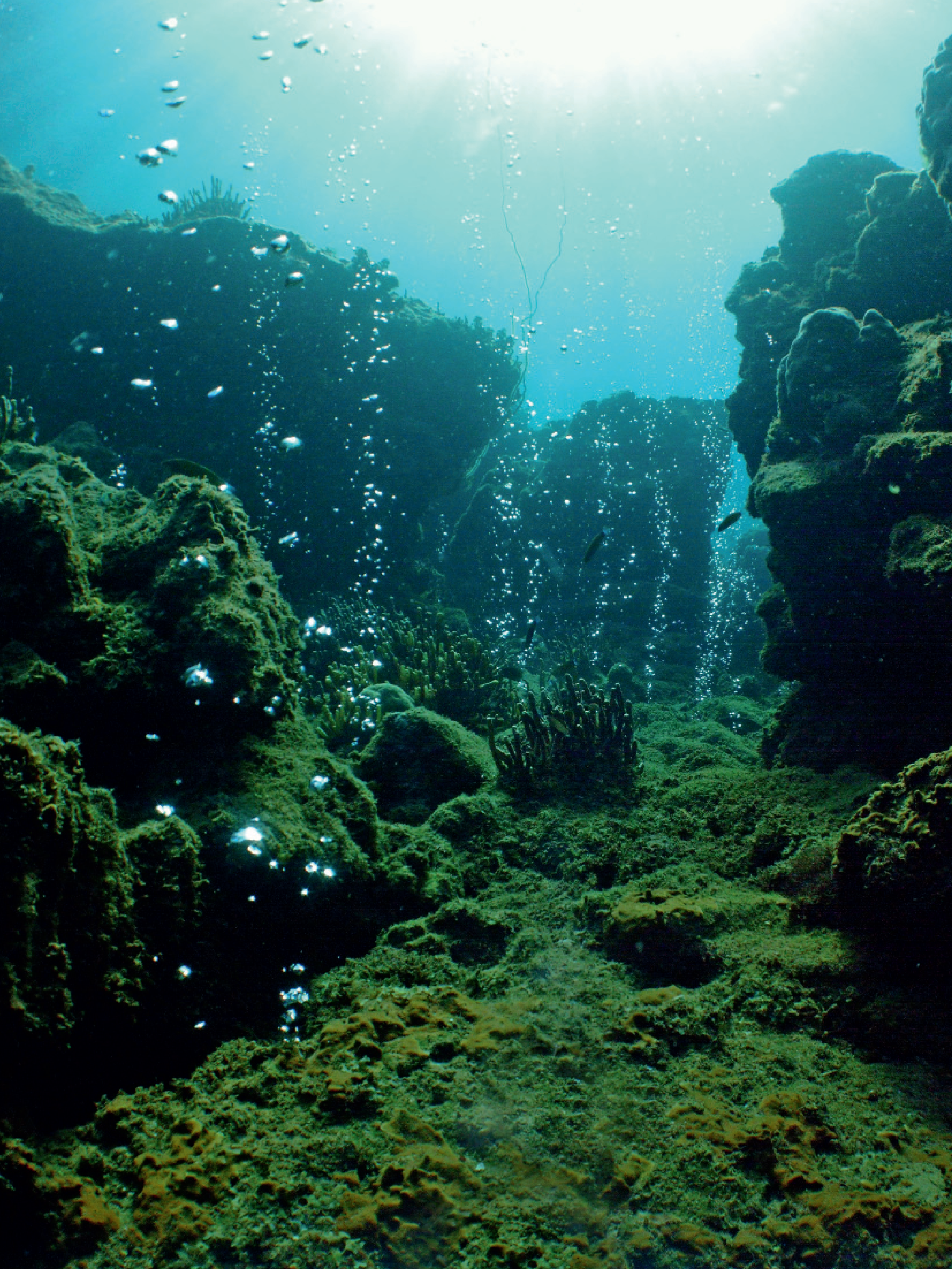
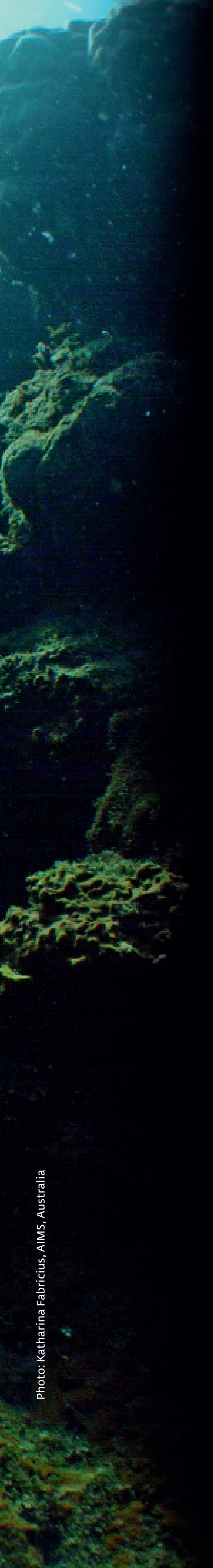




Climate Gives Corals an **Acid Bath**

Life is more abundant here than anywhere else on the planet: tropical coral reefs are the most biodiverse ecosystems in the world. But they are under threat – from acidification of the water. Scientists from the **Max Planck Institute for Marine Microbiology** in Bremen, among them **Martin Glas**, recently spent time off the coast of Papua New Guinea studying how rising carbon dioxide levels and ensuing changes in ocean chemistry affect coral reefs.

TEXT **LISA KLEINE**

They may have felt a bit like Robinson Crusoe: although they were not alone – there were, in fact, fourteen of them – and they spent, not 28 years on a remote island, but around ten days on a boat, the eight scientists from the US, Germany and Australia and their six-man crew were fairly cut off from civilization on their excursion off the southeast coast of Papua New Guinea.

"The part of the peninsula we wanted to get to is not very accessible," explains Martin Glas, doctoral student at Bremen's Max Planck Institute for Marine Microbiology. "There were no asphalt roads, hardly any people and no electricity or running water. And before we started taking our measurements and sampling, we followed traditions and spoke with the village elders of the native tribe to explain our plans to them."

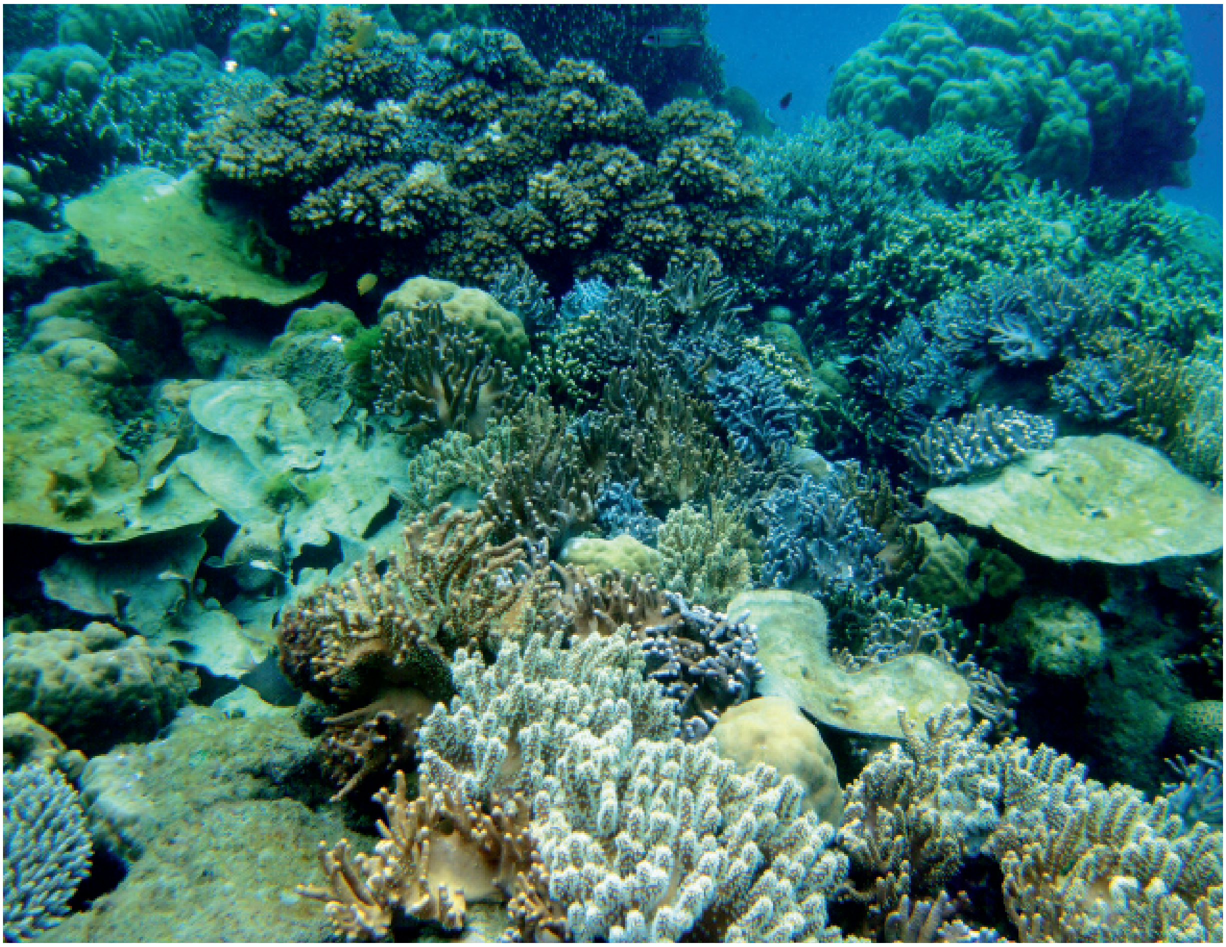
Nevertheless, the scientists had good reason to come to this remote place. They were there to study the influence of carbon dioxide on tropical coral reefs. They know that anthropogenic carbon dioxide emissions not only contribute to the warming of the climate and to changes in living conditions on land, but also in the oceans. If there's more CO_2 in the air, more CO_2 will pass into the water to maintain the solubility equilibrium between air and water.

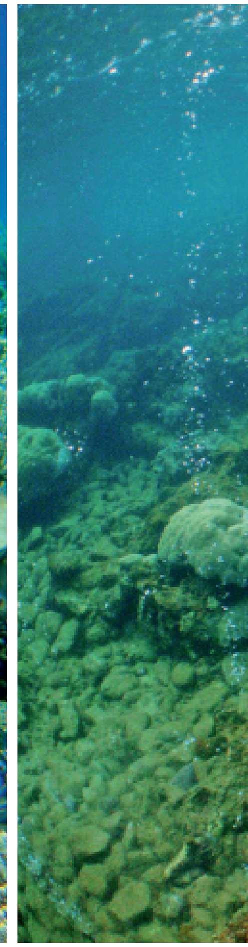
THE CO_2 CONCENTRATION WILL DOUBLE BY 2100

Climatologists from the Intergovernmental Panel on Climate Change (IPCC) estimate that, if developments continue unchecked, the carbon dioxide concentration in the Earth's atmosphere will have doubled by 2100, and the oceans will then be taking up about one-third of the additional carbon dioxide. >

left: Gushing forth from the seafloor: Carbon dioxide from natural seeps before the coast of Papua New Guinea leads to an acidification of the water, thus threatening biodiversity in the coral reefs.

Photo: Katharina Fabricius, AIMS, Australia





Milne Bay Province off the coast of Papua New Guinea is one of nature's labs, where scientists have the opportunity to study the change caused by carbon dioxide in a natural underwater habitat – coral reefs. Volcanic activity on the seabed results in an environment where little bubbles of carbon dioxide rise from three different sources. Papua New Guinea is not the only place where vents like these are found – there are also some in the Mediterranean – but Milne Bay Province holds the promise of inestimable advantages for the scientists.

NATURAL LAB PAINTS AN IMAGE OF THE FUTURE

For one thing, the three vents in question are actually cold seeps. This means the scientists can be sure that changes in the coral reef really can be traced back to the acidification of the water. If they were warm seeps, the differences that occurred there would not be explained solely by the fact that the concentration of carbon dioxide was causing the pH value of the water to fall – they would also be partly a result of the rise in temperature.

"Also, many vents emit a mixture of gases such as carbon dioxide, hydrogen sulfide, methane and other chemical substances. Sulfur compounds alone can kill the coral in those cases," says Martin Glas. In Milne Bay Province, on the other hand, two of the three vents the scientists examined emitted pure CO_2 gas. Their samples were therefore not distorted by the influence of other chemical substances.

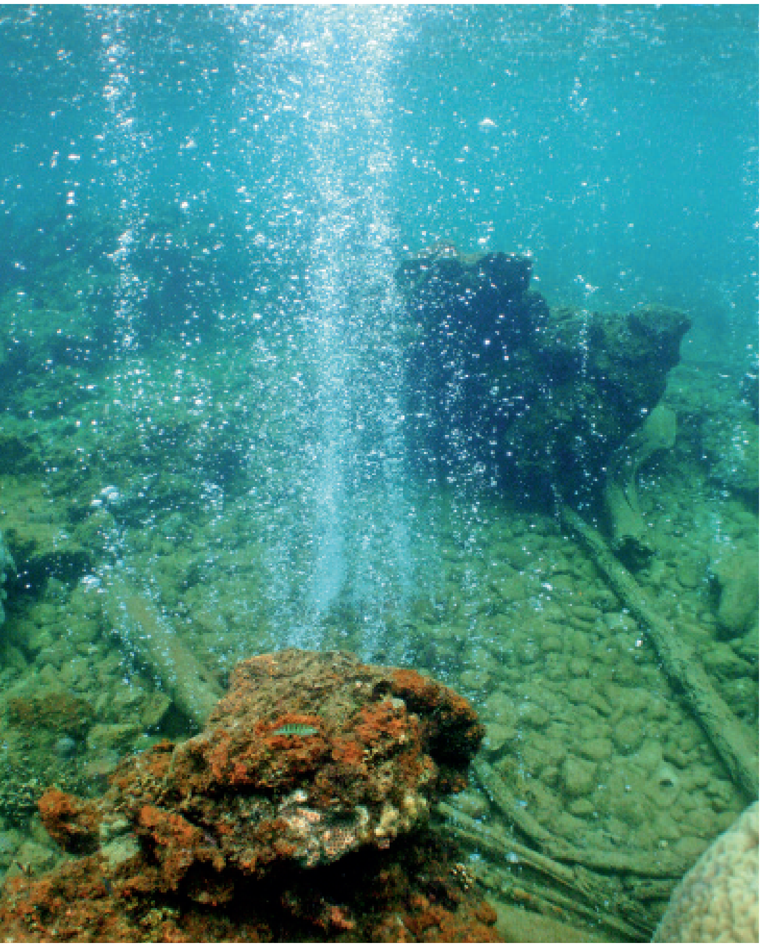
And finally, the vents are located in a complex tropical coral reef ecosystem. Located within the coral triangle – the world's hotspot for coral reef biodiversity – coral reefs here are home to more species than anywhere else in the world, including many calcifying organisms such as crabs, mussels, bivalves, coralline algae and corals. There was a complete ecosystem for the scientists to study here.

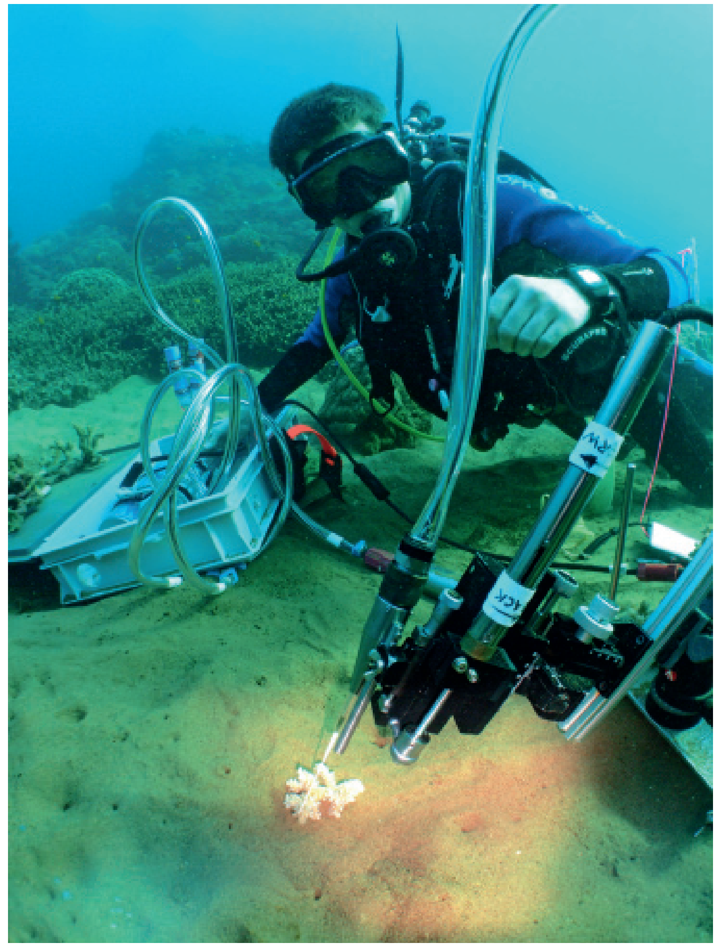
The carbon dioxide gas from the seabed offers Martin Glas and his fellow scientists the opportunity to analyze how a tropical coral reef ecosystem has adapted to higher concentrations of carbon dioxide. Unlike lab experiments, the natural vents in Milne Bay present a much clearer picture of what happens within a highly interactive ecosystem when higher carbon dioxide levels impact a coral reef over many decades.

DECREASING PH LEVELS MEAN LESS DIVERSITY OF CORAL REEFS

In the reefs off the south coast of Papua New Guinea, the plants and animals in the vicinity of the vents are already living in an environment they will face in the future. That's because some of the carbon dioxide emitted from the vents dissolves in the water, making it more acidic – causing a fall in the natural pH value of 8.1. The scientists registered a pH gradient around the vents. The clos-

Photos: Macmillan Publishers Ltd: Nature, 201(2); Katharina Fabricius, AIMS, Australia (from left to right)





left | A coral reef in all its colorful splendour: Far away from the natural carbon dioxide seeps, the ecosystem has the highest biodiversity in the world. Here, the pH levels of water are 8.1.
center | Heavy gushing from this opening in the ground: In this environment, only massive stone coral reefs survive at pH levels of 7.7.
right | Martin Glas, doctoral student at the Max Planck Institute in Bremen, is taking samples before the coast of Papua New Guinea.

er they got to the vents, the lower the pH value was. As the pH value fell, so too did the number of coral species, until they eventually reached a zone where there were virtually no more corals growing. Here, the pH value had sunk below 7.7. And there was almost 40 percent less biodiversity.

"It's not only the corals that were suffering the effects of the higher carbon dioxide level – the prevalence of other marine calcifiers, such as foraminifera and certain algae, also dropped dramatically. These organisms play a major role in maintaining the calcium carbonate balance of the reef. They are key species in a healthy reef system," says Glas.

The biological diversity is shifting. Near the vents, the main species that survive are the very resistant massive, stony corals of the genus Porites. The density of branched and encrusting corals as well as soft corals and sponges has diminished by two-thirds. One of the few organisms that has profited from the increase in carbon dioxide is sea grass. It is now three to four times more prevalent.

"THERE WILL BE SOME WINNERS, BUT A LOT OF LOSERS, TOO"

In the areas with high carbon dioxide levels, the scientists found 50 to 80 percent less juvenile coral. An ecosystem can survive such losses in biodiversity, but it will experience greater fluctuation than before. If only one or a few types of coral are left, a coral reef loses structural integrity and becomes less resistant. "The reef thus becomes more susceptible to natural phenomena, such as tropical cyclones," says the expedition leader, Katharina Fabricius, from the Australian Institute of Marine Science.

Ocean acidification is a chemical process, and it is one that takes a relatively long time. Consequently, forecasts for the year 2100 are already very accurate. Oceanographers do not anticipate a rise in the rate of CO_2 emissions; in fact, they expect it to remain fairly constant in the future. "If tropical coral reefs are subjected to the increased acid content in the ocean, there will be some winners, but a lot of losers, too," says Fabricius.

The decline of the more complex corals and the rise of simpler varieties diminishes the habitat available to the many tens of thousands of species that

The international research crew: Nancy Muehllehner, Katharina Fabricius, Remy Okazaki and Martin Glas (from left to right). Next to them, local natives.

account for the diversity of today's coral reefs. For many marine creatures, coral reefs are not only their nursery, the place they grow to adulthood; they also provide the animals with protection, refuge and food. If coral reefs decline, fish stocks in the oceans will also dwindle. All the more threatening an outlook for mankind given that some two-thirds of the world's population is heavily dependent on the oceans for their food supply.

THERE IS NO REAL SOLUTION YET

"Of course, the CO_2 vents in the seabed are not an exact replica of how the oceans will look in the future," says Martin Glas. Although the pH value is changing at the places the scientists are investigating, the availability of nutrients, for example, is still influenced by the surrounding unaffected ocean. If the ocean becomes more acidic, the food available to plants and animals will be different, which is why the impact on the marine ecosystem could be even more severe than the scientists anticipate. "The way things interact in a coral reef is very complex," explains the scientist.

The tropics have warmed up half a degree Celsius in the past 50 years. Even this slight rise in temperature has led to significant coral bleaching and a decrease in coral growth. The bandwidth of carbon dioxide levels around the Milne Bay seeps is comparable with the figures forecast for the end of the century. It would be catastrophic if the pH value sank below 7.8. "Our research findings prove that we need to reduce carbon dioxide emissions as quickly as possible, otherwise we risk seeing a dramatic loss of coral reef," warns Katharina Fabricius.

Many ideas have been proposed about how to cut carbon dioxide, including CO_2 storage or enhancing the biological pump of the oceans. However, there is no real solution as yet. "All of the approaches taken so far fail to tackle the root of the problem – they merely shift the problem elsewhere," says Martin Glas. Together with his fellow researchers, the Bremen-based scientist is currently testing the expedition results in lab experiments. What he wants to find out is how organisms behave in acidic water and why the larger, unstructured coral species are able to cope with it better than those with small, delicate branches. ◂

GLOSSARY

Biodiversity
refers to the biological diversity of life on our planet. It stands for the diversity of species, the genetic diversity within different species and the diversity of ecosystems.

Coral reef
There are two types of coral reefs: the deep water reef and the tropical coral reef. Tropical coral reefs consist of reef-forming corals and survive only at temperatures of 20 degrees Celsius or more. Since most stony corals in tropical reefs are reliant on sunshine, the reefs cannot be very far below the surface of the water. There are about 600,000 square kilometers of reef surface in the world today. Deep water reefs are home to stony corals, which can stand cooler temperatures and do not need sunlight for their sustenance.

pH value
The abbreviation stands for ***p**otentia **h**ydrogenii* ("potential of hydrogen") and describes a measure of the concentration of hydrogen ions contained in a solution – in other words, a measure of its acidity or alkalinity. The pH value is the negative 10-base log of the hydrogen ion concentration. Water, for example, has a pH value of between 6.0 and 8.5.

Biological pump
is the sum of all biological processes that transport carbon (deriving from the atmosphere) from the surface ocean – the euphotic zone – to the deeper layers. It is a constant biogeochemical process that maintains a carbon balance between the atmosphere, the ocean and deep sea sediments.

Photo: Katharina Fabricius, AIMS, Australia