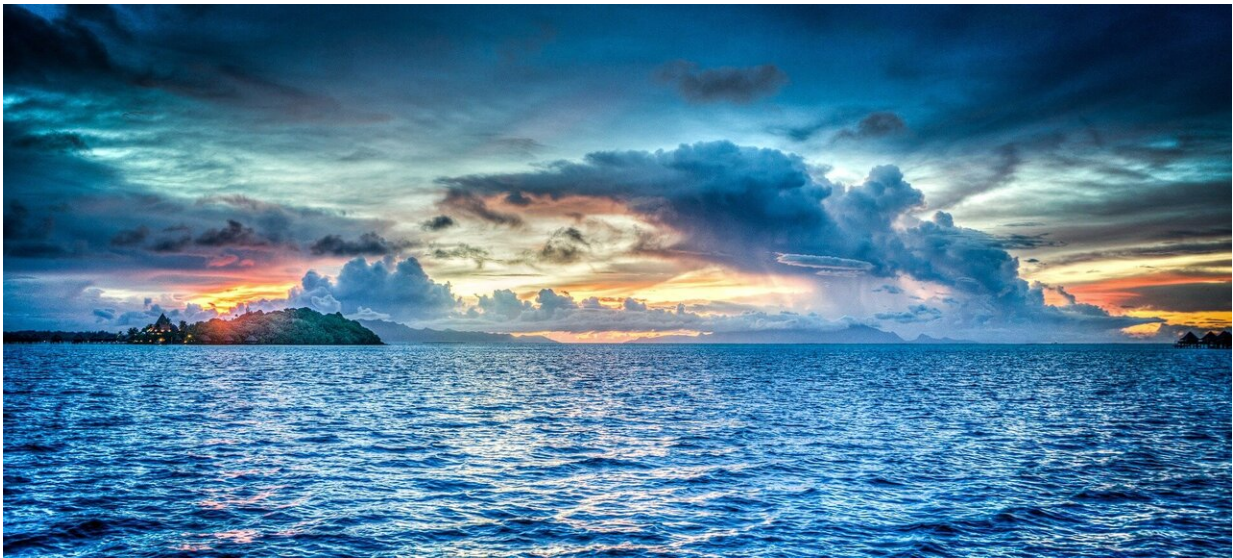


Natural nutrient enrichment 8 million years ago caused today's largest ocean 'dead zone'

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Oxygen-starved ocean "dead zones," where fish and animals cannot survive, have been expanding in the open ocean and coastal waters for several decades as a result of human agricultural and industrial activity. Trying to predict the scale and location of future dead zones, scientists have looked to the past for historical clues.

Today's largest [open ocean](#) dead zone, located in the eastern Pacific Ocean, emerged 8 million years ago as a result of increasing [nutrient](#)

[content](#) in the ocean, an international team of scientists reports today in the *Proceedings of the National Academy of Sciences*.

While the sources of nutrient enrichment today may be different, the mechanics that created what scientists call "oxygen-deficient zones" remain the same, according to Boston College Assistant Professor of Earth and Environmental Sciences Xingchen "Tony" Wang, a lead author of the report. Better understanding of ocean dead zones from the past may help future ocean conservation efforts.

"In order to better protect marine ecosystems and manage fisheries, it is critical to predict how an ocean 'dead zone' will evolve in the future," Wang said.

A coastal ocean dead zone is mainly caused by the flow of excess nutrients humans use on land, such as fertilizer application. In the Northern Gulf of Mexico, anthropogenic nutrients delivered by the Mississippi River annually produce a dead zone as big as the state of New Jersey.

These zones also occur naturally in the open ocean, with the largest found in the eastern Pacific Ocean. "It remains unclear how these dead zones will change as the planet warms. So, we studied the history of the eastern Pacific dead zone in order to better predict its future behavior," Wang said.

The researchers from universities in the U.S., Canada, Taiwan, Germany, and Australia set out to determine the evolution of open ocean dead zones before [human activity](#) began to impact the ocean, Wang said. In addition, did these dead zones always exist? If so, why?

The team examined the chemical composition of ocean sediments near today's largest ocean "dead zone," located in the eastern Pacific Ocean.

The team obtained sediment samples—the "history books" of ocean activity—going back 12 million years and analyzed nitrogen contained in [microfossils](#), known as foraminifera.

The team looked in the dead zones for signs of [denitrification](#), which occurs when [oxygen content](#) is so low that [microbes](#) instead use nitrate to power their biological activity. Nitrogen has two stable isotopes, nitrogen-14 and nitrogen-15, and microbes prefer to consume the lighter isotope of nitrogen-14 during denitrification.

When oxygen deficient zones expand, denitrification zones also expand, raising the nitrogen-15 to nitrogen-14 ratio of the remaining nitrate, which is then recorded in ocean organisms such as foraminifera through the cycling of nitrogen in the [marine ecosystems](#), according to the report.

"By analyzing the nitrogen-15 to nitrogen-14 ratio of [foraminifera](#) in ocean sediments, we can reconstruct the history of the extent of oxygen deficient zones," said Wang.

In addition, the researchers analyzed the phosphorus and [iron content](#) of the same sediments, which reveal the ancient nutrient content in the deep Pacific Ocean, according to the report.

"Deep-ocean nutrient content is hard to reconstruct and our record is the first of its kind over the past 12 million years; its trends have important implications for the global carbon cycle and [climate change](#)," said Woodward W. Fischer, a co-author of the study and professor at the California Institute of Technology.

The sedimentary records showed the team that the largest open ocean dead zones gradually expanded over the past 8 million years, said Wang, who was joined on the project by colleagues from the Max Planck Institute for Chemistry, Princeton University, National Taiwan

University, University of Toronto, Texas A&M University, University of Western Australia, and Caltech.

"Further, the expansion of these dead zones was mainly caused by nutrient enrichment," he said. "This mechanism is similar to the formation of dead zones in today's coastal waters, except that humans are responsible for the current nutrient enrichment."

These findings may help better predict the future behavior of open ocean [dead zones](#), according to the report. For example, human activities have been adding more and more nitrogen to the ocean. They can support the need to improve climate and ocean models to better gauge the impact of anthropogenic nitrogen on the deoxygenation processes in the open ocean.

The researchers were struck by data that showed much lower nutrient content in the ocean prior to 8 million years ago.

"The nutrient increase since 8 million years ago was likely caused by increased weathering and erosion on land, which would increase the delivery of phosphorus to the ocean," said Fischer.

"In addition, terrestrial ecosystems underwent a major transition between 8 and 6 million years ago," Wang said. "Many forests were replaced by less dense grassland, known as the expansion of C4 ecosystems. With more grassland, soil erosion might have increased during this period, and it would have triggered a greater transfer of organic nutrients to the ocean."

Wang said a likely next step in this research would be to determine how the flow of nitrogen into the ocean from human activity can impact the ocean's nutrient cycle.

"The key questions lie in our coastal zones, where the most anthropogenic nitrogen enters the ocean," Wang said. "If most of anthropogenic nitrogen is removed in coastal regions—essentially by denitrification taking place in the sediments—then that could lessen the impact on the whole ocean. Our research group at BC is currently doing some work in the Northern Gulf of Mexico to better understand the fate of anthropogenic [nitrogen](#) in the [ocean](#)."

More information: Xingchen Tony Wang, Oceanic nutrient rise and the late Miocene inception of Pacific oxygen-deficient zones, *Proceedings of the National Academy of Sciences* (2022). [DOI: 10.1073/pnas.2204986119](#). doi.org/10.1073/pnas.2204986119

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