COMMENT

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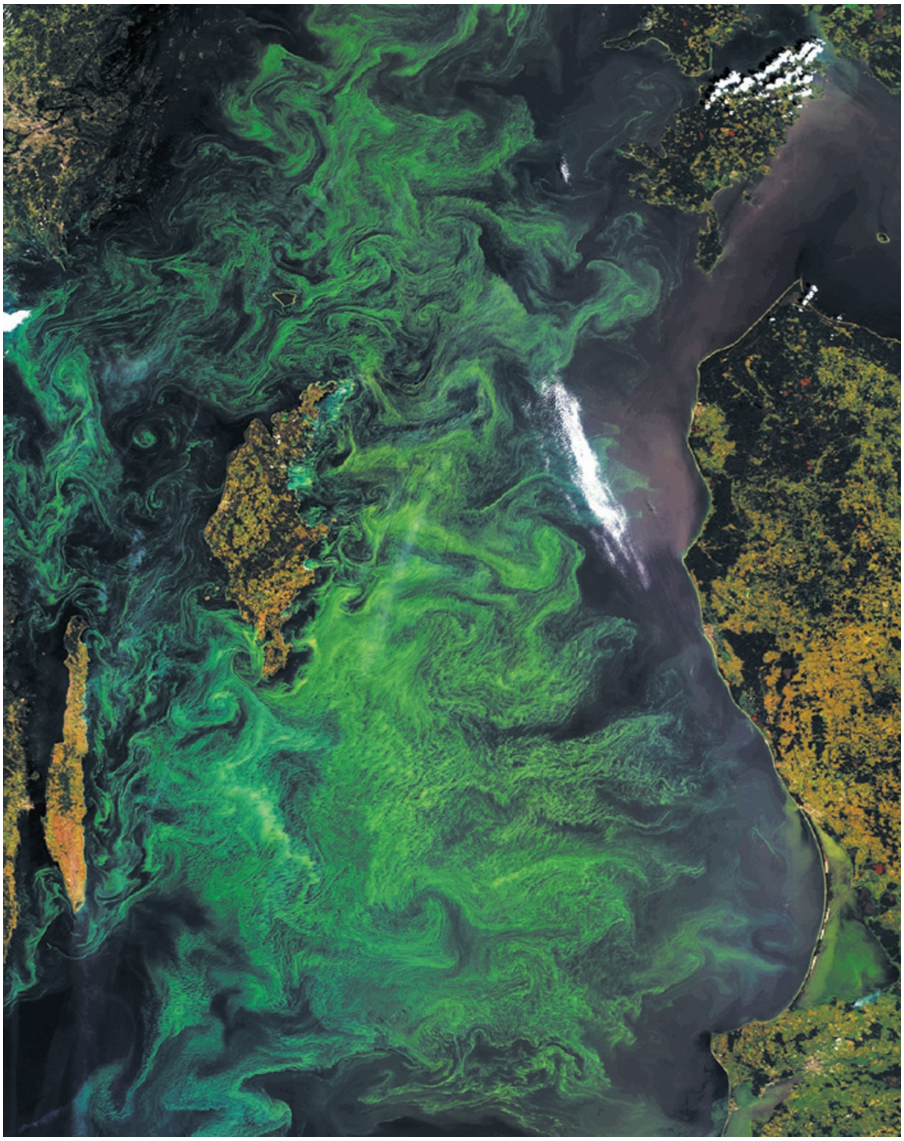


Cyanobacteria cover the Baltic Sea in green slime, spurred by flows of nitrogen and phosphorous.

Save the Baltic Sea

Geoengineering efforts to bring oxygen into the deep Baltic should be abandoned, says **Daniel J. Conley**.

The Baltic Sea holds the world's largest human-induced dead zone: a body of water that has all the symptoms of nutrient overload and oxygen deprivation. Dumping from sewage-treatment plants, farming and industry has poured about 20 million tonnes of nitrogen and 2 million tonnes of phosphorus into the Baltic over the past 50 years[1], spurring algal blooms.

In summer, cyanobacteria cover the beaches in green slime. As these blooms die, they fall to the sea floor and decay, using up available oxygen in the process. The oxygen-deprived bottom waters can no longer support higher forms of life, and the viable habitat for fish such as cod is greatly reduced. Over the past decade, an average of 60,000 square kilometres of the Baltic Sea has been 'hypoxic' each year: lacking enough oxygen to support its normal ecosystem.

Several large-scale geoengineering interventions have been proposed as solutions to this problem. Such radical remediation measures promise impressive improvements in water quality on short timescales. They are popular in the media and politically attractive. But they could also be dangerous. We should not let such schemes detract from the action plan that is already in place to reduce nutrient flows into the Baltic. Models predict that this plan will greatly reduce hypoxia (see 'Breathing life into the Baltic').

STIFLED SEAS

The problem of hypoxic waters is on the rise around the globe. Climate warming is likely to exacerbate matters — warmer temperatures speed up algal decomposition and reduce the rate at which oxygen from the air seeps into ocean surface waters[2]. Low oxygen levels kill sea-floor organisms and change how elements cycle through the system. In hypoxic conditions, the phosphorus-bearing iron oxyhydroxides in sediments dissolve, increasing the release of phosphate into the water. At the same time, low oxygen inhibits denitrifying bacteria in the sediments, boosting nitrogen levels. The net effect is an excess of phosphorous, which fuels nitrogen-fixing cyanobacteria and algal blooms. These decay and lead to ever more hypoxia — a vicious circle.

One potential countermeasure entails using pumps to mix the water[3]. This comes with significant challenges. About ▶

100 pumping stations would be needed throughout the Baltic to transport oxygen-rich water from a depth of about 50 metres to a depth of 125 m, and the pumps must remain operational for several decades. This is projected to cost at least €200 million (US$254 million).

The problem lies in the volumes involved. It has been estimated[4] that between 2 million and 6 million tonnes of oxygen would be required to keep the bottom waters of the Baltic Sea at a level above 2 milligrams of oxygen per litre — the limit for hypoxia. Theoretically, renewable energy sources such as wind power could be used to drive the required pumps at sea[3]. But pumping would also move less-salty water from the surface to deeper regions, potentially interfering with natural patterns of water circulation and the reproductive success of some fish species.

WARMED WATERS

In 2009, the Swedish government spent 30 million Swedish kronor (US$3.8 million) investigating this pumping option. Recent reports from those pilot studies show that the experiments were able to add oxygen (see go.nature.com/gqx2kq). However, some of the effect was counterbalanced by increases in water temperature, which can lower oxygen levels by spurring the metabolism of microbes in sediment. Bottom waters warmed as much as 8 °C at a test site in the coastal waters of Finland, for example. The raised temperatures also increased levels of ammonium, which can stimulate the growth of harmful algae.

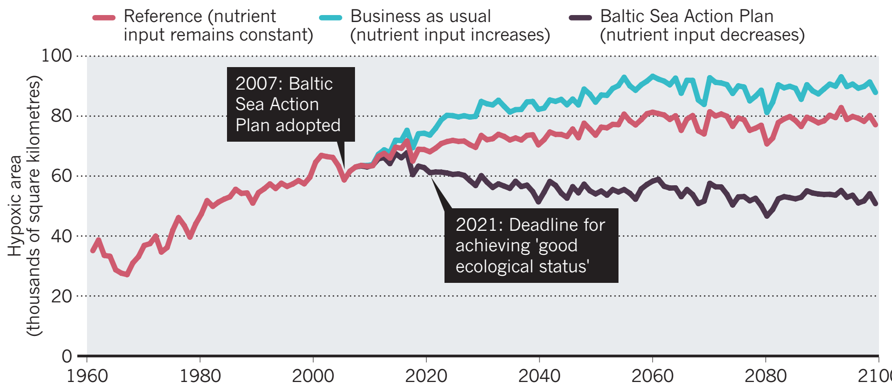
In western Sweden, the pumping disturbed the layers of varying salinity in a deep fjord, altering water turnover and circulation patterns (see go.nature.com/gqx2kq). So far, these projects have been evaluated mostly by proponents of geoengineering. They must be subjected to unbiased, thorough scrutiny.

A second geoengineering approach, currently being trialled on a local scale in Swedish coastal waters, is the addition of chemicals to bind phosphorus in sediments. Tests are being carried out in the Stockholm archipelago using polyaluminium chloride[5], which is used in the treatment of waste water and drinking water. A small-scale field test was successfully conducted in 2011 for a few months, and the research group has received a permit from the regional government for a larger experiment.

Most tests of this technique have been confined to small lakes because of the cost of the chemicals. It is hard to know whether it will work in salty environments, how long the aluminium-bound phosphorus will stay buried in sediments, or what the effects might be on water acidity. Large-scale implementation in the Baltic Sea would have to abide by the 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (the London Convention). This legal framework prevents the use of iron to sequester carbon dioxide in the oceans.

BREATHING LIFE INTO THE BALTIC

Models predict that the action plan to reduce nutrients that flow into the Baltic Sea should be effective at increasing oxygen levels in the water.



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Rapid oxygenation of deep waters by any mechanism carries the risk of releasing a different toxic problem on the Baltic. Waters that are rich in oxygen can attract and support some species, such as deep-digging worms, that physically mix the sediment. This, in turn, can release old contaminants, such as polychlorinated biphenyl and DDT (dichlorodiphenyltrichloroethane), that are currently locked away under the Baltic. Thorough risk analyses of these issues have not been completed.

Yet geoengineering schemes are moving forwards. For example, the Oslo-based company Inocean announced plans to build a demonstration wind-driven pump in the southern Baltic Sea. This project, led by oceanographer Anders Stigebrandt of the University of Gothenburg in Sweden, received 2 million Swedish kronor ($288,000) in funding from the Swedish Agency for Marine and Water Management in Gothenburg this May, with co-funding from the Nordic Investment Bank and the Nordic Environment Finance Corporation, both headquartered in Helsinki. Stigebrandt stresses that full environmental impact studies will be carried out before the project begins.

A better, more cost-effective solution is to attack the root of the problem: excess nutrients. The nine countries that border the Baltic Sea have worked hard to reduce nutrient flows through the Baltic Marine Environmental Protection Commission in Helsinki — also known as the Helsinki Commission — and, since 2008, through the European Union's Marine Strategy Framework Directive. Flows of both nitrogen and phosphorus into the Baltic have fallen since their peaks in the 1980s, mostly because of improved treatment of municipal waste water and reduced discharges from industry.

Phosphorus inputs have dropped by about 30,000 tonnes per year (a 40% reduction from peak loads), and nitrogen by about 400,000 tonnes per year (a 30% reduction). The ambitious Baltic Sea Action Plan (BSAP), signed in 2007 by nations surrounding the Baltic, agrees to cut phosphorus and nitrogen inputs further, by about 42% and 18% from present levels, respectively, by 2016. The goal is to achieve "good ecological status" for the marine environment by 2021.

Such action is needed to improve water quality and ecosystem health. Despite current efforts, measurements of water quality have so far shown only small improvements, and the area of hypoxia continues to increase. Models predict that, with time, the BSAP should be able to reduce the hypoxic area — as long as nutrients continue to be reduced as planned. It is vital that this happens.

The Baltic Sea is on the path to a healthier state. It would be a shame if high-profile geoengineering projects were to divert funds or attention from the BSAP. Yet that could happen. The Swedish marine agency has said that its funding for the pilot mixing project in the southern Baltic should help Sweden to meet its BSAP requirements. Creative thinking and technology are a vital part of the mix. But they should be directed at reducing land-based sources of nutrients into the Baltic Sea, not at expensive and potentially harmful schemes to engineer a solution. ■

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