Corals on Acid
Ocean Acidification – The Other CO₂ Problem

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Talk Outline

What is ocean acidification?
How does it work?
Why do we care?
Results from the field
Atmospheric CO₂ has been increasing at unprecedented rates
What are the consequences of the increase in atmospheric \( \text{CO}_2 \)?
More than 30% of the emitted CO₂ is not in the atmosphere.

Much of this “missing” CO₂ has been adsorbed by the ocean.
Ocean Acidification – The other CO$_2$ problem

Carbon Dioxide

Abundance in Seawater

Acidity

CO$_2$ + H$_2$O $\rightleftharpoons$ H$_2$CO$_3$ $\rightleftharpoons$ HCO$_3^-$ + H$^+$

CO$_3^{2-}$ + H$^+$

Carbonic acid

bicarbonate

protons

carbonate
Evidence of Change

>500 billion tons of CO$_2$ emissions in the ocean

http://hahana.soest.hawaii.edu/hot/products/HOT_surface_CO2.txt
Change in sea surface pH caused by anthropogenic CO₂ between 1700 and 1990
Model results suggest that surface ocean pH will decrease considerably.
Potential impacts on marine organisms & ecosystems

- Reduced calcification rates
- Significant shift in key nutrient and trace element speciation
- Shift in phytoplankton diversity
- Reduced growth, production and life span of adults, juveniles & larvae
- Reduced tolerance to other environmental fluctuations

Changes to:
- Fitness and survival
- Species biogeography
- Key biogeochemical cycles
- Food webs

Reduced:
- Sound Absorption
- Homing Ability
- Recruitment and Settlement
Impacts of Ocean Acidification on Calcification
Ocean Acidification – The other CO₂ problem

Carbon Dioxide

\[ \text{CO}_2 + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{CO}_3 \rightleftharpoons \text{HCO}_3^- + \text{H}^+ \rightleftharpoons \text{CO}_3^{2-} + \text{H}^+ \]

Abundance in Seawater

Acidity
Change in sea surface saturation between 1700 and 1990

Lower $\text{CO}_3^{2-}$-ion concentrations means less $\text{CO}_3^{2-}$ available for organisms that use carbonate minerals to form supporting skeletal structures.

calcification
Representatives Calcifiers

(a) Coralline algae
(b) Halimeda
(c) Foraminifera
(d) Reef-building coral
(e) Deep-water coral
(f) Bryozoans
(g) Mollusks
(h) Echinoderm
(i) Crustacean
(j) Sponges
(k) Polychaetes
(l) Coccolithophore
(m) Pteropod
(n) Cephalopods
(o) Various Larva
Coral Reefs – The Rain Forests of the Ocean
Rich Ecosystems that Provide Important Services

CaCO₃ aragonite skeletons more soluble than calcite

Impacted by many other stressors

May be particularly sensitive to the environment
Ocean acidification is most urgent threat to marine conservation

By the middle of the century there will probably be only a few pockets of coral left, in the North Sea and the Pacific. Millions of species of marine life will be wiped out.

Photograph: Vladimir Leviantovsky/Alamy

Growing Acidity of Oceans May Kill Corals

By Juliet Eilperin
Washington Post Staff Writer
Wednesday, July 5, 2006

The escalating level of carbon dioxide in the atmosphere is making the world's oceans more acidic, government and independent scientists say. They warn that, by the end of the century, the trend could decimate coral reefs and creatures that underpin the

Ocean Acidification Hits Great Barrier Reef

Coral growth has been sluggish since 1990 due to an increase in both sea temperature and acidity as a result of global warming

By David Biello | January 1, 2009 | 12
Manipulation Experiments

Fine and Tchernov, 2007

Corals exposed to low pH seawater lost their carbonate skeleton and stopped calcifying but survived well as “naked” polyps.

Good news for corals bad news for coral reefs
Coral Evolution

A Family Tree of Scleractinia

Long-lived in geological time

First appearance - Paleozoic

Proliferation in Mid-Triassic

Persisted through several episodes of climate change in the last 450 My

Coral calcification declines sharply below aragonite saturation of 2.5
Reynaud et al. 2003

Experimentally-induced by $pCO_2$ increase (450 vs. 734 $\mu$atm)

No effect of doubling $pCO_2$ at 25°C
Increase in $pCO_2$ at 28°C decreases calcification (54%)
If coral reefs are maintained in healthy condition and are given sufficient time, will they acclimate or even adapt to ocean acidification and maintain high calcification rate that sustain reef infrastructure and growth?
Low pH low saturation springs in the back reef lagoon 500m offshore with “control” sites close by for comparison.
Ecosystem Response – Field experiments to investigate community and ecosystem responses and adaptation over long scales
* 3 calcifying corals species settled, grew and calcified under low pH low saturation (10 outside).

* These species (*Porites astreoides, P. divaricata, and Siderastrea radians*) are not major contributors to reef framework.

* Coral species richness & coral colony size decline in proximity to low-saturation.

* Response to ocean acidification is likely to vary across species and environments.
Impact on coral physiology – calcification rate and other coral health parameters (symbionts, tissue thickness and protein content)
Extension – Distance between annual growth bands.

Density – How much aragonite in each volume of skeleton.

Calcification – Product of extension and density.

Cores were scanned intact with a Siemens Volume Zoom Spiral Computerized Tomography (CT) scanner.
Two pairs of Porites cores of equal size from ojos center (a & c - pH 7.6) and control (b & d - pH 8.1) showing differential degrees of boring.
Mechanisms for Acclimation

Tissue thickness – increase to compensate for calcification at low pH

Symbiont clades – May be different symbionts are more adapted?

Symbiont density – More symbionts more resources?

Nutrient levels – Higher nutrients more energy for calcification?
Recruitment

Largest effect on algae

Control

Low pH
Coraline Algae

Field survey: underwater transects @ 5 ojos

Measured percent cover of all calcifying algae & identified to species/genus, (richness, diversity, composition and structure)
Foraminifera

Absolute Abundances

Relative Abundance of Symbiont-bearing
Response to ocean acidification is likely to vary across species and environments. Need to understand genetic mechanisms for calcification.

What are the prospects for adaptation?
More symbionts
More chlorophyll
More protein
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There is a significant difference in gene expression due to coral origin.

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There is a significant difference due to transplantation effect.
Technology

Breeding - "assisted evolution." Cross-breeding organisms for desirable traits

Hybridized - manually breeding “supercorals” capable of living in the increasingly inhospitable sea

Manipulate the bacteria and algae that live within coral

Genetic modification - Crisper

Mitigation, Conservation and Protection, Elimination of Invasive Species Enhancement by Transplantation

Credit: COURTESY O AUSTRALIAN INSTITUTE OF MARINE SCIENCE
Value the ocean
It's the only one we have.
We were life Aquatic