SCIENCE FOR ENVIRONMENT POLICY

Assessing eutrophication by mapping phosphorus circulation in the Baltic Sea

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As estuaries are particularly sensitive to anthropogenic influence, assessing their ecological status is both challenging and especially important. Eutrophication is a key issue for such areas, with phosphorus (P) being a major driver of eutrophication in aquatic systems. This study explores the spatial and seasonal circulation of various forms of phosphorus in Germany's Warnow Estuary, which flows into the Baltic Sea, to assess the levels of eutrophication in the estuary and Baltic coastal waters.

The EU has adopted several directives and initiatives, and implemented numerous measures, to protect its aquatic ecosystems. In 2000, the European Water Framework Directive highlighted that many such ecosystems in Europe — lakes, rivers, and coastal and transitional waters — were significantly polluted by urban waste water and agricultural activity, and set objectives to protect them and enhance their status. In 2008, the Marine Strategy Framework Directive called for a better understanding of how human activities impact and put pressure on our seas (alongside myriad other ambitious goals, such as increased protection of marine biodiversity, new research and legal initiatives; and the formation of an effective strategy for the entire marine environment, considering numerous ecosystem components, anthropogenic pressures and impacts)[1].

Additionally, the EU Biodiversity Strategy for 2030 (adopted in May 2020) seeks to step up the protection and restoration of Europe's ecosystems, and aims to protect 30% of Europe's land and seas by 2030, while comprehensively addressing pressures such as nitrogen and phosphorus pollution. Together, these and other initiatives aim to protect Europe's aquatic ecosystems and restore them to 'good' environmental status by the deadlines set in the directives.

The Baltic Sea is one such ecosystem. While sewage plants have reduced the nutrients they release into this sea in recent years, 97% of the Baltic Sea still exhibits high levels of eutrophication — an excessive richness of nutrients that can cause algal blooms, oxygen depletion and ecosystem degradation. Nutrients, especially nitrogen and phosphorus, predominantly originate from agricultural sources, where nutrient-rich fertilisers drain from fields and animal wastes. For the Baltic Sea, around 95% of the total phosphorus discharge into the sea originates from rivers, and approximately 36% of this originates from agriculture-related sources.

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Assessing eutrophication by mapping phosphorus circulation in the Baltic Sea (continued)

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This study[2] explores the Warnow River in north-eastern Germany, which discharges into the Baltic Sea and has a catchment dominated by agricultural land use. The researchers state that traditionally measured nutrient parameters — total phosphorus (TP) and dissolved molybdate-reactive P (DRP) — are not adequate for environmental monitoring of estuarine nutrient loads; and so the study also determines dissolved non-molybdate-reactive P (DNP), particulate molybdate-reactive P (PRP) and particulate non-molybdate-reactive P (PNP) in addition to TP and DRP[3]. The study adopted an extended monitoring programme from September 2016 to August 2018, allowing the researchers to monitor how these forms of P changed with time, season, space and depth (water column and sediment).

Within the estuary, the concentrations of P forms varied on both spatial and seasonal scales. During estuarine transport, various forms of P — DRP, DNP, PRP, PNP — circulated, but towards the Baltic Sea; upper water layers were characterised by PNP, and deeper waters by DRP. The researchers also saw seasonal variation linked to phosphorus availability, which is highest during the agriculturally productive season (when particulate P, mainly PNP, dominates) and lowest during the regenerative season (when dissolved P, mostly DRP, dominates). The results show that the Warnow Estuary sediment retains 12% of inflowing P, suggesting that the estuary may be a P sink.

Although the researchers conclude that the P reduction targets of the Baltic Sea Action Plan in the Warnow Estuary can be met, achieving the 'good ecological status' objective of the Water Framework Directive (with respect to eutrophication) will not be possible there or in the coastal waters without further reductions. Additionally, assessments of P under environmental legislation should account for P circulation, say the researchers — not only total concentration of P, but also the bioavailable P fractions (DRP, DNP and PRP).

1. The Marine Strategy Framework Directive identifies the key challenges facing the Baltic Sea as being climate change, eutrophication, and unsustainable fishing.

2. This study was funded by the Federal Ministry of Education and Research, Germany (FKZ 033W042A).

3. Phosphorus occurs in both dissolved and particulate forms as a result of various biotic (e.g organism-driven) and abiotic (e.g. precipitation, dissolution, adsorption) processes, and is often categorised by its reactivity with ammonium molybdate (a compound used to measure the abundance of substances in water). Traditional monitoring accounts for TP and DRP; however, shallow, eutrophic aquatic systems often have higher levels of particulate P, and different forms of P are found through the water column (from sediment to surface). Understanding how P is cycled, exchanged and transformed between dissolved and particulate, reactive and non-reactive forms is important to understand ecosystem dynamics. Each form has a different impact on its environment (e.g. dissolved P contributes most to algal growth and is therefore a key driver of eutrophication).