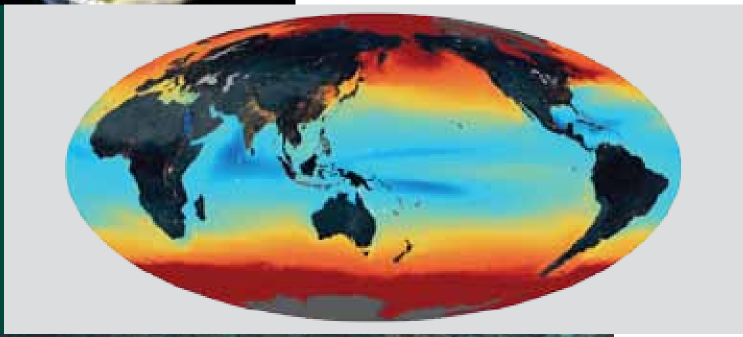
Secretariat of the
Convention on
Biological Diversity

CBD Technical Series
No. 75

75

MAIN FINDINGS AND KEY MESSAGES

An Updated Synthesis of the Impacts of Ocean Acidification on Marine Biodiversity



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Introduction

Marine and coastal biodiversity provide enormous benefits for human well-being and are critical to global geo-chemical processes, such as climate regulation and carbon cycling. However, the oceans are facing major threats due to rising levels of carbon dioxide in the atmosphere. In addition to driving global climate change, increasing concentrations of carbon dioxide affect ocean chemistry, impacting marine ecosystems and compromising the health of the oceans and their ability to provide important services to the global community. The impacts of ocean acidification are beginning to be felt in some areas, but future projections indicate even more broad-reaching impacts if action is not taken.

In October 2014, the Secretariat of the Convention on Biological Diversity (CBD) published *Technical Series No. 75: An Updated Synthesis of the Impacts of Ocean Acidification on Marine Biodiversity*,* in response to a request from the Conference of the Parties to the CBD (decision XI/18).

This report provides a synthesis of the impacts of ocean acidification on marine biodiversity based upon current literature and emerging research, and represents an enormous scientific effort by researchers and experts from around the world to synthesize the best available and most up-to-date information on the impacts of changing ocean pH on the health of the world's oceans. Drawing upon this report, this booklet was prepared to highlight the Executive Summary of the report, which outlines its main findings and key messages. The full report is available at: **www.cbd.int/doc/publications/cbd-ts-75-en.pdf**

Among its findings, CBD Technical Series No. 75 notes that ocean acidification has increased by around 26 per cent since pre-industrial times and that, based on historical evidence, recovery from such changes in ocean pH can take many thousands of years. The report outlines how ocean acidification impacts the physiology, sensory systems and behaviour of marine organisms, and undermines ecosystem health. Furthermore, it shows that impacts due to ocean acidification are already underway in some areas and that future projected impacts could have drastic, irreversible impacts on marine ecosystems. Despite the growing body of information on ocean acidification, the report points out key knowledge gaps and, in light of the many complex interactions related to ocean chemistry, stresses the difficulty of assessing how future changes to ocean pH will affect marine ecosystems, food webs and ecosystems, and the goods and services they provide.

MAIN FINDINGS AND KEY MESSAGES

OCEAN ACIDIFICATION AND AWARENESS OF ITS CONSEQUENCES

1. **Ocean acidification has increased by around 26% since pre-industrial times**
In the past 200 years, it is estimated that the ocean has absorbed more than a quarter of the carbon dioxide released by human activity, increasing ocean acidity (hydrogen ion concentration) by a similar proportion. It is now nearly inevitable that within 50 to 100 years, continued anthropogenic carbon dioxide emissions will further increase ocean acidity to levels that will have widespread impacts, mostly deleterious, on marine organisms and ecosystems, and the goods and services they provide. Marine calcifying organisms seem particularly at risk, since additional energy will be required to form shells and skeletons, and in many ocean areas, unprotected shells and skeletons will dissolve.
2. **International awareness of ocean acidification and its potential consequences is increasing**
Many programmes and projects are now investigating the impacts of ocean acidification on marine biodiversity and its wider implications, with strong international linkages. The United Nations General Assembly has urged States to study ocean acidification, minimize its impacts and tackle its causes. Many United Nations bodies are focusing attention on these issues.

GLOBAL STATUS AND FUTURE TRENDS OF OCEAN ACIDIFICATION

3. **Seawater pH shows substantial natural temporal and spatial variability**
The acidity of seawater varies naturally on a diurnal and seasonal basis, on a local and regional scale, and as a function of water depth. Coastal ecosystems and habitats experience greater variability than those in the open ocean, due to physical, geochemical and biological processes, and terrestrial influences.
4. **Substantial natural biological variability exists in organisms' responses to pH changes**
Metadata analyses, combining results from many experimental studies, show that there are different, but consistent, patterns in the response of different taxonomic groups to simulated future ocean acidification. There can interactions with other factors.
5. **Surface waters in polar seas and upwelling regions are increasingly at risk of becoming undersaturated with respect to calcium carbonate, dissolving shells and skeletons which are not protected by an organic layer**
In waters where pH is already naturally low (in high latitudes, coastal upwelling regions and on the shelf slope), widespread undersaturation of the commonest forms of biologically-formed calcium carbonate, aragonite and calcite, is expected to develop during this century. Benthic and planktonic molluscs are amongst the groups likely to be affected, as well as cold-water corals and the structural integrity of their habitats.
6. **International collaboration is underway to improve monitoring of ocean acidification, closely linked to other global ocean observing systems**
A well-integrated global monitoring network for ocean acidification is crucial to improve understanding of current variability and to develop models that provide projections of future conditions. Emerging technologies and sensor development increase the efficiency of this evolving network.

WHAT THE PAST CAN TELL US: PALEO-OCEANOGRAPHIC RESEARCH

7. **During natural ocean acidification events that occurred in the geological past, many marine calcifying organisms became extinct**
   High atmospheric carbon dioxide has caused natural ocean acidification in the past, linked to "coral reef crises". During the Paleo-Eocene Thermal Maximum (PETM, ~56 million years ago), the species extinctions were less severe than earlier events; however, the atmospheric changes that occurred then were much slower than those happening today.

8. **Recovery from a major decrease in ocean pH takes many thousands of years**
   The paleo-record shows that recovery from ocean acidification can be extremely slow; following the PETM, for example, this took around 100,000 years.

IMPACTS OF OCEAN ACIDIFICATION ON PHYSIOLOGICAL RESPONSES

9. **Ocean acidification has implications for acid-base regulation and metabolism for many marine organisms**
   When external hydrogen ion levels substantially increase, extra energy may be required to maintain the internal acid-base balance. This can lead to reduced protein synthesis and reduction in fitness. Such effects are greatest for sedentary animals, but can be mitigated if food supply is abundant, and increasing metabolism may offset detrimental effects in some species.

10. **Impacts of ocean acidification upon invertebrate fertilization success are highly variable, indicating the potential for genetic adaptation**
    Experimental studies on the impact of ocean acidification on fertilization show that some species are highly sensitive, whilst others are tolerant. Intra-specific variability indicates the scope for a multigenerational, evolutionary response.

11. **Ocean acidification is potentially detrimental for calcifying larvae**
    Early life stages of a number of organisms seem to be particularly at risk from ocean acidification, with impacts including decreased larval size, reduced morphological complexity, and decreased calcification.

12. **Ocean acidification can alter sensory systems and behaviour in fish and some invertebrates**
    Impacts include the loss of ability to discriminate between important chemical cues. Individuals may become more active and liable to exhibit bolder, riskier behaviour.

IMPACTS OF OCEAN ACIDIFICATION ON BENTHIC COMMUNITIES

13. **Around half of benthic species have lower rates of growth and survival under projected future acidification**
    For corals, molluscs and echinoderms, many studies show reduction in growth and survival rates with ocean acidification. However, these responses are variable, and some species can live at low pH conditions.

14. **Many seaweed (macroalgae) and seagrass species can tolerate, or may benefit from, future ocean acidification**
    Non-calcifying photosynthetic species, which are frequently abundant near natural CO_2 seeps, may benefit from future ocean acidification. Calcifying macroalgae are, however, negatively impacted. High densities of seagrass and fleshy macroalgae can significantly alter the local carbonate chemistry, with potential benefit for neighbouring ecosystems.

IMPACTS OF OCEAN ACIDIFICATION ON PELAGIC COMMUNITIES

15. **Many phytoplankton could potentially benefit from future ocean acidification**
    Non-calcifying phytoplankton (e.g., diatoms) can show increased photosynthesis and growth under high CO_2 conditions. The response of calcifying phytoplankton (e.g., coccolithophores) is more variable, both between and within species. Mesocosm experiments provide insights into the community shifts that might arise through competitive interactions, as well as the balance between increased photosynthesis and decreased calcification. The response of bacterio-plankton to ocean acidification has not been well studied, but altered decomposition rates would have implications for nutrient cycling.

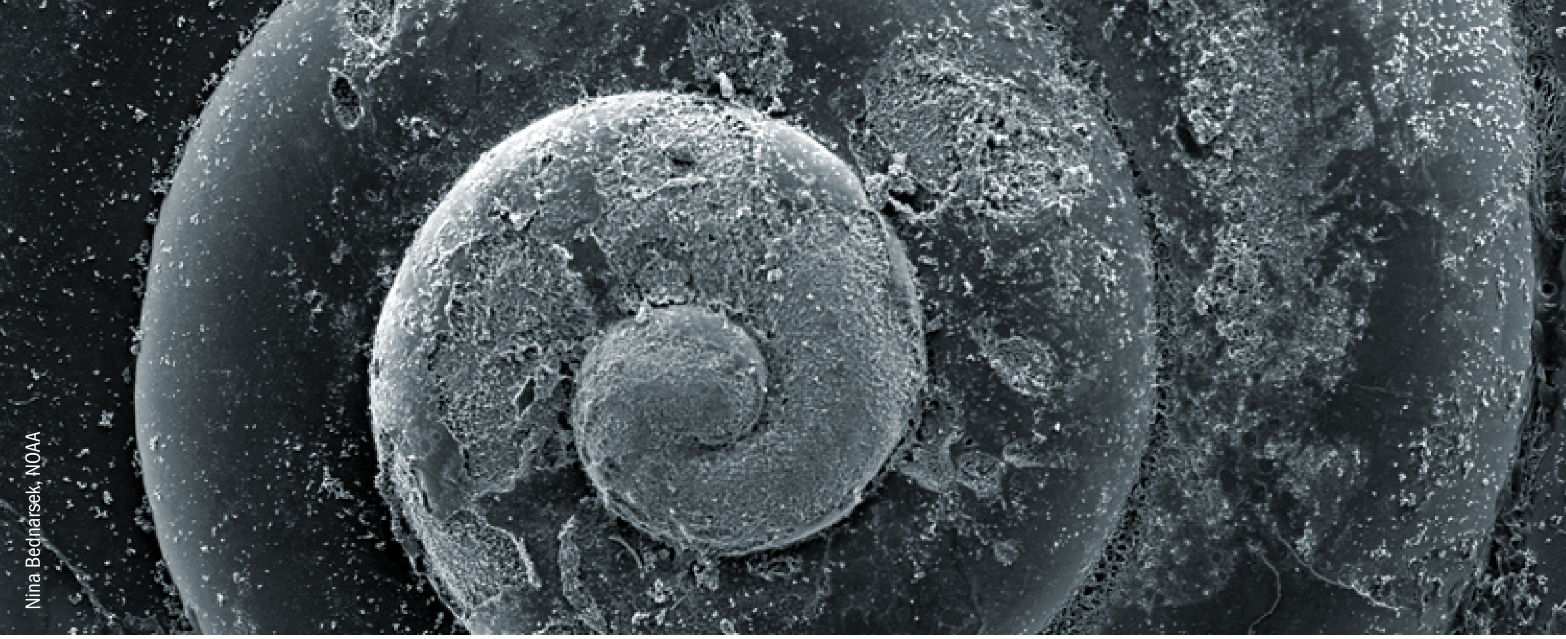
16. **Planktonic foraminifera and pteropods seem likely to experience decreased calcification or dissolution under projected future conditions**
    The shells of both of these groups are liable to experience dissolution if calcium carbonate saturation drops below 1. Decreases in shell thickness and size of planktonic foraminifera may also decrease the efficiency of future carbon transport between the sea surface and the ocean interior.

IMPACTS OF OCEAN ACIDIFICATION ON BIOGEOCHEMISTRY

17. **Ocean acidification could alter many other aspects of ocean biogeochemistry, with feedbacks to climatic processes**
    High CO_2 may alter net primary productivity, trace gas emissions, nitrogen-carbon ratios in food webs and exported particulate matter, and iron bioavailability. The scale and importance of these effects are not yet well-understood.

IMPACTS OF OCEAN ACIDIFICATION ON ECOSYSTEM SERVICES AND LIVELIHOODS

18. **Impacts of ocean acidification on ecosystem services may already be underway**
    Ocean acidification is apparently already impacting aquaculture in the north-west United States of America, further decreasing the pH of upwelled water, which has a naturally low saturation state for calcium carbonate. High mortalities in oyster hatcheries can, however, be mitigated by monitoring and management measures. Risks to tropical coral reefs are also of great concern, since the livelihoods of around 400 million people depend on such habitats. Research on the socio-economic impacts of ocean acidification has only recently started and is growing rapidly.



RESOLVING UNCERTAINTIES

19. **Existing variability in organism response to ocean acidification needs to be investigated further, to assess the potential for evolutionary adaptation**
    Multi-generational studies with calcifying and non-calcifying algal cultures show that adaptation to high CO_2 is possible for some species. Such studies are more difficult to conduct for long-lived organisms, and variability in adaptive capacity is likely. Even with adaptation, community composition and ecosystem function are still likely to change.

20. **Research on ocean acidification increasingly needs to involve other stressors, as will occur under field conditions in the future**
    Acidification may interact with many other changes in the marine environment, local and global; these "multiple stressors" include temperature, nutrients, and oxygen. In situ experiments on whole communities (using natural CO_2 vents or CO_2 enrichment mesocosms) provide a good opportunity to investigate impacts of multiple stressors on communities, to increase our understanding of future impacts.

SYNTHESIS

21. **Ocean acidification represents a serious threat to marine biodiversity, yet many gaps remain in our understanding of the complex processes involved and their societal consequences**
    Ocean acidification is currently occurring at a geologically unprecedented rate, subjecting marine organisms to an additional, and worsening, environmental stress. Experimental studies show the variability of organisms' responses to simulated future conditions: some are impacted negatively, some positively, and others are apparently unaffected. Furthermore, responses to ocean acidification can interact with other stressors and vary over time, with some potential for genetic adaptation. This complexity of natural processes makes it extremely challenging to assess how future ocean acidification will affect natural marine communities, food webs and ecosystems, and the goods and services they provide. Nevertheless, substantive environmental perturbations, increased extinction risk for particularly vulnerable species, and significant socio-economic consequences all seem highly likely. Research priorities to reduce the uncertainties relating to future impacts include greater use of natural high-CO_2 analogues, the geological record, and well-integrated observations, together with large-scale, long-term and multi-factorial experimental studies.

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* CBD Technical Series no. 75 was edited by Dr. Sebastian Hennige (Heriot-Watt University, UK), Professor J. Murray Roberts (Heriot-Watt University, UK) and Dr. Phillip Williamson (Natural Environment Research Council and University of East Anglia, UK) and produced in collaboration with a team of experts from around the world, peer-reviewed by Parties to the CBD, with the financial support of the United Kingdom of Great Britain and Northern Ireland (through the UK Ocean Acidification Research Programme and the Natural Environment Research Council, the Department for Environment, Food and Rural Affairs, and the Department of Energy and Climate Change). A complete list of lead authors and reviewers is available in the full report (https://www.cbd.int/doc/publications/cbd-ts-75-en.pdf).

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