A Quest For Resilient Reefs

CORALS ARE THREATENED BY THE OCEAN'S CHANGING CHEMISTRY

by Lonny Lippsett

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A coralscape carpets the seafloor off Nukuoro atoll in the Pacific. Will corals adapt to changing conditions?

A conversation with WHOI biogeochemist Anne Cohen

Anne Cohen's forte is corals. From the skeletons of massive corals, she has extracted long-term records of changing ocean and climate conditions. In lab experiments and expeditions, she is investigating how these changes may affect coral reef ecosystems across the global tropics.

In many ways, corals are a poster child for ocean conservation, but they're not just a pretty face, right?

Yes, every year tens of millions of people from around the world flock to the Great Barrier Reef, the Caribbean, or Palau in the far western Pacific to enjoy a magical adventure. But coral reefs are far more than just tourist destinations.

All the coral reefs in the world together occupy less than one percent of the ocean seafloor—a tiny area of the global ocean. Yet 25 percent all ocean species—an estimated 9 million species—are found on coral reefs. They really are the biodiversity centers of our oceans. In addition, 25 percent of all the fish consumed by humans on this planet come from coral reefs.

Beyond tourism and food, coral reefs are barriers that protect coastlines from sea-level rise and storm surges. It is estimated that coral reefs provide about $375 billion to the global economy each year. This is a staggering amount of money for an ecosystem that we think of largely as a tourism destination. And all this is made possible by a little organism—something that looks very much like a sea anemone, and in fact, is related to a sea anemone—called a coral polyp.

Tell us about this little organism.

What these coral polyps are doing, day in, day out, seven days a week, 365 days a year, is taking calcium ions [Ca^{2+}] and carbonate ions [CO_3^{2-}] from the seawater, and combining those ions to make a mineral called calcium carbonate [$CaCO_3$]. Polyps produce a special kind of calcium carbonate called aragonite at extraordinarily high rates, and they fashion these aragonite crystals into the most incredible structures, true feats of architectural design. When we snorkel or scuba-dive on reefs, the amazing diversity of structures we see—the massive elkhorn corals, brain corals, big platy corals—are all produced by tiny coral polyps.

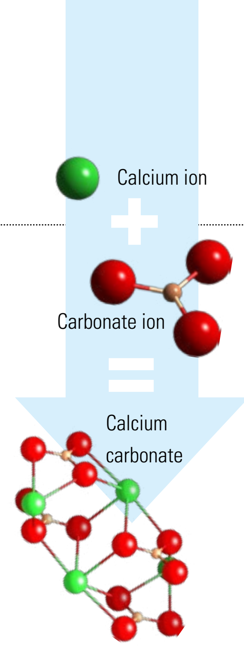
What has changed in the ocean to put corals at risk?

For the past several thousand years, the concentration of carbonate ions in seawater has remained relatively stable. Corals evolving over that time period have adapted to building their calcium carbonate skeletons with seawater at a concentration of about 240 micromoles per kilogram of seawater.

Since the Industrial Revolution, we have increased the burning of fossil fuels and sent more carbon dioxide into our atmosphere. Almost 30 percent of that carbon dioxide has been absorbed by the ocean, causing a fundamental change in the seawater chemistry. The carbon dioxide reacts with water molecules, creating more free hydrogen ions that drive down the pH of seawater and make it more acidic. Some of the hydrogen ions bind with existing carbonate ions in seawater to form bicarbonate. The net result is that the concentration of carbonate ions declines, so that corals have less of it to build their skeletons. We are predicting that by the end of this century, the concentration of carbonate ions that corals desperately need to grow will drop to less than half of preindustrial levels.

What happens when carbonate-ion levels drop?

We've conducted experiments in which we've reared baby corals at various carbonate-ion concentrations in lab tanks. We manipulate the carbonate-ion concentration by pumping



more or less carbon dioxide into the tanks. When we lower the carbonate-ion concentration by just half, we see fundamental changes in the ability of baby corals to build their skeletons. Their skeletons are distorted. Their aragonite crystals change shape. They can't grow them at the rate needed to prevent predation by coral reef fishes and smothering by algae. By the time we got to the lower carbonate-ion concentrations predicted for 2100, those baby corals were struggling so much that they just died after a few weeks.

Other experiments have been conducted at carbonate-ion concentrations that we predict for 200 to 300 years from now. At those levels, the calcium carbonate skeletons of adult corals completely dissolve away, leaving naked polyps. If the corals could grow new skeleton, which is highly unlikely, they wouldn't be able to maintain them.

Are there real-world examples of this happening?

There are a few sites around the world where carbon dioxide is released by undersea volcanic activity and vents up through the base of the reefs. This gives us an opportunity to examine what happens to marine ecosystems exposed to elevated levels of carbon dioxide. In one such reef in Papua New Guinea where this has happened for several decades now, the reef transitions from a highly functional, highly diverse, species-rich reef ecosystem into an algae-dominated system with few corals—not something that we want to go diving on, and certainly not an ecosystem that is providing the essential ecosystem services that the world needs.

But you've also found the opposite—resilient reefs.

Knowing that we are faced with this enormous problem of rising carbon dioxide levels and ocean chemistry changes, we at Woods Hole Oceanographic Institution have partnered with The Nature Conservancy and Conservation International on a global search for the world's most resilient reefs—reefs that have the best chance of surviving future climate change and ocean acidification. Right now, we're investigating about 14 reef systems across the Pacific Ocean.

A lot of our intensive work is focused on the coral reef archipelago of Palau, where we've teamed up with scientists at the Palau International Coral Reef Center headed by scientist Yimnang Golbuu; with delegates of the Palauan government; and with The Nature Conservancy to identify reef communities that have the best chance of surviving climate change and ocean acidification. We have set out instruments to measure seawater pH, carbonate ion concentration, CO_2 levels, and temperature to see how the corals respond to these conditions. With support from The Tiffany & Co. Foundation, we have set up lab experiments at the Palau reef center to manipulate CO_2 and test the resilience of different coral species.

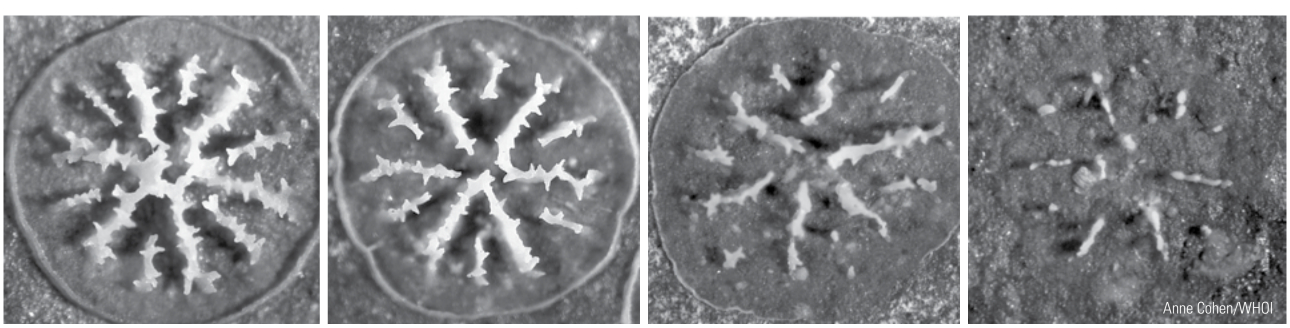
We discovered reef communities in the Palauan Rock Islands that, unlike those in Papua New Guinea, are thriving under naturally acidic conditions. These are highly diverse communities with exceptional coral cover, reproducing, doing their thing, under conditions equivalent to the levels of acidification we're predicting for the tropical oceans by the end of this century. We don't know yet how they're doing it, but they have figured out how to live under these conditions.

What's the ultimate goal?

To find and optimize the protection of coral reefs that have the greatest chance to survive climate change and acidification occurring this century. That's what it comes down to, pretty much. Palau is a tiny nation, but it's a world leader in conservation of its marine resources. About 40 percent of Palau's marine and terrestrial area is already protected, motivated largely by the need to protect spawning grounds for fisheries. We're introducing a new criterion into the decision-making on where to create marine protected areas—resilience against climate change and ocean acidification.

These resilient communities are few and far between, although we expect to identify more as we continue our search. The partnerships that we establish with conservation organizations and local scientists and governments are incredibly important, because that's how scientific information gets communicated and included in the decision-making to ensure the protection of coral reefs. ▲

Above, corals combine calcium and carbonate ions in seawater to make calcium carbonate skeletons. Lower ocean pH means fewer carbonate ions available for corals to build skeletons. Below (l to r), skeletons of baby corals grown in lab tanks with seawater containing diminishing carbonate-ion concentrations, ranging from today's levels (far left) to lower levels predicted for 2200 (far right).



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