THE NATIONAL ACADEMIES

REPORT IN BRIEF

KEY FINDINGS

Ocean Acidification:

A National Strategy to Meet the Challenges of a Changing Ocean

The ocean has absorbed a significant portion of all human-made carbon dioxide emissions, benefiting society by moderating the rate of climate change, but also causing unprecedented changes to ocean chemistry. Carbon dioxide taken up by the ocean decreases the pH of the water and leads to a suite of chemical changes collectively known as ocean acidification. The long term consequences of ocean acidification are not known, but are expected to result in changes in many ecosystems and the services they provide to society. This report, requested by Congress, reviews the current state of knowledge and identifies gaps in understanding, with the following key findings.

1. **Ocean chemistry is changing at an unprecedented rate and magnitude due to human-made carbon dioxide emissions to the atmosphere.** The average pH of ocean surface waters has decreased by about 0.1 pH unit —from about 8.2 to 8.1–since the beginning of the industrial revolution, and model projections show an additional 0.2-0.3 drop by the end of the century, even under optimistic scenarios of carbon dioxide emissions.

2. **Changes in seawater chemistry are expected to affect marine organisms that use carbonate to build shells or skeletons.** For example, decreased concentrations of calcium carbonate make it difficult for organisms such as coral reef-building organisms, and commercially important mollusks like oysters and mussels, to grow or to repair damage. If the ocean continues to acidify, the water could become corrosive to calcium carbonate structures, dissolving coral reefs and even the shells of marine organisms.

Ocean Chemistry

The ocean takes up carbon dioxide from the atmosphere, and as the gas dissolves in seawater it forms carbonic acid. This decreases the concentration of carbonate ions in the water and reduces the availability of calcium carbonate for corals and other calcifying organisms. Under more acidic conditions, more carbonate ions will form bicarbonate.

3. **It is currently not known how various marine organisms will acclimate or adapt to the chemical changes resulting from acidification.** Based on current knowledge, it appears likely that there will be ecological winners and losers, leading to shifts in the composition of many marine ecosystems.

4. **The committee finds that the federal government has taken positive initial steps by developing a national ocean acidification program.** The recommendations in this report provide scientific advice to help guide the program.

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5. **More information is needed to fully understand and address the threat that ocean acidification may pose to marine ecosystems and the services they provide.** Research is needed to assist federal and state agencies in evaluating the potential impacts of ocean acidification, particularly to:
   - understand processes affecting acidification in coastal waters;
   - understand the physiological mechanisms of biological responses;
   - assess the potential for acclimation and adaptation;
   - investigate the response of individuals, populations, and communities;
   - understand ecosystem-level consequences;
   - investigate the interactive effects of multiple stressors;
   - understand the implications for biogeochemical cycles; and
   - understand the socioeconomic impacts and informing decisions.

6. **The national ocean acidification program will need to adapt in response to new research findings.** Because ocean acidification is a relatively new area of research, the program will need to adapt in response to findings, such as the identification of important biological metrics, analyses of the socioeconomic impact of ocean acidification, and inclusion of concerns from stakeholder communities.

7. **A global network of chemical and biological observations is needed to monitor changes in ocean conditions attributable to acidification.** Existing observation systems were not designed to monitor ocean acidification, and thus do not provide adequate coverage or measurements of carbon parameters, such as total alkalinity, pH, and dissolved inorganic carbon, or biological constituents such as nutrients, oxygen, and chlorophyll. Adding sites in vulnerable ecosystems, such as coral reefs or polar regions, and in areas of high variability, such as coastal regions, would improve the observation system.

8. **International collaboration will be critical to the success of the program.** Ocean acidification is a global problem that requires a multinational research approach. Such collaborations also afford opportunities to share resources, including expensive large-scale facilities for ecosystem-level manipulation, and expertise that may be beyond the capacity of a single nation.

9. **The national ocean acidification program should support the development of standards for measurements and data collection and archiving to ensure that data is accessible and useful to researchers now and in the future.** Steps should be taken to make information available to policy makers and the general public in a timely manner.

Committee on the Development of an Integrated Science Strategy for Ocean Acidification Monitoring, Research, and Impacts Assessment: François M. M. Morel (*Chair*), Princeton University; **David Archer**, University of Chicago; **James P. Barry,** Monterey Bay Aquarium Research Institute; **Garry D. Brewer,** Yale University; **Jorge E. Corredor,** University of Puerto Rico, Mayagüez; **Scott C. Doney,** Woods Hole Oceanographic Institution; **Victoria J. Fabry,** California State University, San Marcos; **Gretchen E. Hofmann,** University of California, Santa Barbara; **Daniel S. Holland,** Gulf of Maine Research Institute, Portland; **Joan A. Kleypas,** National Center for Atmospheric Research, Boulder; **Frank J. Millero,** University of Miami, Florida; **Ulf Riebesell,** Leibniz Institute of Marine Sciences, Kiel, Germany; **Susan Park** *(Study Director)**, **Susan Roberts** *(Study Director)***, **Kathryn Hughes** (*Program Officer),* National Research Council. *Until January 2010, **Beginning January 2010

The National Academies appointed the above committee of experts to address the specific task requested by the United States Congress. The members volunteered their time for this activity; their report is peer-reviewed and the final product approved by both the committee members and the National Academies. This report derivative was prepared by the National Research Council based on the committee's report. For more information, contact the Ocean Studies Board at (202) 334-2714 or http://dels.nas.edu/osb.