Widespread coral-algae symbioses endured historical climate changes

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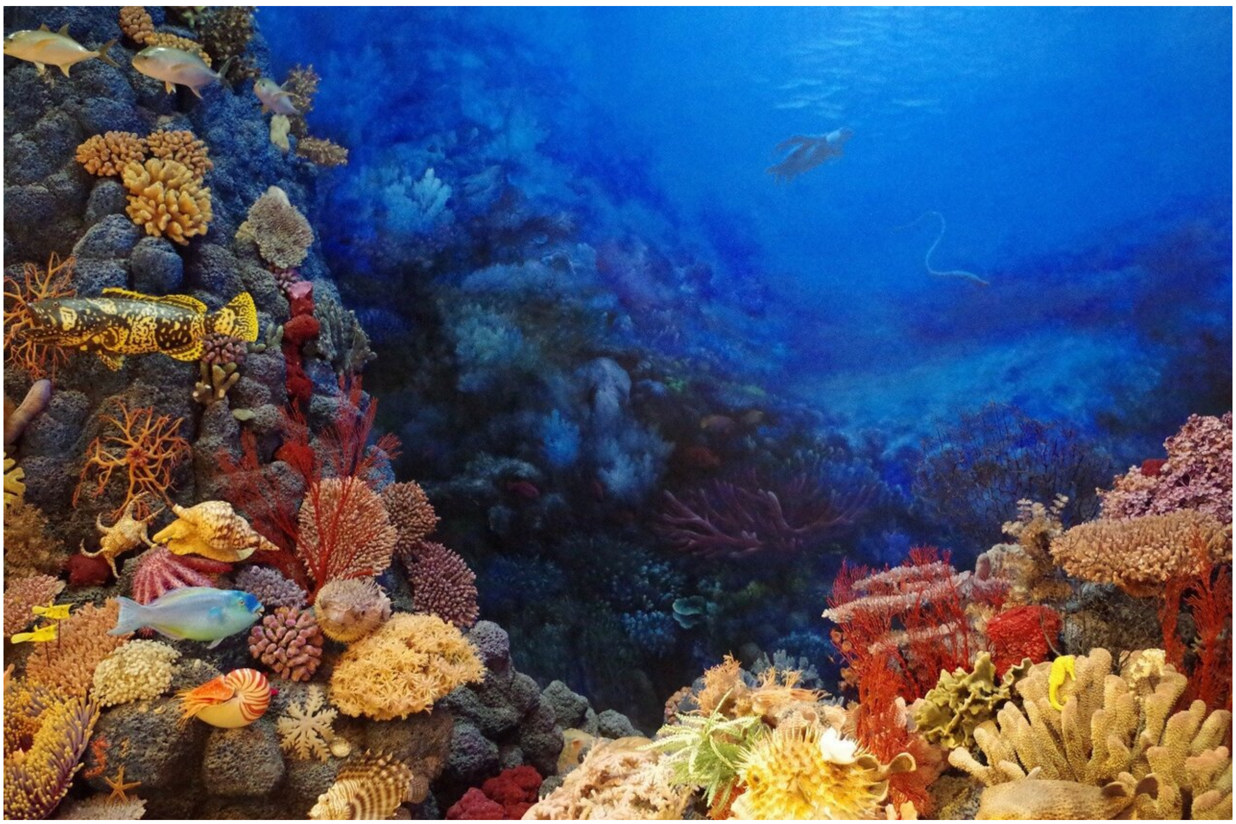

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One of the most important and widespread reef-building corals, known as cauliflower coral, exhibits strong partnerships with certain species of symbiotic algae, and these relationships have persisted through periods of intense climate fluctuations over the last 1.5 million years, according to a new study led by researchers at Penn State. The findings suggest that these corals and their symbiotic algae may have the capacity to adjust to modern-day increases in ocean warming, at least over the coming decades.

Cauliflower corals—which are in the genus Pocillopora—are branching corals that provide critical habitat for one-quarter of the world's fish and many kinds of invertebrates, such as lobsters, sea urchins and giant clams. They are common throughout the Indo-Pacific—the region extending from eastern Africa north to India and Southeast Asia, across Australia and encompassing Hawaii—and are capable of long-range dispersal and rapid growth, making them among the first species to repopulate reefs damaged by typhoons and events of mass coral bleaching and mortality.

"We found that Pocillopora has maintained a close relationship with certain species of algae in the genus Cladocopium over repeated oscillations in Earth's climate," said Todd LaJeunesse, professor of biology, Penn State. "Our findings reinforce how stable and resilient these relationships are over deep time."

LaJeunesse explained that corals comprise hundreds to hundreds of thousands of individual animals, called polyps. Tiny, single-celled algae, known as dinoflagellates, live inside these polyps' tissues, giving the corals their color and providing the animals with up to 90% of their energy needs through the products of photosynthesis. These dinoflagellates significantly influence the capacity of corals to deal with environmental stressors.

For two decades, LaJeunesse and his colleagues have been collecting coral samples from around the world, using molecular-genetic techniques to identify the coral and algal species, documenting the specificity of the partnerships (some species of algae are highly specific to certain species of coral, whereas others are generalists and can associate with many different types of coral) and determining how these partnerships have changed through evolutionary history.

"Important biological discoveries are more likely when working with accurate species resolution—in this case, for both coral and dinoflagellate," said LaJeunesse. "Research on the biology of photosynthetic corals has been hampered by a lack of good taxonomic resolution. Our work on resolving these species is highly detailed and currently among the most sophisticated."

The team used a combination of genetic, ecological and morphological—the outward appearance of an organism—techniques to examine Cladocopium that associate with Pocillopora. Specifically, they relied on a variety of genetic markers—or DNA sequences with known locations on chromosomes—to determine the genetic identities of the species. They also used a microscope to visualize and image the Cladocopium cells. The findings published on May 20 in the *ISME Journal*, the official journal of the International Society for Microbial Ecology.

"With this research, we now know that Cladocopium, the most common genus of coral symbionts, comprises hundreds of species," said Kira Turnham, graduate student in biology, Penn State. "We were able to identify and describe two species, which we named Cladocopium latusorum and Cladocopium pacificum, and with this resolution, were able to deduce the age of their partnerships and unique importance to specific host corals."

Next, the team investigated whether Cladocopium from geographically dispersed populations of Pocillopora were reproductively isolated or displayed connectivity. They found that populations of both species, like their Pocillopora hosts, are genetically well-connected across the tropical and sub-tropical Pacific Ocean, indicating a capacity for long-range dispersal.

For instance, Turnham said, "Cladocopium latusorum spans the Indian and Pacific Oceans—from the eastern shores of Tanzania to the Coral Triangle, Great Barrier Reef in Australia and Panama. This connectivity between populations in different locations may contribute to the resiliency of these species to endangerment or extinction threats."

To determine how old the partnerships are, the researchers used a "molecular clock"—an analysis that assesses DNA sequence divergence over time—to estimate when the two Cladocopium species diverged from their common ancestor. They found that the species arose during the late Pliocene to early Pleistocene epochs, at a time when their coral host was also forming new species.

"There has been considerable talk about corals' ability to shuffle their dinoflagellate species to improve their ability to withstand global warming," said LaJeunesse. "While some of this may be true, most corals have a very limited assortment of species with which they are able to associate. We have shown that with this limited number of compatible symbionts, Pocillopora have been able to deal with major changes in climate every 100,000 years for the past 1 to 2 million years."

Turnham noted that despite their persistence through time, the strict nature of the relationship between Pocillopora and Cladocopium may limit their ability to evolve in response to increased warming compared to corals that can associate with more thermally tolerant dinoflagellates.

"Ultimately," she said, "the broad geographic distributions and geological age of these and other coral-algal combinations must be considered in forecasting their response to ocean warming, and guide decisions when planning for their conservation."

More information: Kira E. Turnham et al, Mutualistic microalgae co-diversify with reef corals that acquire symbionts during egg development, *The ISME Journal* (2021). DOI: 10.1038/s41396-021-01007-8

Provided by Pennsylvania State University

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