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Mass extinction in oceans can be avoided by curbing fossil fuels

Near the end of the Permian Period, roughly 252 million years ago, a single supercontinent dominated the planet. The ocean around it was traversed by bony fish covered in armored plates and sea scorpions the size of modern humans. Segmented arthropods such as trilobites ruled the deep, along with all manner of brachiopods, which looked like clams but weren't, and ammonoids, which resembled shelled nautiluses but were more like squids and octopuses.

Today those creatures are known from the fossil record: At the end of the Permian, 90 percent of all marine life was wiped out by the largest extinction event in Earth's history. Scientists today suspect it was caused by massive releases of carbon dioxide, probably from volcanic activity in a region called the Siberian Traps. The most common cause of death, a team of researchers showed in 2018, was likely physiological stress from warming seas and oxygen loss, a byproduct of the climate change caused by greenhouse gases.

In a paper published in the journal Science, two of the scientists who made that 2018 discovery argue that, if our own greenhouse emissions continue unchecked, warming waters and oxygen loss at sea could by themselves lead to a mass extinction rivalling the planet's five worst catastrophes. They suggest it could be significant enough to erase much of the species diversification that has occurred since the end-Cretaceous extinction that killed the dinosaurs 65 million years ago.

But, the researchers contend, we can alter this trajectory. Curbing emissions rapidly could reduce extinction risks by 70 percent. Combining greenhouse gas reductions with concerted efforts to halt ocean pollution, overfishing, habitat destruction, and other marine stresses would give ocean life an even better chance of long-term survival.

"If we turn around our emissions quickly, we could still lose something like five percent of marine species," says co-author Curtis Deutsch, a climate scientist at Princeton University. "At two degrees [Celsius] of warming, you could see a 10 percent loss. There will be a change in the overall community of species that live in most places. But these are relatively small numbers. We'd be avoiding a mass extinction."

Denise Breitburg, an ocean oxygen expert at the Smithsonian Environmental Research Center, who did not participate in study, calls the findings "stark but important." She added that the work offers a "basis for hope" that "we can preserve much of the ocean's life."

"This paper crystalised the choices in front of us," said Malin Pinsky, an ocean scientist at Rutgers University in New Jersey, who co-authored an opinion piece that appeared alongside the study. "This feels like a once-in-humanity moment to preserve the future of life on the planet."

Low-oxygen water

The key to the new research by Deutsch and lead author Justin Penn, an associate research scholar at Princeton, is not just figuring out how warming temperatures impact oxygen in the seas—but also how marine life uses that oxygen.

In the past 15 years or so, new research has shown that natural low-oxygen zones in the ocean are expanding rapidly, but unevenly, pushing much of marine life to an ever-narrower band of oxygen-rich water near the surface. These deoxygenated regions, from the Bay of Bengal to a stretch of the Atlantic off West Africa to large regions

of the eastern Pacific, have grown by nearly 1.7 million square miles since the 1960s and are pushing upward by as much as three feet per year. Off southern California, 650 feet below the surface, oxygen has dropped by nearly a third in some places in the past quarter century. Areas of the sea completely devoid of oxygen have increased fourfold since the middle of the last century.

Unlike coastal dead zones, such as the one that regularly appears in the Gulf of Mexico, these low-oxygen zones are not a result of nutrient pollution running off the land. They're driven by rising temperatures. As surface waters warm, they absorb less dissolved oxygen from the air above. Because the warm water is lighter than the cold water below, that reduces ocean mixing, meaning less oxygen winds up in the deep.

That development is already scrambling marine life, reducing habitat for some species and concentrating prey for others. Billfish, such as marlin and sailfish, are shortening by hundreds of feet their dives for food. They, along with sharks, tunas, Pacific cod, herring, and mackerel, instead are spending more time bunched up near the surface, making it easier for fishing fleets—or birds and sea turtles—to catch them.

There are other shifts, some of them odd. Some crabs and squid struggle to see in low oxygen conditions. Many tiny zooplankton, food for larger creatures in the sea, already live at the very limits of their oxygen threshold and won't likely survive more decreases without moving to new places. Low oxygen is reducing reproduction for some fish and increasing diseases in others.

The most significant change involves respiration. The warmer it gets, the more oxygen creatures require to sustain their energy demands. But that's happening as the oxygen supply in the ocean is being reduced.

"It's really, really disturbing," said Matthew Long, an ocean scientist with the National Center for Atmospheric Research. "As global warming continues to progress, we're changing the basic metabolic state of the largest ecosystem on Earth."

Instructive scenario

Penn and Deutsch gathered metabolic data for dozens and dozens of ocean animal species, from shellfish to sharks, from all oceans, latitudes, and depths, to see just how much oxygen each needs to survive. They collected data on how temperatures are already changing and then used computer simulations to find out how the critical oxygen tolerance and minimum habitat each species required would likely change as temperatures continue to rise.

"There are lots of good reasons to think we're representing a global look and capturing a wide spectrum even though we're only looking at a relatively small number of species," Deutsch says.

Some species, such as tuna, clearly would move as their habitat was constrained, while less mobile species, such as corals, would not have that option. The fossil record also helped the duo recognise just how much habitat loss is necessary to extinguish a species or a local population. They calibrated the models and their projections against the ocean changes they'd reconstructed in 2018 for the end-Permian extinction event.

The researchers found that under the highest emissions scenario—one in which our emissions continue to soar, which many scientists say now appears unlikely—ocean warming and oxygen loss would wipe out more species by the end of the century than all other ocean stressors, such as overfishing and pollution, combined.

But the losses won't be evenly distributed. Tropical seas would lose the most species—but many of them would survive by moving to colder regions. Creatures found largely in higher latitude seas, like the highly productive North Pacific, where much of North America gets its fish, would be much more vulnerable.

"Tropical species are more likely to survive because as warm, hypoxic conditions become globally widespread, these species are already adapted to those types of environments," Penn said. "Cold, high O2 species have nowhere to go to seek refuge." That same pattern—greater extinction risk for polar species—was also detected in the fossil record of the end-Permian extinction.

The new study is "an impressive piece of work," said Karen Wishner, a biological oceanographer at the University of Rhode Island. The researchers "really get the big picture"—but, she adds, life in the ocean is complex and there's still a lot to learn about how animals may react to changing conditions. "Individual species do have their own ways of adapting," Wishner said.

The important takeaway, Deutsch said, is that these species losses are predictable. "The change is pretty linear," he said. For every half degree Celsius of temperature rise, species extinctions rise by a few percentage points.

In other words, even if we control emissions rapidly, some losses will be unavoidable—global temperatures have already increased about 1 degree Celsius. But if we limit temperature increase to what countries agreed to under the 2015 Paris accord, no more than two degrees Celsius, losses would likely stay below 10 percent.

Out of 2.2 million ocean species, that "is still a large absolute number," Penn said. "But it's an order of magnitude less than what it could be.

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