State of the Science FACT SHEET

Ocean Acidification

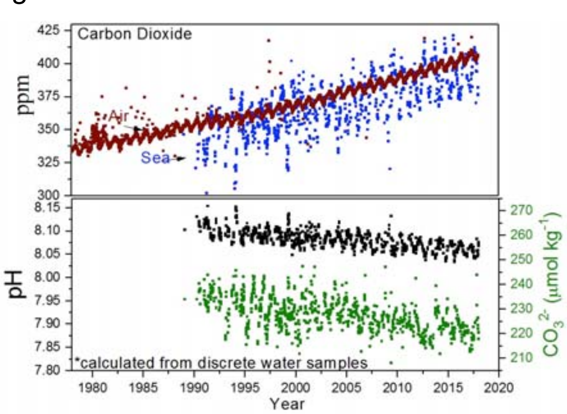
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION • UNITED STATES DEPARTMENT OF COMMERCE

This document represents the state of the science on ocean acidification including its effects on marine life and ecosystems in addition to its socio-economic consequences as developed by NOAA.

What is Ocean Acidification?

Ocean acidification (OA) refers to changes in ocean carbon chemistry over extended periods in response to rising levels of atmospheric carbon dioxide (CO_2). The rise in atmospheric CO_2 is due to the burning of fossil fuels such as coal, gas, cement production, and oil, along with land use change. When absorbed by the ocean and Great Lakes, CO_2 reduces pH (signifying an increase in acidity) and causes a decrease in the availability of carbonate ions important to mineral formation of shells and coral reef frameworks.

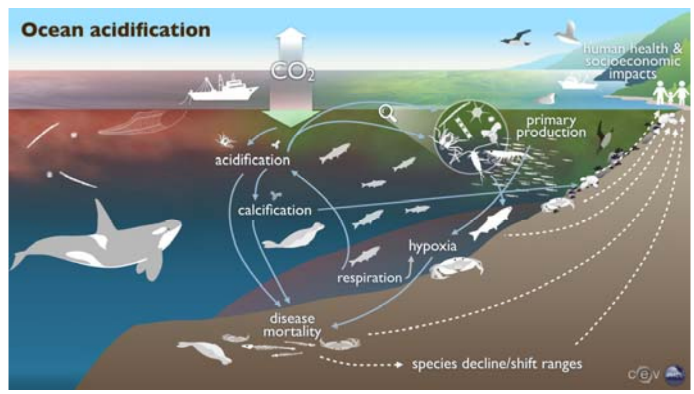
Global surface ocean pH has declined on average by approximately 0.1 since the Industrial Revolution, an increase in acidity of about 30%. Ocean pH is projected to decline by an additional approximately 0.3 over the next century unless global carbon emissions are significantly curtailed. These changes can be observed in extended ocean time-series and are at least ten times faster than any period over the past 50 million years. Local factors controlling carbon chemistry (e.g., upwelling, riverine discharge, nutrient loading, biological respiration) further impact acidification at regional and local scales. Understanding acidification and predicting the consequences for marine resources and services is necessary for informing national and international carbon mitigation discussions and enabling local communities to better prepare for and adapt to such changes.



As CO_2 increases (top), the ocean's pH and carbonate ion concentrations decline (bottom). Measurements near Mauna Loa Observatory in Hawaii. Adapted from Dore et al. 2009. Proc Natl Acad Sci USA 106:12235-12240.

What are the Impacts to Marine Life?

Laboratory and field studies allow for a better understanding of the implications of OA. Species vary in their sensitivity to OA, with some responding positively, some negatively, and others not at all. Overall, studies demonstrate that many marine species will likely experience adverse effects on health, growth, reproduction, and survival, particularly in early life-stages. OA research still requires more studies to answer the numerous questions related to OA consequences on biology.



OA is expected to impact organisms and cause changes to the marine food web. These changes lead to socio-economic consequences. Predicting how OA will impact marine ecosystems and the services they provide demands a multidisciplinary and cross-agency approach (Figure credit: Simone Alin, NOAA Pacific Marine Environmental Laboratory, and Hunter Hadaway, University of Washington Center for Environmental Visualization)

Organisms that produce calcium carbonate structures like corals, shellfish, coralline algae, pteropods, and urchins, are generally most sensitive to OA because it may compromise their ability to build and maintain their structure. The sensitivity of highly valued habitats like oyster beds and coral reefs could lead to changes that disrupt ecosystem function and alter food web dynamics. Coral reefs will likely experience a decline in their ability to sustain calcification production, limiting their capacity to recover from damage and offer coastal communities protection from acute disturbance events such as storms.

Both calcifying and non-calcifying organisms have negative health effects from exposure to OA. OA affects the nervous system function of some fish, which impacts their ability to navigate and detect predators. Predators could experience indirect effects from food web interactions (e.g., loss of their food source). On the other hand, some seagrasses and phytoplankton may benefit from OA, further shifting community composition and the food webs we are dependent on.

OA is not occurring in isolation; species are simultaneously exposed to OA and other stressors including low oxygen and increased temperatures. These many stresses can have complex effects on species, sometimes amplifying one another but other times reducing overall species response. NOAA is conducting laboratory and field studies on the impact of multiple stressors on marine organisms to better predict future implications of a high CO_2 world.

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

Globally, marine ecosystem services may be impacted by OA; thus socio-economic modeling efforts represent an important aim of the NOAA OA research strategy. Should OA broadly impact marine habitats and alter marine resource availability as anticipated, substantial revenue declines, job losses, and indirect economic costs could occur[1]. Effects to human communities could include changes in shellfish harvest, coral and oyster reef ecosystem services, and indirect impacts across marine food webs. Select examples include:

- Coral reefs provide habitat for an estimated one million species and offer food, income, and coastal protection to about 500 million people globally. NOAA has identified OA as a contributing threat to coral reefs in the Endangered Species Act listings. OA serves as an additional stress to an already challenged ecosystem threatened by unsustainable fishing, warming seas, and pollution. The Environmental Protection Agency estimates $140 billion loss in reef-based recreation in Hawaii, South Florida, and Puerto Rico from OA and temperature effects[2].
- In 2015, total U.S. shellfish landings were valued at $2.8 billion[3]. An estimated $230 million in costs to U.S. shellfish harvest is expected under continued CO_2 emissions[2]. OA is already affecting key sectors of this industry. Failures at Pacific oyster hatcheries beginning in 2007 have been linked to OA[4]. In response to OA concerns, states and regions around the U.S., such as Washington, Oregon, California, Maine, and Maryland have developed task forces and action plans to evaluate and combat problems of acidification in local waters[5][6][7][8][9]. Similar panels are now being created in various regions through the United States.

NOAA's Research on Ocean Acidification

Regional differences in OA rates and variable species sensitivity[10] contribute to large uncertainties with respect to the precise impacts to the Blue Economy in coming decades. NOAA works to reduce this uncertainty through OA monitoring, modeling, species response research, and examining potential socio-economic impacts. NOAA collects long-term, high-quality OA observations within ocean, coastal, and coral reef environments to identify the changes in carbon chemistry over time making this data and derived products available to the international science community and decision makers. Knowledge of how local processes can alter the dynamics of OA is needed to inform local management actions to prevent, mitigate, or adapt to OA. The OA observations are guiding experiments conducted on commercially and ecologically significant organisms to better predict how OA may impact ecosystems and the services they provide. NOAA also continues to develop state-of-the-art global and regional oceanographic models that can simulate historical changes and project future OA conditions for use by scientific and resource management communities. Finally, informing society about the growing concerns of OA through education and outreach resources is an important part of all NOAA efforts.

Additional resources are available from the NOAA Ocean Acidification Program at: www.oceanacidification.noaa.gov

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