A Primer on Ocean Acidification

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Earth’s history shows us that communities change
often in response to changing climatic conditions
What will ecological communities of the future look like?
Ocean acidification is an increase in ocean acidity due to increased atmospheric CO$_2$
Acidity is a measure of H\(^+\).

pH is the scale used to measure how acidic or how basic something is.

pH is measured on the log scale.

Change of 0.1 pH units is a 30% change in concentration of H\(^+\).

What is acidity? What is pH?
The pH scale was developed by Prof. Sørensen at the Carlsberg brewery laboratory in 1909.
Acidification has already occurred
Ocean acidification in Hawaii

\[
\text{CO}_2(\text{atmos}) \leftrightarrow \text{CO}_2(\text{aq}) + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{CO}_3 \leftrightarrow \text{H}^+ + \text{HCO}_3^- \leftrightarrow 2\text{H}^+ + \text{CO}_3^{2-}
\]

Carbon dioxide (µatm)

Year

Dore et al., 2009
Ocean acidity could increase 100-150% by the year 2100.
Nutrients and acidification

**Nutrients**

- NO, SO₂, CO₂ emissions

**Phytoplankton bloom**

**Phytoplankton die**

**Bacteria bloom**

**Bacteria consume oxygen, respire carbon dioxide**

From Kelly et al. 2011
What is the fate of marine communities under ocean acidification?
Physiological processes are sensitive to carbon dioxide and pH.
OA can have many effects

Respiration

Development

Behavior/Nervous system

Growth
Why focus on larvae and juveniles?

Vellutini and Migotto 2010
What we know

What we can infer
Shells are calcium carbonate

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Calcium carbonate \( \leftrightarrow \) Carbonate + Calcium

\[ \text{CaCO}_3 \leftrightarrow \text{CO}_3^{2-} + \text{Ca}^{2+} \]
Three commercial shellfish species

Pacific oyster

High pH

Low pH

Day 1

Day 4

E. Brunner, G. Waldbusser
Species response can vary

Eastern oyster

Suminoe oyster

Miller et al 2009, photos from National Geographic
There will be surprises!

Munday et al. 2009, 2010;

Sun et al. 2011, Fu et al. 2010
Seawater pH is changing very quickly.
A natural experiment in Italy

Low CO$_2$  High CO$_2$

J. Hall-Spencer
Complex systems have complex responses
OA negatively affects pteropods

Busch et al., 2014
OA will affect marine food webs

Which species are affected by OA will drive the nature of the food web response
OA will affect marine food webs

Species affected by OA will also be affected by predator-prey interactions
OA will affect marine food webs

OA will impact species unaffected by changes in pH via predator-prey interactions
OA will affect marine food webs

OA impacts on just one or a few species can have big effects on the food web and ecosystem services.
Impacts of multiple stressors
People are part of the food web
Who is working on OA?

Federal Govt:
- United States Congress
- Department of State
- Environmental Protection Agency
- United States Geological Survey
- NOAA
- National Science Foundation
- NASA
- U.S. Fish & Wildlife Service
- U.S. Department of Commerce
- Bureau of Ocean Energy Management
- USDA
- Pacific Northwest National Laboratory

States: Washington, Maine, Maryland, California/Oregon/Washington/BC

Universities, NGOs, educational and outreach organizations

IAEA, UN, FAO, tribal nations, EU, SIDS
What we know

- The ocean is acidifying rapidly
- Some species will be sensitive to OA
- Biological responses to OA are variable
- Impacts of OA will ripple through food webs
- Other stressors can exacerbate species response
- The OA community is growing and active
Extra slides
Oysters in Netart’s Bay

Google maps

Barton et al. 2012
Production is lower with lower pH

Growth in feeding stage slower with lower pH

Barton et al. 2012