

Volcanic bubbles help foretell the fate of coral in more acidic seas

By 2100 Australian and global coral reef communities will be slow to recover, less complex, and dominated by fleshy algae, as high carbon dioxide changes ocean chemistry.

An international study published today in [Communications Biology](#) has used unique coral reefs in Papua New Guinea to determine the likely impact of ocean acidification on coral reefs in the face of climate change.

Oceans are becoming more acidic as they absorb carbon dioxide from the atmosphere, and that acid will dissolve coral limestone. But it's hard to predict what impact this will have on whole ecosystems from studies using aquariums and models.

The research team, led by the Australian Institute of Marine Science (AIMS), studied entire coral reefs, locally enriched with CO₂ that is seeping from the sea floor, near some of Papua New Guinea's remote shallow submarine volcanoes.

Dr. Katharina Fabricius, a coral researcher at AIMS in Townsville and senior author on the paper, says the research has revealed which species can thrive under lifelong exposure to elevated CO₂.

"These unique natural laboratories are like a time machine," said Dr Fabricius.

"The CO₂ seeps have allowed us to study the reefs' tolerance limits and make predictions. How will coral reefs cope if emissions are in line with the Paris Agreement level emissions? How will they respond to higher CO₂ emissions scenarios?"

In 2000 Dr Fabricius came across bubbles of gas emerging through coral reefs while surveying species in Milne Bay, about 500 km east of Port Moresby. In 2009, as ocean acidification emerged as an issue, she thought back to that experience, had samples of the gas analysed and discovered it was nearly pure CO₂.

The scene was set for the creation of a unique living laboratory and a decade-long research program to study how tropical marine ecosystems may adapt and how organisms acclimatise after generations of exposure to high CO₂.

Dr Sam Noonan, also from AIMS and first author on the paper, said: "These Papua New Guinea reefs are telling us that with every bit of increase in CO₂, we will see fewer corals and more fleshy algae. Importantly, we also found far fewer baby corals, which means reefs won't be able to grow and recover quickly. That has implications for all the species that depend on them,



Top: Volcanic seeps in PNG: only boulder corals are found in areas of severe ocean acidification

Bottom: A research vessel over volcanic seeps in PNG

Credit: © AIMS, Katharina Fabricius

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including humans. Many coastal communities depend on fish that start their lives using coral reefs for shelter and food.”

Oceans are slightly alkaline with a pH of 8.0, but their acidity has already increased by 30%. As CO₂ emissions rise, the ocean pH is predicted to decline further down to a pH of 7.8 by the year 2100.

“By studying organisms at 37 sites along a 500-metre gradient of CO₂ exposure, we were able to see what happens as CO₂ increases. There was no sudden collapse or tipping point, instead, as the CO₂ increased, we saw fleshy algae became dominant, replacing and smothering coral and calciferous algae,” Dr Fabricius said.

The reefs are hard to reach, requiring a flight into Papua New Guinea, a second to Milne Bay Province, then six hours in a boat.

“The coral reefs in Milne Bay are amazing, and the local people so welcoming. It was a real privilege to work at their reefs with these volcanic CO₂ seeps, which are globally unique,” Dr Fabricius continued.

“Ocean acidification is a massive global problem, which has been understudied and underreported to date. This research is a first of its kind, presenting unique field data and allowing us to assess how whole communities change in the real world.

“We have observed coral reefs starting to change in response to CO₂ gradients in the Great Barrier Reef. The Papua New Guinea reefs tell us what will happen next.

“The more CO₂ we emit into the atmosphere, the greater the changes will be to coral reefs and the coastal communities which depend on them. This is on top of the impact of global warming and sea level rise.”

The research was conducted with colleagues from The University of Western Australia and Saudi Arabia.

Abstract: progressive changes in coral reef communities with increasing ocean acidification

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Ocean acidification from increasing atmospheric CO₂ is progressively affecting seawater chemistry, but predicting ongoing and near-future consequences for marine ecosystems is challenging without empirical field data.

Here we quantify tropical coral reef benthic communities at 37 stations with varying exposure to submarine volcanic CO₂ seeping, and determine the aragonite saturation state (Ω_{Ar}) where significant changes occur in situ.

With declining Ω_{Ar} , reef communities displayed progressive retractions of most reef-building taxa and a proliferation in the biomass and cover of non-calcareous brown and red algae, without clear tipping points.

The percent cover of all complex habitat-forming corals, crustose coralline algae (CCA) and articulate coralline Rhodophyta declined by over 50% as Ω_{Ar} levels declined from present-day to 2, and importantly, the cover of some of these groups was already significantly altered at an Ω_{Ar} of 3.2. The diversity of adult and juvenile coral also rapidly declined.

We further quantitatively predict coral reef community metrics for the year 2100 for a range of emissions scenarios, especially shared socio-economic pathways SSP2-4.5 and SSP3-7.0.

The response curves show that due to ocean acidification alone, reef states will directly depend on CO₂ emissions, with higher emissions causing larger deviations from the reefs of today.

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