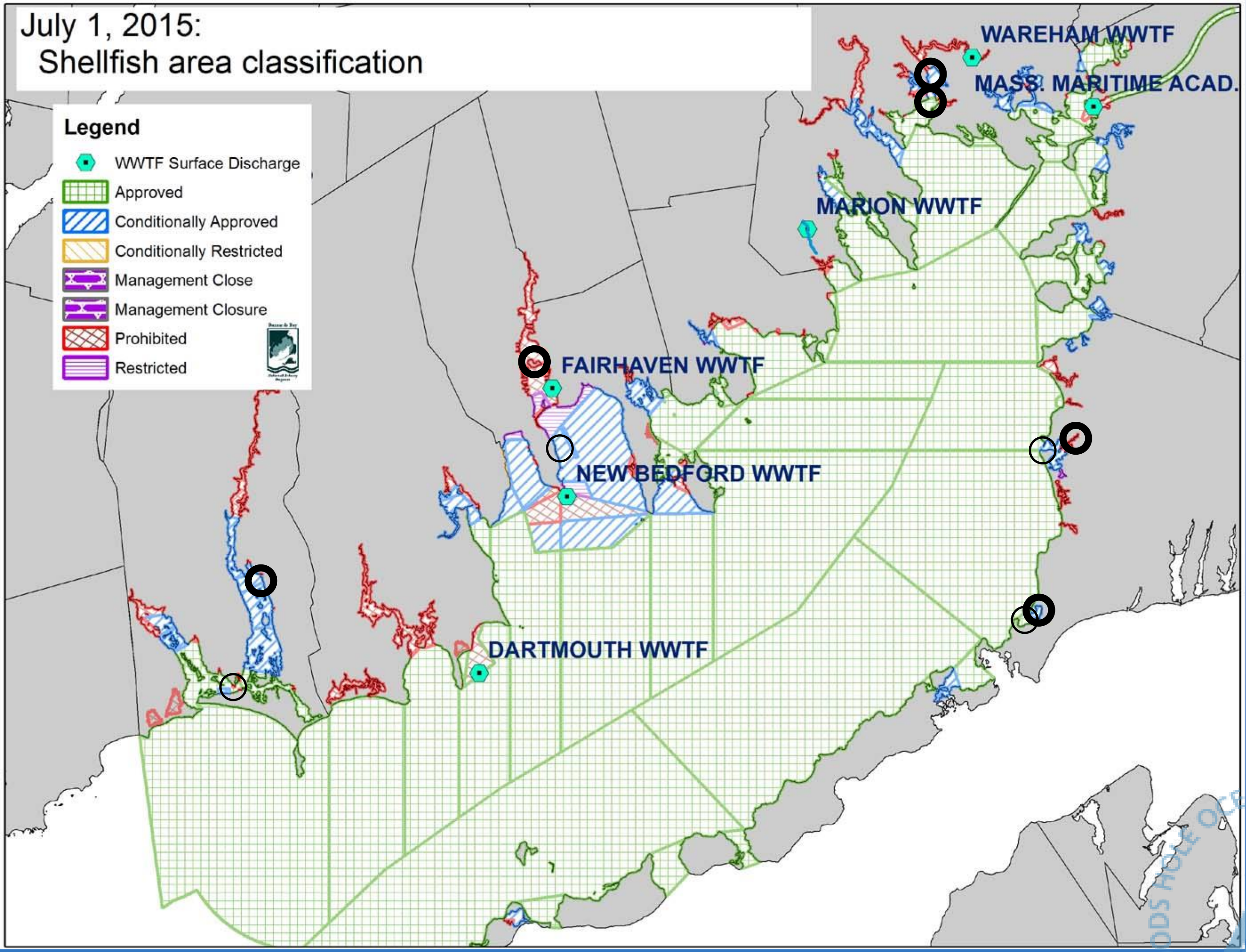
Aragonite saturation state



Ω<1
corrosive

Buzzards Bay shellfish area classification

Ω<1
corrosive

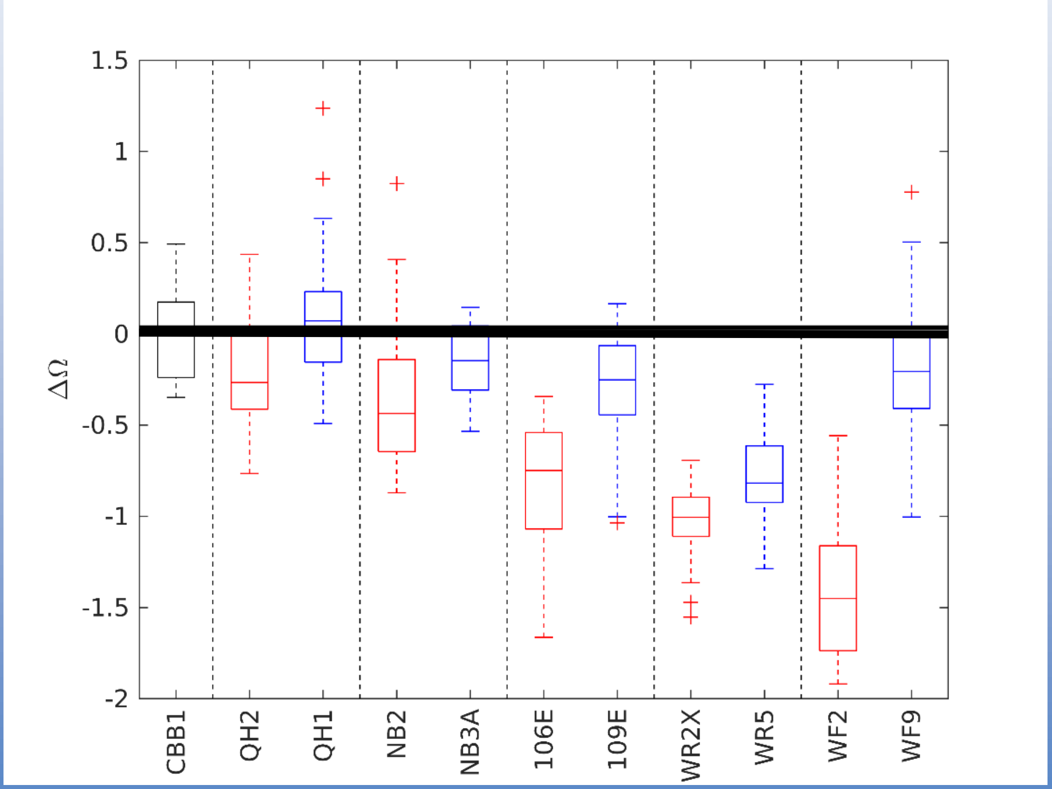


Buzzards Bay National Estuary Program

What causes the variation in saturation state we observe?

$$\Delta\Omega = \Omega_{obs} - \Omega_{reference}$$

Ω<1
corrosive



$$\Delta\Omega = \Delta\Omega_T + \Delta\Omega_S + \Delta\Omega_{mixing} + \Delta\Omega_{biology} + error$$

Temperature

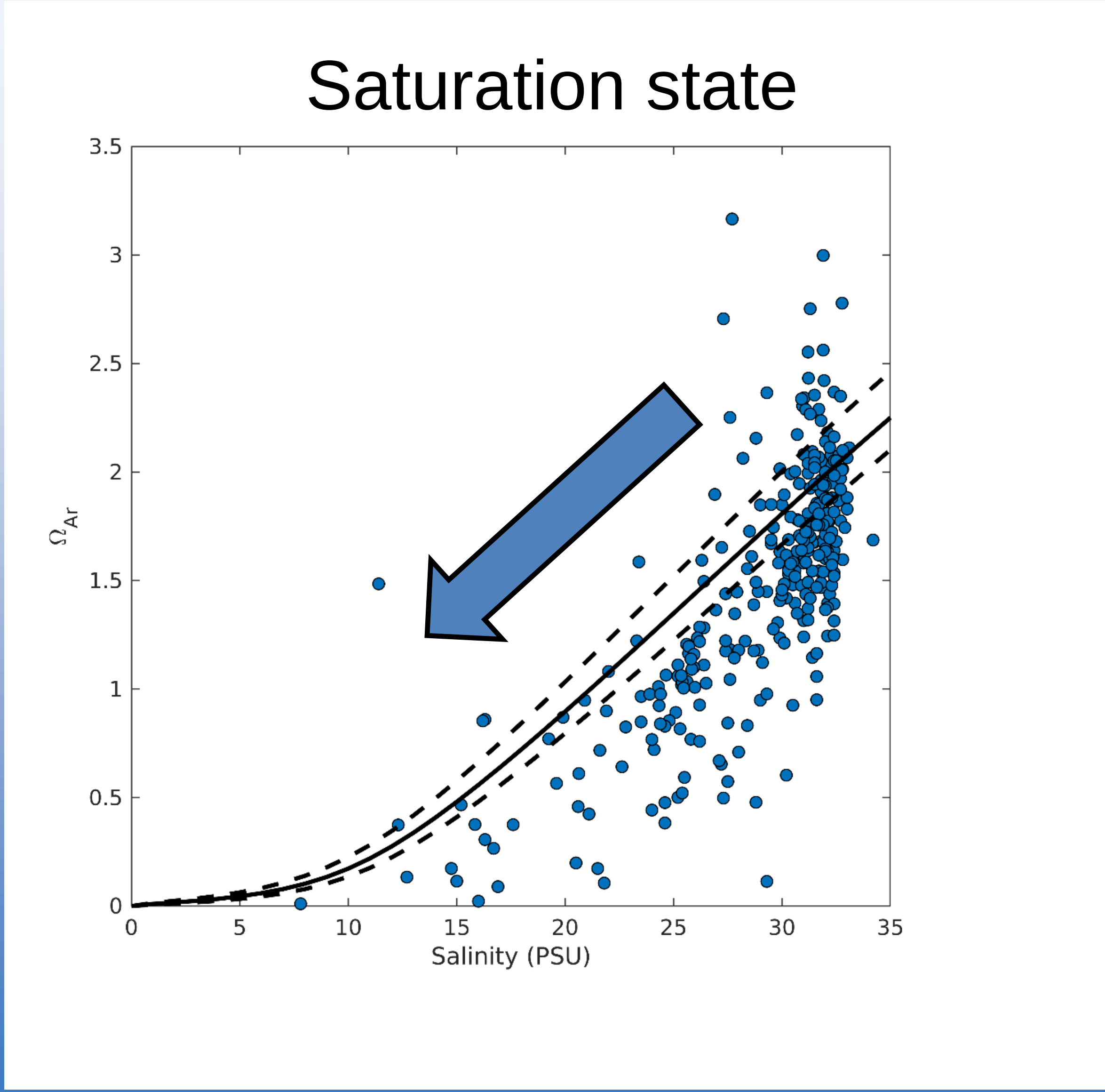
Salinity

Mixing with freshwater

Biological processes

Dilution effects on saturation state

Ω<1
corrosive



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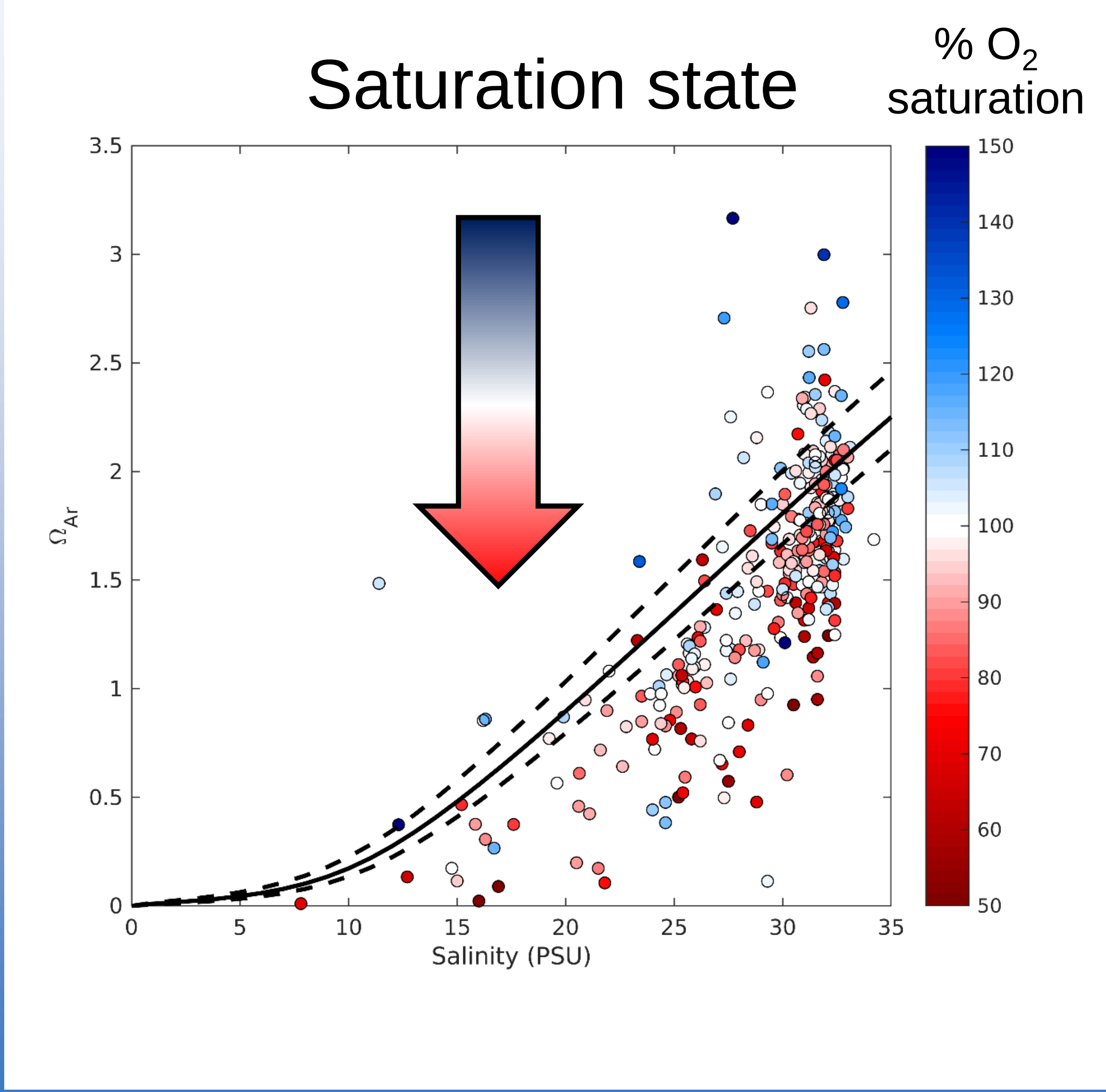
Biological effects on saturation state



Ω<1

corrosive

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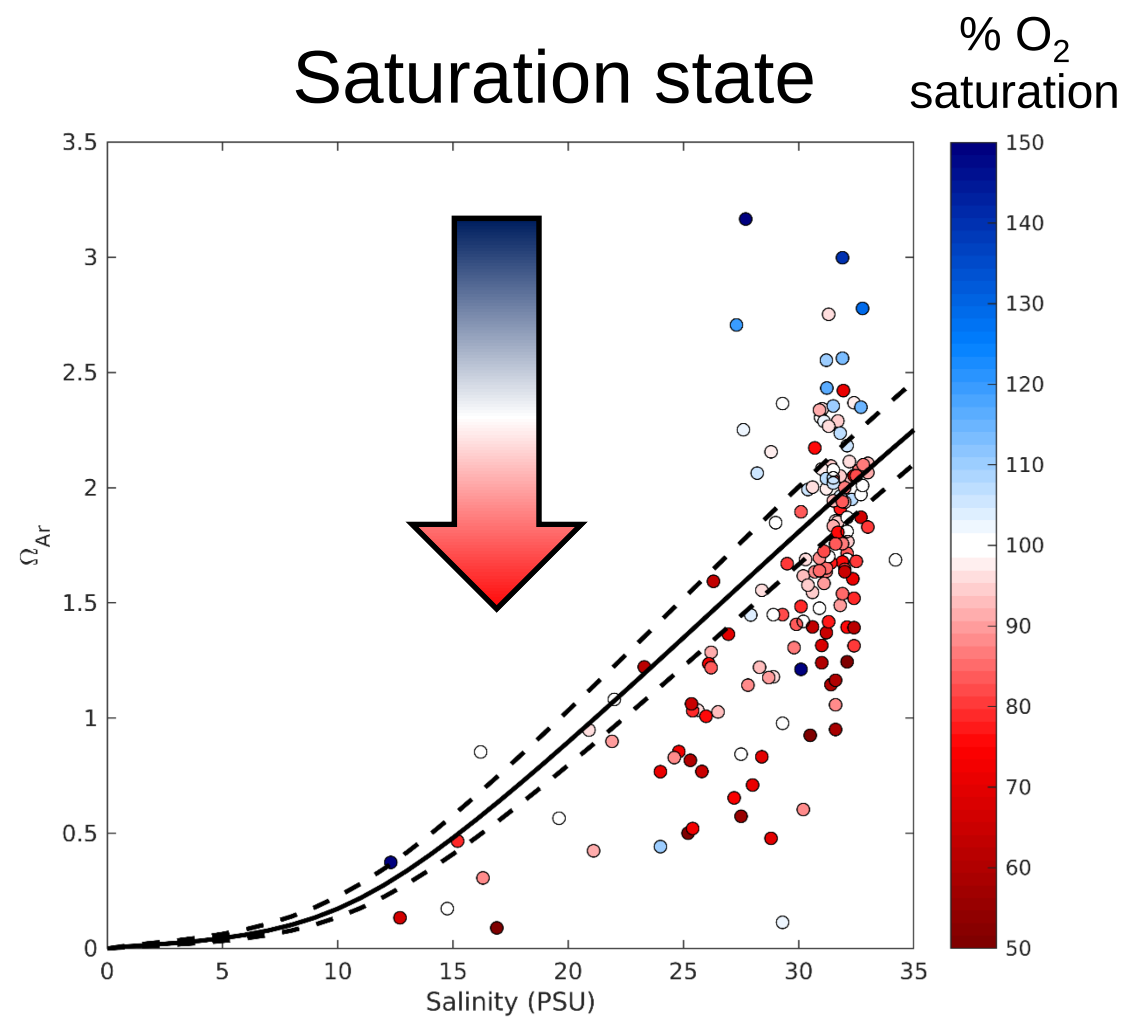
Biological effects on saturation state

Ω<1
corrosive

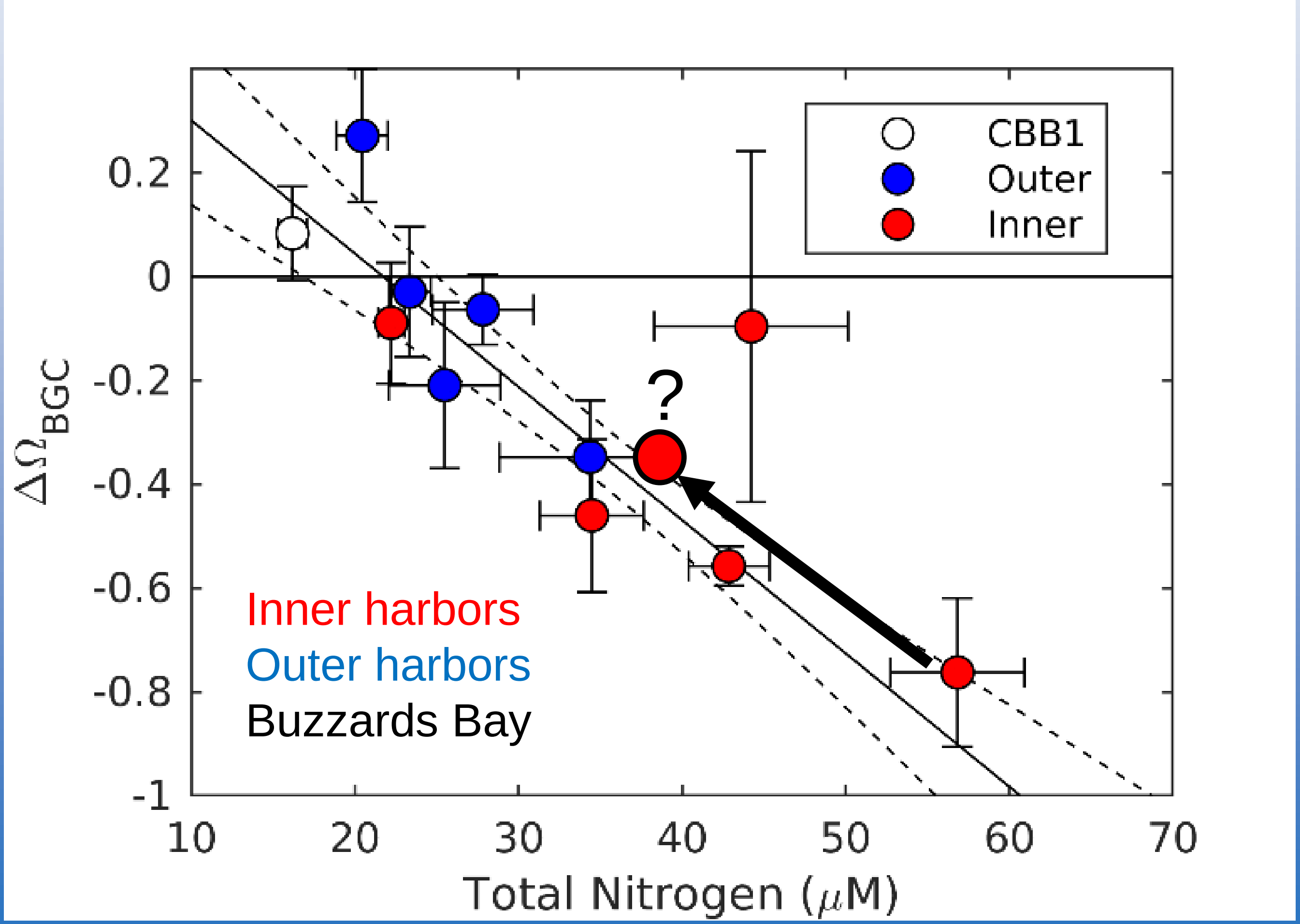


Especially strong during the "growing season"

$$\Delta\Omega = \Delta\Omega_T + \Delta\Omega_S + \Delta\Omega_{mixing} + \Delta\Omega_{biology} + error$$

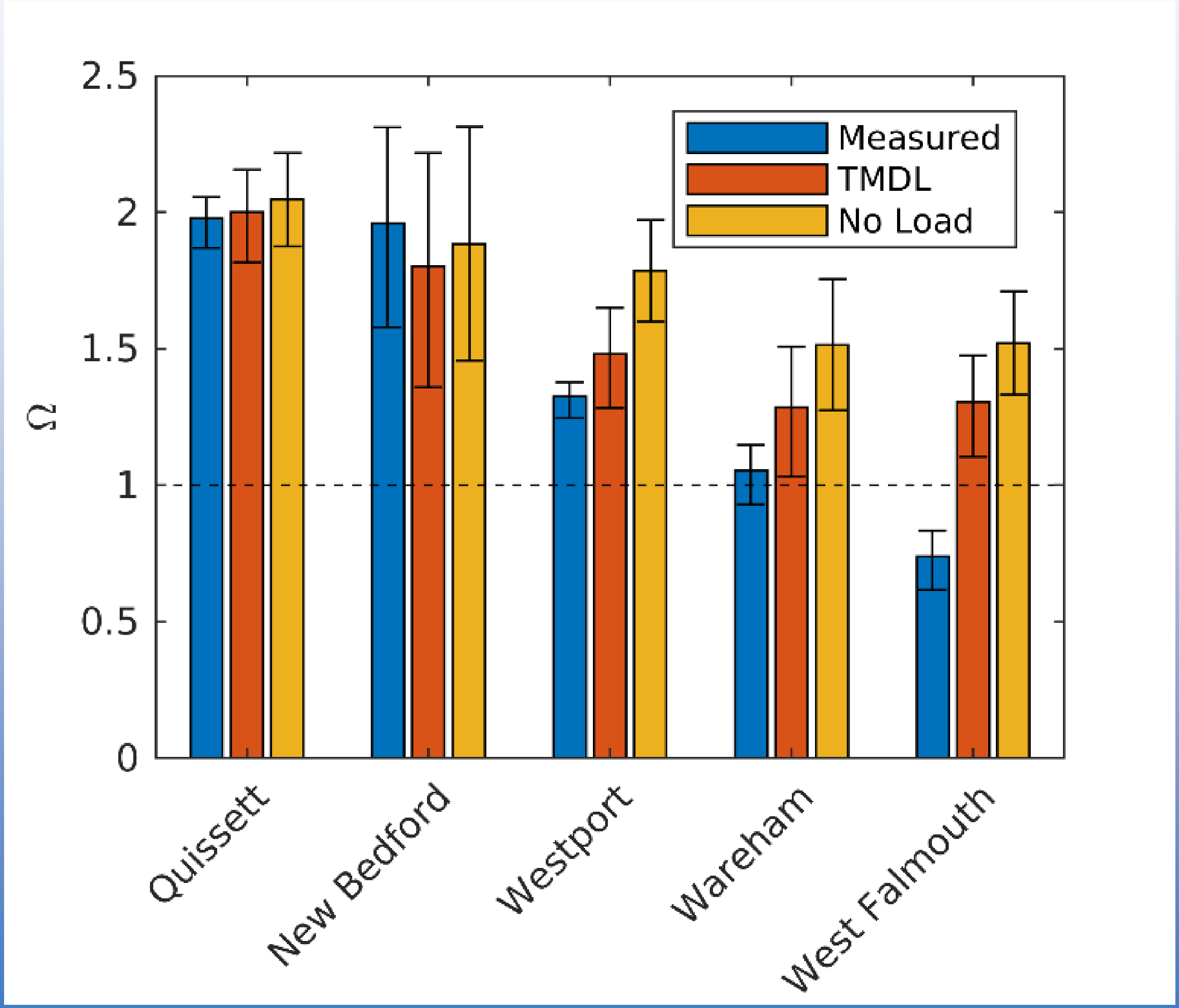
How much of the variation in omega is from eutrophication?

$$\Delta\Omega = \boxed{\Delta\Omega_T + \Delta\Omega_S + \Delta\Omega_{mixing}} + \boxed{\Delta\Omega_{biology}} + error$$



Future loading scenarios

Ω<1
corrosive



Threshold and No Anthropogenic Load TN concentrations from MEP reports

Conclusions

Eutrophication and relative freshwater inputs both important in driving estuarine saturation state variability

Critical shellfishing areas in estuarine waters often experience saturation states less than 1 indicating significant vulnerability

Framework could provide estimates of additional benefits to attaining nitrogen loading management targets

Thanks to collaborators, funders, field help

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buzzards BAY COALITION

Sea Grant Massachusetts Institute of Technology

Woods Hole Sea Grant

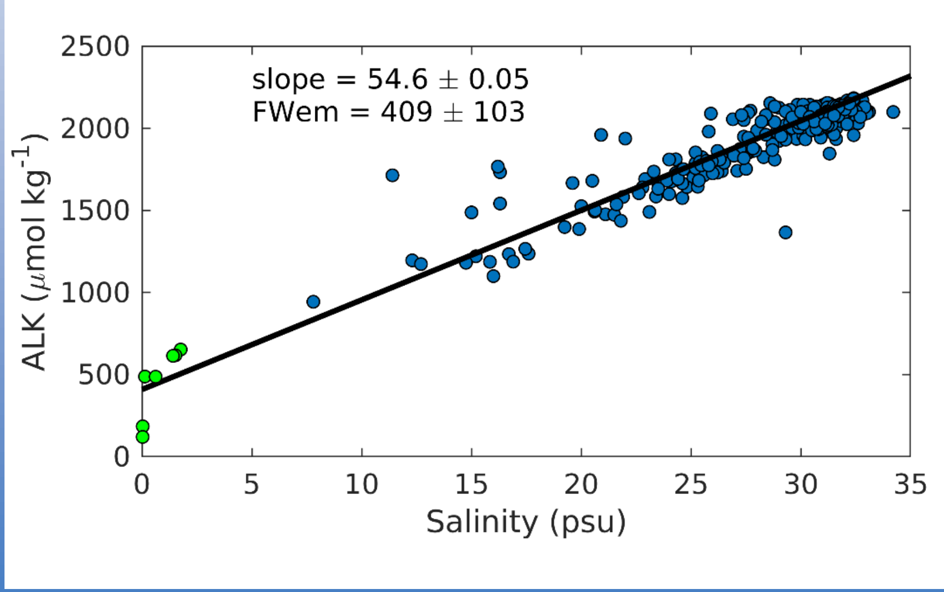
MacArthur Foundation

Woods Hole Oceanographic Institution 1930

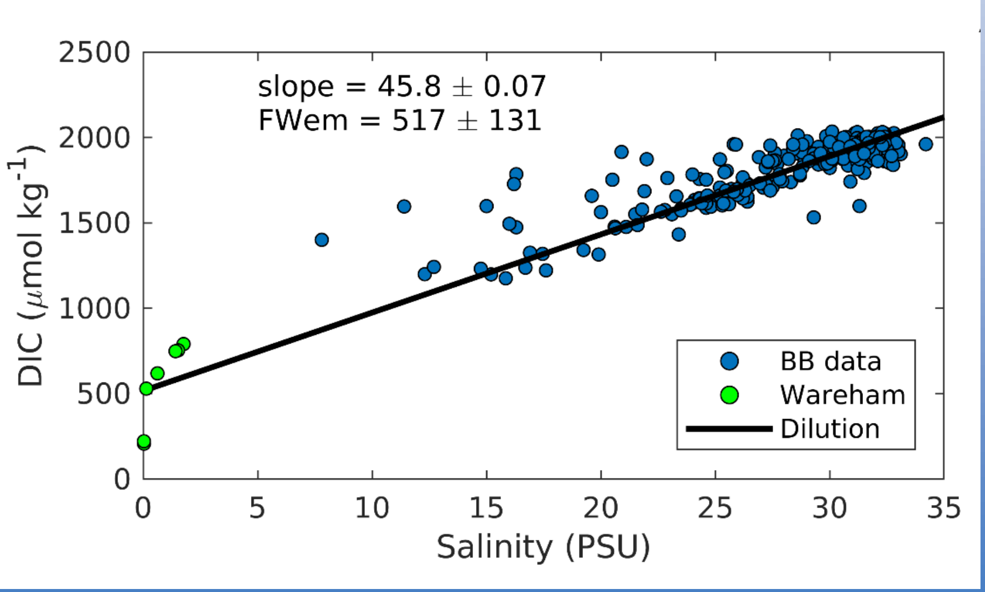
Dilution

Dilution drives first order differences in carbonate chemistry we see across all embayments regardless of underlying water quality.

Alkalinity



Dissolved inorganic carbon



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