Directly Measuring Ocean Acidification

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Introduction

Basin-wide surveys of seawater pH were conducted in the North Pacific Ocean on a transect between Honolulu, Hawaii, and Kodiak, Alaska, in 1991 and 2006 (Byrne et al., 2010).

Ocean pH in the upper half mile of the ocean declined significantly over the 15-year period.

Chemistry of Ocean Acidification:
- Anthropogenic (i.e., human-produced) carbon dioxide (CO₂) is released to the atmosphere by burning coal and oil, and other human activities (C + O₂ → CO₂).
- CO₂ enters the surface ocean from the atmosphere.
- CO₂ reacts in seawater to form carbonic acid (CO₂ + H₂O → H₂CO₃).
- Carbonic acid releases protons (H₂CO₃ → H⁺ + HCO₃⁻), thereby increasing ocean acidity and lowering seawater pH.

CO₂ Transfer: Atmosphere → Ocean

pH Changes

Long-term Pacific Ocean measurements show that surface-ocean pH closely tracks changes in atmospheric CO₂. This relationship is expected to more than double surface-ocean acidity during this century as atmospheric CO₂ continues to increase.

Subsurface CO₂ Penetration

Measurements along a 2300-mile transect between Hawaii and Alaska documented a substantial decline in upper-ocean (0-800 m) seawater pH between 1991 and 2006:
- In the surface wind-mixed layer (depths to ~100 m), pH declined about 0.0017/yr, also in close correspondence with changes in atmospheric CO₂.
- Between 100 and 800 m (~0.5 mi), pH declines were due in approximately equal proportions to (a) natural ocean variability, and (b) transport of anthropogenic CO₂ from the surface ocean to greater depths.

Impacts

On Ocean Chemistry

On Organisms

Carbonate Ion (CO₃²⁻) Concentrations in Surface Waters from CCSM Climate Model

Declines in pH are accompanied by declines in carbonate ion (CO₃²⁻) concentrations in seawater, and carbonate is an essential component of calcium carbonate (CaCO₃) shells.

Model predictions that assume unabated CO₂ emissions (IPCC A2 scenario) indicate that CO₃²⁻ concentrations will decline to levels below those required for shell and reef formation over much of the world ocean by the end of the century.

The ecological consequences of declining ocean pH and diminishing carbonate ion concentrations are not well understood, but changing ocean chemistry is expected to have major impacts (Faby et al., 2009; Kleypas et al., 2009).

There will likely be some winners (seagrasses) and some losers (calcifying organisms, such as clams, oysters, corals, lobsters, and pteropods, and their predators, such as pink salmon).

Conclusions

- Surface-ocean acidification is keeping pace with rising atmospheric CO₂.
- Acidification is penetrating the subsurface ocean.
- Reduction in ocean pH and carbonate ion concentrations will likely have major consequences for ocean life, but at present, the overall impacts on marine ecosystems are poorly understood.
- Continued ocean chemistry monitoring as well as studies of ecosystem sensitivity are needed.

References


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