State of the Science FACT SHEET

Ocean Acidification

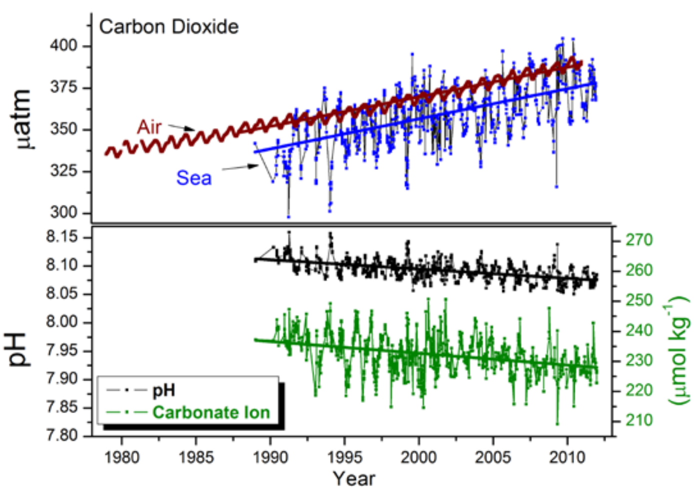
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION • UNITED STATES DEPARTMENT OF COMMERCE

This document represents the ocean acidification (OA) state of the science as developed by the NOAA Ocean Acidification Program.

What is Ocean Acidification?

Ocean acidification (OA) refers to long-term changes in global ocean carbon chemistry in response to rising levels of atmospheric carbon dioxide (CO_2). OA acidifies ocean and Great Lakes surface waters (i.e., reducing pH), enriches them waters in CO_2, and causes a decrease in the availability of carbonate ions important to carbonate mineral formation (e.g., shells, reef frameworks, marine sediments). Today's ocean pH has globally declined by 0.1 since the industrial revolution and is nearly certain to decline by an additional 0.3 over the next century unless global carbon emissions are significantly curtailed. Such changes are at least ten times faster than at any time over the past 50 million years and can readily be observed in extended ocean time-series observations. Local factors controlling carbonate chemistry (e.g., upwelling, riverine discharge, nutrient loading, hypoxia, organic carbon remineralization) further modify OA at regional and local-scales. Understanding OA and predicting the consequences for marine resources is necessary for informing national and international carbon mitigation discussions and enabling local communities to better prepare and adapt to such changes.

A Changing Ocean



A two decade time-series of ocean acidification in the surface ocean near Mauna Loa Observatory in Hawaii. Adapted from Dore et al., 2009. Proc Natl Acad Sci USA 106:12235-12240.

What are the Impacts for Marine Life?

Earth's history reveals several acidification events in the past which impacted the abundance, diversity, and evolution of calcifying organisms throughout the world's oceans. Laboratory and field studies help scientist to better understand the implications of modern OA event transpiring in response to human activities. These studies demonstrate that many marine species will likely experience adverse effects on health, growth, reproduction, and survival in response to increasing OA, particularly in early life-stages.

An Ecological Challenge

Predicting how OA will impact marine ecosystems and the services they provide demands a multidisciplinary and cross-agency approach.

Most species of coral, calcifying algae, coccolithophores, and molluscs (including some economically important oysters), grow slower under OA. A limited number of studies prevent drawing generalized conclusions with regards to the effects on marine crustaceans (e.g., copepods, crabs, lobsters, crayfish, shrimp, krill and barnacles). However, decreases in survival, growth rate, and egg production in some species have been reported. Effects on non-calcifying organisms have also been demonstrated including on the development of larval stages of some fish and on the ability to detect predators. Reduced survival and growth of echinoderms, including sea urchins, sand dollars, seastars, sea cucumbers, and brittlestars may also occur. Some phytoplankton taxa and seagrasses may benefit from OA, likely furthering shifts in community composition.

What Are the Potential Socio-Economic Consequences of Ocean Acidification?

Globally, marine ecosystem services have been estimated at a total annual value of US$20 trillion[1] many of which could be impacted by OA. Socioeconomic modeling efforts represent an important aim of the NOAA OA research strategy.

The Societal Concerns

Ocean acidification is likely already impacting the oyster hatchery industry of the Pacific Northwest. Active monitoring efforts are helping these industries devise adaptive strategies. Photo Credit: Taylor Shellfish Puget Sound hatchery.

Should OA broadly impact marine habitats and alter marine resource availability as anticipated, substantial revenue declines, job losses, and indirect economic costs would occur[2]. Effects to human communities would include changes in shellfish harvest, coral and oyster reef ecoservices, and indirect impacts across the marine food webs. A few examples are:

- Coral reef environments provide habitat for an estimated one million species, and offer food, income, and coastal protection for about 500 million people globally. NOAA has identified OA as a contributing threat to coral reefs in the recently proposed Endangered Species Act (ESA) listings for 66 coral species.

- In 2009, U.S. shellfish revenue represented about half the total landings revenue estimated at $3.9 billion. OA has already been identified as impacting key sectors of the shellfish industry along the Pacific Northwest. Failures at oyster hatcheries between 2007 and 2012 were linked with changes in ocean chemistry. Washington's seafood industry is estimated to contribute to over 42,000 jobs and at least $1.7 billion of the gross state product through profits and employment at businesses such as neighborhood seafood restaurants, distributors, and retailers. In 2012, the Blue Ribbon Panel was convened by Washington Gov. Gregoire uniting scientists, decision makers, industry stakeholders, tribal representatives, and conservation community representatives to address the issue. The panel reviewed the best available science and has produced a set of 42 recommendations to guide Washington's response to OA[3].

[1] Costanza, R., et al., 1997. The value of the worlds ecosystem services and natural capital. Ecol. Econom. 25 (1), 3–15.

[2] Cooley, S. R. and S. C. Doney (2009). "Anticipating ocean acidification's economic consequences for commercial fisheries." Environmental Research Letters 4(2): 024007.

NOAA's Ocean Acidification Efforts

Understanding how OA is unfolding and the impacts to marine resources are the principal goals of NOAA's OA efforts. A global network of ship surveys and time-series station observations have provided a strong foundation to understand OA globally. However, characterizing OA at regional and local scales, particularly within coastal margins and estuaries, remains a key challenge. Knowledge of how local processes can alter the dynamics of OA is critical to informing management actions to prevent, mitigate, or adapt to OA. NOAA is working to establish long-term high quality OA observations within ocean, coastal, and coral reef environments. Chemical monitoring tied to ecosystem response monitoring is an important aspect. Such efforts are advanced through a network of targeted and volunteer ship surveys, fixed mooring observations, and development of advanced technologies. This information is being tailored to inform experiments conducted on commercially and ecologically significant taxa to advance eco-forecasting and socioeconomic modeling efforts. All these efforts are geared towards improving our understanding of how OA occurs regionally and teasing out the broad range of vulnerabilities to better inform local management and adaptation practices.

Resources for Additional Information

NOAA laboratories contribute to several international and national research programs studying OA. National coordination is organized through the Interagency Working Group on OA and the Ocean Carbon and Biogeochemistry Program among others. The International Coordination Centre on OA is further expected to facilitate information sharing between researchers and policymakers across the globe. Additional resources are available from the NOAA Ocean Acidification Program.

[3] Washington State Blue Ribbon Panel on Ocean Acidification (2012): Ocean Acidification: From Knowledge to Action, Washington State's Strategic Response. H. Adelsman and L. Whitely Binder (eds). Washington Department of Ecology, Olympia, Washington. Publication no. 12-01-015.