November 2019

OCEAN DEOXYGENATION

Oxygen (O_2) is vital to life in the ocean, and as the sea temperature rises oxygen becomes less soluble, via a process known as deoxygenation (Gao et al., 2019). Alongside the related threats of ocean heating and acidification, this is one of the most alarming climate change impacts on the ocean.

Low oxygen waters are described as hypoxic. Hypoxic water has oxygen concentrations below 2mg per litre – a level so low that it is detrimental to most organisms and very few species can survive. Hypoxia is sometimes described as the ocean running out of breath. It occurs when the oxygen in water is used up at a faster rate than it is replenished.

CAUSES

Reduced oxygen levels in coastal areas has long been associated with the runoff of nutrients from fertilisers and sewage, from land to sea. However, this threat is being exacerbated by ocean heating and is now affecting the open ocean.

Nutrient run-off

The level of dissolved oxygen in coastal marine systems has been declining since the middle of the 20th century because of intensive agricultural practices, land use changes and ocean heating. Since 1950, more than 500 coastal sites have reported oxygen concentrations below 2mg per litre – but just 10% of them had reported hypoxia before 1950 (Breitburg et al., 2018).

Nutrient enrichment, or eutrophication, is the primary driver behind increased coastal hypoxia. This is caused by nutrients (mainly nitrogen and phosphorous) and biomass from agriculture, aquaculture, human waste and fossil fuel combustion stimulating algae growth.

Many of the worst affected coastal zones are those receiving discharge from major rivers in heavily populated or intensive agriculture areas, including the Baltic and Black seas, Bay of Bengal, South China Sea and the Gulf of Mexico. The combination of increased warming of shallow coastal waters and eutrophication means that the rate of oxygen loss in these coastal systems is faster than in the open ocean.

This type of deoxygenation is known to be reversible by better management of nutrients and reducing the flow into the sea.

Ocean heating

In the open ocean, global heating driven by emissions of greenhouse gases is the prime cause of deoxygenation. Rising sea temperatures reduce the supply of oxygen in the ocean because oxygen is less soluble in warmer water. Higher temperatures lead to more stratification (the layering of water of different salinity and density) because the higher oxygen surface water does not mix well with deeper waters with less oxygen.

Between 1970 and 2010 the open ocean lost 0.5 to 3.3% of oxygen overall from the ocean surface to 1000 m and oxygen minimum zones increased by 3-8% (IPCC, 2019).

Climate driven deoxygenation is occurring over vastly larger areas of the ocean than nutrient run-off and will be difficult if not impossible on reasonable timescales to reduce. The reduction strategy has to be to reduce carbon dioxide emissions as well as other compensatory measures such as protecting and recovering carbon sinks like forests, soils and coastal ecosystems.

IMPACTS

Oxygen is critical to a healthy ocean and marine life of all kinds, from the coast to the deep sea, from shrimps to sharks. In some cases, animals can move away from low oxygen waters, but often they are trapped. Some species, such as coral and shellfish, are unable to escape resulting in large-scale organism death and 'dead zones' (NOAA, n.d.). As a recent study warned, major extinction events in Earth's history have been associated with warm climates and oxygen-deficient oceans (Breitburg et al., 2018).

Impacts of deoxygenation on the ocean include:

- reduced growth and reproduction, altered behaviour, and increased disease and mortality in marine animals
- reduced quality and quantity of habitat for economically and ecologically important species
- changes to the structure of marine food webs
- increased mortality of corals and associated fauna
- amplification of ocean acidification because increased respiration by marine organisms increases CO_2
- contribution to global heating (due to the microbes that proliferate at very low oxygen levels producing more nitrous oxide – a powerful greenhouse gas).

If left unchecked, oxygen decline will result in significant loss of biodiversity, impact fisheries and the communities dependent on them and cause knock-on effects such as falling tourism and reduced marine ecosystem services. The north Atlantic, north Pacific and Antarctic are expected to be worst affected.

The latest IPCC report states that by 2100 it is very likely that the total oxygen content of the ocean will have declined by 3.2-3.7% relative to 2000, if greenhouse gas emissions continue to rise (RCP8.5). Under the low emissions scenario in which greenhouse gas emissions are significantly reduced (RCP2.6) the total oxygen content of the ocean will rise by 1.6-2% (IPCC, 2019).

Further research, observation and community engagement are needed to understand the causes and extent of hypoxia in order to develop effective adaption and mitigation strategies.

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