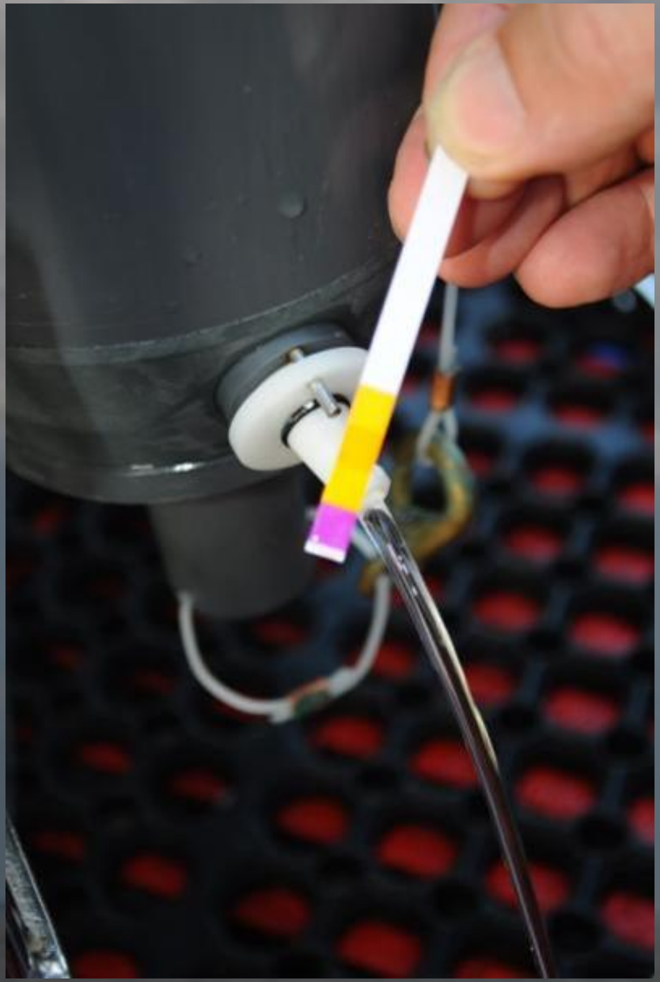
Ocean and Coastal Acidification in the Gulf of Maine: The Role of NECAN and partners



Gulf of Maine Council on the Marine Environment

December 5, 2016

Matthew Liebman, Ph.D

with assistance from Ivy Mlsna

US EPA Region 1, Boston MA

I just drove to this meeting and emitted CO_2. What is the global fate of anthropogenic CO_2 Emissions (2000-2010)?

+ ~10 billion tons carbon per year

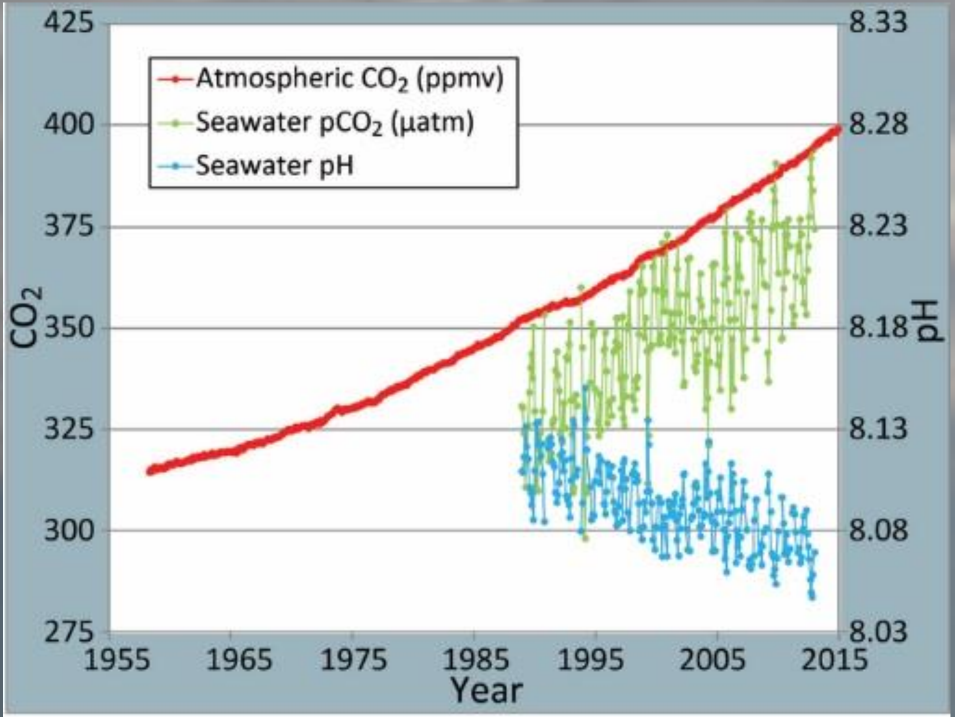
Atmosphere 47%

Land 27%

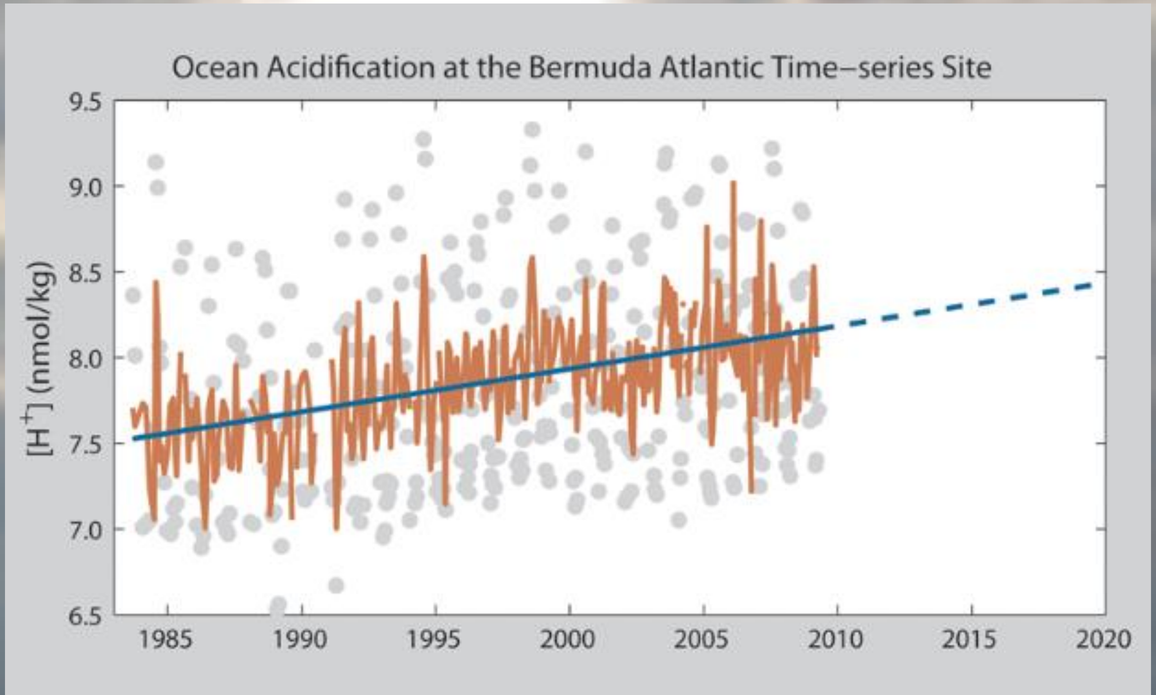
Oceans 26%

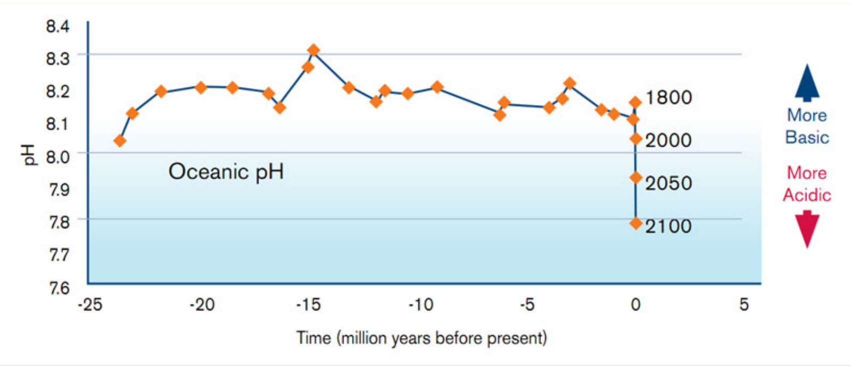
LeQuere et al. Nature Geosciences 2009; Global Carbon Project 2011

Ocean Acidification is caused by increases in CO_2 emissions absorbed by the ocean

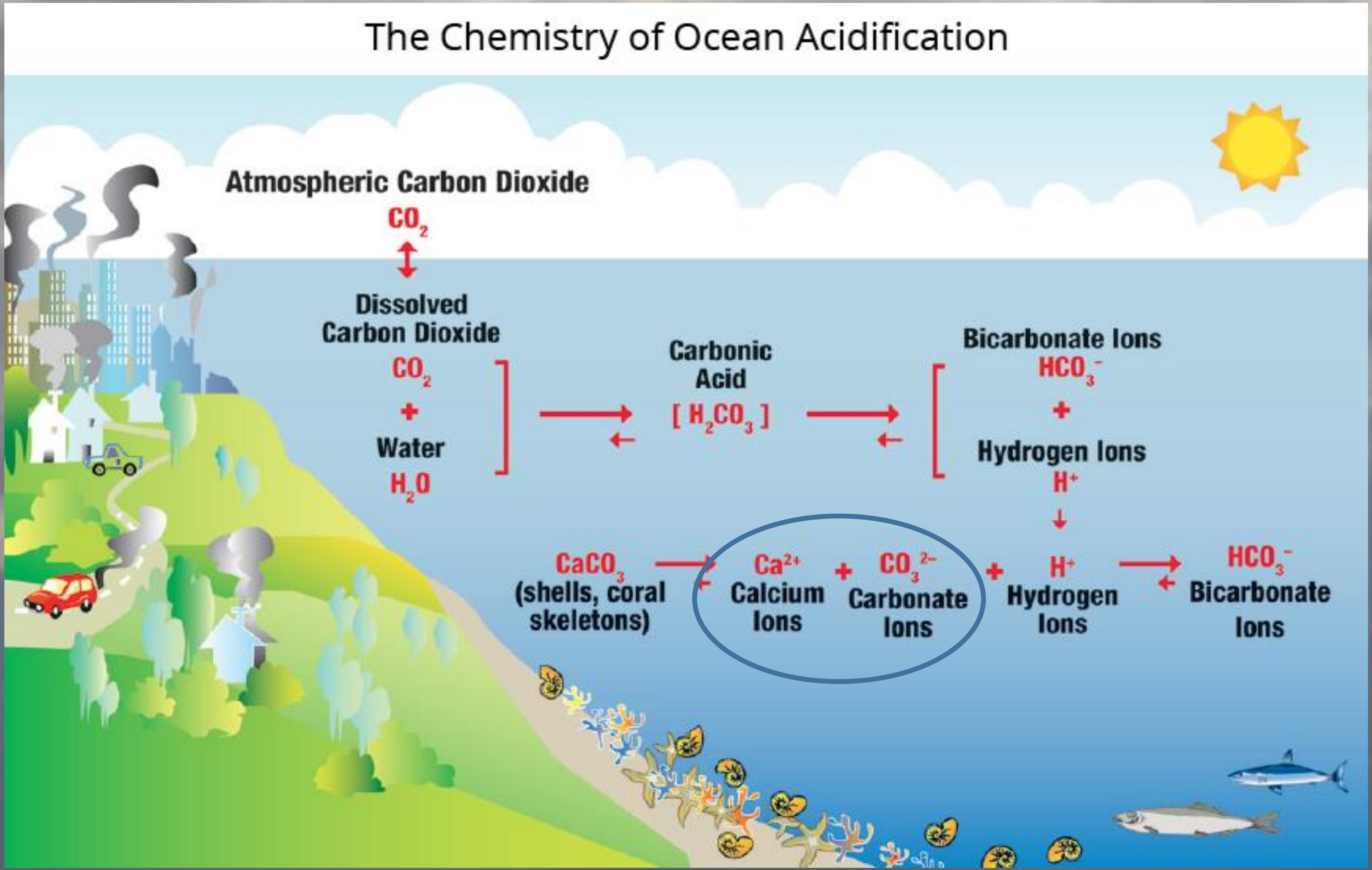


This graph shows the correlation between rising levels of carbon dioxide (CO_2) in the atmosphere at Mauna Loa with rising CO_2 levels in the nearby ocean at Station Aloha. As more CO_2 accumulates in the ocean, the pH of the ocean decreases. (modified after R. A. Feely, Bulletin of the American Meteorological Society, July 2008).



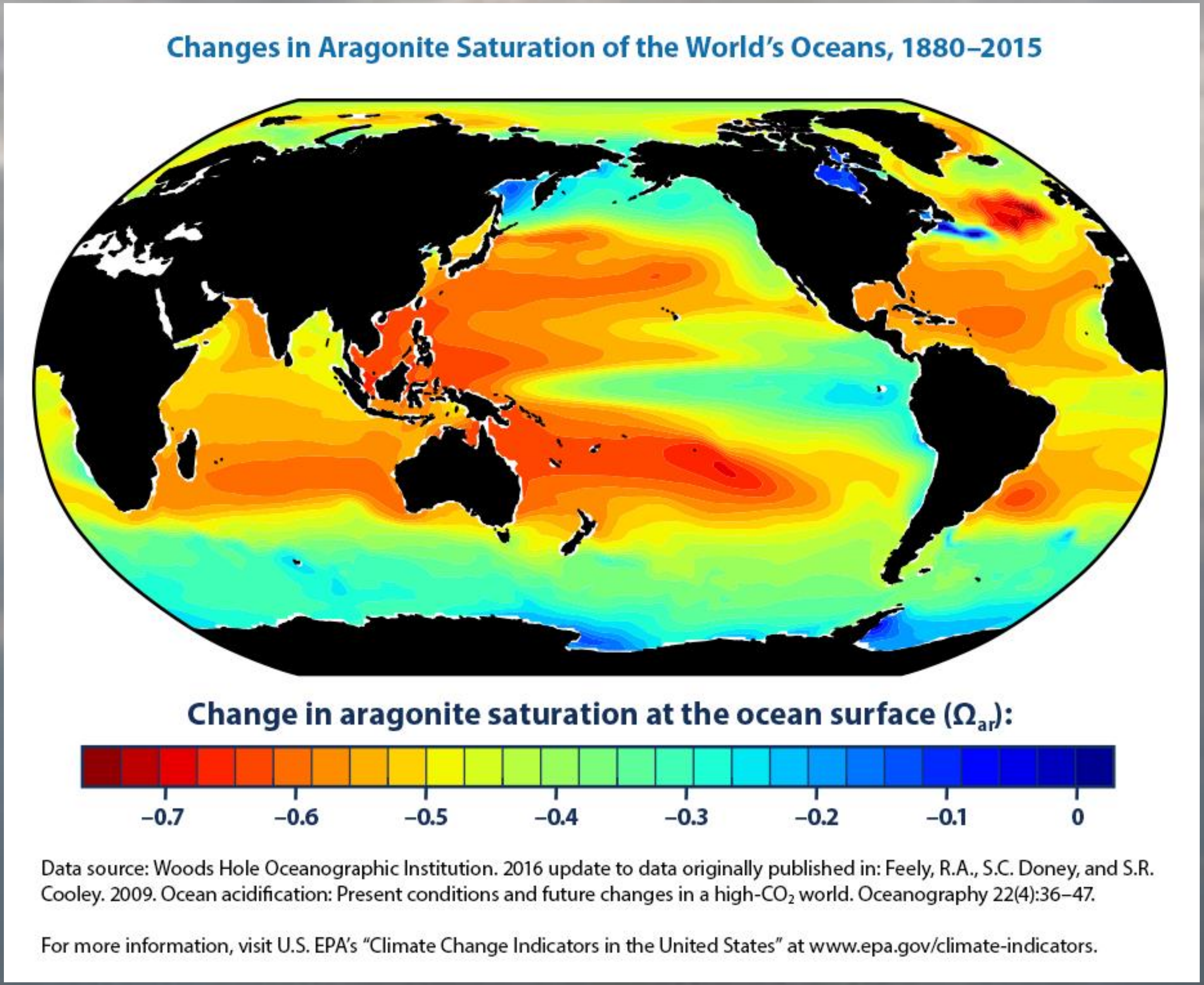


Omega, or calcium carbonate (***aragonite***) ***saturation*** is a good measure of impact of OCA



Source: NECAN website
www.necan.org

The Gulf of Maine is one of the world's hotspots for lower pH



The Gulf of Maine is more susceptible to OA because it is cold and has lower buffering capacity

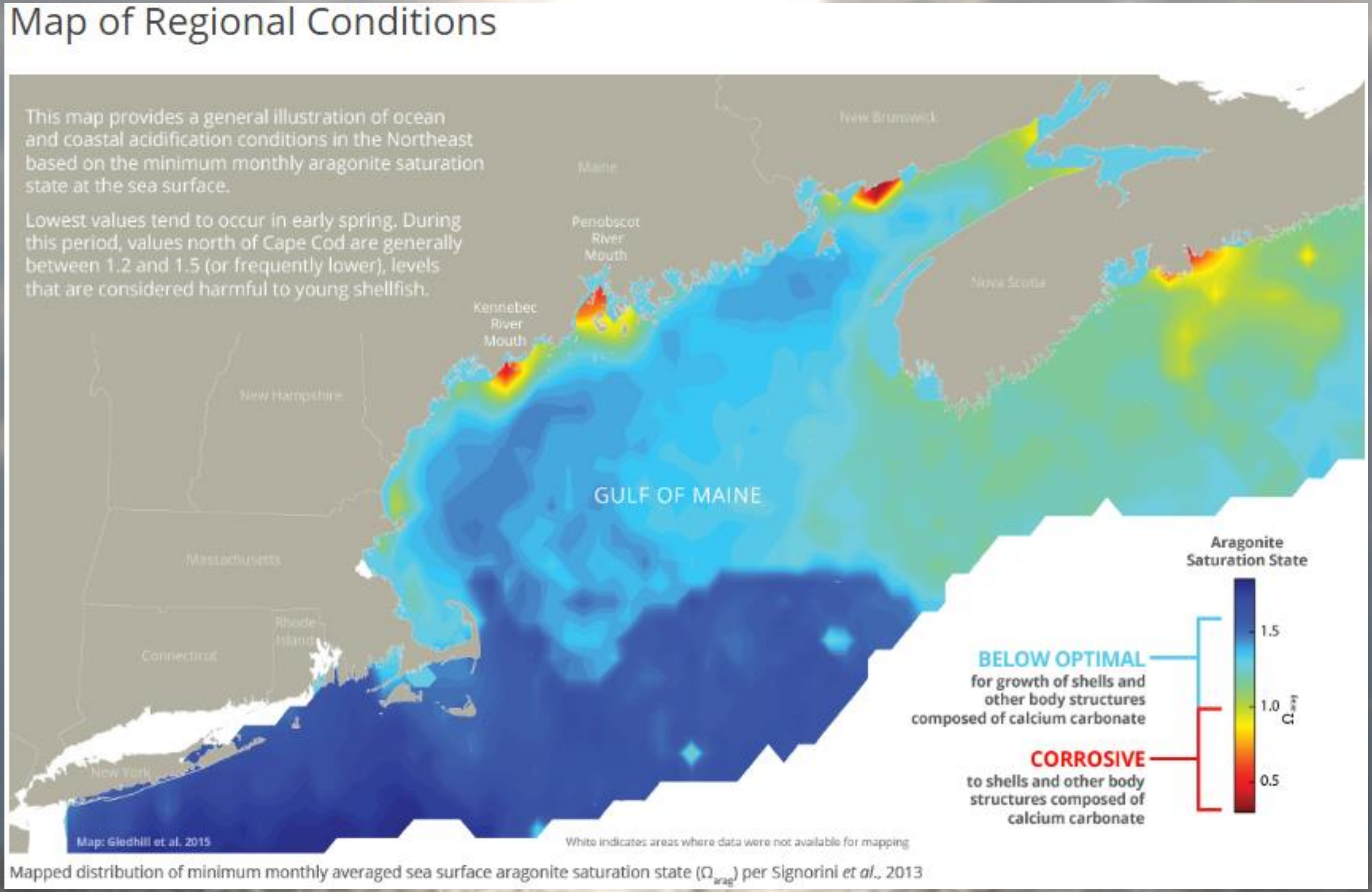
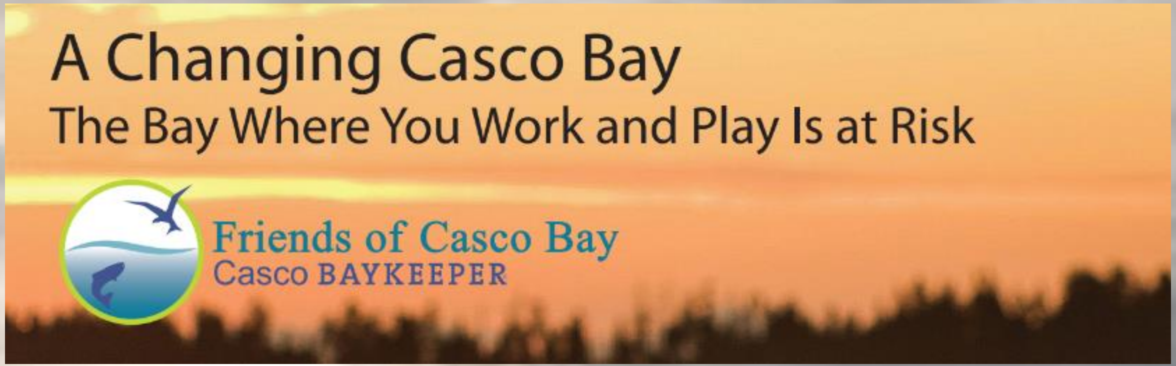


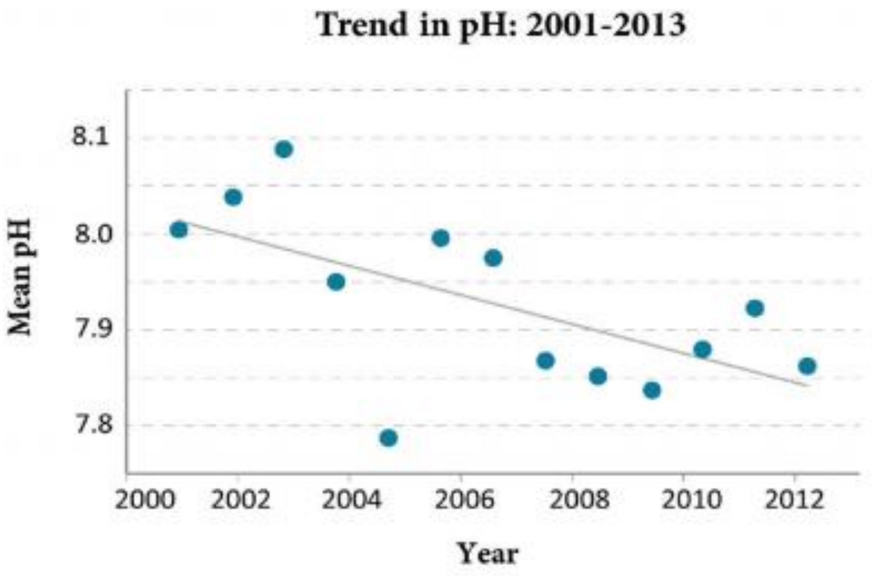
Figure from NECAN oceanography journal article (Gledhill *et al.*, 2015) modified for NECAN website

We see evidence for declining pH locally as well: Casco Bay pH is declining



We See a Disturbing Trend in the pH of Bottom Water

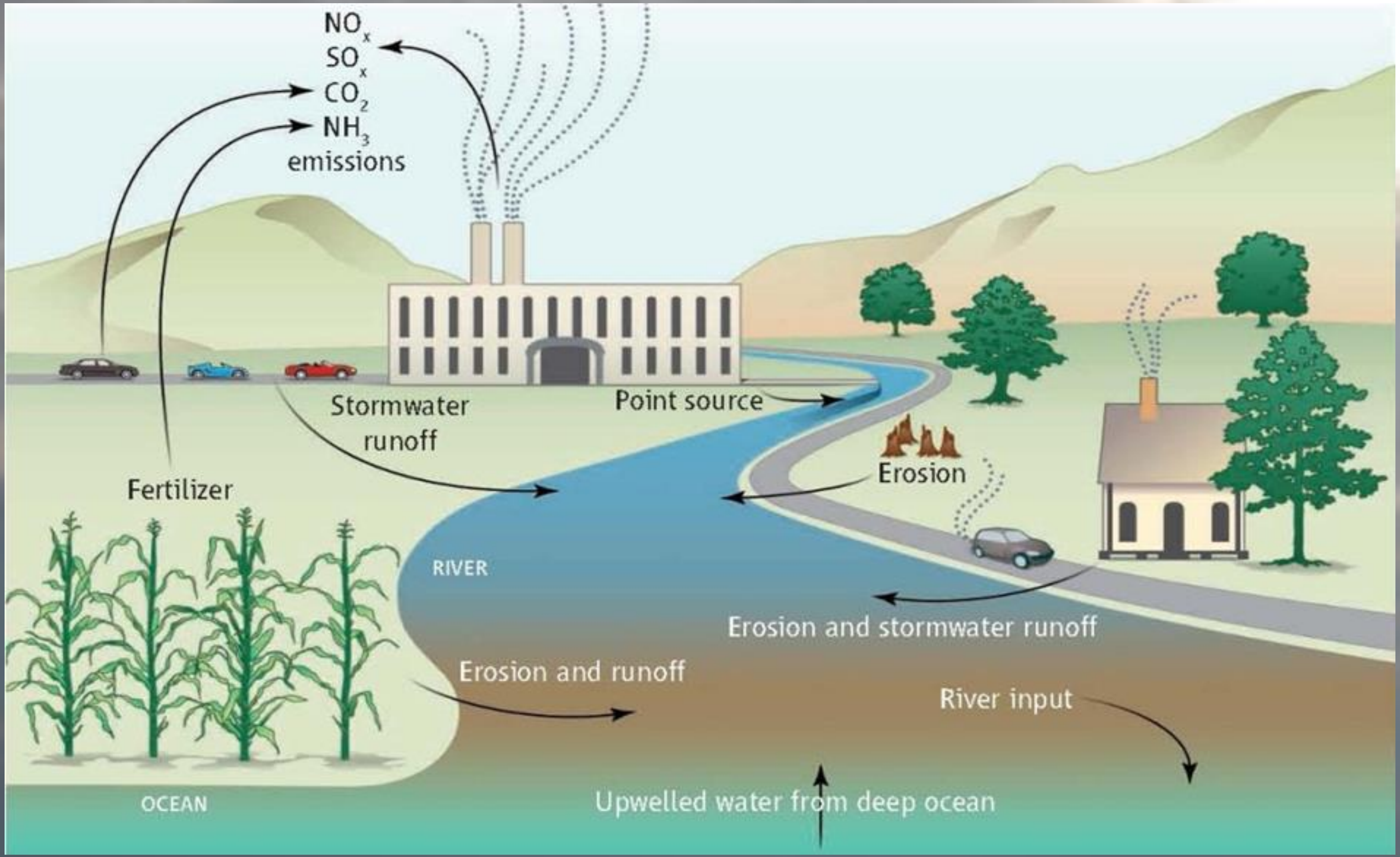
Measurements at our sentinel sites show a decline in the pH of the bottom water. The points on the graph to the right show annual mean pH for each of thirteen years and illustrate high variability; the dots bounce all over the graph. While this is not surprising, given that coastal systems everywhere exhibit high variability, we did not expect to see this statistically significant downward trend in pH, with the overall slope of the line dropping 0.014 pH units per year over the thirteen-year period. This is a serious and disturbing trend.



At our sentinel sites over the past decade, pH has been trending in the wrong direction.

$y = -0.01x + 36.6, R^2 = 0.39$*

Coastal acidification is the process where coastal sources modify and enhance ocean acidification

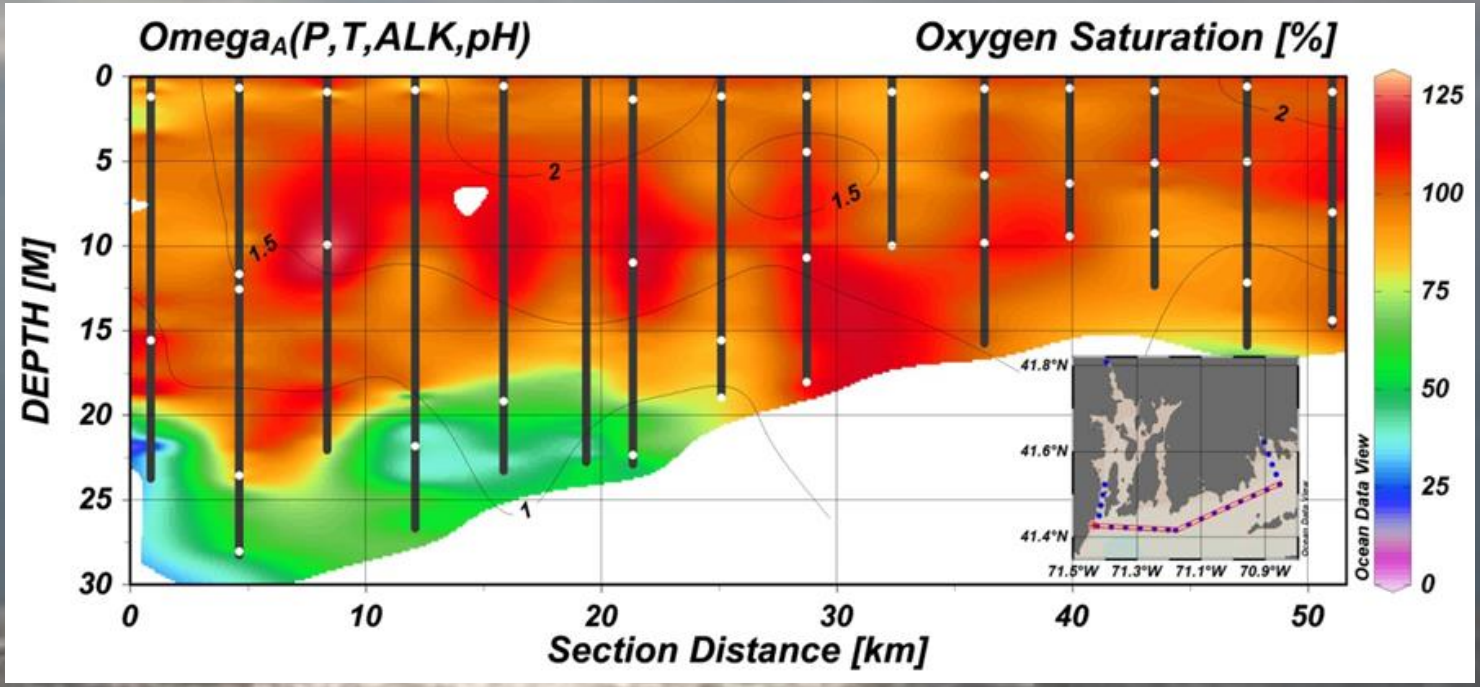


Doney et al. PNAS 2007; Doney Science 2010; Kelly et al. Science 2011

Nutrient Enhanced Coastal Acidification

- Nutrient enrichment
- Enhanced primary production
- Microbial respiration delivers more CO_2 to bottom waters

Lower aragonite saturation found in areas of lowered oxygen which is associated with nutrient enrichment (Narragansett bay data)



Evidence of riverine drivers of coastal acidification

Eos, Vol. 89, No. 50, 9 December 2008

EOS
EOS, TRANSACTIONS, AMERICAN GEOPHYSICAL UNION

VOLUME 89 NUMBER 50
9 DECEMBER 2008
PAGES 513–528

Coastal Acidification by Rivers: A Threat to Shellfish?

commercially valuable clam *Mya arenaria* in the western Gulf of Maine. This organism spawns when ocean temperatures reach about 10°C and has a presettlement, planktonic stage of about 21 days in which the organism floats freely in the water. During

Eos, Vol. 89, No. 50, 9 December 2008

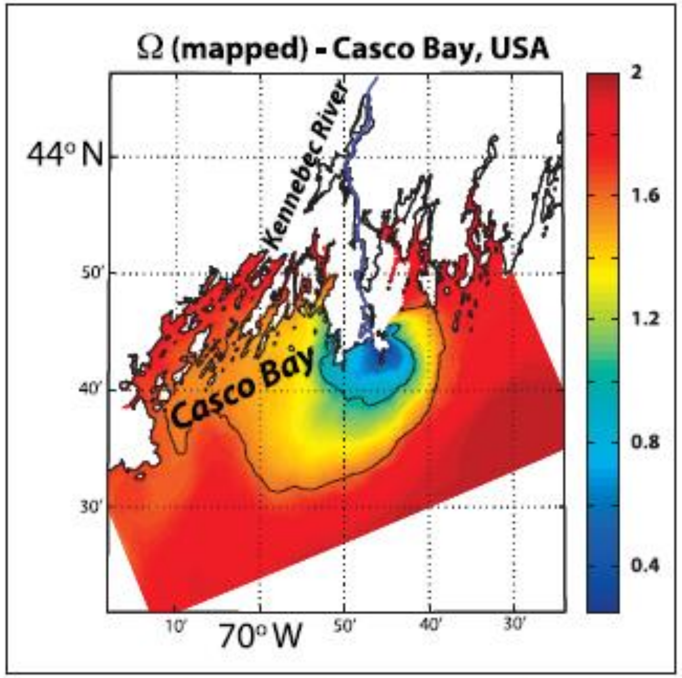
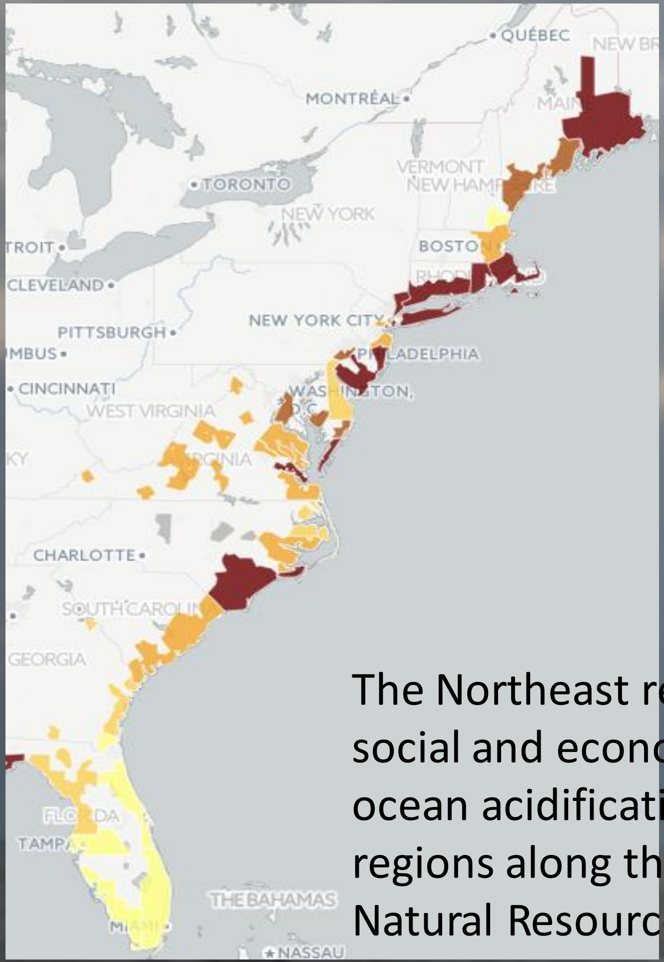
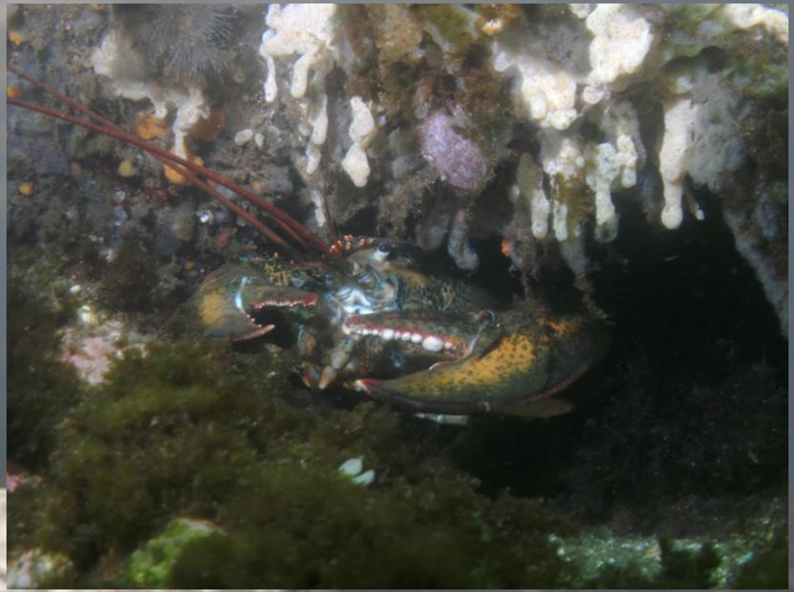


Fig. 2. Mapped Ω for the surface waters of the Kennebec plume and Casco Bay, Gulf of Maine, on 20 June 2005. Contours of Ω = 1.0 (inner) and Ω = 1.6 (outer) are shown as black curves. The 1.6 contour intersects the outer islands and peninsulas of Casco Bay, where the value of the shellfish harvest exceeds $35 million per year. The Kennebec is a moderately sized river system whose average discharge is 438 cubic meters per second.

New England is vulnerable to ocean and coastal acidification because of our reliance on commercial shellfish industry

In 2012, New England landed **301,185 metric tons of finfish and shellfish** (earning **$1.2 billion in landings revenue**!) - ⅔ of these landings ($800 million in landings revenue) can be attributed to American lobster and sea scallop (Gledhill et al., 2015)





The Northeast region shows a relatively higher social and economic sensitivity to the impacts of ocean acidification on mollusk harvests than other regions along the Atlantic coast. (Ekstrom et al; Natural Resources Defense Council 2015)

Mollusk shells are at risk of dissolving

Limnol. Oceanogr., 54(4), 2009, 1037–1047

Death by dissolution: Sediment saturation state as a mortality factor for juvenile bivalves

Mark A. Green,[a,*] George G. Waldbusser,[b] Shannon L. Reilly,[a] Karla Emerson,[a] and Scott O'Donnell[a]

[a] Department of Natural Science, Saint Joseph's College of Maine, Standish, Maine
[b] Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science, Solomons, Maryland

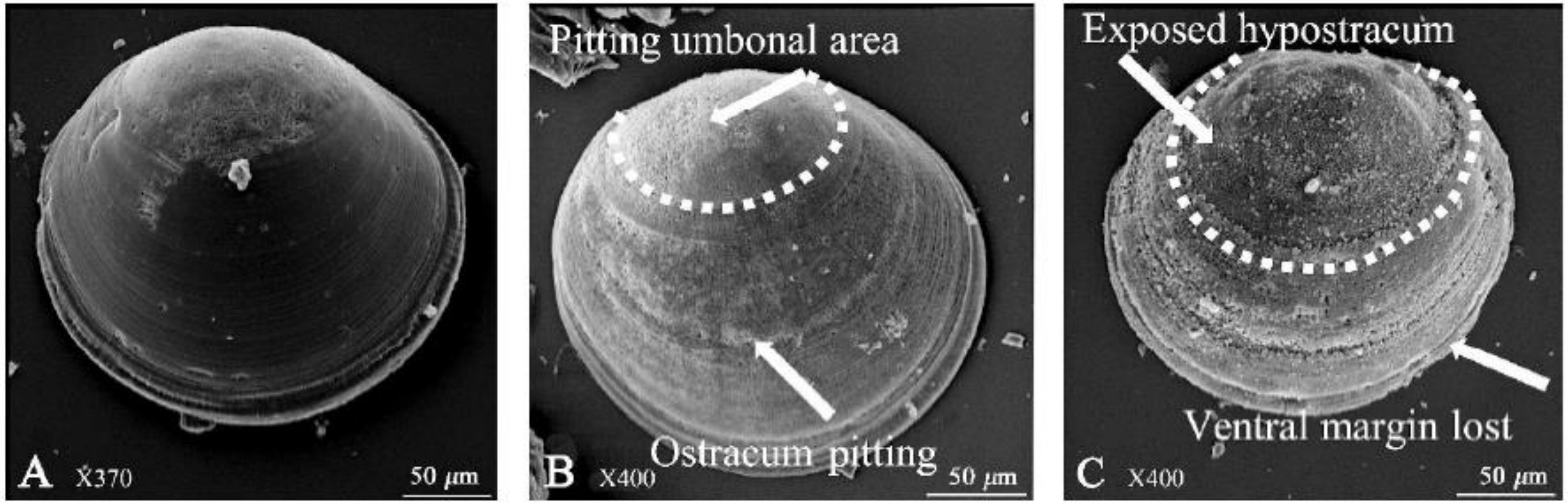
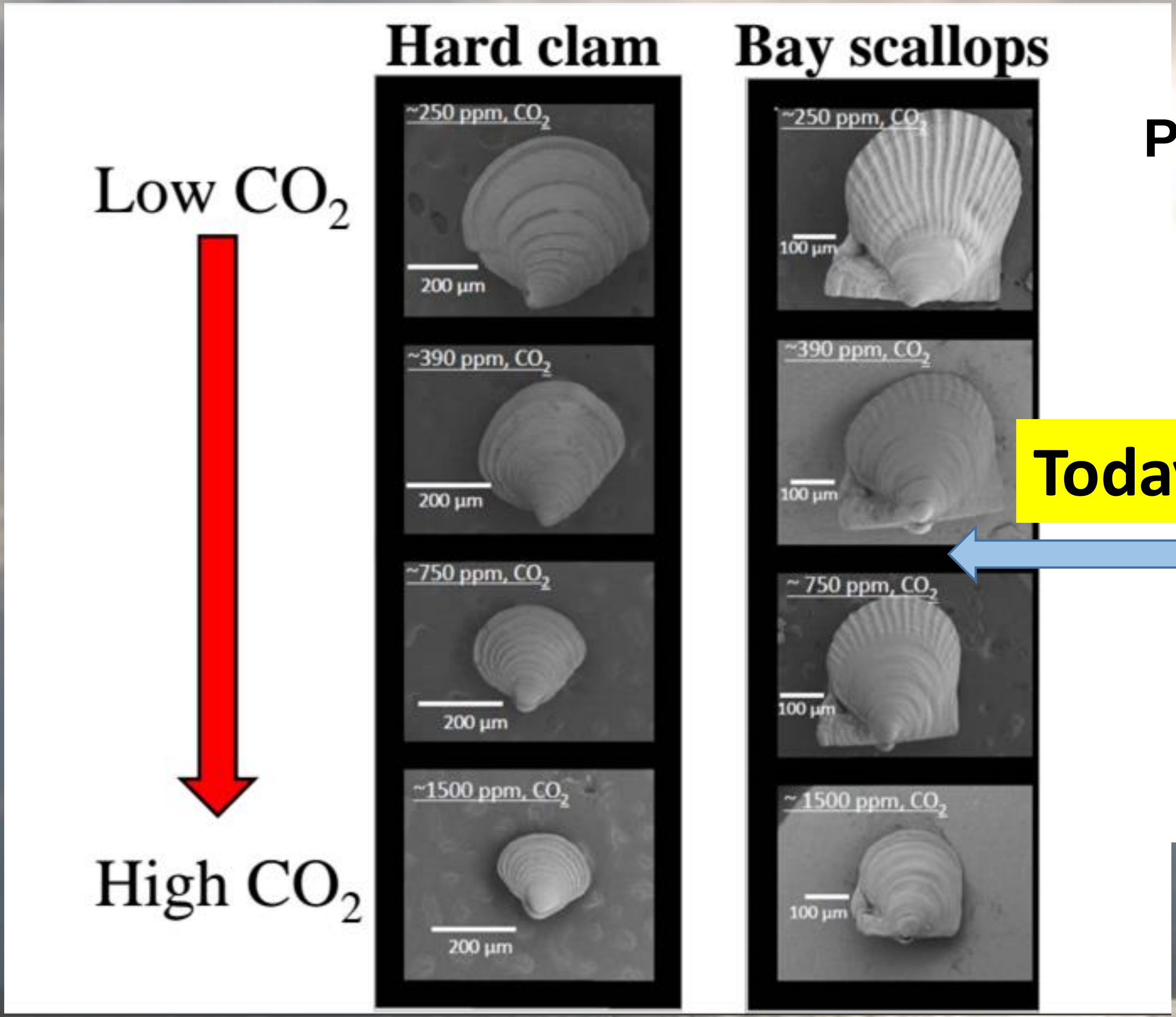


Fig. 7. Scanning electron micrographs (SEM) of representative 0.2-mm *M. mercenaria* reared in sediments maintained at $\Omega_{aragonite} = 0.6$. Clams were removed from sediment plugs at 0, 4, and 7 d (A, B, and C, respectively). Magnification and scale bars are shown, as well as significant effects to various parts of the shell.



Pre-Industrial

Today's pCO2

Year 2100

Talmadge and Gobler PNAS 2010

Events on the West Coast inspired creation of NECAN

Oyster farmers worried as climate change lowers ocean pH

By Lizzie Johnson | August 14, 2015 | Updated: August 15, 2015 8:20am

The West Coast Ocean Acidification and Hypoxia Science Panel

MAJOR FINDINGS, RECOMMENDATIONS, AND ACTIONS

THEME 1 ADDRESS LOCAL FACTORS THAT CAN REDUCE OAH EXPOSURE		THEME 2 ENHANCE THE ABILITY OF BIOTA TO COPE WITH OAH STRESS		THEME 3 EXPAND AND INTEGRATE KNOWLEDGE ABOUT OAH	
RECOMMENDATION 1 Reduce local pollutant inputs that exacerbate OAH	Action 1.1: Generate an inventory of areas where local pollutant inputs are likely to exacerbate OA. Action 1.2: Develop robust predictive models of OAH. Action 1.3: Develop an incentive-based strategy for reducing pollutant inputs.	RECOMMENDATION 4 Reduce co-occurring stressors on ecosystems	Action 4.1: Integrate OA effects into the management of ocean and coastal ecosystems and biological resources.	RECOMMENDATION 6 Establish a coordinated research strategy	Action 6.1: Create agreement among the multiple organizations that fund OAH research to establish joint research priorities.
RECOMMENDATION 2 Advance approaches that remove CO_2 from seawater	Action 2.1: Use demonstration projects to evaluate which locations are optimal for implementing CO_2 removal strategies. Action 2.2: Generate an inventory of locations where conservation or restoration of aquatic vegetated habitats can be successfully applied to mitigate OA. Action 2.3: Consider CO_2 removal during the habitat restoration planning process.	RECOMMENDATION 5 Advance the adaptive capacity of marine species and ecosystems	Action 5.1: Inventory the co-location of protected areas and areas vulnerable to OAH. Action 5.2: Evaluate the benefits and risks to active enhancement of adaptive capacity.	RECOMMENDATION 7 Build out and sustain a West Coast monitoring program that meets management needs	Action 7.1: Define gaps between monitoring efforts and management needs. Action 7.2: Enhance comparability of and access to OAH data.
RECOMMENDATION 3 Revise water quality criteria	Action 3.1: Agree on parameters that will be part of OAH criteria.			RECOMMENDATION 8 Expand scientific engagement to meet evolving management needs	Action 8.1: Create a science task force.

Limacina helicina shell dissolution as an indicator of declining habitat suitability owing to ocean acidification in the California Current Ecosystem

N. Bednaršek[1], R. A. Feely[1], J. C. P. Reum[2], B. Peterson[3], J. Menkel[4], S. R. Alin[1] and B. Hales[5]

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[4]Oregon State University, Cooperative Institute for Marine Resources Studies, Hatfield Marine Science Center, 2030 SE Marine Science Drive, Newport, OR 97365, USA
[5]College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis, OR 97331, USA

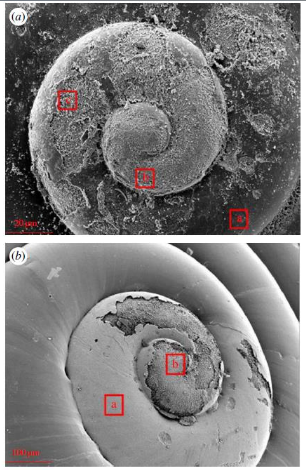


Figure 2. SEM images of shells of the pteropod *Limacina helicina helicina* f. *pacifica* sampled during the 2011 cruise showing signs of *in situ* dissolution from (*a*) an onshore station, with the entire shell affected by dissolution, and (*b*) from the offshore region, with only the protoconch (first whorl) affected. Indicated in the figure are: a, intact surface; b, Type I dissolution; and c, severe dissolution (Type II or Type III): see Material and methods for description of dissolution types. (Online version in colour.)

What are we doing about this?
NECAN has connected policy makers, stakeholders and researchers

- State of the Science workshop
- Oceanography journal article
- Webinars in 2014 and 2016 highlight new science and policy
- Stakeholder workshops focus on concerns about shellfishing, nutrients, ecosystem change
- Workshops recommended practical monitoring guidance (funded by EPA HQ and written by EPA Narragansett lab scientists
- Communication (website, video, newsletter)
- Presentations at meetings (RARGOM, RAE, NERACOOS, NEOSEC)
- Policy Working Group tracks legislation and distributes information to lawmakers
- Set research and implementation priorities

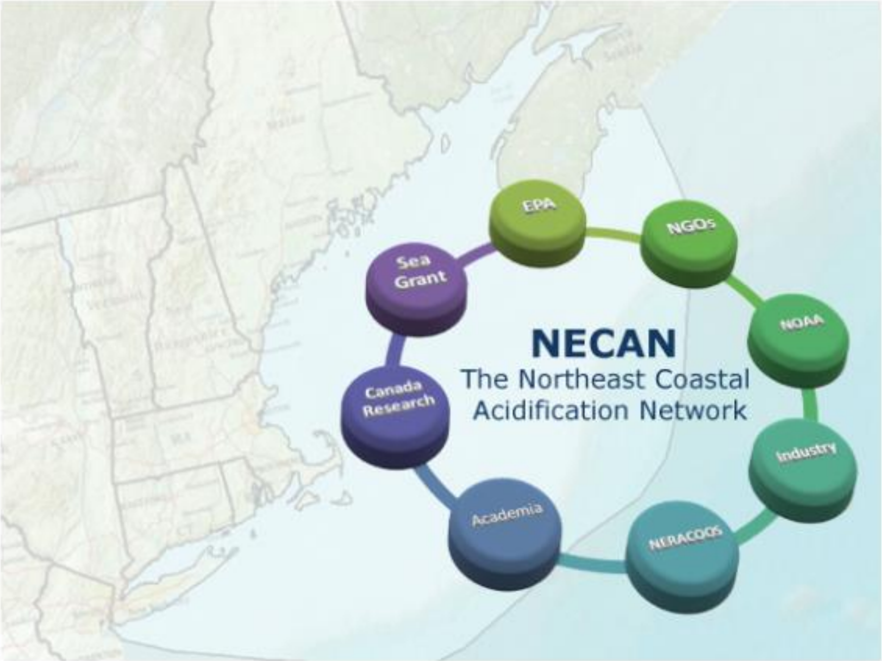
NORTHEAST
COASTAL ACIDIFICATION
NETWORK

www.necan.org

About Us

Developing Regional Understanding and Local Solutions

The Northeast Coastal Acidification Network (NECAN) represents a nexus of scientists, federal and state resource managers, and marine industry partners dedicated to coordinating and guiding regional observing, research, and modeling endeavors focused on ocean and coastal acidification (OCA). We focus on the waters from Long Island Sound to the Scotian Shelf, including the coastal waters of New York, Connecticut, Rhode Island, Massachusetts, New Hampshire, Maine, New Brunswick, and Nova Scotia.

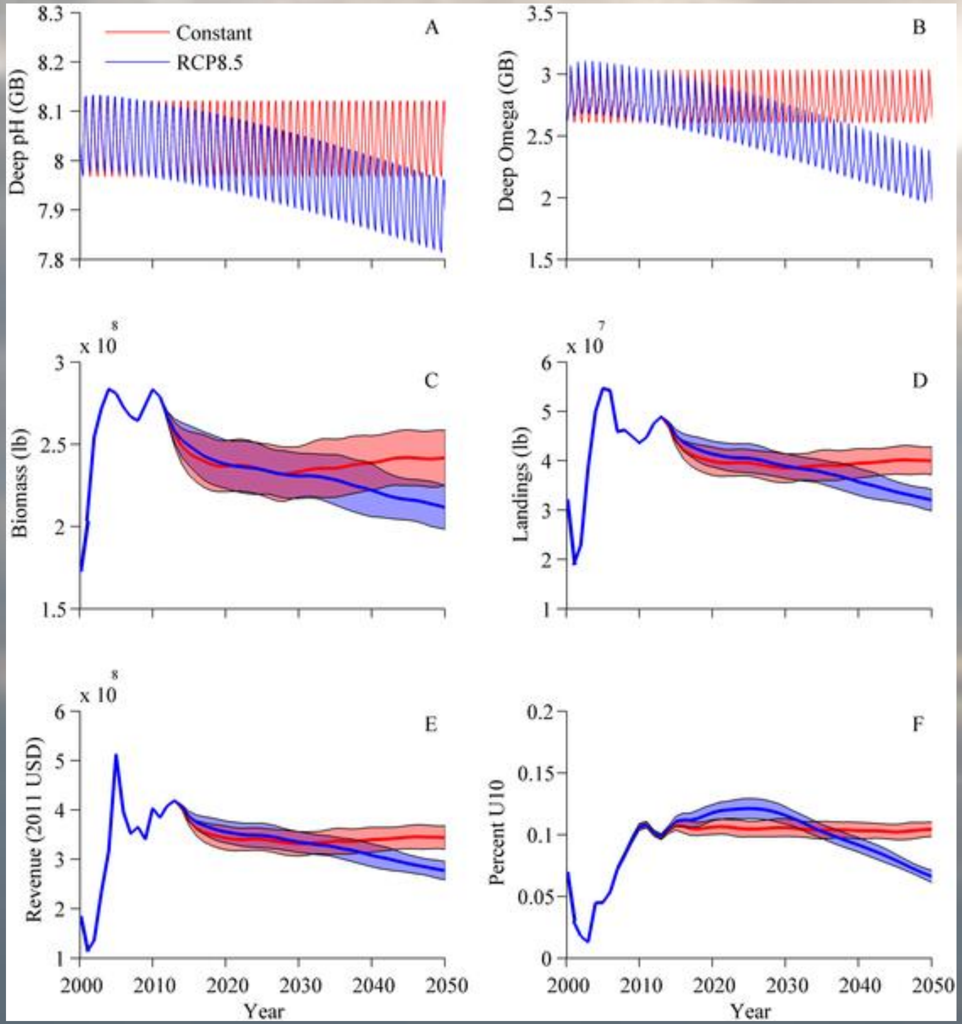


NECAN serves as an interface between research and industry interests and facilitates sharing of state-of-the-science information. The overarching goal is to better identify critical vulnerabilities to ocean and coastal acidification, particularly with respect to regionally important and economically significant marine resources. Our efforts make it possible for OCA information resources and data products to be tailored to and informed by the interests of regional stakeholders and decision-makers.

We publish an email newsletter, produce publications, hold stakeholder workshops, provide webinars by experts, and help create and distribute videos.

Fig 10. Mean ± SD (n = 100) model forecasts out to 2050 using CO2 forcing from RCP 8.5 and 1.4°C SST warming (blue) and forecasts with constant 2008 CO2 concentration and temperature (red).

Image from Cooley *et al.,* and Doney NECAN webinar on scallop model



Cooley SR, Rheuban JE, Hart DR, Luu V, Glover DM, et al. (2015) An Integrated Assessment Model for Helping the United States Sea Scallop (Placopecten magellanicus) Fishery Plan Ahead for Ocean Acidification and Warming. PLOS ONE 10(5): e0124145. doi:10.1371/journal.pone.0124145
http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0124145

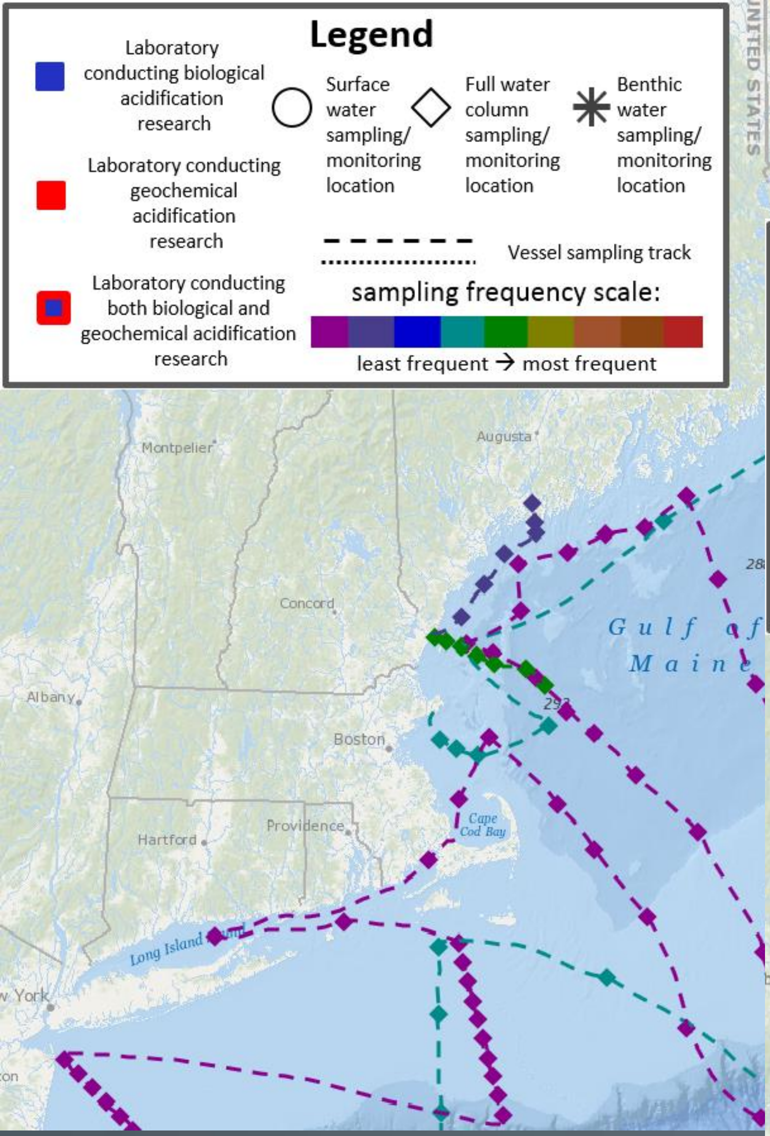
PLOS ONE

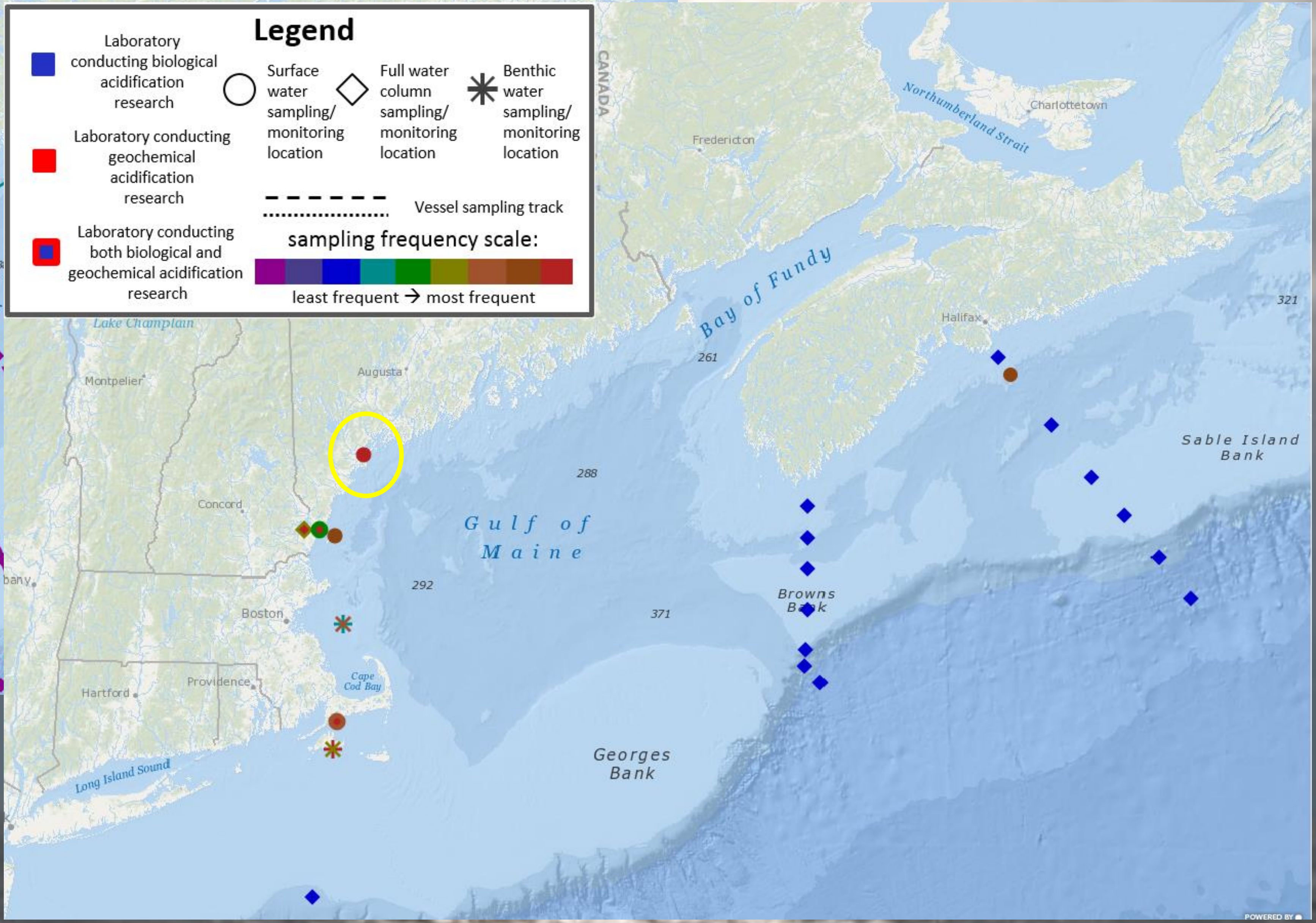
Research Priorities for NECAN
Incorporated into RFP's of NOAA and Sea Grant

Research Priorities for the Northeast

In order to more accurately forecast how changing OCA conditions will affect the Northeast region's ecosystems, it is necessary to move beyond limited-focus studies. NECAN proposes the following topics, in no particular order, as research priorities.

- **Studies on commercially important species to evaluate their sensitivity to OCA conditions,** including American lobster (*Homarus americanus*), blue crab (*Callinectes sapidus*), Jonah crab (*Cancer borealis*), rock crab (*Cancer irroratus*), horseshoe crab (*Limulus polyphemus*), sea scallop (*Placopecten magellanicus*), and many species of finfish, using populations from within the NECAN area.
- **Multistressor studies** considering increased pCO_2 (decreased Ω_{arag}) combined with one or more other stressors such as temperature, hypoxia, salinity, ultraviolet exposure, or trace metal exposure specific to this region.
- **Multiple life-stage and/or multi-generational studies** that follow one or more organisms through multiple life stages exposed to increased pCO_2.
- **Trophic interaction/indirect effect studies** that consider how species' interactions with other species or with their environments may change as a result of increased pCO_2.
- **Studies considering species responses to variable pCO_2 conditions** to better reflect conditions in nature.
- **Process investigations** to quantify the relative magnitude of the effects of each of the primary forcing agents (air-sea exchange, upwelling, river/stream, estuary, benthic/pelagic biology, vertical mixing) on Ω_{arag} dynamics and trends across the region.
- **Climate-quality monitoring** of the net changes in carbonate chemistry using a strategic design that permits quantifying net changes in the dominant forcing terms, including the boundary conditions (e.g., Scotian Shelf chemistry, upwelling waters, rivers).
- **Establish carbonate chemistry long-term trends** across the region including *hindcasting* to the pre-industrial period, *forecasting* impending conditions at weekly to seasonal scales, and *projecting* long-term changes in carbonate chemistry under IPCC scenarios.
- **Field studies** to help us move from single-species effects to ecosystem effects and improve our understanding of how OCA affects organisms in their natural environments.


Legend
Laboratory conducting biological acidification research
Laboratory conducting geochemical acidification research
Laboratory conducting both biological and geochemical acidification research
Surface water sampling/ monitoring location
Full water column sampling/ monitoring location
Benthic water sampling/ monitoring location
Vessel sampling track
sampling frequency scale:
least frequent → most frequent
UNITED STATES
CANADA
Northumberland Strait
Charlottetown
Fredericton
Montpelier
Augusta
Concord
Albany
Boston
Hartford
Providence
Cape Cod Bay
Gulf of Maine
Long Island
New York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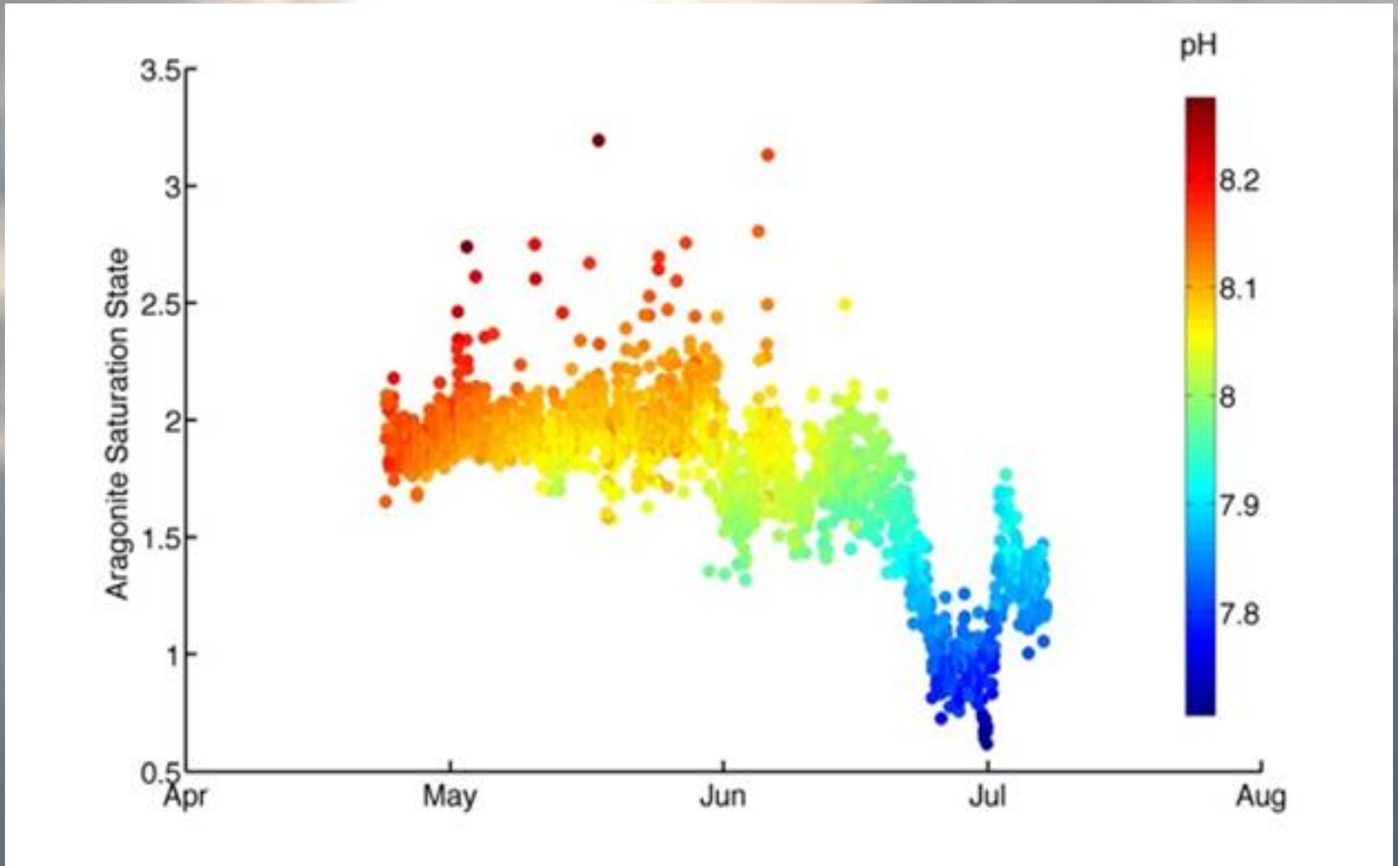
Charlottetown
Fredericton
Bay of Fundy
Halifax
Lake Champlain
Montpelier
Augusta
Concord
Boston
Hartford
Providence
Cape Cod Bay
Long Island Sound
Gulf of Maine
Browns Bank
Georges Bank
Sable Island Bank
261
288
292
321
371

What is EPA doing? We are assessing variability in the coastal areas working with National Estuary Programs

EPA is interested primarily in estuarine and coastal waters
We need to improve our monitoring capacity in coastal waters and determine appropriate parameters and standards
An integral goal of EPA's water program and climate strategy
We are interested in helping communities adapt to climate change.



Preliminary data from CBEP/UNH system showing influence of end of spring bloom on aragonite saturation

Instrumentation in Casco Bay, sponsored by Casco Bay Estuary Partnership and EPA Office of Water and University of New Hampshire

- Seafet pH sensor made by Satlantic
- Colorimetric Sunburst Submersed Automated Monitoring Instrument (SAMI) for CO_2 owned by UNH
- Optical DO sensor
- Conductivity (salinity) and temperature sensors

The SeaFET™ Ocean pH sensor is an ion selective field effect transistor (ISFET) type sensor for accurate long-term pH measurements in salt water.

Maine Ocean and Coastal Acidification (MOCA) Partnership is promoting information sharing

From Maine Coastal Ocean Observing Alliance discussed at MOCA symposium in June

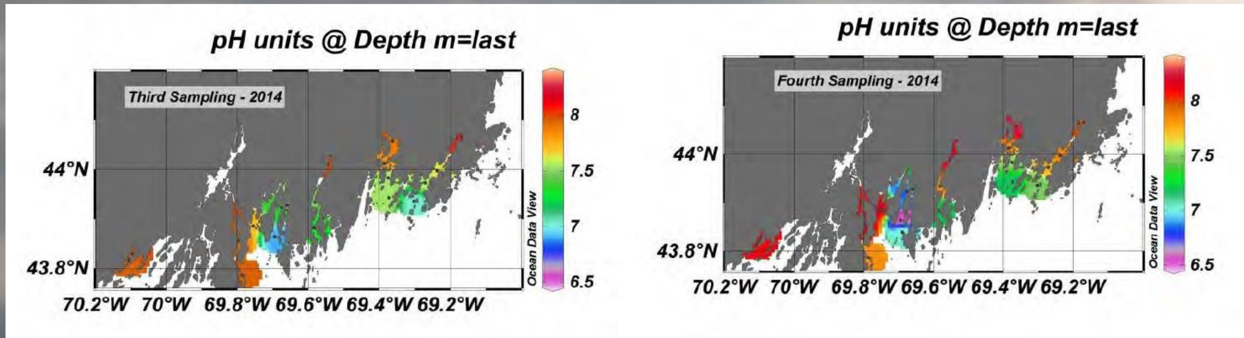
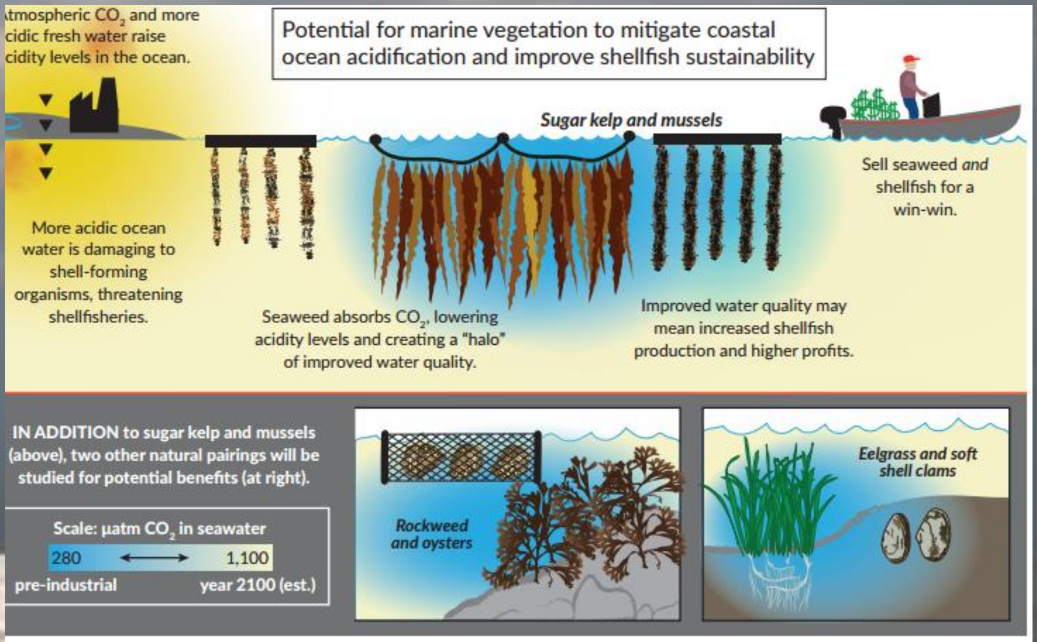


Figure 61. Bird's-eye view of pH measurements during the Third Sampling (left) and Fourth Sampling (right). Top row shows pH at the surface, middle plots show pH at a depth of 5m, bottom plots show pH at the lowest depth sampled for each station. Plots were produced using Ocean Data View (Schlitzer, R., Ocean Data View, http://odv.awi.de, 2014.). Gridded fields represent an interpolation between data points and as such are an approximation for data visualization purposes.

Island Institute project discussed at MOCA partnership meeting in November on remediation options



Six Takeaways

- Ocean Acidification (OA) is happening now
- OA is exacerbated by coastal influences
- We are already seeing effects in the Gulf of Maine
- NECAN is helping connect stakeholders to the best and current science
- EPA is helping coastal managers monitor and understand variability in estuaries
- MOCA is a NECAN partner and is working on state-specific actions