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Global warming blamed for Earth's largest mass extinction

by **Justin Penn**[1] | Phd student

[1]: University of Washington, School of Oceanography, Seattle, USA

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ABSTRACT

The cause of the largest mass extinction in Earth history – termed "the Great Dying" – has long remained elusive. Our research demonstrates a causal link between global warming, ocean oxygen loss and extinction, with dramatic implications for marine life under future climate change.

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The industrial burning of fossil fuels is adding greenhouse gases to the atmosphere, trapping heat near the planet's surface and warming the oceans. A major effect of warming is to reduce the amount of dissolved oxygen (O_2) found in the sea. This effect arises for two main reasons. First, warmer water holds less gas from the atmosphere. Second, warming slows the physical mixing of O_2 rich waters from the surface ocean to the abyss.

Ocean temperature also affects the amount of O_2 required by marine life. When the environment warms, rates of organismal metabolism go up. Because the amount of O_2 required by an animal depends on its metabolic rate, warmer waters mean organisms require more O_2, even as the environment is less able to provide it. If the biological O_2 demand exceeds its environmental supply, the oceans could no longer support water-breathing species.

Roughly 252 million years ago, at the end of the Permian period, such conditions became widespread. The Earth experienced the worst mass extinction in its history, removing over 90% of species from the ocean, in what's been called "the Great Dying". During this period, massive volcanic eruptions emitted greenhouse gases to the atmosphere, warming the tropics by 10ºC and causing dramatic O_2 loss from the ocean. Additional impacts from the eruptions would have included the acidification of seawater, changes in ocean fertility, heavy metal poisoning as well as the microbial production of toxic gases. Together this soup of factors has been implicated in "the Great Dying." However, tracking down which one of these potential killers was the immediate cause of the extinction has proven difficult.

To understand the role of ocean warming and O_2 loss in the end-Permian marine mass extinction, our team simulated the climate transition at the Permian/Triassic boundary in a state-of-the-art computer model of the climate system by injecting the virtual atmosphere with greenhouse gases to mimic the long-term effect of volcanism. The resulting rise in simulated ocean temperatures and loss of O_2 agree with measures of these variables recorded in the chemical composition of Permian/Triassic-aged rocks, indicating that the modeled environmental changes are realistic.

The impact of warming and O_2 loss on marine life also depends on biological traits: the sensitivities of marine animals to temperature and O_2. We estimated these biological traits using published laboratory measurements from living species. By combining the measured traits with the climate simulations, we determined changes in the ocean's O_2 supply to biological demand during the climate transition. We found that before warming, the ocean had enough O_2 to meet the biological demand of diverse species. However, because warming speeds up metabolic rates while depleting the O_2 supply, large regions of the ocean would have become uninhabitable after the climate change. Habitat loss would have hit some species harder than others, leaving a unique fingerprint on the biogeography of extinction risk: extinctions are predicted to have been more common for higher latitude species than for those in the tropics. This gradient of extinction risk arises because species living in the tropics were better adapted to high temperature, low O_2 conditions before the extinction compared to those living in cold, O_2-rich polar waters.

To test the predicted fingerprint of climate change-driven extinction, we analyzed the marine fossil record. We found that extinction in the end-Permian fossil record was indeed more common for animals living at higher latitudes, consistent with the model predictions. This correspondence in the biogeography of extinction between the model and fossils implies that ocean warming and oxygen loss were major causes of "the Great Dying".

The end-Permian marine extinction holds important lessons for the future of life in the oceans because its drivers – rising temperatures and declining O_2 - are also direct consequences of industrial fossil fuel emissions. Decreases in seawater O_2 along with warming have already been detected in the modern oceans. If future emissions are left unchecked, by 2300 C.E., the amount of warming is predicted to approach a third to half of that during "the Great Dying." Because the physiological need to breathe O_2 is fundamental to all animal life, this raises the possibility of future extinctions arising from a similar cause as in the ancient past.