

Cyanobacterial Bloom Index (CyaBI)

This pre-core indicator and its threshold values are yet to be commonly agreed in HELCOM.

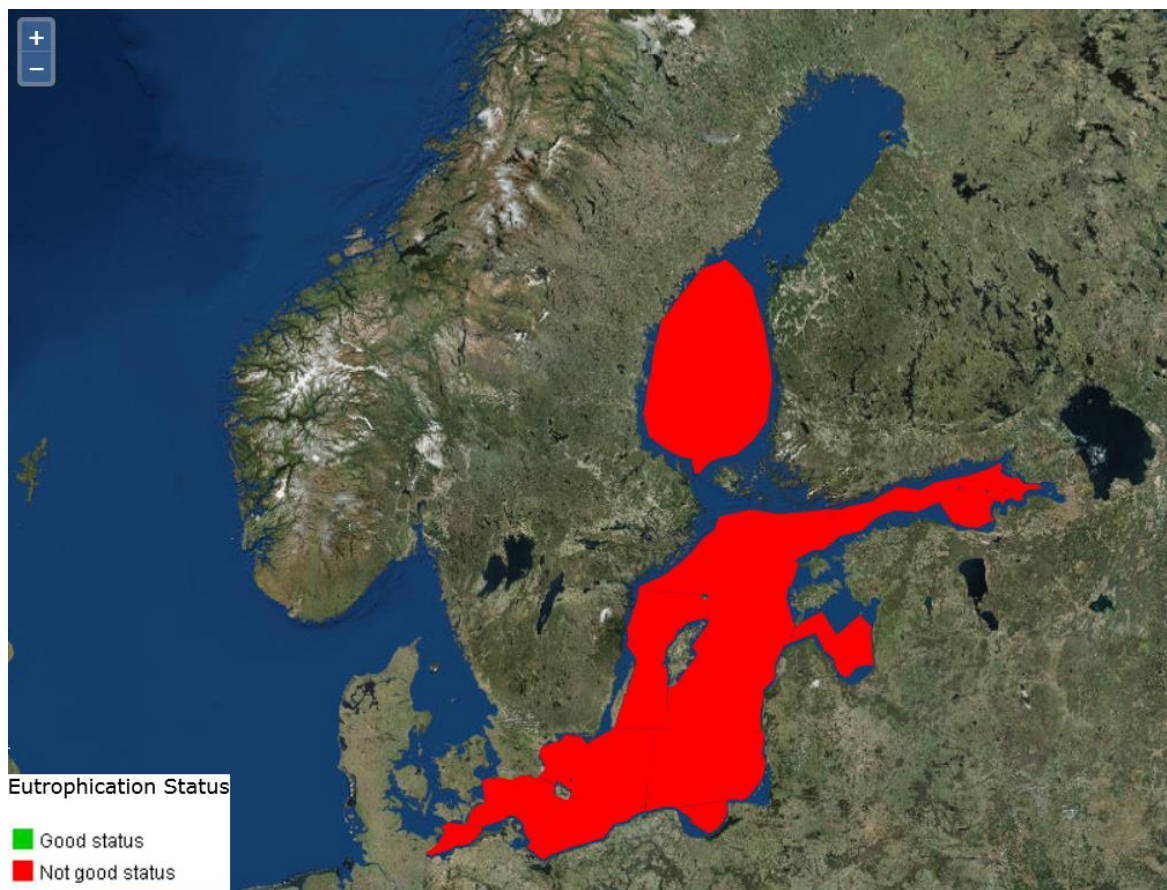
The indicator is included as a test indicator for the purposes of the mid-2017 'State of the Baltic Sea' report, and the results are to be considered as intermediate.

Key Message

This pre-core indicator evaluates cyanobacterial surface accumulations and cyanobacteria biomass during the summer period (20th June – 31st August) and covers the assessment period 2011-2015.

Of the 10 assessed open-sea sub-basins, good status for according to the cyanobacteria bloom index (CyaBI biomass below defined threshold value, which reflects good conditions) was not achieved in any sub-basin.

The sub-basins causing greatest concern regarding status in the assessment period 2011-2015 were Northern Baltic Proper and Gulf of Riga. The sub-basins closest to good status were Arkona Sea, Bornholm Sea, Eastern Gotland Basin and Western Gotland Basin.



Key message figure 1: Status assessment results based on the evaluation of the indicator 'Cyanobacterial Bloom Index'. The assessment is carried out using Scale 4 HELCOM assessment units (defined in the [HELCOM Monitoring and Assessment Strategy Annex 4](#)).

The confidence of the presented cyanobacteria status estimate was high (ES-score 100) for the 7 basins where both Earth Observation (EO-) and biomass-estimates could be applied. The threshold confidence was moderate (ET-Score 50).

The indicator is applicable in the waters of all countries bordering the Baltic Sea. The indicator is operational in the following open sea assessment units: The Bothnian Sea, Gulf of Finland, Northern Baltic Proper, Gulf of Riga, Western Gotland Basin, Eastern Gotland Basin, Bornholm Basin, Gdansk Basin, Arkona Sea and Bay of Mecklenburg. The indicator in its current form is not relevant in the Kattegat, Great Belt, the Sound, Kiel Bay, the Quark or in the Bothnian Bay. The indicator is not applicable in the Åland Sea.

Relevance of the core indicator

The indicator describes the symptoms of eutrophication in the sea areas caused by nutrient enrichment. Especially phosphorus load in a dominantly nitrogen-limited environment is considered the main anthropogenic pressure affecting the indicator. Human populations as well as anthropogenic activities such as agriculture and industry contribute the majority of nutrient input to the Baltic Sea. Eutrophication is driven by a surplus of the nutrients nitrogen and phosphorus in the sea. Nutrient over-enrichment causes elevated levels of algal and plant growth, increased turbidity, oxygen depletion, changes in species composition and nuisance blooms of algae (HELCOM, 2013). The indicator reflects also changes in the phytoplankton community. These are related to the changes in nutrient composition and climate, and have direct impact on sea-use and ecosystem service. Extensive cyanobacterial blooms have a potentially negative impact on the biodiversity of marine ecosystems as well as on its socio-economic value.

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 - D5C3 The number, spatial extent and duration of harmful algal bloom events are not at levels that indicate adverse effects of nutrient enrichment
Secondary link	Favourable status of Baltic Sea biodiversity	D1 Biodiversity - D1C6 The condition of the habitat type, including its biotic and abiotic structure and its functions (e.g. its typical species composition and their relative abundance, absence of particularly sensitive or fragile species or species providing a key function, size structure of species), is not adversely affected due to anthropogenic pressures.
Other relevant legislation:		

Cite this indicator

HELCOM (2017). Cyanobacteria bloom index. HELCOM pre-core indicator report. Online. [Date Viewed], [Web link].

ISSN 2343-2543

Download full indicator report

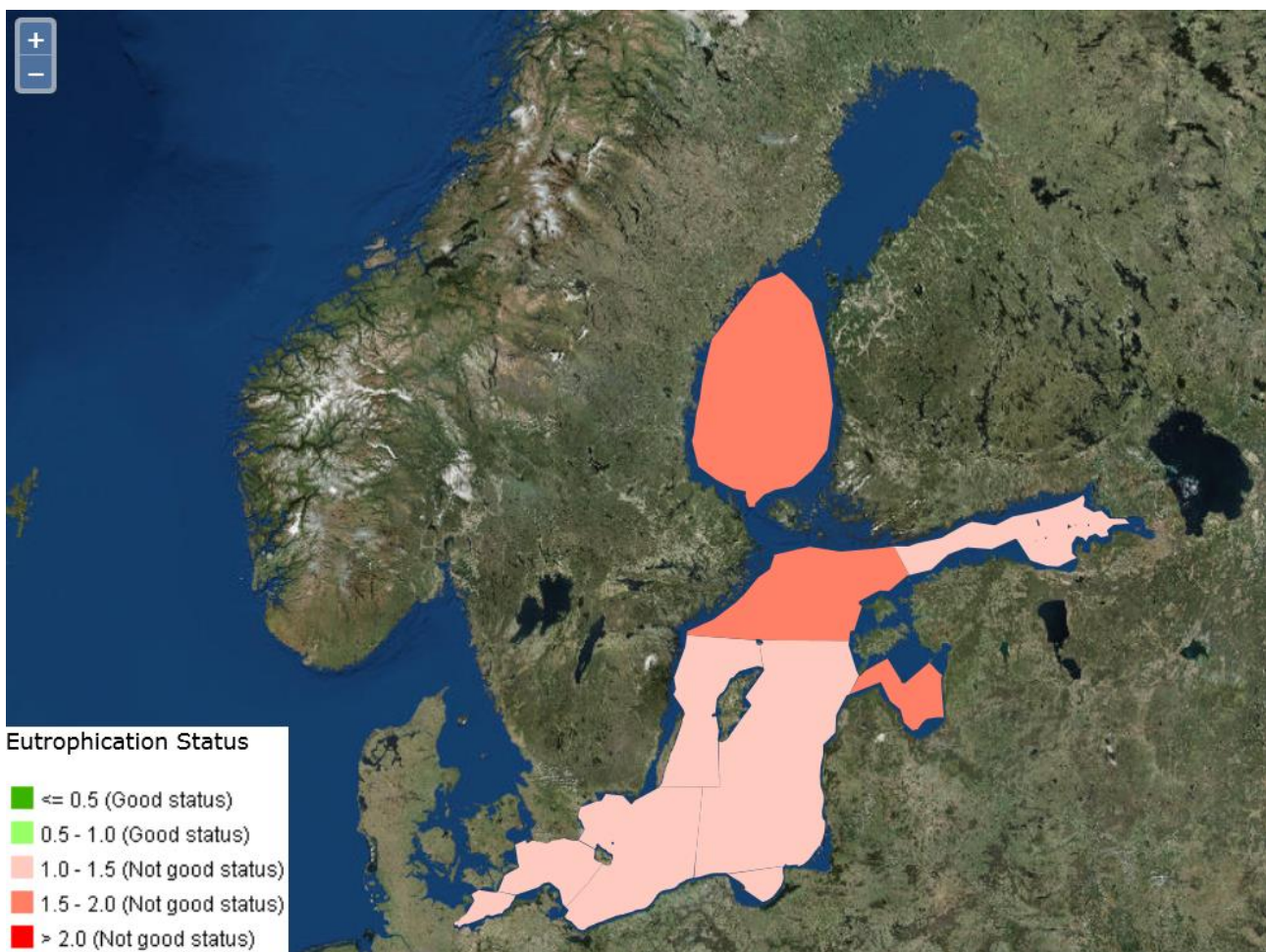
[HOLAS II component – Pre-core indicator report – web-based version July 2017](#) (pdf)

Results and Confidence

This pre-core indicator and its threshold values are yet to be commonly agreed in HELCOM.

The indicator is included as test indicator for the purposes of the mid-2017 'State of the Baltic Sea' report, and the results are to be considered as intermediate.

Good status was not reached in any of the assessment units where the indicator was applied. The sub-basins causing greatest concern regarding status during the assessment period 2011-2015 were the Northern Baltic Proper and Gulf of Finland, where the eutrophication ratio (ER) was ≥ 1.30 . ER was also high in the Bothnian Bay, as a result of low threshold value expressing a lower natural level of cyanobacterial blooms. The assessment units closest to good status were the Arkona Sea, Bornholm Sea, Eastern Gotland Basin and Western Gotland Basin.



Results figure 1. Status of cyanobacterial surface accumulations, 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 $ER \leq 1.00$.

Results table 1. Information on threshold values, present concentration and status (good status /not good status) of the Cyanobacterial Bloom indicator. The indicator values are based on two parameters, Cyanobacterial Surface Accumulations and Cyanobacteria biomass (See Good Environmental Status table 1 and Assessment protocol).

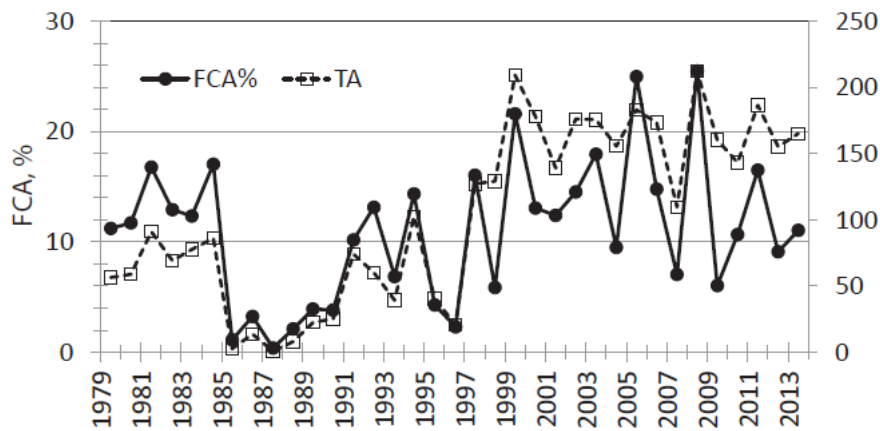
HELCOM ID	Name of assessment unit	Proposed threshold value (normalized between 0-1, with 1 expressing good status)	Estimate 2011-2015 (normalized between 0-1, with 1 expressing good status)	Eutrophication ratio (ER)	Status (fail/achieve threshold value)
SEA-001	Kattegat	Not relevant	Not relevant	Not relevant	Not relevant
SEA-002	Great Belt	Not relevant	Not relevant	Not relevant	Not relevant
SEA-003	The Sound	Not relevant	Not relevant	Not applicable	Not relevant
SEA-004	Kiel Bay	Not relevant	Not relevant	Not relevant	Not relevant
SEA-005	Bay of Mecklenburg	0.92	0.72	1.29	fail
SEA-006	Arkona Sea	0.90	0.85	1.06	fail
SEA-007	Bornholm Sea	0.87	0.80	1.09	fail
SEA-008	Gdansk Basin	0.98	0.83	1.19	fail
SEA-009	Eastern Gotland Basin	0.84	0.76	1.10	fail
SEA-010	Western Gotland Basin	0.87	0.78	1.11	fail
SEA-011	Gulf of Riga	0.90	0.53	1.71	fail
SEA-012	Northern Baltic Proper	0.77	0.45	1.71	fail
SEA-013	Gulf of Finland	0.90	0.69	1.30	fail
SEA-014	Åland Sea	Not applicable	Not applicable	Not applicable	Not applicable
SEA-015	Bothnian Sea	0.58	0.37	1.55	fail
SEA-016	The Quark	Not relevant	Not relevant	Not relevant	Not relevant
SEA-017	Bothnian Bay	Not relevant	Not relevant	Not relevant	Not relevant

Long-term trends

Blooms of nitrogen-fixing cyanobacteria are a natural phenomenon in the Baltic Sea (Bianchi et al. 2000, Poutanen & Nikkilä 2001, Westman et al. 2003), and have been observed in early phytoplankton sampling already in the early 1900s (Hällfors et al. 2012). The blooms became extensive during the 20th century, and have occurred commonly in the Baltic Proper and the Gulf of Finland since the 1960s (Finni et al. 2001, Poutanen & Nikkilä 2001).

The longest satellite based time series on algae accumulations from the Baltic Sea is presented by Kahru and Elmgren (2014). According to this satellite-based investigation, cyanobacterial blooms have increased in the Baltic Sea since the late 1970s (Result figure 2). Also, the total area covered by the blooms has

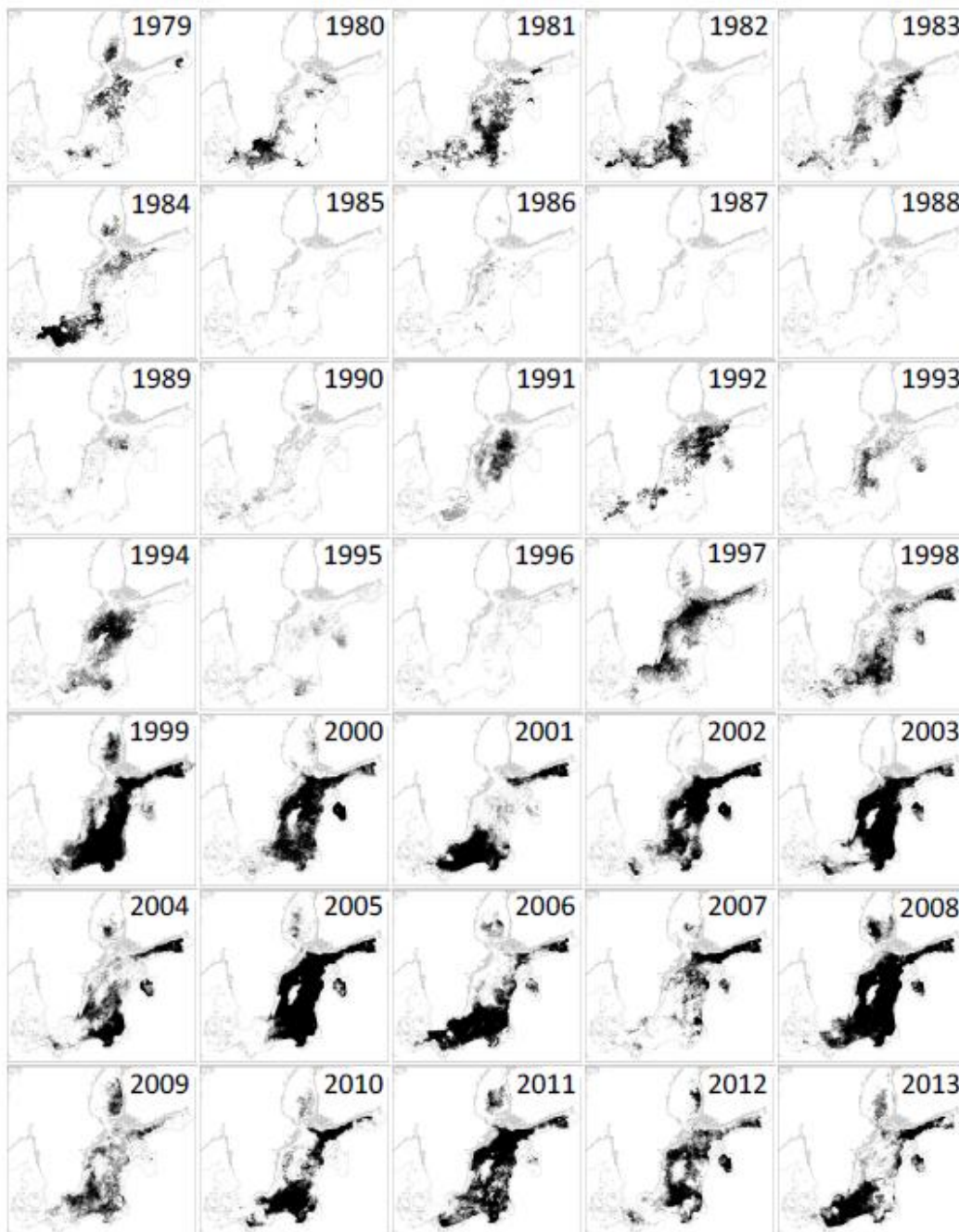
increased during this time. However, the development has not been linear as the period with the lowest amount of blooms occurred in the late 1980s – early 1990s.



Result figure 2: Mean areal fraction of cyanobacteria accumulations (FCA%) and total accumulated area affected (TA) in the entire Baltic Sea between 1979 and 2013. From Kahru and Elmgren (2014).

The general trend in indicator status of sub-basins is decreasing for Northern Baltic Proper and Western Gotland Basin. For the Gulf of Finland and Eastern Gotland Basin, recent years show slightly better status than during the time period of 1998-2010. However, observations before 1996 show on average higher status years than the years following this time point.

The increase of cyanobacterial blooms in the late 1900s first commenced in the Baltic Proper and soon after they were also observed in the Gulf of Finland and Gulf of Riga. Blooms have been rare in the Bothnian Sea up until the early 2000s (Result figure 3).

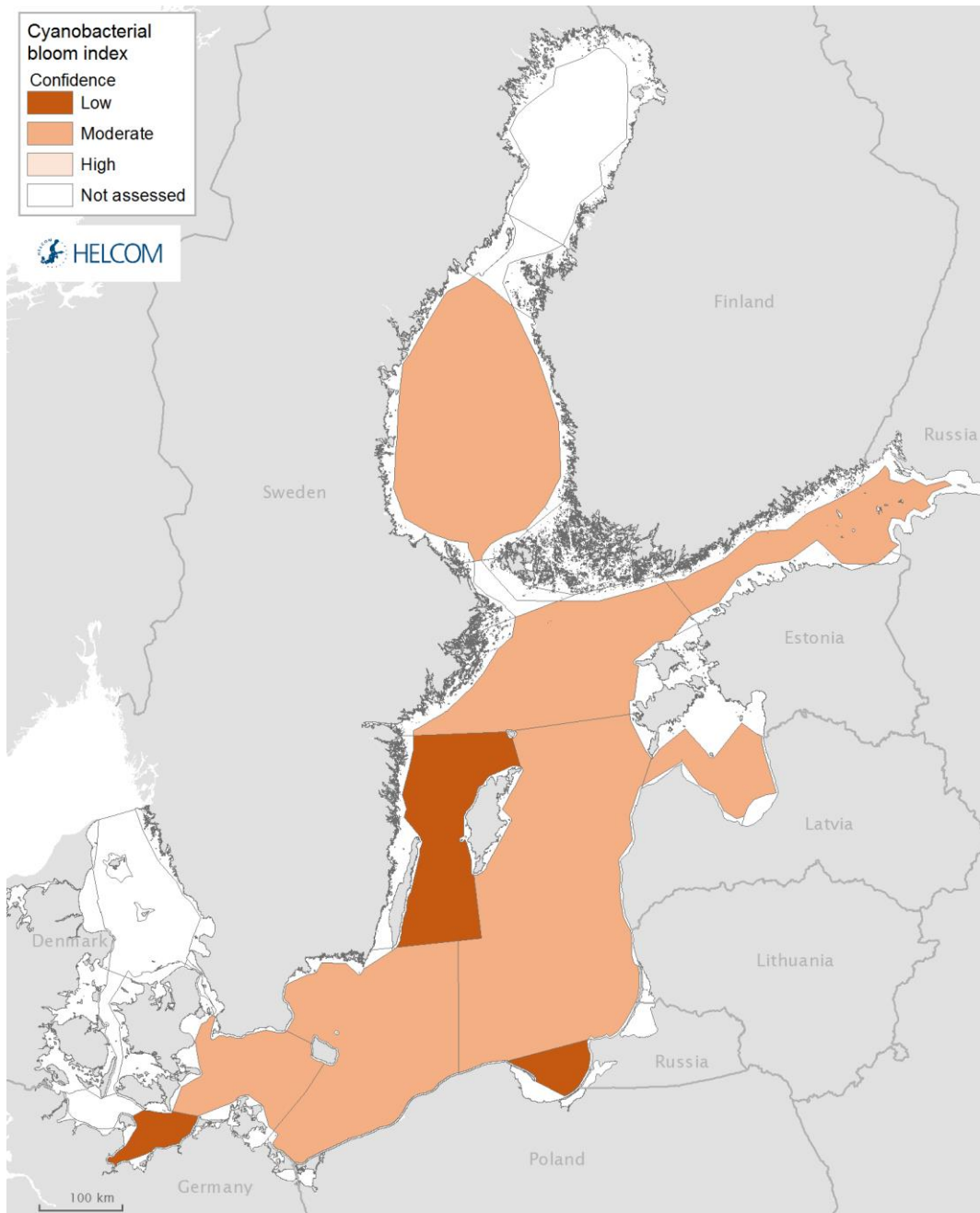


Result figure 3: Mean fraction of cyanobacteria accumulations (FCA) in July-August between 1979 and 2014. From Kahru and Elmgren (2014).

Confidence of the indicator status evaluation

The confidence of the status estimate was high (ES-score 100) for the 7 basins where both Earth Observation (EO-) and biomass-estimates could be applied: the Arkona Sea, Bornholm Sea, Eastern Gotland Basin, Gulf of Riga, Northern Baltic Proper, Gulf of Finland and Bothnian Sea. Three sub-basins showed decreased status confidence, due to one or more lacking parameters: the Gdansk Basin, Western Gotland Basin and Bay of Mecklenburg.

The threshold confidence was moderate (ET-Score 50). The dataset used to derive threshold conditions was started from year 1979 (or 1990, when only biomass data available). The variability in the datasets used in setting the threshold value affects the confidence estimates of this boundary value.



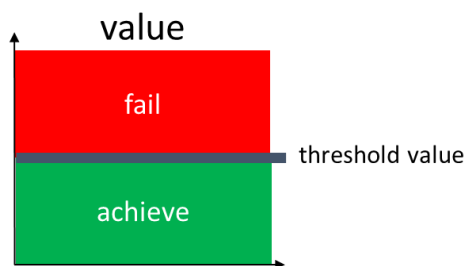
Result figure 4. Indicator status confidence, determined by combining information on data availability and reliability of threshold-setting protocol. Low indicator confidence calls for increase in monitoring.

Good Environmental Status

This pre-core indicator and its threshold values are yet to be commonly agreed in HELCOM.

The indicator is included as test indicator for the purposes of the mid-2017 'State of the Baltic Sea' report, and the results are to be considered as intermediate.

The indicator uses assessment unit specific threshold values that are presented as normalized values. The indicator is based on two parameters: (1) cyanobacterial surface accumulation (CSA) and (2) cyanobacterial biomass. A threshold value is set for each parameter for each assessment unit, and the combined indicator threshold value is an average of the two. Observation values that are below the threshold value indicate good status (Good Environmental Status figure 1).



Good environmental status figure 1. Schematic representation of the averaged and normalized threshold value applied in the cyanobacteria bloom index pre-core indicator, the threshold values are assessment unit specific (see Good environmental status table 1).

If either parameter is not applicable to a specific assessment unit, then only one parameter is used as the threshold value. If both parameters are applicable, then an averaged normalized value is used as the threshold value. The specific values for each parameter and the proposed overall threshold value are listed in Good Environmental status table 1.

Good environmental status table 1. Summary table of assessment unit specific threshold values in the open-sea areas. Detailed information on estimating the threshold values is provided in Annex 1.

HELCOM ID	Assessment unit (open sea)	Proposed CSA threshold value (normalized between 0-1, with 1 expressing good status)	Proposed cyanobacteria biomass threshold value (normalized between 0-1, with 1 expressing good status)	Proposed threshold value for CyaBI (normalized threshold between 0-1, with 1 expressing good status)	Comments on indicator protocol
SEA-001	Kattegat	Not relevant	Not relevant	Not relevant	
SEA-002	Great Belt	Not relevant	Not relevant	Not relevant	
SEA-003	The Sound	Not relevant	Not relevant	Not relevant	
SEA-004	Kiel Bay	Not relevant	Not relevant	Not relevant	
SEA-005	Bay of Mecklenburg	Not applicable	0.92	0.92	Indicator based only on biomass
SEA-006	Arkona Sea	0.86	0.94	0.90	Indicator average of CSA and biomass
SEA-007	Bornholm Sea	0.86	0.87	0.87	Indicator average of CSA and biomass
SEA-008	Gdansk Basin	0.98	na	0.98	Indicator only based on CSA
SEA-009	Eastern Gotland Basin	0.84	0.84	0.84	Indicator average of CSA and biomass
SEA-010	Western Gotland Basin	0.87	na	0.87	Indicator based only on CSA
SEA-011	Gulf of Riga	0.92	0.88	0.90	Indicator average of CSA and biomass
SEA-012	Northern Baltic Proper	0.77	0.77	0.77	Indicator average of CSA and biomass
SEA-013	Gulf of Finland	0.96	0.83	0.90	Indicator average of CSA and biomass
SEA-014	Åland Sea	Not applicable	Not applicable	Not applicable	
SEA-015	Bothnian Sea	0.86	0.30	0.58	Indicator average of CSA and biomass
SEA-016	The Quark	Not relevant	Not relevant	Not relevant	
SEA-017	Bothnian Bay	Not relevant	Not relevant	Not relevant	

Method description for deriving the threshold values

The threshold values for the assessment units were derived separately for the two long-term datasets used for the two indicator parameters:

- 1 - cyanobacterial surface accumulations (CSA); the independent satellite-based time series on algae accumulations from 1979-2014 in the Baltic Sea by Kahru and Elmgren (2014) and
- 2 - biomass; data on *in-situ* observations of cyanobacteria biomass 1990-2015 collated by the HELCOM PEG group (Wasmund et al. 2015).

The threshold values are derived by combining statistical analysis of long-term data with expert judgement. The main concern in proposing threshold values is the lack of sound and consistent historical data. The data starting from 1970s or 1980s, which are available in the threshold setting datasets do not correspond to “no, or very little human impact” that could be used as a reference condition. As cyanobacterial blooms are a natural phenomenon in the Baltic Sea the threshold values do not need to describe a status with no blooms, but rather a status without extensive and potentially harmful blooms. This status should be consistent with sustainable use of the sea by humans.

Investigations of stable nitrogen and carbon isotope composition as well as of the organic carbon content of sediments have shown that the increase in nutrients and productivity began already in the 1950s–1960s (Andrén et al., 2000; Struck et al., 2000; Poutanen & Nikkilä, 2001). According to Finni et al. (2001), cyanobacterial blooms have become common in the open sea in both the Baltic Proper and the Gulf of Finland since at least the 1960s.

To meet this aim of identifying time periods with low bloom intensity, the thresholds were derived based on the time periods within the available datasets where the status was already impacted by eutrophication but the bloom intensity was low. Within the time periods covered by the available datasets, the status covers varying levels of cyanobacterial blooms. To distinguish the shorter periods of low bloom intensity in comparison to the general level, the shift detection method based on an algorithm (Rodinov 2004) was used; or if no such periods were distinguished, the averages of separate years with lower bloom intensity were calculated using the quartile method. The shift-detection method was successfully applied to all assessment units for the satellite-based cyanobacterial surface accumulations (CSA) (parameter 1) with data available since 1979. The data could be extended from 1992 to 1979 by using results provided by Kahru & Elmgren (2014), transforming corresponding indicator variables using a linear model between the two data sets (Anttila et al. *in prep*).

The shift-detection method was also applied to detect biomass threshold values in the Bothnian Sea, where cyanobacterial blooms did not occur regularly before the late 1990s. In the remaining assessment units where biomass data was not available from a time period before the vast increase of cyanobacterial blooms, threshold values were estimated using the quartile expressing lowest biomass.

Assessment Protocol

This pre-core indicator and its threshold values are yet to be commonly agreed in HELCOM.

The indicator is included as test for the purposes of the mid-2017 'State of the Baltic Sea' report, and the results are to be considered as intermediate.

The 'Cyanobacterial bloom index' indicator evaluates the increase in cyanobacterial blooms, taking into account different aspects of the bloom phenomenon. As a multiparametric index, it has the advantage of taking into account different types of data, e.g. observed from different platforms: remotely (satellites) or *in-situ* (measurements in the sea), and measured using varying techniques.

All applied parameters must fulfill the following requirements: they 1) describe a relevant aspect of cyanobacteria accumulations not already considered by the other parameters, 2) have sub-basin specific threshold values and 3) be updatable by status values for the sub-basin division and status period defined for the existing indicator.

This HELCOM pre-core indicator (CyaBI) consists of two parameters: 1) **cyanobacterial surface accumulations (CSA)**, combining information of volume, length of bloom period and severity of surface accumulations estimated from remote sensing observations and 2) the **cyanobacteria biomass** in the water column analyzed from in-situ observations. The parameters are normalized, to allow combined use of the different parameters in the index.

The CSA (parameter 1) relies on high-frequency data, and is optimal for describing the bloom formation at the surface. However, this parameter is strongly influenced, not only by eutrophication, but also by climate-related variation including wind conditions. The cyanobacteria biomass (parameter 2) supplements CSA by providing information of the actual amount of cyanobacteria in the water column. Due to less frequent monitoring, neither the status evaluation nor the threshold values of cyanobacteria biomass have sufficient confidence to stand alone as a HELCOM core indicator. Combining the two parameters, allows for deriving more reliable status estimates: an indicator expressing the consequence of increased cyanobacteria (the blooms) with high confidence; yet related strongly to changes in the actual amount of cyanobacteria, and subsequently, to eutrophication.

The 'Cyanobacterial bloom index' indicator responds negatively to increasing eutrophication, i.e. low values indicate increased eutrophication.

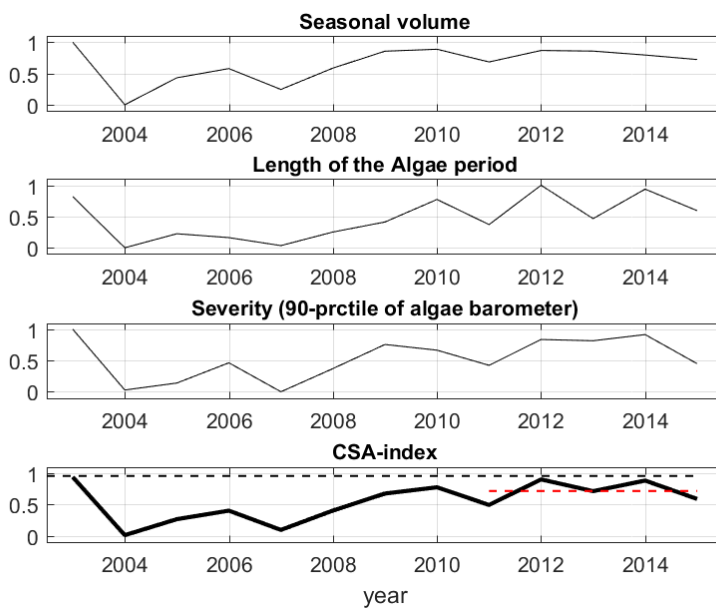
Parameter 1: Cyanobacterial surface accumulations (CSA)

The main data source used in the development of the indicator was satellite data derived from the daily algal bloom product of the Finnish Environment Institute (SYKE), which is in turn based on chlorophyll-*a* and turbidity products. The observations were interpreted to estimate the potentiality of surface algae accumulations in four classes [0-3 i.e. no, potential, likely and evident] (www.syke.fi/surfacealgalblooms). The spatial aggregation of daily Earth Observation (EO) observations from the assessment units was conducted by calculating an algae barometer value. The algae barometer (AB) value is a weighted sum of the proportion of positive algae observations in the different classes in an assessment area (Eq. 1; Rapala et al. 2012).

$$AB = \frac{1}{n_{tot}} (n_{\#cl1} + n_{\#cl2} \times 2 + n_{\#cl3} \times 3) \quad \text{Eq. 1}$$

where n_{tot} is the total number of algae observations, and $n_{\#cl1}$, $n_{\#cl2}$, and $n_{\#cl3}$ are the number of algae observations in classes 1-3.

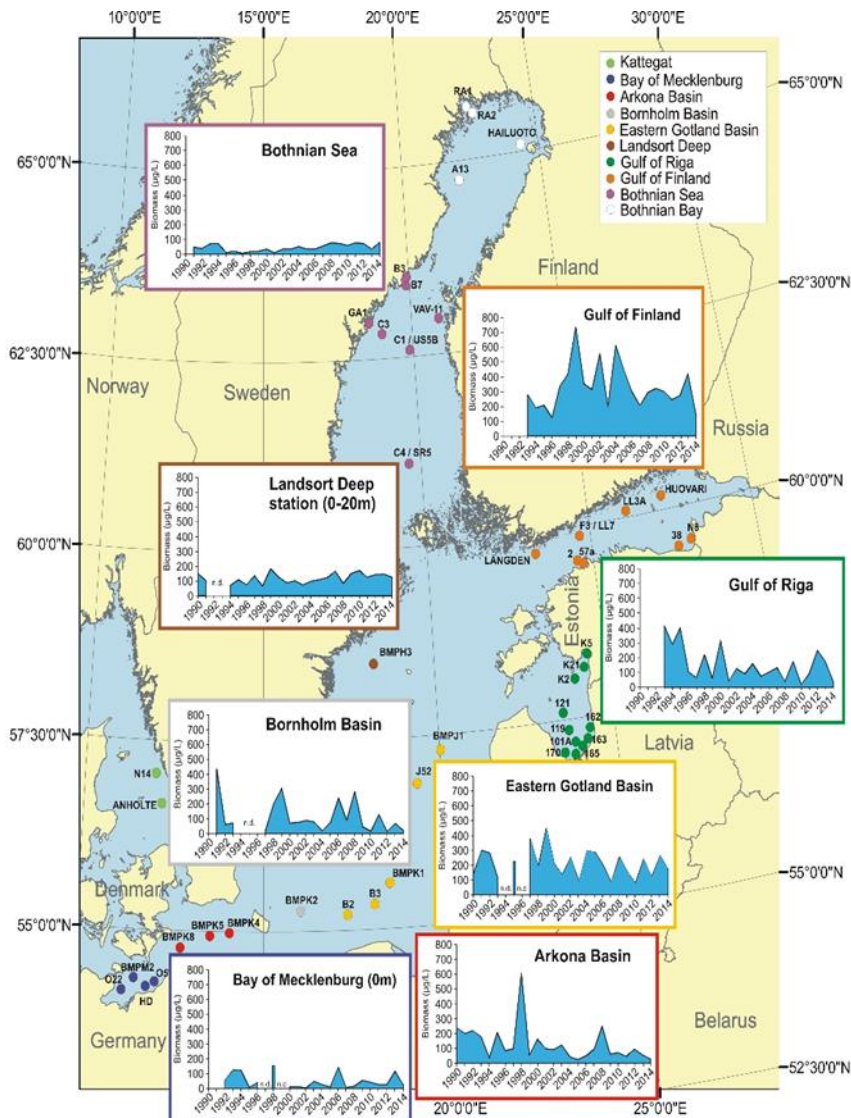
Seasonal bloom characteristics were estimated using an empirical cumulative distribution function (ECDF) drawn from seasonal observations of daily algae barometer values from each assessment area. ECDF gives the cumulative proportion of the seasonal algae barometer values. The bloom characteristics (i.e. the indicative variables of CSA) were defined for each assessment unit as follows: 1) seasonal volume, i.e. the areal coverage above the ECDF functions, 2) length of the algal surface accumulation period, i.e. the percentage of observations with algae barometer values above zero, and 3) bloom severity, i.e. the 90-percentile of the algae barometer observations. The CSA index time series was derived by taking an average from the normalized time series of the indicative variables and grouping all the three EO-based parameters together.



Assessment protocol figure 1. An example (Gulf of Finland) of grouping the normalized EO-based parameters (from top to bottom) A) seasonal bloom volume, B) length of bloom period and C) Severity of blooms into D) a combined cyanobacterial surface accumulation (CSA) parameter. As the indicator responds negatively to increased eutrophication, 1 represents the best conditions and 0 the worst. Black dashed horizontal line indicates the parameter-specific target condition and the red dashed line indicates the estimate for 2011-2014.

Parameter 2: Cyanobacteria biomass

Cyanobacteria biomass was analyzed by microscope from water samples. The data used in the indicator parameter originated from Estonian, Finnish, German, Latvian, Lithuanian, Polish and Swedish national monitoring data, and was collated by the HELCOM phytoplankton expert group (PEG), in order to produce a HELCOM Baltic Sea Environmental Fact Sheet, updated annually (Wasmund et al. 2015). The main sampling locations are presented in Assessment protocol figure 2.



Assessment protocol figure 2. Map of the regularly sampled stations, containing one graph on diazotrophic cyanobacteria biomass per area (seasonal mean biomass $\mu\text{g/L}$). Names of some Finnish coastal stations are abbreviated. Stations in Bothnian Bay, Kiel Bay and Kattegat have been tested but the results are not presented.

The data included biomass analyses (wet weight in $\mu\text{g/L}$) of integrated samples (0-10 m, less at some shallower coastal stations; 0-20 m at the Landsort Deep; surface = 0-1 m in Bay of Mecklenburg). Sampling at the Finnish high-frequency coastal stations "Hailuodon ed int.asema", "Suomenl Huovari Kyvy-8A", "UUS-23 Längden" and "Vav-11 V-4" reached from surface to the depth of 2x Secchi depth (usually 0-8m); they could be integrated into the existing data series without problems. Genera included in the index include: *Nodularia*, *Aphanizomenon* and *Dolichospermum* (previously *Anabaena*).

The information is based on national monitoring samples analyzed and identified by phytoplankton experts, using the mandatory HELCOM methods (HELCOM 2014). Additional explanations on the counting procedure in size classes is given by Olenina et al. (2006). Sampling frequency was variable and dependent on national monitoring cruises. At least one sample per month has to be available to allow the calculation

of the seasonal average. This precondition could also be fulfilled by pooling nearby stations. Only with a few exceptional cases are data presented despite missing data from one month out of three.

Monthly means were calculated from the single data, which served as a basis for calculation of seasonal mean values.

Assessment units

The pre-core indicator is applicable in 10 open sea assessment units (at least one nautical mile seawards from the baseline).

The indicator is applicable in the following open sea assessment units: Bothnian Sea, Gulf of Finland, Northern Baltic Proper, Gulf of Riga, Western Gotland Basin, Eastern Gotland Basin, Bornholm Sea, Gdansk Basin, Arkona Sea and Bay of Mecklenburg. The indicator is currently not relevant in the Kattegat, the Sound areas, the Bothnian Bay and the Quark due to the absence of cyanobacterial bloom formations, and in its present form, not applicable in Åland Sea or coastal areas. It is also not used in the Kiel Bay, as the relevance of the indicator remains un-certified.

The indicator is assessed within the geographical assessment unit level 4 proposed by HELCOM: open sea sub-basin areas and coastal waters WFD coastal types and bodies. The assessment units are defined in the [HELCOM Monitoring and Assessment Strategy Annex 4](#).

Relevance of the Indicator

This pre-core indicator and its threshold values are yet to be commonly agreed in HELCOM.

The indicator is included as test for the purposes of the mid-2017 'State of the Baltic Sea' report, and the results are to be considered as intermediate.

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 cyanobacterial blooms, this indicator also contributes to the overall eutrophication assessment along with the other eutrophication core indicators. The integrated eutrophication assessments of the open sea areas is based on an integration of the evaluation of several core indicators. Since cyanobacterial blooms are affected also by non-eutrophication related changes (see chapter 'Role of cyanobacterial blooms in the ecosystem'), the indicator should receive a low weight, unless unusually high relationship to eutrophication is shown.

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".

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). The Commission Decision on GES (2017) defines 'Harmful algal blooms (e.g. cyanobacteria) in the watercolumn' as the criteria element to be assessed using the criteria D5C3 'The number, spatial extent and duration of harmful algal bloom events are not at levels that indicate adverse effects of nutrient enrichment'.

Role of cyanobacterial blooms in the ecosystem

Surface blooms of nitrogen-fixing cyanobacteria, though considered to be a natural phenomenon (Bianchi et al. 2000), have become extensive and frequent in many parts of the Baltic Sea since the 1990s (Finni et al. 2001). The blooms consist partly of the toxic species *Nodularia spumigena*, which has been reported to have negative effects on grazing zooplankton (Engström et al. 2000, Sellner et al. 1994, Sopanen et al. 2009). Cyanobacteria have been shown to have allelopathic effects on other phytoplankton groups and increasing effects on bacteria (Suikkanen et al. 2004, 2005). Since a major part of the cyanobacteria biomass generated during the bloom events eventually is settled on the bottom, it potentially increases oxygen depletion in stratified areas (Vahtera et al. 2007a). Thus, extensive cyanobacterial blooms potentially have a negative impact on the biodiversity of both the pelagic and the benthic communities.

The increase of cyanobacterial blooms is partly caused by anthropogenic nutrient enrichment, especially the proportional increase of dissolved phosphorus. Also other, non-eutrophication related, causes have

been suggested: hydrographic changes, such as increased temperature, decreased salinity or more frequent vertical mixing; changes in micronutrients or trace metals as well as changes in the phytoplankton relations may have an effect (Kahru et al. 1994).

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	

Monitoring Requirements

This pre-core indicator and its threshold values are yet to be commonly agreed in HELCOM.

The indicator is included as test for the purposes of the mid-2017 'State of the Baltic Sea' report, and the results are to be considered as intermediate.

Monitoring methodology

Monitoring of cyanobacteria in the Contracting Parties of HELCOM is described on a general level in the **HELCOM Monitoring Manual in the [sub-programme phytoplankton species composition, abundance and biomass](#)**.

Specific monitoring guidelines are under development with the aim to be included in the HELCOM Monitoring Manual at a later stage.

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 [sub-programme phytoplankton species composition, abundance and biomass](#)**

The temporal and spatial coverage of the satellite remote sensing data used can be considered high in the open sea areas as well as in the outer coastal assessment areas of the Baltic Sea.

Cyanobacterial biomass monitoring takes place according to the national monitoring programmes.

Description of optimal monitoring

For remote sensing data, annually at least 30 daily spatial aggregates from valid bloom observations in an assessment area should be applied from the period between June 20th – August 30th in order to derive the annual bloom characteristics information. The compilation of observations is expected to be distributed spatially within the assessment unit in a non-biased way.

For biomass data, at least one sample per month has to be available to allow the calculation of seasonal averages. This precondition could also be fulfilled by pooling nearby stations.

Data and updating

This pre-core indicator and its threshold values are yet to be commonly agreed in HELCOM.

The indicator is included as test for the purposes of the mid-2017 'State of the Baltic Sea' report, and the results are to be considered as intermediate.

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) Cyanobacteria bloom index. HELCOM pre-core indicator report. Online. [Date Viewed], [Web link].

ISSN 2343-2543

Metadata

Result: Cyanobacterial bloom index

Data source:

The remote sensing data source was the daily surface algae products of the Finnish Environment Institute (SYKE) from the years 2003-2014 (operative version of the product can be found on www.syke.fi/surfacealgalblooms), which are in turn based on the respective chlorophyll *a* and turbidity products. The remote sensing data used in this study were produced with same methods as the operative version but reprocessed in order to provide as harmonized data set as possible.

Chlorophyll *a* concentrations were derived for the MERIS observations using BEAM plug-in processor MERIS Case-2 Water Properties Processor (FUB) according to Schroeder et al. (2007) and Schroeder et al. (2007a; 2007b). The MERIS turbidity estimations applied the BEAM plug-in processor Case 2 Regional (C2R; version 1.6.2) according to Doerffer and Schiller (2007). The use of this processor for MERIS data is supported also by other studies conducted in the Baltic Sea by Kratzer et al. (2008), Beltrán-Abaunza et al. (2014) and Harvey et al. (2015). The MODIS chlorophyll *a* and turbidity were derived according to Maritorena et al. (2002; 2010) and O'Reilly et al. (1998; 2000). In the case of MODIS data, the algorithms for chlorophyll *a* and turbidity were adjusted to the best performance when compared to *in situ* data (available monitoring programme observations).

The cyanobacteria biomass was collected and analysed by the HELCOM PEG group.

Geographical coverage:

- Spatial coverage of remote sensing observations, namely the average cloud-free area in satellite images varied between 18-31%. It must be noted that totally cloudy images were included in these calculations. The indicator can be applied for the open sea and outer coastal assessment areas of the Baltic Sea.
- Cyanobacteria biomass was observed at HELCOM COMBINE stations situated in the Kiel Bay, Bay of Mecklenburg, Arkona Basin, Bornholm Basin, Eastern Gotland Basin, Northern Baltic Proper, Gulf of Riga, Gulf of Finland and Bothnian Sea.

Temporal coverage:

- Remote sensing is observed to give at least one valid observation in an assessment area on an average of 49% of days between June 20th – August 31th
- cyanobacteria biomass observations were monthly.

Data aggregation: The 2011-2015 values for each sub-basin were estimated as an inter-annual summer (20th of June – 31st of August) averages.

Contributors and references

Contributors

Saku Anttila^{*1}, Vivi Fleming-Lehtinen², Jenni Attila¹, Sofia Junttila¹ and Heidi Hällfors¹

1) Finnish Environment Institute (SYKE), P O Box 140, FI-00251, Helsinki, Finland.

2) Baltic Marine Environment Protection Commission

* email address saku.anttila@ymparisto.fi

HELCOM Expert Network on Eutrophication

Archive

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

[HOLAS II component – Pre-core indicator report – web-based version July 2017](#) (pdf)

References

Anonymous. 2000. DIRECTIVE 2000/60/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 October 2000 establishing a framework for Community action in the field of water policy (Water Framework Directive). Official Journal of the European Union, L 327/2, 22.12.2000.

Anonymous. 2008. Directive 2008/56/EC of the European Parliament and the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). Official Journal of the European Union, L 164/19, 25.06.2008.

Bianchi TS, Engelhaupt, E, Westman, P, Andrén, T, Rolff, C and Elmgren, R. 2000. Cyanobacterial blooms in the Baltic Sea: Natural or human-induced? *Limnology and Oceanography* 45:716-726.

Engström, J, Koski, M, Viitasalo, M, Reinikainen, M, Repka, S and Sivonen, K. 2000. Feeding interactions of the copepods *Eurytemora affinis* and *Acartia bifilosa* with the cyanobacteria *Nodularia* sp.

Finni, T., Kononen, K., Olsonen, R., Wallström, K., 2001. The history of cyanobacterial blooms in the Baltic Sea. *Ambio* 30, 172-178. *Journal of Plankton Research* 22:1403-1409.

HELCOM, 2007. Activities 2006 Overview. *Baltic Sea Environment Proceedings* 112. 74 pp. <http://helcom.fi/Lists/Publications/BSEP112.pdf>

HELCOM. 2012. HELCOM core indicators, final report of the HELCOM CORESET project. *Baltic Sea Environment Proceedings* 136. 71 pp. <http://helcom.fi/Lists/Publications/BSEP136.pdf>

HELCOM. 2013. Eutrophication status of the Baltic Sea 2007-2011 - A concise thematic assessment. *Baltic Sea Environment Proceedings* 143. 41 pp. Available online at <http://helcom.fi/Lists/Publications/BSEP143.pdf>

Hällfors H, Backer H, Leppänen J-M, Hällfors S, Hällfors G and Kuosa H. The northern Baltic Sea phytoplankton communities in 1903-1911 and 1993-2005: a comparison of historical and modern species data. *Hydrobiologia* DOI 10.1007/s10750-012-1414-4.

Kahru, M., Elmgren, R. 2014. Satellite detection of multi-decadal time series of cyanobacteria accumulations in the Baltic Sea. *Biogeosciences Discussions*, 11, 3319-3364.

Kahru M, Horstmann U and Rud O 1994. Satellite detection of increased cyanobacteria blooms in the Baltic Sea: natural fluctuation or ecosystem change? *Ambio* 23:469-472.

Maritorena S, Siegel, DA, Peterson, AR, 2002. Optimization of a semianalytical ocean color model for global-scale applications. *Applied Optics*, 41: 2705-2714.

Maritorena S, Fanton d'Andon, OH, Mangin, A, Siegel, DA, 2010. Merged Satellite Ocean Color Data Products Using a Bio-Optical Model: Characteristics, Benefits and Issues. *Remote Sensing of Environment*, 114, 8: 1791-1804.

O'Reilly, J. E., Maritorena, S., Mitchell, B. G., Siegel, D. A., Carder, K. L., Garver, S. A., Kahru, M. and McClain, C. 1998. Ocean color chlorophyll algorithms for SeaWiFS. *Journal of Geophysical Research: Oceans* (1978–2012), 103(C11), 24937-24953.

O'Reilly, JE, Maritorena, S, Siegel, DA, O'Brien, MC, Toole, D, Mitchell, BG, Kahru, M, Chavez, FP, Strutton, P, Cota, GF, Hooker, SB, McClain, CR, Carder, KL, Müller-Karger, F, Harding, L, Magnuson, A, Phinney, D, Moore, GF, Aiken, J, Arrigo, KR, Letelier, R, Culver, M, 2000. Ocean color chlorophyll algorithms for SeaWiFS, OC2, and OC4: Version 4. In S. B. Hooker, & E. R. Firestone (Eds.), *SeaWiFS Postlaunch Calibration and Validation Analyses, Part 3, NASA Technical Memorandum, 2000-206892*, vol. 11 (pp. 9 – 27). Greenbelt, MD: NASA Goddard Space Center.

Poutanen, E. L. & Nikkilä, K. (2001). Carotenoid pigments as tracers of cyanobacterial blooms in recent and post-glacial sediments of the Baltic Sea. *AMBIO: A Journal of the Human Environment*, 30(4), 179-183.

Rapala, J, Kilponen, J, Järvinen, M, Lahti, K. 2012. Finland: guidelines for monitoring of cyanobacteria and their toxins. In Chorus, I. (ed.). *Current approaches to Cyanotoxin risk assessment, risk management and regulations in different countries*. Umweltbundesamt publications, 63: 54-62.

Rodionov, S. N. 2004. A sequential algorithm for testing climate regime shifts. *Geophysical Research Letters*, 31(9), L09204.

Rodionov, S., & Overland, J. E. 2005. Application of a sequential regime shift detection method to the bering sea ecosystem. *ICES Journal of Marine Science*, 62(3), 328-332.

Schroeder, TH, Behnert, I, Schaale, M, Fisher, J, Doerffer, R, 2007a. Atmospheric correction for MERIS above Case-2 waters. *International Journal of Remote Sensing*, 28, pp. 1469–1486.

Schroeder, TH, Schaale, M, Fisher, J, 2007b. Retrieval of atmospheric and oceanic properties from MERIS measurements: A new Case-2 water processor for BEAM. *International Journal of Remote Sensing*, 28: 5627-5630.

Sellner, KG, Olson, MM and Kononen, K, 1994. Copepod grazing in a summer cyanobacteria bloom in the Gulf of Finland. *Hydrobiologia* 292/293:249-254.

Sopanen, S, Uronen, P, Kuuppo, P, Svensen, C, Rühl, A, Tamminen, T, Granéli, E and Legrand, C, 2009. Transfer of nodularin to the copepod *Eurytemora affinis* through the microbial food web. *Aquat. Microb. Ecol.* 55:115-130.

Suikkanen, S, Fistarol, GO and Granéli, E, 2004. Allelopathic effects of the Baltic cyanobacteria *Nodularia spumigena*, *Aphanizomenon flos-aquae* and *Anabaena lemmermannii* on algal monocultures. *Journal of Experimental Marine Biology and Ecology* 308:85-101.

Suikkanen, S, Fistarol, GO and Granéli, E, 2005. Effects of cyanobacterial allelochemicals on a natural plankton community. *Marine Ecology Progress Series* 287:1-9.

Vahtera E, Conley DJ, Gustafsson BG, Kuosa H, Pitkänen H, Savchuk OP, Tamminen T, Viitasalo M, Voss M, Wasmund N, Wulff F, 2007a. Internal ecosystem feedbacks enhance nitrogen-fixing cyanobacteria blooms and complicate management in the Baltic Sea. *Ambio* 36:186-194.

Wasmund N, Busch S, Göbel J, Gromisz S, Högländer H, Jaanus A, Johansen M, Jurgensone I, Karlsson C, Kownacka J, Kraśniewski W, Lehtinen S, Olenina I, v. Weber M, 2015. Cyanobacteria biomass. HELCOM Baltic Sea Environment Fact Sheet 2015, Published 18 September 2015. <http://helcom.fi/baltic-sea-trends/environment-fact-sheets/eutrophication/cyanobacteria-biomass/>

HELCOM core indicator report,
ISSN 2343-2543