Oxygen debt

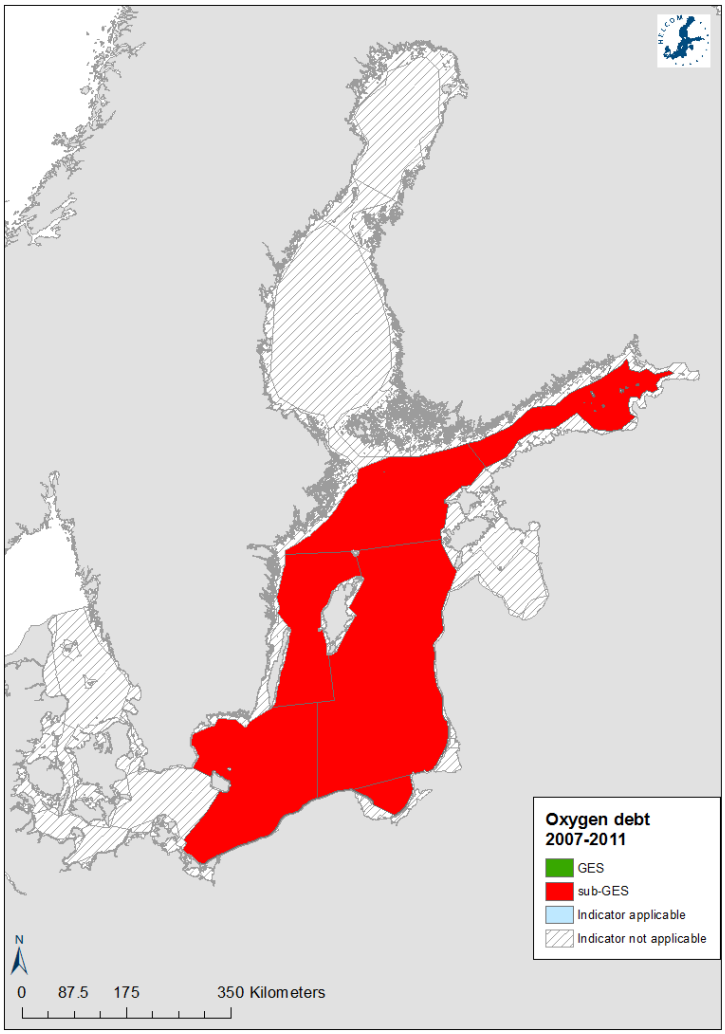
Key Message

Oxygen debt is an applicable indicator in the Bornholm Basin, Western Gotland Basin, Eastern Gotland Basin, Northern Baltic Proper and Gulf of Finland. Good environmental status (GES) has not been achieved in any of these sub-basins.

Oxygen debt below the halocline has increased both in the Baltic Proper and the Bornholm Basin since the early 1900's. The increase has been strong in the Baltic Proper, where the level has increased approximately 25% since the level observed under 1900-1920.

The confidence of the presented chlorophyll-a status estimate is high in all the sub-basins where the indicator was applied.

Average oxygen debt below halocline. (Open dynamic map viewer in new tab)



Relevance of the core indicator

Organic matter decomposition to bottom waters increases along with increasing eutrophication. This leads to increasing oxygen consumption and subsequent decrease in bottom oxygen concentration. This core indicator focuses on one important aspect of the complex phenomenon, but does not alone assess the eutrophication status.

Policy relevance of the core indicator

	Primary importance	**Secondary importance**
BSAP segment and objective	A Baltic Sea unaffected by eutrophication	
MSFD descriptor and criteria	5.3. Indirect effects of nutrient enrichment	
Other relevant legislation	Water Framework Directive	

Cite this indicator

Pyhälä M, Fleming-Lehtinen V, Laamanen M, Łysiak-Pastuszak E, Carstens M, Leppänen J-M, Leujak W, Nausch G, Carstensen, J. 2014. Oxygen debt - HELCOM Core Indicator Report. Online. [Date Viewed], http://www.helcom.fi/baltic-sea-trends/indicators/oxygen/

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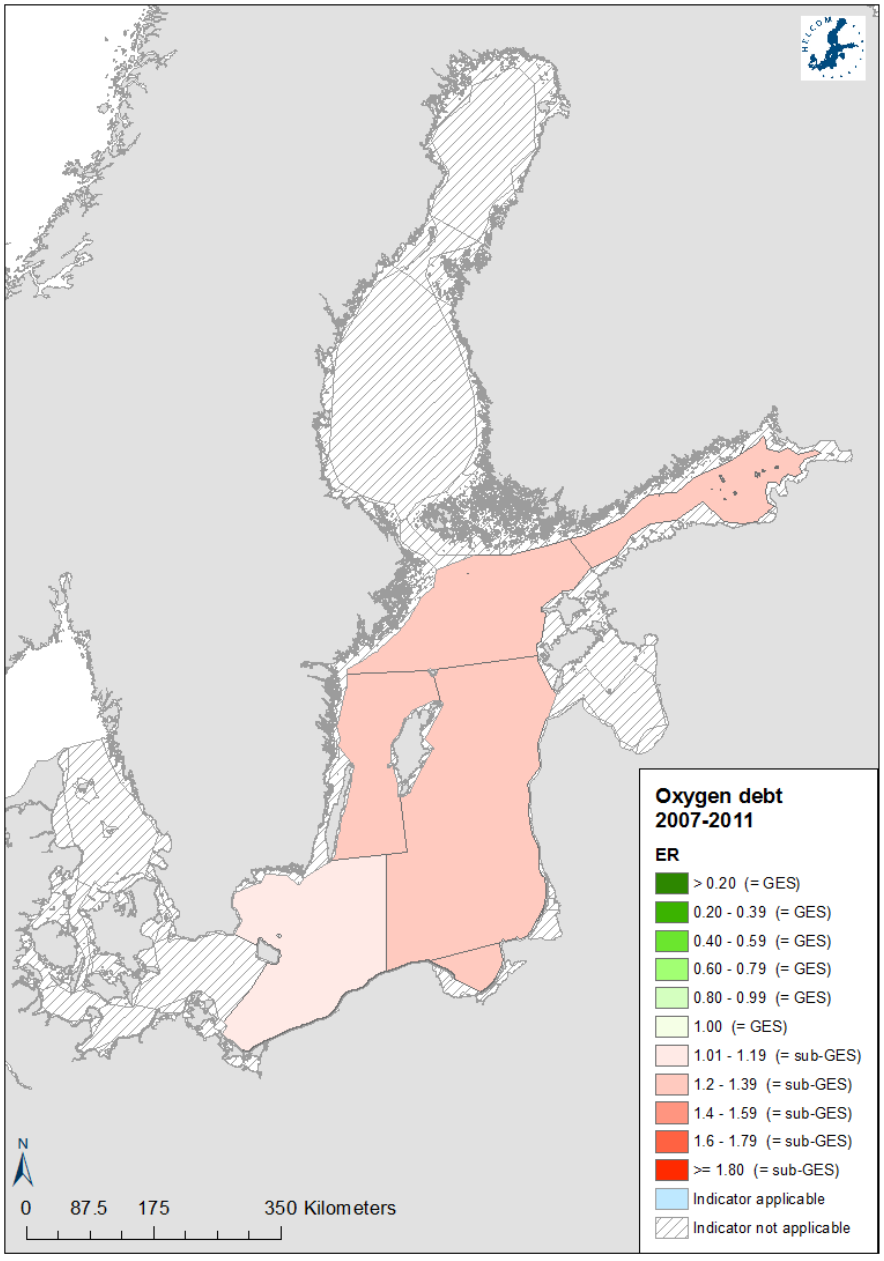
Core indicator – web version 2015 (pdf)

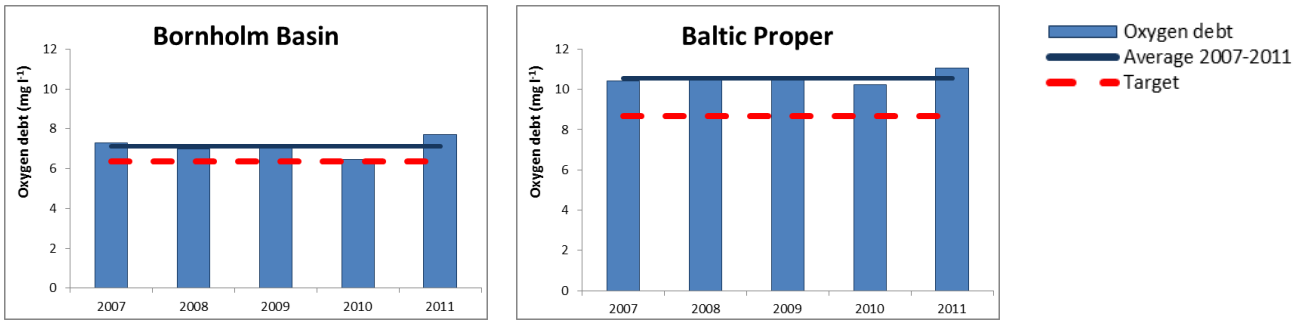
Results and Confidence

Current status of oxygen debt

Oxygen debt is an applicable indicator in the Bornholm Basin, Gdansk Basin, Western Gotland Basin, Eastern Gotland Basin, Northern Baltic Proper and Gulf of Finland. Good environmental status (GES) has not been achieved in any of these sub-basins. In Arkona Basin, however, oxygen debt is only slightly below the GES-boundary.



Results figure 1: Status of the oxygen debt indicator, presented as eutrophication ratio (ER). ER shows the present concentration in relation to the GES boundary, increasing along with increasing eutrophication. The GES-boundary has been reached when ER ≤ 1.00.



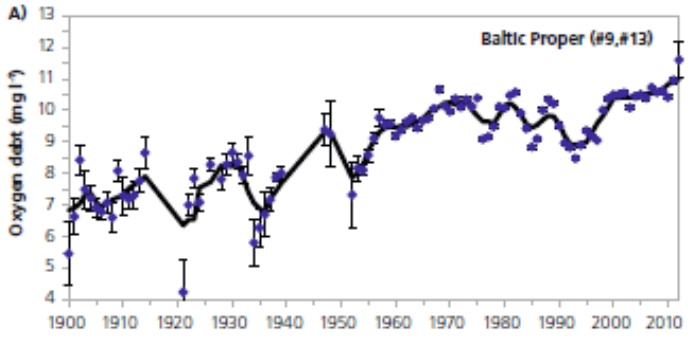
Results figure 2: Average oxygen debt below halocline (black line; average for years 2007-2011) and target levels as agreed by HELCOM HOD 39/2012 (red broken line).

Results Table 1**:** GES targets, present concentration (as average 2007-2011), eutrophication ratio (ER) and status of oxygen debt in the open-sea basins. ER is a quantitative value for the level of eutrophication, calculated as the ratio between the GES target and the present concentration – when ER > 1, GES has not been reached.

Sub-basin	**Target (mg l^{-1})**	**Average 2007-2011 (mg l^{-1})**	**Eutrophication ratio, ER**	**STATUS**
Bornholm Basin	6.37	7.10	1.12	SubGES
Eastern Gotland Basin	8.66	10.54	1.22	SubGES
Gdansk Basin	8.66	10.54	1.22	SubGES
Western Gotland Basin	8.66	10.54	1.22	SubGES
Northern Baltic Proper	8.66	10.54	1.22	SubGES
Gulf of Finland	8.66	10.54	1.22	SubGES

Long-term trends

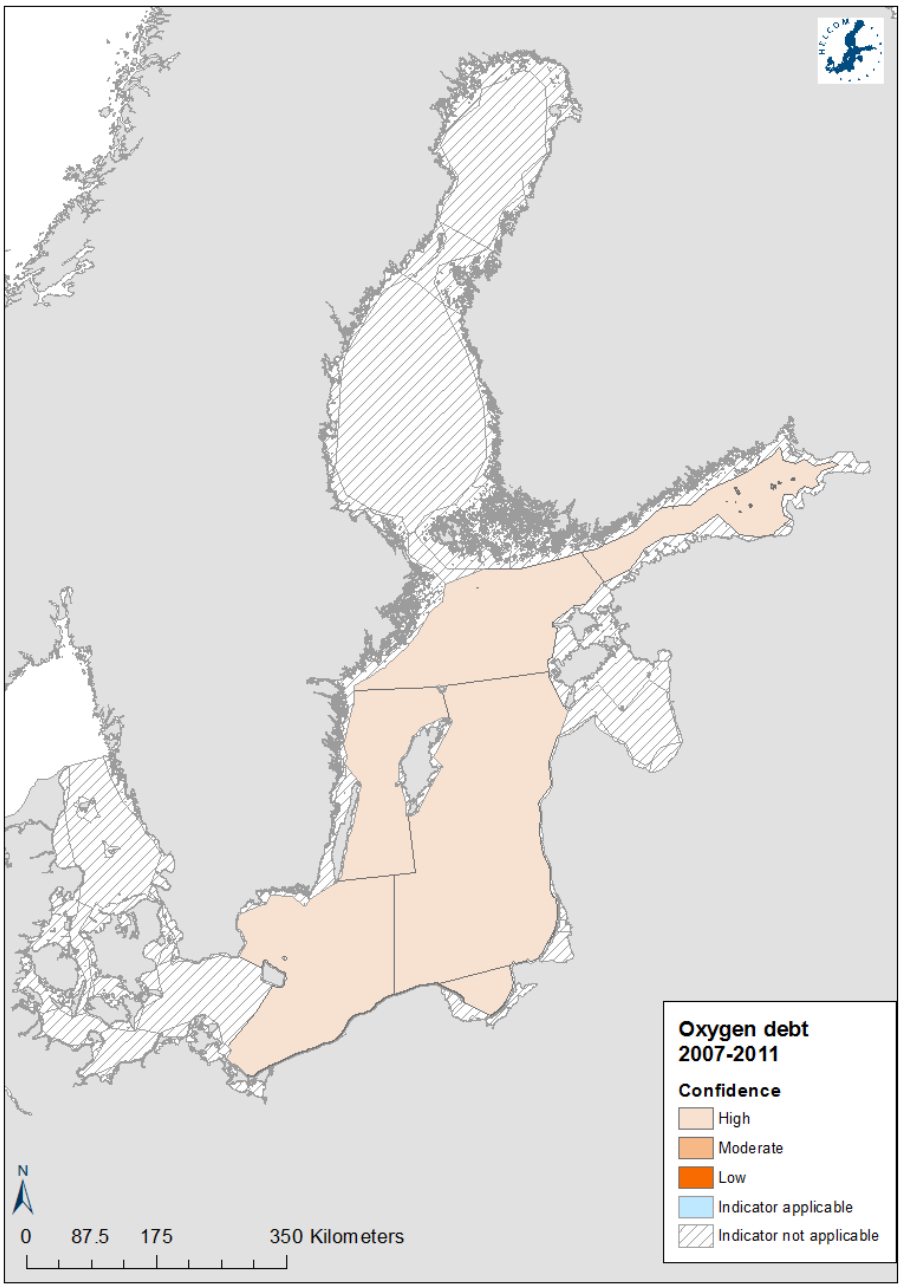
Oxygen debt below the halocline has increased both in the Baltic Proper and the Bornholm Basin since the early 1900's. The increase has been strong in the Baltic Proper, where the level has increased approximately 25% since the level observed under 1900-1920.



Results figure 3: Long-term trend in oxygen debt in the Baltic Proper (from BSEP 133). The spatial and seasonal patterns are separated across the years, using a GLM-GAM model according to Carstensen et al. 2006. Lines indicate the five-year moving average and error bars represent 95% confidence limits of the means.

Confidence of the indicator status evaluation

The confidence of the indicator status estimate, based on the spatial and temporal coverage of data as well as the accuracy of the target-setting protocol, was *high* in all the sub-basins where the indicator was applicable.



Results figure 4. Indicator confidence, determined combining information on data availability and the accuracy of the target-setting protocol. Low indicator confidence calls for increase in monitoring.

The indicator confidence was estimated through confidence scoring of the target (ET-Score) and the indicator data (ES-Score). The ET-Score was rated based on the uncertainty of the target setting procedure. The ES-Score is based on the number as well as spatial and temporal coverage of the observations for the assessment period 2007-2011. To estimate the overall indicator confidence, the ET- and ES-Scores were combined. See Andersen et al. 2010 and Fleming-Lehtinen et al. 2015 for further details.

Good Environmental Status

Good environmental status is measured in relation to scientifically based and commonly agreed sub-basin-wise target levels.

These GES boundaries were based on the results obtained in the TARGREV project (HELCOM 2013a), taking also advantage of the work carried out during the EUTRO PRO process (HELCOM 2009) and national work for WFD. The final targets were set through an expert evaluation process done by the intersessional activity on development of core eutrophication indicators (HELCOM CORE EUTRO) and the targets were adopted by the HELCOM Heads of Delegations 39/2012.

HELCOM_ID	Basin	Target (mg l^{-1})
SEA-001	Kattegat	>2
SEA-002	Great Belt	>2
SEA-003	The Sound	>2
SEA-004	Kiel Bay	
SEA-005	Bay of Mecklenburg	
SEA-006	Arkona Sea	
SEA-007	Bornholm Sea	6.37
SEA-008	Eastern Gotland Basin	8.66
SEA-009	Gdansk Basin	8.66
SEA-010	Western Gotland Basin	8.66
SEA-011	Northern Baltic Proper	8.66
SEA-012	Gulf of Riga	
SEA-013	Gulf of Finland	8.66
SEA-014	Åland Sea	
SEA-015	Bothnian Sea	
SEA-016	The Quark	
SEA-017	Bothnian Bay	

Assessment Protocol

Eighteen open sea area sub-basins (at least one nautical mile seawards from the baseline) were assessed using the HEAT 3.0 tool according to the HELCOM division of the Baltic Sea. The assessment units for the indicator are the open Baltic Sea sub-basins (HELCOM 2013b).

The assessments of the open sea areas were based on an integration of state data from core set indicators on winter inorganic nitrogen (DIN) and phosphorus (DIP) concentrations, chlorophyll *a* concentrations, water transparency (Secchi depth) and oxygen conditions below halocline (oxygen debt, only for Bornholm Basin and Baltic Proper).

The indicators were grouped under the following three "criteria" as described in the Commission Decision (2010/477/EU): 1. Nutrient levels, 2. Direct Effects, 3. Indirect Effects. Oxygen debt is listed under Criteria 3: Indirect effects.

Relevance of the Indicator

Eutrophication assessment

The status of eutrophication is assessed using five core indicators. Each indicator focuses on one important aspect of the complex phenomenon. In addition to providing an indicator evaluation of the levels of deep-bottom oxygen debt, this indicator will also contribute to the next overall eutrophication assessment to be completed in 2018 along with the other eutrophication core indicators.

Policy relevance

Eutrophication is one of the four thematic segments of the HELCOM Baltic Sea Action Plan (BSAP) with the strategic goal of having a Baltic Sea unaffected by eutrophication (HELCOM 2007). Eutrophication is defined in the BSAP as a condition in an aquatic ecosystem where high nutrient concentrations stimulate the growth of algae which leads to imbalanced functioning of the system. The goal for eutrophication is broken down into five ecological objectives, of which one is "natural oxygen levels".

The EU Marine Strategy Framework Directive (Anonymous 2008) requires that "human-induced eutrophication is minimized, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algal blooms and oxygen deficiency in bottom waters" (Descriptor 5). "Dissolved oxygen" is listed as an indicator for assessing the criterium for "indirect effects of nutrient enrichment" (5.3).

The EU Water Framework Directive (Anonymous 2000) requires good ecological status in the European coastal waters. Good ecological status is defined in Annex V of the Water Framework Proposal, in terms of the quality of the biological community, the hydrological characteristics and the chemical characteristics, including dissolved oxygen.

Role of oxygen debt in the ecosystem

Oxygen depletion is a common effect of eutrophication in the bottom waters of coastal marine ecosystems and is becoming increasingly prevalent worldwide (HELCOM, 2002). It is caused by the consumption of oxygen by the microbial processes responsible for the degradation of organic matter accumulating at the sea fl oor. Oxygen depletion may result in hypoxia (literally 'low oxygen') or even anoxia (absence of oxygen). These events may be (1) episodic, (2) annually occurring in summer/autumn (most common), or (3) persistent (typical of the deep basins of the Baltic Sea). Oxygen depletion has a clear impact on biogeochemical cycles. Anoxic periods cause the release of phosphorus from sediment. Dissolved inorganic phosphorus (DIP) is significantly negatively correlated with oxygen conditions. The concentration of DIP can vary greatly from year to year depending on the release of phosphorus from sediments under anoxia (Matthäus et al. 2008). Ammonium is also enriched under hypoxic conditions. The DIP and ammonium from the bottom waters can be mixed into the upper water column and enhance algal blooms. Thus, hypoxia results in large changes in the biogeochemical cycle, which may enhance eutrophication.

Human pressures linked to the indicator

Oxygen depletion is an indirect effect of eutrophication, i.e. increase of organic matter descending to the bottom. It also has an indirect link to anthropogenic pressures, through increased anthropogenic nutrient loads and subsequent increase of organic matter descending to the bottom.

Monitoring Requirements

Monitoring requirements

For assessment purposes, at least 15 observations should be made yearly in each assessment unit. The compilation of observations is expected to be distributed spatially within the assessment unit in a non-biased way.

HELCOM Monitoring manual

In the **HELCOM monitoring manual**, under **Hydrochemistry >> Sub-programme water column chemical characteristics**, see further information on:

Regional coordination

Purpose of monitoring

Monitoring concepts

Assessment requirements

Data providers and access

References

Data and updating

Access and use

The data and resulting data products (tables, figures and maps) available on the indicator web page can be used freely given that the source is cited. The indicator should be cited as following:

HELCOM (2015) Oxygen debt. HELCOM core indicator report. Online. [Date Viewed], [Web link].

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Metadata

Data source: The average for 2007-2011 was estimated using monitoring data provided by the HELCOM Contracting Parties, and kept in the HELCOM COMBINE database, hosted by ICES (www.ices.dk), added with data from the Baltic Encironment Database, hosted by the Baltic Nest Institute (http://www.balticnest.org). Representatives of the Contracting Parties were given the opportunity to review the data, and to supply any missing monitoring observations, in order to achieve a complete dataset.

Description of data: The data includes the sum of *in-situ* temperature, salinity and oxygen profiles, determined as explained in the HELCOM COMBINE manual. Dissolved oxygen measurements made at the depth below the halocline were used in the assessment.

Geographical coverage: The observations are distributed in the sub-basins according to the HELCOM COMBINE programme, added occasionally with data from research cruises.

Temporal coverage: The raw data includes observations throughout they year, during the assessment period 2007-2011.

Data aggregation: The 2007-2011 averages for each sub-basin were produced as inter-annual estimates, determined using a GLM-GAM procedure to exclude spatio-temporal bias.

Arrangements for updating the indicator

For the 2007-2011 assessment, the data was collated during the HELCOM TARGREV project, reviewed by the HELCOM CORE EUTRO inter-sessional group and processed by Jacob Carstensen, BNI.

For update of future eutrophication assessments, the HELCOM EUTRO-OPER is concentrating in streamlining the process from data reporting to indicator and assessment update.

View data

View assessment data: assessment_data_2007-2011_oxy.xlsx

For raw data, contact ICES.

Contributors and references

Contributors

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Archive

This version of the HELCOM core indicator report was published in June 2015:

Core indicator – web version 2015 (pdf)

Additional relevant publications

Eutrophication status of the Baltic Sea 2007-2011 - A concise thematic assessment (2014)

Approaches and methods for eutrophication target setting in the Baltic Sea region (2013)

HELCOM core indicators. Final report of the HELCOM CORESET project (2013)

Eutrophication in the Baltic Sea. An integrated thematic assesment of the effects of nutrient enrichment in the Baltic Sea region (2009)

Development of tools for assessment of eutrophication in the Baltic Sea (2006)

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