Congressional Research Service

Ocean Acidification

Eugene H. Buck
Specialist in Natural Resources Policy

Peter Folger
Specialist in Energy and Natural Resources Policy

April 24, 2009

Congressional Research Service
7-5700
www.crs.gov
R40143

CRS Report for Congress
Prepared for Members and Committees of Congress

Summary

With increasing concentrations of carbon dioxide (CO_2) in the atmosphere, the extent of effects on the ocean and marine resources is an increasing concern. One aspect of this issue is the ongoing process whereby seawater becomes acidified (i.e., ocean acidification) as more CO_2 dissolves in it, causing hydrogen ion concentration in seawater to increase. Scientists are concerned that increasing hydrogen ion concentration could reduce growth or even cause death of shell-forming animals (e.g., corals, molluscs, and certain planktonic organisms) as well as disrupt marine food webs and the reproductive physiology of certain species. While not yet fully understood, the ecological and economic consequences of ocean acidification could be substantial.

Scientists are concerned that increasing acidification could alter biogeochemical cycles, disrupt physiological processes of marine organisms, and damage marine ecosystems. This report does not discuss the effects of increasing thermal stress to marine organisms and ecosystems (e.g., coral bleaching) related to climate change. However, marine ecosystems are likely to be affected by the synergistic effects of factors involved in both thermal and acidification processes.

Congress is beginning to focus attention on better understanding ocean acidification and determining how this concern might be addressed. In the 111th Congress, the Federal Ocean Acidification Research And Monitoring Act of 2009 (Title XII, Subtitle D, of P.L. 111-11) 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.

Contents

Contacts

Introduction

On January 30, 2009, a Monaco Declaration was signed by more than 150 marine scientists from 26 countries, calling for immediate action by policymakers to reduce carbon dioxide emissions so as to avoid widespread and severe damage to marine ecosystems from ocean acidification.[1] The Monaco Declaration is based on the *Research Priorities Report* developed by participants in an October 2008 international symposium on "The Ocean in a High-CO_2 World,"[2] organized by UNESCO's Intergovernmental Oceanographic Commission, the Scientific Committee on Oceanic Research, the International Atomic Energy Agency, and the International Geosphere Biosphere Programme. While not yet fully understood, the ecological and economic consequences of ocean acidification could be substantial. Legislative attention by Congress on ocean acidification currently is focused on authorizing, funding, and coordinating research to increase knowledge about ocean acidification and its potential effects on marine ecosystems.

What Is Ocean Acidification?

The complex interplay between rising carbon dioxide (CO_2) levels in the atmosphere and the ocean's chemistry is a process that scientists have recognized for decades. As increasing CO_2 from the atmosphere dissolves in seawater, seawater chemistry is altered. The prevailing pH (a measure of acidity) of water near the ocean surface is around 8.1, or slightly alkaline.[3] Ocean acidification is the name given to the ongoing process whereby pH decreases as seawater becomes acidified when 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 the water becomes more acidified.

Scientists are concerned that increasing acidification could alter biogeochemical cycles, disrupt physiological processes of marine organisms, and damage marine ecosystems. This report does not discuss the effects of increasing thermal stress to marine organisms and ecosystems (e.g., coral bleaching) related to climate change. However, marine ecosystems are likely to be affected by the synergistic effects of factors involved in both thermal and acidification processes.

At What Rate Is Ocean Acidification Occurring? What Factors Affect This Rate?

Over the past several decades, the oceans annually have absorbed 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

---

[1] A copy of this declaration is available at http://scrippsnews.ucsd.edu/Releases/doc/MonacoDeclaration.pdf.

[2] The full report is available at http://ioc3.unesco.org/oanet/Symposium2008/ResearchPrioritiesReport_OceanHighCO2WorldII.pdf.

[3] 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 level of 7.0 is defined as "neutral."

into the atmosphere each year.[4] It has been estimated that a total of more than 530 billion tons of CO_2 have been absorbed by the ocean between 1800 and 1994,[5] with the average pH of water near the ocean surface decreasing (i.e., acidity increased) by almost 0.1 pH unit.[6] That increase sounds small, but it represents an increase of 26% in the concentration of hydrogen ions, because the pH scale is logarithmic (i.e., water with a pH of 7 is 10 times more acidified than water with a pH of 8, and 100 times more acidified than water with a pH of 9). Open ocean observational records of declining pH are available from the Hawaiian Ocean Time-Series Station in the Pacific and the Bermuda Atlantic Time-Series Station in the Atlantic.[7] Up to a point, as atmospheric CO_2 continues to increase, the oceans will continue to become more acidified; one estimate suggests that the rate of CO_2 uptake by the oceans could stabilize at around 5 billion metric tons per year by 2100.[8]

All gases, such as CO_2, are less soluble with increasing water temperature. Thus, marine waters near the poles have a much greater capacity for dissolving CO_2 than do ocean waters in the tropics. In addition, dissolved CO_2 is transported into ocean depths at these high latitudes (i.e., deep water formation mechanism) since the lower-temperature waters are of higher density, causing greater convection to occur than happens in the more stratified tropical oceans. If temperature were the only factor affecting the rate of ocean acidification and its impacts on physical and biological features, these impacts might be more likely to occur in marine waters nearer the poles. However, in addition to temperature, other factors modulate the impact of CO_2 on marine waters. Cellular respiration and organic decomposition add CO_2 to seawater, and photosynthesis removes it. Deep oceanic water is enriched in CO_2 due to respiration in the absence of photosynthesis and, when brought to the surface by equatorial currents (i.e., upwelling), can place CO_2-enriched seawater in contact with the atmosphere where it can absorb even more CO_2. Hence, the tropics, and most notably tropical coral reefs, are also vulnerable to near-term effects. An additional factor is the potential increase in storm activity at higher latitudes, as some climate models suggest.[9] CO_2 and other acidic gasses such as nitrogen dioxide are also dissolved in rainwater.[10] An increase in North Atlantic or western North Pacific storms could significantly accelerate the acidification of surface ocean waters in these regions.

Key scientific questions concern which factors may affect the future rate of acidification, especially whether the rate of increase will remain constant in direct relationship to the amount of CO_2 in the atmosphere or whether other factors will accelerate or decelerate this acidification rate. There is also the question of equilibrium—that is, how long it might take the acidification process of ocean waters, should the currently increasing atmospheric emission rate of CO_2 eventually be

---

[4] Richard A. Feely, Pacific Marine Environmental Laboratory, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, World Ocean Forum, Nov. 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.

[5] C. L. Sabine, "The Oceanic Sink for Anthropogenic CO_2," *Science*, v. 305 (2004): 367-371.

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

[7] See http://hahana.soest.hawaii.edu/hot/hot_jgofs.html and http://www.bios.edu/research/bats.html.

[8] David Archer, "Fate of Fossil Fuel CO_2 in Geologic Time," *Journal of Geophysical Research*, v. 110 (2005): C09S05, doi:10.1029/2004JC002625.

[9] See the Intergovernmental Panel on Climate Change's *Technical Paper on Climate Change and Water*, available at http://www.ipcc.ch/meetings/session28/executive_summary.pdf.

[10] Rainwater is naturally acidic at a pH of around 5.6, and downwind of pollution sources has been measured as low as pH 3.0.

able to be stabilized or diminished, to come into equilibrium with the concentration of atmospheric CO_2. An adjunct to this question is how long might it take the rate of ocean acidification to slow (or even begin to decrease) in response to any measures that might be taken to slow, halt, or even reverse the increasing concentration of CO_2 in the atmosphere. Additional questions relate to how ocean circulation, which eventually controls CO_2 uptake rate, might change in response to rising temperatures caused by greenhouse gas emissions.

What Are Some of the Potential Effects of Ocean Acidification?

Since the marine environment is complex and some of the likely changes may be years in the future, the potential effects identified in this section, although many are supported by laboratory experimentation, are primarily conjecture and/or forecasts. However, field studies are beginning to provide a more direct view of potential ocean acidification problems.[11]

A lower pH affects marine life in the oceans and is related to other changes in ocean chemistry. In addition to the lower pH, another consequence of the increased amount of dissolved CO_2 in the ocean is the production of more bicarbonate ions (HCO_3^{1-}). As more CO_2 dissolves into the ocean, bicarbonate ions form at the expense of carbonate ions (CO_3^{2-}), which scientists often describe by the following reaction:

$$CO_2 + CO_3^{2-} + H_2O = 2HCO_3^{1-}$$

The abundance and availability of carbonate ions are critical to many shell-forming marine organisms. At current average ocean pH levels (about 8 or above), ocean waters near the surface have ample carbonate ions to support shell formation and coral growth. However, as increased amounts of carbonic acid form in the ocean from higher CO_2 levels in the atmosphere, pH gets lower and the amount of carbonate ions in the oceans decreases, resulting in fewer carbonate ions available for making shells.

Organisms make biogenic calcium carbonate for their shells by combining calcium ions (Ca^{2+})—which are abundant in the oceans—with carbonate ions to form solid calcium carbonate ($CaCO_3$). Certain marine organisms (e.g., corals and pteropods) precipitate one mineral type of calcium carbonate called aragonite, and other marine organisms (e.g., foraminifera and coccolithophorids) use another type called calcite. A third type of calcium carbonate—high magnesium calcite—is precipitated by echinoderms (sea urchins, starfish, and sea cucumbers) and some coralline algae (an encrusting form of red algae that forms calcareous crusts like coral). Under present conditions of ocean chemistry, these forms of calcium carbonate are relatively stable in waters near the ocean surface, except for certain areas of high upwelling activity.[12]

---

[11] See, for example, K. K. Yates and R. B. Halley, “Diurnal Variations in Rates of Calcification and Carbonate Sediment Dissolution in Florida Bay,” *Estuaries and Coasts*, v. 29 (2006): 24-39; and 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): 357-369.

[12] Results from a 2007 National Oceanic and Atmospheric Administration survey along the U.S. West Coast documented the first undersaturated waters at the ocean surface along the California coast, brought to the surface by seasonal upwelling. See Richard A. Feely et al., “Evidence for Upwelling of Corrosive “Acidified” Water onto the Continental Shelf,” *Science*, v. 320, no. 5882 (June 13, 2008): 1490-1492.

Water near the ocean surface currently is supersaturated (i.e., more concentrated than normally possible and therefore not in equilibrium) with calcite, high magnesium calcite, and aragonite, meaning that organisms easily can form shells from all of these mineral types. However, as more carbonic acid is formed in water near the ocean surface from higher levels of CO_2 in the atmosphere, the level of saturation decreases. If the ocean waters become undersaturated, then shells made from all of these minerals would tend to dissolve. Shells made from high magnesium calcite would tend to dissolve first, at lower concentrations of carbonic acid (and thus at higher pH values) than would shells made from aragonite. Shells made from calcite would dissolve at higher concentrations of carbonic acid than those made from aragonite.[13] Thus, organisms that incorporate high magnesium calcite (i.e., echinoderms and some coralline algae) are likely to be the "first responders" to ocean acidification.[14]

Ocean waters at depths of thousands of feet are undersaturated with respect to all forms of biogenic calcite, which is why most of the shells from dead organisms that "rain" down from the ocean surface dissolve before reaching the ocean floor.[15] Because of the combined effects of increased CO_2 solubility in colder waters and increased solubility of calcium carbonate in cold water, some suggest that marine surface waters closer to the poles may become undersaturated within the next 50 years.[16] Researchers at the Antarctic Climate and Ecosystems Cooperative Research Centre have demonstrated significant reductions in shell mass and thickness of several Southern Ocean marine plants and animals that appear consistent with the projected effects of recent increased acidification of the ocean.[17]

In response to ocean acidification, scientists have projected that mussel and oyster calcification, and thus shell strength, could decrease significantly by the end of the 21st century, according one Intergovernmental Panel on Climate Change scenario.[18] There is also the concern that increased acidification may dissolve marine calcium carbonate sediments with potential harm to species and communities residing in and on these sediments.[19] Since many of these organisms provide food or modify habitat for other organisms, the well-being of these carbonate-dependent species will affect other species. Because of these interrelationships, the potential indirect effects of acidification on other marine organisms is not well understood. While some have raised concerns that ocean acidification, by harming calcifying plankton species, could shift ecological balances so as to increase populations of some noncalcifying species, there appears to be no significant

---

[13] See Railsback, *Some Fundamentals of Mineralogy and Geochemistry*, at http://www.gly.uga.edu/railsback/Fundamentals/820HMC-LMCSolubilities05LS.pdf.

[14] Andreas J. Andersson, Fred T. Mackenzie, and Nicholas R. Bates, "Life on the Margin: Implications of Ocean Acidification on Mg-Calcite, High Latitude and Cold-Water Marine Calcifiers," *Marine Ecology Progress Series*, v. 373 (2008): 265-273.

[15] Recent research suggests that no more than about 30% of the calcium carbonate produced in the surface ocean each year is buried in shallow or deep sea sediments; the rest dissolves on its way down the water column. See Feely et al. (2004), p. 365.

[16] Orr et al. (2005).

[17] Bruce Mapstone, "Acid Oceans in the Spotlight," *Antarctic Climate and Ecosystem News*, edition 4 (August 2008): 1.

[18] Frederic Gazeau et al., "Impact of Elevated CO_2 on Shellfish Calcification," *Geophysical Research Letters*, v. 34, no. 7 (Apr. 16, 2007): L07603 (5 p.).

[19] M. Gehlen, L. Bopp, and O. Aumont, "Short-term Dissolution Response of Pelagic Carbonate Sediments to the Invasion of Anthropogenic CO2: A Model Study," *Geochem. Geophys. Geosyst.*, v. 9 (Feb. 16, 2008): Q02012.

relationship between jellyfish abundance and acidified conditions, and any role of pH in structuring zooplankton communities is believed to be tenuous.[20]

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 living in the nearshore shelf along the North American west coast[21] as well as coral reefs in the eastern tropical Pacific.[22]

There are also concerns that increasing acidification of ocean waters could alter the ability of some organisms to conduct essential biochemical and physiological processes.[23] For example, scientists have found that, when exposed to water of pH 7.7, roughly equivalent to acidity levels predicted for the year 2100, sea urchin sperm swam much more slowly. Overall, fertilization fell by 25%, and in almost 26% of cases where the eggs were fertilized, they did not survive long enough to develop into larvae.[24] While marine invertebrates in general, and their early developmental stages in particular, are believed to be more sensitive to environmental disturbance, available data to assess their vulnerability to ocean acidification is contradictory.[25]

Although evidence suggests that larval and juvenile fish are more susceptible to changes in ocean water pH than adults, larval and juvenile fish exposed to exceedingly high CO_2 concentrations (more than 100 times current levels) suffered little apparent harm.[26] Fish appear to be among the more tolerant marine animals. These scientists believe that "the relative tolerance of fish may relate to high capacity for internal ion and acid-base regulation via direct proton excretion, and an intracellular respiratory protein that results in a high oxygen-carrying capacity and substantial venous oxygen reserve."[27]

The fossil record indicates that marine organisms may be quite sensitive to ocean acidification—about 55 million years ago, a large injection of CO_2 into the deep ocean, presumably resulting from a massive methane release, was followed by the extinction of some species of benthic

---

[20] A. J. Richardson and M. J. Gibbons, "Are Jellyfish Increasing in Response to Ocean Acidification?," *Limnology and Oceanography*, v. 53, no. 5 (2008):2040-2045.

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

[22] D. P. Manzello et al., "Poorly Cemented Coral Reefs of the Eastern Tropical Pacific: Possible Insights into Reef Developments in a High-CO_2 World," *Second Symposium on the Ocean in a High-CO_2 World*, Monaco, October 6-9, 2008.

[23] Hans-O. Pörtner, "Ecosystem Effects of Ocean Acidification in Times of Ocean Warming: A Physiologist's View," *Marine Ecology Progress Series, v.* 373 (2008): 203-217.

[24] Jon N. Havenhand, Fenina-Raphaeia Buttler, Michael C. Thorndyke, and Jane E. Williamson, "Near-Future Levels of Ocean Acidification Reduce Fertilization Success in a Sea Urchin," *Current Biology*, v. 18, no. 15 (August 2008): 651-652.

[25] S. Dupont and M. C. Thorndyke, "Impact of CO_2-Driven Ocean Acidification on Invertebrates Early Life History—What We Know, What We Need to Know and What We Can Do," *Biogeosciences Discussions*, v. 6 (2009): 3109-3131.

[26] A. Ishimatsu et al., "Effects of CO_2 on Marine Fish: Larvae and Adults," *Journal of Oceanography*, v. 60, no. 4 (2004): 731-741.

[27] V. J. Fabry et al., "Impacts of Ocean Acidification on Marine Fauna and Ecosystem Processes," *ICES Journal of Marine Science*, v. 65 (2008): 414-432.

foraminifera.[28] However, others caution that paleo-events may be imperfect analogs to current conditions.[29]

Some have raised questions downplaying the potential harm to coral reefs from ocean acidification. Differences of opinion exist on the relative effects of climate change as expressed in increased CO_2 when compared to increased ocean temperature. Opinion has been expressed that, in marine systems, increased temperature may have detrimental effects comparable to or larger than those seen from increased CO_2 concentration, for corals and for phytoplankton.[30] Although calcification rates in massive *Porites* coral were reported to have declined over a 16-year study period by approximately 21% in two regions on Australia's Great Barrier Reef, these findings were consistent with other studies of the synergistic effect of elevated seawater temperatures and CO_2 concentrations on coral calcification.[31] While ocean acidification may not appear currently to be killing corals, such acidification is slowing development of coral larvae into juvenile colonies.[32]

In support of the ability of certain corals to survive decreasing pH, stony and soft corals have been grown successfully in open systems with water from a saltwater well at a pH between 7.5 and 7.8 since the 1970s.[33] However, given the high level of adaptation in corals to facilitate calcification via complex processes, at least some corals may be sensitive to changes in pH because of adaptation to invariant pH, with evidence coming primarily from the discovery that periods of high CO_2 in the geological past were often also periods of low aragonite-coral abundances and diversity.[34] Others have found that certain species of coral survive in the laboratory at a pH 7.3 to 7.6 after their calcified structure dissolves by functioning similar to sea anemones, and retaining the ability to recalcify when pH is increased.[35] However, in the natural marine environment, predation could be a significant factor in limiting the viability of such "naked" corals, and it is unlikely that such organisms could form reefs and attract the diverse community that constitutes a coral reef.

Concern has also arisen that lower ocean water pH will diminish low-frequency (below 10 KHz) sound absorption in the ocean, increasing noise levels within the auditory range critical for environmental, military, and economic interests.[36] Frequency-dependent decreases to sound

---

[28] J. C. Zachos et al., "Rapid Acidification of the Ocean During the Paleocene-Eocene Thermal Maximum," *Science*, v. 308 (2005): 1611-1615.

[29] Scott C. Doney et al., "Ocean Acidification: The Other CO_2 Problem," *Annual Review of Marine Science*, v. 1 (January 2009): 169-192.

[30] Clinton E. Hare et al., "Consequences of Increased Temperature and CO2 for Phytoplankton Community Structure in the Bering Sea," *Marine Ecology Progress Series*, v. 352 (2007), p. 14.

[31] T. F. Cooper et al., "Declining Coral Calcification in Massive *Porites* in Two Nearshore Regions of the Northern Great Barrier Reef," *Global Change Biology*, v. 14 (2008): 529-538.

[32] R. Albright et al., "Effect of Aragonite Saturation State on Settlement and Post-Settlement Growth of *Porites astreoide*s Larvae," *Coral Reefs*, v. 27, no. 3 (2008): 485-490.

[33] M. J. Atkinson, B. Carlson, and G. L. Crow, "Coral Growth in High Nutrient, Low-pH Seawater: A Case Study of Corals Cultured at the Waikiki Aquarium, Honolulu, Hawaii," *Coral Reefs*, v. 14, no. 4 (1995): 215-223.

[34] Personal communication, John W. McManus, Director, National Center for Coral Reef Research, Rosenstiel School of Marine and Atmospheric Science, University of Miami, February 21, 2009.

[35] Maoz Fine and Dan Tchernov, "Scleractinian Coral Species Survive and Recover from Decalcification," *Science*, v. 315, no. 5820 (March 30, 2007): 1811.

[36] Keith C. Hester et al., "Unanticipated Consequences of Ocean Acidification: A Noisier Ocean at Lower pH," *Geophysical Research Letters*, v. 35 (2008): L19601, doe:10.1029/2008FL034913.

absorption related to the current decrease in pH of about 0.1 pH unit may exceed 12%, and an anticipated pH decrease of 0.3 pH units by mid-century may result in an almost 40% decrease in sound absorption. It is unknown how marine mammals might be affected by and adapt to an ocean increasingly transparent to sound at low frequencies.

What Are the Natural and Human Responses That Might Limit or Reduce Ocean Acidification?

Several natural feedback mechanisms can act to moderate the process of acidification. The more acidified the ocean becomes, the less CO_2 will be dissolved. In addition, the warmer the seawater becomes, the less CO_2 will dissolve. Speculative questions exist related to what might occur should the oceans reach a ceiling (i.e., equilibrium) in their ability to take up CO_2, and atmospheric CO_2 levels continue to increase. Even with increasing concentrations of atmospheric CO_2, scientists predict that the oceans are not likely to reach pH values of less than 7 (neutral).

Our ability to reduce ocean acidification through artificial means is unproven. Proposals have suggested the addition of chemicals to the ocean, such as (1) using iron compounds to stimulate planktonic algae growth whereby the increased photosynthesis might capture/remove dissolved $CO_{2,}$ or (2) using limestone to neutralize (i.e., buffer) the more acidified streams and rivers near where they enter oceans and close to sources of limestone or add limestone powder directly to the ocean where deeper, lower pH water upwells.[37] Other measures might include habitat restoration/creation, such as planting seagrass. Unless a massive global effort is mounted, these techniques will at best 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. 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 acidity of marine waters. Because of the continuing increase in CO_2 levels in the atmosphere, and its resident time there, acidification of the oceans will likely continue for decades. Even if atmospheric CO_2 were to return to pre-industrial levels, it would likely 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.[38]

What Is the Federal Government Doing About Ocean Acidification?

Much of the current federal attention to ocean acidification focuses on research to better understand the chemical processes involved and to become better able to predict how ocean ecosystems might respond to increasing acidification.

---

[37] 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, 21 p.

[38] The Royal Society, *Ocean Acidification Due to Increasing Atmospheric Carbon Dioxide*, Policy Document 12/05 (June 2005), 60 p.

The National Science Foundation (NSF) was the first federal agency to become involved in research related to ocean acidification. The modern surveys of CO_2 in the oceans can be traced to the NSF-sponsored Joint Global Ocean Flux Study (JGOFS), which originated in recommendations from a National Academies of Science workshop in 1984.[39] The more modern concerns over ocean acidification arose from a May 2004 Paris workshop chaired by the now-president of the National Academy of Sciences, Ralph Cicerone.[40] In April 2005, NSF, the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Geological Survey sponsored a workshop on the impacts of ocean acidification on coral reefs and other marine calcifiers.[41] In Section 701 of P.L. 109-479, Congress called for an 18-month comprehensive national study by the National Research Council of the National Academies of Science on how CO_2 emissions absorbed into the oceans may be altering fisheries, marine mammals, coral reefs, and other natural resources.[42] This study was commissioned by NOAA and NSF in October 2008, with initial planning meetings held in early April 2009.

A variety of programs conducted within the NOAA help to gain a better understanding of ocean acidification.[43] The Pacific Marine Environmental Laboratory's CO_2 shipboard measurements and monitoring buoys provide data that help discern seasonal changes in the oceanic carbon system. The Atlantic Oceanographic and Meteorological Laboratory monitors changes in CO_2 and pH through the use of chemical sensors on ships and moorings. NOAA's Repeat Hydrography Program provides data on the large-scale changes to the carbon system and rates of ocean acidification over decadal time scales. Sea Grant supports research on the effects of ocean acidification on coral reefs in Hawaii. NOAA's Geophysical Fluid Dynamics Laboratory participated in the Ocean-Carbon Cycle Model Intercomparison Project (OCMIP2) to develop an international collaboration to improve the predictive capacity of carbon cycle models. NOAA's Alaska Fisheries Science Center has been conducting exposure studies of blue king crab larval survival due to reduced pH and has developed an ocean acidification research plan.[44] NOAA's Southwest Fisheries Science Center has been evaluating the long-term impacts of low pH on marine plankton in the California Current and off Antarctica. Projects funded by the NOAA Global Carbon Cycle program at NOAA laboratories and universities provide information to address the CO_2 and pH changes in the ocean. NOAA estimates that its annual expenditures for these ocean acidification research and related programs in FY2008 were about $4.3 million; for FY2009, NOAA has requested $4.06 million.[45]

---

[39] For additional background, see http://www1.whoi.edu/jgofMission.html.

[40] Ralph Cicerone, "The Ocean in a High CO_2 World," *Eos*, v. 85, no. 37 (September 14, 2004): 351, 353.

[41] J. A. Kleypas et al., *Impacts of Ocean Acidification on Coral Reefs and Other Marine Calcifiers: A Guide for Future Research*, report of a workshop held April 18-20, 2005, St. Petersburg, FL, sponsored by NSF, NOAA, and the U.S. Geological Survey (June 2006), 88 p.

[42] 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.

[43] Testimony by Dr. Richard A. Feely, NOAA Office of Oceanic and Atmospheric Research, before the House Committee on Science and Technology, Subcommittee on Energy and Environment, June 5, 2008.

[44] Alaska Fisheries Science Center, *Forecast Fish, Shellfish, and Coral Population Responses to Ocean Acidification in the North Pacific Ocean and Bering Sea*, National Marine Fisheries Service (Juneau, AK: August 2008), AFSC Processed Report 2008-7, 35 p.

[45] Personal communication from Jonathan Kelsey, Congressional Affairs Specialist, Office of Legislative Affairs, NOAA, (202) 482-0809, Dec. 11, 2008.

The National Aeronautics and Space Administration (NASA) has a number of space projects that contribute to a better understanding of ocean acidification.[46] NASA's Ocean Carbon and Biogeochemistry (OCB) research program focuses on improving our understanding of how ocean ecosystems respond to climate change and ocean acidification using space-borne global observing capabilities and integrating new knowledge into predictive models. NASA provides the capacity to remotely sense the effects of ocean acidification on ocean biology and chemistry, and expand the interpretation of data obtained from in-water measurements to regional and global scales to address appropriate research questions.

The Environmental Protection Agency (EPA) published notice on April 15, 2009, that it was reviewing the current aquatic life criterion for marine pH to determine if a revision was warranted to protect designated uses pursuant to Section 304(a)(1) of the Clean Water Act. In addition, EPA is seeking ideas for effective strategies to address the impacts of ocean acidification.[47]

What Is the Congressional Interest in Ocean Acidification?

Congressional attention has focused primarily on addressing the cause of ocean acidification—increasing atmospheric CO_2.[48] To date, legislative attention to ocean acidification has focused on authorizing, funding, and coordinating research to increase knowledge about ocean acidification and its potential effects on marine ecosystems.

In the 111th Congress, the Federal Ocean Acidification Research And Monitoring Act of 2009 (Title XII, Subtitle D, of P.L. 111-11) 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.

In comparison to previous sessions of Congress, legislative interest in ocean acidification expanded significantly in the 110th Congress.[49]

---

[46] See http://oco.jpl.nasa.gov/, http://modis.gsfc.nasa.gov/about/, http://oceancolor.gsfc.nasa.gov/SeaWiFS/, and http://so-gasex.org/media.html.

[47] 74 *Fed. Reg*. 17484-17487.

[48] See CRS Current Legislative Issue "Climate Change", available at http://apps.crs.gov/cli/cli.aspx?PRDS_CLI_ITEM_ID=2645&from=3&fromId=2522.

[49] For more details on ocean acidification legislation in the 110th Congress, see the section "Climate Change" in CRS Report RL33813, *Fishery, Aquaculture, and Marine Mammal Legislation in the 110th Congress*, by Eugene H. Buck.

Author Contact Information

Eugene H. Buck
Specialist in Natural Resources Policy
gbuck@crs.loc.gov, 7-7262

Peter Folger
Specialist in Energy and Natural Resources Policy
pfolger@crs.loc.gov, 7-1517