Ocean acidification and its impacts on marine ecosystems

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SDG14: Conserve our Oceans

- Largest ecosystem on the planet and crucial to all life on earth.
- Regulate the climate.
- Produces a sixth of all animal protein we consume.
- Provides livelihoods for ~ 3 billion people worldwide.
- Worth an estimated $US 3 trillion - $US 6 trillion to the global economy.
The ocean is changing at an unprecedented rate.
Atmospheric CO₂

CO₂ dissolves in water

CO₂ (aq)

Forms Carbonic Acid

H₂CO₃

Breaks down to form bicarbonate and hydrogen ions

HCO₃⁻ + H⁺

Carbonate ions react with these 'extra' hydrogen ions

CO₃²⁻
Ocean acidification affects calcification

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

CaCO$_3$ saturation state \((\Omega) = \frac{[\text{Ca}^{2+}] [\text{CO}_3^{2-}]}{k_{sp}}\)
Polar oceans will become corrosive to shell material within decades.

Models project that cold waters soon become corrosive to aragonite, a (CaCO3) mineral in some marine shells & skeletons. Latest model projections (IPCC AR5 WG1, 2013)
Ocean acidification is happening first and fastest in the Arctic

Over much of the Arctic, the pteropod *Limacina helicina* will become unable to precipitate CaCO₃ by the end of the century under the RCP 8.5 scenario.
Ocean acidification affects already visible

The US west coast shellfish industry is seeing unprecedented levels of larval mortality in commercial hatcheries—linked to lower $\Omega_{\text{aragonite}}$.

Dissolution of pteropod shells already observable in the Southern Ocean and the Californian upwelling.
OA affects on corals - a particular concern.

- Coral reefs cover 0.1% of the ocean but house over 25% of marine biodiversity (> million species).
- Warm-water coral reefs are already under stress, with >50% currently in poor health.
- OA slows calcification, and hence recovery from bleaching.
Energetic cost of ocean acidification.
Early life stages – embryos, larvae and juveniles – may be much more sensitive to OA than adults.
Over 50% benthic invertebrates and fish species studied to date at risk.

Whitmann and Pörtner (2013)
These invertebrates play key roles in marine ecosystem functioning.
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OA interacts with other stressors

Synergistic interactions (greater than the sum of effects) have been found in over 66% of studies looking at OA-multi-stressors effects.
Risk to ecosystems very high without reduced carbon emissions:

<table>
<thead>
<tr>
<th>Risk of Impact</th>
<th>Low Carbon Emissions</th>
<th>High Carbon Emissions</th>
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</thead>
<tbody>
<tr>
<td>Seagrass (m)</td>
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<td>Mangroves</td>
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<td>Warm-water corals</td>
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<td>Pteropods (h)</td>
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<tr>
<td>Bivalves (m)</td>
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<td>Krill (h)</td>
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<tr>
<td>Fin fish</td>
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</table>
Risks to goods and services reduced by lowered carbon emissions:

- Coastal protection
- Coral reef recreation
- Bivalve fisheries, aquaculture (m)
- Fin fish fisheries (t)
- Fin fish fisheries (m,t)
- Open ocean carbon uptake
Global OA Observation Network

Sites in Global OA Observing network – mostly chemistry only: www.goa-on.org

A global OA observing network is being developed to relate chemical and biological changes, but there are currently many gaps in coverage.
Strong exiting EU ocean acidification expertise from past programmes and initiatives:

### National
- **2008:**
  - UK Ocean Acidification research programme
  - *main science support*
- **2009:**
  - Germany BIOACID
    - *Phase 1*
  - Biological Impacts of Ocean Acidification
    - *Phase 2*
- **2010:**
  - EPOCA: European Project on Ocean Acidification
- **2011:**
- **2012:**
- **2013:**
  - Also CarboChange, MEECE, EuroBasin & CoralFISH
- **2014:**
- **2015:**

### EU
- **2008:**
  - MedSeA
    - Mediterranean Sea Acidification in a changing climate
- **2009:**
- **2010:**
- **2011:**
- **2012:**
  - OSPAR-ICES OA Study Group
- **2013:**
- **2014:**
  - OA International Coordination Centre
- **2015:**

### International
- **2008:**
  - Also OAiRUG, SOLAS, IMBER, SOCAT & GLODAP
- **2009:**
- **2010:**
- **2011:**
- **2012:**
- **2013:**
- **2014:**
- **2015:**

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**The Ocean Nexus**