Ocean Acidification

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What Is Ocean Acidification?

Ocean acidification is the process whereby seawater becomes less alkaline (or more acidic).[1] It is a concern to Congress because of the potential harm ocean acidification may cause to marine resources, and resource dependent industries and communities. Ocean chemistry is changing as increasing amounts of anthropogenic CO_2 from the atmosphere dissolve in seawater. When atmospheric CO_2 dissolves into the ocean, it forms carbonic acid (H_2CO_3). Some of the carbonic acid dissociates in ocean waters, producing hydrogen ions (H^+). As the number of hydrogen ions increases, the pH of the ocean decreases, and becomes less alkaline.[2]

The oceans absorb about 2 billion metric tons of the approximately 7 billion metric tons of carbon that all the countries in the world release as CO_2 into the atmosphere each year.[3] The average pH of water near the ocean surface has decreased by almost 0.1 pH unit due to the addition of CO_2,[4] a 26% increase in the concentration of hydrogen ions.[5] As atmospheric CO_2 continues to increase, ocean pH will likely continue to decrease. One prediction suggests that continued burning of fossil fuels and future uptake of CO_2 by the ocean could reduce ocean pH by 0.3-0.5 units.[6] However, many questions remain with regard to the actual rate at which the pH in the oceans will decrease and how quickly the oceans will respond to changes in CO_2 emissions.

Potential Effects of Ocean Acidification

While not yet fully understood, the ecological and economic consequences of ocean acidification could be substantial. Scientists are concerned that increasing hydrogen ion concentration in seawater could alter biogeochemical cycles, disrupt physiological processes of marine organisms, and damage marine ecosystems. Since the marine environment is complex and some of the likely changes may occur years into the future, the potential effects of ocean acidification are primarily supported by laboratory experimentation, modeling, and forecasts. However, field studies are beginning to provide a more direct view of potential ocean acidification problems.[7]

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[1] The prevailing pH (a measure of hydrogen ion concentration) of water near the ocean surface is around 8.1, or alkaline. The pH scale is an inverse logarithmic representation of hydrogen proton (H+) concentration, indicating the activity of hydrogen ions (or their equivalent) in the solution. A pH of less than 7.0 is considered acidic, while a pH greater than 7.0 is considered basic (alkaline); a pH of 7.0 is defined as "neutral."

[2] For a more detailed discussion of ocean acidification, see CRS Report R40143, *Ocean Acidification*, by (name reda cted) and (name redacted).

[3] Richard A. Feely, Pacific Marine Environmental Laboratory, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, World Ocean Forum, November 13-14, 2006, at http://www.thew2o.net/events/oceans/oa_q_and_a.php; and Richard A. Feely et al., "Impact of Anthropogenic CO_2 on the $CaCO_3$ System in the Oceans," *Science* (2004), vol. 305, pp. 362-366.

[4] James C. Orr et al., "Anthropogenic Ocean Acidification over the Twenty-First Century and Its Impact on Calcifying Organisms," *Nature*, vol. 437 (2005), pp. 681-686.

[5] Because the pH scale is logarithmic (i.e., water with a pH of 6 is 10 times less acidic than water with a pH of 5, and 100 times less acidic than water with a pH of 4).

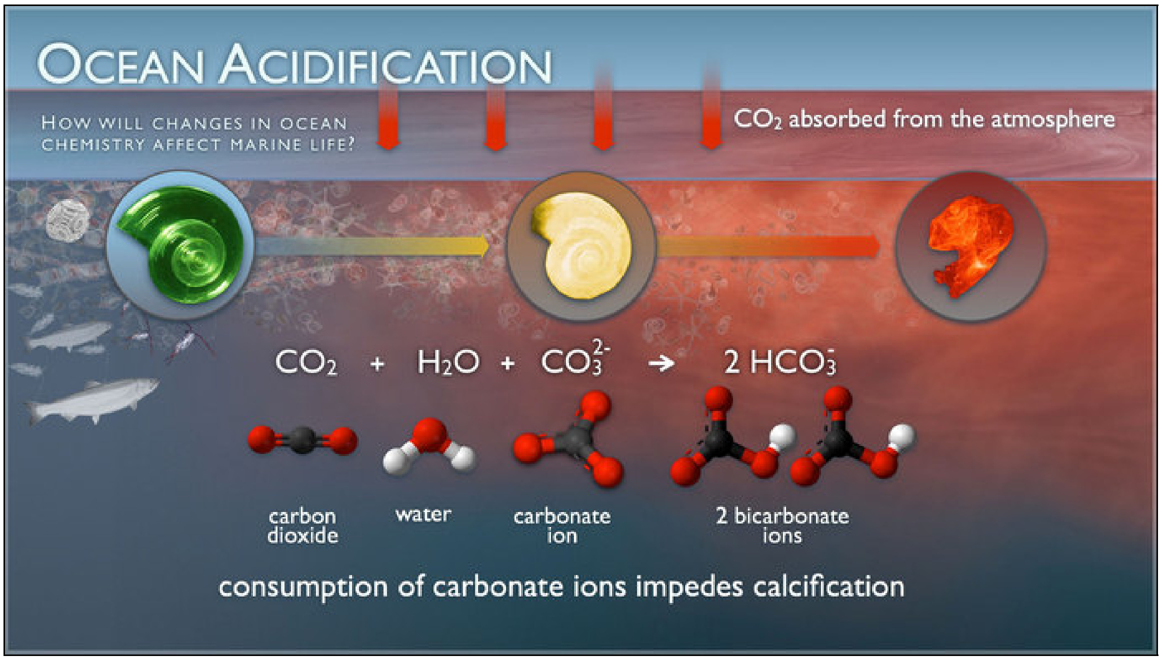
[6] A. J. Andersson et al., "Coastal Ocean and Carbonate Systems in the High CO_2 World of the Anthropocene," *American Journal of Science*, v. 305 (2005), pp. 875–918.

[7] See, for example, K. K. Yates and R. B. Halley, CO_3^{2-} Concentration and pCO_2 Thresholds for Calcification and Dissolution on the Molokai Reef Flat, Hawaii," *Biogeosciences*, v. 3 (2006), pp. 357-369.

The abundance and availability of carbonate ions (CO_3^{2-}) are critical to many shell-forming marine organisms. (See **Figure 1**.) At current average ocean pH levels (about 8 or above), most ocean waters near the surface still support shell formation and coral growth. However, increasing hydrogen ion concentration could consume carbonate ions and reduce growth or even cause death of shell-forming animals (e.g., corals, mollusks, and certain planktonic organisms) as well as disrupt marine food webs and the reproductive physiology of certain species.

Coastal areas with upwelling of deeper waters may be at risk from detrimental effects of ocean acidification much more quickly. Concerns have been expressed for benthic calcareous organisms such as mussels, clams, and oysters living in the nearshore shelf along the North American west coast.[8] Oyster growers in the Pacific Northwest have experienced severe larval mortalities resulting in multi-year reproductive failures that may be related to changing ocean chemistry.[9]

Figure 1. How Ocean Acidification Could Affect Shell-Forming Organisms



Source: NOAA Pacific Marine Environmental Laboratory, Carbon Program, http://www.pmel.noaa.gov/co2/story/Ocean+Acidification.

Potential Responses to Ocean Acidification

Policies to address ocean acidification face obstacles related to scientific uncertainty, the global nature of the problem, and the temporal mismatch between current actions and future costs. Reducing CO_2 emissions to the atmosphere and/or removing CO_2 from the atmosphere (i.e., carbon sequestration) currently appear to be the only practical ways to minimize the risk of large-scale and long-term changes to the pH of marine waters. Because of the continuing increase in

[8] Richard A. Feely et al., "Evidence for Upwelling of Corrosive "Acidified" Water onto the Continental Shelf," *Science*, v. 320, no. 5882 (June 13, 2008), pp. 1490-1492.

[9] Eric Scigliano, "The Great Oyster Crash," *Onearth* (August 17, 2011); available at http://www.onearth.org/article/oyster-crash-ocean-acidification.

CO_2 levels in the atmosphere, and its resident time there, pH of ocean waters will likely continue to decrease for decades. Even if atmospheric CO_2 were to return to pre-industrial levels, it could possibly take tens of thousands of years for ocean chemistry to return to a condition similar to that occurring at pre-industrial times more than 200 years ago.[10]

Some have proposed adding chemicals to the ocean—ocean engineering—to mitigate ocean acidification. These proposals have included adding iron compounds to enhance phytoplankton growth and consume CO_2; adding limestone to neutralize (i.e., buffer) the lower-pH streams and rivers that empty into oceans or directly to the ocean where deeper, lower-pH water upwells;[11] or pumping the calcium bicarbonate byproduct of limestone scrubbers at natural gas power plants directly into the ocean.[12] Unless a massive global effort is mounted, these techniques will be effective only on a very local scale. In addition, manipulation of ocean chemistry has the potential to damage or otherwise alter the marine environment and ecosystems in unforeseen ways.[13]

Congressional and Federal Actions

Congressional attention has focused primarily on addressing the broader cause of ocean acidification—increasing concentrations of atmospheric CO_2.[14] To date, legislative attention specific to ocean acidification has focused on promoting and coordinating monitoring and research to increase knowledge about ocean acidification and its potential effects on marine ecosystems. An effort to document the state of knowledge on ocean acidification was required by Section 701 of P.L. 109-479: Congress called for an 18-month comprehensive national study by the National Research Council of the National Academy of Sciences.[15] In September 2010, *Ocean Acidification: A National Strategy to Meet the Challenges of a Changing Ocean* was published by the National Research Council.[16] The report examined the anticipated consequences of ocean acidification on fisheries, protected species, coral reefs, and other natural resources, and identified research and monitoring needed to address ocean acidification.

The 111th Congress passed the Federal Ocean Acidification Research and Monitoring Act of 2009 (FOARAM; Title XII, Subtitle D, of P.L. 111-11). FOARAM directed the Secretary of Commerce to establish an ocean acidification program within NOAA, established an interagency committee to develop an ocean acidification research and monitoring plan, and authorized appropriations through FY2012 for NOAA and the National Science Foundation.

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[10] The Royal Society, *Ocean Acidification Due to Increasing Atmospheric Carbon Dioxide*, Policy Document 12/05 (June 2005).

[11] L. D. D. Harvey, "Mitigating the Atmospheric CO_2 Increase and Ocean Acidification by Adding Limestone Powder to Upwelling Regions*," Journal of Geophysical Research*, v. 103 (2008): C04028.

[12] Greg H. Rau, "CO_2 Mitigation via Capture and Chemical Conversion in Seawater," *Environmental Science and Technology*, v. 45, no. 3 (2011), pp. 1088–1092.

[13] For more information on geoengineering, see CRS Report R41371, *Geoengineering: Governance and Technology Policy*, by (name redacted) and (name redacted).

[14] See CRS Issue in Focus, "Climate Change Science and Technology," available at http://www.crs.gov/pages/subissue.aspx?cliid=3878&parentid=2522&preview=False.

[15] This measure required the Secretary of Commerce to request that the National Research Council study acidification of the oceans and how this process affects the United States. See http://www.noaanews.noaa.gov/stories2008/20081020_oceanacid.html.

[16] Available at http://www.nap.edu/openbook.php?record_id=12904&page=R1. In May 2011, a booklet, *Ocean Acidification: Starting with the Science*, based on the longer report was released, and is available at http://dels.nas.edu/resources/static-assets/materials-based-on-reports/booklets/OA1.pdf.

FOARAM established an interagency working group on ocean acidification (IWGOA), chaired by a representative from NOAA. IWGOA includes representatives from the National Science Foundation, Bureau of Ocean Energy Management, U.S. Department of State, Environmental Protection Agency, National Aeronautics and Space Administration, U.S. Geological Survey, U.S. Fish and Wildlife Service, and U.S. Navy. The IWGOA was charged with developing a strategic research and monitoring plan to guide federal research on ocean acidification. In 2012, a draft of the *Strategic Plan for Federal Research and Monitoring of Ocean Acidification* was released and sent to the National Research Council for review.[17] The strategic research plan attempts to provide a common vision and specific goals to coordinate activities of federal agencies. The plan is organized into the following seven themes:

1. monitoring of ocean chemistry and biological impacts;
2. research to understand responses to ocean acidification;
3. modeling to predict changes in the ocean carbon cycle;
4. technology development and standardization of measurements;
5. assessment of socioeconomic impacts and development;
6. education, outreach, and engagement strategy; and
7. data management and integration.

FOARAM also directed the IWGOA to submit a report to Congress every two years that summarizes federally funded ocean acidification activities. The most recent report for FY2010 and FY2011 identifies funding levels by agency and by the strategic themes used in the strategic research plan. In FY2011, total federal funding for ocean acidification activities was approximately $29 million.[18]

To date, the only bill related to ocean acidification that has been introduced during the 113th Congress is the Coral Reef Conservation Act Amendments of 2013 (S. 839). S. 839 would include ocean acidification in the criteria used to evaluate project proposals for studying threats to coral reefs and developing responses to coral reef losses. On July 30, 2013, the Senate Committee on Commerce, Science, and Transportation ordered S. 839 to be reported.

[17] Interagency Working Group on Ocean Acidification, *Strategic Plan for Federal Research and Monitoring of Ocean Acidification*, March 2012, http://www.st.nmfs.noaa.gov/iwgoa/DRAFT_Ocean_Acidification_Strategic_Research_Plan.pdf.

[18] Interagency Working Group on Ocean Acidification et al., Second Report on Federally Funded Ocean Acidification Research and Monitoring Activities and Progress on a Strategic Research Plan, http://www.st.nmfs.noaa.gov/iwgoa/documents/IWG-OA_Budget_Report-Official_Final_Version.pdf.

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