Study: Living coral reefs provide better protection from tsunami waves

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Healthy coral reefs provide their adjacent coasts with substantially more protection from destructive tsunami waves than do unhealthy or dead reefs, a Princeton University study suggests.

Initially spurred by the tsunami that devastated the coastlines of the Indian Ocean two years ago, a team of scientists developed the first-ever computer model of a tsunami strike against a reef-bounded shoreline, using a volcanic island as an example. The model demonstrates that healthy reefs offer the coast at least twice as much protection as dead reefs. The finding provides the first quantitative confirmation of a widely held theory regarding the value of living coral reefs as a defense against tsunami waves, which are often generated by powerful undersea earthquakes.

Princeton professor Michael Oppenheimer said his team's work will give scientists the ability to quantify how much any given reef will benefit its particular stretch of coast.

"Healthy reefs have rougher surfaces, which provide friction that slows the waves substantially in comparison with smoother, unhealthy ones," said Oppenheimer, the Albert G. Milbank Professor of Geosciences and International Affairs. "Scientists had never before studied this effect by the numbers, nor had they ever analyzed it over a wide variety of coastal shapes. This study provides yet another motivating factor for protecting the planet's coral reefs from degradation."

The team's findings appear in the Dec. 14 edition of the journal, *Geophysical Research Letters*. In addition to Oppenheimer, other team members include Robert Hallberg, who is head of the Oceans and Climate Group at the National Oceanic and Atmospheric Administration's Geophysical Fluid Dynamics Lab, and Catherine Kunkel, who is the paper's lead author. Kunkel spearheaded the work during her senior undergraduate year at Princeton, from which she graduated with a physics degree in June.

Though anecdotal observations of reefs' effects on tsunami abounded after the 2004 Indian Ocean strike, Kunkel said, it was difficult to form any real conclusions because so many of these observations came after the fact. The goal of this study, which began as Kunkel's senior thesis project, was to provide a systematic framework by which to examine the assumption that healthy reefs protect shorelines more effectively.

"For our purposes, we assumed that the health of the reef would only be important in terms of the drag it exerted on the wave," said Kunkel, who is currently working as a research assistant at Tsinghua University in China. "If you have a healthy reef, it has lots of live coral branching out, sticking a lot of small obstacles into the water. A dead reef, on the other hand, is not as rough -- it tends to erode and exerts less drag on the wave."

A turbulent mountain of water crashing over a complicated rough surface presented Kunkel with a number of obstacles for her own study -- specifically, how to find a way to express each of these effects with a mathematical formula that a computer could employ to simulate it. Different complex parameters had to be considered one by one: the width and depth of the reef; the roughness of its surface; the size of the lagoon behind it; and the slope of the coast beyond. And the overarching element was the wave itself and its interaction with all these obstacles. Eventually, Kunkel found a set of equations that provided a limited but

comprehensive picture of a tsunami strike.

"We had to idealize a number of factors, because we wanted to create a model that could be used for a general shoreline," Kunkel said. "For example, we had to consider a perfectly even ocean floor, because uneven ones can funnel a wave into a certain area."

Despite the limitations of the model, Oppenheimer said it provides a sound basis for the team's conclusions.

"The general conclusion is that a healthy reef might provide twice as much protection as a dead one," he said. "This could translate into sparing large sections of inshore area from destruction."

Because coral reefs are dying from rising ocean temperatures, increasing ocean acidity, and direct human damage, Oppenheimer said the findings offer yet another reason to protect these fragile offshore ecosystems.

"This study shows yet another way that protecting the environment relates to humanity in a very tangible way," he said. "Villages get built behind coral reefs for good reasons, and this is one of them."

Kunkel said that she hoped the study would inspire other scientists to continue the research by obtaining more observational data. Incorporating such data into the team's theoretical model, she said, would then allow scientists to plan better for future tsunami strikes along local coastlines.

"We now have a basic idea of what variables are important, but if you want to quantify the effectiveness of a barrier reef around a particular island, you'd want to model that island directly," Kunkel said.

Source: Princeton University