Ocean Acidification

A Summary for Policymakers from the Second Symposium on the Ocean in a High-CO_2 World

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Intergovernmental Oceanographic Commission of UNESCO

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Marine Environment Laboratories (MEL) of the International Atomic Energy Agency

Scientific Committee on Oceanic Research

THE OCEAN IN A HIGH CO_2 WORLD SYMPOSIUM

The second symposium on the Ocean in a High-CO_2 World was held on 6–9 October 2008 at the Oceanography Museum of Monaco under the High Patronage of His Serene Highness Prince Albert II. The meeting brought together 220 scientists from 32 countries to assess what is known about ocean acidification impacts on marine chemistry and ecosystems, and to address the socio-economic and policy perspectives of these impacts.

This document summarises new research findings presented at the symposium. The results are synthesised in a scientific report, Research Priorities for Ocean Acidification (2009), available from www.ocean-acidification.net.

Background

The ocean absorbs approximately 25% of the CO_2 added to the atmosphere from human activities each year, greatly reducing the impact of this greenhouse gas on the climate.

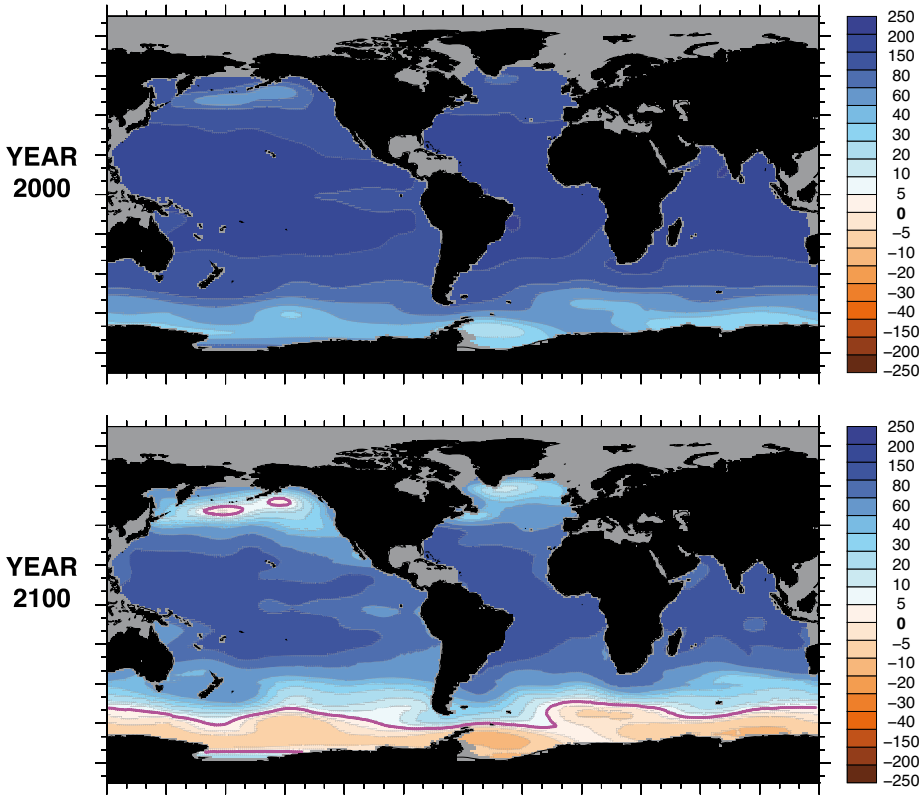
When CO_2 dissolves in seawater, carbonic acid is formed. This phenomenon, called ocean acidification, is causing seawater to become corrosive to the shells and skeletons of numerous marine organisms. It also affects the reproduction and physiology of some marine organisms.

These impacts have now been detected in living organisms in several regions around the world. Within decades, the chemistry of the tropical oceans will not sustain coral reef growth while large parts of the polar oceans will become corrosive to calcareous marine organisms. These far-reaching changes will impact food webs, biodiversity and fisheries.

RECOMMENDATIONS

Adverse effects can only be avoided by limiting future atmospheric CO_2 levels.

A global early warning and forecast network is required.



Within decades, acidity levels in the polar oceans are projected to reach levels sufficient to dissolve some shells.

Calculated aragonite saturation state in terms of excess carbonate ion concentration (umol kg-1). Blue indicates surface waters that are favourable to calcium carbonate formation and red colours indicate waters that are corrosive to calcifying organisms. Adapted from Orr *et al.* (2005) *Nature* 437, 681-686.
Figure credit: James Orr, Marine Environment Laboratories (MEL-IAEA), Monaco.

Cover: Ironbridge coal-fired power station at night, Shropshire, England, January 2007.

THE OCEAN IS ACIDIFYING RAPIDLY

Ocean acidity has increased by 30% since the beginning of the Industrial Revolution. If the concentration of atmospheric CO_2 continues to increase at the current rate, the ocean will become corrosive to the shells of many marine organisms by the end of this century. **How or if marine organisms may adapt is not known.**

This increase is 100 times faster than any change in acidity experienced by marine organisms for at least the last 20 million years. Sixty-five million years ago, ocean acidification was linked to mass extinctions of calcareous marine organisms, an integral part of the marine food web. At that time, coral reefs disappear from the geologic record and it took millions of years for coral reefs to recover.

Today's human-induced acidification represents a rare event in the geological history of our planet.

Background

The average concentration of atmospheric CO_2 is currently 385 parts per million (ppm), 38% higher than the pre-industrial level of 280 ppm.

Half of this increase has occurred in the last 30 years. Current CO_2 emissions are greater than projected for the worst-case scenario formulated by the Intergovernmental Panel on Climate Change a decade ago.

CO_2 and pH time series in the North Pacific Ocean

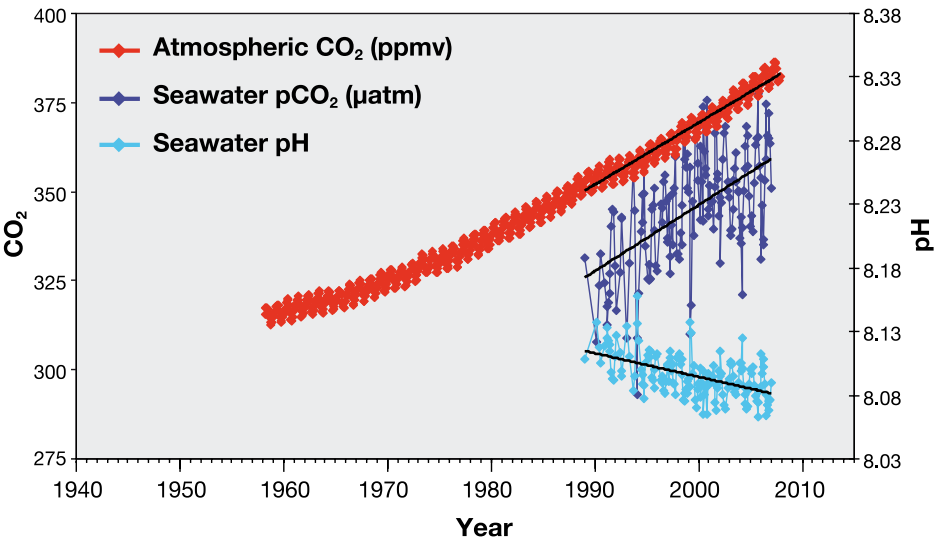


Figure credit: Richard A. Feely, Pacific Marine Environmental Laboratory, National Oceanic and Atmospheric Administration, USA, with atmospheric data from Pieter Tans and seawater data from David Karl. Adapted from Feely (2008) in Levinson and Lawrimore (eds), *Bull. Am. Meteorol. Soc*, 89(7): S58.

Observations collected over the last 25 years show consistent trends of increasing acidity in surface waters that follow increasing atmospheric CO_2.

Photo credit: Ulf Riebesell

OCEAN ACIDIFICATION IS A DIRECT RESULT OF CO_2 EMISSIONS, NOT CLIMATE CHANGE

While climate change and its impacts have significant uncertainties, **the chemical changes occurring in the ocean as a result of increasing atmospheric CO_2 are observable now and highly predictable into the future.**

When CO_2 dissolves in seawater, carbonic acid is formed. It is this chemical reaction that leads to ocean acidification, and **it is independent of climate change.**

Reduction of global temperatures and the concentration of other greenhouse gases will not reduce ocean acidification. Ocean acidification is not a peripheral climate issue – it is **the other CO_2 problem.**

Negotiations aimed at reducing greenhouse gas emissions must take ocean acidification into account. Geoengineering approaches to combat climate change by reflecting sunlight, for example, will not solve the ocean acidification problem.

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HOW WILL MARINE ECOSYSTEMS RESPOND?

Most studies show a decrease in calcification, including shell and skeleton formation, with increasing acidification. Marine organisms have different calcification responses at different stages of their life cycle. **Some early-life stages are particularly sensitive to acidification.**

For marine animals, including invertebrates and some fish, accumulation of CO_2 in the body may also result in disturbances of processes other than calcification, **leading to overall changes in the organism's morphology, metabolic state, physical activity and reproduction.**

While some groups of phytoplankton, such as coccolithophores, may be adversely affected by ocean acidification, others, including nitrogen-fixing cyanobacteria, may benefit from elevated CO_2 levels. **Impacts on phytoplankton and other sensitive species may cause disturbances to marine food webs that will affect fisheries.**

By the middle of this century, it is expected that coral calcification rates will decline by about one third, and **erosion of corals will outpace new growth.** Many reefs may no longer be sustainable.

Experiments have shown that ocean acidification hinders calcification of deep-sea corals. **By 2100, 70% of cold-water corals will be exposed to corrosive waters.** Cold-water coral ecosystems provide habitat, feeding grounds, and nursery areas for many deep-water organisms, including commercial fish species.

Background

Selective breeding of one species of oyster shows that resistance to acidification can be increased, suggesting that **some level of adaptation may be possible for some organisms.** However, the adaptability of most organisms to increasing acidity is unknown.

The severity of these impacts is likely to depend in part on the **interaction of acidification with other environmental stresses, such as rising ocean temperatures, over-fishing and land-based sources of pollution.** In two species of crab, ocean acidification decreases the resistance to temperature extremes, indicating enhanced sensitivity to warming as well as the potential for shrinking areas of species distribution.

Naturally high-CO_2 environments, such as some coastal zones influenced by upwelling or river inputs, or areas receiving volcanic or hydrothermal CO_2 inputs, may provide a glimpse into marine ecosystems of the future. These areas show low biodiversity and a high number of invasive species.

By the middle of this century, many reefs may no longer be sustainable.

Photo credit: Armin Form

HOW WILL OCEAN ACIDIFICATION AFFECT SOCIETIES AND ECONOMIES?

Ocean acidification may trigger a chain reaction of impacts through the marine food web that will affect the multi-billion dollar commercial fisheries and shellfish industries, as well as threatening the **food security for millions of the world's poorest people.** Larval fish and shellfish may be especially vulnerable.

Ocean acidification may render most regions of the ocean inhospitable to coral reefs, affecting **tourism, food security, shoreline protection, and biodiversity.** Coral reefs may be particularly affected because of the combined impact of coral bleaching caused by increased water temperatures and ocean acidification.

The ocean's capacity to absorb CO_2 from the atmosphere is being degraded by ocean acidification, which will make it more difficult to stabilise atmospheric CO_2 concentrations.

The cost of stabilising atmospheric CO_2 at a level that will avoid most of the negative impacts is lower than the cost of inaction, and stabilisation is achievable with technology that can be deployed now and in the near future.

Background

When they die, the hard shells of small ocean organisms sink to the ocean floor, locking away carbon for a long time. This is part of the ocean's carbon pump and lighter shells will transfer less carbon to the deep ocean. The cost of the ecosystem service provided by the ocean's carbon pump can be estimated by applying current prices in carbon credit markets. With the carbon market price range of US $20 to $200 per tonne of carbon, ocean uptake of CO_2 represents an annual subsidy to the global economy of US$40 - 400 billion, or 0.1–1% of the Gross World Product. **The projected decrease in efficiency of the ocean carbon pump could represent an annual loss of billions of dollars.**

International negotiations to keep atmospheric **CO_2 levels below 550 ppm, or even 450 ppm, may fail to prevent much of the polar oceans from becoming corrosive** to the shells of key marine species. Even at these CO_2 levels, projections indicate net reef growth in tropical areas can't keep pace with reef erosion and dissolution.

Photo credit: Arne Körtzinger

Ocean acidification may threaten the food security of millions of the world's poorest people.

OCEAN ACIDIFICATION RESEARCH IS IN ITS INFANCY

Ocean acidification is a relatively new field of study, with **62% of the research papers on the subject published since 2004.**

Despite advances in understanding the impacts of elevated CO_2 concentrations on a wide range of marine organisms, we are still **unable to make meaningful projections of impacts** on marine ecosystems and fisheries as a whole, or to **identify thresholds** beyond which marine ecosystems may not recover.

Globally, **there are relatively few sites with multi-decadal measurements of the chemical and ecosystem variables needed to provide a baseline for the timely assessment of ocean acidification impacts.** A global early warning and forecast network coordinated across nations is required for research, management and verification of stabilisation actions.

Background

Most studies on marine organisms have only examined the responses of single species to one environmental factor, such as an increase in acidity, CO_2, or temperature. Methods must be developed to examine the full ecosystem response to multiple environmental factors, using scenarios for expected conditions in the next few decades.

Long-term studies and selective breeding experiments are required to understand adaptation and evolution pathways. Identifying genes involved in calcification and acid-base balance and means to measure the expression of these genes will be important for understanding the adaptability of marine organisms to changes in acidity.

The global scale of the acidification suggests that options for mitigation are likely to be very limited, especially on short timescales. Research is needed to understand whether addition of alkaline substances to the ocean could counter acidification in specific areas, the degree to which acidification impacts can be offset by reducing other environmental stresses, such as eutrophication, and the optimal management of marine ecosystems to counter these and other combined threats.

User groups to guide research should include policy experts with interests that span the relevant environmental, industry and conservation sectors.

62% of ocean acidification research papers have been published since 2004.

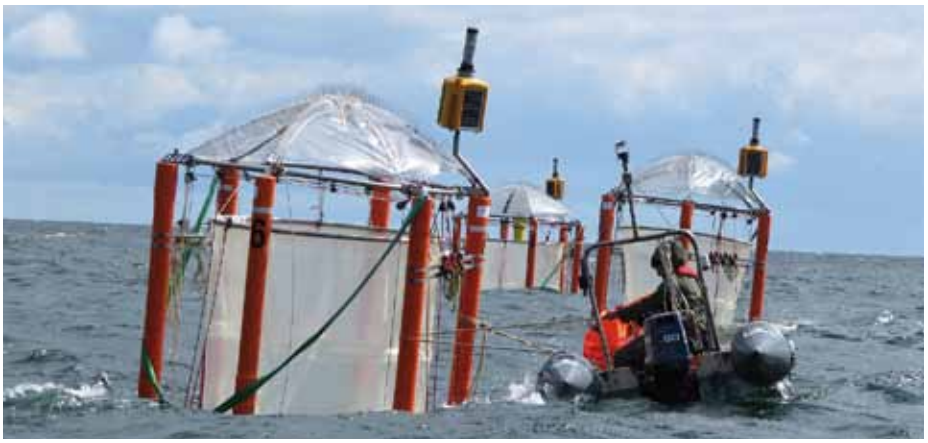

Photo credit: Ulf Riebesell

SYMPOSIUM SPONSORS

The nongovernmental **Scientific Committee on Oceanic Research** (www.scor-int.org) was established by the International Council of Scientific Unions in 1957 to promote international cooperation in all areas of ocean science.

The **Intergovernmental Oceanographic Commission** (http://ioc-unesco.org) was established by the United Nations Educational, Scientific and Cultural Organization (UNESCO) in 1960 to provide Member States of the United Nations with an essential mechanism for global cooperation in the study of the ocean.

The **International Geosphere-Biosphere Programme** (www.igbp.net) is an international scientific research programme that studies the interactions between biological, chemical and physical processes and human systems, to develop and impart the understanding necessary to respond to global change.

The **Marine Environment Laboratories (MEL) of the International Atomic Energy Agency** (www-naweb.iaea.org/naml) promotes UN interagency efforts to protect the seas, and carries out research on ocean acidification by combining isotopes with manipulative experiments and by using numerical models to better understand and project how acidification may alter marine resources during the 21st century.

www.ocean-acidification.net

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The results outlined here are synthesised in the scientific report Orr *et al*. (2009) Research Priorities for Ocean Acidification available from: www.ocean-acidification.net