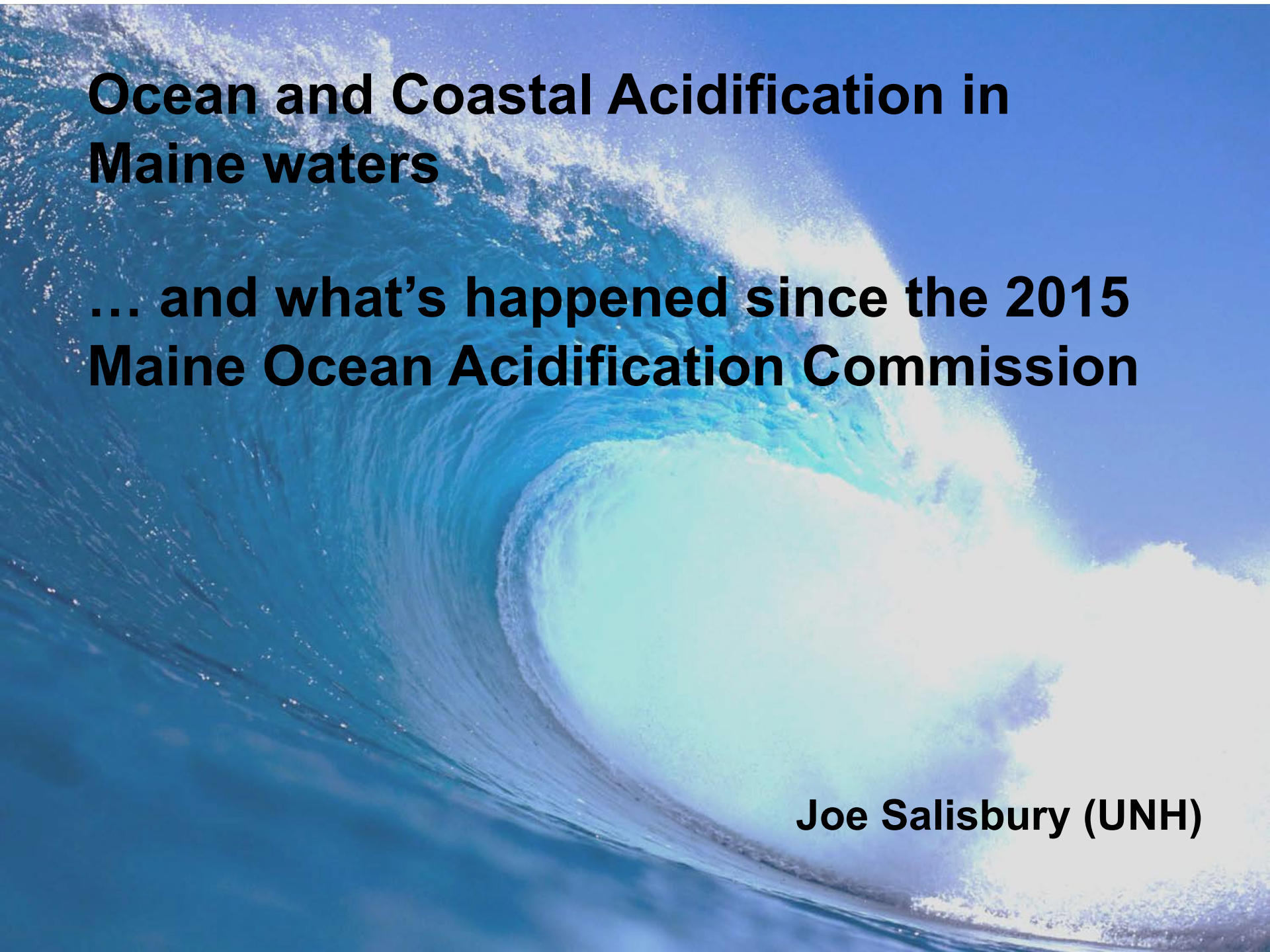

Ocean and Coastal Acidification in Maine waters

… and what's happened since the 2015 Maine Ocean Acidification Commission

Joe Salisbury (UNH)

Outline

a) Ocean Acidification
   - Background
   - Maine's unique setting

b) Acidification processes near to shore

c) What's happened since the report?
   - Progress
   - Items still pending

STATE OF MAINE
126th LEGISLATURE
SECOND REGULAR SESSION

Final Report
of the

COMMISSION TO STUDY THE EFFECTS OF COASTAL AND OCEAN ACIDIFICATION AND ITS EXISTING AND POTENTIAL EFFECTS ON SPECIES THAT ARE COMMERCIALLY HARVESTED AND GROWN ALONG THE MAINE COAST

January 2015

Members:
Sen. Christopher K. Johnson, Chair
Sen. Brian D. Langley
Rep. Michael G. Devin, Chair
Rep. Wayne R. Parry
Rep. Joan W. Welsh
Dr. Suzanne N. Arnold
Dr. Mark A. Green
Jon Lewis
Kathleen Leyden
Dr. Larry M. Mayer
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Bill Mook
Richard Nelson
Joe Payne
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Dr. Meredith M. White

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The commission identified and unanimously adopted six overarching goals and twenty-five recommendations to achieve those goals. A synopsis of the recommendations can be found in Appendix E. The commission identified and adopted the following six goals:

1. Invest in Maine's capacity to monitor and investigate the effects of ocean acidification and determine impacts of ocean acidification on commercially important species and the mechanisms behind the impacts;

2. Reduce emissions of carbon dioxide;

3. Identify and reduce local land-based nutrients and organic carbon that contribute to ocean acidification by strengthening and augmenting existing pollution reduction efforts;

4. Increase Maine's capacity to mitigate, remediate and adapt to the impacts of ocean acidification;

5. Inform stakeholders, the public and decision-makers about ocean acidification in Maine and empower them to take action; and

6. Maintain a sustained and coordinated focus on ocean acidification.

The Earth's CO_2 budget

8.3±0.4 PgC/yr 90%

1.0±0.5 PgC/yr 10%

=

4.3±0.1 PgC/yr
46%

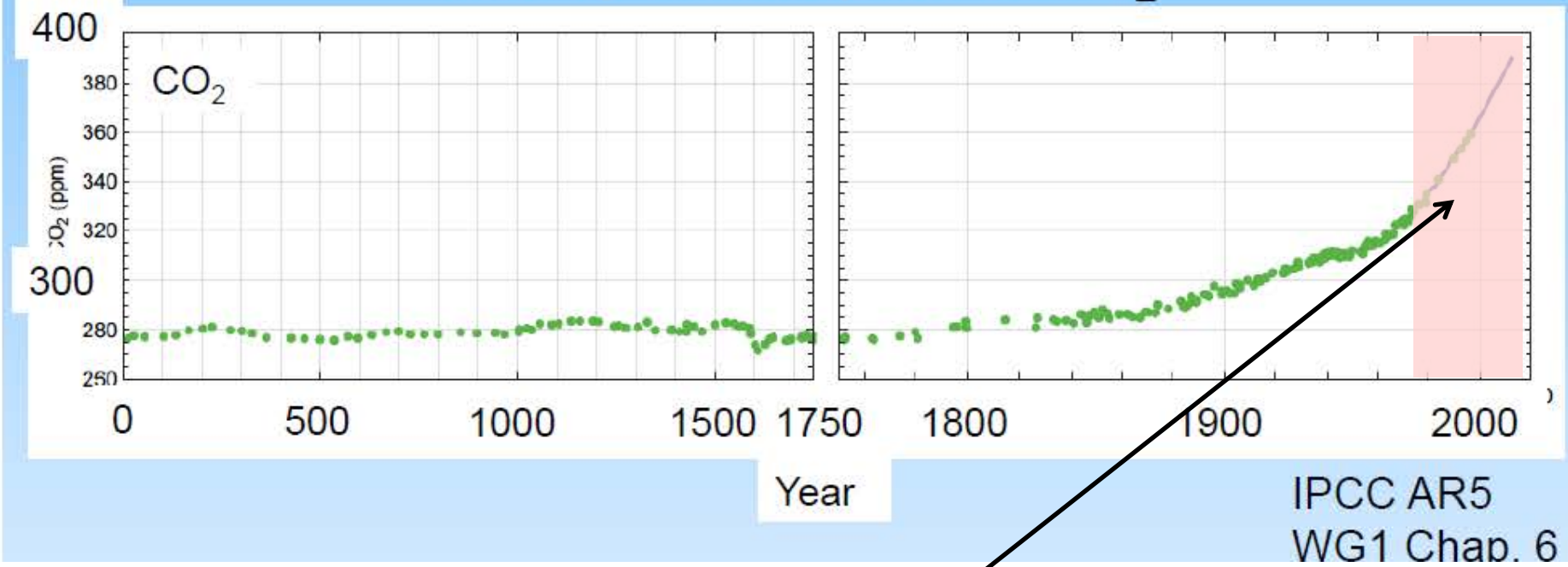
2.6±0.8 PgC/yr
28%

Calculated as the residual
of all other flux components

26%
2.5±0.5 PgC/yr

Source: Le Quéré et al. 2015

Rising Atmospheric CO_2

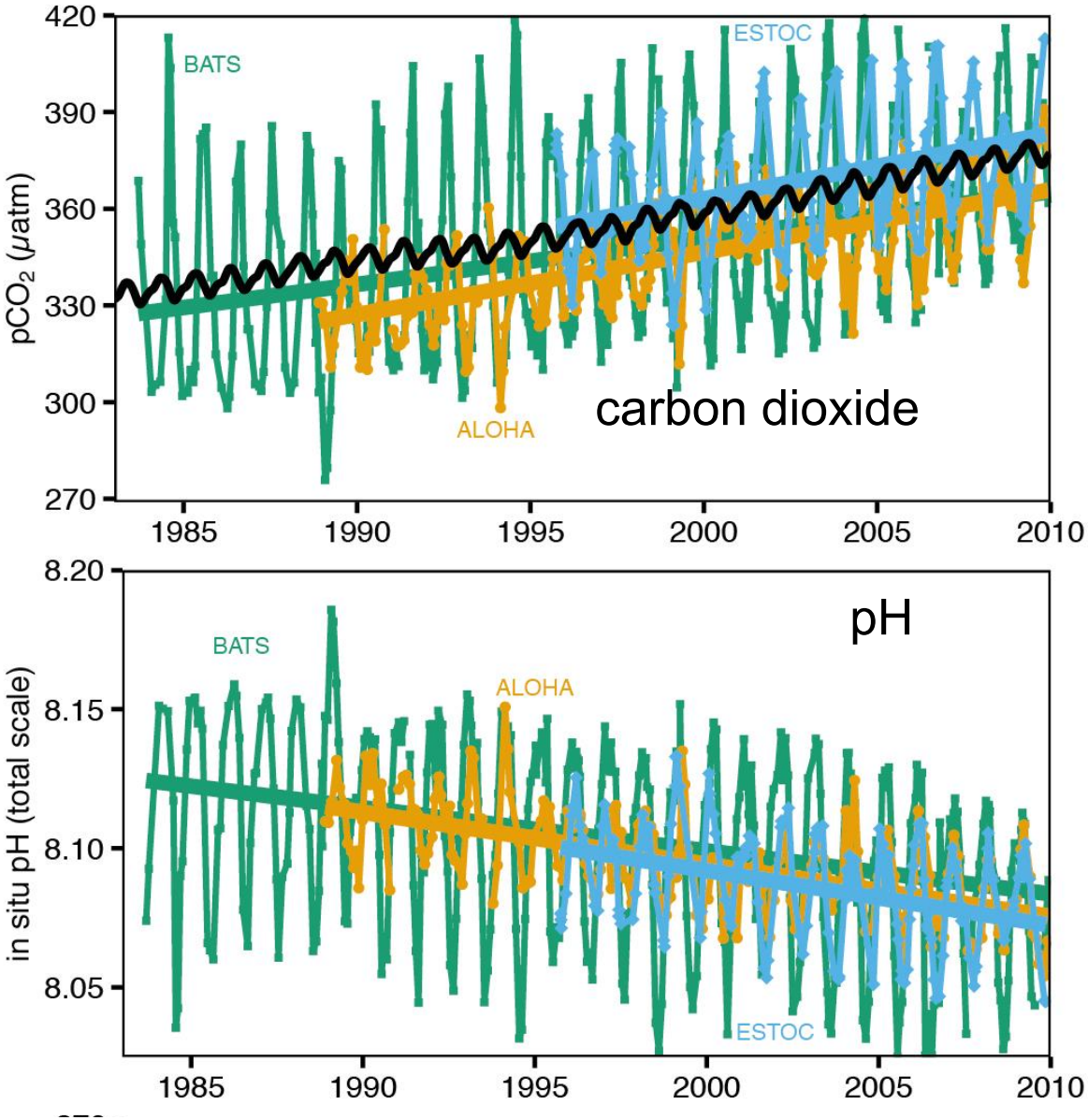


Causing global warming?

Probably, but not 100% agreement

Causing your ocean to acidify?

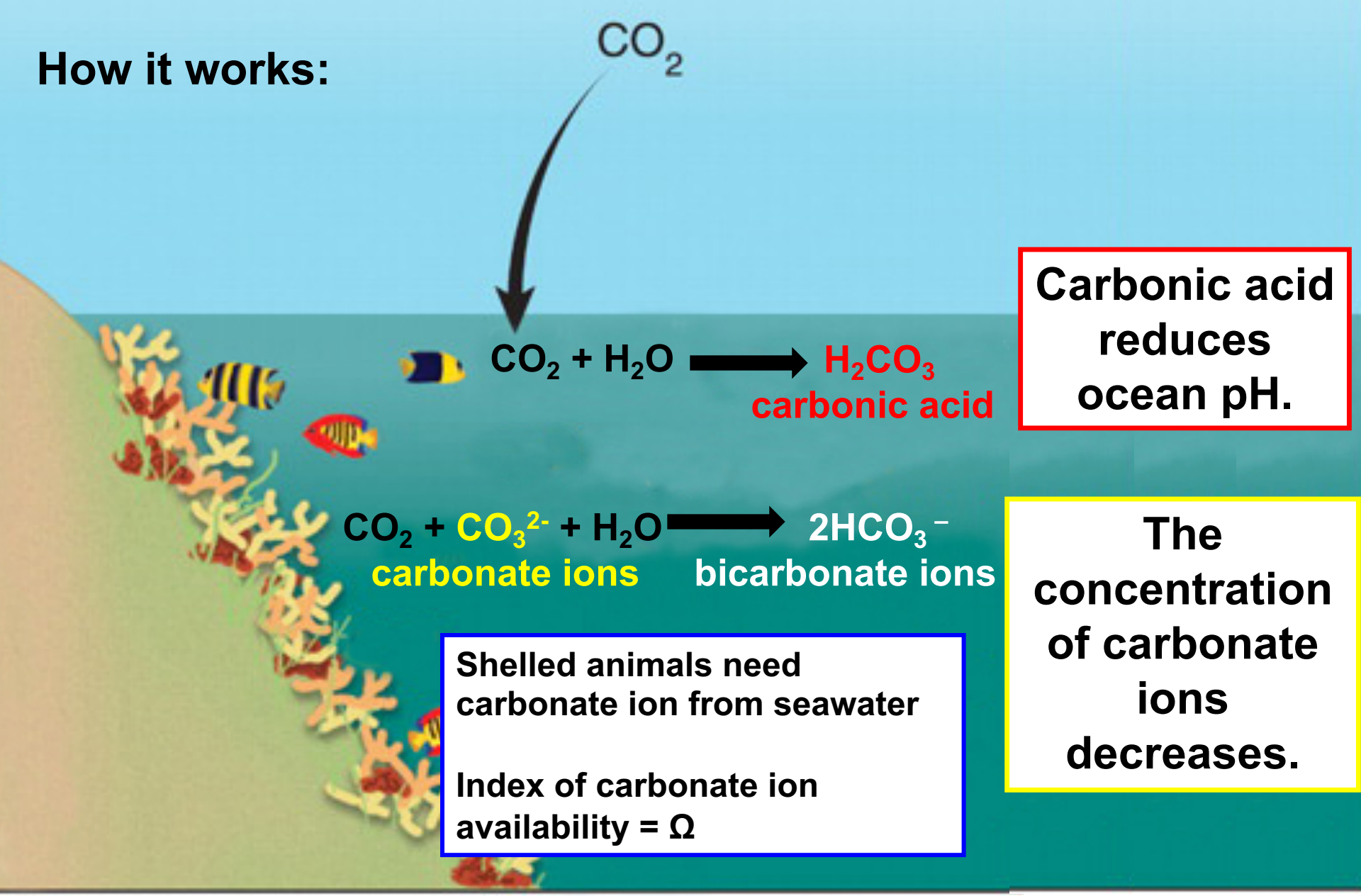
Definitely



Changing Seawater Chemistry

IPCC 2014
WG1, Chapter 3
Doney et al. Ann. Rev. Mar. Sci. 2009
Dore et al. PNAS 2009

How it works:



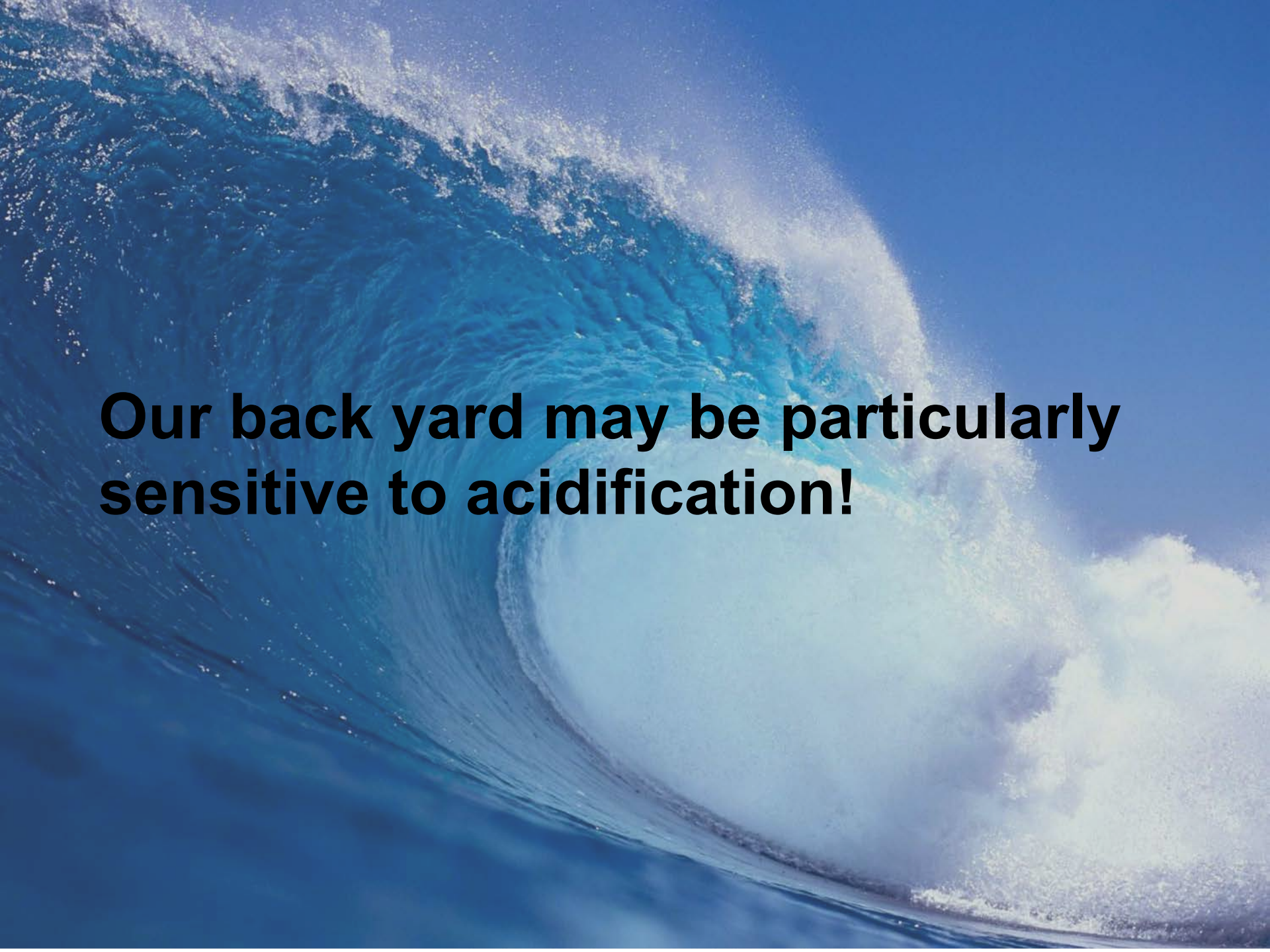
Carbonic acid reduces ocean pH.

The concentration of carbonate ions decreases.

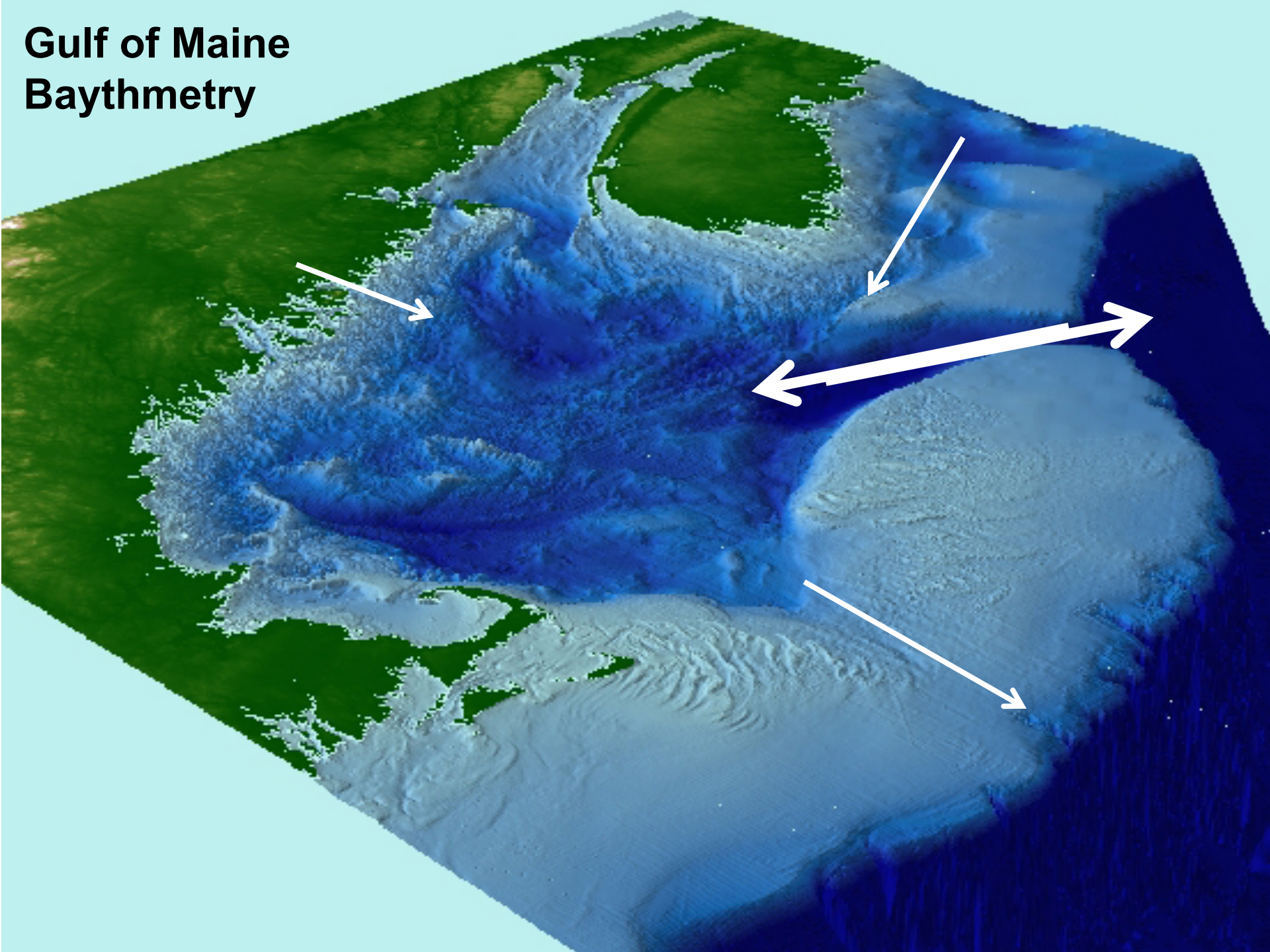
Shelled animals need carbonate ion from seawater

Index of carbonate ion availability = Ω

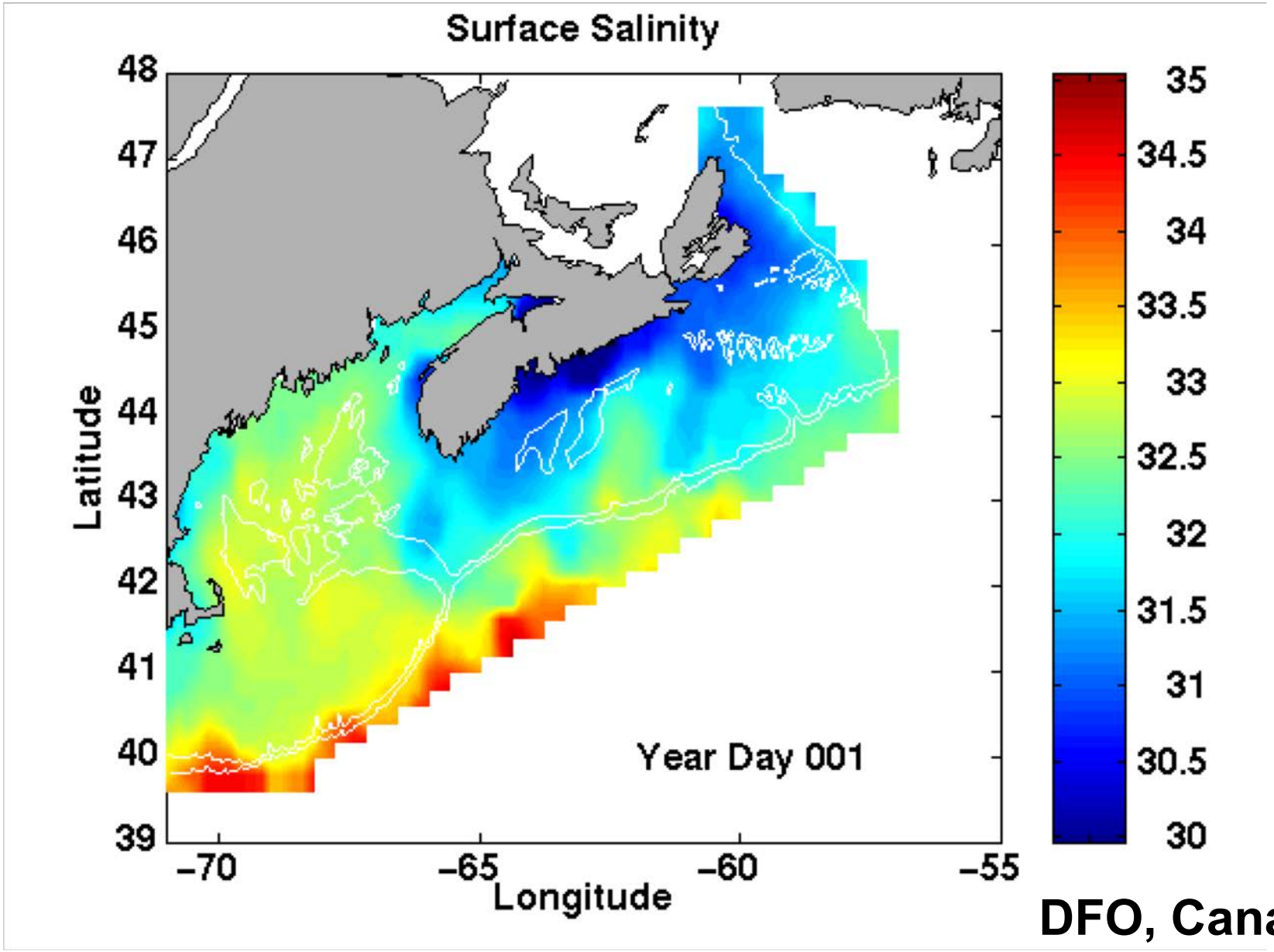
Ω > 1.6 necessary for optimal growth in some shellfish


Our back yard may be particularly sensitive to acidification!

Gulf of Maine Baythmetry

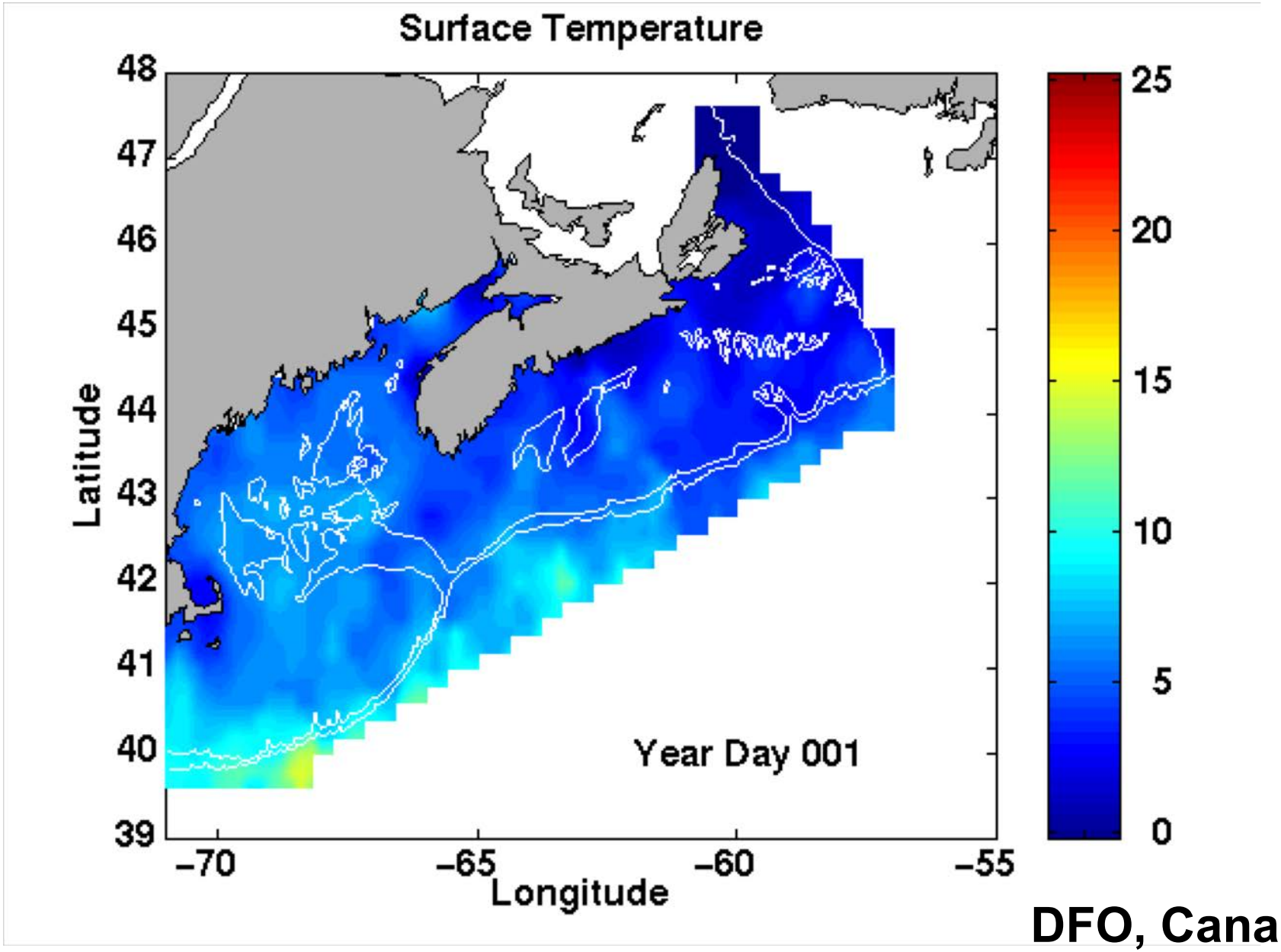


Fresher water can be more sensitive to acidification than saltier water



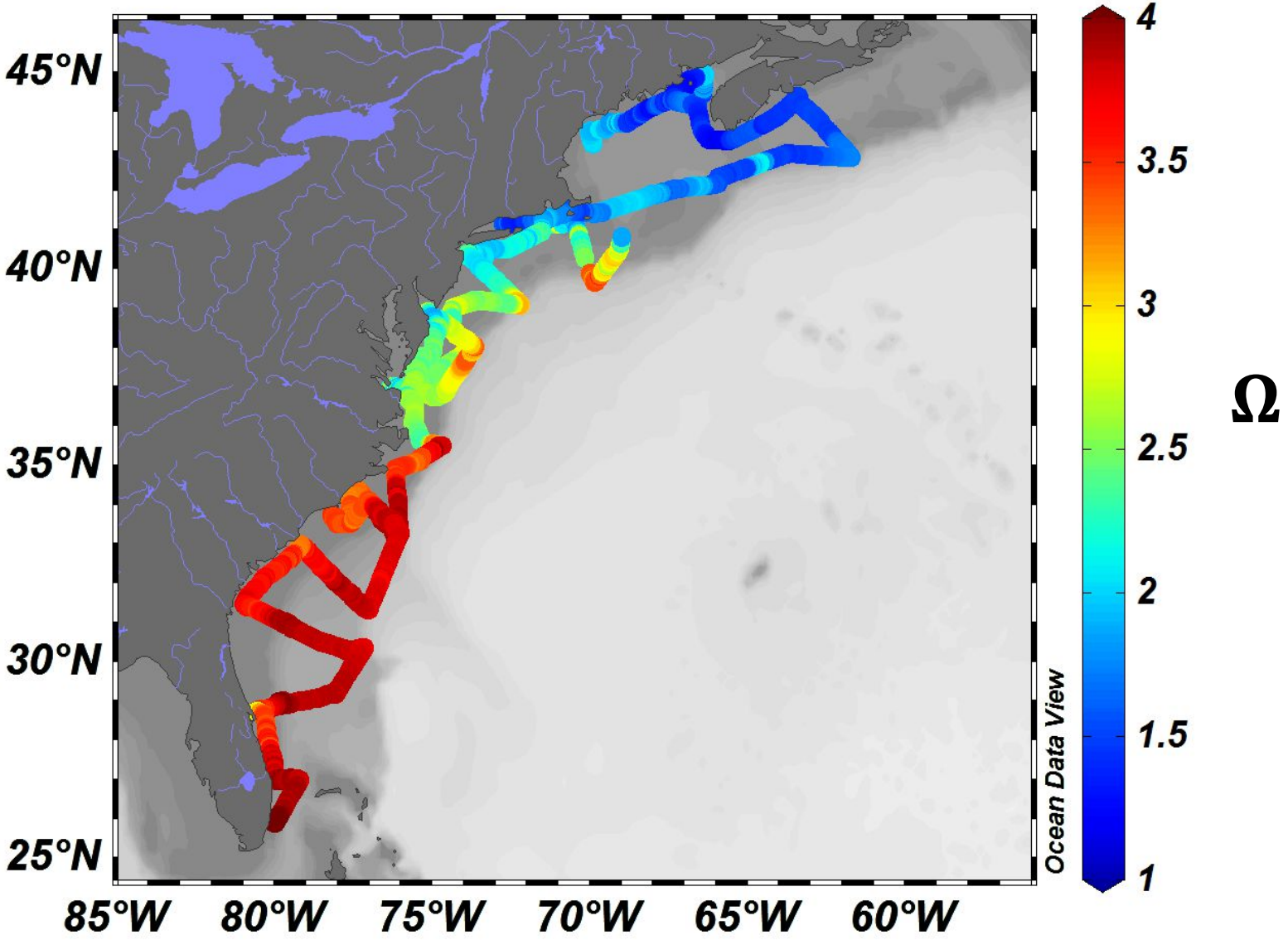
DFO, Canada

Colder water tends to be more acidic and lower omega than warmer



DFO, Canada

Ω data from the ECOA cruise, summer 2015.



Preliminary data from Cai's U Delaware group

Two more drivers: 1) an unprecedented warming

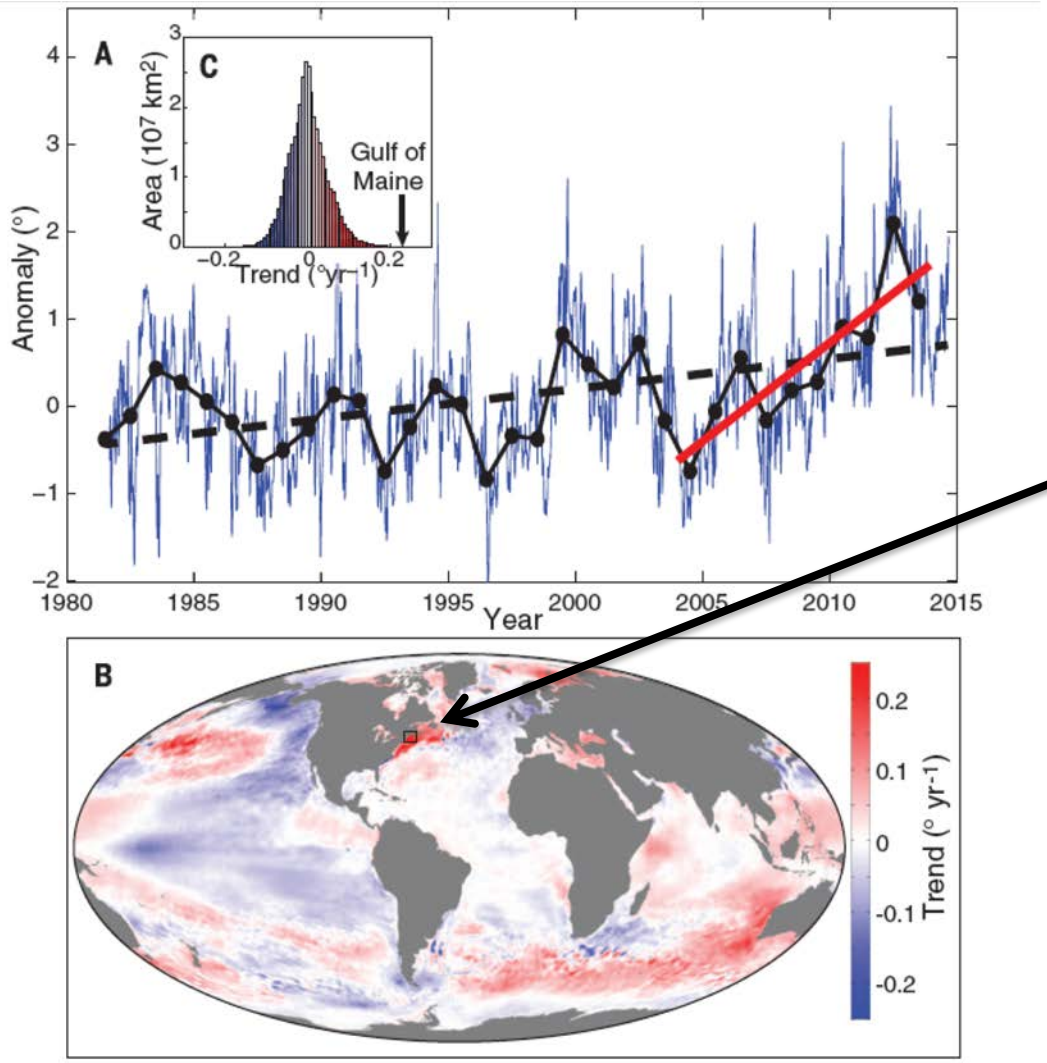
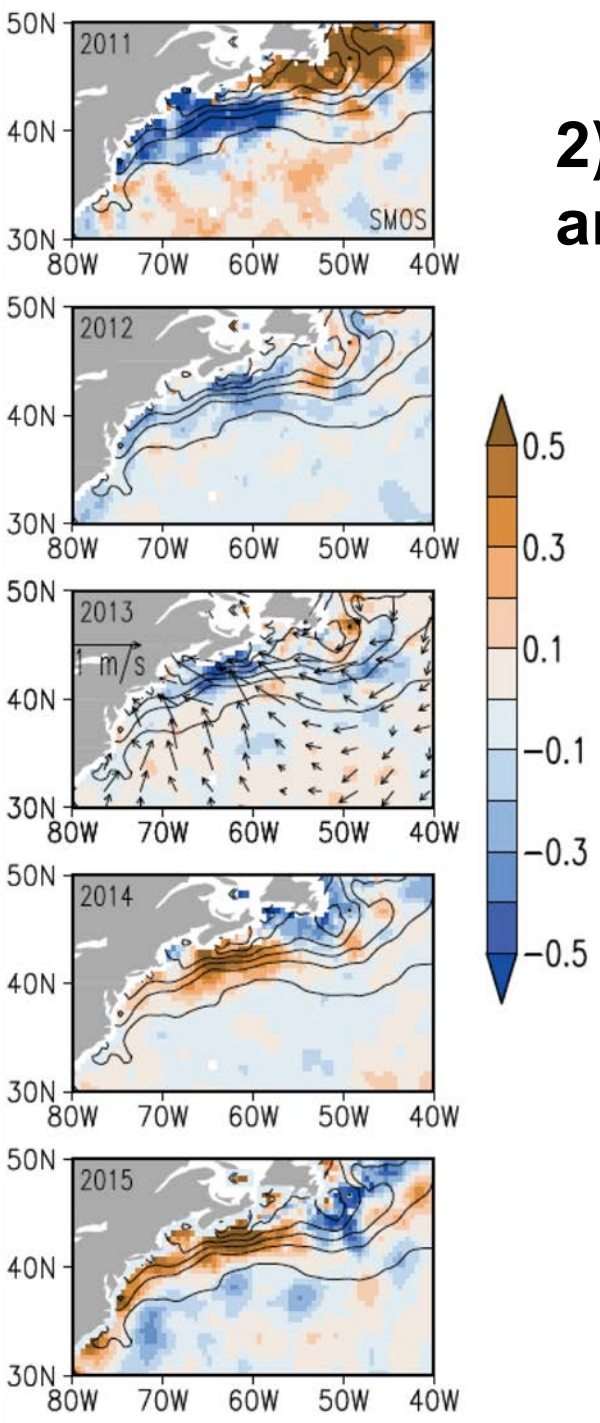


Fig. 1. Sea surface temperature trends from the Gulf of Maine and the global ocean. (**A**) Daily (blue, 15-day smoothed) and annual (black dots) SST anomalies from 1982 to 2013, showing the long-term trend (black dashed line) and trend over the decade 2004–2013 (red solid line). (**B**) Global SST trends, 2004–2013. The Gulf of Maine is outlined in black. (**C**) Histogram of global 2004–2013 SST trends, with the trend from the Gulf of Maine indicated at the right extreme of the distribution.

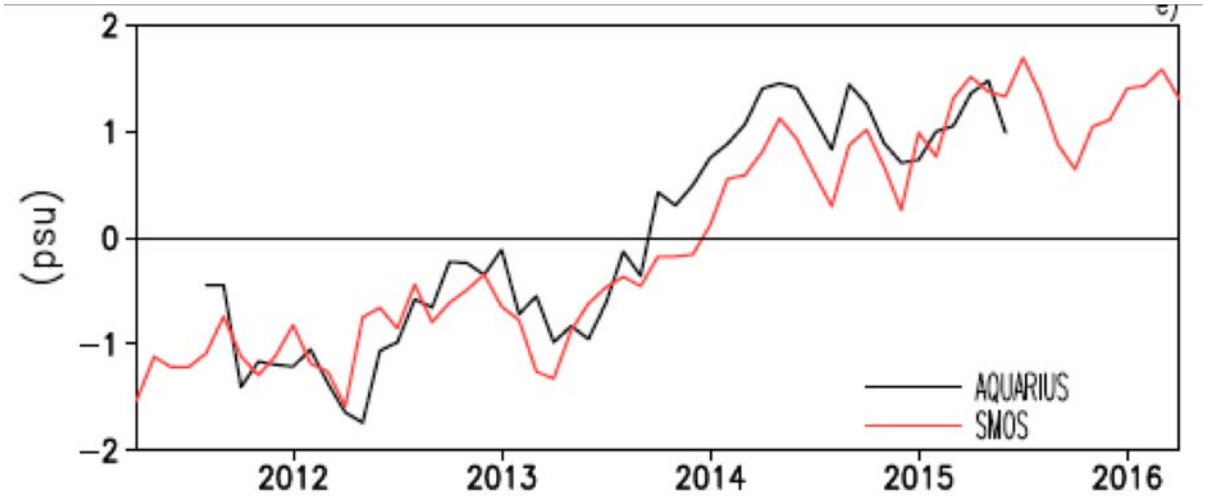
In the last decade the Gulf of Maine has warmed faster than 99.9% of the world's ocean.

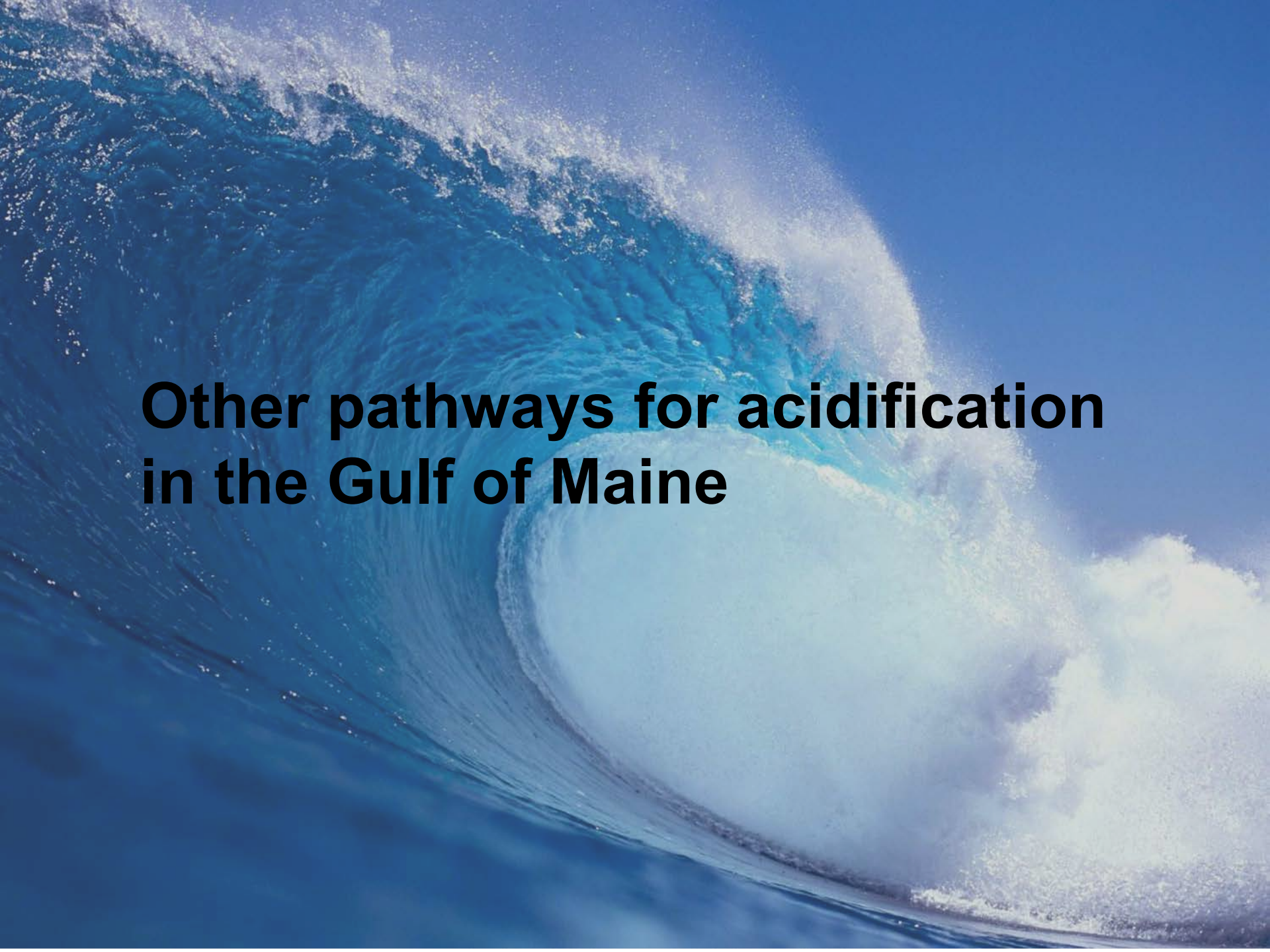
Pershing et al, Science

2) The warming was accompanied by and increase in salinity of ~1.2



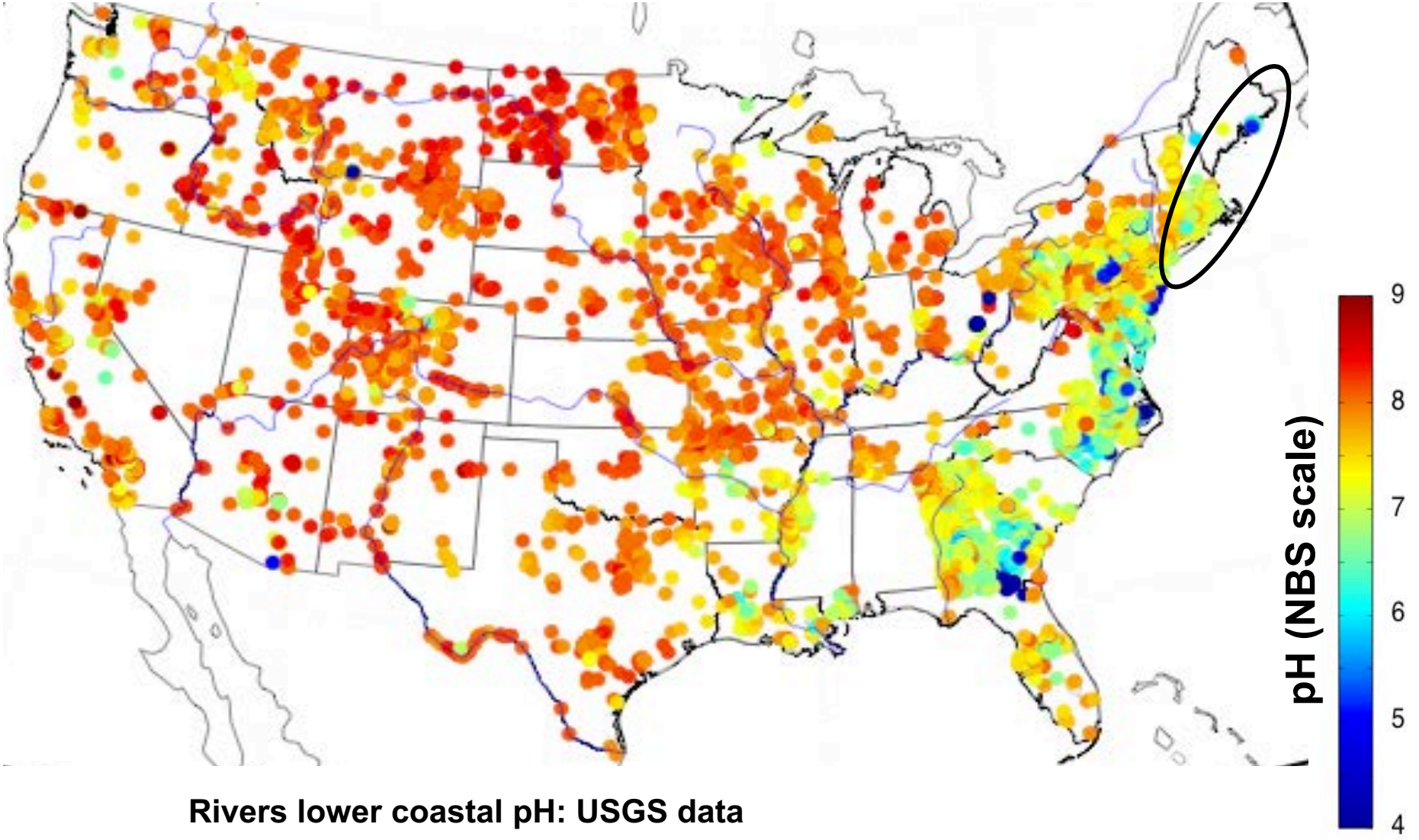
Recent salinity changes in the Northwest Atlantic (Grodsky et al, 2017)





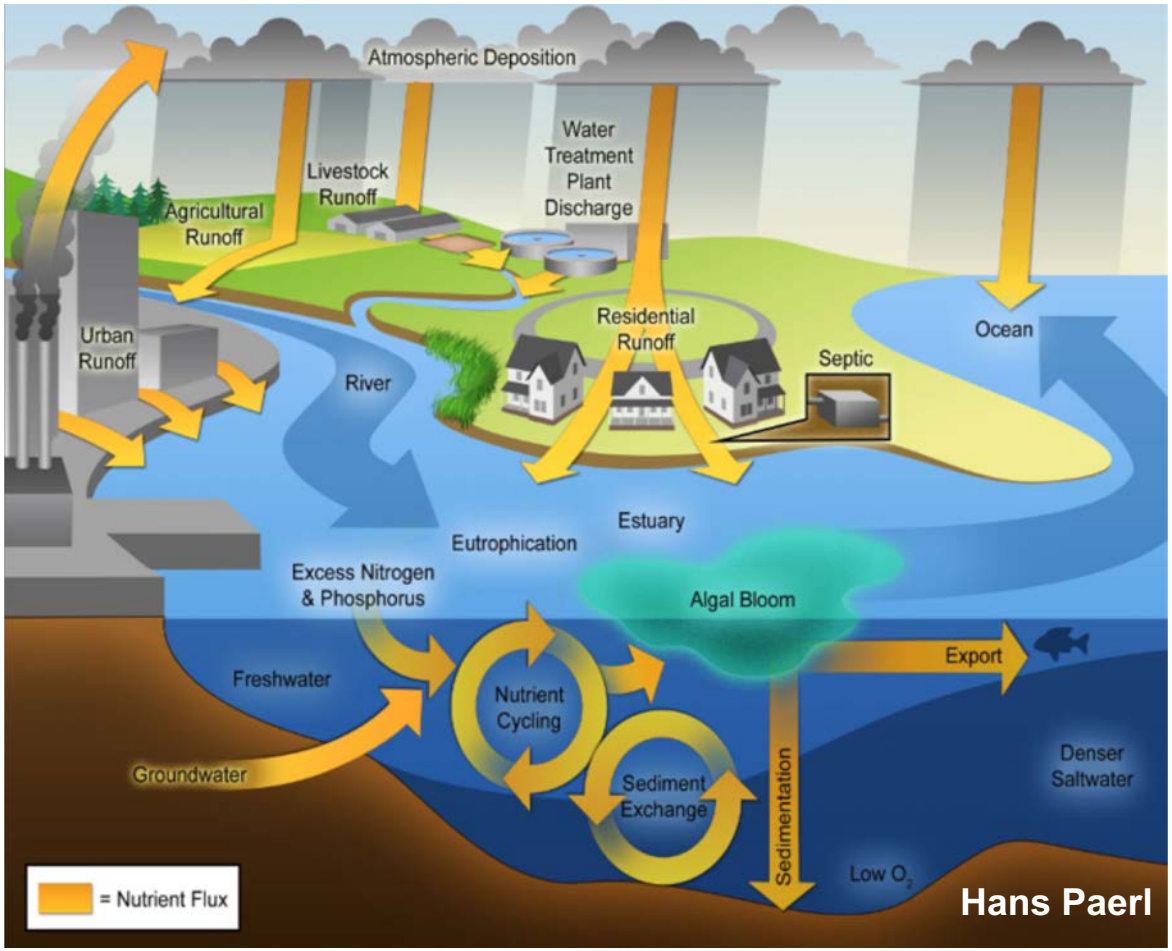
Other pathways for acidification in the Gulf of Maine

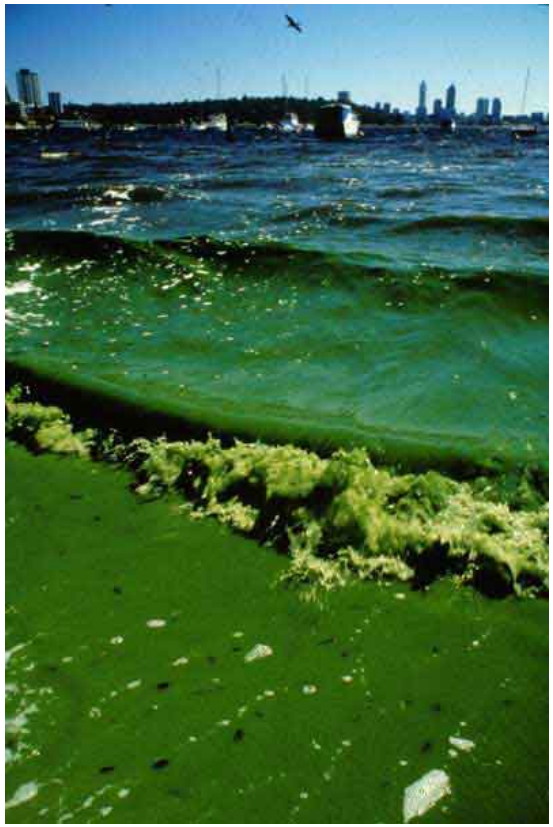
Coastal and Estuarine Acidification – Local freshwater is acidic



Rivers lower coastal pH: USGS data

Coastal “acidification”

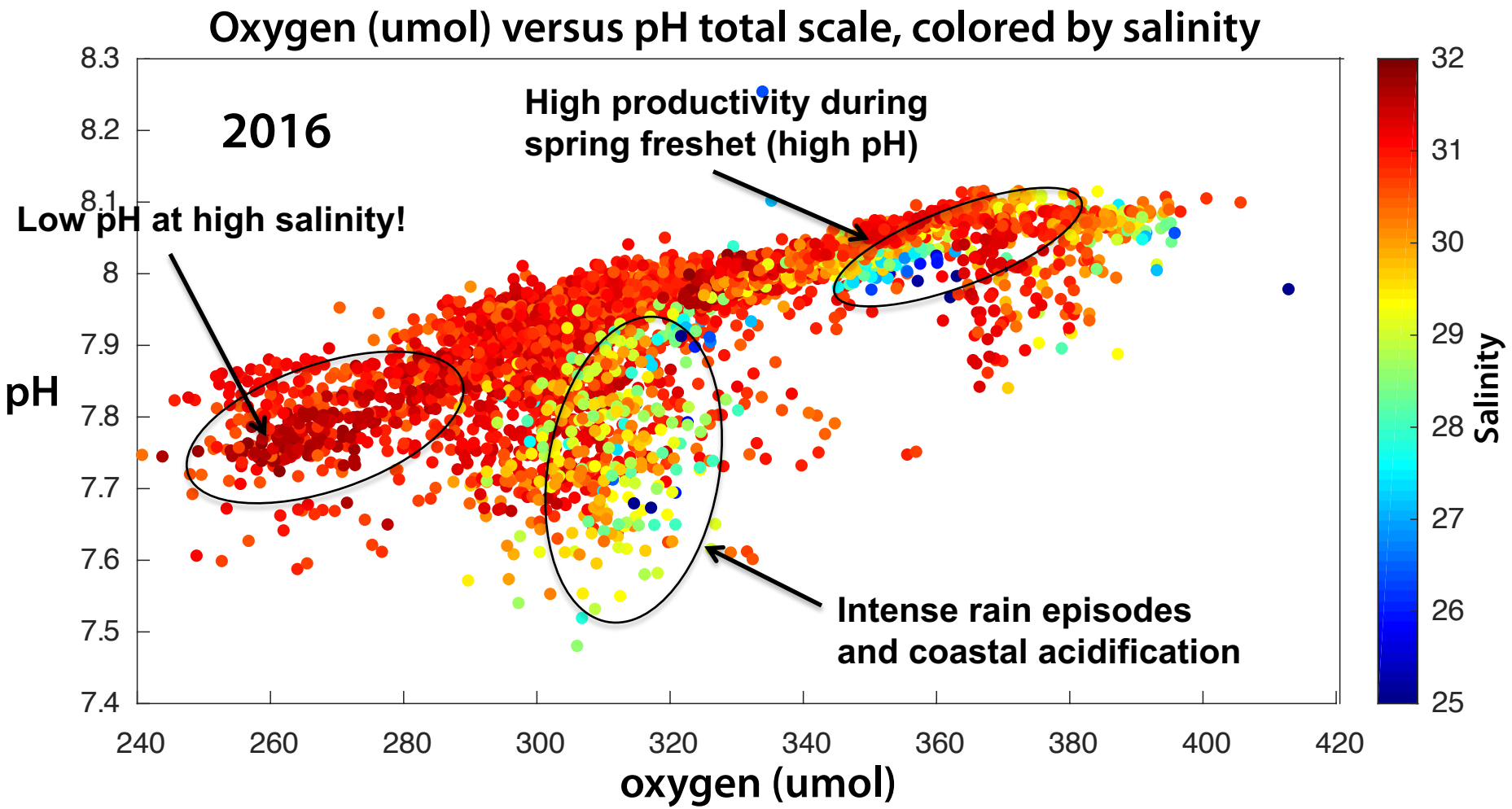




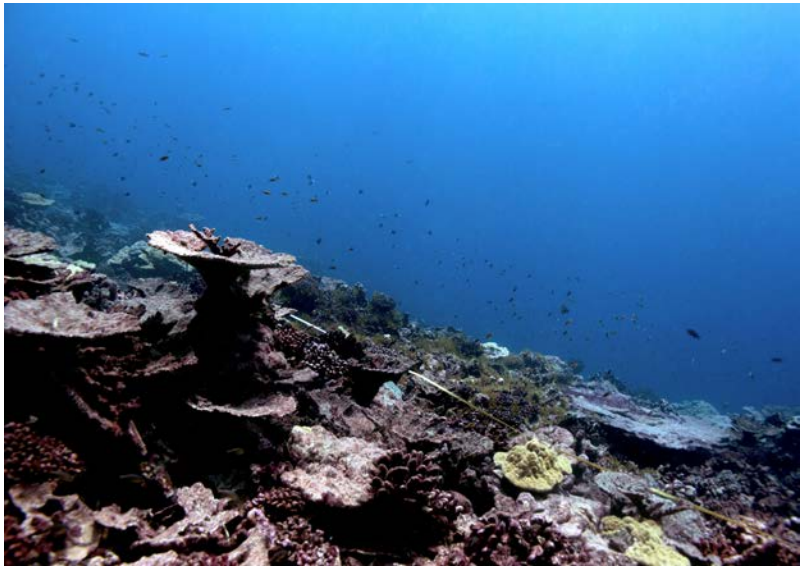
O_2 + food → CO_2 + H_2O → carbonic acid

Causes very low pH and Ω at the sediment interface

Data from SMCC dock in Casco Bay shows coastal and oceanic acidification



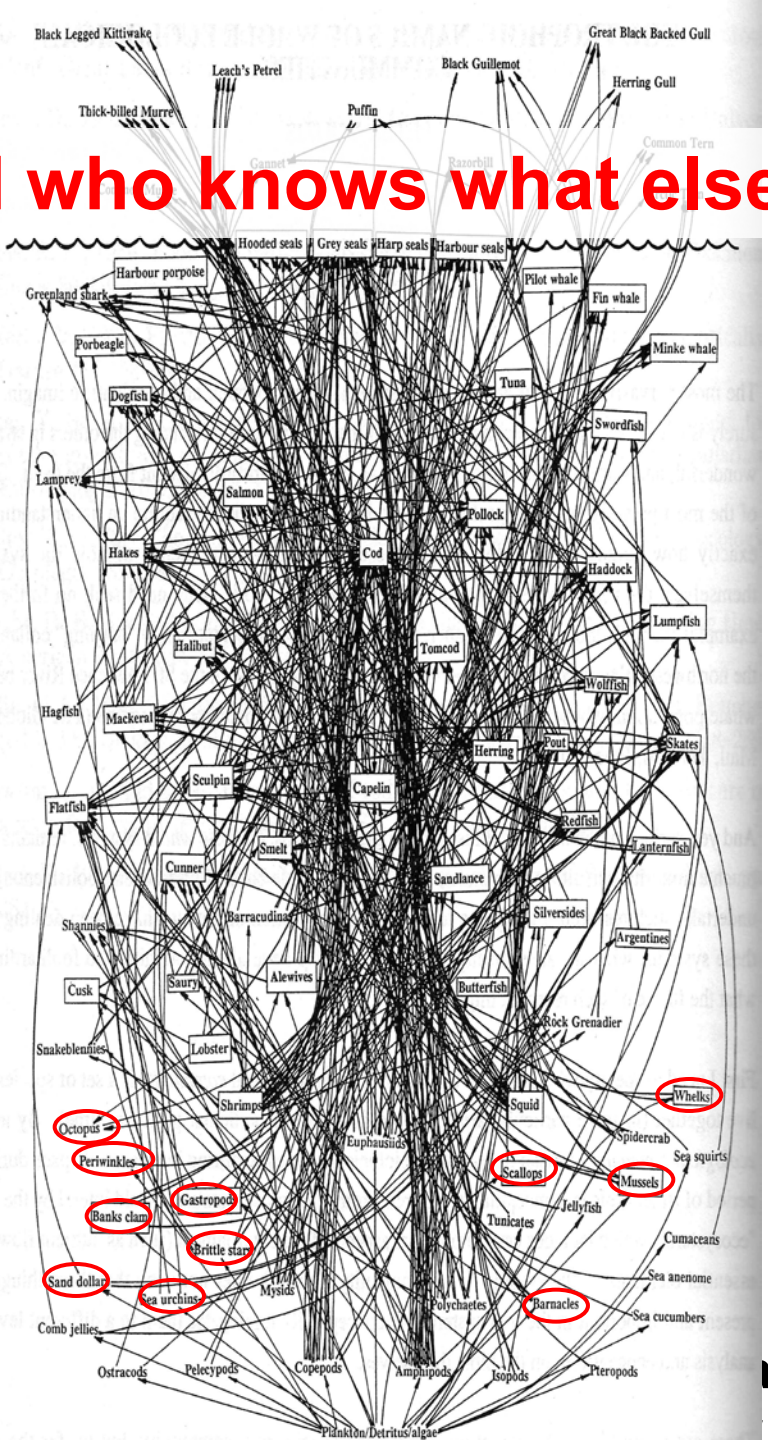
Potential implications of incr



Reduced calcification and ecosystem services from corals

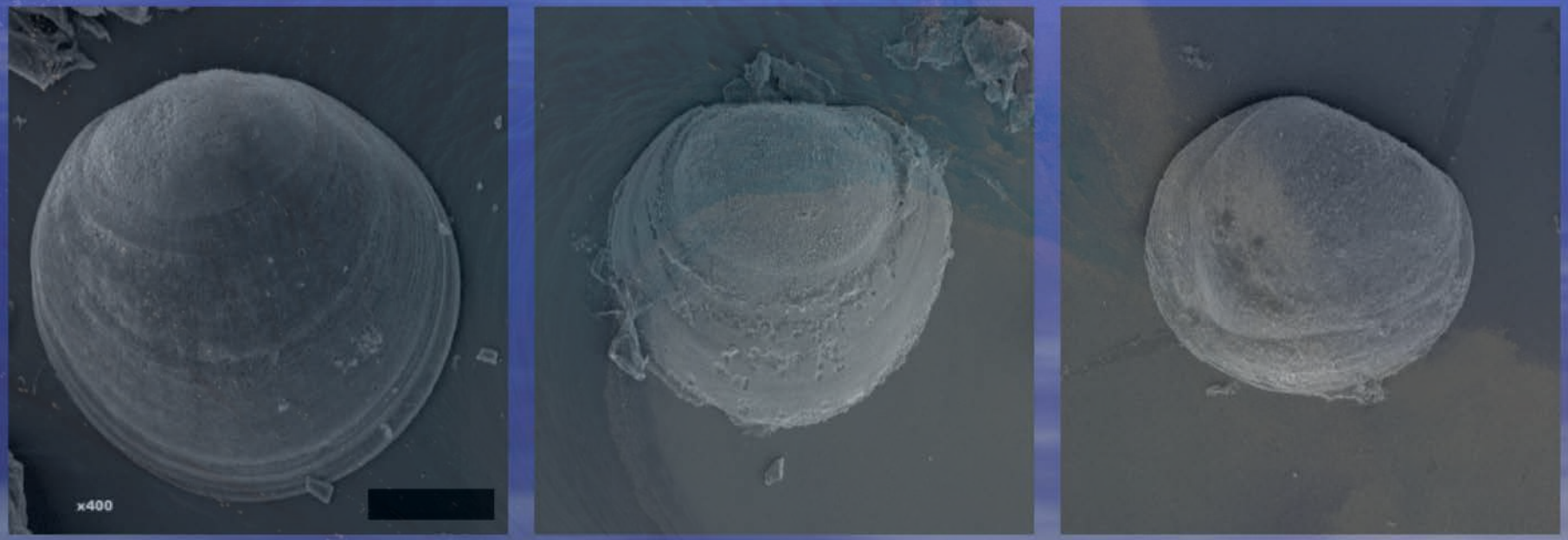
Interventions needed for optimal shellfish production

And who knows what else?



Reductions in growth of larval shellfish

SEM's of larval-stage *M. mercenaria* reared in undersaturated seawater.
Size ≈ 100µm, mag. = 370-400X, pH = 7.5, $\Omega_{aragonite}$ = 0.5.



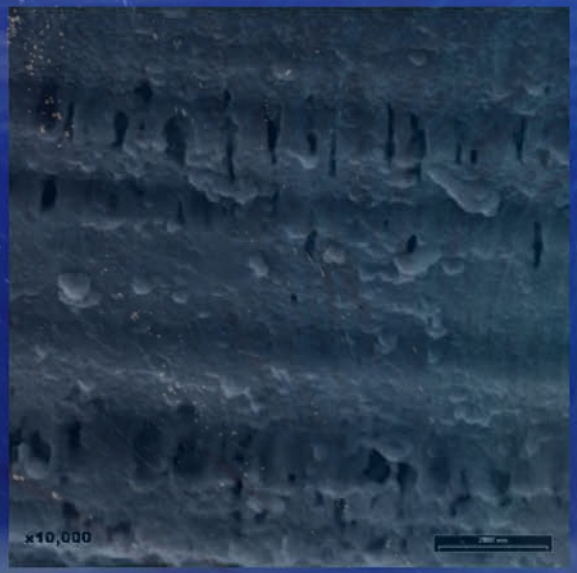
T= 0 hours

T = 24 hours

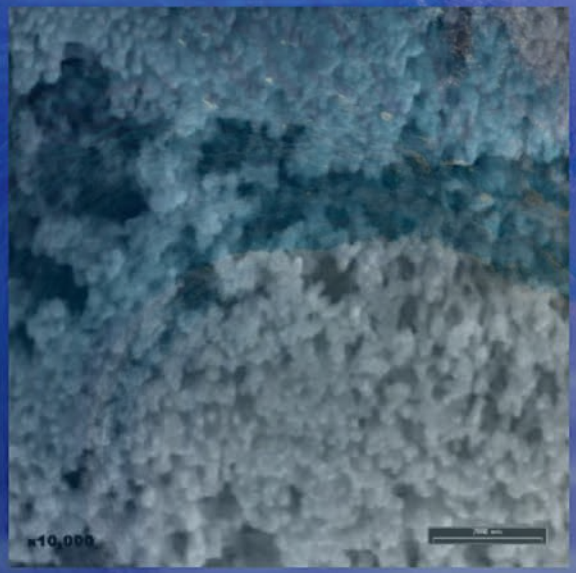
T = 72 hours

Mark Green

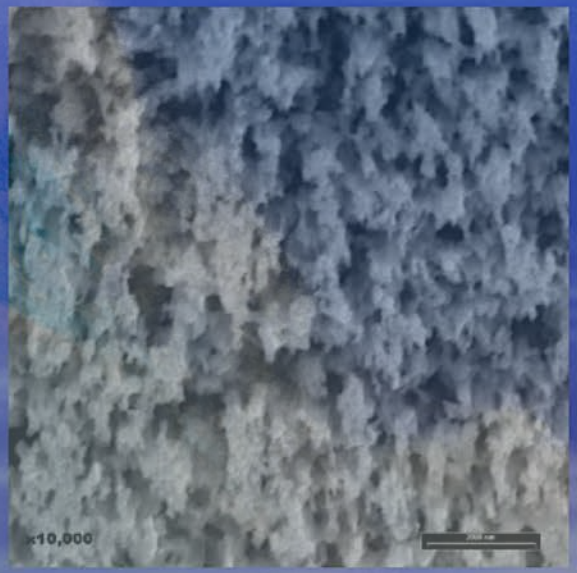
SEM's of ventral-margin of *M. mercenaria* reared in undersaturated seawater.
Magnification = 10,000X



T= 0 hours



T = 24 hours



T = 72 hours

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January 2015

Recent lobster research and OA commission report

Effects of pH on calcium uptake by lobster. Nagle et al, 2018

Decreased calcium uptake with continued ocean acidification may significantly affect calcification processes during periodic molting, potentially influencing mortality.

Decreased growth and increased shell disease in early benthic phase Homarus americanus in response to elevated CO_2, McLean et al, 2018

Lobsters in the elevated CO_2 treatments were also more susceptible to shell disease.

Linking rising pCO_2 and temperature to the larval development and physiology of the American lobster, Waller, et al, 2017

Together (warming and increased CO_2) these results suggest that projected end-century warming will have greater adverse effects than increased pCO_2 on larval survival, and changing pCO_2 may have a complex effect on larval metabolism and behaviour.

Recent shellfish research

Projected impacts of future climate change, ocean acidification, and management on the US Atlantic sea scallop fishery (Rheuban et al, 2018)

… ocean acidification has the potential to reduce sea scallop biomass by approximately 13% by the end of century

Interactive effects of acidification, hypoxia, and thermal stress on growth, respiration, and survival of four North Atlantic bivalves (Stevens and Gobler, 2018)

Low levels of dissolved oxygen and pH individually reduced the survival, shell growth, and/or tissue weight of each bivalve, with A. irradians being the most vulnerable species.

So, where do we stand in terms of stated goals?

The commission identified and unanimously adopted six overarching goals and twenty-five recommendations to achieve those goals. A synopsis of the recommendations can be found in Appendix E. The commission identified and adopted the following six goals:

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2. Reduce emissions of carbon dioxide;

3. Identify and reduce local land-based nutrients and organic carbon that contribute to ocean acidification by strengthening and augmenting existing pollution reduction efforts;

4. Increase Maine's capacity to mitigate, remediate and adapt to the impacts of ocean acidification;

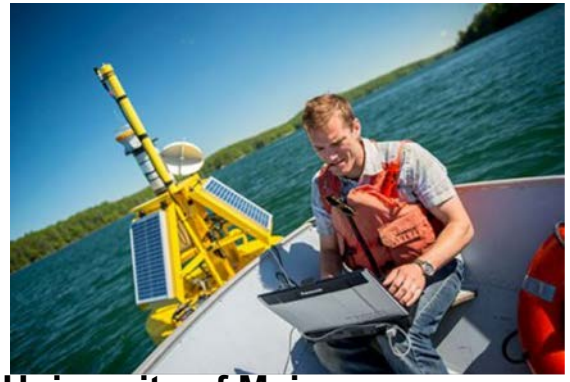
5. Inform stakeholders, the public and decision-makers about ocean acidification in Maine and empower them to take action; and

6. Maintain a sustained and coordinated focus on ocean acidification.

1. Invest in Maine's capacity to monitor OA

Bigelow Labs

Bowdoin Coastal Lab



University of Maine

Island Institute

University of New Hampshire

Friends of Casco Bay

Casco Bay Estuary Partnership

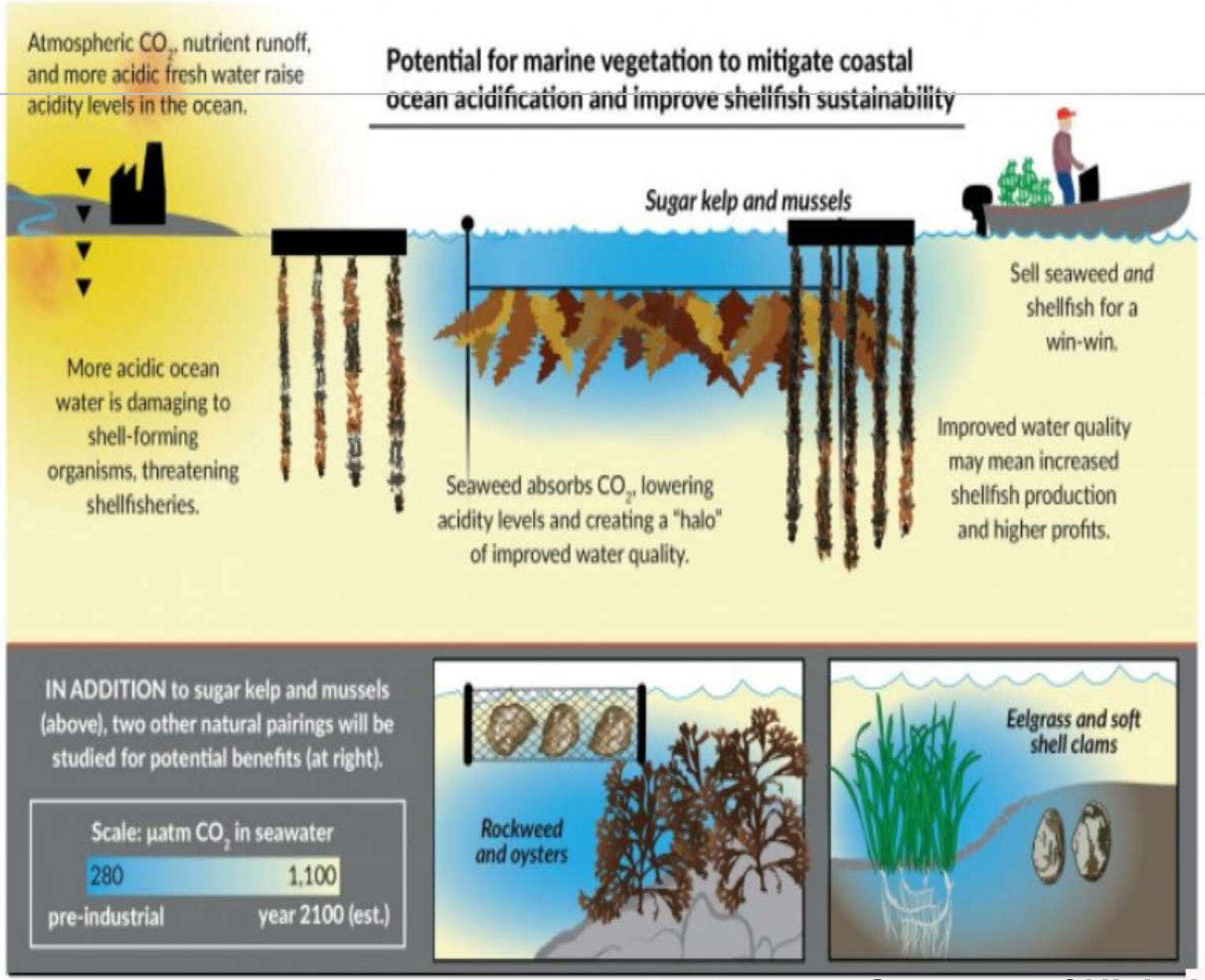
2. Reduce emissions of carbon dioxide

The Northeast's carbon trading system works quite well. It just doesn't reduce much carbon.

The Regional Greenhouse Gas Initiative, explained.

By David Roberts | @drvox | david@vox.com | Feb 28, 2017, 9:10am EST

3. Increase Maine's capacity to mitigate, remediate and adapt to OA



Courtesy of Nichole Price

SEPTEMBER 4, 2017

FOCUS: STARTUPS / ENTREPRENEURSHIP

From seed to market: How one oyster farmer leverages a growing market

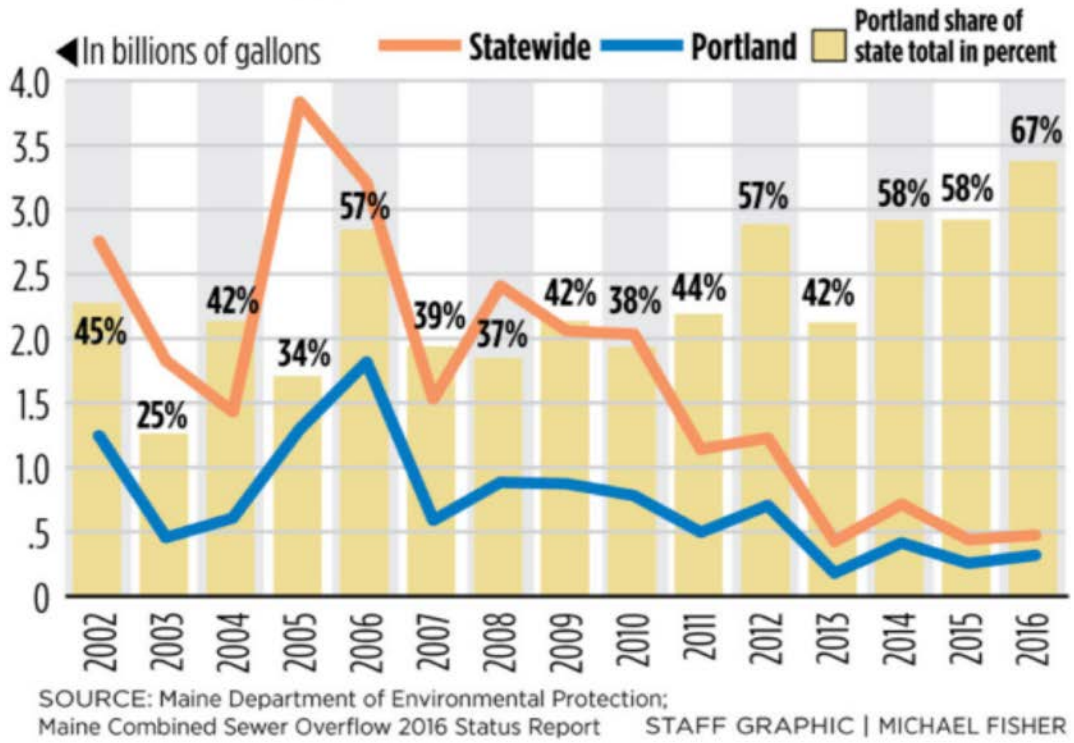
PHOTO / FRED FIELD

Bill Mook with a bag of his prized oysters at **Mook Sea Farm** by the Damariscotta River in Walpole. Some of his oyster cages are visible in the background in the river.

4. Identify and reduce local land-based nutrients…

Maine's sewer overflows

Maine communities discharge hundreds of millions of gallons of stormwater mixed with raw sewage into local waterways every year when storms overwhelm treatment systems. Portland has dramatically reduced its "combined sewer overflows" from 1.8 billion gallons in 1988 to 318 million gallons last year after more than $100 million in infrastructure upgrades.



SOURCE: Maine Department of Environmental Protection; Maine Combined Sewer Overflow 2016 Status Report

STAFF GRAPHIC | MICHAEL FISHER

Portland Press Herald

Conclusions:

-Gulf of Maine sensitive to acidification from atmosphere, land and sea

-Ocean conditions and ecosystems here are changing rapidly with much at stake

-Much has been accomplished in the years since the OA commission report

-Is it enough? Must continue to follow recommendation #6 …. Maintain a sustained and coordinated focus on OA