Ecological engineering is a breath of life for marine ecosystems

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Harmful algal blooms can develop and lower the oxygen content of the oceans
Credit: Askewmind

Oxygen is essential for many life forms. But we don't often give it the attention it deserves because we assume that it is always there. While oxygen is ubiquitous in our atmosphere, it is not necessarily the case for many bodies of water like rivers, lakes or even oceans. Here a lack of oxygen can result in significant impacts on the ecosystem like the killing of fish that subsequently float to the surface. But artificially oxygenating water can breathe new life, as we found recently while working with a fjord in Sweden.

Lack of oxygen and the death of wildlife is a phenomenon that can be observed not only in lakes but also in marine environments – which might seem surprising given the mixing of water by ocean currents. Oceans generally contain oxygen – we call them "oxic" – but we easily forget that this has not always been the case.

If we look back in Earth's history the original oceans were without oxygen (anoxic) and had a significantly different water chemistry than today. With the advent of photosynthetic bacteria, the oceans became oxygenated over time. Initially the oxygen concentrations were fairly low (hypoxic) compared to present-day levels, but over time oxygen increased in the water and the atmosphere. This meant that hypoxic and anoxic areas were more and more on the retreat.

Nowadays, areas with hypoxic and anoxic waters are re-appearing all around the globe, from the eastern Pacific (several places on the west coast of Canada, the US, Central America, Chile, and Peru), to the Bay of Bengal (India), the Arabian Sea, the Black Sea, the Baltic and the Namibian shelf.

How do oxygen-deprived waters develop?

Different mechanisms drive the development of hypoxic and anoxic waters in different regions and will result in different water chemistries. In areas with upwelling of cold water to the surface (for example off the coasts of Peru and Chile), nutrient-rich deep water is transported to the surface. This causes blooms of photosynthetic bacteria and algae to form. The increased organic carbon in the water serves as a nutrient source for other microbes, and they in turn lower the oxygen concentration by respiration, creating hypoxic water.

Deployment of scientific equipment to determine the water quality in the Byfjord.

In contrast, places like the Baltic have large and deep basins that have a naturally low frequency of water exchange (for example with the North Sea) and therefore receive little input of oxygen-rich water from outside. This often results in hypoxic conditions in these basins. In addition, non-treated waste-water, nutrient runoff from farmland and the dumping of organic waste increase the nutrient loading of Baltic waters. This results in blooms of photosynthetic bacteria and algae and, subsequently, the increased abundance of other bacteria which eat them. Their respiration draws down the oxygen concentration to a point where no oxygen is left.

Obviously, really low levels of oxygen (or its total absence) will be harmful to fish and many other life forms. Additionally, microbial processes that don't require oxygen take over in waters where there isn't any, creating further problems such as massive decreases in available nitrogen. When huge blooms of toxic cyanobacteria form, it is more likely that toxins will come into contact with humans.

Increasing surface temperatures in the oceans as a result of climate change will further decrease the oxygen content in surface waters, leading to the expansion of already known low to nil oxygen marine waters, and the formation of new ones. This is more than an ecological problem: the economy also suffers due to detrimental effects on fisheries, tourism and water quality.

Are there solutions? Yes and no. In some regions there is no obvious way to address the challenge. In others, such as the Baltic, remediation is possible and several ways to solve the problem have been suggested. Reducing the input of nutrients into the Baltic, for example, would treat the cause of the problem, and initiatives to improve waste-water treatment have been introduced.

Oxygenating the water

But we can also treat the symptom itself. One idea is to oxygenate the water by increasing the frequency of naturally occurring inflows of oxygen-rich water from the North Sea with the help of wind-driven pumps in an ecological engineering project.

Our Swedish colleagues tested this idea in a large-scale experiment in the Swedish Byford. Electrically-driven pumps were installed and the water column was mixed by pumping surface water to outlets in the basin that lacked oxygen. While the capacity of the pump was not high enough to introduce sufficient oxygen to completely oxygenate the basin, the disturbance of the water column triggered inflows of oxygen-rich water from a neighbouring oxygen-rich fjord. This resulted in a significant increase in oxygen throughout the water column, including the anoxic basin. Throughout this process we monitored the response of the bacterial community in the fjord using molecular methods.

Testing the waters

Our recent work shows that oxygen-requiring bacteria, initially only present in surface waters, could also be found in the deep basin after oxygenation. They replaced the community of anaerobic bacteria observed there previously, showing that oxygen had reached the depths of the fjord and was supporting life. Overall it became clear that the change of the bacterial community was similar to what could have been expected in a natural oxygenation event, such as the mixing of waters.

Could ecological engineering to oxygenate anoxic marine zones be the solution for the future? Maybe. Reducing human inputs of nutrients into these zones is important, and these programmes should be continued as they address the root of the problem. However, ecological engineering is another option to oxygenate certain marine zones. This will especially help in systems where large amounts of nutrients are stored in the sediments; these would take a long time to be restored naturally even if all further nutrient input were stopped immediately.

But especially for the Baltic, the question is not only whether an oxygenation project is technically feasible or ecologically meaningful, but also whether it is economically viable and whether there is the political will to commit to a long-term project such as this.

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