3D models provide unprecedented look at corals' response to bleaching events

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Researchers use a timeseries of coral reef 3D models to study coral bleaching in Maui. Credit: Smith Lab, 100 Island Challenge

In a study, published July 31 in the journal *PLOS ONE*, marine biologists from Scripps Institution of Oceanography at UC San Diego and Arizona State University provide a first-of-its-kind glimpse into coral "bleaching" responses to stress, using imaging technology to pinpoint coral survival rates following multiple bleaching events off the island of Maui.

Using a time series of coral reef 3D models from Maui, a team of researchers led by Scripps Oceanography's Smith Lab tracked the bleaching response of 1,832 coral colonies from 2014 to 2021. The seven-year data set provided detailed imagery of the reefs year-by-year, allowing the team to identify patterns of coral growth and survivorship through sequential bleaching events that occurred in 2015 and 2019.

The researchers aimed to distinguish between two different processes: natural selection, where only the hardiest corals in a population survive, and acclimatization, where an individual coral becomes more heat tolerant over time as it is exposed to heat stress.

While some corals bleached and died during the study, the corals that survived both bleaching events showed hopeful signs of resilience. Among these survivors, the researchers found little evidence that bleaching impacted coral growth over time. This unexpected finding has the potential to inform approaches to coral reef conservation and restoration.

"This is one of the first studies to use this type of time series to look at multiple coral bleaching events and how the processes of acclimatization and selection play out," said lead author Orion McCarthy, a recent graduate of Scripps Oceanography who conducted the research as a Ph.D. student.

"We found that older corals, which are more likely to have survived multiple bleaching events, could be a good source of outplants for coral restoration."

As the oceans warm due to climate change, coral reefs are threatened by bleaching events. These prolonged warming events stress corals and may ultimately lead to their deaths, yet some corals have managed to survive. Researchers around the globe are trying to understand what makes certain corals more resilient than others in an effort that can inform coral restoration projects.

During prolonged ocean warming events, stressed corals expel beneficial algae that live inside their tissues. This causes corals to turn white and "bleach."

Bleaching doesn't cause corals to immediately die, but it does deprive them of their main source of food. If water temperatures remain elevated for too long, bleaching can cause widespread coral mortality. However, low- to moderate-strength bleaching events are most likely to leave behind some surviving coral colonies. These survivors reshape the makeup of the reef and its response to future bleaching events.

The two bleaching events measured in this study were both moderate-strength, with a sustained increase in sea-surface temperatures of more than 1 degree Celsius (1.8 degrees Fahrenheit) for several months.

Despite facing similar heat stress in 2015 and 2019, corals did not always respond in the same way. Some corals bleached and died after the first event, some didn't bleach in either event, some bleached both times but still survived, and some that bleached the first time didn't bleach the second time. Moreover, hardy survivors were often located right next to more sensitive corals that perished, even though both were the same species and experienced the same environmental conditions.

Several species of coral showed signs of acclimatization to bleaching, notably Porites lobata. Populations of Pocillopora corals fared the worst, with the lowest levels of survivorship.

"Based on our observations, we recommend that restoration practitioners in Hawaii should focus on colonies of Porites and Montipora with a proven track-record of growth and survival," said McCarthy, who now works as a science lead for Sustainable Surf, a nonprofit organization that supports restoration projects focused on coral reefs and other marine ecosystems.

The researchers credited innovative 3D technology with enabling them to detect signs of acclimatization and selection that would have been difficult to track and quantify using traditional in-water surveys. The time series was launched in 2014 by Scripps Oceanography marine biologist Jennifer Smith, a co-author on the study, and her former Ph.D. student Emily Kelly, who now works at the World Economic Forum.

For the past decade, Smith and other members of her lab, including McCarthy, have used large-area imaging, or photogrammetry, to capture a 3D snapshot of coral reefs at fixed sites off Maui.

The scuba diving scientists use specialized underwater cameras to capture thousands of overlapping images of the reef, repeating this process year after year. In the lab, these images are processed using advanced software that seamlessly stitches together thousands of 2D pictures into a detailed 3D model of the underwater landscape.

Their work in Maui is part of a broader coral reef monitoring initiative called the 100 Island Challenge, which aims to describe global patterns of coral reef change over time using large-area imagery.

"This approach has revolutionized our ability to study long-term changes in coral reef communities at very fine scales," said Smith, a professor of marine biology at Scripps Oceanography.

"We can literally watch these systems change in 3D; we can watch corals grow and shrink and visualize how they respond to global stressors. We can use the knowledge gained from using this approach for education and outreach and our results can help to inform management and conservation action."

McCarthy compared the process of tracking coral fates through multiple bleaching events to studying human health outcomes following numerous pandemic-like events. By following the responses of individuals during a single event—for example, the COVID-19 pandemic—researchers can infer whether certain traits or qualities are aligned with better or worse health outcomes.

If a second pandemic event occurred a short time later, researchers could then look at those data to better understand who survived the first event, and how those survivors fared during the second event. The same logic holds true for corals and bleaching events.

The authors noted that efforts to address climate change—the primary driver of ocean warming—are crucial for securing better outcomes for coral reefs. Severe bleaching events have the potential to cause widespread coral mortality, highlighting the urgency to prevent such dire outcomes through global action to address climate change.

"Coral reefs are dynamic and bleaching isn't necessarily going to kill every coral—at least not in the short term—so there is still cause for hope for these reefs and a need for active conservation," said McCarthy.

"Tools like 3D modeling are allowing us to get a more specific understanding of which corals are living and which ones aren't, and we can use that information to help guide coral restoration efforts."

In addition to McCarthy and Smith, the study was co-authored by Ph.D. student Morgan Winston from the University of Arizona.

More information: Corals that survive repeated thermal stress show signs of 4 selection and acclimatization, *PLoS ONE* (2024).

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