NTU Singapore Study Finds Most Indo-Pacific Coral Reefs at Risk of Drowning from Rising Seas

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NTU EOS Research Fellow Dr Riovie Ramos (left) holding a reef core, which records the processes that built a reef over time, while Nanyang Assistant Professor Kyle Morgan (right) is holding a skeleton of an _Acropora_ sp. coral – one of the competitive corals that dominated much of the framework of Holocene reefs. (Image credit: NTU Singapore)

Nanyang Technological University, Singapore (NTU Singapore) scientists have found that most coral reefs across the Indo-Pacific may struggle to grow fast enough to keep pace with accelerating sea-level rise.

The study found that 76 percent of the reef sites surveyed do not have the capacity to keep pace with projected sea-level rise under a high greenhouse gas emissions scenario, threatening coastal protection and marine habitats.

The researchers also identified a critical threshold. When relative sea level rises by more than 5.3 millimeters a year, there is a greater than 90 percent chance that reefs will be unable to maintain their upward growth.

This threshold is likely to be surpassed within 35 years unless global greenhouse gas emissions are substantially reduced.

Published in *Nature Communications* this month, the study was led by NTU's Earth Observatory of Singapore (EOS) Research Fellow Dr. Riovie Ramos and Nanyang Assistant Professor Kyle Morgan, who is also the Associate Chair (Graduate Studies) at NTU's Asian School of the Environment (ASE).

A Race Reefs Have Run for Thousands of Years

For thousands of years, coral reefs have survived rising seas by building themselves upwards and outwards over time.

Corals and other organisms produce calcium carbonate, the hard material that forms the reef's structure. This allows reefs to remain close to the sea surface, where corals receive sunlight and the reef can break the force of waves approaching the coast.

But reefs can grow only so quickly. If sea level rises faster than a reef can build upwards, the reef will sit under progressively deeper water, a process scientists call reef drowning.

The living corals may not disappear immediately, but the reef can lose the shallow, complex structure that protects coastlines and provides habitats for fish and other marine life.

Asst. Prof. Morgan said: "Coral reefs have kept pace with rising seas for thousands of years, but the rate of sea-level rise expected in the coming decades could exceed the limits of most reefs."

"When that happens, reefs will become progressively submerged. They may still contain living corals, but they will no longer function in the same way, potentially allowing greater wave energy to reach the coastline and increasing risks to coastal communities," he explained.

Ancient Reefs Reveal the Limits of Growth

To determine how quickly entire reefs can grow over long periods, the NTU-led team compiled 288 ancient reef records from 92 sites across the Indo-Pacific.

The records span the Holocene, the geological period covering roughly the past 11,700 years.

Layers of hard, limestone-like material left behind by corals and other reef-forming organisms—known as skeletal carbonate—allowed the researchers to reconstruct how quickly reefs grew during earlier periods of sea-level change.

Unlike measurements of individual coral colonies, the records account for the growth of the entire reef framework. They include the effects of coral growth, erosion, breakage, dissolution, and the movement of reef material.

The analysis found that long-term reef growth is controlled by a combination of sea-level change, coral communities, and local physical conditions.

Lead author Dr. Riovie Ramos added: "An individual coral can grow relatively quickly, but that does not mean an entire reef will build upwards at the same rate.

"Reef cores can show us how much structure was preserved after accounting for growth, erosion and other natural processes, which then provides a more realistic measure of whether reefs can keep pace with future sea-level rise."

Changing Coral Communities Could Speed up Reef Drowning

The researchers found that the type of coral community present also affects how quickly reefs can build.

Ancient reefs were predominantly formed by competitive corals that produced substantial, structurally complex frameworks.

Many reefs today are increasingly dominated by smaller, disturbance-tolerant corals, described by scientists as “weedy” species.

These corals can recolonize damaged reefs but may not build reef structures as quickly or as extensively as the corals that dominated in the past. Such species would further hinder the ability of reefs to maintain their structural integrity against rapid submergence.

Repeated marine heatwaves, coral bleaching, ocean acidification, pollution, and other human pressures may further reduce the ability of reefs to produce and maintain their structures.

Drowning Reefs Leave Coastlines Exposed

Coral reefs form natural offshore barriers that reduce the energy of waves before they reach the coast.

As water above a reef becomes deeper, larger waves can cross it. This may increase coastal erosion and flooding risks for low-lying islands and tropical coastlines.

The loss of complex reef structures could also reduce the habitats available to fish and other marine organisms, affecting fisheries, tourism, and communities that depend on reefs for food and income.

The researchers said reducing local pressures, including pollution, overfishing, and physical damage, could help reefs maintain healthy coral communities and continue producing reef material.

However, local conservation and reef restoration cannot fully compensate if sea levels rise faster than reefs can grow.

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