Loss of oxygen in bodies of water identified as new tipping point

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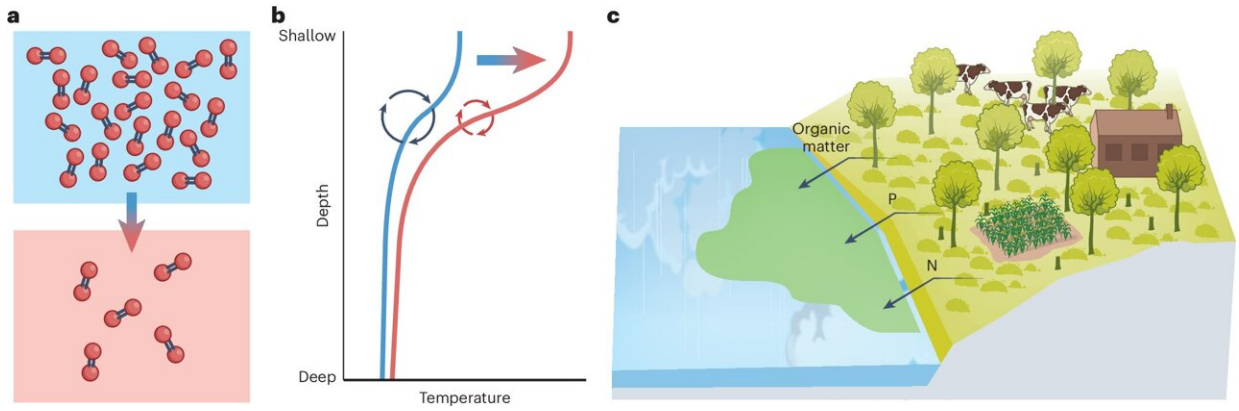

a–c, Many regions have exhibited substantial deoxygenation due to factors including reduced DO solubility at higher temperatures (a); increases in density difference between layers in the water column, which reduces the ventilation of deep-water habitats (the blue line is the conceptual historic profile of temperature through the water column, and the red line is an example contemporary profile; the circular arrows indicate the relative strength of mixing between depths in the water column in these two profiles) (b); and increases in organic matter and nutrient (phosphorous (P) and nitrogen (N)) fluxes that stimulate algal growth, bacterial respiration and overall greater DO consumption (c). Credit: *Nature Ecology & Evolution* (2024). DOI: 10.1038/s41559-024-02448-y

Oxygen concentrations in our planet's waters are decreasing rapidly and dramatically—from ponds to the ocean. The progressive loss of oxygen

threatens not only ecosystems, but also the livelihoods of large sectors of society and the entire planet, according to the authors of an international study involving GEOMAR published today in *Nature Ecology & Evolution*.

They call for the loss of oxygen in water bodies to be recognized as another planetary boundary in order to focus global monitoring, research and political measures.

Oxygen is a fundamental requirement of life on planet Earth. The loss of oxygen in water, also referred to as aquatic deoxygenation, is a threat to life at all levels. The international team of researchers describes how ongoing deoxygenation presents a major threat to the livelihoods of large parts of society and for the stability of life on our planet.

Previous research has identified a suite of global scale processes, referred to as planetary boundaries, that regulate the overall habitability and stability of the planet. If critical thresholds in these processes are passed, the risk of large-scale, abrupt or irreversible environmental changes ("tipping points") increases and the resilience of our planet, its stability, is jeopardized.

Among the nine planetary boundaries are climate change, land use change, and biodiversity loss. The authors of the new study argue that aquatic deoxygenation both responds to, and regulates, other planetary boundary processes.

"It's important that aquatic deoxygenation be added to the list of planetary boundaries," said Professor Dr. Rose from the Rensselaer Polytechnic Institute in Troy, New York, lead author of the publication. "This will help support and focus global monitoring, research, and policy efforts to help our aquatic ecosystems and, in turn, society at large."

Across all aquatic ecosystems, from streams and rivers, lakes, reservoirs, and ponds to estuaries, coasts, and the open ocean, dissolved oxygen concentrations have rapidly and substantially declined in recent decades.

Lakes and reservoirs have experienced oxygen losses of 5.5% and 18.6% respectively since 1980. The ocean has experienced oxygen losses of around 2% since 1960. Although this number sounds small, due to the large ocean volume it represents an extensive mass of oxygen lost.

Marine ecosystems have also experienced substantial variability in oxygen depletion. For example, the midwaters off of Central California have lost 40% of their oxygen in the last few decades. The volumes of aquatic ecosystems affected by oxygen depletion have increased dramatically across all types.

"The causes of aquatic oxygen loss are global warming due to greenhouse gas emissions and the input of nutrients as a result of land use," says co-author Dr. Andreas Oschlies, Professor of Marine Biogeochemical Modelling at GEOMAR Helmholtz Centre for Ocean Research Kiel.

"If water temperatures rise, the solubility of oxygen in the water decreases. In addition, global warming enhances stratification of the water column, because warmer, low-salinity water with a lower density lies on top of the colder, saltier deep water below.

"This hinders the exchange of the oxygen-poor deep layers with the oxygen-rich surface water. In addition, nutrient inputs from land support algal blooms, which lead to more oxygen being consumed as more organic material sinks and is decomposed by microbes at depth."

Areas in the sea where there is so little oxygen that fish, mussels or crustaceans can no longer survive threaten not only the organisms

themselves, but also ecosystem services such as fisheries, aquaculture, tourism and cultural practices.

Microbiotic processes in oxygen-depleted regions also increasingly produce potent greenhouse gases such as nitrous oxide and methane, which can lead to a further increase in global warming and thus a major cause of oxygen depletion.

The authors warn: We are approaching critical thresholds of aquatic deoxygenation that will ultimately affect several other planetary boundaries.

Professor Dr. Rose states, "Dissolved oxygen regulates the role of marine and freshwater in modulating Earth's climate. Improving oxygen concentrations depends on addressing the root causes, including climate warming and runoff from developed landscapes.

"Failure to address aquatic deoxygenation will, ultimately, not only affect ecosystems but also economic activity, and society at a global level."

Aquatic deoxygenation trends represent a clear warning and call to action that should inspire changes to slow or even mitigate this planetary boundary.

More information: Kevin C. Rose et al, Aquatic deoxygenation as a planetary boundary and key regulator of Earth system stability, *Nature Ecology & Evolution* (2024). DOI: 10.1038/s41559-024-02448-y

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