How Will Ocean Acidification Impact Marine Life and Ecosystems?

Anthropogenic ocean acidification is currently in progress and is measurable [Very High Confidence]

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Valuable ocean resources under threat

• Fish is main protein source for 1 billion people (and growing)
• Fisheries employ ~10% of world population, 90% small-scale
• Coral reefs support $30-375 Billion
• Ocean provides half of oxygen we breathe

Subsistence fisherman in Fiji
Coral reef in South Pacific
Past acidification events led to mass extinctions of marine life

- 55 million years ago, Paleo-Eocene Thermal Maximum (PETM) acidification event
- 10,000s years for shells to reappear in fossil record
- Current rapid rate of acidification (~10X faster than PETM) makes adaptation unlikely for most species

Anthropogenic ocean acidification will adversely affect many calcifying organisms [Medium Confidence]
Threats to organisms from reduction in pH

"Life is a struggle, not against sin, not against the Money Power, not against malicious animal magnetism, but against hydrogen ions." H.L. Mencken

Change in human blood pH by **0.03 pH units** leads to serious health problems.

At current emissions rates, we will reduce ocean pH **0.3 additional pH units** by 2100.
Commercialey and ecologically important species affected differently

<table>
<thead>
<tr>
<th>GROUPS</th>
<th>Molluscs</th>
<th>Echinoderms</th>
<th>Crustaceans</th>
<th>Finfish</th>
<th>Corals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current estimated global commercial value*</td>
<td>$24 billion</td>
<td>$0.7 billion</td>
<td>$37 billion</td>
<td>$65 billion</td>
<td>$30-375 billion$</td>
</tr>
</tbody>
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Sensitivity (percent of species affected)$\wedge$

<table>
<thead>
<tr>
<th>Species (%)</th>
<th>Positive</th>
<th>None</th>
<th>Negative</th>
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<tbody>
<tr>
<td>100</td>
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Effects
- Positive
- None
- Negative

Summary for Policymakers (adapted from Wittmann & Pörtner 2013)
Key links in food chains susceptible

- Sea star, sea cucumber, brittle star, sea urchin adults, larvae and eggs
- Krill embryo development
- Pteropods – already dissolving in Southern Ocean

Brittle star larvae die after 7 days in lower pH.

Krill larvae develop abnormally in high CO₂.

Bednarsek et al. (2012)

Dupont et al. (2010)

Kawaguchi et al. (2010)
Potential fisheries and aquaculture impacts

- Indirect effects on fish through food web interactions
- Potential direct behavioral, neurological impacts
- Fish larvae appear more sensitive
- Shellfish highly vulnerable – molluscs one of most sensitive groups studied

Fisherman in Trennganu, Malaysia. Photo Credit: Theodore Groves

Woman harvesting oysters in Xiamen, China. Photo Credit: Michael Yamashita
Impacts in vulnerable regions to be seen within decades

- Polar regions
- Tropical coral reefs
- Cold-water coral reefs
- Upwelling areas
- Estuaries

These ecosystems support the world’s most productive fisheries

pH 2100

Developing coastal countries and small island states at high risk.

Upwelling of corrosive water to the surface off the coast of Oregon.

Feely et al. (2008)
CO\(_2\) vents: windows into future high CO\(_2\) ecosystems

- 30% less biodiversity near CO\(_2\) vent vs. outside
- Regime shift from calcareous species to algae/seagrasses

Courtesy: J. Hall-Spencer
Ocean acidification is not acting alone

- Warming, deoxygenation, pollution, overfishing, coastal development compound effects of acidification
- Threats to ocean services:
  - Jobs, food security (fisheries + aquaculture), pharmaceuticals, tourism, recreation, cultural value, biodiversity, climate regulation, shoreline protection

Hoegh-Guldberg et al. (2007)

- 375 ppm +1 C
- 450-500 ppm +2 C
- >500 ppm +3 C

Hoegh-Guldberg et al. (2007)
Conclusions

- We can expect ecosystem changes based on variable species responses.
- Many developing coastal nations and small island nations are at highest risk.
- Most vulnerable ecosystems are also economically significant.
- Ocean acidification is acting alongside and with other stressors.

Reducing CO₂ emissions will slow the progress of ocean acidification [Very High Confidence]

Acknowledgments