Federal Ministry
of Education
and Research

Science Year 2016*17
SEAS AND OCEANS

Ocean Acidification

The Other Carbon Dioxide Problem

Global Change and Ocean Change Are Inextricably Linked

Two thirds of the Earth's surface are covered by water – truly we live on a blue planet! Despite this, the impact of climate change on land has been investigated much more thoroughly than its effects on marine habitats.

For decades, our seas and oceans have been absorbing ever-increasing amounts of carbon dioxide, which causes them to acidify. Some marine plants and animals are responding positively to the change, others are being negatively affected – their roles in the marine food web are reorganized. In addition, there is a variety of other environmental factors that can amplify or ameliorate the change. What we know for sure: biodiversity will decline. Moreover, the ocean cannot absorb endless amounts of carbon dioxide (CO_2). As the quantity of CO_2 taken up by the ocean gradually declines, the greenhouse effect accelerates.

Researchers are working at untangling the ocean's responses to climate change and assessing the impacts this will have on human society. The deeper they look into the system, the clearer the complex interrelations between its components become.

Seas and oceans are tremendously important for life on our planet, as well as home to an enormous variety of plants and animals. With its research funding, the BMBF is helping to unravel how exactly rising carbon dioxide emissions and ocean acidification are affecting the life in the ocean. In addition, we are developing strategies designed to ensure that future generations will also be able to benefit from and enjoy the enormous biodiversity that currently exists in our seas and oceans.

Johanna Wanka

Prof. Dr. Johanna Wanka
Federal Minister of Education and Research

Carbon Dioxide – When the Seas Acidify

Since the beginning of the Industrial Revolution, the ocean has absorbed around 30 percent of all the carbon dioxide released into the atmosphere by human activities. By providing this invaluable service, the ocean slows down global climate change.

BIOACID – The German Research Network on Ocean Acidification

"Since 2009, the German Research Network on Ocean Acidification BIOACID (Biological Impacts of Ocean Acidification www.bioacid.de) investigates how marine communities respond to ocean acidification and what the consequences are for the marine food web and the transformation of energy and materials in the ocean. Our goal is to determine potential economic and societal impacts and to provide well-founded policy recommendations. Critical to the success of BIOACID is the involvement of researchers representing a wide range of disciplines from 20 institutions nationwide."

Prof. Dr. Ulf Riebesell, GEOMAR Helmholtz Centre for Ocean Research Kiel

In turn, however, as the CO_2 dissolves in seawater, it triggers a chemical reaction with far-reaching consequences: carbonic acid is produced, lowering the seawater pH. This also decreases the concentration of carbonate ions. Calcifying organisms such as bivalves, corals, and various plankton species need exactly these molecules to build their shells and skeletons. These and other marine organisms need to spend more energy to regulate their bodily functions in acidifying waters. This energy will no longer be available for growth, reproduction, or resistance to other environmental stresses. At the same time, some species, such as seagrass and blue-green algae, may benefit from the additional CO_2 dissolved in seawater.

The responses of marine communities to ocean acidification will reduce biodiversity. This is likely to have a string of repercussions, and may also affect our food supply. In order to avert serious risks, anthropogenic CO_2 emissions need to be limited.

As ocean acidification continues, the biodiversity in coral reefs decreases and habitats deteriorate.

What We Know

It has only been about ten years since scientists began studying the consequences of ocean acidification. But they have already made some groundbreaking discoveries concerning its impacts on marine life.

- The more the ocean acidifies, the less additional carbon dioxide it can absorb. Its function as a "CO_2 sink", which helps attenuate climate change, will in all likelihood decline. As a result, the greenhouse effect will keep accelerating and growing in intensity.

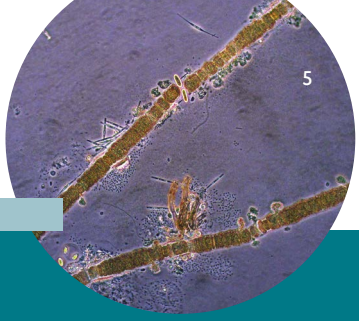
- Many organisms will suffer from ocean acidification – especially animals that build their shells and skeletons from calcium carbonate. Echinoderms such as starfish will also be negatively affected. However, some species will benefit from the additional carbon dioxide in the water: These could include seagrass, jellyfish, and picoplankton – which are among the smallest marine organisms. This will severely change the marine ecosystem; biodiversity will decrease.

- A large part of the world's coral reefs have already been destroyed or seriously damaged. Drastically reducing global CO_2 emissions, as outlined in the Paris Agreement negotiated in December 2015 at the 21st Climate Change Conference, could save about half of the planet's tropical reefs.

A sea without butterflies

"'Sea butterflies' is the nickname of pteropods, swimming sea snails. These little animals use their foot, which is shaped like a pair of wings, to flap their way through the ocean. When you look at them with the naked eye, or under a microscope, they look quite graceful. These sea butterflies are also tremendously important for the marine food web, but their extremely thin, easily dissolved calcareous shell makes them particularly sensitive to ocean acidification. In certain regions of the world, their shells are already being affected. If sea butterflies are not able to survive in a more acidified ocean, other species might take their roles. But a sea without butterflies? That's something I'm scared to think about."

Dr. Silke Lischka, GEOMAR Helmholtz Centre for Ocean Research Kiel

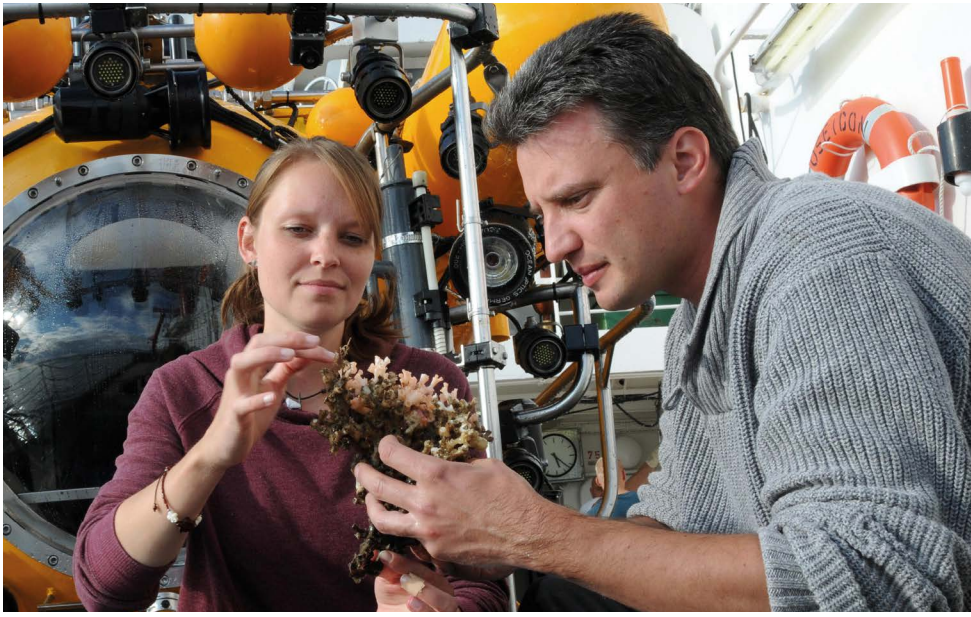


Blue-green algae as winners of ocean acidification?

"Every summer, beaches need to be closed off due to blooms of toxic cyanobacteria. Some laboratory and field studies suggest that, together with other factors, increased carbon dioxide concentrations could stimulate the growth of these organisms in the Baltic Sea – especially if the water temperatures rise at the same time."

Dr. Nicola Wannicke, Leibniz Institute for Baltic Sea Research, Warnemünde (IOW)

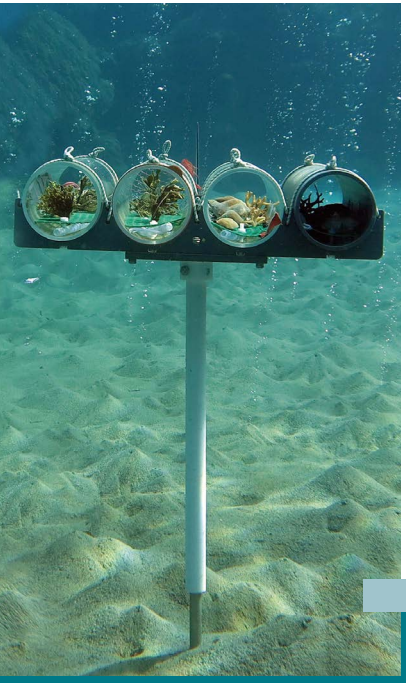
- Marine organisms have to face additional stress factors on top of ocean acidification: rising seawater temperatures, loss of oxygen, eutrophication, overfishing, and pollution can make the effects of ocean acidification even worse.



GEOMAR researchers examining cold-water coral samples obtained during an expedition with the manned research submersible JAGO off the Norwegian coast.

A Miniature Version of the Ocean

Laboratory experiments are a great way to study how individual species respond to altered environmental conditions: no other organisms influence their development, and important parameters can be adjusted precisely. This enables scientists to identify underlying mechanisms and responses that characterize the species being studied.

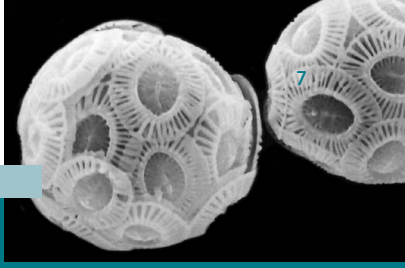


However, to simulate the future ocean with its tightly woven food web and complex species interactions science needs more sophisticated setups. That is why BIOACID biologists and engineers developed what are referred to as "benthocosms." These unique test chambers enable scientists to study how plants and animals respond to changes in solar radiation, temperature, currents, pH, salinity, carbon dioxide concentration, and nutrients. Natural communities can also be isolated directly in the ocean by using the "KOSMOS mesocosms" developed in Kiel. Each one of these gigantic floating test tubes holds 55 cubic meters of water along with all the plankton living in it. The carbon dioxide concentrations in them can be adjusted to match those expected in the future. Mesocosm studies clearly show that complex interdependencies determine how marine ecosystems respond to ocean acidification.

Where the future has already arrived

"Sites of natural carbon dioxide venting from the seafloor (seeps) are locally creating the environmental conditions expected for the future ocean. These areas provide ideal study grounds to learn about the long-term impact of ocean acidification on entire ecosystems. For example, in Papua New Guinea, we were able to study how corals, seagrass, seaweed, plankton, and microorganisms respond to the reduced pH at CO_2 vents. My initial observations revealed that the microbial community composition changes – and with it the nutrient supply to other reef inhabitants, along with other important factors in the reef. Other studies have shown that coral reef biodiversity decreases and habitats deteriorate."

Christiane Hassenrück, Max-Planck-Institute for Marine Microbiology, Bremen



How are things looking for *Emiliania*?

"The single-celled coccolithophore Emiliania *huxley is not only a producer of biomass, but also an important calcifier in the ocean. While growing, this organism converts carbon dioxide into organic carbon and surrounds its cells with a cover of tiny calcium carbonate platelets. In laboratory experiments,* Emiliania *adapted to ocean acidification through evolution. We used a mesocosm field experiment to check whether this adaptation also helps the organism in its natural setting. We are curious to see how our lab strains managed under natural conditions."*

Dr. Kai Lohbeck, GEOMAR Helmholtz Centre for Ocean Research Kiel / University of Gothenburg

With the help of KOSMOS mesocosms, scientists study the effects of ocean acidification directly in the ocean.

Ocean Services

People have lived from the ocean for as long as we can remember. Many of the "services" that the sea provides to us may be altered by global change and ocean acidification. BIOACID researchers interviewed stakeholders from the fishing, tourism, and environmental protection sectors in Norway: Have they already noticed any effects of global change? What consequences do they expect for their sectors?

If fish stocks change in size or range due to climate change, fishing will need to adapt accordingly. But the small boats used by traditional inshore fisheries are often unable to follow migrating stocks into the high seas. In the far north of Norway, more and more fish disappear from the fjords. As a result, the local population – and the indigenous Sami in particular – are losing an important part of their livelihood and culture.

Race to the North Pole

"As a result of global warming, North Atlantic cod migrates further north. What was formerly a short summer visit to the west coast of Spitsbergen has turned into a year-long stay and into a serious problem for the Polar cod inhabiting these waters. Especially the sensitive juvenile fish compete for habitat and food. To compensate for the effects of ocean acidification, these animals need to invest more energy. The Polar cod in particular is being further debilitated by this."

Dr. Felix C. Mark, Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI)

When the Bill Comes Due

"The ocean absorbs a large part of the world's atmospheric carbon dioxide emissions. If you were to assign a monetary value to this 'service,' it would fall somewhere between 60 and 500 billion Euros a year. The other side of the coin is the cost of ocean acidification, for example a decline in fishery revenues. It's hard to determine a specific figure for these costs, since the biological consequences of ocean acidification – for bivalves and fish stocks, for instance – are not yet fully understood. To limit the costs of ocean acidification the industry will have to adapt in time. For example, reducing fishing pressure could compensate for the increased environmental stress on stocks, stabilizing revenue at an adjusted level."

Prof. Dr. Martin Quaas, University of Kiel

Cutter in northern Norway. The fishing industry here already faces effects of climate change.

New Challenges for Ocean Acidification Research

In the past few years, ocean acidification research has become an integral part of the international research agenda. But many questions still remain unanswered.

In addition to ocean acidification, rising temperatures, loss of oxygen, eutrophication, pollution, and other factors have an impact on the development of marine organisms. But which of these effects dampen or amplify each other? How does the biotic community respond as a whole? Laboratory experiments have shown that marine organisms can adapt to ocean acidification through evolution. But will they be able to keep up with the rapid rate of change while sustaining their functions? And how do results from the laboratory translate to a natural environment?

Interdisciplinary research helps to answer these questions. Long-term experiments can reveal the effects of multiple stress factors across many generations at the community level. Moreover, laboratory research must be closely linked to field studies and model simulations. This is the only way in which science can estimate how the ocean will change and how this will ultimately affect mankind.

Divers checking a mesocosm.

How can the remaining carbon budget be distributed fairly?

"To keep the consequences of climate change within acceptable boundaries and to meet the '2-degree target', we can release only an additional 1,000 gigatons of carbon dioxide into the atmosphere. A key question for experts on climate ethics is how the remaining carbon budget can be distributed in a fair manner. One pragmatic solution would be to use a per capita approach, which would yield a value of two tons per year and person. This would entail dramatic CO_2 reductions not only for industrialized nations, but also for emerging nations."

Prof. Dr. Konrad Ott, University of Kiel

From Research to Society

Prof. Dr. Hans-Otto Pörtner (IPCC working group co-chair) and Prof. Dr. Ulf Riebesell (BIOACID coordinator) communicating on ocean acidification.

Climate change research has long ceased to be the purview of ivory tower scientists. Society expects science to provide reliable and verified assessments of the impacts of climate change on our daily lives. Both the political and business sectors use these results for their strategic decisions, and look for experts' advice. A growing number of scientists view themselves also as communicators who in addition to conducting top-level research interact with the public to explain their findings.

In the final phase of BIOACID, the project members will integrate their results to evaluate risks and uncertainties associated with ocean acidification. Their findings will then be incorporated into the upcoming Assessment Report on Global Climate Change prepared by the Intergovernmental Panel on Climate Change (IPCC) and provide a scientific basis for the UN's annual Climate Change Conference.

From knowing to acting

"A societal change towards sustainable lifestyles and industries will only be possible if all stakeholders participate and work together. Natural science can provide the knowledge base, but this in itself is not sufficient. What is really important is to practice new ethical standards – habits such as the emission-intensive commuting to work need to be assessed critically. Our society, businesses, and politicians alike have to realize that simply shifting the problem elsewhere is not a solution – for instance, moving to new fishing grounds far from Europe as our seas are being overfished."

Prof. Dr. Felix Ekardt, Research Unit Sustainability and Climate Policy, Leipzig / Berlin

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