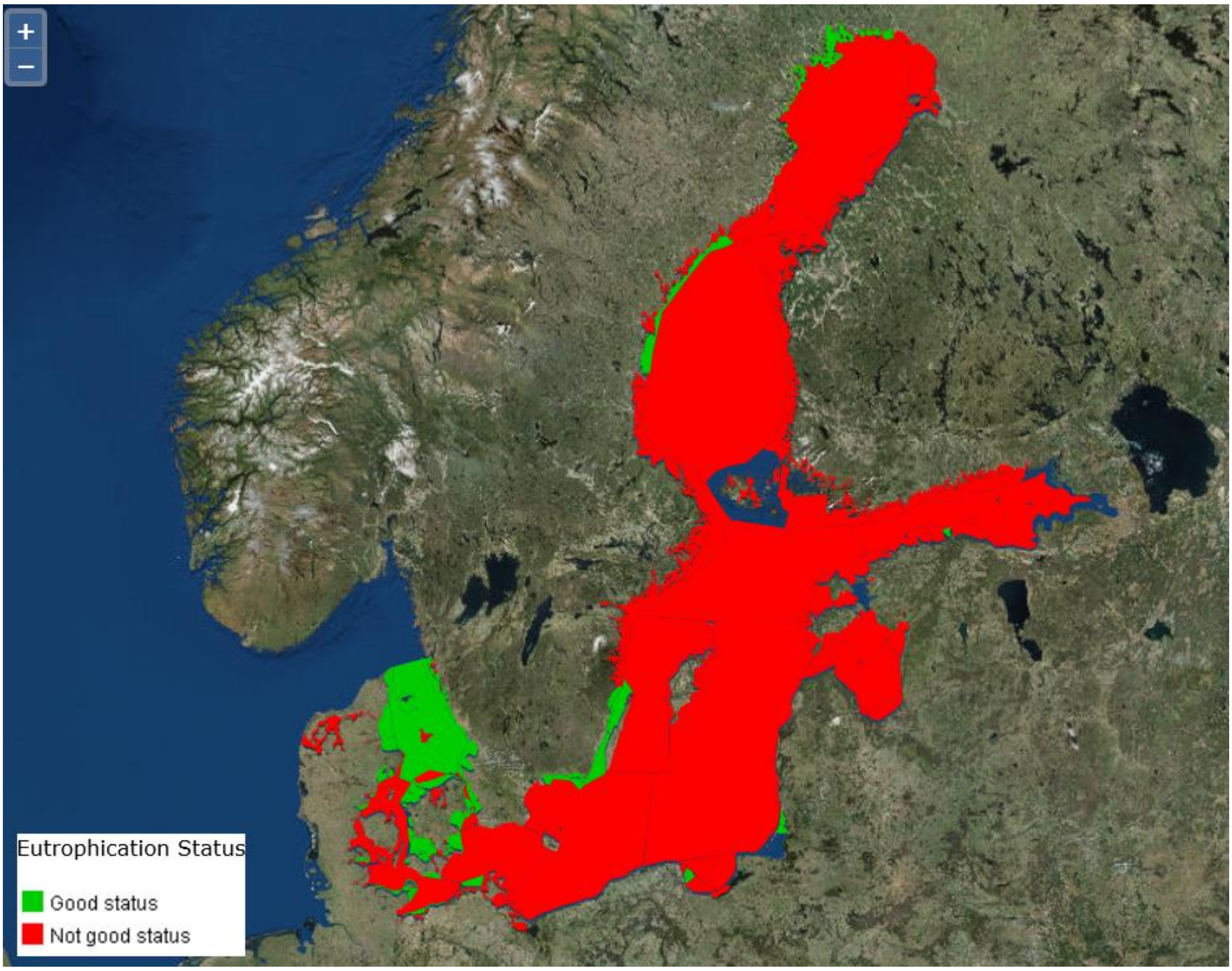
HELCOM core indicator report
July 2017

Chlorophyll-*a*

Key Message

The core indicator evaluates the average chlorophyll-*a* concentration in the surface water (0 – 10 m) during summer (June – September) during the assessment period 2011-2015.

In open sea areas, good status of chlorophyll-a was achieved in the Kattegat. In the remaining 16 sub-basins, the status was not good. In coastal waters, good status is found in some areas along coasts of Sweden, Denmark, Germany, Poland, Lithuania and Estonia.



Key message figure 1: Status assessment results based evaluation of the indicator 'chlorophyll a'. The assessment is carried out using Scale 4 HELCOM assessment units (defined in the HELCOM Monitoring and Assessment Strategy Annex 4).

In many sub-basins the summer-time chlorophyll-a has increased until the 1990s (Arkona Sea, Kattegat) or early 2000s (Bothnian Bay, Northern Baltic Proper, Gulf of Riga, and Western Gotland Basin), but turned to decrease thereafter. Only in the Gulf of Finland, Bothnian Sea and Eastern Gotland Basin, has the increase continued.

The confidence of the presented chlorophyll-a status estimate is moderate in all open sea assessment unit except the Quark and Åland Sea, where the confidence is low.

The indicator is applicable in the waters of all countries bordering the Baltic Sea.

Relevance of the core indicator

Phytoplankton increases along with increased eutrophication as a result of increased nutrient concentrations. Chlorophyll-a concentration is used as a proxy of phytoplankton biomass.

Policy relevance of the core indicator

	BSAP Segment and Objectives	**MSFD Descriptors and Criteria**
Primary link	Baltic Sea unaffected by eutrophication	D5 Human-induced eutrophication - D5C2 Chlorophyll a concentrations are not at levels that indicate adverse effects of nutrient enrichment
Secondary link		
Other relevant legislation: EU Water Framework Directive		

Cite this indicator

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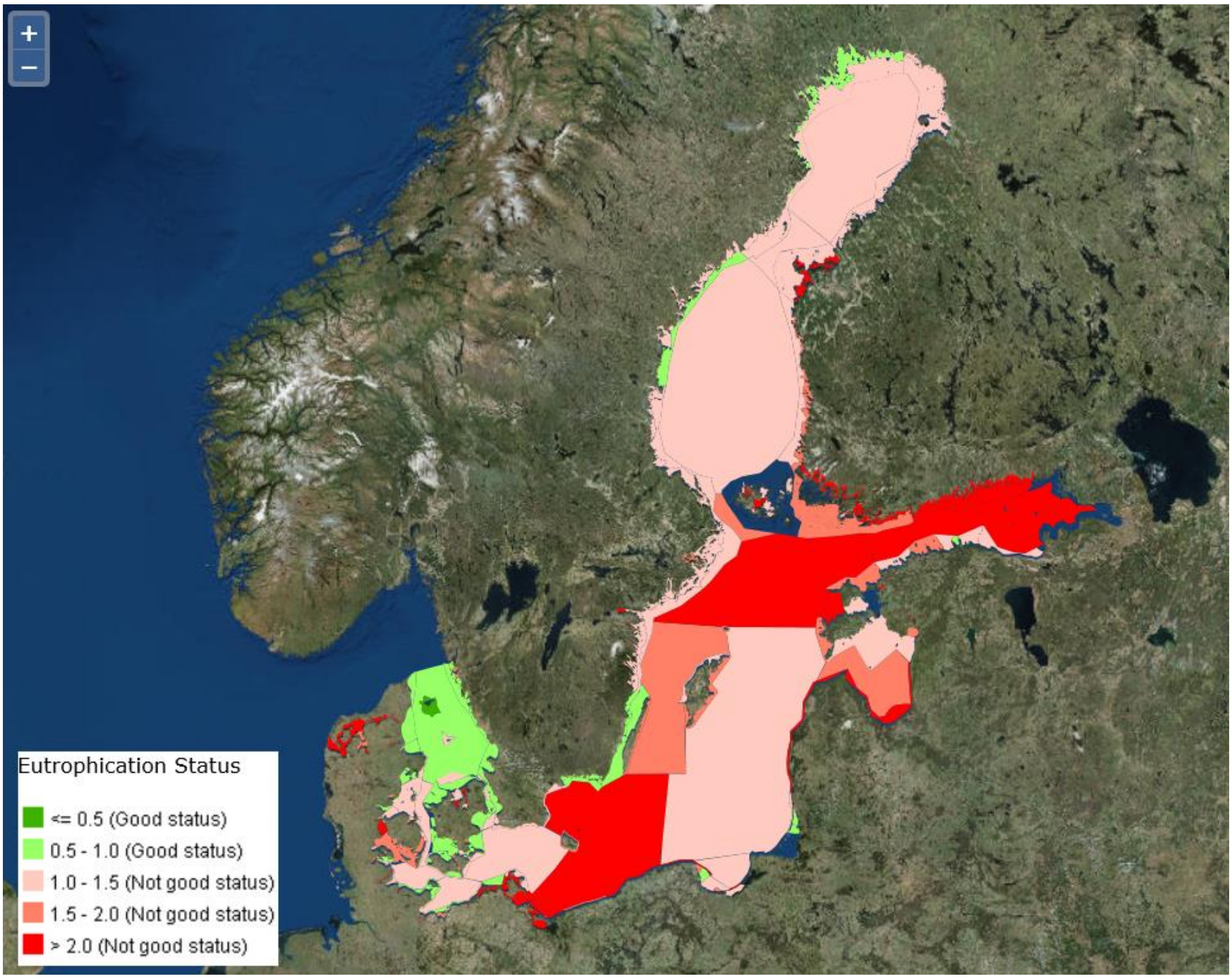
Results and Confidence

Current status of the Baltic Sea chlorophyll-*a*

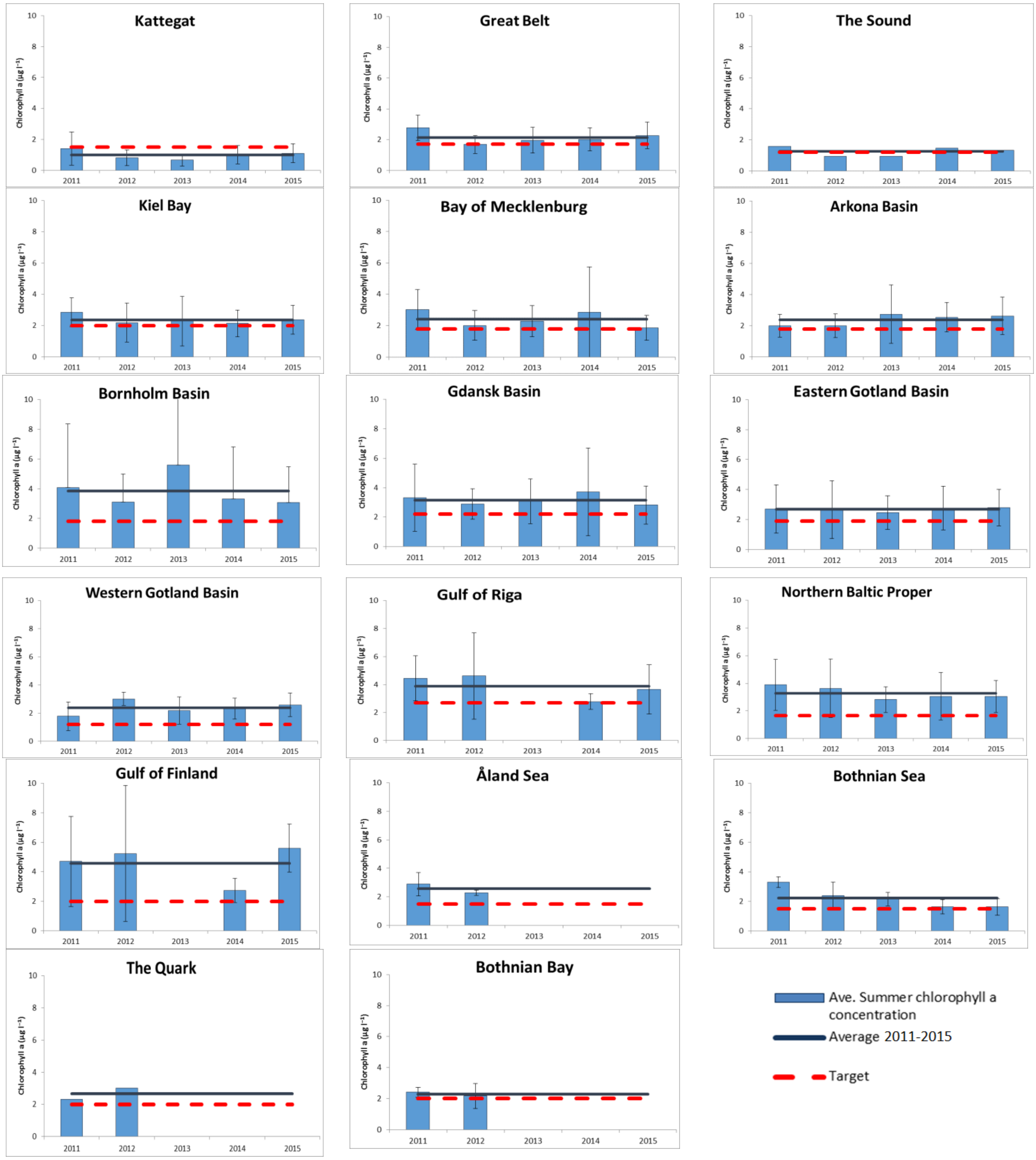
In open sea areas, the good status (concentrations of chlorophyll-a below the threshold value) has been achieved in the Kattegat. In the remaining 16 sub-basins, the status was not good. The status was most alarming in the Gulf of Finland, Northern Baltic Proper and Bornholm Basin.

In coastal waters, good status is found in some areas along coasts of Sweden, Denmark, Germany, Poland, Lithuania and Estonia.

The open sea assessment units causing greatest concern regarding chlorophyll-a status are the Åland Sea, Western Gotland Basin, Arkona Basin and Gdansk Basin. The status of Bothnian Bay, Quark and Bay of Mecklenburg are only somewhat below threshold for achieving good status.



Results figure 1. Status of the Chlorophyll-a indicator, presented as eutrophication ratio (ER). ER shows the present concentration in relation to the threshold value, increasing along with increasing eutrophication. The threshold value is ER ≤ 1.00.



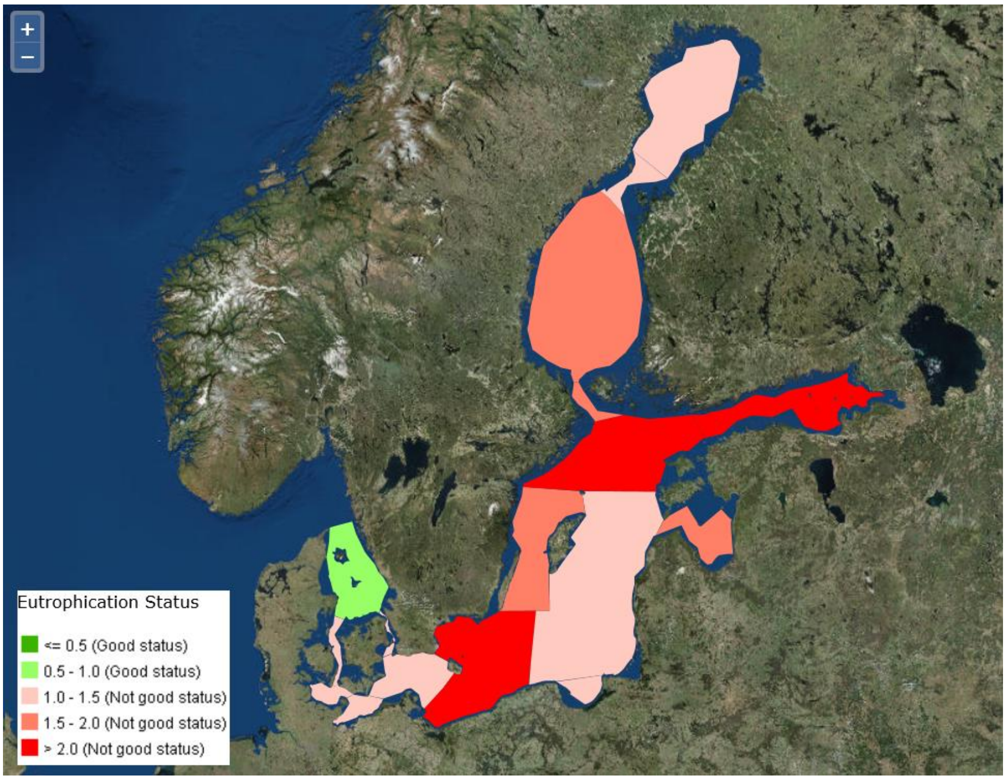
Results figure 2. Summer (June-September) chlorophyll-a concentration (black line, average for 2011-2015) and threshold value as agreed by HELCOM HOD 39/2012 (red broken line). No data was available for empty spaces. It should be noted that the results for Bornholm Basin strongly depend on stations in the open-sea area of Pomeranian Bay, which is influenced by the Odra plume.

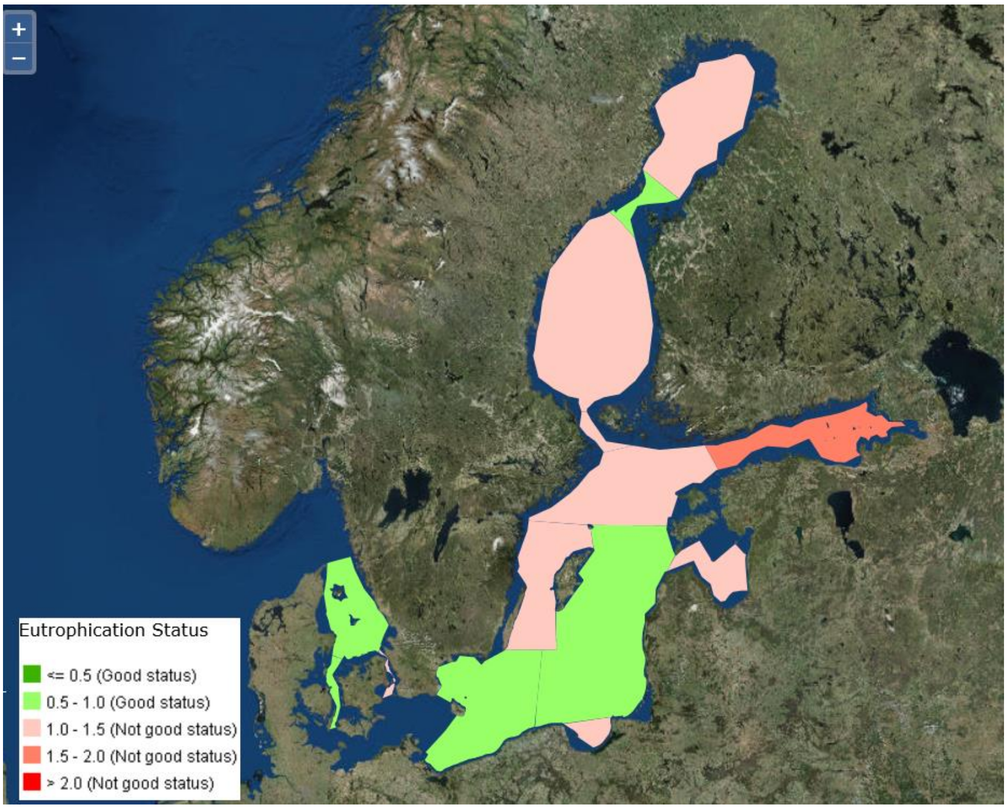
Results table 1. Threshold values, present concentration (as average 2011-2015), eutrophication ratio (ER) and status of Chlorophyll-a in the open-sea basins. ER is a quantitative value for the level of eutrophication, calculated as the ratio between the threshold value and the present concentration – when ER > 1, good status has not been reached.

Sub-basin	**Threshold value ($\mu g\ l^{-1}$)**	**Average 2011-2015 ($\mu g\ l^{-1}$)**	**Eutrophication ratio, ER**	**STATUS (fail/achieve threshold value)**
Kattegat	1.50	0.99	0.663	achieve
Great Belt	1.70	2.14	1.262	fail
The Sound	1.20	1.21	1.01	fail
Kiel Bay	2.00	2.31	1.155	fail
Bay of Mecklenburg	1.80	2.32	1.287	fail
Arkona Basin	1.80	2.60	1.445	fail
Bornholm Basin	1.80	4.93	2.739	fail
Eastern Gotland Basin	1.90	2.74	1.441	fail
Gdansk Basin	2.20	3.26	1.481	fail
Western Gotland Basin	1.20	2.35	1.962	fail
Northern Baltic Proper	1.65	3.49	2.116	fail
Gulf of Riga	2.70	4.17	1.545	fail
Gulf of Finland	2.00	4.65	2.326	fail
Aland Sea	1.50	2.59	1.725	fail
Bothnian Sea	1.50	2.34	1.560	fail
The Quark	2.00	2.66	1.328	fail
Bothnian Bay	2.00	2.29	1.147	fail

Chlorophyll-a estimates measured on different platforms

The chlorophyll-a indicator is updated using both in-situ and remote sensing data.





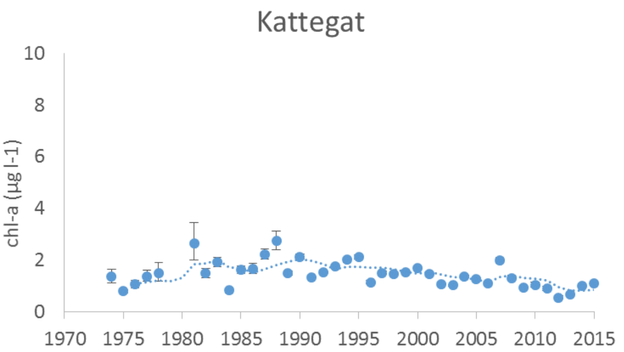
Results figure 3: Status of the chlorophyll-a -indicator, as measured in-situ (top) and via satellite (bottom, available only for years 2011 and 2016), presented as eutrophication ratio (ER). ER shows the present concentration in relation to the threshold value, increasing along with increasing eutrophication. The threshold value has been reached when ER ≤ 1.00. The overall chlorophyll-a estimate is based of combined annual information of the two parameters.

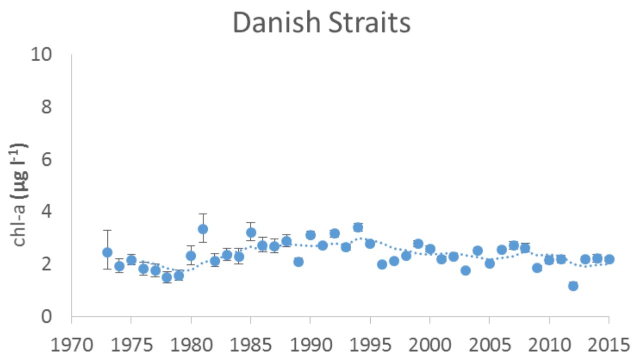
Long-term trends

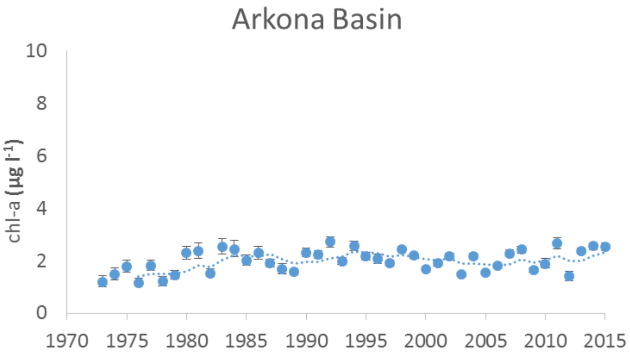
The long-term trends are provided as additional information and do not influence the status assessment. It should be noted that the information is not presented in the HELCOM assessment units, but for areas as defined in the BALTSEM model.

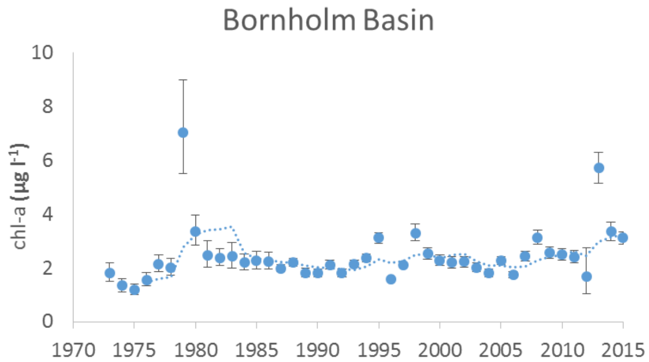
An increase in summer chlorophyll-*a* concentration was evident in most of the Baltic Sea sub-basins from the 1970s to the present. Only in the southwestern areas, the Kattegat and Arkona Sea, was the increase not observed. In the Bornholm Sea even a decrease in summer chlorophyll-*a* concentration could be observed (Fleming-Lehtinen et al. 2008).

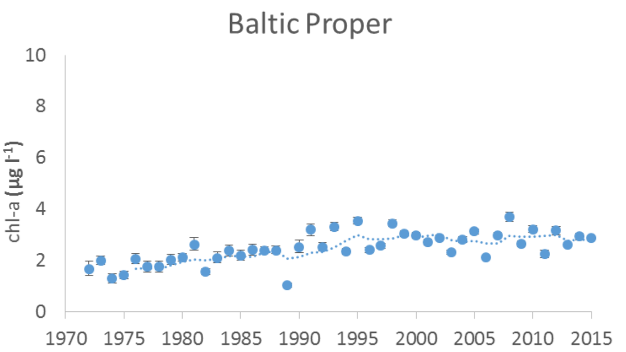
The increase in chlorophyll-*a* concentration was most pronounced in the northern areas: the Gulf of Finland, Northern Baltic Proper, Bothnian Bay, Bothnian Sea, Eastern Gotland Basin and the Gulf of Riga. In some of these areas, especially the Gulf of Riga, the concentration has turned to a decrease.

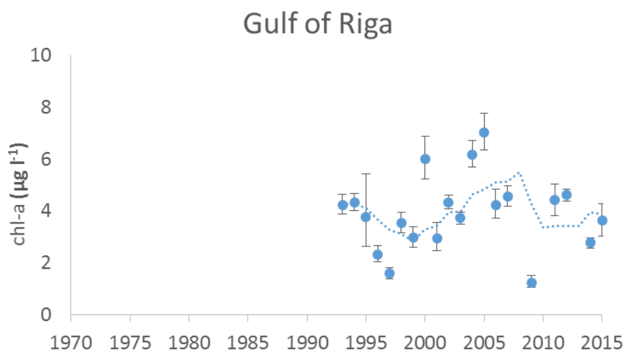


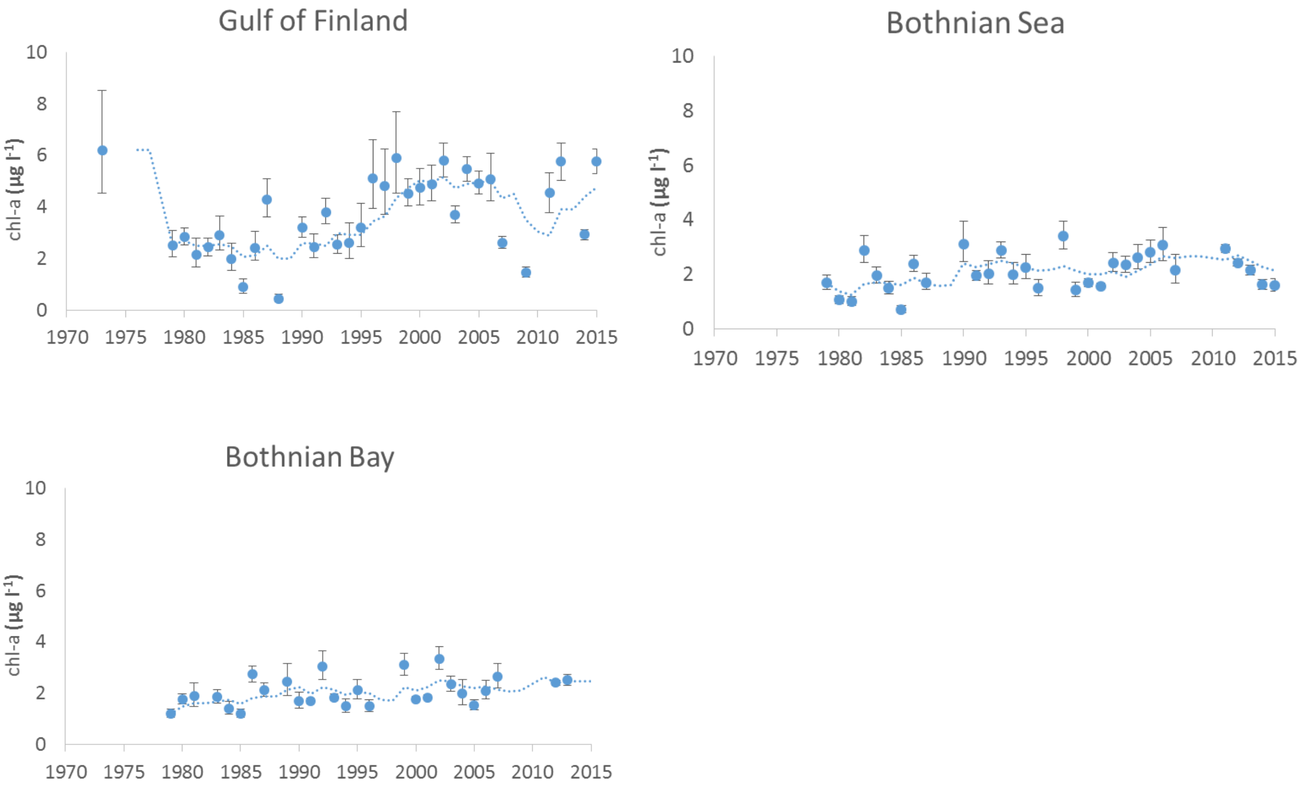








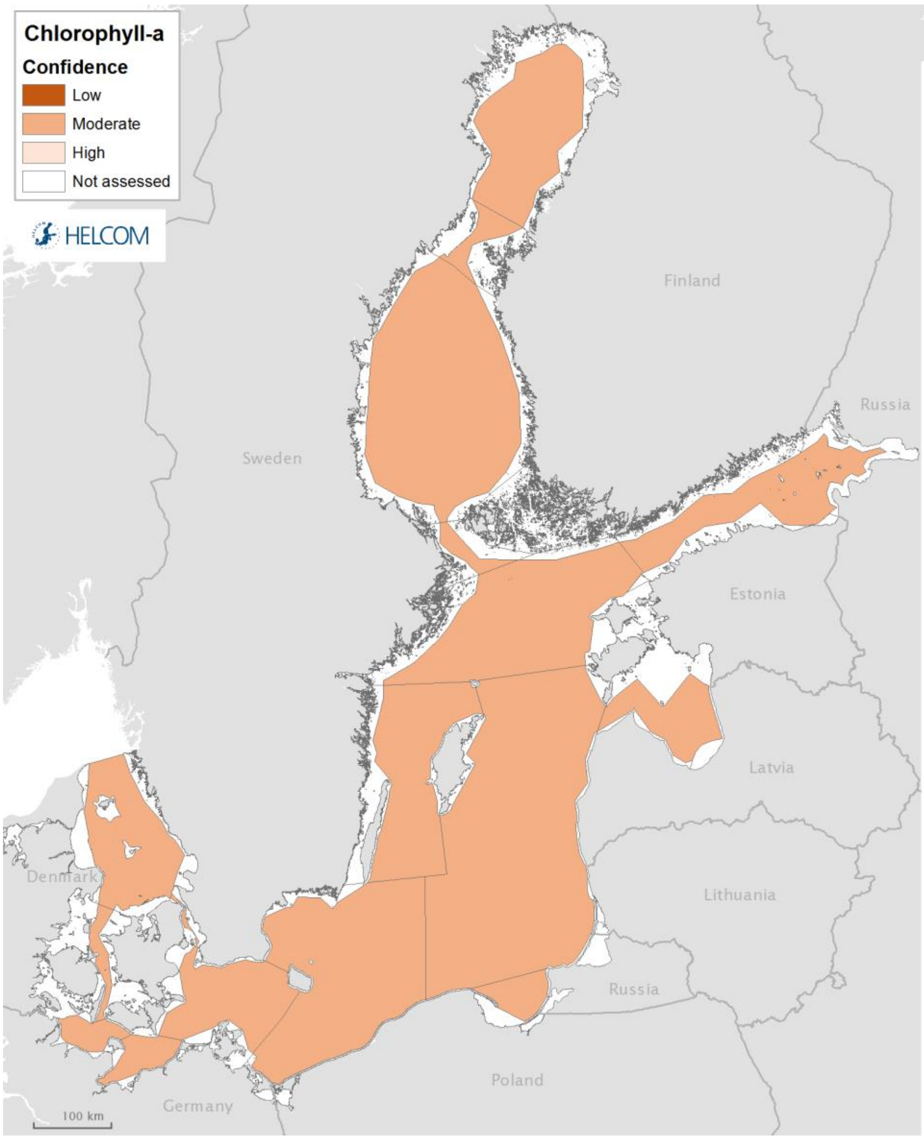




Results figure 4**.** Long-term trends *in-situ* chlorophyll-a concentrations in summer (Jun-Sep) in the BALTSEM basins (see BSEP 133) for 1970-2015. The data until 2012 is from TARGREV project. The spatial and seasonal patterns of historical data are separated across the years, using a GLM-GAM model according to Carstensen et al. 2006. Data for 2013-2015 are based on data extraction from the assessment database and show annual average concentrations for each sub-basin. Dashed lines indicate the 5-year moving average and error bars represent standard errors (SE).

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 threshold value-setting protocol, was **moderate**.

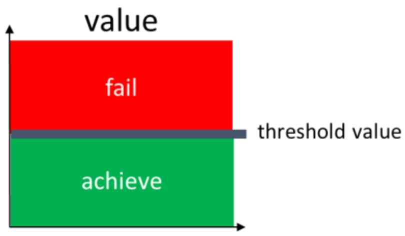


Results figure 5. Indicator confidence, determined combining information on data availability and the accuracy of the threshold-setting protocol. Low indicator confidence calls for increase in monitoring.

The indicator confidence was estimated through confidence scoring of the threshold value (ET-Score) and the indicator data (ES-Score). The ET-Score was rated based on the uncertainty of the threshold value setting procedure. The ES-Score is based on the number as well as spatial and temporal coverage of the observations for the assessment period 2011-2015. 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 threshold value, which defines the concentration that should not be exceeded (Good Environmental Status figure 1).



Good environmental status figure 1. Schematic representation of the threshold value applied in the chlorophyll-*a* core indicator, the threshold values are assessment unit specific (see Good environmental status table 1).

Some of the open-sea indicator threshold values were based on the results obtained in the TARGREV project (HELCOM 2013), taking also advantage of the work carried out during the EUTRO PRO process (HELCOM 2009) and national work for EU WFD implementation. The TARGREV values were derived as geometrical means, thus bearing close resemblance to median values (J. Carstensen, pers. comm.). The final threshold values were set through an expert evaluation process done by the intersessional activity on development of core eutrophication indicators (HELCOM CORE EUTRO) and the threshold value were adopted by the HELCOM Heads of Delegations 39/2012.

Good environmental status table 1. Assessment unit specific threshold values for the chlorophyll-*a* core indicator.

HELCOM_ID	Assessment unit (open sea)	Threshold value (µg l–1)
SEA-001	Kattegat	1.5
SEA-002	Great Belt	1.7
SEA-003	The Sound	1.2
SEA-004	Kiel Bay	2.0
SEA-005	Bay of Mecklenburg	1.8
SEA-006	Arkona Sea	1.8
SEA-007	Bornholm Sea	1.8
SEA-008	Eastern Gotland Basin	1.9
SEA-009	Gdansk Basin	2.2
SEA-010	Western Gotland Basin	1.2
SEA-011	Northern Baltic Proper	1.7
SEA-012	Gulf of Riga	2.7
SEA-013	Gulf of Finland	2.0
SEA-014	Åland Sea	1.5
SEA-015	Bothnian Sea	1.5
SEA-016	The Quark	2.0
SEA-017	Bothnian Bay	2.0

Assessment Protocol

The average chlorophyll-a is a combined estimate of two types of data: in-situ measurements (1) and EO-data (2). They were combined as annual averages, applying weighting based on data availability and methodological confidence. The indicator specifics are presented in Assessment protocol table 1.

More information is found in the eutrophication assessment manual.

Assessment protocol table 1. Specifications of the core indicator chlorophyll-*a*.

Indicator	Chlorophyll-*a*
Response to eutrophication	positive
Parameters	Chlorophyll-*a* concentration ($\mu g\ l^{-1}$)
Assessment period	June 2011 – September 2015
Assessment season	Summer = June + July + August + September
Depth	Surface = average in the 0 – 10 m layer
Removing outliers	No outliers removed
Removing close observations	No close observations removed
Indicator level (ES)	Defined as using multiple data types. The final ES is defined as an average of the annual estimates. Annual ES estimates are defined through (for an example where EO- and *in-situ* data are used for the indicator) $ES_y =$ $\frac{\frac{M(insitu)}{M(insitu+M(eo)}+\frac{SC(insitu)}{SC(insitu)+SC(eo)}}{2\times ES(insitu)}+\frac{\frac{M(eo)}{M(eo)+M(insitu)}+\frac{SC(eo)}{SC(eo)+SC(insitu)}}{2\times ES(eo)}$, where *M* = methodological correction factor, agreed by the eutrophication network, values given in table below, and *M(insitu)* + *M(eo)* + *M(fb)* = 1

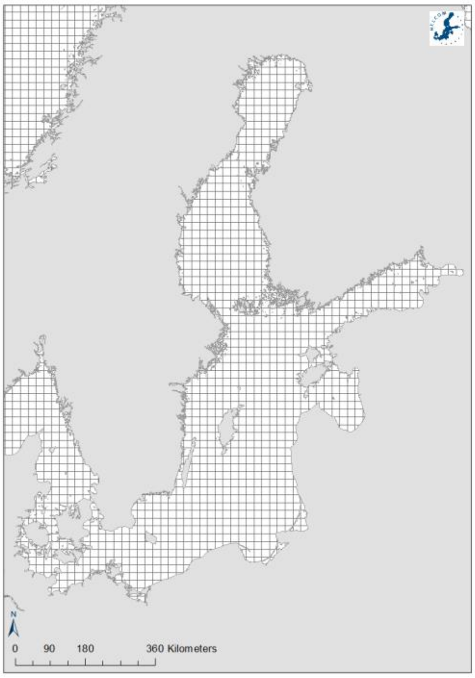
Sub-basin	$m_{in\text{-}situ}$	m_{EO}	$m_{fb}{}^{*}$
SEA-001 The Kattegat	0.55	0.45	0
SEA-001 Great Belt	0.55	0.45	0
SEA-003 The Sound	0.55	0.45	0
SEA-004 Kiel Bay	1	0	0
SEA-005 Bay of Mecklenburg	1	0	0
SEA-006 Arkona Basin	1	0	0
SEA-007 Bornholm Basin	0.55	0.45	0
SEA-008 Gdansk Basin	0.55	0.45	0
SEA-009 Eastern Gotland Basin	0.55	0.45	0
SEA-010 Western Gotland Basin	0.55	0.45	0
SEA-011 Gulf of Riga	0.70	0.30	0
SEA-012 Northern Baltic Proper	0.55	0.45	0
SEA-013 Gulf of Finland	0.55	0.45	0
SEA-014 Åland Sea	0.55	0.45	0
SEA-015 Bothnian Sea	0.55	0.45	0
SEA-016 The Quark	0.55	0.45	0
SEA-017 Bothnian Bay	0.55	0.45	0

* so far m_{fb} = 0, since ferrybox data is not used yet

	in-situ = water sample measurements from HELCOM COMBINE *EO* = daily earth observation on 20K grid *fb* = daily ferrybox observation on 20K grid *SC* = confidence correction factor assigned according to ES-Score, see reasoning described below. For ZERO SC=0, for LOW SC= 0.2, for MODERATE SC=0.75, for HIGH SC=1.0 *ES(in-situ)* = arithmetic average of *in-situ* observations in assessment unit during assessment season during year *y* *ES(eo)* and *ES(fb)* = geometric average of EO/fb grid cell data in assessment unit during assessment season during year *y*
Eutrophication ratio (ER)	ER = ES / ET
Status confidence (ES-Score)	ES-Score will be calculated separately for each data type. The same criteria will be used for all data types, based on their *n*, as described below. n_y*(in-situ)* = number of observations n_y*(EO)*, n_y*(fb)* = the number of 20K grid cells containing data, multiplied with the number of observation days during year *y* ES-Score is classified as described in BSEP 143, but an additional ZERO-class is taken into use. ZERO (0), if there are no status observations LOW (0.2), if no more than 5 annual status observations are found during one or more years. MODERATE (0.75), if more than 5 but no more than 15 status observations are found per year. HIGH (1.0), if more than 15 spatially non-biased status observations are found each year. To calculate the overall indicator confidence, the indicator ES-Score is calculated using the weighted average of the ES-Scores from the different observation methods. Weighting factors are the methodological correction factors presented above.
Indicator threshold value confidence	MEDIUM; exception: Kattegat LOW
Indicator confidence (I-Score)	Confidence (%) = average of ES-Score and ET-Score

The *in-situ* chlorophyll-*a* data (1) is extracted and analyzed in laboratory, as explained in the HELCOM COMBINE manual. Measurements made at the depth of 0 – 10 m from the surface were used in the assessment.

The satellite-based EO-dataset (2) for 2011 was calculated at SYKE using ENVISAT/MERIS instrument observations with FUB bio-optical model (Schroeder et al., 2007). The accuracy of the bio-optical algorithm to determine chlorophyll-a concentrations has been validated against ICES monitoring station dataset during HELCOM EUTRO-OPER-project. The EO chl-a account for the surface layer depends on the transparency of the water. Cloudy areas have been removed from the dataset. The data was reported as daily statistics of 20K grid cells (Assessment protocol figure 1). The year 2016 will be updated during the autumn using Sentinel3 OLCI-instrument data.



Assessment protocol figure 1. Earth observation data are reported as 20K grid cells.

Assessment units

The core indicator is applicable in the 17 open sea assessment units (exceeding one nautical mile seawards from the baseline)

In the coastal units the indicator is assessed using comparable indicators developed nationally for the purposes of assessments under the EU Water Framework Directive.

The assessment units are defined in the HELCOM Monitoring and Assessment Strategy Annex 4.

Further work required

In order to increase indicator confidence, the number of observations used in indicator update should be increased in several basins. The use of remote sensing and ship-of-opportunity data for estimating should be tested and developed further, with the aim of producing the next assessment using also Ferrybox data.

Relevance of the Indicator

Eutrophication assessment

The status of eutrophication is assessed using several core indicators. Each indicator focuses on one important aspect of the complex issue. In addition to providing an indicator-based evaluation of the dissolved inorganic phosphorous, this indicator also contributes to the overall eutrophication assessment along with the other eutrophication core indicators.

Policy relevance

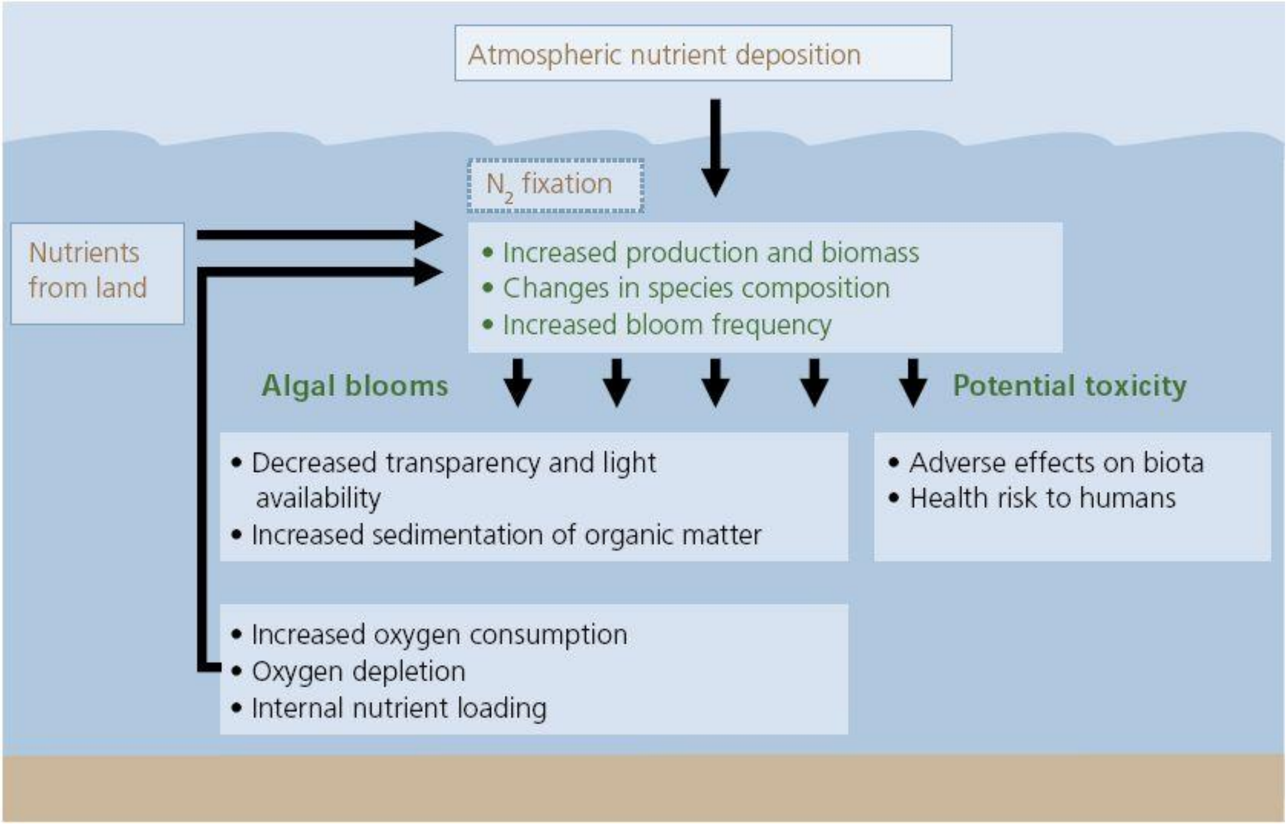
Eutrophication is one of the four thematic segments of the HELCOM Baltic Sea Action Plan (BSAP) with the strategic goal of having a Baltic Sea unaffected by eutrophication (HELCOM 2007). Eutrophication is defined in the BSAP as a condition in an aquatic ecosystem where high nutrient concentrations stimulate 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 levels of algal blooms”. Increase in phytoplankton can be assessed using chlorophyll-*a* as a proxy.

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). “Chlorophyll-a in the water column” is listed as a criteria element for assessing the criterion for D5C2 ‘Chlorophyll a concentrations are not at levels that indicate adverse effects of nutrient enrichment’.

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 Directive, in terms of the quality of the biological community, the hydromorphological characteristics and the chemical characteristics. Chlorophyll *a* is used as a proxy for phytoplankton biomass and as such, it was used in the WFD intercalibration exercise.

Role of chlorophyll-*a* in the ecosystem

Phytoplankton quantity is a direct proxy of eutrophication, as it lined to the increase of nutrient concentrations. The nutrient load is in some areas supplemented by internal nutrient loading from the bottom, accelerated by oxygen depletion. Phytoplankton increase in turn adds to the oxygen depletion, when sedimenting to the bottom, causing a vicious circle of eutrophication. Biotic and abiotic changes, such as climate change or changes in herbivory, also affect the phytoplankton quantity.



Relevance figure 1. Simplified conceptual model for chlorophyll-*a*.

Human pressures linked to the indicator

	General	MSFD Annex III, Table 2a
Strong link		Substances, litter and energy - Input of nutrients – diffuse sources, point sources, atmospheric deposition
Weak link		

The increase of chlorophyll *a*, a proxy of phytoplankton biomass, in the water column is dependent on nutrient concentrations, and thus linked strongly to anthropogenic nutrient loads from land and air. The concentration of chlorophyll *a* is a proxy for phytoplankton biomass. The amount of phytoplankton in the water depends on the balance between phytoplankton growth and loss factors such as grazing. As phytoplankton growth is stimulated by nutrients, the chlorophyll-a concentration has a tendency to increase with nutrient inputs. However, a simultaneous increase in zooplankton biomass or other grazers, due to the higher food availability might to some degree counteract this effect.

Monitoring Requirements

Monitoring methodology

Monitoring of chlorophyll-a in the Contracting Parties of HELCOM is described on a general level in the **HELCOM Monitoring Manual in the sub-programme Pigments.**

Monitoring guidelines specifying the sampling strategy are adopted and published.

Current monitoring

The monitoring activities relevant to the indicator that are currently carried out by HELCOM Contracting Parties are described in the HELCOM Monitoring Manual

Sub-programme: monitoring concepts table

Description of optimal monitoring

Regional monitoring of chlorophyll-a concentration is considered sufficient to support the indicator evaluation.

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 (2017) Chlorophyll-*a*. HELCOM core indicator report. Online. [Date Viewed], [Web link].

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Metadata

Result: Chlorophyll-a

Data source: The average chlorophyll-a was combined estimate of two types of data:

1) *In-situ* 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 Gulf of Finland year database, hosted by the Finnish Environment Institute.

2) The original source of the satellite-based EO-chl-a dataset is calculated at SYKE using ENVISAT/MERIS instrument data (2011) and Sentinel3 OLCI (2016, will be updated in June/August 2017). It has been validated by SYKE, and kept at the eutrophication assessment database hosted by ICES. For the assessment period 2011-2016, data was available only during 2011 and 2016.

Geographical coverage: The observations are distributed in the sub-basins according to the HELCOM COMBINE programme, added occasionally with data from research cruises. In-situ data was used in all open-sea assessment units, while EO-data was applied only in SEA-001…003 and SEA-007…017.

Temporal coverage: The estimates are based on observations made between June – September. In-situ estimates include observations made during 2011-2016, whereas EO-data was available only during 2011 and 2016.

Data aggregation: The 2011-2015 values for each sub-basin were estimated as an inter-annual summer (June-September) averages.

Contributors and references

Contributors

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Archive

This version of the HELCOM core indicator report was published in July 2017:

HOLAS II component - Core indicator report – web-based version July 2017 (pdf)

Older versions of the core indicator report are available:

Core indicator report – web-based 2015 (pdf)

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Additional relevant publications

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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 assessment 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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