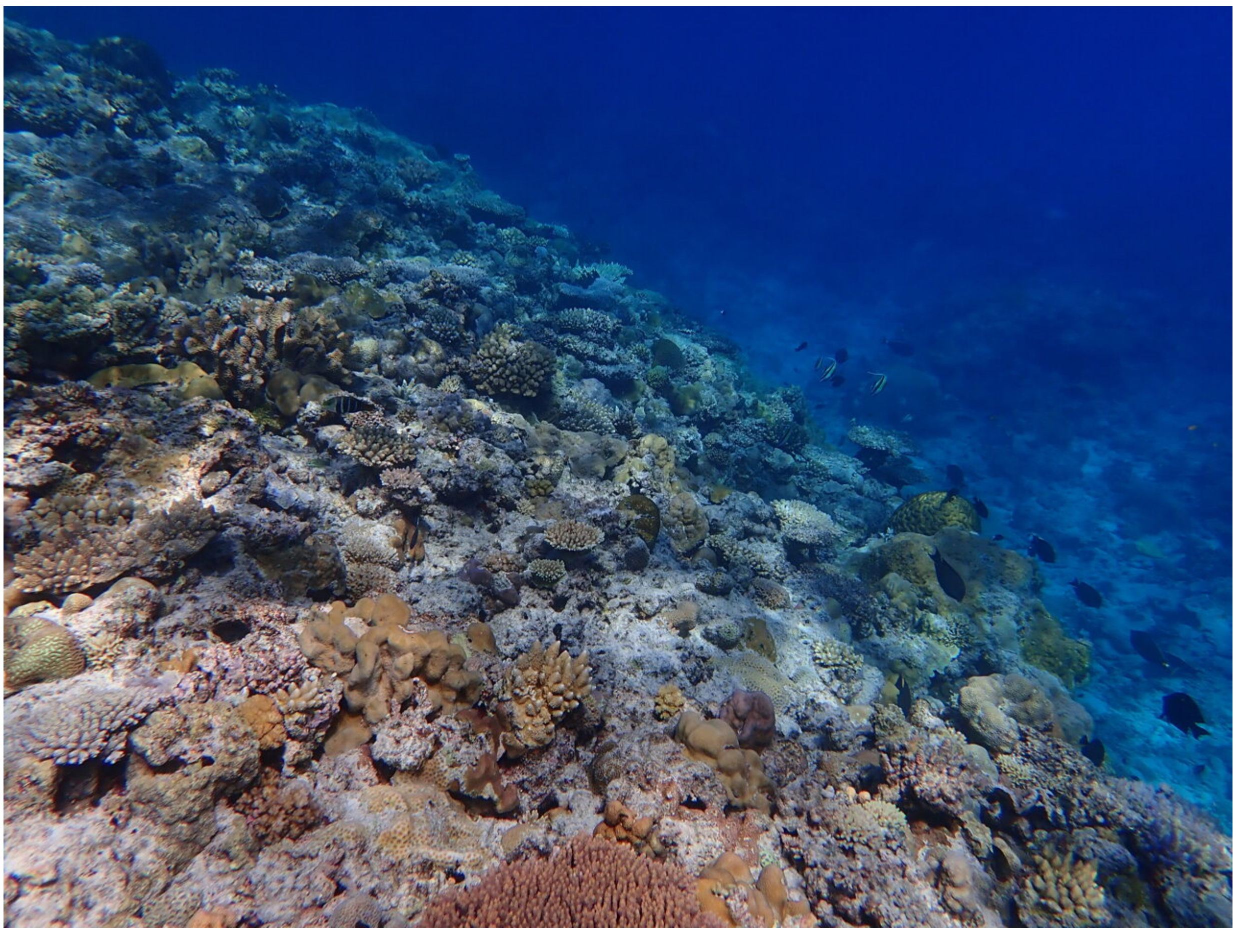
New study provides first comprehensive look at oxygen loss on coral reefs

March 16 2023



Coral reefs at a study site off Taiping Island, South China Sea. Credit: Yi Bei Liang

A new study is providing an unprecedented examination of oxygen loss on coral reefs around the globe under ocean warming. Led by researchers at UC San Diego's Scripps Institution of Oceanography and a large team of national and international colleagues, the study captures the current state of hypoxia—or low oxygen levels—at 32 different sites, and reveals that hypoxia is already pervasive on many reefs.

The overall decline of oxygen content across the world's oceans and coastal waters—a process known as ocean deoxygenation—has been well documented, but hypoxia on coral reefs has been relatively underexplored. Oxygen loss in the ocean is predicted to threaten marine ecosystems globally, though more research is needed to better understand the biological impacts on tropical corals and coral reefs.

The study, published March 16 in the journal *Nature Climate Change*, is the first to document oxygen conditions on coral reef ecosystems at this scale.

"This study is unique because our lab worked with a number of collaborators to compile this global oxygen dataset especially focused on coral reefs—no one has really done that on a global scale before with this number of datasets," said marine scientist Ariel Pezner, now a postdoctoral fellow at the Smithsonian Marine Station in Florida. "We were surprised to find that a lot of coral reefs are already experiencing what we would define as hypoxia today under current conditions."

The authors found that low oxygen levels are already happening in some reef habitats now, and are expected to get worse if ocean temperatures continue to warm due to climate change. They also used models of four different climate change scenarios to show that projected ocean warming and deoxygenation will substantially increase the duration, intensity, and severity of hypoxia on coral reefs by the year 2100.

The analysis was led by Pezner while she was a Ph.D. student at Scripps Oceanography, where she worked in the Scripps Coastal and Open Ocean BiogeochemistrY Research (SCOOBY) lab alongside biogeochemist Andreas Andersson.

Pezner and colleagues used autonomous sensor data to explore oxygen variability and hypoxia exposure at 32 diverse reef sites across 12 locations in waters off Japan, Hawaii, Panama, Palmyra, Taiwan, and elsewhere. Many of the datasets were collected using SeapHOx sensors, instruments originally developed by the lab of Scripps Oceanography researcher Todd Martz. These and other autonomous sensors were deployed in different coral reef habitats, where they measured temperature, salinity, pH, and oxygen levels every 30 minutes.

The SCOOBY lab and partners collected most of the data in an effort to characterize seawater chemistry and reef metabolism in different coral reef environments. The international partners were instrumental in facilitating research logistics and access to many study sites. Several contributors also shared data from their own studies. At Scripps Oceanography, the Martz Lab, Smith Lab, and Tresguerres Lab all made significant contributions to the study.

Historically, hypoxia has been defined by a very specific concentration cutoff of oxygen in the water—less than two milligrams of oxygen per liter—a threshold that was determined in the 1950s. The researchers note that one universal threshold may not be applicable for all environments or all reefs or all ecosystems, and they explored the possibility of four different hypoxia thresholds: weak (5 mg/L), mild (4 mg/L), moderate (3 mg/L), and severe hypoxia (2 mg/L).

Based on these thresholds, they found that more than 84 percent of the reefs in this study experienced "weak to moderate" hypoxia and 13 percent experienced "severe" hypoxia at some point during the data collection period.

As the researchers expected, oxygen was lowest in the early morning at all locations and highest in the mid-afternoon as a result of nighttime respiration and daytime photosynthesis, respectively. During the day when primary producers on the reef have sunlight, they photosynthesize and produce oxygen, said Pezner. But at night, when there is no sunlight, there is no oxygen production and everything on the reef is respiring—breathing in oxygen and breathing out carbon dioxide—resulting in a less oxygenated environment, and sometimes a dip into hypoxia.

This is a normal process, said Andersson, the study's senior author, but as ocean temperature increases, the seawater can hold less oxygen while the biological demand for oxygen will increase, exacerbating this nighttime hypoxia.

"Imagine that you're a person who is used to sea-level conditions, and then every night you have to go to sleep somewhere in the Rocky Mountains, where the air has less oxygen. This is similar to what these corals are experiencing at nighttime and in the early morning when they experience hypoxia," said Andersson. "And in the future, if the duration and intensity of these hypoxic events gets worse, then it might be like sleeping on Mount Everest every night."

The researchers found that as global temperatures continue to rise and marine heat waves become more frequent and severe, low oxygen conditions on coral reefs are likely to become more common. Using projections adopted from climate models, the team calculated that by the year 2100, the total number of hypoxic observations on these reefs will increase under all warming scenarios, ranging from an increase of 13 to 42 percent under one scenario to 97 to 287 percent under a more extreme scenario relative to now.

The researchers said that continued and additional oxygen measurements on coral reefs over different seasons and longer time scales will be "imperative" for establishing baseline conditions, tracking potential hypoxic events, and better predicting future impacts on reef ecology, health, and function.

"Baseline oxygen conditions varied widely among our reef habitats, suggesting that a singular definition of 'hypoxia' may not be reasonable for all environments," said Pezner. "Determining which thresholds are relevant will be important moving forward in making predictions about how reefs might change under warming and oxygen loss."

More information: Ariel Pezner, Increasing hypoxia on global coral reefs under ocean warming, *Nature Climate Change* (2023). DOI: 10.1038/s41558-023-01619-2.
www.nature.com/articles/s41558-023-01619-2

Provided by University of California - San Diego