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
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

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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 CO₂ budget

\[ 8.3 \pm 0.4 \, \text{PgC/yr} \quad 90\% \]

\[ 1.0 \pm 0.5 \, \text{PgC/yr} \quad 10\% \]

\[ 4.3 \pm 0.1 \, \text{PgC/yr} \quad 46\% \]

\[ 2.6 \pm 0.8 \, \text{PgC/yr} \quad 28\% \]

\[ 2.5 \pm 0.5 \, \text{PgC/yr} \quad 26\% \]

Calculated as the residual of all other flux components.

Source: Le Quéré et al. 2015
Causing global warming? 
Probably, but not 100% agreement

Causing your ocean to acidify? 
Definitely
Changing Seawater Chemistry

IPCC 2014
WG1, Chapter 3
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 = $\Omega$

$\Omega > 1.6$ necessary for optimal growth in some shellfish.
Our back yard may be particularly sensitive to acidification!
Fresher water can be more sensitive to acidification than saltier water
Colder water tends to be more acidic and lower omega than warmer
Ω data from the ECOA cruise, summer 2015.

Preliminary data from Cai’s U Delaware group
In the last decade the Gulf of Maine has warmed faster than 99.9% of the world’s ocean.
2) The warming was accompanied by an 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”

\[ \text{O}_2 + \text{food} \rightarrow \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{carbonic acid} \]

Causes very low pH and Ω at the sediment interface.
Data from SMCC dock in Casco Bay shows coastal and oceanic acidification.

Oxygen (umol) versus pH total scale, colored by salinity.

- **2016**
  - High productivity during spring freshet (high pH)
  - Low pH at high salinity!

- Intense rain episodes and coastal acidification

Data from SMCC dock in Casco Bay shows coastal and oceanic acidification.
Potential implications of increasing ocean acidity:

- Stress on floating shells
- Reductions in future scallop catch
- 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 $\approx 100\mu m$, mag. $= 370-400X$, pH $= 7.5$, $\Omega_{\text{aragonite}} = 0.5$. 

$T = 0$ 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

Mark Green
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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?

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1. Invest in Maine’s capacity to monitor OA

- Bigelow Labs
- Bowdoin Coastal Lab
- Island Institute
- Friends of Casco Bay
- University of Maine
- University of New Hampshire
- 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

Atmospheric CO₂, nutrient runoff, and more acidic fresh water raise acidity levels in the ocean.

Potential for marine vegetation to mitigate coastal ocean acidification and improve shellfish sustainability.

Sugar kelp and mussels

More acidic ocean water is damaging to shell-forming organisms, threatening shellfisheries.

Seaweed absorbs CO₂, lowering acidity levels and creating a "halo" of improved water quality.

IN ADDITION to sugar kelp and mussels (above), two other natural pairings will be studied for potential benefits (at right).

Eelgrass and soft shell clams

Rockweed and oysters

Scale: µatm CO₂ in seawater

280 1.100
pre-industrial year 2100 (est.)

Sell seaweed and shellfish for a win-win.

Improved water quality may mean increased shellfish production and higher profits.

Courtesy of Nichole Price
From seed to market: How one oyster farmer leverages a growing market

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.

In billions of gallons

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<tr>
<td>2016</td>
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</table>

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