Diverse coral communities persist, but bioerosion escalates in Palau's low-pH waters

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Staghorn coral (Acropora cervicornis). Credit: Wikipedia, CC BY 2.5

As the ocean absorbs atmospheric carbon dioxide (CO2) released by the burning of fossil fuels, its chemistry is changing. The CO2 reacts with water molecules, lowering the ocean's pH in a process known as ocean acidification. This process also removes carbonate ions, an essential ingredient needed by corals and other organisms to build their skeletons and shells.

Will some corals be able to adapt to these rapidly changing conditions? If so, what will these coral reefs look like as the oceans become more acidic?

In addition to laboratory experiments that simulate future ocean conditions, scientists are studying coral reefs in areas of the ocean where low pH is naturally occurring to try and answer important questions about ocean acidification, which threatens coral reef ecosystems worldwide.

One such place is Palau, an archipelago in the far western Pacific Ocean. The tropical, turquoise waters of the Palau Rock Islands are naturally more acidic due to a combination of biological activity and the long residence time of seawater within its maze of lagoons and inlets. Seawater pH within the Rock Island lagoons is as low now as the open ocean is projected to be as a result of ocean acidification near the end of this century.

A new study led by scientists at Woods Hole Oceanographic Institution (WHOI) found that the coral reefs there seem to be defying the odds, showing none of the predicted responses to low pH except for an increase in bioerosion—the physical breakdown of coral skeletons by boring organisms such as mollusks and worms. The paper is to be published June 5 in the journal *Science Advances*.

'Based on lab experiments and studies of other naturally low pH reef systems, this is the opposite of what we expected,' says lead author Hannah Barkley, a graduate student in the WHOI-MIT joint program in oceanography.

Experiments measuring corals' responses to a variety of low pH conditions have shown a range of negative impacts, such as fewer varieties of corals, more algae growth, lower rates of calcium carbonate production (growth), and juvenile corals that have difficulty constructing skeletons.

'Surprisingly, in Palau where the pH is lowest, we see a coral community that hosts more species, and has greater coral cover than in the sites where pH is normal,' says Anne Cohen, a co-author on the study and Barkley's advisor at WHOI. 'That's not to say the coral community is thriving because of it, rather it is thriving despite the low pH, and we need to understand how.'

When the research team compared the communities found on Palau's reefs with those in other reefs where pH is naturally low, they found increased bioerosion was the only shared common feature.

'Our study revealed increased bioerosion to be the only consistent community response, as other signs of ecosystem health varied at different locations,' Barkley says.

'This is important because on coral reefs, the balance between calcium carbonate production and removal by bioerosion and dissolution is very tight,' adds Cohen. 'So even if rates of production are not affected by ocean acidification—as we see on Palau—an increase in bioerosion can shift reefs to a state of net calcium carbonate removal, threatening their survival.'

Rapidly changing chemistry

Since the beginning of the Industrial Revolution, ocean pH has fallen by 0.1 pH units, which represents an increase in acidity of approximately 30 percent. For marine life that has evolved over millions of years in relatively stable pH conditions, this kind of rapid change doesn't allow for much time to adapt. By the end of this century, pH levels are projected to be nearly 150 percent more acidic, resulting in a pH that the oceans haven't experienced for more than 20 million years.

There are several sites around the world where CO2 is released by undersea volcanic activity that vents up from the seafloor through the base of the reefs, creating a much lower pH environment than is currently found in the open ocean. These 'natural' laboratories are giving scientists a rare opportunity to examine what is already happening to corals dealing with lower pH levels predicted for the future.

One example is a coral reef system located among the volcanic islands of Papua New Guinea. Here, streams of gas bubbles rise up from the seafloor, lowering the pH of the overlying seawater. Similar low pH conditions are found at vent sites off Japan, freshwater seeps in Mexico, and upwelling areas in regions of the eastern tropical Pacific Ocean.

'The coral reef system at the Papua New Guinea vent site is an algae-dominated one with few species of corals,' says Barkley. 'We see responses much like those shown in many lab experiments at some of the other naturally low pH coral reef sites as well, particularly lower calcium carbonate production. But we don't see the same responses across all of the sites, especially not at the coral reefs in Palau Rock Islands. The coral communities there are thriving, except for higher rates of bioerosion.'

In collaboration with the Palau International Coral Reef Center, members of Cohen's lab have been conducting fieldwork there since 2011. The research team collected water and coral skeletal core samples from eight sites across the Palau reef system, and deployed pH, light, salinity and flow sensors to characterize the seawater environment in which the corals grew. The research team also collected and analyzed data on the community composition as well.

The skeletal cores were scanned at the Computerized Scanning and Imaging Facility at WHOI. The Computerized Axial Tomography technology generates a 3-D image of the cores, revealing detailed information not visible to the naked eye, including coral growth rates, skeletal densities and the extent of bioerosion.

Using an automated program written in Matlab, the team used the 3-D images to quantify the proportion of the coral skeletons that had been eroded by organisms, and the severity of bioerosion of each coral. As the pH of the reef seawater drops, more frequent and severe bioerosion scars were revealed in the coral scans.

'We see coral skeletons that are eaten up and have holes on the top and sides. The coral almost looks like Swiss cheese because of the volume that's been removed,' says Barkley.

Barkley and her colleagues found bioerosion rates in Palau corals increased eleven-fold as pH decreased from the barrier reefs to the Rock Island bays. When comparing those results to other low pH reef sites, a definite pattern emerged.

'All of these naturally low pH sites that Hannah compared are different from one another in terms of physical setting, ecological connectivity, frequencies of variability and so on. What she discovered is that the only common and consistent response to -across all these sites is significantly increased bioerosion,' says Cohen.

'This paper illustrates the value of comprehensive field studies,' adds David Garrison, program director in the National Science Foundation's Division of Ocean Sciences, which funded the research. 'Contrary to laboratory findings, it appears that the major effect of ocean acidification on Palau Rock Island corals is increased bioerosion rather than direct effects on coral species.'

The riddle of resilience

So how do Palau's low pH reefs thrive despite significantly elevated levels of bioerosion? The researchers aren't certain yet, but hope to be able to answer that question in future studies. They also don't completely understand why conditions created by ocean acidification seem to favor bioeroding organisms. One theory is that skeletons grown under more acidic conditions are less dense making them easier for bioeroding organisms to penetrate coral skeletons. But that is not the case on Palau, Barkley says, 'Because we don't see a correlation between skeletal density and pH on Palau.'

A previous study published January 2015 in the journal *Geology* by Thomas DeCarlo, a member of Cohen's lab and a co-author on this paper, showed that the influence of pH on bioerosion is exacerbated by high levels of nutrients. That finding implies that local management strategies, such as controlling runoff from land, can help to slow the impact of ocean acidification on coral reef decline. Increased runoff from areas of intense agriculture and coastal development often carries high levels of nutrients that will interact with decreasing pH to accelerate coral reef decline.

Though coral reefs cover less than one percent of the ocean, these diverse ecosystems are home to at least a quarter of all marine life. In addition to sustaining fisheries that feed hundreds of millions of people around the world, coral reefs protect thousands of acres of coastline from waves, storms, and tsunamis.

'On the one hand, the results of this study are optimistic,' Cohen says. 'Even though many experiments and other studies of naturally low pH reefs show that ocean acidification negatively impacts calcium carbonate production, as well as coral diversity and cover, we are not seeing that on Palau. And that gives us hope that some coral reefs—even if it is a very small percentage—might be able to withstand future levels of ocean acidification. But there's also a cautionary side, even for those coral communities able to maintain their diversity and growth as the oceans become more acidic, increased rates of bioerosion and dissolution seem inescapable.'

More information: Changes in coral reef communities across a natural gradient in seawater pH, advances.sciencemag.org/content/1/5/e1500328

Provided by Woods Hole Oceanographic Institution

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