What was the eutrophication status of the Baltic Sea in 2003-2007?

Authors

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Key message

The whole Baltic Sea except the open Bothnian Bay and certain coastal areas in the Gulf of Bothnia were affected by eutrophication during 2003-2007.

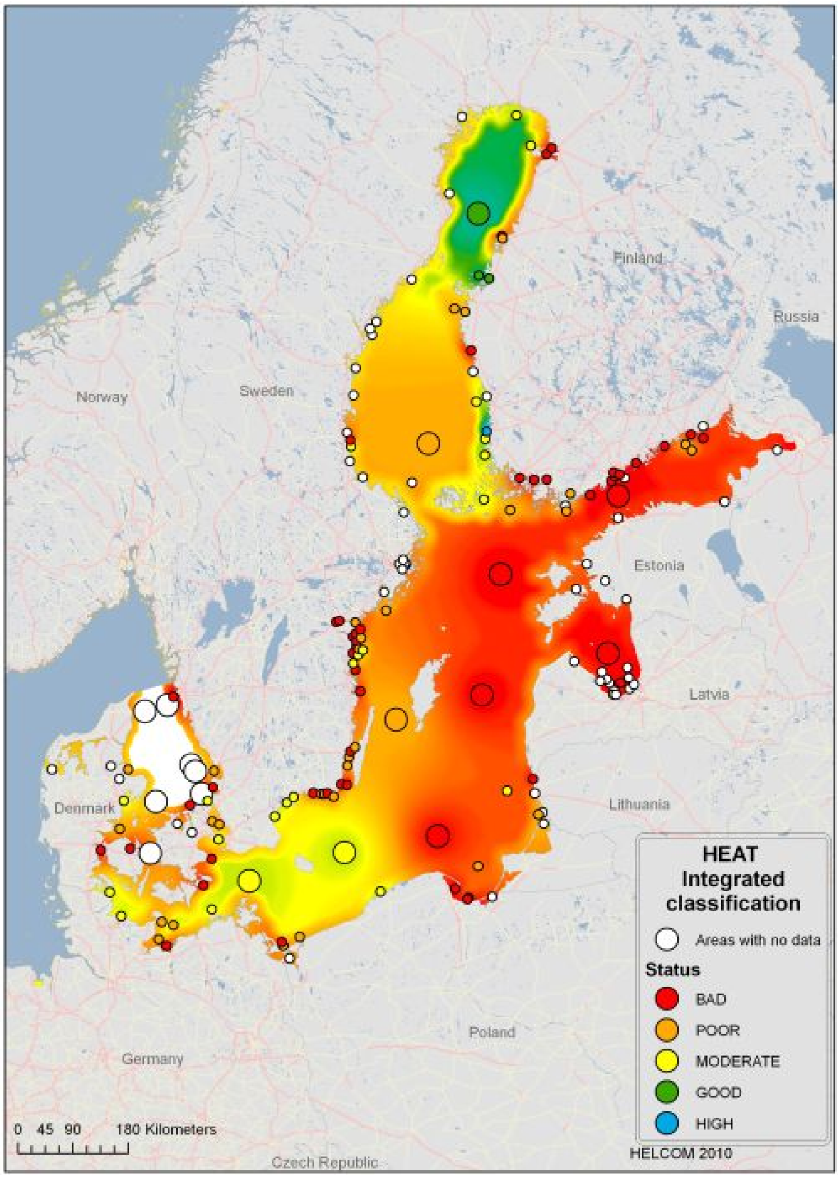


Figure 1. *The eutrophication status of the Baltic Sea based on average data for 2003-2007 at 110 assessment units in the Baltic Sea. The assessments are based on an integration of the results from core set indicators on nutrient (nitrogen and phosphorus) concentrations, chlorophyll a concentrations, water transparency and zoobenthos communities using the HELCOM Eutrophication Assessment Tool (HEAT). The interpolated map has been produced in three steps: 1) the integrated status of coastal assessment units have been interpolated along the shores, 2) the integrated status of open sea basins have been interpolated and 3) the coastal and open interpolations have been combined using a smoothing function. The larger circles indicate the status of open sea assessment units and the smaller circles that of the coastal assessment units.*

Policy relevance

Eutrophication is addressed by one of the four thematic segments of the HELCOM Baltic Sea Action Plan. The strategic goal of HELCOM related to eutrophication is a *Baltic Sea unaffected by eutrophication.*

This Integrated Core Set Indicator Report provides an assessment of the eutrophication status of the Baltic Sea based on averaged data for the years 2003-2007. The assessment is derived using the HELCOM eutrophication assessment tool (HEAT) and HELCOM Core Set Indicators for eutrophication. The methodology and an assessment for the period

2001-2006 are described in the Integrated thematic assessment of the effects of nutrient enrichment in the Baltic Sea (HELCOM 2009).

The HELCOM goal for eutrophication is broken down into five ecological objectives: *Concentrations of nutrients close to natural levels*, *clear water, natural level of algal blooms, natural distribution and occurrence of plants and animals*, *natural oxygen levels*. Each objective is reflected by one or more HELCOM Core Set Indicators for eutrophication. These indicators are weighted depending on their ecological significance for the site being assessed and combined under the quality elements *physico-chemical features, plankton* and *benthic invertebrate fauna*. Finally the overall integration of the eutrophication status is derived from the results of each of the quality assessments using the HEAT tool.

Eutrophication is also addressed by the EU Marine Strategy Framework Directive, as one of the qualitative descriptors of Good Environmental Status contained in Annex I of the Directive is "Human induced eutrophication does not cause adverse effects to the ecosystem".

Sub-regional assessment of eutrophication status in the Baltic Sea

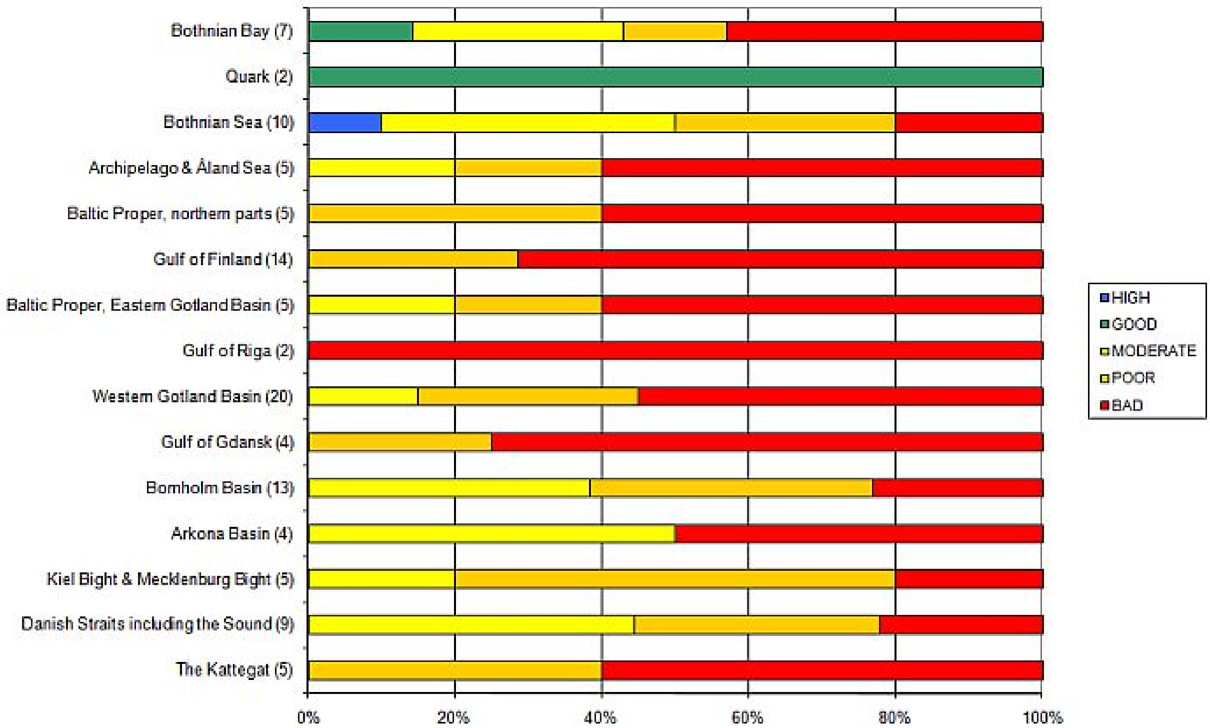


***Figure 2.** Overview of eutrophication classifications per sub-basin based on the application of the HELCOM Eutrophication Assessment Tool (HEAT).*

All sub-basins except for the Quark have areas classified as *poor* or *bad*. All areas assessed in the Gulf of Riga were assessed to have a bad eutrophication status. All basins of the Baltic Sea including the open parts of the Bothnia Sea were classified as *affected by eutrophication*. The reason for classifying the open parts of the Bothnian Sea as *affected* is related to a well-documented increase in chlorophyll-a concentrations (see HELCOM 2009 for details). For most of the coastal water in the Baltic Sea, the general picture is that nutrient concentrations and chlorophyll-a concentrations are elevated, not only compared to so-called reference conditions but also compared to target values. For most open basins, the benthic invertebrates are outside the range of what is being considered as being a *good* status. Only four out of 110 coastal waters were classified as having *good* or *high* status. All of these four areas are located in the Gulf of Bothnia. It is noteworthy that all coastal areas outside the Gulf of Bothnia are classified as *affected by eutrophication*. The explanations for having impaired conditions include elevated levels of nutrients and chlorophyll-a, loss of submerged aquatic vegetation as well as periods of oxygen depletion affecting in particular benthic invertebrates.

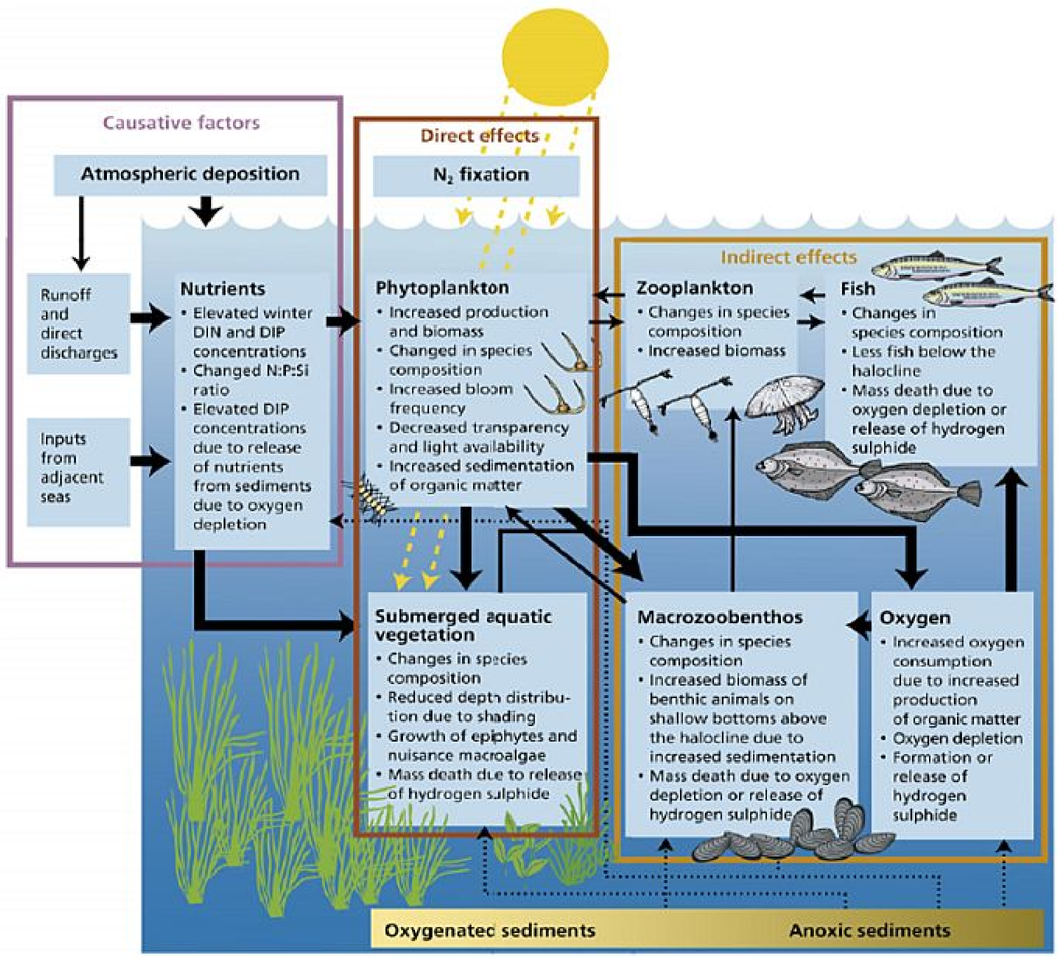
A conceptual model for eutrophication in the Baltic Sea

The word 'eutrophication' has its roots in Greek: 'eu' meaning 'well' and 'trope' meaning 'nourished'. The modern use of the word is related to nutrient enrichment as a consequence of nutrient inputs. The problems of eutrophication are generally related to changes in the structure and functioning of the marine ecosystem.

A primary effect is an increase in the production of planktonic algae, often manifested as algal blooms. This increased production of organic matter often has secondary and drastic negative consequences, e.g. reduced water transparency, increased sedimentation, increased mineralization and oxygen consumption leading to oxygen depletion in bottom waters. Benthic communities such as meadows of submerged aquatic vegetation are directly affected by reduced water transparency. Benthic invertebrate communities and fish are affected by oxygen depletion, the ultimate effects being kills of animals. A conceptual model of eutrophication is given in the figure below.

The limited water exchange with the North Sea, stratification of the water column, and the long residence time of water are the main reasons for the sensitivity of the Baltic Sea to eutrophication. High nutrient loads in combination with long residence times of water means that nutrients discharged to the sea will remain for a long time. In addition, the vertical stratification of the water masses increases the vulnerability of the Baltic Sea to eutrophication. The most important effect of stratification in terms of eutrophication is that it hinders or prevents ventilation and oxygenation of the bottom waters and sediments by vertical mixing of water, a situation that often leads to oxygen depletion. Hypoxia and anoxia have an effect on nutrient transformations, such as nitrification and denitrification processes, as well as the capacity of the sediments to bind phosphorus. In the absence of oxygen, sediments release significant quantities of phosphorus to the overlying water.

Large parts of the Baltic Sea are in a state of so-called repressed recovery, sometimes referred to as a vicious cycle, because of interconnected processes involving nitrogen, phosphorus and oxygen. Widespread hypoxia facilitates the release of phosphorus from sediments and fuels blooms of nitrogen fixing blue-green algae that tend to counteract reductions in external loads of nitrogen and phosphorus.



Technical data

Data source: The HELCOM countries have provided status concentrations for 2003-07. See the technical data for the individual core set indicators on water clarity, nutrient concentration, chlorophyll-a and benthic invertebrate fauna for more information.

Description of data: See the technical data for the individual core set indicators on water clarity, nutrient concentration, chlorophyll-a and benthic invertebrate fauna for more information.

Geographical coverage: All regions of the Baltic Sea.

Temporal coverage: : The data used here are based on average values for 2003-2007 (for more details see the technical data for the individual core set indicators on water clarity, nutrient concentration, chlorophyll-a and benthic invertebrate fauna for more information.

Methodology and frequency of data collection: See the technical data for the individual core set indicators on water clarity, nutrient concentration, chlorophyll-a and benthic invertebrate fauna for more information.

Methodology of data analyses: Status classifications for 189 assessment units on water transparency, nitrogen and phosphorus concentrations, chlorophyll concentrations and benthic invertebrate fauna have been weighted and combined using the HELCOM Eutrophication Assessment Tool (HEAT) to produce a final integrated eutrophication classification of bad to high status.

The status of the Baltic Sea according to the different indicators has been classified using the multi-metric indicator-based HEAT tool. Each area was assessed using information on reference conditions (RefCon) and acceptable deviation from reference condition (AcDev) combined with national monitoring data from the period 2003–2007. The basic assessment principle is RefCon ± AcDev = EutroQO, where the latter is a "eutrophication quality objective" (or target) corresponding to the boundary between good and moderate ecological status. When the actual status data (average for 2003-2007) exceeds the EutroQO or target, the area in question is regarded as *affected by eutrophication.*

The Ecological Quality Ratio (EQR) is a dimensionless measure of the observed value (AcStat) of an indicator compared with the reference value (RefCon). The ratio is equal to 1.00 if actual status is better than or equal to reference conditions and approaches 0.00 as deviation from reference conditions becomes large. The value of EQR is used to assign a quality class to the observed status. The classes in descending order of quality are RefCon, High, Good, Moderate, Poor, Bad. The central definition of the quality classes is given by the value of acceptable deviation (AcDev).

For a complete explanation of the methodology used, please see Andersen et al (2010) and thematic integrated assessment on eutrophication of the Baltic Sea (HELCOM 2009).

The eutrophication status maps were produced by spatially interpolating the values for the areas listed in the data table. ArcGIS 9.3.1 was used to interpolate the open and coastal areas. The coastal areas interpolation was delimited by a 6 nautical miles buffer along the coastline. The result was then joined to the open sea areas and the final map was processed to add a smoother transition between coast and open sea areas.

Strength and weaknesses of data: See the technical data for the individual core set indicators on water clarity, nutrient concentration, chlorophyll-a and benthic invertebrate fauna for more information.

Reliability, accuracy, robustness, uncertainty (at data level): The accuracy of classification results was tested in the thematic integrated assessment on eutrophication of the Baltic Sea. The accuracy was found to be in general good although there is some room for improvement. This has been documented indirectly via the secondary assessment of confidence where the data on which the classification is based on is scored in terms of accuracy. The secondary assessment found that 145 of 189 areas had an acceptable confidence while the remaining 44 areas had an unacceptable low confidence. Areas with low confidence in general are found in the southeastern or northern parts of the Baltic Sea.

Further work required (for data level and indicator level): The integrated eutrophication indicator report will be updated annually based on updated and new data from the core set of eutrophication indicators.

References

Andersen, J.H., P. Axe, H. Backer, J. Carstensen, U. Claussen, V. Fleming-Lehtinen, M. Järvinen, H. Kaartokallio, S. Knuuttila, S. Korpinen, M. Laamanen, E. Lysiak-Pastuszak, G. Martin, F. Møhlenberg, C. Murray, G. Nausch, A. Norkko, & A. Villnäs. 2010. Getting the measure of eutrophication in the Baltic Sea: towards improved assessment principles and methods. Biogeochemistry. DOI: 10.1007/s10533-010-9508-4.

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