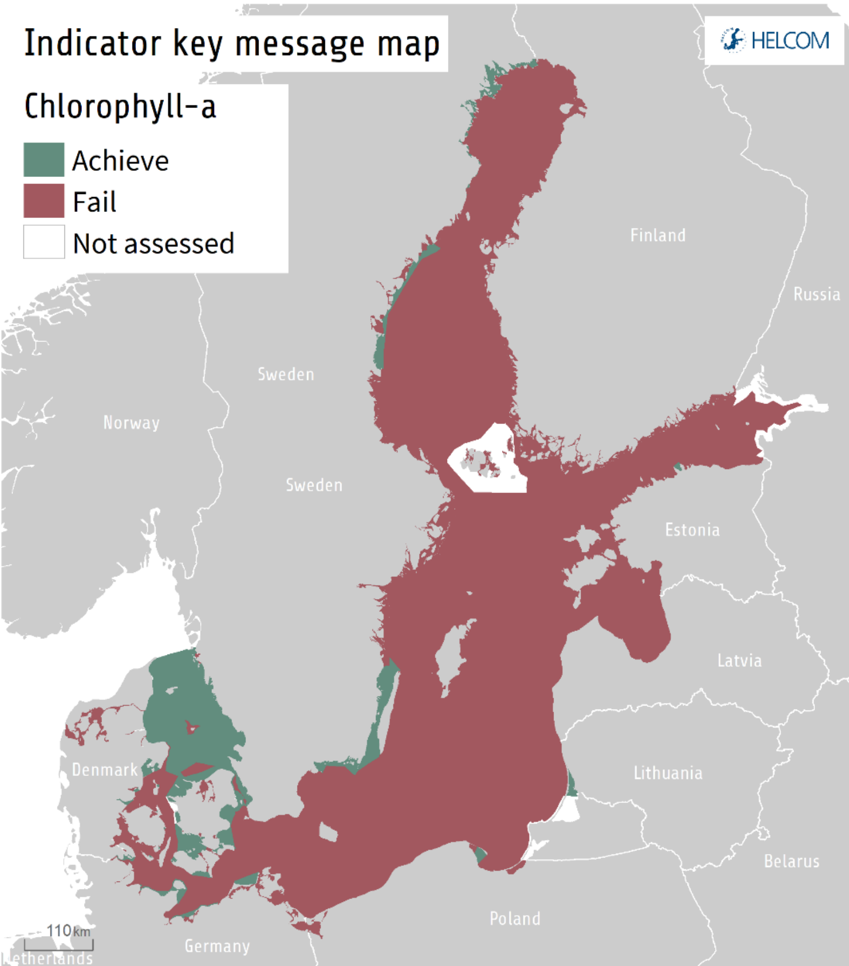
HELCOM core indicator report
July 2018

Chlorophyll-*a*

Key Message

This core indicator evaluates the average chlorophyll-*a* concentration in surface water (0 – 10 m) during summer (June – September) during the assessment period 2011-2016.

In open sea areas, good status of chlorophyll-a was only 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 for Sweden, Denmark, Germany, Poland, Lithuania and Estonia (Key message figure 1).



Key message figure 1. Status assessment results evaluation for 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). Note the open sea area of The Sound is red (fails the threshold value). **Click here to access interactive map at the HELCOM Map and Data Service: Chlorophyll a.**

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

The confidence of the presented chlorophyll-a status estimate is **high** in all open sea assessment unit except Kattegat, where the confidence is moderate.

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

Relevance of the core indicator

Phytoplankton abundance and biomass increases due to increased eutrophication, directly 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

HELCOM (2018). Chlorophyll *a*. HELCOM core indicator report. Online. [Date Viewed], [Web link].

ISSN 2343-2543

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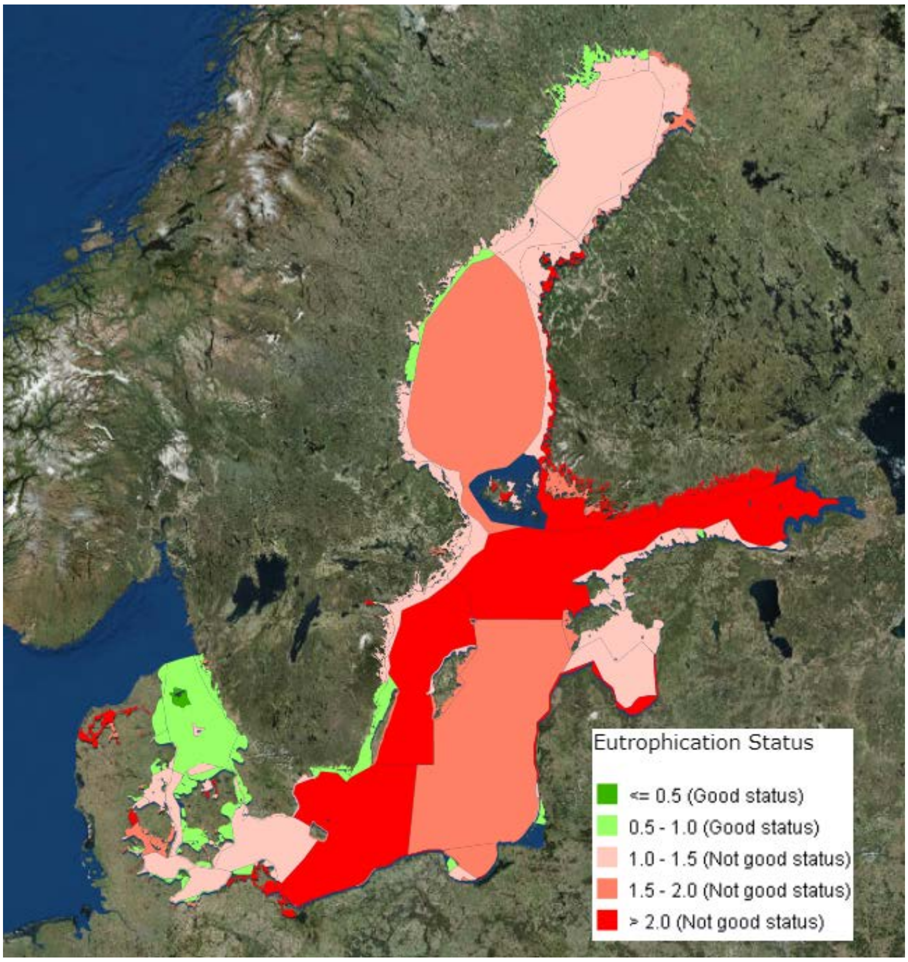
Chlorophyll a HELCOM core indicator 2018 (pdf)

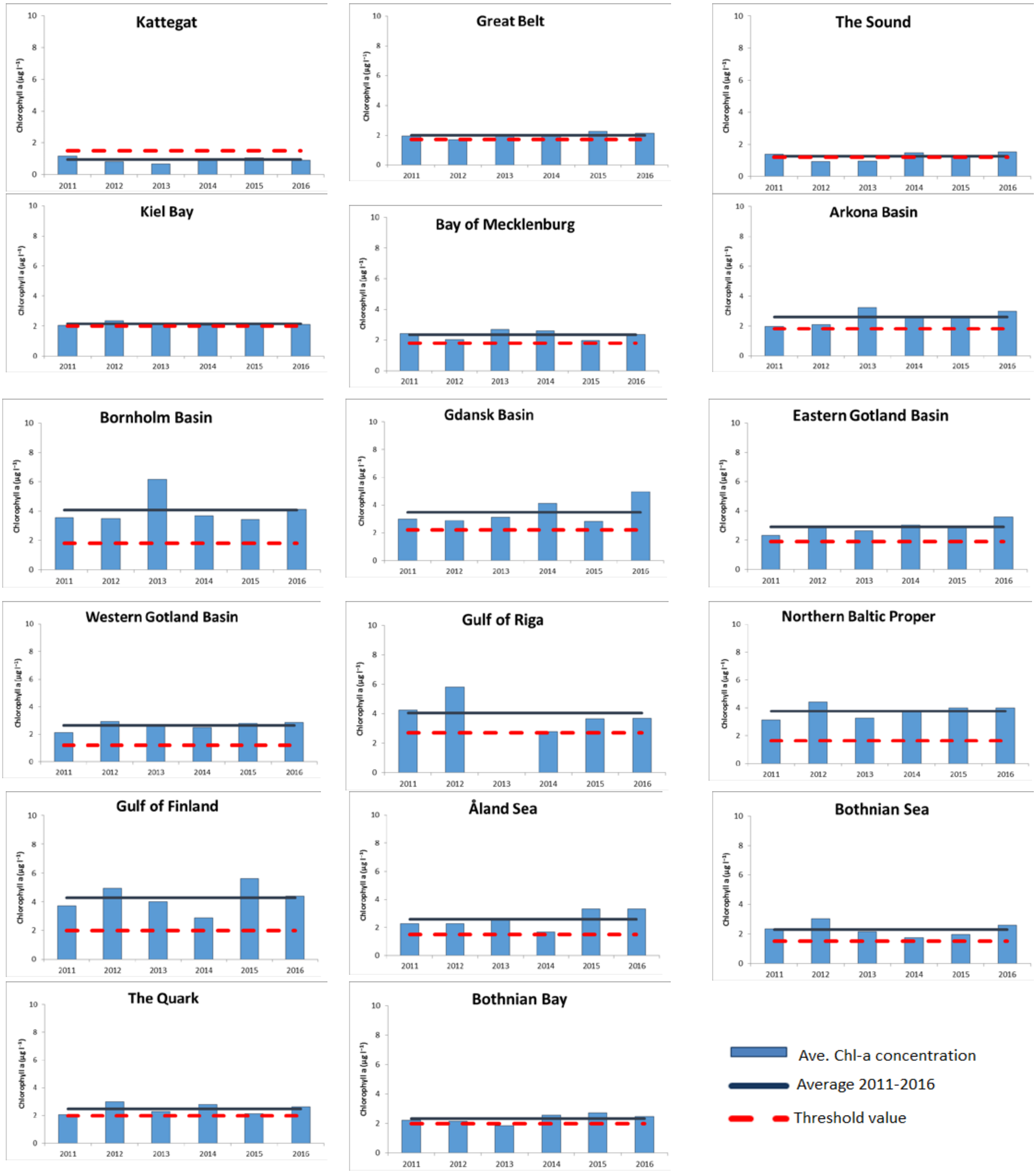
Results and Confidence

Current status of the Baltic Sea chlorophyll-*a*

In open sea areas, good status (concentrations of chlorophyll-a below the threshold value) has been achieved in the Kattegat. In the remaining 16 sub-basins the threshold value was failed, thus the status was not good. The open sea assessment units causing greatest concern regarding chlorophyll-a status (ER > 2.0) are the Gulf of Finland, Northern Baltic Proper, Western Gotland Basin, and Bornholm Basin. The Bothnian Sea, Åland Sea, Eastern Gotland Basin and Gransk Basin (ER values between 1.5 and 2.0), and the Bothnian Bay, The Quark, Gulf of Riga, Arkona Basin, Bay of Mecklenburg, Kiel Bay, Great Belt and The Sound (ER values between 1.0 and 1.5), fail their threshold values more narrowly and thus also receive not good status (Results figure 1 and Results Table 1). Trends during the current assessment period and the respective threshold values for open sea areas are shown in Results Figure 2, and longer term trends are discussed in detail below.



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 2011-2016) and threshold value as agreed by HELCOM HOD 39/2012 (red broken line). Where no data was available an empty spaces is shown where the bar would be. 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 2011-2016), 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 (µg l^{-1})	Average 2011-2016 (µg l^{-1})	Eutrophication ratio, ER	STATUS (fail/achieve threshold value)
Kattegat	1.50	0.94	0.63	achieve
Great Belt	1.70	2.00	1.18	fail
The Sound	1.20	1.26	1.05	fail
Kiel Bay	2.00	2.16	1.08	fail
Bay of Mecklenburg	1.80	2.34	1.30	fail
Arkona Basin	1.80	2.59	1.44	fail
Bornholm Basin	1.80	4.08	2.27	fail
Gdansk Basin	2.20	3.49	1.59	fail
Eastern Gotland Basin	1.90	2.90	1.52	fail
Western Gotland Basin	1.20	2.64	2.20	fail
Gulf of Riga	2.70	4.04	1.50	fail
Northern Baltic Proper	1.65	3.79	2.30	fail
Gulf of Finland	2.00	4.27	2.13	fail
Aland Sea	1.50	2.59	1.72	fail
Bothnian Sea	1.50	2.30	1.53	fail
The Quark	2.00	2.48	1.24	fail
Bothnian Bay	2.00	2.334	1.17	fail

In coastal waters, good status is found in some areas for Sweden, Denmark, Germany, Poland, Lithuania and Estonia. Certain coastal assessment units had very high (ER > 2.0) eutrophication ratios (Results figure 1 and Results Table 2).

Results table 2. Results for national coastal chlorophyll-a indicators by coastal WFD water type/water body. The table includes information on the assessment unit (CODE, defined in the HELCOM Monitoring and Assessment Strategy Annex 4), assessment period (start year and end year), average concentration during assessment period, threshold values, units, and Eutrophication Ratio (ER). The ER is coloured red or green to denote if the status evaluation has been failed or achieved, respectively. *indicates data used are annual, all other data are for the summer season, - indicates only status provided and not raw result value.

CODE	Period	Average	Threshold value	Units	Eutrophication ratio (ER)
DEN-001	2007-2013	5.30	2.10	µg l^{-1}	2.52
DEN-002	2007-2013	4.10	3.60	µg l^{-1}	1.14
DEN-003	2007-2013	1.50	1.70	µg l^{-1}	0.88
DEN-006	2007-2013	1.00	2.10	µg l^{-1}	0.48
DEN-007	2007-2013	1.50	2.10	µg l^{-1}	0.71
DEN-008	2007-2013	2.60	2.10	µg l^{-1}	1.24
DEN-009	2007-2013	3.10	2.10	µg l^{-1}	1.48
DEN-010	2007-2013	1.40	2.10	µg l^{-1}	0.67
DEN-011	2007-2013	1.40	1.60	µg l^{-1}	0.88
DEN-012	2007-2013	1.70	2.10	µg l^{-1}	0.81
DEN-013	2007-2013	1.70	2.10	µg l^{-1}	0.81
DEN-014	2007-2013	7.20	3.60	µg l^{-1}	2.00
DEN-015	2007-2013	1.30	2.10	µg l^{-1}	0.62

DEN-016	2007-2013	1.90	2.10	µg l-1	0.90
DEN-017	2007-2013	3.50	2.10	µg l-1	1.67
DEN-018	2007-2013	1.90	1.50	µg l-1	1.27
DEN-019	2007-2013	1.90	1.70	µg l-1	1.12
DEN-020	2007-2013	1.70	1.50	µg l-1	1.13
DEN-021	2007-2013	1.60	1.70	µg l-1	0.94
DEN-022	2007-2013	3.70	2.10	µg l-1	1.76
DEN-023	2007-2013	1.60	2.10	µg l-1	0.76
DEN-024	2007-2013	13.10	2.10	µg l-1	6.24
DEN-025	2007-2013	2.70	1.70	µg l-1	1.59
DEN-027	2007-2013	7.70	3.60	µg l-1	2.14
DEN-028	2007-2013	1.70	3.60	µg l-1	0.47
DEN-030	2007-2013	4.80	3.60	µg l-1	1.33
DEN-031	2007-2013	2.20	2.10	µg l-1	1.05
DEN-033	2007-2013	1.20	2.10	µg l-1	0.57
DEN-034	2007-2013	19.50	7.00	µg l-1	2.79
DEN-035	2007-2013	43.80	7.00	µg l-1	6.26
DEN-036	2007-2013	24.80	7.00	µg l-1	3.54
DEN-037	2007-2013	1.50	2.10	µg l-1	0.71
DEN-038	2007-2013	26.60	3.60	µg l-1	7.39
DEN-039	2007-2013	8.10	3.60	µg l-1	2.25
DEN-040	2007-2013	258.00	2.10	µg l-1	122.86
DEN-041	2007-2013	171.90	7.00	µg l-1	24.56
DEN-042	2007-2013	2.90	2.10	µg l-1	1.38
DEN-043	2007-2013	9.20	2.10	µg l-1	4.38
DEN-044	2007-2013	28.30	3.60	µg l-1	7.86
DEN-045	2007-2013	13.40	3.60	µg l-1	3.72
DEN-046	2007-2013	2.70	3.60	µg l-1	0.75
DEN-047	2007-2013	4.50	2.10	µg l-1	2.14
DEN-048	2007-2013	2.20	3.60	µg l-1	0.61
DEN-049	2007-2013	3.80	2.10	µg l-1	1.81
DEN-050	2007-2013	1.90	2.10	µg l-1	0.90
DEN-051	2007-2013	2.40	1.50	µg l-1	1.60
DEN-052	2007-2013	4.00	3.60	µg l-1	1.11
DEN-053	2007-2013	5.80	3.60	µg l-1	1.61
DEN-054	2007-2013	2.20	1.70	µg l-1	1.29
DEN-055	2007-2013	2.00	1.90	µg l-1	1.05
DEN-057	2007-2013	3.10	2.10	µg l-1	1.48
DEN-060	2007-2013	3.50	2.10	µg l-1	1.67
DEN-061	2007-2013	29.40	2.10	µg l-1	14.00
DEN-062	2007-2013	7.90	2.10	µg l-1	3.76
DEN-063	2007-2013	8.50	2.10	µg l-1	4.05
DEN-064	2007-2013	4.40	2.10	µg l-1	2.10
DEN-065	2007-2013	3.80	2.10	µg l-1	1.81
DEN-066	2007-2013	2.00	2.10	µg l-1	0.95
DEN-067	2007-2013	2.30	3.60	µg l-1	0.64
DEN-068	2007-2013	3.50	3.60	µg l-1	0.97
DEN-069	2007-2013	7.30	3.60	µg l-1	2.03
DEN-070	2007-2013	1.70	3.60	µg l-1	0.47
DEN-071	2007-2013	1.20	3.60	µg l-1	0.33
DEN-072	2007-2013	5.40	3.60	µg l-1	1.50
DEN-074	2007-2013	8.60	7.00	µg l-1	1.23
DEN-075	2007-2013	4.90	3.60	µg l-1	1.36
DEN-076	2007-2013	1.50	1.60	µg l-1	0.94
DEN-077	2007-2013	1.80	1.60	µg l-1	1.13
DEN-078	2007-2013	2.00	1.90	µg l-1	1.05

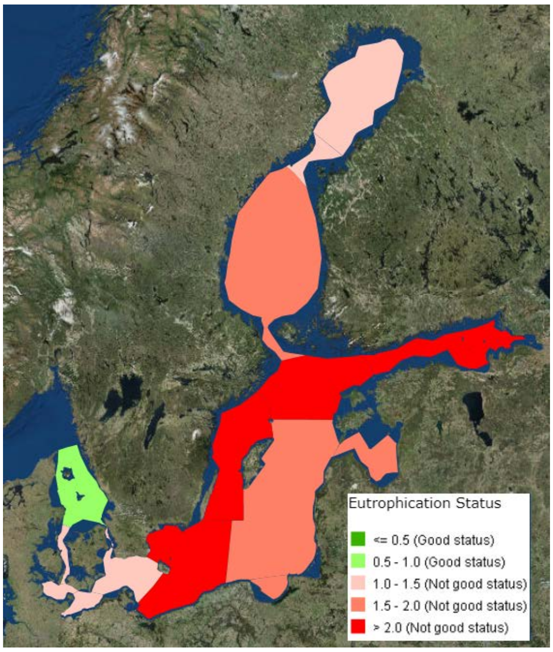
DEN-079	2007-2013	2.00	2.10	µg l-1	0.95
DEN-080	2007-2013	1.90	2.10	µg l-1	0.90
DEN-082	2007-2013	1.20	2.10	µg l-1	0.57
DEN-083	2007-2013	5.90	3.60	µg l-1	1.64
DEN-084	2007-2013	1.50	2.10	µg l-1	0.71
DEN-085	2007-2013	0.50	1.60	µg l-1	0.31
DEN-086	2007-2013	8.40	3.60	µg l-1	2.33
DEN-087	2007-2013	11.10	6.00	µg l-1	1.85
DEN-088	2007-2013	44.50	9.00	µg l-1	4.94
DEN-089	2007-2013	19.50	6.00	µg l-1	3.25
DEN-091	2007-2013	5.50	2.10	µg l-1	2.62
DEN-092	2007-2013	1.10	1.60	µg l-1	0.69
DEN-093	2007-2013	1.50	1.70	µg l-1	0.88
DEN-095	2007-2013	2.00	1.60	µg l-1	1.25
DEN-096	2007-2013	1.30	1.50	µg l-1	0.87
DEN-097	2007-2013	1.80	2.10	µg l-1	0.86
DEN-098	2007-2013	2.10	1.50	µg l-1	1.40
DEN-099	2007-2013	1.30	2.10	µg l-1	0.62
DEN-100	2007-2013	2.70	2.10	µg l-1	1.29
DEN-101	2007-2013	1.90	2.10	µg l-1	0.90
DEN-102	2007-2013	2.90	1.50	µg l-1	1.93
DEN-103	2007-2013	2.70	1.50	µg l-1	1.80
DEN-104	2007-2013	3.20	1.50	µg l-1	2.13
DEN-105	2007-2013	1.70	1.60	µg l-1	1.06
DEN-106	2007-2013	1.10	1.60	µg l-1	0.69
DEN-107	2007-2013	1.70	1.60	µg l-1	1.06
DEN-108	2007-2013	1.90	1.90	µg l-1	
EST-001	2011-2016	4.46	3.70	µg l-1	1.21
EST-002	2016	5.23	3.70	µg l-1	1.41
EST-003	2014	2.65	2.70	µg l-1	0.98
EST-004	2011-2016	3.35	2.70	µg l-1	1.24
EST-005	2011-2016	3.89	2.70	µg l-1	1.44
EST-006	2011-2016	3.98	2.70	µg l-1	1.47
EST-007	2011-2014	2.28	1.60	µg l-1	1.42
EST-008	2011-2015	7.04	2.40	µg l-1	2.93
EST-009	2015	2.83	2.40	µg l-1	1.18
EST-010	2012	4.15	1.60	µg l-1	2.59
EST-011	2012	2.45	1.60	µg l-1	1.53
EST-012	2011-2016	4.48	3.00	µg l-1	1.49
EST-013	2011-2016	6.63	4.50	µg l-1	1.47
EST-014	2016	2.57	2.40	µg l-1	1.07
EST-015	2013	2.91	2.40	µg l-1	1.21
EST-016	2011-2016	2.51	2.40	µg l-1	1.05
FIN-001	2011-2016	8.40	3.00	µg l-1	2.80
FIN-002	2011-2016	4.70	2.30	µg l-1	2.04
FIN-003	2011-2016	9.00	3.50	µg l-1	2.57
FIN-004	2011-2016	5.80	2.50	µg l-1	2.32
FIN-005	2011-2016	4.70	2.50	µg l-1	1.88
FIN-006	2011-2016	6.70	3.30	µg l-1	2.03
FIN-007	2011-2016	2.60	2.20	µg l-1	1.18
FIN-008	2011-2016	5.60	2.70	µg l-1	2.07
FIN-009	2011-2016	2.80	2.10	µg l-1	1.33
FIN-010	2011-2016	5.70	3.30	µg l-1	1.73
FIN-011	2011-2016	3.00	2.20	µg l-1	1.36
FIN-012	2011-2015	12.60	3.00	µg l-1	4.20
FIN-013	2011-2015	3.00	2.40	µg l-1	1.25

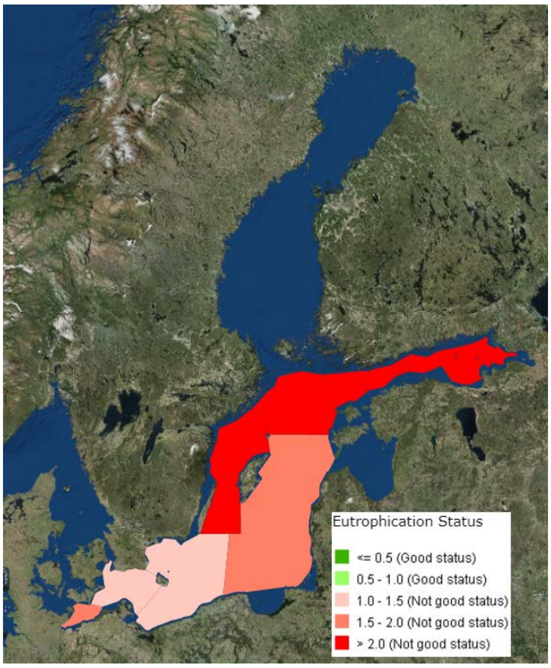
GER-001	2007-2012	3.10	1.95	µg l⁻¹	1.59
GER-002	2007-2012	3.10	1.95	µg l⁻¹	1.59
GER-003	2007-2012	2.90	1.95	µg l⁻¹	1.49
GER-004	2007-2012	1.79	1.90	µg l⁻¹	0.94
GER-005	2007-2012	8.30	2.40	µg l⁻¹	3.46
GER-006	2007-2012	1.91	1.90	µg l⁻¹	1.01
GER-007	2007-2012	121.40	12.70	µg l⁻¹	9.56
GER-008	2007-2012	92.40	12.70	µg l⁻¹	7.28
GER-009	2007-2012	40.25	2.40	µg l⁻¹	16.77
GER-010	2007-2012	2.00	2.30	µg l⁻¹	0.87
GER-011	2007-2012	11.47	2.40	µg l⁻¹	4.78
GER-012	2007-2012	14.95	2.40	µg l⁻¹	6.23
GER-013	2007-2012	15.65	2.40	µg l⁻¹	6.52
GER-014	2007-2012	81.90	2.40	µg l⁻¹	34.13
GER-015	2007-2012	2.85	2.30	µg l⁻¹	1.24
GER-016	2007-2012	64.37	12.70	µg l⁻¹	5.07
GER-017	2007-2012	84.35	12.70	µg l⁻¹	6.64
GER-018	2007-2012	5.40	2.30	µg l⁻¹	2.35
GER-019	2007-2012	10.43	2.30	µg l⁻¹	4.53
GER-020	2007-2012	71.65	12.70	µg l⁻¹	5.64
GER-021	2007-2012	5.93	1.95	µg l⁻¹	3.04
GER-022	2007-2012	2.43	1.90	µg l⁻¹	1.28
GER-023	2007-2012	2.43	1.90	µg l⁻¹	1.28
GER-024	2007-2012	2.09	1.90	µg l⁻¹	1.10
GER-025	2007-2012	18.50	1.95	µg l⁻¹	9.49
GER-026	2007-2012	54.70	2.40	µg l⁻¹	22.79
GER-027	2007-2012	54.70	2.40	µg l⁻¹	22.79
GER-028	2007-2012	2.10	1.90	µg l⁻¹	1.11
GER-029	2007-2012	2.37	1.90	µg l⁻¹	1.25
GER-030	2007-2012	1.80	1.90	µg l⁻¹	0.95
GER-031	2007-2012	2.25	1.90	µg l⁻¹	1.18
GER-032	2007-2012	7.75	1.95	µg l⁻¹	3.97
GER-033	2007-2012	1.80	1.90	µg l⁻¹	0.95
GER-034	2007-2012	1.80	1.90	µg l⁻¹	0.95
GER-035	2007-2012	1.80	1.90	µg l⁻¹	0.95
GER-036	2007-2012	1.22	1.90	µg l⁻¹	0.64
GER-037	2007-2012	1.10	1.95	µg l⁻¹	0.56
GER-038	2007-2012	1.82	1.90	µg l⁻¹	0.96
GER-039	2007-2012	1.80	1.90	µg l⁻¹	0.95
GER-040	2007-2012	2.10	1.90	µg l⁻¹	1.11
GER-041	2007-2012	2.16	1.90	µg l⁻¹	1.14
GER-042	2007-2012	9.86	1.95	µg l⁻¹	5.06
GER-043	2007-2012	17.24	2.40	µg l⁻¹	7.18
GER-044	2007-2012	25.48	2.40	µg l⁻¹	10.62
GER-111	2007-2012	31.53	2.40	µg l⁻¹	13.14
LAT-001	2007-2012	3.85	1.80	µg l⁻¹	2.14
LAT-002	2007-2012	3.85	1.80	µg l⁻¹	2.14
LAT-003	2007-2012	5.53	2.70	µg l⁻¹	2.05
LAT-004	2007-2012	5.53	2.70	µg l⁻¹	2.05
LAT-005	2007-2012	6.03	3.00	µg l⁻¹	2.01
LIT-001	2011-2015	0.35	0.55	µg l⁻¹	1.57
LIT-002	2011-2015	0.52	0.61	µg l⁻¹	1.17
LIT-003	2011-2015	0.29	0.61	µg l⁻¹	2.10
LIT-004	2011-2015	0.70	0.68	µg l⁻¹	0.97
LIT-005	2011-2015	0.63	0.57	µg l⁻¹	0.90
LIT-006	2011-2015	0.29	0.42	µg l⁻¹	1.45

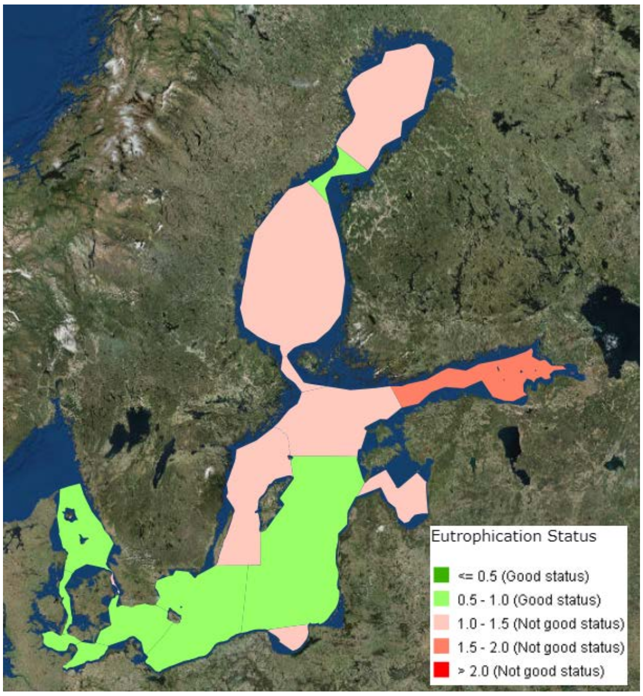
POL-001*	2011-2016	27.43	20.00	µg l-1	1.37
POL-002*	2011-2016	34.16	20.00	µg l-1	1.71
POL-003*	2011-2016	51.49	23.20	µg l-1	2.22
POL-004*	2011-2016	5.00	2.00	µg l-1	2.50
POL-005	2011-2016	3.67	3.76	µg l-1	0.98
POL-006	2011-2016	4.25	3.76	µg l-1	1.13
POL-007	2011-2016	10.32	3.80	µg l-1	2.72
POL-008	2011-2016	10.73	5.50	µg l-1	1.95
POL-009	2011-2016	11.09	7.50	µg l-1	1.48
POL-010	2011-2016	3.11	1.90	µg l-1	1.64
POL-011	2011-2016	6.85	3.15	µg l-1	2.17
POL-012	2011-2016	6.85	1.90	µg l-1	3.61
POL-013	2011-2016	4.17	1.90	µg l-1	2.19
POL-014	2011-2016	4.83	1.90	µg l-1	2.54
POL-015	2011-2016	5.63	1.90	µg l-1	2.96
POL-016	2011-2016	5.86	1.90	µg l-1	3.08
POL-017	2011-2016	4.58	1.90	µg l-1	2.41
POL-018	2011-2016	6.63	3.15	µg l-1	2.10
POL-019	2011-2016	3.57	1.90	µg l-1	1.88
SWE-001	2011-2016	-	0.57	µg l-1	0.76
SWE-003	2011-2016	-	0.67	µg l-1	0.76
SWE-004	2011-2016	-	0.67	µg l-1	0.89
SWE-005	2011-2016	-	0.59	µg l-1	0.94
SWE-006	2011-2016	-	0.67	µg l-1	1.10
SWE-007	2011-2016	-	0.67	µg l-1	0.95
SWE-008	2011-2016	-	0.67	µg l-1	0.96
SWE-009	2011-2016	-	0.67	µg l-1	1.52
SWE-010	2011-2016	-	0.67	µg l-1	1.31
SWE-011	2011-2016	-	0.67	µg l-1	1.50
SWE-012	2011-2016	-	0.67	µg l-1	1.19
SWE-013	2011-2016	-	0.67	µg l-1	2.68
SWE-014	2011-2016	-	0.67	µg l-1	1.26
SWE-015	2011-2016	-	0.67	µg l-1	1.31
SWE-016	2011-2016	-	0.61	µg l-1	1.24
SWE-017	2011-2016	-	0.60	µg l-1	1.21
SWE-018	2011-2016	-	0.61	µg l-1	1.04
SWE-019	2011-2016	-	0.60	µg l-1	0.81
SWE-020	2011-2016	-	0.57	µg l-1	1.22
SWE-021	2011-2016	-	0.55	µg l-1	1.29
SWE-022	2011-2016	-	0.52	µg l-1	0.98
SWE-023	2011-2016	-	0.55	µg l-1	1.11
SWE-024	2011-2016	-	0.67	µg l-1	1.62
SWE-025	2011-2016	-	0.67	µg l-1	1.86

Chlorophyll-a estimates measured on different platforms

The chlorophyll-a indicator is a multiparametric indicator and is based on combined data from in-situ measurements, FerryBox flow-through measurements (in open sea areas) and remote sensing data (Earth Observation satellite data in open sea areas – only for the year 2011). Data are combined where applicable (and agreed on by Contracting Parties) and where available to evaluate the indicator status, for example FerryBox data is only applied in some agreed open sea areas and remote sensing satellite data is only incorporated for 2011.


Eutrophication Status
<= 0.5 (Good status)
0.5 - 1.0 (Good status)
1.0 - 1.5 (Not good status)
1.5 - 2.0 (Not good status)
> 2.0 (Not good status)


Eutrophication Status
<= 0.5 (Good status)
0.5 - 1.0 (Good status)
1.0 - 1.5 (Not good status)
1.5 - 2.0 (Not good status)
> 2.0 (Not good status)



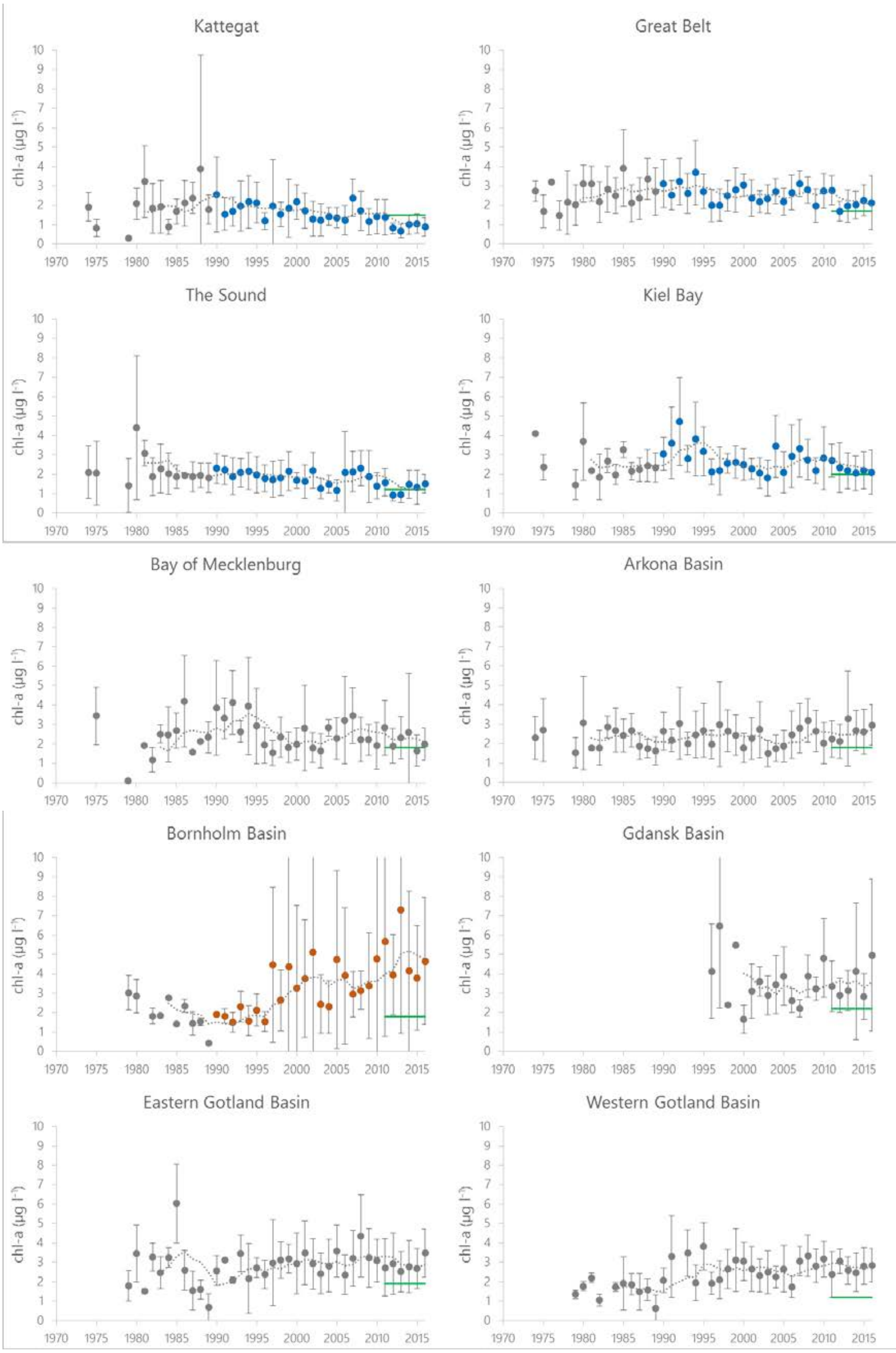
Results figure 3. Status of the chlorophyll-a -indicator shown based on each individual methodology: measured in-situ (top), FerryBox (middle) and remote sensing satellite (bottom – NOTE: only available for year 2011), presented as eutrophication ratio (ER). ER shows the present concentration in relation to the threshold value, increasing along with increasing eutrophication. The threshold value has been reached when ER ≤ 1.00. The overall chlorophyll-a status evaluation is based of combined annual information of the three parameters (as and where available).

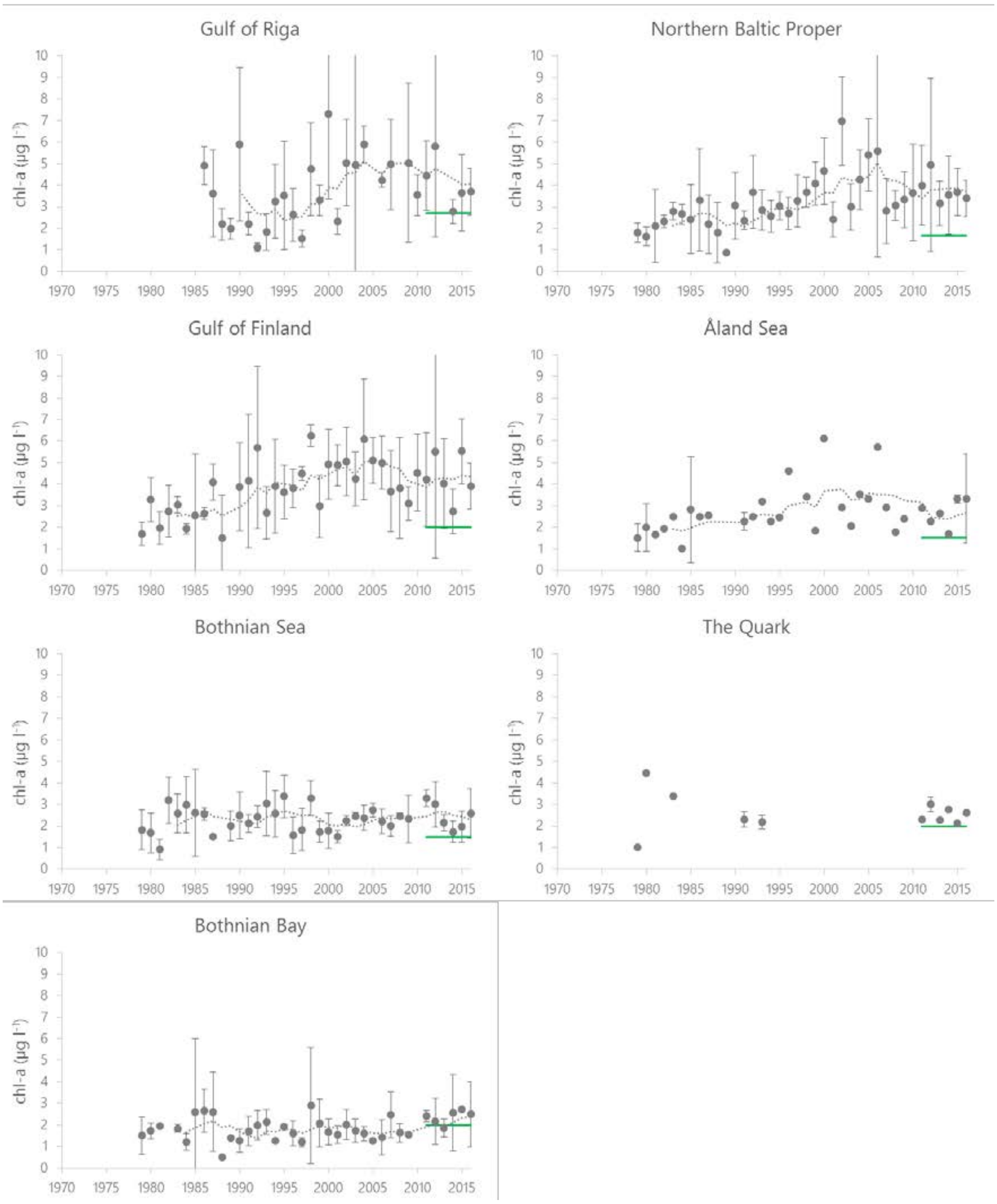
Long-term trends

The long-term trends are provided as additional information and do not influence the status assessment for the current assessment period (2011-2016).

An increase in summer chlorophyll-*a* concentration was evident in most of the Baltic Sea sub-basins from the 1970/80s to the late 1990s/early 2000s. Only in some southwestern areas, the Kattegat and Arkona Sea, were these increases not observed. In the Bornholm Basin a decrease in summer chlorophyll-*a* concentration could even be observed during this period (Fleming-Lehtinen et al. 2008).

Chlorophyll-a concentration trends suggest that during the 1990-2016 period there has been little change. There are some exceptions, for example in the most southwestern parts of the Baltic Sea, where decreasing trends are observed and the Bornholm Basin where an increasing trend is seen (Results Figure 4). These decreasing trends corresponds well with decreases in nitrogen inputs and concentrations in the southwestern parts, where nitrogen is considered the most limiting nutrient for phytoplankton growth. In the central and eastern parts of the Baltic Sea, where summer chlorophyll-a concentration is mainly related to phosphorus concentrations the indicator shows no changes. A significant increasing (deteriorating) trend was detected only in the Bornholm Basin, which is attributed to influence from measurements at shallow stations in the Pomeranian Bay and outflow from the river Odra.

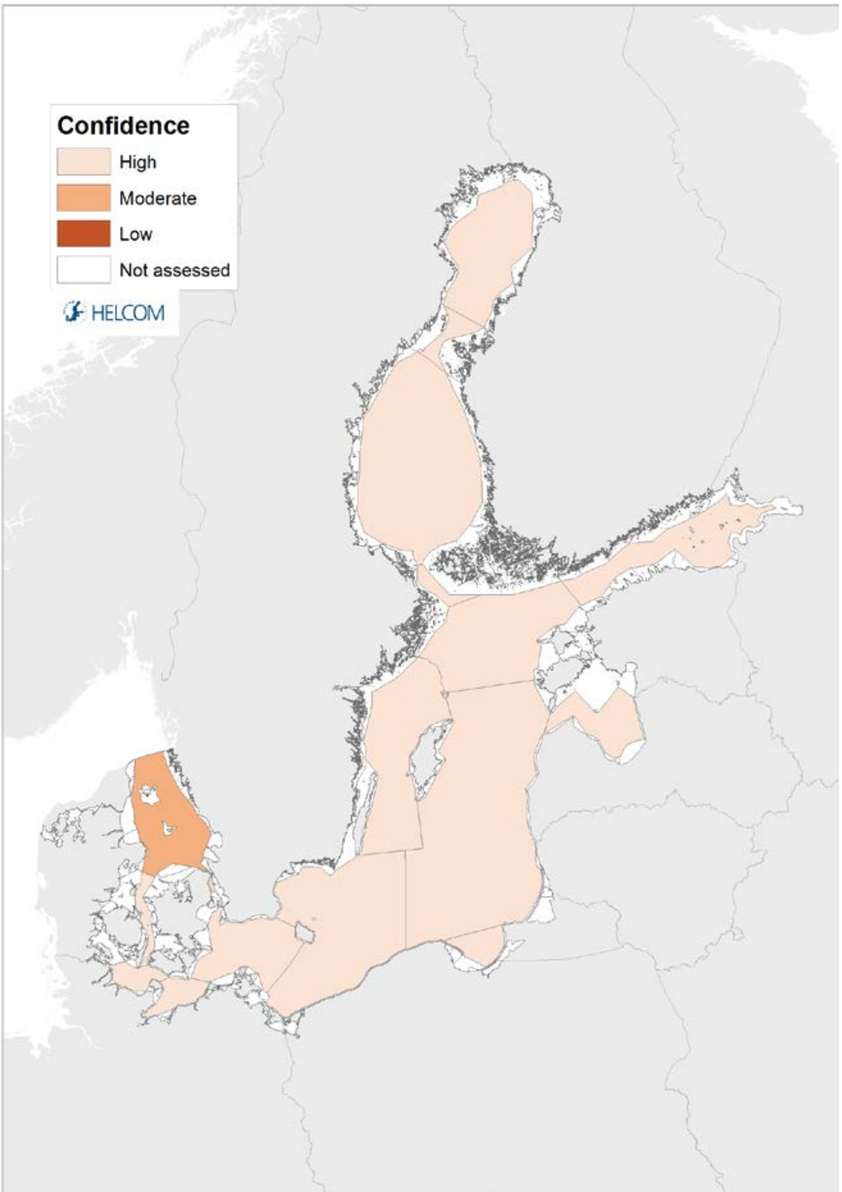

Kattegat
Great Belt
The Sound
Kiel Bay
Bay of Mecklenburg
Arkona Basin
Bornholm Basin
Gdansk Basin
Eastern Gotland Basin
Western Gotland Basin
chl-a (µg l⁻¹)
1970 1975 1980 1985 1990 1995 2000 2005 2010 2015



Results figure 4. Temporal development of chlorophyll-a (chl-a) concentrations in the open-sea assessment units from 1970s to 2016. Dashed lines show the five-year moving averages and error bars the standard deviation. Green lines denote the indicator threshold value. Significance of trends was assessed with a Mann-Kendall non-parametric tests for period from 1990-2016. Significant ($p<0.05$) improving trends are indicated with blue and deteriorating trends with orange colour.

Confidence of the indicator status evaluation

The confidence of the indicator status evaluation, based on the spatial and temporal coverage of data as well as the accuracy of the threshold value-setting protocol, was **high** for all assessment units, except the Kattegat, where it was **moderate** due to lower confidence in the applied target.

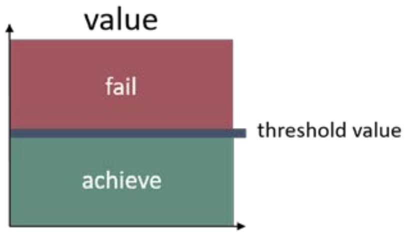


Results figure 5. Indicator confidence, determined by combining information on data availability and the accuracy of the threshold-setting protocol. Low indicator confidence calls for increase in monitoring or scientific re-evaluation of threshold values and targets.

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 2011-2016. 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.

Thresholds and Status evaluation

Status evaluation is carried out against scientifically based and commonly agreed sub-basin specific threshold values, i.e. the concentration that should not be exceeded (Thresholds and Status evaluation figure 1).



Thresholds and Status evaluation figure 1. Schematic representation of the threshold value applied in the chlorophyll-*a* core indicator, the threshold values are assessment unit specific (see Thresholds and Status evaluation table 1).

Some of the open-sea indicator threshold values are based on the results obtained in the TARGREV project (HELCOM 2013), also taking 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 during intersessional activity to develop the core eutrophication indicators (HELCOM CORE EUTRO), and the threshold value were adopted by the HELCOM Heads of Delegations 39/2012.

Thresholds and Status evaluation 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 Basin	1.8
SEA-007	Bornholm Basin	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 concentration in open sea assessment units is a combined estimate of as many as three types of data (depending on availability, applicability and regional agreement): 1) in-situ measurements 2) Earth Observation (EO) remote sensing satellite data, and 3) FerryBox data. These data are 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 (µg l^{-1})
Assessment period	June 2011 – September 2016
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	0.55	0.45	0
SEA-005 Bay of Mecklenburg	0.55	0.45	0
SEA-006 Arkona Basin	0.55	0.45	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	0.48	0.39	0.13
	SEA-013 Gulf of Finland	0.50	0.40	0.10
	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

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

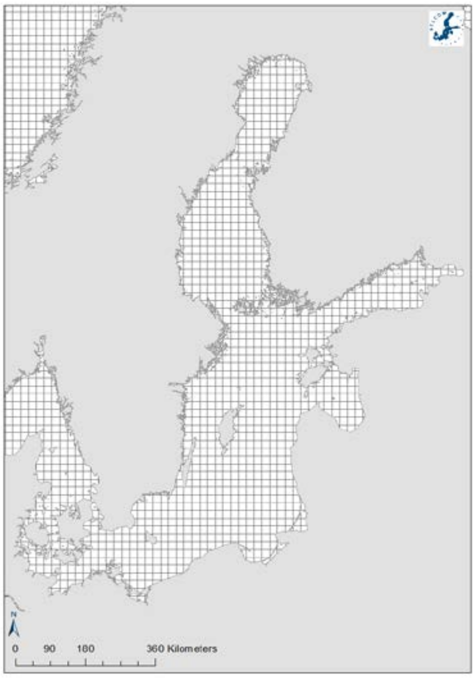
The *in-situ* chlorophyll-*a* data (1) is generated via samples from laboratory extracted and analyzed material, as explained in the HELCOM COMBINE manual. Measurements made at the depth of 0 – 10 m from the surface are used in the assessment.

The satellite-based EO-dataset (2) for 2011 was calculated at SYKE using the 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 values 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).

Information based on flow-through system onboard ferrylines (FerryBox data, 3) was collected and validated by SYKE, and was reported to ICES as daily averages in 20K spatial grids (Fig. 1). As selected ferries operating on the Baltic Sea are the platform for FerryBox flow-through systems and only specific routes are followed (https://www.ferrybox.com/routes_data/routes/baltic_sea/index.php.en) then data availability is not evenly distributed across all HELCOM sub-basins. To remove possible spatial bias, which might be considerable in areas with spatial sampling gradients, we suggest that the Ferrybox-based chla estimate is corrected to represent the entire area. This correction is done at each HELCOM sub-basin, based on a longer-term reference data, which was achieved using remote sensing MERIS estimates from 2002-2011. The correction is done separately for each year within the assessment period, according to the following formula:

$$F_{\mathrm{corr}} = \frac{1}{n}\sum_{i=1}^{n} \frac{ref_{\mathrm{ave}}}{ref_{\mathrm{i}}} F_i \text{ , where}$$

F_{corr} is the corrected Ferrybox chla estimate in a HELCOM sub-basin,
n is the number of grid cells in the HELCOM sub-basin,
ref_i is the grid cell (geometrical) average for the reference data (MERIS 2002-2011, Figure 2),
ref_{ave} is the sub-basin avegage of the reference data and
F_i is the (geometrical) average Ferrybox chla estimate for grid cell 'i'.



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

In coastal areas the indicator is assessed using comparable indicators developed nationally for the purposes of assessments under the EU Water Framework Directive and data can be derived from different seasons (see Results table 2).

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

The use of remote sensing and ship-of-opportunity data for estimating should be developed further, with the aim of extending the temporal coverage of satellite data and spatial coverage of ferry-box 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

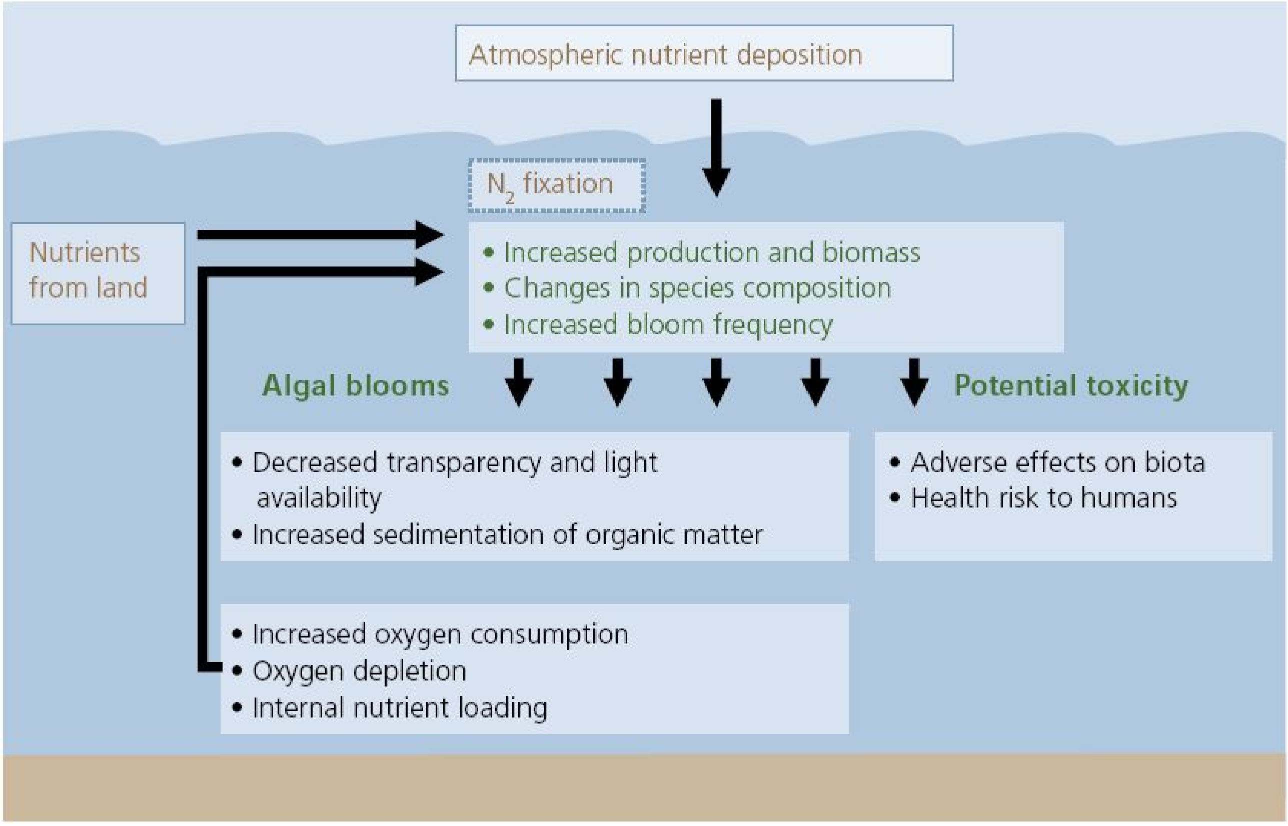
Eutrophication is one of the four thematic segments of the HELCOM Baltic Sea Action Plan (BSAP) with the strategic goal of having a Baltic Sea unaffected by eutrophication (HELCOM 2007). Eutrophication is defined in the BSAP as a condition in an aquatic ecosystem where high nutrient concentrations stimulate 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”. Increases in phytoplankton abundance and biomass 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

Chlorophyll-a concentrations are a reliable proxy measurement for phytoplankton biomass, though it is also known that some phytoplankton can control their chlorophyll concentrations in response to certain environmental conditions. Phytoplankton quantity and biomass is a direct proxy of eutrophication as it is linked to the increase of nutrient concentrations. The nutrient load is also supplemented by internal nutrient loading from bottom sediments in some areas, accelerated by oxygen depletion. Phytoplankton increase in turn adds to 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 (2018) Chlorophyll-*a*. HELCOM core indicator report. Online. [Date Viewed], [Web link].

ISSN 2343-2543

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). 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.

3) FerryBox flow-through data is reported to ICES by Contracting Parties, to be included into the eutrophication assessment database. It is reported according to the QA/QC guidance for FerryBox Flow-through information, providing adequate metadata and quality information, including the following:

- (arithmetic and) geometric mean
- mode (most frequently occurring value in dataset)
- standard deviation
- percentiles (5,25, 50, 75, 95)
- N of observations that were used to derive statistics

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.

Data aggregation: The 2011-2016 values for each sub-basin were estimated as an inter-annual summer (June-September) averages.

Contributors and references

Contributors

Vivi Fleming-Lehtinen[1], Joni Kaitaranta[2], Laura Hoikkala[2], Jenni Attila[1], participants of HELCOM IN-Eutrophication

[1] Finnish Environment Institute, SYKE, Finland

[2] Secretariat of the Helsinki Commission

Archive

This version of the HELCOM core indicator report was published in July 2018:

Chlorophyll a HELCOM core indicator 2018 (pdf)

Earlier versions of the core indicator report include:

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

Core indicator report – web-based 2015 (pdf)

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Schroeder, T., Behnert, I., Schaale, M., Fischer, J., & Doerffer, R. (2007). Atmospheric correction algorithm for MERIS above case-2 waters. Int. J. Remote Sens., 28, 1469–1486, doi:10.1080/01431160600962574, 2007.

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 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)

HELCOM core indicator report,
ISSN 2343-2543