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).

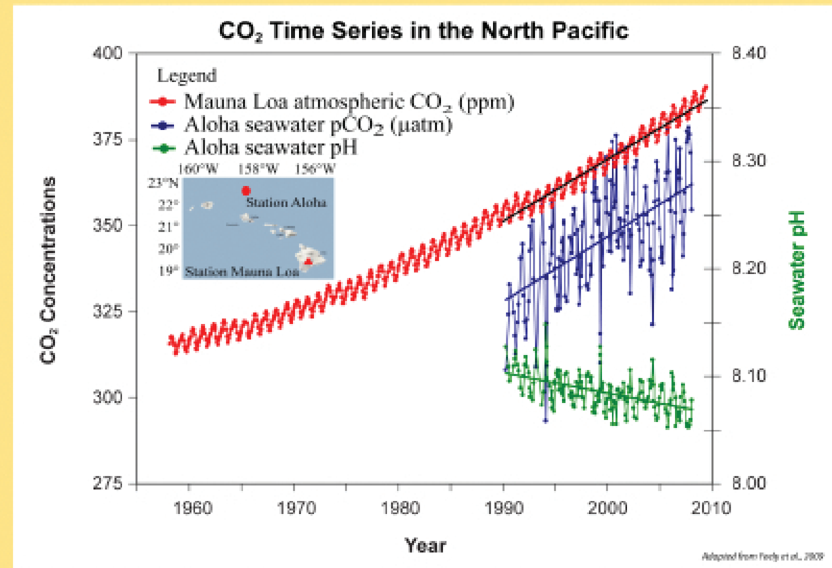
Ocean pH in the upper half mile of the ocean declined significantly over the 15-year period.

Chemistry of Ocean Acidification:

- Anthropogenic (= human-produced) carbon dioxide (CO_2) is released to the atmosphere by burning coal and oil, and other human activities ($C + O_2 \rightarrow CO_2$)
- CO_2 enters the surface ocean from the atmosphere
- CO_2 reacts in seawater to form carbonic acid ($CO_2 + H_2O \rightarrow H_2CO_3$)
- Carbonic acid releases protons ($H_2CO_3 \rightarrow HCO_3^- + H^+$), thereby increasing ocean acidity and lowering seawater pH

pH Changes

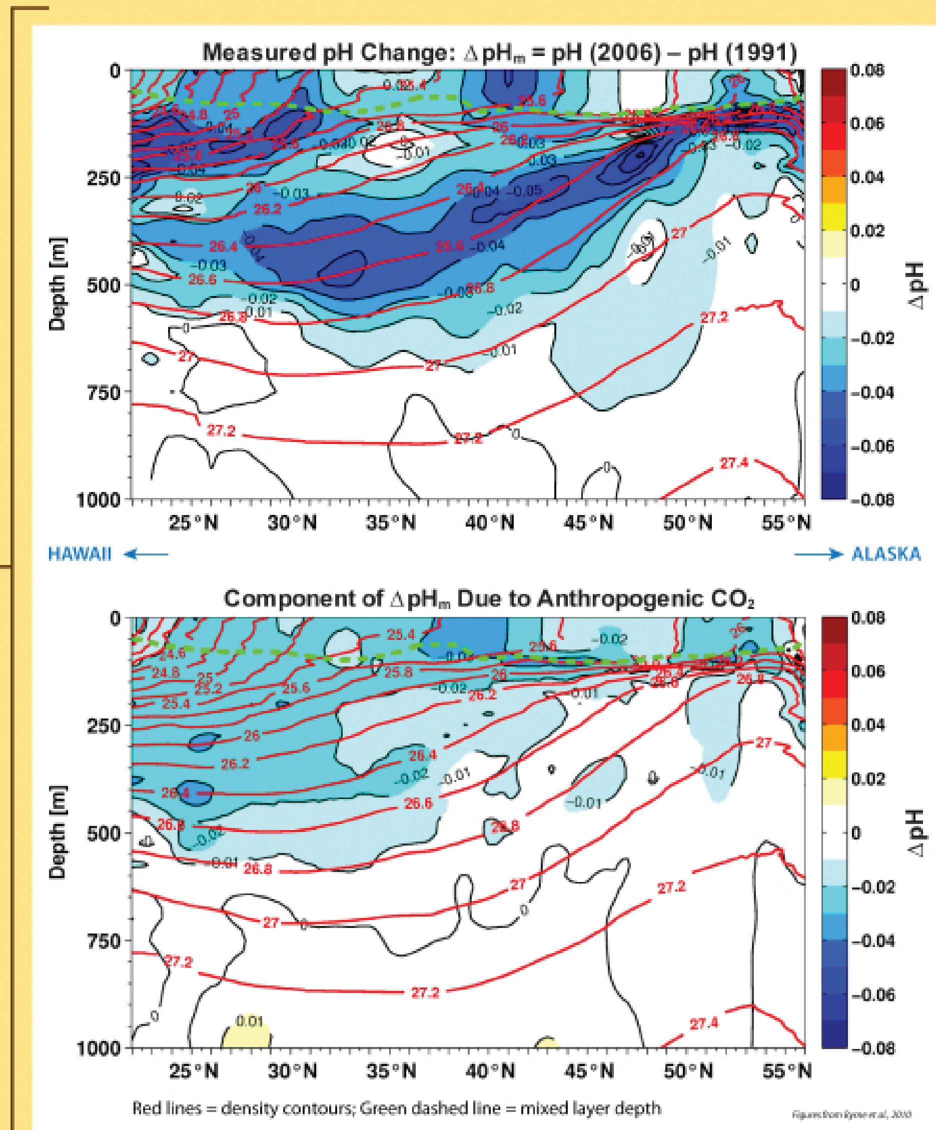
CO_2 Transfer: Atmosphere → Ocean



Long-term Pacific Ocean measurements show that surface-ocean pH closely tracks changes in atmospheric CO_2.

This relationship is expected to more than double surface-ocean acidity during this century as atmospheric CO_2 continues to increase.

Subsurface CO_2 Penetration

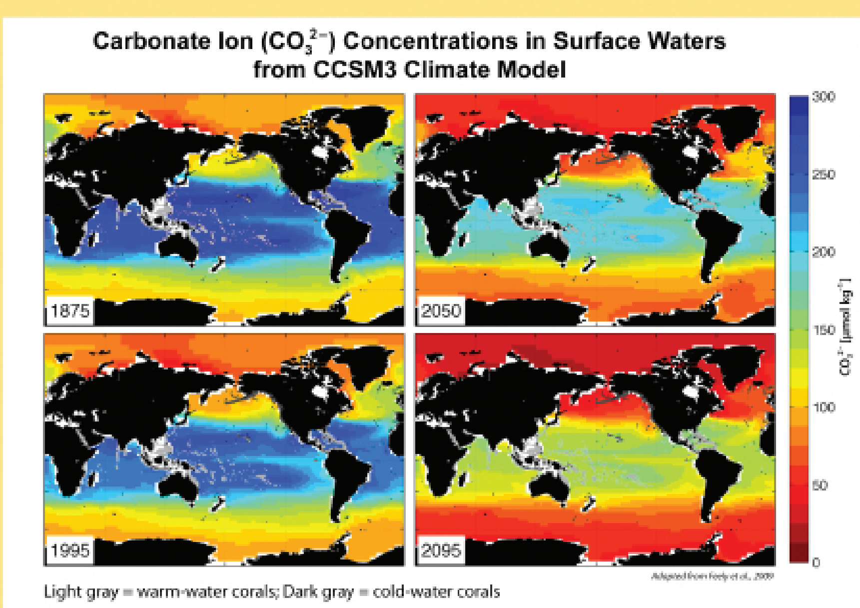


Measurements along a 2300-mile transect between Hawaii and Alaska document a substantial decline in upper-ocean (0–800 m) seawater pH between 1991 and 2006:

- In the surface wind-mixed layer (depths to ~100 m), pH declined about -0.0017/yr, also in close correspondence with changes in atmospheric CO_2
- 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 CO_2 from the surface ocean to greater depths

Impacts

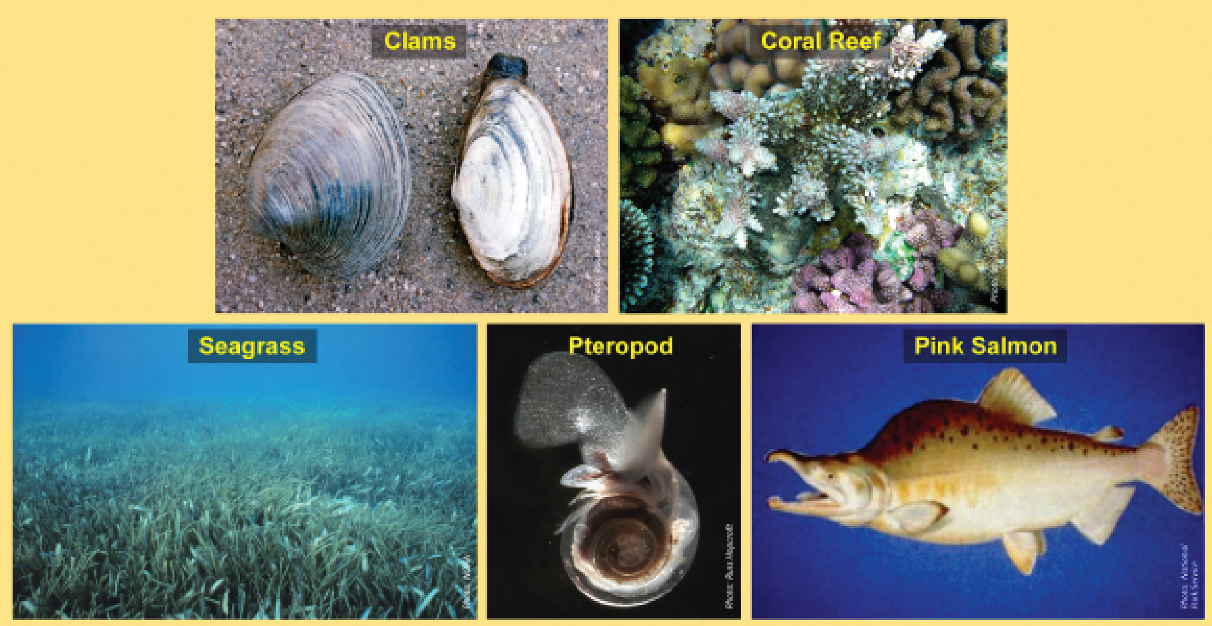
On Ocean Chemistry



Declines in pH are accompanied by declines in carbonate ion (CO_3^{2-}) concentrations in seawater, and carbonate is an essential component of calcium carbonate ($CaCO_3$) shells.

Model predictions that assume unabated CO_2 emissions (IPCC A2 scenario) indicate that CO_3^{2-} 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.

On Organisms



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 (Fabry 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 CO_2
- 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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