Baltic Marine Environment Protection Commission

EUTRO-OPER Final Report

Making eutrophication assessments operational

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Final report of the project

‘MAKING HELCOM EUTROPHICATION ASSESSMENTS OPERATIONAL (HELCOM EUTRO-OPER)’

Contents

1 Introduction of the EUTRO-OPER project

The ‘Project on making HELCOM eutrophication assessments operational (EUTRO-OPER)’ aimed toward a regularly updated high-quality thematic assessment of eutrophication status, produced through an operational and streamlined process. It was a continuation to the CORE EUTRO process, stemming from the EUTRO-, EUTRO PRO- and TARGREV projects, which have since 2005 developed the HELCOM core set of eutrophication indicators, with boundaries of good environmental status and assessment methodology, ending up in the latest update of eutrophication status in the Baltic Sea in 2007-2011 (see ANNEX 1).

The EUTRO-OPER project piloted the production of assessment products through efficient data flow processes. During the project, the entire assessment process, from monitoring and data aggregation to assessment calculation, was defined and documented, together with the protocols as well as responsibilities of QA/QC guidance and review. The project continued to improve the quality of the existing eutrophication status core indicators through enabling use of remote sensing and ship-of-opportunity data. Gaps in the present set of core indicator were investicated and new indicators were proposed. In addition, steps toward coordination of harmonizing the coastal and open sea eutrophication assessment were taken.

Main outcomes

1. Fully operational eutrophication assessment work flow with documented review process (chapter 7).
2. Four new pre-core and two new candidate indicators of eutrophication (chapter 6).
3. Proposal for approach for including new data types with high spatial or temporal resolution into the update of core indicators, with implementation on the update of chlorophyll-*a* using both *in-situ* and satellite data (chapter 4).
4. Proposal for including satellite based earth observation data (EO-data) in the update of the chlorophyll-*a* indicator (chapter 4).
5. Proposal for improved harmonization of coastal and open-sea assessments, through testing and implementing HEAT 3.0 for coastal assessment units and including coastal indicators into the assessment work flow (chapter 2).
6. Proposal for visualizing distance to target in the eutrophication assessment and eutrophication indicators (chapter 3).
7. Core indicator web-reports, updated for the 2007-2011 assessment (chapter 5).
8. Input to the HELCOM Monitoring Manual, through filling information on eutrophication-related monitoring parameters (chapter 3).

Deliverables

EUTRO-OPER test assessment. A dataview of the test assessment, including data and assessment products, together with transparent documentation of review process.

Eutrophication assessment manual. A concise manual explaining the processes and protocols of the assessment work flow, to be used by experts taking part in producing the assessment as well as any party interested in learning about the assessment methodology in more detail.

EUTRO-OPER project report: a description of project activities and results, to inform about the work conducted in the project and to provide background for the continuation of the eutrophication assessment work.

Project duration

January 2014 – December 2015

Project participants

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Project meetings

Meeting	Date	Location	Meeting site
EUTRO-OPER 1-2014	24-25 March 2014	Helsinki, Finland	https://portal.helcom.fi/meetings/EUTRO-OPER%201-2014-129/default.aspx
EUTRO-OPER 2-2014	7 May 2014	On-line	https://portal.helcom.fi/meetings/EUTRO-OPER%202-2014-124/default.aspx
EUTRO-OPER 3-2014	3 September 2014	On-line	https://portal.helcom.fi/meetings/EUTRO-OPER%203-2014-158/default.aspx
EUTRO-OPER 4-2014	9-11 February 2015	Gdynia, Poland	https://portal.helcom.fi/meetings/EUTRO-OPER%204-2015-217/default.aspx
EUTRO-OPER 5-2014	2 June 2015	On-line	https://portal.helcom.fi/meetings/EUTRO-OPER%205-2015-262/default.aspx
EUTRO-OPER 6-2014	8 September 2015	On-line	https://portal.helcom.fi/meetings/EUTRO-OPER%206-2015-287/default.aspx
EUTRO-OPER 7-2014	24-25 November 2015	Gothenburg, Sweden	https://portal.helcom.fi/meetings/EUTRO-OPER%207-2015-305/default.aspx

2 Toward harmonization of coastal and open-sea assessment

The HELCOM assessment in open-sea areas is based on commonly agreed HELCOM core indicators of eutrophication. The overall assessment is produced using the HELCOM Eutrophication Assessment Tool (HEAT), version 3.0 (Andersen et al. 2011, Fleming-Lehtinen et al. 2015). The assessment tool is updated to fulfil the requirements and criteria set by MSFD (Anon. 2008), using weighted average to estimate criteria status, and the one-out-all-out –principle between criteria to estimate overall eutrophication status. The requirements and criteria of MSFD is applicable both for coastal and open sea areas.

Coastal waters up to 1 nautical mile are currently assessed under the Water Framework Directive (WFD, Anon. 2000). The results of the WFD assessment, in the form of ecological status, were used as such in the HELCOM eutrophication assessment 2007-2011 for coastal waters of the contracting parties being also EU Member States. The assessment of the ecological status is indicator-based, relying on information achieved on the biological quality elements phytoplankton, macrophytes and macrozoobenthos. They are combined by the One-Out-All-Out (OOAO) Principle. Physico-chemical parameters such as nutrients, oxygen and Secchi depth are only used as supporting parameters in the WFD assessment process. The assessment of ecological status under the WFD is not an assessment of eutrophication as required by the Marine Strategy Framework Directive under descriptor 5, and not directly compatible with the HELCOM eutrophication assessment for open-sea areas.

In order to harmonize the HELCOM eutrophication assessment for coastal and open-sea areas, and to fulfil the requirements of MSFD (Anon. 2008, 2010), application of common assessment criteria through use of HEAT 3.0 throughout the assessment area would be desirable. However, since the WFD assessment was designed to reflect the main anthropogenic impacts in the coastal zone and the most important impact currently is eutrophication, it is desirable that WFD and MSFD arrive at a comparable assessment results concerning eutrophication.

2.1 Proposal for harmonization of coastal and open sea assessments

We propose, that in order to increase harmony between the eutrophication assessments made in coastal and open-sea areas, HEAT 3.0 will be used as the assessment tool in both, with the below specifications. The assessment will thus take advantage of the information reported for the WFD (Anon. 2000), when fulfilling the requirements of the MSFD (Anon 2008, 2010).

	Open sea assessment units	**Coastal assessment units**
Assessment tool	HEAT 3.0	HEAT 3.0
Indicators	HELCOM CORE indicators of eutrophication	Indicators reported nationally under WFD by the contracting parties being also EU Member States
Update of indicator	Using data monitored under HELCOM COMBINE or otherwise agreed for the eutrophication assessment	Using values reported in the WFD by the contracting parties being also EU Member States; these values are aligned with the WFD assessment cycles
GES boundary	GES boundary / target agreed under HELCOM (during the TARGREV and CORE EUTRO procedures)	The Good / Moderate boundary reported in the WFD by the contracting parties being also EU Member States
Indicator confidence	Status confidence based on availability of monitoring data (described in detail in HELCOM 2014) Confidence of GES boundary based on boundary-setting methodology (based on results in HELCOM 2013, described in detail in HELCOM 2014)	Confidence of G/M boundary based on whether intercalibration is done successfully.
Assessment unit division	Seventeen open-sea assessment units, according to the HELCOM Monitoring and Assessment Strategy	Division of coastal area into water bodies / water types, according to HELCOM Monitoring and Assessment Strategy

Eutrophication assessment update procedure	Updated using the data and information flow developed under HELCOM EUTRO-OPER	Updated using the data and information flow developed under HELCOM EUTRO-OPER

2.2 Introduction to assessment tools presently used in the Baltic Sea

The eutrophication status in the HELCOM region has previously been assessed regionally using the HELCOM Eutrophication Assessment Tool (HEAT). The earlier version, HEAT 1.0, is based on WFD requirements and was used in the HELCOM Initial Holistic Assessment (HELCOM 2010), for both coastal and open sea assessments. HEAT 3.0 is based on the MSFD criteria and requirements, and was used in the latest thematic assessment 2007-2011 of the open sea areas of the Baltic Sea (HELCOM 2014), the coastal region was not included in this assessment. In order to be able to harmonize the coastal and open sea assessments, better understanding of the differences between the tools and methodologies is needed.

We present results on how the eutrophication assessment on a selection of coastal water types in the Baltic Sea varies with the use of different assessment tools such as HEAT 1.0, HEAT 3.0 and nationally WFD-assessments. There is also a need to harmonize assessment methodologies between the Baltic Sea and the North Sea region. For that reason, one Swedish coastal water type in Kattegat was also assessed using the “Common Procedure for the Identification of the Eutrophication Status of the OSPAR Maritime Area”, (OSPAR 2013-08), hereafter referred to as COMP in this test. Kattegat is included in two sea conventions, HELCOM and OSPAR, and is thus assessed by the region’s different methods.

2.2.1 Methodology

WFD versus MSFD

One of the main differences between the WFD and the MSFD is the aggregation of indicators. In the WFD, eutrophication related indicators are grouped as biological and physical-chemical quality elements (Table 1). The biological elements, QE1-QE3, are the most important group in the status classification and include phytoplankton, macrovegetation and invertebrate bottom fauna. Physical-chemical elements, QE4 include nutrients, water transparency and dissolved oxygen. They are used mainly as supportive elements, only when the ecological status of the other quality elements is good. Under MSFD, the eutrophication related indicators for descriptor 5 are grouped in a different way; as criteria C1) Nutrient levels, C2) Direct effects and C3) Indirect effects of nutrient enrichment. Direct effects include phytoplankton, water transparency and abundance of opportunistic macro vegetation. Indirect effects include abundance of perennial seaweed and sea grass and dissolved oxygen.

Another main difference between WFD and MSFD is approach for overall status estimation. The WFD assessment results in one of five status classes for **ecological** status; high, good, moderate, poor or bad. The MSFD assessment on the other hand results in one of two status classes for **environmental** status; GES (good environmental status) or subGES. Good ecological and good environmental status is not equally comparable since the method for classifying good status is different.

To assess the **ecological status,** the ecological quality ratio (EQR), calculated for indicators in a assessment unit, provides the indicator-specific status. Indicators with a numerically positive (+) response to nutrient input are treated differently from indicators with negative (-) response:

EQR = RefCon/AcStat (+)
EQR = AcStat/RefCon (-)
$0 \le EQR \le 1$

where RefCon is the reference condition and AcStat is the actual status of the parameter for the assessed time period. An EQR close to 1 indicate high status and close to 0 indicate bad status. Regarding biological parameters, the class boundary for the good/moderate boundary shall be determined through intercalibration processes and the other boundaries are set nationally. When data are not available for the water body to be assessed expert judgement may be used. According to the directive, the supporting parameters need only to be assessed if the biological elements show good or high status. The final ecological status is estimated using the one out-all out principle meaning that the element having the worst status determines the final status.

The **environmental** status is on the other hand given through a holistic assessment using the ecosystem approach where GES is determined for 11 descriptors, including Descriptor 5 (eutrophication). No specific requirements on the method on estimating indicators status or overall eutrophication for MSFD reporting have been provided by the European Commission during the course of the EUTRO-OPER project.

HEAT 1.0 methodology

The grouping of indicators in HEAT 1.0 is based on the WFD, where four groups named QE1-QE4 are used (see Table 2.1). RefCon and AcStat are used to calculate the EQR for each indicator, similarly to WFD. Indicators within a group are then averaged, using weighted averaging as appropriate. Each indicator is also given an acceptable deviation (AcDev) from the RefCon, to specify the distance to the Good/Moderate class boundary. The mean acceptable deviation within a group is used to determine the class boundaries for each group and a status class can be assigned (Table 2.2). The final eutrophication status is estimated using the one out-all out principle between groups, meaning that the group with the lowest status determines the result. As for the WFD, five classes are used. The upper limit for AcDev is 110% for indicators which are positively related to eutrophication and 52.5% for indicators which are negatively related. The methodology of HEAT 1.0 is described in more detailed by Andersen et al. (2011). An example of an HEAT 1.0 template is shown in Figure 2.1.

HEAT 3.0 methodology

The grouping of indicators in HEAT 3.0 is in line with the MSFD, grouping into three criteria (C1-C3) accordingly (Table 2.1). In this version of HEAT there is an option to either use RefCon and AcDev to calculate the indicator-specific GES-boundary (EUT_target = RefCon ± AcDev), or to use a pre-defined indicator-specific GES boundary (EUT_target). The eutrophication ratio (EUT_Ratio) is determined as a relation between AcStat and EUT_target. The EUT_Ratio, indicating indicator status, is defined between 0 and 2 where 1.0 is the Good/Moderate boundary and also GES/subGES boundary. Each group (criteria) is then given a eutrophication sum (EUT_sum) which is a weighted average of the EUT_Ratios included in that criteria. From this EUT_sum the criteria status class is determined. In contrast to HEAT 1.0, the class boundary limits in HEAT 3.0 are linear and fixed and hence not dependent on AcDev (Table 2.3).

The final status class is determined by the one out-all out principle, where the criteria with the lowest status determines the status. An example of an HEAT 3.0 template is shown in Figure 2.2.

HEAT 3.0 provides a classification into five classes (High, Good, Moderate, Poor and Bad), as do HEAT 1.0 and WFD. With an aim of fulfilling the requirements for MSFD reporting, only the Good-

Moderate boundary was used in the HELCOM eutrophication assessment 2003-2007, as a boundary between GES and SubGES. For testing assessment results between the aggregation tools in EUTRO-OPER, however, the five-class system was found more useful due to its similarity with the other approaches, and this classification was therefore used.

Table 2.1. Grouping of indicators in WFD and MSFD.

	WFD Quality element		MSFD Criteria		
Indicator	Biological elements (QE1-QE3)	Physical-chemical elements (QE4)	Nutrient levels (C1)	Direct effects (C2)	Indirect effects (C3)
Chl-a	QE1			C2	
Biovolume	QE1			C2	
Macrovegetation	QE2			C2	C3
Invertebrate fauna	QE3				
DIN (win)		QE4	C1		
DIP (win)		QE4	C1		
TN (win)		QE4	C1		
TP (win)		QE4	C1		
TN (sum)		QE4	C1		
TP (sum)		QE4	C1		
Secchi depth (sum)		QE4		C2	
Oxygen concentration (aut)		QE4			C3

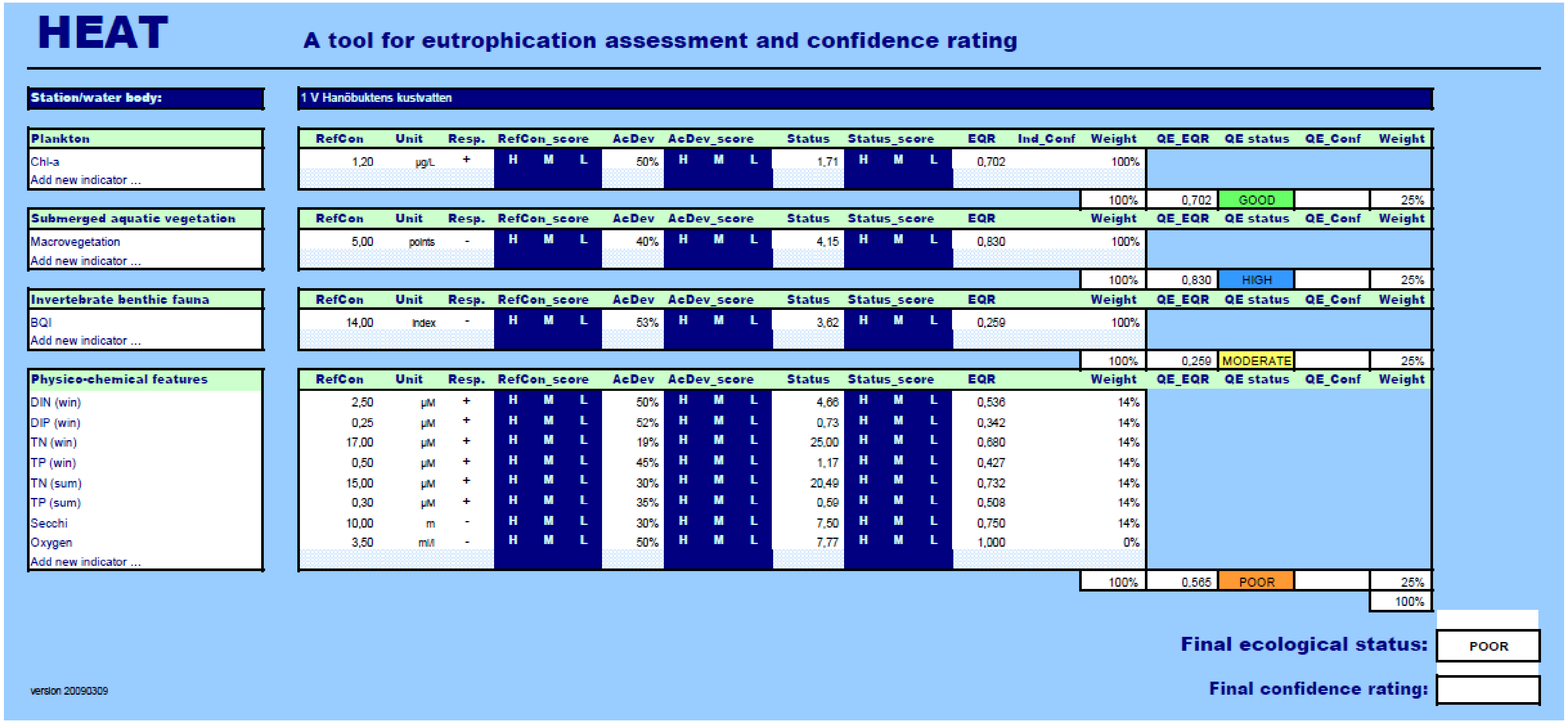
Table 2.2. How class boundary values between status classes are defined in HEAT 1.0.An example with acceptable deviation (AcDev) =50% is given.

	Indicators with a numerical **positive** relationship to nutrient input		Indicators with a numerical **negative** relationship to nutrient input	
Class boundary	Boundary value	EQR with AcDev = 50%	Boundary value	EQR with AcDev = 50%
$EQR_{RefCon/High}$	0.95	0.95	0.95	0.95
$EQR_{High/Good}$	$0.5EQR_{RefCon/High} + 0.5EQR_{Good/Moderate}$	0.81	$0.5EQR_{RefCon/High} + 0.5EQR_{Good/Moderate}$	0.73
$EQR_{Good/Moderate}$	1/(1+ AcDev)	0.67	(1- AcDev)	0.5

$EQR_{Moderate/Poor}$	$0.5EQR_{Good/Moderate} + 0.5EQR_{Poor/Bad}$	0.53	$0.5EQR_{Good/Moderate} + 0.5EQR_{Poor/Bad}$	0.28
$EQR_{Poor/Bad}$	$2EQR_{Good/Moderate} - EQR_{RefCon/High}$	0.38	$2EQR_{Good/Moderate} - EQR_{RefCon/High}$	0.05

Table 2.3. Status class boundary limits in HEAT 3.0.

Status class	Range
High	$0.00 \leq$ EUT_Ratio ≤ 0.50
Good	$0.50 \leq$ EUT_Ratio ≤ 1.00
Moderate	$1.00 \leq$ EUT_Ratio ≤ 1.50
Poor	$1.50 \leq$ EUT_Ratio ≤ 2.00
Bad	EUT_Ratio > 2.00



HEAT

A tool for eutrophication assessment and confidence rating

Station/water body: 1 V Hanöbuktens kustvatten

	RefCon	Unit	Resp.	RefCon_score	AcDev	AcDev_score	Status	Status_score	EQR	Ind_Conf	Weight	QE_EQR	QE status	QE_Conf	Weight
Plankton															
Chl-a	1,20	µg/L	+	H M L	50%	H M L	1,71	H M L	0,702		100%				
Add new indicator ...															
											100%	0,702	GOOD		25%
Submerged aquatic vegetation	RefCon	Unit	Resp.	RefCon_score	AcDev	AcDev_score	Status	Status_score	EQR		Weight	QE_EQR	QE status	QE_Conf	Weight
Macrovegetation	5,00	points	-	H M L	40%	H M L	4,15	H M L	0,830		100%				
Add new indicator ...															
											100%	0,830	HIGH		25%
Invertebrate benthic fauna	RefCon	Unit	Resp.	RefCon_score	AcDev	AcDev_score	Status	Status_score	EQR		Weight	QE_EQR	QE status	QE_Conf	Weight
BQI	14,00	Index	-	H M L	53%	H M L	3,62	H M L	0,259		100%				
Add new indicator ...															
											100%	0,259	MODERATE		25%
Physico-chemical features	RefCon	Unit	Resp.	RefCon_score	AcDev	AcDev_score	Status	Status_score	EQR		Weight	QE_EQR	QE status	QE_Conf	Weight
DIN (win)	2,50	µM	+	H M L	50%	H M L	4,66	H M L	0,536		14%				
DIP (win)	0,25	µM	+	H M L	52%	H M L	0,73	H M L	0,342		14%				
TN (win)	17,00	µM	+	H M L	19%	H M L	25,00	H M L	0,680		14%				
TP (win)	0,50	µM	+	H M L	45%	H M L	1,17	H M L	0,427		14%				
TN (sum)	15,00	µM	+	H M L	30%	H M L	20,49	H M L	0,732		14%				
TP (sum)	0,30	µM	+	H M L	35%	H M L	0,59	H M L	0,508		14%				
Secchi	10,00	m	-	H M L	30%	H M L	7,50	H M L	0,750		14%				
Oxygen	3,50	ml/l	-	H M L	50%	H M L	7,77	H M L	1,000		0%				
Add new indicator ...															
											100%	0,565	POOR		25%
															100%

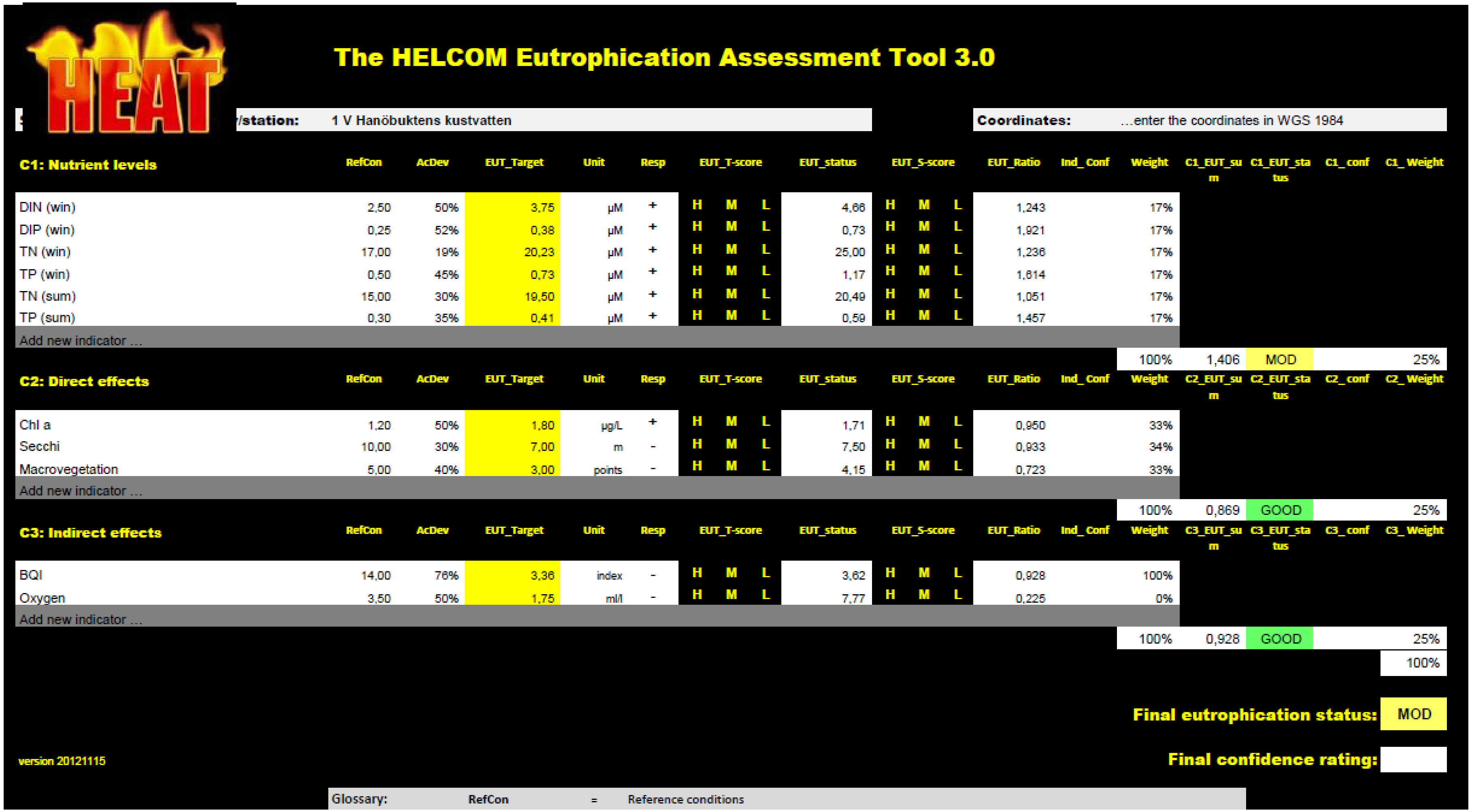
Final ecological status: POOR

Final confidence rating:

version 20090309

Figure 2.1. Example of an HEAT 1.0 template.

Figure 2.2 Example of an HEAT 3.0 template.



HEAT

The HELCOM Eutrophication Assessment Tool 3.0

/station: 1 V Hanöbuktens kustvatten

Coordinates: …enter the coordinates in WGS 1984

C1: Nutrient levels	RefCon	AcDev	EUT_Target	Unit	Resp	EUT_T-score	EUT_status	EUT_S-score	EUT_Ratio	Ind_Conf	Weight	C1_EUT_sum	C1_EUT_status	C1_conf	C1_Weight
DIN (win)	2,50	50%	3,75	µM	+	H M L	4,66	H M L	1,243		17%				
DIP (win)	0,25	52%	0,38	µM	+	H M L	0,73	H M L	1,921		17%				
TN (win)	17,00	19%	20,23	µM	+	H M L	25,00	H M L	1,236		17%				
TP (win)	0,50	45%	0,73	µM	+	H M L	1,17	H M L	1,614		17%				
TN (sum)	15,00	30%	19,50	µM	+	H M L	20,49	H M L	1,051		17%				
TP (sum)	0,30	35%	0,41	µM	+	H M L	0,59	H M L	1,457		17%				
Add new indicator …															
											100%	1,406	MOD		25%

C2: Direct effects	RefCon	AcDev	EUT_Target	Unit	Resp	EUT_T-score	EUT_status	EUT_S-score	EUT_Ratio	Ind_Conf	Weight	C2_EUT_sum	C2_EUT_status	C2_conf	C2_Weight
Chl a	1,20	50%	1,80	µg/L	+	H M L	1,71	H M L	0,950		33%				
Secchi	10,00	30%	7,00	m	-	H M L	7,50	H M L	0,933		34%				
Macrovegetation	5,00	40%	3,00	points	-	H M L	4,15	H M L	0,723		33%				
Add new indicator …															
											100%	0,869	GOOD		25%

C3: Indirect effects	RefCon	AcDev	EUT_Target	Unit	Resp	EUT_T-score	EUT_status	EUT_S-score	EUT_Ratio	Ind_Conf	Weight	C3_EUT_sum	C3_EUT_status	C3_conf	C3_Weight
BQI	14,00	76%	3,36	index	-	H M L	3,62	H M L	0,928		100%				
Oxygen	3,50	50%	1,75	ml/l	-	H M L	7,77	H M L	0,225		0%				
Add new indicator …															
											100%	0,928	GOOD		25%
															100%

Final eutrophication status: MOD

Final confidence rating:

version 20121115

Glossary: RefCon = Reference conditions

OSPAR COMP methodology

In the OSPAR region eutrophication status is assessed using the OSPAR Comprehensive Procedure (COMP). Assessed parameters are grouped in four categories;

Category 1. The degree of nutrient enrichment (riverine inputs, direct charges, nutrient concentrations, N/P ratio)

Category 2. Direct effects of nutrient enrichment (chlorophyll-a, phytoplankton, macrophytes)

Category 3. Indirect effects of nutrient enrichment (oxygen deficiency, zoobenthos, fish, organic carbon)

Category 4. Other possible effects such as algal toxins.

If status of the assessed parameter is above the assessment level, the parameter is scored as (+) meaning elevated level, else the score is (-). The assessment level is defined as the background level + 50%. First an initial classification is made, see table 4.

Table 2.4. Procedure of initial assessment in COMP.

5.4 The initial classification shall be as follows:

a. areas showing an increased degree of nutrient enrichment accompanied by direct and/or indirect/ other possible effects are regarded as **'problem areas'**;

b. areas may show direct effects and/or indirect or other possible effects, when there is no evident increased nutrient enrichment, for example, as a result of transboundary transport of (toxic) algae and/or organic matter arising from adjacent/remote areas. These areas could be classified as **'problem areas'**;

c. areas with an increased degree of nutrient enrichment where:

(i) either there is firm, scientifically based evidence of the absence of (direct, indirect, or other possible) eutrophication effects – these are classified initially as '**non-problem areas'**, although the increased degree of nutrient enrichment in these areas may contribute to eutrophication problems elsewhere;

(ii) or there is not enough data to perform an assessment or where the data available is not fit for the purpose – these are classified initially as **'potential problem areas'**;

The overall classification of the assessment unit is done using the above criteria, with a possibility to include other information based on expert judgement (Table 2.5).

Table 2.5. Template for the overall COMP assessment.

Key to the table

NI Riverine inputs and direct discharges of total N and total P

DI Winter DIN and/or DIP concentrations

NP Increased winter N/P ratio

Ca Maximum and mean chlorophyll *a* concentration

Ps Area-specific phytoplankton indicator species

Mp Macrophytes including macroalgae

O_2 Oxygen deficiency

Ck Changes/kills in zoobenthos and fish kills

Oc Organic carbon/organic matter

At Algal toxins (DSP/PSP mussel infection events)

\+ = Increased trends, elevated levels, shifts or changes in the respective assessment parameters

\- = Neither increased trends nor elevated levels nor shifts nor changes in the respective assessment parameters

? = Not enough data to perform an assessment or the data available is not fit for the purpose

Note: Categories I, II and/or III/IV are scored '+' in cases where one or more of its respective assessment parameters is showing an increased trend, elevated levels, shifts or changes.

Area	**Category I** Degree of nutrient enrichment		**Category II** Direct effects		**Category III and IV** Indirect effects/other possible effects				Initial classification	Appraisal of all relevant information (concerning the harmonised assessment parameters, their respective assessment levels and the supporting environmental factors)	Final classification	Assessment period
	NI		Ca		O_2		At					
	DI		Ps		Ck							
	NP		Mp		Oc							
	NI		Ca		O_2		At					
	DI		Ps		Ck							
	NP		Mp		Oc							
	NI		Ca		O_2		At					
	DI		Ps		Ck							

	NP		Mp		Oc						

2.3 Results of testing HEAT 3.0 in coastal areas

To investigate the comparability of assessment results achieved by HEAT 3.0 and WFD, we applied HEAT 3.0 in the coastal zone based on WFD indicator data, and compared the assessment results against the current WFD classification of these waters. This work was lead by Sweden, with contributions from Estonia, Finland, Latvia and Poland. In German waters, testing was done separately by a German national project.

2.3.1 Testing assessment tools in selected coastal areas

Testing procedure

The present test includes data on 33 selected coastal water bodies from five countries: Estonia, Finland, Latvia, Poland and Sweden.

- Estonia; one water body in Gulf of Finland
- Finland; three coastal water types were tested, number of water bodies in brackets; Outer coastal waters of the Bothnian Bay (5), the Quark (1) and The Archipelago & western Gulf of Finland (4)
- Latvia; one coastal water type were assessed, LAT 001
- Poland; one coastal type was tested for Polish waters, the Gdansk Basin (SEA 009) with three water bodies
- Sweden; three coastal water types were tested, number of tested water bodies in brackets: 7-Arkona-Hanö Bukt (9), 23-Outer Bothnian Bay (7) and 4-Kattegat (2). Location map and classification schemes for the Swedish test sites are presented in Annex B.

Data on RefCon, AcStat, AcDev and class boundaries of all indicators used in WFD for reporting ecological status (biological and physical-chemical) have been provided from participating countries from the latest WFD classification (2013). The information has been inserted in HEAT 1.0 and HEAT 3.0 tools and resulting status have been compared with the national WFD assessment. In the test, all indicators in a sub-group have been equally weighted. The confidence rating has not been considered.

Result and Discussion

The detailed result of the testing procedure for each water body is shown in ANNEX 2A, where also comments are made per country.

According to the WFD, quality elements QE1-QE3 containing biological indicators should be primarily assessed. If the status is moderate or lower, the final status is determined by QE1-QE3, and there is no need to assess the supporting elements, QE4. If the biological quality elements are classified to good or high status the physical-chemical parameters comprising QE4 shall also be assessed. The result of the QE4 assessment has in this case the potential to downgrade the ecological status result given by QE1-QE3. However, for some of the tested water bodies the final status is good even if the biological parameters have been assessed to moderate or lower. In these cases expert judgment has been included in the assessment procedure. This can be due to high uncertainty in the biological parameters and because of little or no monitoring data. This complicated the comparison to HEAT assessments, that have no option for expert judgment.

The HEAT assessments are mostly stricter than the national WFD-classification. To summarize, in more than 50% of the tests both HEAT-versions generate lower status (Table 2.6) than the national WFD. The change is mostly only one status class and never no more than two status classes. For some cases the status is changed from GES to sub-GES when HEAT is applied.

The main difference between national WFD and HEAT 1.0 assessments is most likely due to differences in class boundary setting, since the grouping of indicators is same, or to results adjusted due to expert judgement. The HEAT tool is stricter, since no indicators are determined 'supplementary'. It is difficult to compare the class boundaries for HEAT 3.0 to class boundaries of WFD and HEAT 1.0, due to the changed calculation method. When comparing the WFD and HEAT class boundaries, the major difference is found at the lower classes.

The grouping of HEAT 3.0, which differs from WFD and HEAT 1.0 grouping, is another major reason for the differences in results. However, the good/moderate boundary is the same for all three assessments apart from HEAT 1.0 in cases where results differ due to limitations in estimation of acceptable deviation.

One benefit of using HEAT is that it simplifies comparison of results between countries, since the methodology is uniform. However, the possibility to change AcDev and the weighting procedure still room leave room for individual tuning of the national assessment.

The term AcDev has a slightly different use in the assessment tools: in HEAT 1.0 it sets the classification boundaries, whereas in HEAT 3.0 it may be used to produce a target together with RefCon. HEAT 3.0 has fixed class boundaries.

Combining results from several coastal water bodies, assessed independently in WFD, into larger coastal water types was found to be a challenge (in the cases where this needed to be done). This was solved by estimating how representative each water body was within the water type, based on the percentage of its coverage, and using this information for determining the status. The overall status was determined by the status class most spatially representative in the water type. As an example: water type A has three water bodies (1, 2and 3). Water body 1 has good, 2 has poor and 3 has bad status. Water body 1 represents 60 %, 2 represents 30 % and 3 represents 10 % of the water type area. The final status for A is thus good since this is the most representative for the type.

Table 2.6. Change in assessments made with HEAT 1.0 and HEAT 3.0 compared with national WFD assessments. A number of 33 coastal water bodies have been tested. The change in status (higher, none, lower) is presented as number and percentages. Below is how many test units have changed one status class vs. two status classes. No assessment unit changed its status class more than two classes.

	HEAT 1.0	HEAT 3.0
Higher status than WFD One - /two status classes	3 (10%) ½	6 (20%) 6/0
No change in status	10 (30%)	8 (27%)
Lower status than WFD One - /two status classes	17 (57%) 11/6	16 (53%) 11/5

For the Swedish coastal water type Kattegat, the test also included assessment using OSPAR COMP (Table 2.7). There are only data from two water bodies in the water type; the other bodies are assessed with expert judgment. In COMP, the assessment level is calculated as a 50% deviation from the background level. In Table 2.7, the national assessment level is also included where they differ.

All assessed parameters are below assessment levels and hence Kattegat coastal water is classified as a non-problem area using COMP. Kattegat is assessed with moderate status in the WFD and high vs. good status in HEAT 1.0 and HEAT 3.0 respectively.

Table 2.7. **Assessment of Swedish water type 4-Kattegat using OSPAR COMP.**

Parameter	Background level	Assessment level	Status level 2007-2012		Score	
	Water type 4 Kattegat S =20	Water bodies	Water bodies		Water bodies	
		Onsala kv and N m Hallands kv	Onsala kv	N m Hallands kv	Onsala kv	N m Hallands kv
DIN (winter)	4.5	6.75	6.71	5.63	(-)	(-)
DIP (winter)	0.4	0.6	0.53	0.53	(-)	(-)
TN (winter)	17	22[a] /25.5[b]	17.9	17.83	(-)	(-)
TP (winter)	0.7	0.9[a]/1.05[b]	0.84	0.86	(-)	(-)
TN (summer)	12	16[a] / 18[b]	14	14.39	(-)	(-)
TP (summer)	0.4	0.56[a] /0.6[b]	0.42	0.42	(-)	(-)
Chlorophyll	1.0	1.5	1.21	0.97	(-)	(-)
Biovolume	0.5	1.1[a] 0.75[b]	Not assessed	No data		
Macrovegetation	5	3	Not assessed	4.5		(-)
Oxygen	3.5	2.1	4.45	4.70	(-)	(-)
Overall assessment					(-)	

[a]G/M class boundary in WFD

[b] OSPAR Assessment level: Background level+50%

2.3.2 German results of testing HEAT 3.0 in national coastal waters

Based on report by AquaEcology (UBA, 2014)

Short description of the German project

The task of the project carried out by AquaEcology was to apply HEAT 3.0 to the coastal WFD water bodies using data from the WFD assessment and to compare the assessment results with the ultimate aim to suggest an appropriate assessment tool for eutrophication within the 1 nautical mile zone.

As an example, the project used WFD data for the time period 2007-2011 for water bodies of Mecklenburg-Vorpommern (see Figure 2.3).

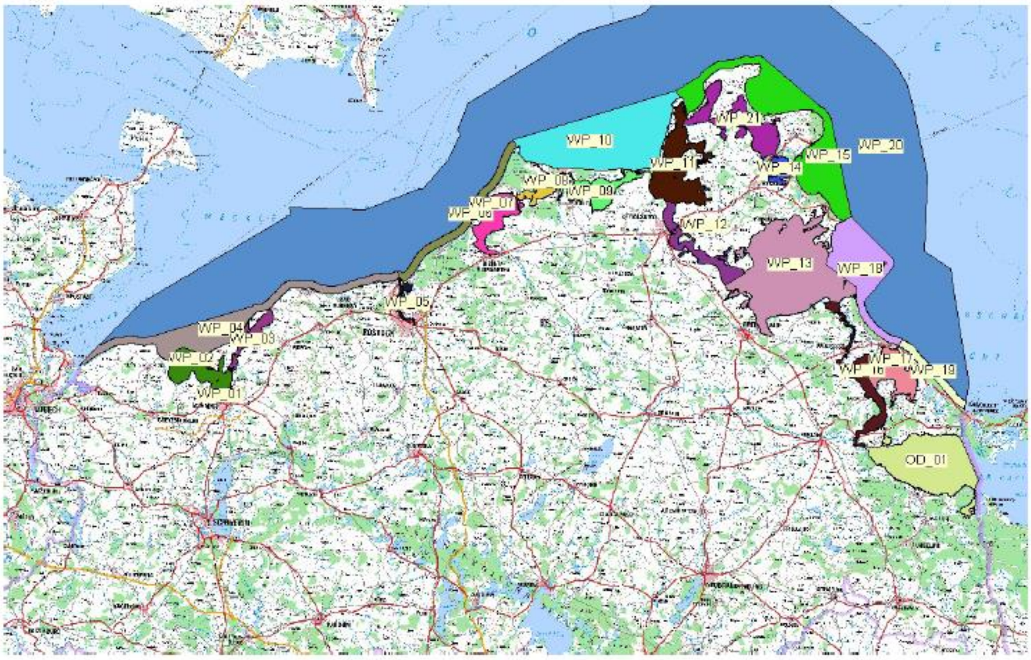


Figure 2.3. Water bodies of the WFD along the Baltic Sea coast of Mecklenburg-Vorpommern used as assessment units in the project (map kindly provided by Mario von Weber, LUNG, 2012).

Data on nutrient levels (DIN, DIP), direct effects (Secchi depth, chlorophyll-*a*) and indirect effects (macrophytes and macrozoobenthos) were kindly provided by LUNG (Landesamt für Umwelt, Naturschutz und Geologie). Oxygen data were not available and hence this indirect effect parameter has not been used. For the assessment the HEAT 3.0 version 20121115 (as presented at EUTRO 7/2012) was used. Class boundaries for HEAT 3.0 have been used as presently expressed in the tool (high status 0-≤0,5; good status 0,5-≤1, moderate status 1,5-≤2, bad status >2, Fleming-Lehtinen et al. 2015), with the class-boundary between good/moderate corresponding to the class boundary used in the WFD.

Results

Tables 2.8 and 2.9 provide an overview of the results. To get a better understanding of the assessment process, HEAT 3.0 was not only applied as the full tool, but was applied separately to nutrients (DIN, DIP), direct effects (Chl a and Secchi depth), macrophytes and macrozoobenthos. For these separate applications, the class boundaries as defined by Jesper Andersen were used and not the class boundaries of the WFD (but note that the decisive boundary good/moderate is the same for WFD and HEAT 3.0). These separate assessment results and the overall assessment have been compared to the WFD classification of “ecological status” for 2009 and 2012.

Table 2.8. Overview of project results as follows: WRRL-ÖZ: WFD assessments of "ecological status" for 2009 and 2012, respectively; HEAT:DIN = HEAT 3.0 for DIN only; HEAT:DIP = HEAT 3.0 for DIP only; HEAT Chla = HEAT 3.0 for chlorophyll a only; HEAT: Secchi = HEAT 3.0 for Secchi depth only. For the assessment of DIN and DIP the old target levels were used.

Wasserkörperbez.	Wasserkörper	Typ	WRRL: ÖZ 2009	WRRL: ÖZ 2012	HEAT: DIN	HEAT: DIP	HEAT: Chl-a	HEAT: Secchi
Kleines Haff	DE_CW_OD_01	B1	4	4	5	5	5	5
Wismarbucht, S	DE_CW_WP_01	B2	4	5	5	5	5	5
Wismarbucht, N	DE_CW_WP_02	B2	4	3	4	5	5	5
Wismarbucht, SH	DE_CW_WP_03	B2	4	3	5	4	5	5
Suedl.MB/TM-WM	DE_CW_WP_04	B3	3	4	5	5	4	4
Unterwarnow	DE_CW_WP_05	B2	4	4	5	5	5	5
Ribn. See/Saaler B	DE_CW_WP_07	B1	5	5	5	2	5	5
Koppelstr/Bodst.B	DE_CW_WP_08	B1	4	4	5	4	5	5
Barther B, Grabow	DE_CW_WP_09	B2	4	5	5	2	5	5
Prerowb/DO bis DB	DE_CW_WP_10	B3	3	4	2	4	4	5
Westruegensche B	DE_CW_WP_11	B2	4	4	3	2	5	5
Strelasund	DE_CW_WP_12	B2	4	4	3	3	5	5
Greifwalder Bodden	DE_CW_WP_13	B2	4	4	3	4	5	5
KlJasmunder B	DE_CW_WP_14	B2	5	5	5	1	5	5
Peenestrom	DE_CW_WP_16	B1	5	5	5	5	5	5
Achterwasser	DE_CW_WP_17	B1	5	5	5	3	5	5
Pommersche B, S	DE_CW_WP_19	B3	4	4	5	5	5	5
Nordruegensche B	DE_CW_WP_21	B2	4	5	4	2	5	5

Table 2.9. Overview of project results as follows: WRRL-ÖZ: WFD assessments of "ecological status" for 2009 and 2012, respectively; HEAT: NI = HEAT 3.0 for nutrients only; HEAT:DE = HEAT 3.0 applied for direct effects Chlorophyll a and Secchi depth only, HEAT: MP = HEAT 3.0 applied for macrophytes only, HEAT: MZ = HEAT 3.0 applied for macrozoobenthos only and HEAT: Gesamt = HEAT 3.0 applied for all parameters.

Wasserkörper	Typ	WRRL: ÖZ 2009	WRRL: ÖZ 2012	HEAT: NI 2007-2011	HEAT: DE 2007-2011	HEAT: MP 2007-2011	HEAT: MZ 2007-2011	HEAT: Gesamt 2007-2011
DE_CW_OD_01	B1	4	4	5	5	4	5	5
DE_CW_WP_01	B2	4	5	5	5	2	3	5
DE_CW_WP_02	B2	4	3	5	5	3	2	5
DE_CW_WP_03	B2	4	3	5	5	3	3	5
DE_CW_WP_04	B3	3	4	5	4	5	3	5
DE_CW_WP_05	B2	4	4	5	5	5	3	5
DE_CW_WP_07	B1	5	5	5	5	3	5	5
DE_CW_WP_08	B1	4	4	5	5	3	3	5
DE_CW_WP_09	B2	4	5	5	5	3	4	5
DE_CW_WP_10	B3	3	4	3	5	5	2	5
DE_CW_WP_11	B2	4	4	3	5	3	3	5
DE_CW_WP_12	B2	4	4	3	5	3	3	5
DE_CW_WP_13	B2	4	4	3	5	3	3	5
DE_CW_WP_14	B2	5	5	4	5	3	5	5
DE_CW_WP_16	B1	5	5	5	5	5	5	5
DE_CW_WP_17	B1	5	5	5	5	5	5	5
DE_CW_WP_19	B3	4	4	5	5		3	5
DE_CW_WP_21	B2	4	5	3	5	3	3	5

The general finding was that HEAT 3.0 predominantly results in a classification that is worse than the WFD classification. Of the 18 water bodies assessed all were classified as bad by HEAT 3.0, while under the WFD for the 2009 assessment only 4 were classified as bad, while 12 were classified as poor and 2 as moderate. The main reason for HEAT 3.0 resulting in worse assessment results was the bad status of the nutrients and direct effects (Secchi depth and chlorophyll-*a*). Since HEAT 3.0 uses the One-Out-All-Out Principle the physico-chemical parameters had a direct and strong influence on the overall assessment result. The biological quality elements macrophytes and macrozoobenthos were assessed as often having a status that was better than "bad"; nevertheless, this status did not improve the final assessment results, because the OOAO principle was applied.

The question needs to be raised why the physico-chemical parameters were assessed as being worse than the biological quality elements, when at the same time, from a cause-effect point of view the status of the biology should correspond to the nutrient status as causative factor. At least for the German coastal waters, the answer seems to be that the procedure to derive background and target concentrations for nutrients and chlorophyll-*a* was not well aligned with the procedure to derive class boundaries for macrophytes and macrozoobenthos. In fact, quite different approaches were used.

Influence of the revised target levels for nutrients

In Germany nutrient target levels (boundary between good/moderate) were revised and finalized in 2014 (Schernewski et al. 2015). Since target levels for dissolved nutrients could not reliably be derived by modeling, future assessments will be based on total nutrients only. The revised target levels resulted predominantly in an improvement of the assessment for TN and TP (see table 2.10) but this improvement only in few cases resulted in an improvement of the overall classification, so that the HEAT 3.0 assessments for TN and TP remained predominantly "poor" or "bad".

Table 2.10. Comparison of old and new assessment levels for TN and TP as follows: "HEAT TN alte OW" = TN old assessment levels; "HEAT TP alte OW" = TP old assessment levels; "HEAT TN neue OW" = TN new assessment levels; "HEAT TP neue

OW" = TP new assessment leves, "Vergleich Bewertung TN/TP" = Comparison of the assessment for TN, TP with "green +" indicating an improved assessmemt and "red cross" a deterioration in the assessment.

Wasserkörperbez.	Wasserkörper	Typ	HEAT: TN MW 01-12 alte OW	HEAT: TP MW 01-12 alte OW	HEAT: TN MW 01-12 neue OW	HEAT: TP MW 01-12 neue OW	Vergleich Bewertung TN	Vergleich Bewertung TP
Kleines Haff	DE_CW_OD_01	B1	5	5	5	5	+	+
Wismarbucht, S	DE_CW_WP_01	B2	5	5	4	5	+	+
Wismarbucht, N	DE_CW_WP_02	B2	4	4	3	3	+	+
Wismarbucht, SH	DE_CW_WP_03	B2	5	5	4	4	+	+
Suedl.MB/TM-WM	DE_CW_WP_04	B3	4	4	3	4	+	+
Unterwarnow	DE_CW_WP_05	B2	5	5	5	5	+	+
Ribn. See/Saaler B	DE_CW_WP_07	B1	5	5	5	5	+	+
Koppelstr/Bodst.B	DE_CW_WP_08	B1	5	5	5	5	+	+
Barther B, Grabow	DE_CW_WP_09	B2	5	5	5	5	+	−
Prerowb/DO bis DB	DE_CW_WP_10	B3	3	3	4	4	−	−
Westruegensche B	DE_CW_WP_11	B2	5	4	5	5	−	−
Strelasund	DE_CW_WP_12	B2	5	4	5	5	+	−
Greifwalder Bodden	DE_CW_WP_13	B2	5	4	5	5	−	−
KlJasmunder B	DE_CW_WP_14	B2	5	5	5	5	+	+
Peenestrom	DE_CW_WP_16	B1	5	5	5	5	+	+
Achterwasser	DE_CW_WP_17	B1	5	5	5	5	+	+
Pommersche B, S	DE_CW_WP_19	B3	5	5	5	4	+	+
Nordruegensche B	DE_CW_WP_21	B2	5	5	5	5	+	−

Comparison of EUT and EQR values

HEAT 3.0 uses "eutrophication ratios" (EUT) to calculate the class boundaries for the classification while the WFD uses "environmental quality ratios" (EQRs) (see Figure 2.4).

EQR normiert	>0.8	0.8 - 0.6	0.6 - 0.4	0.4 - 0.2	<0.2
	high	good	moderate	poor	bad
EUT:	<0.5	0.5 - 10	10 - 15	15 - 2.0	>2.0

Figure 2.4. The five assessment classes and their corresponding EQR or EUT values.

Assessments for different parameters were compared using EQR and EUT values. Nutrients and chlorophyll-*a* were predominantly assigned to the same class (mostly "bad"), irrespective of the use of EQR or EUT values. These parameters were assessed as being still very far away from the bad/poor boundary so that the procedure used to calculate the class boundary did not have an influence on the assessment result. By contrast, for macrophytes and macrozoobenthos the picture is quite different and differences in the classification occurred much more often, but did not affect the good/moderate boundary (see table 2.11).

Table 2.11 Comparison of the classification of macrophytes (MP) and macrozoobenthos (MZ) using EQR or EUT values. Median values were used.

Wasserkörperbez.	Wasserkörper	Typ	EQR MP	EUT MP	EQR MZ	EUT MZ
Kleines Haff	DE_CW_OD_01	B1	0,300	2,000	0,230	2,609
Wismarbucht, S	DE_CW_WP_01	B2	0,620	0,968	0,570	1,053
Wismarbucht, N	DE_CW_WP_02	B2	0,520	1,154	0,610	0,984
Wismarbucht, SH	DE_CW_WP_03	B2	0,500	1,200	0,510	1,188
Suedl.MB/TM-WM	DE_CW_WP_04	B3	0,200	3,000	0,520	1,154
Unterwarnow	DE_CW_WP_05	B2	0,250	2,400	0,550	1,091
Ribn. See/Saaler B	DE_CW_WP_07	B1	0,600	1,017	0,050	12,000
Koppelstr/Bodst.B	DE_CW_WP_08	B1	0,540	1,111	0,410	1,463
Barther B, Grabow	DE_CW_WP_09	B2	0,460	1,304	0,360	1,667
Prerowb/DO bis DB	DE_CW_WP_10	B3	0,200	3,000	0,630	0,952
Westruegensche B	DE_CW_WP_11	B2	0,490	1,224	0,590	1,017
Strelasund	DE_CW_WP_12	B2	0,400	1,500	0,510	1,176
Greifwalder Bodden	DE_CW_WP_13	B2	0,450	1,333	0,580	1,034
KlJasmunder B	DE_CW_WP_14	B2	0,410	1,463	0,190	3,158
Peenestrom	DE_CW_WP_16	B1	0,200	3,000	-	-
Achterwasser	DE_CW_WP_17	B1	-	-	0,200	3,000
Pommersche B, S	DE_CW_WP_19	B3	-	-	0,410	1,463
Nordruegensche B	DE_CW_WP_21	B2	0,400	1,500	0,430	1,395

Comparison of chlorophyll-a concentrations and phytoplankton index

While HEAT 3.0 uses only chlorophyll-a concentrations for the assessment of the phytoplankton community under the WFD a more complex phytoplankton index (Sagert et al. 2008) is used. The index considers in addition the total biovolume and the biovolume of Cyanophyceae and Chlorophyceae. In general, the classification based on Chlorophyll-a provides assessment results that are worse compared to the classification based on the phytoplankton index (see table 2.12). To obtain harmonization between WFD and HEAT it would therefore be desirable if HEAT would use the phytoplankton index for assessments in coastal waters rather than just chlorophyll-a.

Table 2.12. Comparison of the assessment of chlorophyll-a only ("HEAT-Bewertung") and the assessment based on the phytoplankton index ("WRRL-Bewertung").

Stationen	Wasserkörper	Chl-a Konz. µg/l	HEAT-Bewertung	PPI_{CW}	WRRL-Bewertung
KHM	OD-01	70.66	5	0.35	4
KHO	OD-01	63.41	5	0.24	4
GB19	WP-13	14.52	5	0.32	4
S66	WP-12	18.16	5	0.27	4
UW4	WP-05	18.92	5	0.31	4

Overall conclusions

- Looking at the decisive boundary good/moderate all investigated water bodies fail to achieve good status under the WFD and under HEAT 3.0. Differences in the assessments using HEAT 3.0 and WFD currently only occur between the assessment classes moderate, poor and bad. These differences are due to the following:
  - The application of the OOAO-assessment principle in HEAT 3.0 that allows physico-chemical parameters (nutrients, secchi depth) to play the same role in the assessment as the biological quality elements
  - The different methods used to set class boundaries (EQR versus EUT)
  - Differences in the parameters used for the assessment (chlorophyll a versus phytoplankton index)
- Most eutrophication parameters assessed, in particular the nutrients, chlorophyll-*a* and secchi depth are currently still far away from the poor/bad boundary. With future improvements in these parameters more differences between WFD and HEAT 3.0 assessment can be expected. Such differences could then also affect the good/moderate boundary and could lead to assessment outcomes were under the WFD the assessment is already in good status while under HEAT 3.0 the assessment is still only moderate. Such discrepancies would give contradicting signals to water managers and should be avoided if possible.

Way forward

In Germany the discussion of how to assess coastal water bodies under the MSFD descriptor 5 is currently ongoing. The national working group on "Eutrophication, Nutrients and Plankton" has developed a recommendation based on the results of the project which has also been agreed at higher levels. This recommendation contains the following points:

- For the assessment of descriptor 5 "eutrophication" of the MSFD in coastal waters the regional assessment tools HELCOM HEAT 3.0 and OSPAR COMP should be applied in the future. At the same time, a comparison with the WFD assessment results needs to be undertaken. Discrepancies that concern the good/moderate boundary will need to be analysed and interpreted and a final classification will be determined based on expert judgment.
- As far as possible HEAT 3.0 and COMP should use the same assessment parameters as the WFD and the decisive class boundary good/moderate needs to be in agreement between the regional assessment tools and the WFD.
- HEAT 3.0 should be further developed in order to make improvements in single parameters more visible, e.g. by choosing an appropriate graphic representation to overcome the disadvantages of the OOAO-principle.

3 Visualizing distance to target

The visual presentation of the eutrophication assessment result of the Baltic Sea, which is severely affected eutrophication, faces separate challenges in comparison to a completely or partly non-eutrophied area. When all sub-basins are estimated to be in non-good status, presenting the actual magnitude of the eutrophication problem becomes more useful than simply indicating compliance with the targets.

When considering additional approaches to illustrate distance from GES for eutrophication status in the open sea, several features should be taken into account (table 3.1). First and foremost, the approach should be applicable to the MSFD criteria. Other useful properties are the possibility for harmonization against the WFD requirements. For practical reasons, the applied assessment tools should be able to utilize the approach, either directly or after some adjustments. And in order to achieve additional value for management purposes, the assessment should provide information on the distance from GES as well as warning on the risk of falling from GES to SubGES – in the present situation the prior seems more convenient than the latter, if one or the other has to be chosen. In general introducing uncertainty as part of the status assessment, instead of as a separate feature, might be useful.

3.1 Proposal for visualizing distance to GES in eutrophication maps

We propose to visualize the distance to GES at the level of overall eutrophication using MSFD classification into GES / SubGES, divided further into 5 eutrophication levels set at even intervals (Figure 3.1). This is an improvement to the present approach, where only classes GES and SubGES are used.

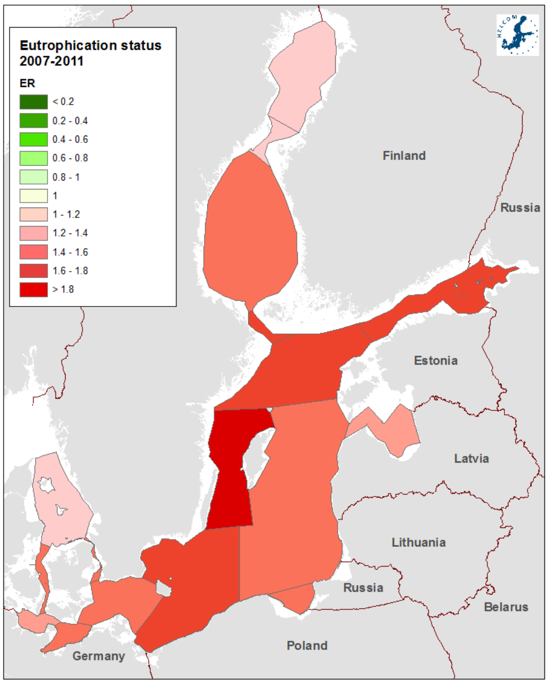


Figure 3.1. A map illustrating overall eutrophication 2007-2011 in the open Baltic Sea, visualizes using the proposed approach.

We propose to provide the user also with finer resolution of assessment levels (e.g. 10) as well as the present GES / SubGES division.

3.2 Determining the approach

We simulated alternative approaches for estimating distance to GES. We started with four alternatives and discussed their characteristics (Figure 3.2).

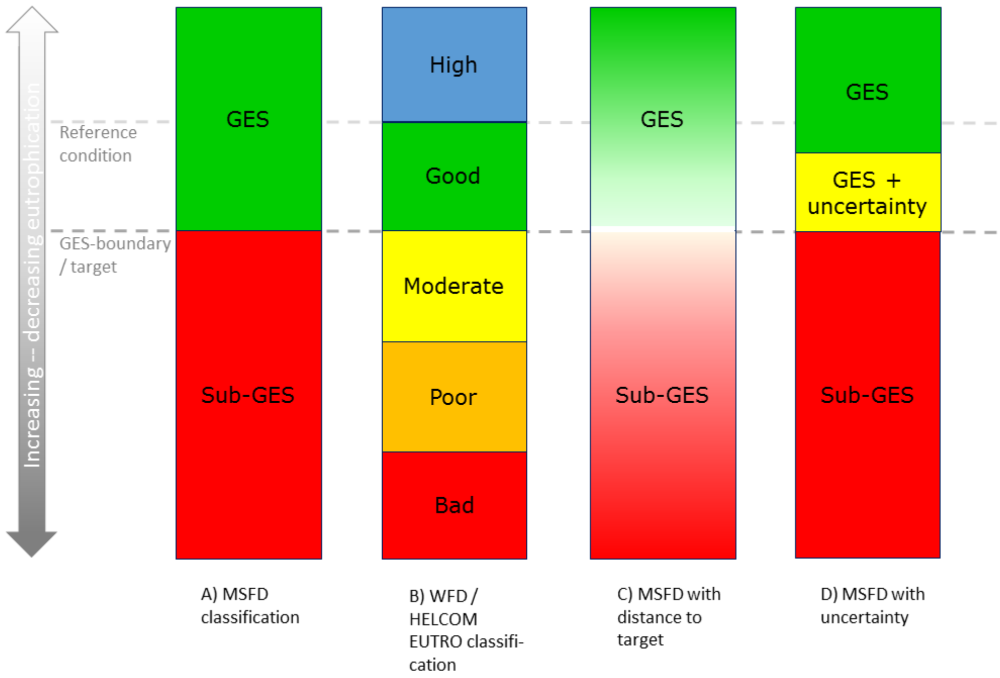


Figure 3.2. Illustrations of four alternative approaches for visualizing eutrophication status and whether the GES-boundary has been achieved.

Approach A: MSFD classification (GES / SubGES)

The present HELCOM eutrophication status assessment (2007-2011) has been produced using a simple classification into either good status (GES) or below good status (SubGES, Figure 3.2 approach A).

This approach provides sufficient information to fulfill the requirements of Article 9 of the MSFD. It also allows using the HELCOM assessment for open-sea areas and WFD assessment of ecological status side by side, as was done in the present HELCOM eutrophication status assessment (2007-2011, Figure 3.3). This line of thinking naturally assumes that the two assessments as well as their class boundaries for GES/subGES vs good/moderate status are harmonized, which at present is not fully the case.

Approach A is presently used in indicator reports under other themes in HELCOM, and using this approach would ensure visual harmony between thematic indicator and assessment reports.

The main disadvantage of the present approach however is, that it does not reveal the distance to GES (Figure 3.4 panel A). It is difficult to detect slight improvement or deterioration of status as response to human actions, and it does not point out the areas of most concern, in a situation when all or most areas are below GES.

Approach B: Five-class system (High / Good / Moderate / Poor / Bad)

The earlier HELCOM eutrophication status assessment (2003-2007) was based on a five-class classification system, which was used also for estimating ecological status in the WFD. In this approach, the status is estimated as HIGH, GOOD, MODERATE, POOR or BAD (Figure 3.2 approach B).

As Approach A, approach B allows using HELCOM assessment for open-sea basins and the coastal assessment of ecological status side by side, since HEAT 3.0 technically allows using a five-level classification. Using a similar five-class visualization as is used for WFD ecological status might however be misleading, since the two classification approaches are not harmonized.

A disadvantage of the approach is, that it is not visually in line with approach A, which is presently used in indicator reports under other themes in HELCOM.

The use of five classes is however a considerable improvement from the two-class system used in approach A. For the open Baltic Sea sub-basins, the present SubGES eutrophication status can be classified into three “sub-classes”, allowing the manager to recognize the areas of most concern (Figure 3.4 panel B).

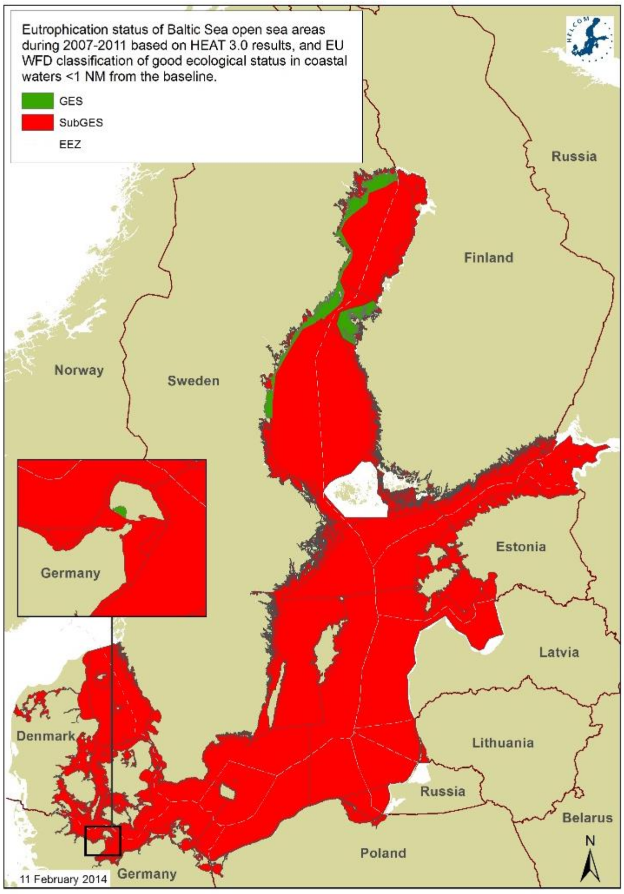


Figure 3.3. The eutrophication status for coastal and open sea areas, as assessed for the present (2007-2011, left) and the previous (2003-2011, right) HELCOM assessment.

Approach C: MSFD classification (GES / SubGES) combined with distance to target levels

A new approach not used in previous eutrophication assessments would be adapting a numeric scale instead of a class scale. This could be done by using the Eutrophication Ratio (ER), calculated from indicator status and GES target, as a numerical value indicating eutrophication status. The eutrophication ratio could be visualized in shades of green (where ER ≥ 1 and status is GES) and red (where ER < 1 and status is SubGES, Figure 3.2 approach C).

The most significant disadvantage of approach C is that it is not compatible with the methodology used in the assessment of ecological status under WFD. This problem is naturally avoided if HEAT 3.0 is used for assessing both coastal and open-sea areas (see proposal in chapter 2).

An advantage of approach C is that though it is not identical, it is visually in line with approach A, which is presently used in indicator reports under other themes in HELCOM.

For management purposes, approach C provides a more detailed picture of the eutrophication status than the other approaches presented. This would be very useful in the Baltic Sea, where all open-sea basins and most of the coastal areas are classified below good status, but actually to a varying degree (Figure 3.4 panel C)

Approach D: MSFD classification combined with information of uncertainty when estimating GES

Another new approach, discussed also informally at the level of certain pressure indicators (the HELCOM nutrient inputs) as well as in other contexts, would be to include information of uncertainty into the status assessment. In order to follow the precautionary principle, we adjusted this approach to include uncertainty only when GES is met, agreeing that uncertainty is irrelevant in cases where GES cannot be shown. In practice, the approach introduces a new sub-class, where GES has been estimated but with low confidence (Figure 3.2 approach D). The approach encourages toward intensive monitoring in cases of low uncertainty – but does not enable achieving 'uncertain' eutrophication status through decreased monitoring activity when GES is not expected to be met.

The strength of this approach is that it partly combines the status and uncertainty assessments in the same map, and in this way implement the precautionary principle. 'Uncertain' status would lead to actions, at least in the form of introduced monitoring activities, instead blindly accepting an uncertain evaluation of reaching GES.

However, in the case of the open Baltic Sea, applying this approach in the present eutrophication status (2007-2011) would not bring any added information, as no single sub-basin is classified into GES (Figure 3.4 panel D). It could be combined to approaches B and C, but risk un-simplifying the outcome, making it more difficult for non-expert viewers to understand.

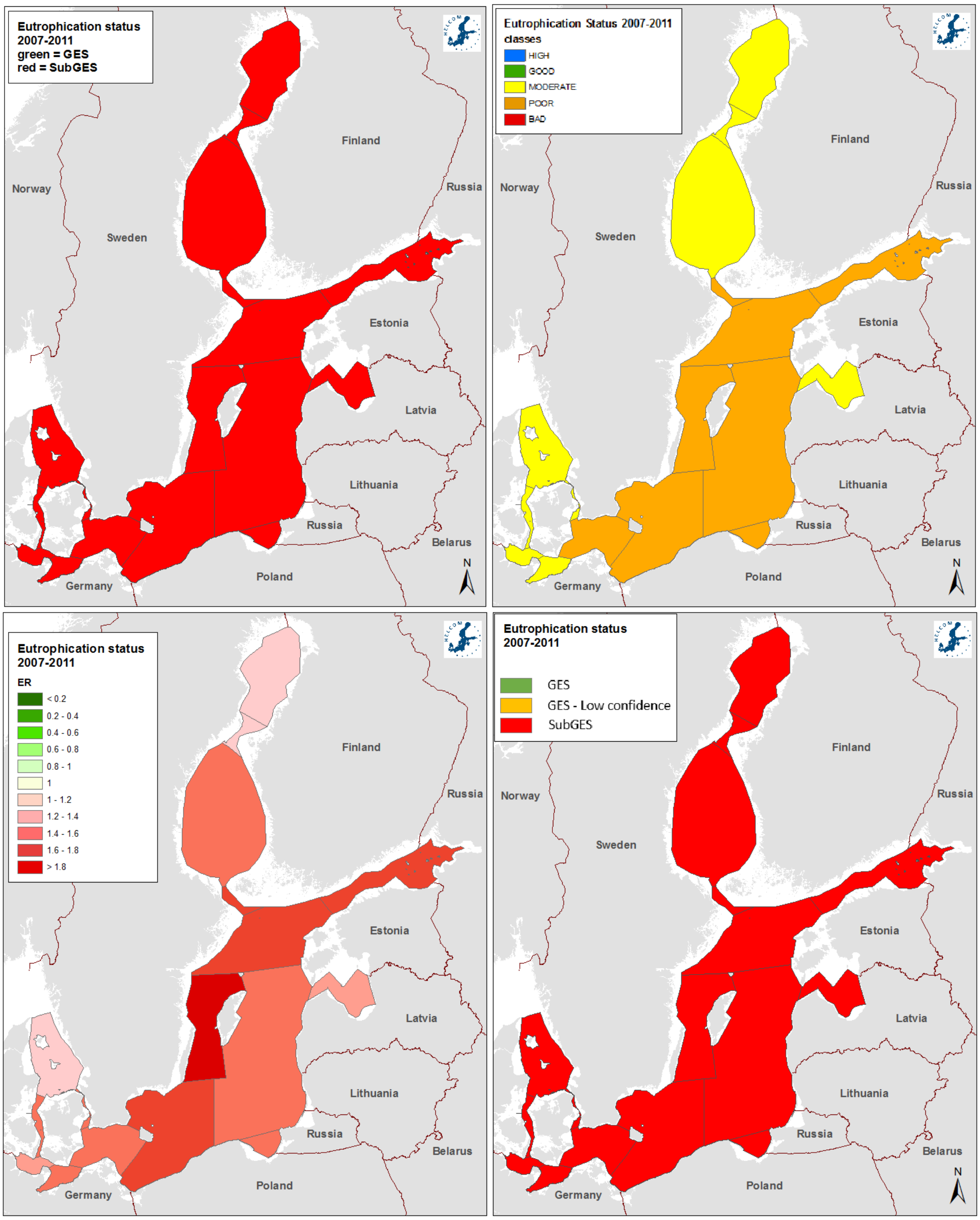


Figure 3.4. Eutrophication status for 2007-2011 in the Baltic Sea expressed using the four approaches: A) MSFD classification, B) the five-class system, C) MSFD classification combined with distance to target information and D) MSFD classification with uncertainty information.

Choosing approach for further simulations

Of the tested approaches, B and C showed clearly most benefits (Table 3.1). Of these two, approach C was found more appropriate, since it was in line with the approach aimed at in other indicator and assessment reports. Especially together with the proposal on using HEAT in the assessment of eutrophication in coastal areas, this alternative was found best.

Table 3.1: A summary on the degree in which the alternative approaches (presented in Figure 3.2) fulfil possible requirements identified to an assessment. Green = Fulfills more or less completely, orange = fulfills partly, red = does not fulfill.

	A	B	C	D
Applicable to MSFD criteria	Green	Orange	Green	Green
Possibility for visual harmonization against WFD	Orange	Green	Orange	Red
In line with the approach aimed at in other HELCOM thematic reports	Green	Red	Orange	Red
Present assessment tools supports the approach fully / after some adjustments	Green	Green	Green	Orange
Provides information on estimating approach from SubGES to GES	Red	Green	Green	Red
Provides information on warning of risk on falling from GES to SubGES	Red	Green	Green	Orange
Includes the uncertainty into the assessment	Red	Red	Red	Green

3.3 Defining the most suitable approach in detail

Dividing the two classes GES / SubGES into further sub-classes, or levels, provides more discrete information on how far the status actually is from GES. Increasing the number of sub-classes will naturally provide more information, but might also complicate the map further.

3.3.1 Number of levels

When considering the number of sub-classes to be used, the five-class system was taken as a starting point, in order to enable harmonization against the WFD classification used in HEAT 3.0. Also a 10-class system was tested, and shown to detect more accurately the areas of least concern (Figure 3.5 and 3.6).

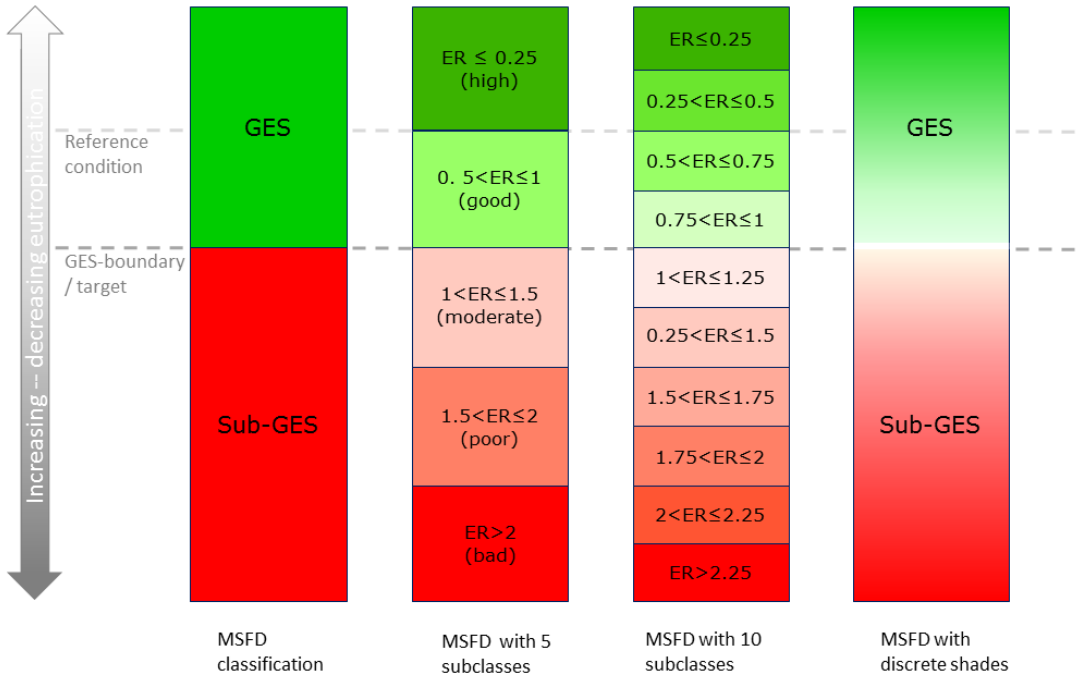


Figure 3.5. Illustrations of the present (MSFD classification) and two alternative approaches (MSFD with 5 subclasses, MSFD with 10 subclasses) for visualizing eutrophication status and whether the GES-boundary has been achieved. For comparison, also an approach with discrete shades of red and green is shown.

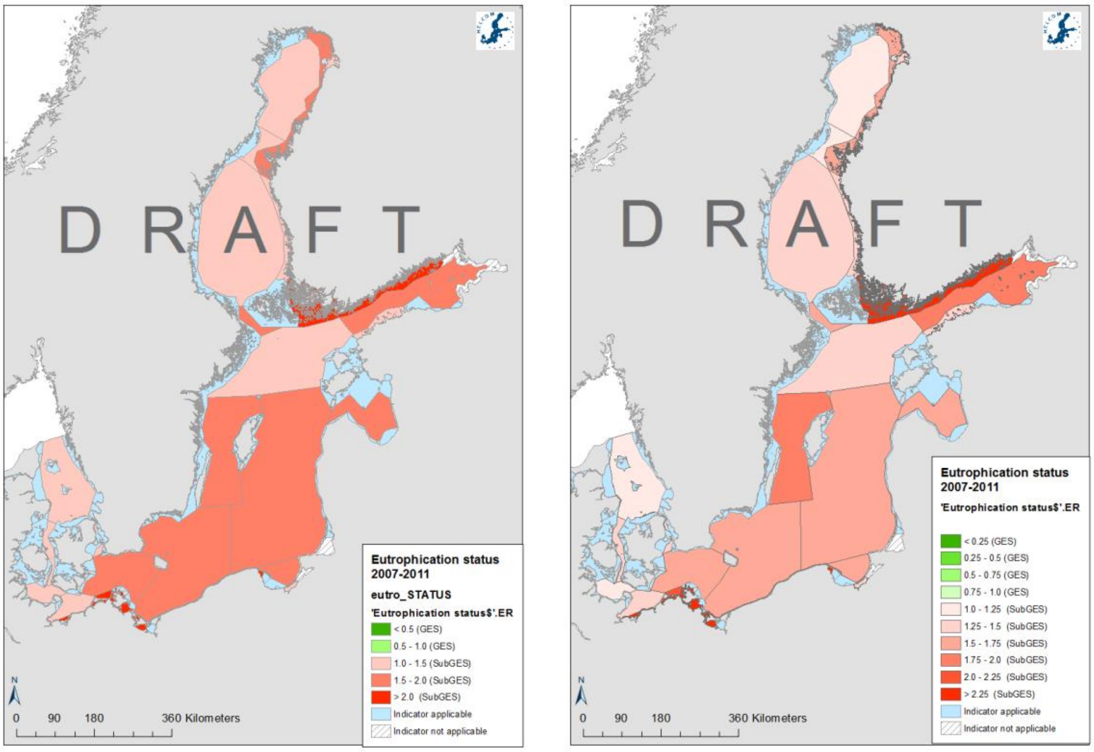


Figure 3.6. Map illustrations of eutrophication status using the two alternative sub-classification: MSFD with 5 subclasses (left panels) and MSFD with 10 subclasses (right panels). The data for open-sea sub-basins is from the HELCOM eutrophication assessment 2007-2011, and for coastal sub-basins from the results of testing of HEAT in coastal areas (EST, GER, POL) or calculated from the coastal indicator data delivered by to EUTRO-OPER. Note that the results for coastal areas are thus preliminary and should not be used to communicate eutrophication status as assessed by HELCOM or the Contracting Parties.

3.3.2 On scales

The scaling used in HEAT 3.0 is based on even intervals for ER values between 0 and 2 (GES = 1). In theory, there is no maximum for ER, and much higher values occur, especially in some coastal areas. The suggested visualization focuses on showing differences at values relatively near GES. It is not sensitive to values far from GES, but instead gives them all the same dark shade of red. Extending the scale to high values, possibly in a non-linear way, might provide more information in situations far from GES. Naturally accuracy is then lost at values close to GES (Figure 3.7).

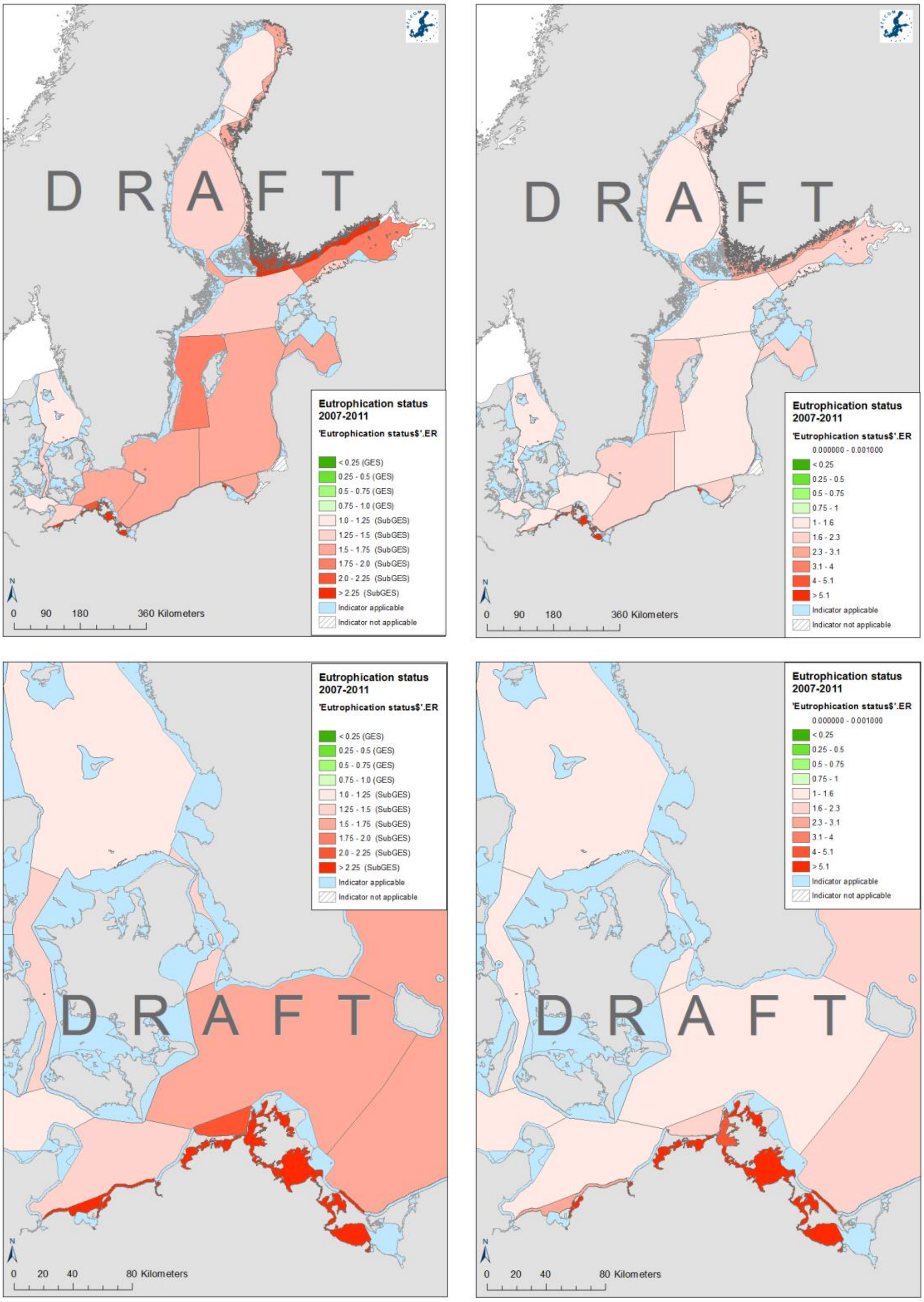


Figure 3.7. Map illustrations of eutrophication status using the 10-class sub-classification with examples of two different scales: linear scaling until ER=2 (left panels, same as presented in Figure 3.6) and non-linear scaling (right panels). The data for open-sea sub-basins is from the HELCOM eutrophication assessment 2007-2011, and for coastal sub-basins from the results of testing of HEAT in coastal areas (EST, GER, POL) or calculated from the coastal indicator data delivered by to EUTRO-OPER. Note that the results for coastal areas are thus preliminary and should not be used to communicate eutrophication status as assessed by HELCOM or the Contracting Parties.

4 Including new data types to indicator update

The 'Eutrophication status of the Baltic Sea' (HELCOM 2014) concluded, *inter alia*, that the confidence of chlorophyll-*a* and Secchi depth indicators would be substantially increased by including also remotely sensed and automated observations to the update of these indicators. EUTRO-OPER 1-2014 agreed to investigate further the possibilities of updating the chlorophyll-*a* indicator using also these data-types, and including them into the assessment data flow. Finland was welcomed to take lead of the work.

4.1 Proposal for including multiple data types in indicator update

Proposal of reporting format of high-resolution data

As the annual volume of high-resolution data may be thousands, if not millions of times as high as for traditionally monitored *in-situ* data, we propose that it is reported to the eutrophication assessment database as aggregated data products. The proposed spatial resolution of the products is 20K (Figure 4.1) and the temporal resolution is 1 day. This resolution was found sufficient for maintaining the spatial variations in the data.

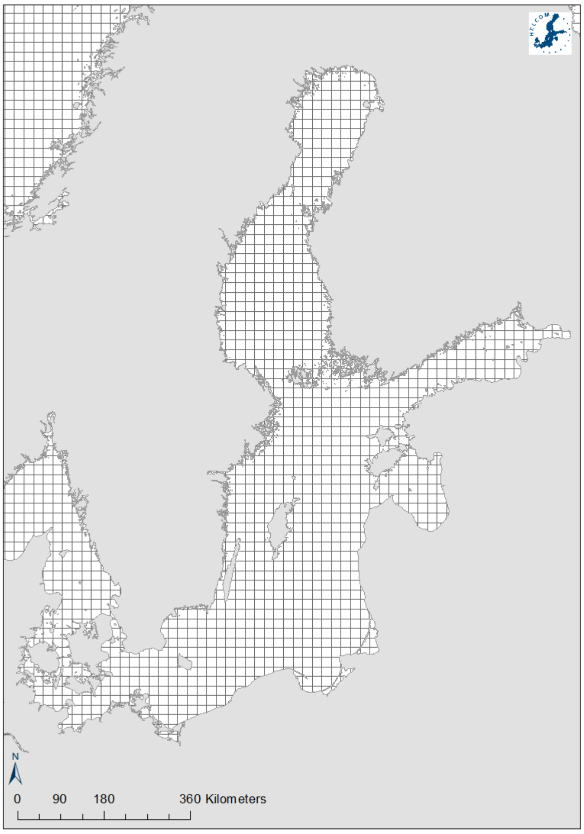


Figure 4.1. HELCOM 20 km grid division.

Examples of such high resolution data are:

- Satellite-based Earth Observations (EO-data), with annual observation (i.e. pixel) number as high as 65 million for assessment area

- Ferrybox flow-through observations, with annual observation number between 4-5 digits per assessment unit
- Results of data assimilation models (eg. DIVA)

New data types must always be tested and agreed to be used, before introducing them to be used in the eutrophication assessment update.

Proposal for updating indicators combining *in-situ* data with other data types

Based on the reasoning in chapter 4.3, we propose using weighted averaging when combining the two data types to produce a final status estimate. In order to assure harmony between areas not covered by all data types, and to continue taking advantage of the available in-situ data, we further propose that the weighing should be based on confidence scores and methodological correction factors.

The confidence correction factors are determined according to the status confidence (table 4.1). The status confidence is produced as an outcome of the eutrophication assessment work flow, and based on the number of monitoring data available (HELCOM 2014). When the correction factors are used, they are normalized against the sum of confidence correction factors.

Table 4.1. Number of annual monitoring observations during indicator period, and subsequent tatus confidence and confidence correction factor.

Number of observations	Status confidence	Confidence correction factor
0	NA	0
1 – 5	LOW	0.2
6 – 15	MODERATE	0.75
> 15	HIGH	1.0

The methodological correction factors are agreed by experts representing contracting parties and responsible of the eutrophication assessment (the eutrophiction network). They are based on validation results and information on data collection methods, depending on the data type in question. They are determined for each assessment unit separately, so that the sum of methodological correction factors in a specific assessment unit is 1.0.

Proposal including EO data into the assessment data flow

We propose to add EO chlorophyll-*a* data to HELCOM assessment database to increase the confidence of chlorophyll-*a* indicator, especially in areas with low *in-situ* monitoring input. The EO-based information is reported, as proposed for high-resolution data, in 20K grid spatial / 1 day temporal data products, providing the following statistics:

- (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

EO data allows for derivation of time series and histograms for each assessment area. This type of data may not be storable in the HELCOM database. Nevertheless, time series and histograms can be provided otherwise for assistance of assessment work.

In addition to the whole assessment area, we see that for cross comparisons between the MS (monitoring station) information and EO data, it is advisable to store data around most commonly used monitoring stations. This requires the identification of monitoring station locations that are of largest interest. For these station locations, a median value using 3x3 pixels around monitoring station location is most preferable.

The update of the chlorophyll-*a* indicator is done according to proposal above, using confidence- and methodological correction factors. When determining confidence correction factor (according to table 4.1), each 20K / 1d grid product is treated as observation. Tentative methodological correction factors were produced, based on the data set and information available during the testing of EUTRO-OPER (table 4.2).

Table 4.2. Tentative methodological correction factors for in-situ chlorophyll-*a* ($m_{in\text{-}situ}$) and EO-based chlorophyll-a estimate (m_{EO}).

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

4.2 Testing update with multiple data types, chlorophyll-*a* example

This chapter provides considerations for inclusion of EO (Earth Observation, i.e. remote sensing) data to the HELCOM Eutrophication assessment database. For the results in this report, the EO data has been processed at SYKE. The EO instrument used for this report is MERIS (MEdium Resolution Imaging Spectrometer). MERIS L1A reflectances were processed to chl-a concentrations using a BEAM plug-in processor MERIS Case-2 Water Properties Processor, FUB (version beam-wew-water-1.2.10, Schroeder et al., 2007b).

In comparison with the monitoring station measurements, the volume of EO and flow-through instrument observations is large. For example, during year 2011, 37 station measurements were made on HELCOM area SEA-012, Northern Baltic Proper. In contrast, 29.6 million non-cloudy EO observations were recorded during the growing season of the same year. Due to large volume of the observations it is not feasible to add all to the assessment database, but rather to include regional and sub-regional statistics for a given period. HELCOM 10K and 20K grids were studied as calculation units for delivering EO data for the assessment to provide spatially balanced data on different parts of assessment areas.

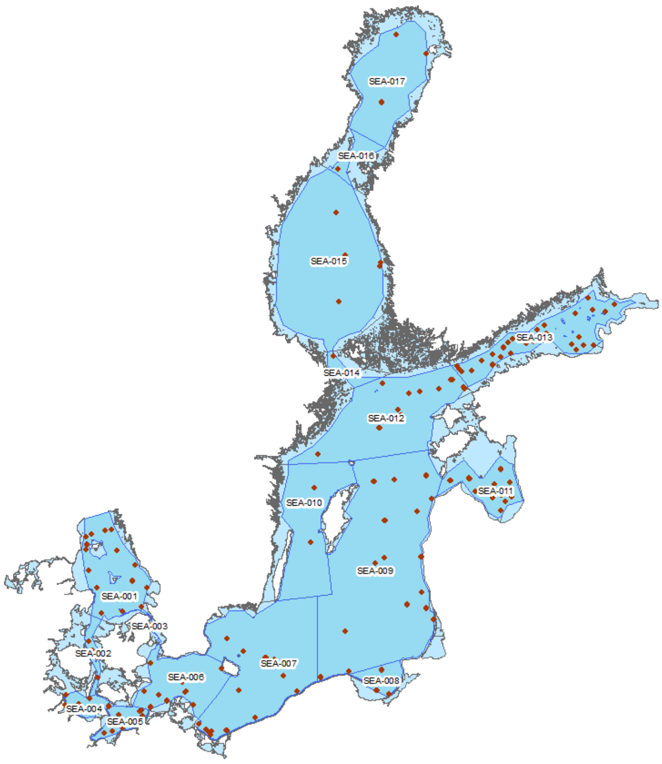
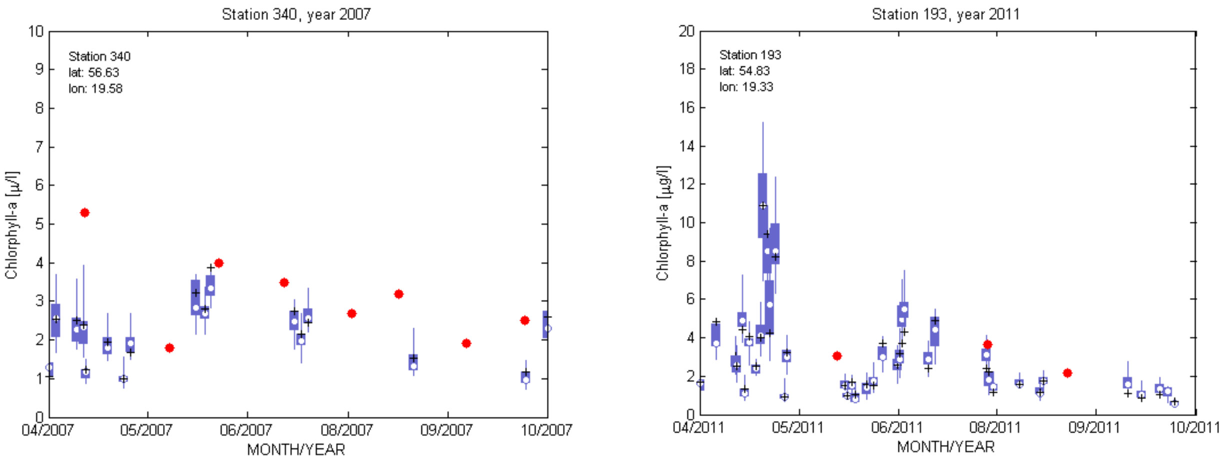


Figure 4.2. a) HELCOM regions and monitoring station locations identified by numbers on the Baltic Sea. ICES data complemented with the assessment 2007-2011 dataset (HELCOM 2014) data was utilized in comparisons against EO data (2007-2011).

4.3 Results of comparison between EO and monitoring station data

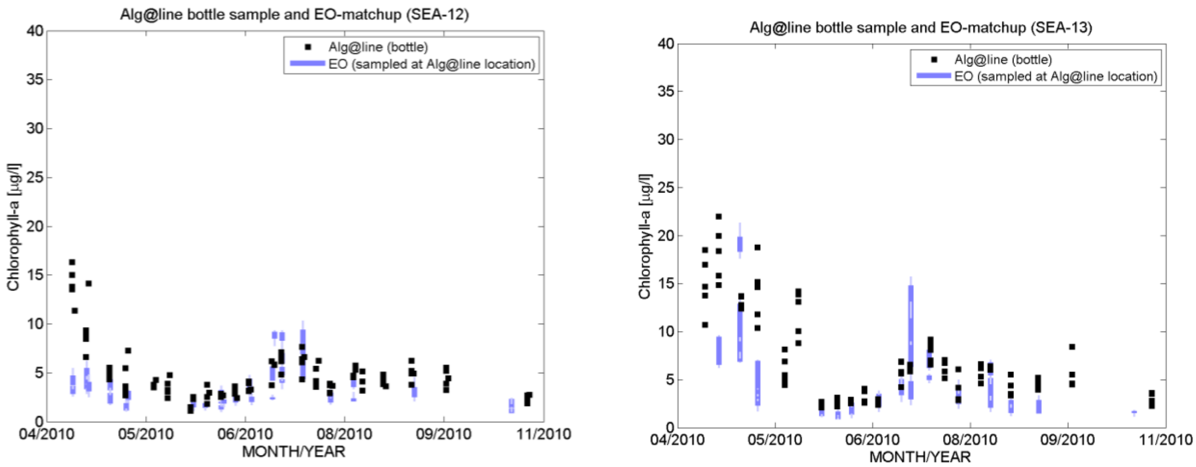
Before using EO chl-a data for the interpretation of the chlorophyll-*a* concentrations in HELCOM assessment areas, their validity in comparison to the ICES monitoring station measurements (hereafter referred as MS) was analyzed for the period of 2007 - 2011. The comparison analysis between EO and ICES was made using 3x3 pixel median values of EO data around the monitoring station locations. Non-cloudy EO observations that occur on the same day as ICES measurements were included in comparison. With the match-up set, the absolute bias that describes differences between ICES and EO chlorophyll-*a* results is less than 5 µg/l on 76.3 % of the dataset and less than 2 µg/l for 54% of the match-ups. Typical periods with high discrepancy between ICES station and EO data are cyanobacteria season and spring bloom, both of which are very dynamic periods with high temporal and spatial variation.

Figures 4.3, 4.4 and 4.5 show the correspondences of the EO, Alg@line and ICES datasets on time series with all the observations included.



a) b)

Figure 4.3. Example of time series of chlorophyll-*a* [µg/l] observations using EO (blue bars) and monitoring station measurements (red dots). EO data is collected using 3x3 pixels around a) station 340, year 2007 and b) station 193, year 2011.



a) b)

Figure 4.4. Example of time series of chlorophyll-*a* [µg/l] observations using EO (blue bars) and Alg@line measurements (black squares). EO data is collected using 3x3 pixels on water sample locations on Alg@line ship route. HELCOM assessment areas a) SEA-12 (Northern Baltic Proper) and b) SEA-13 (Gulf of Finland).

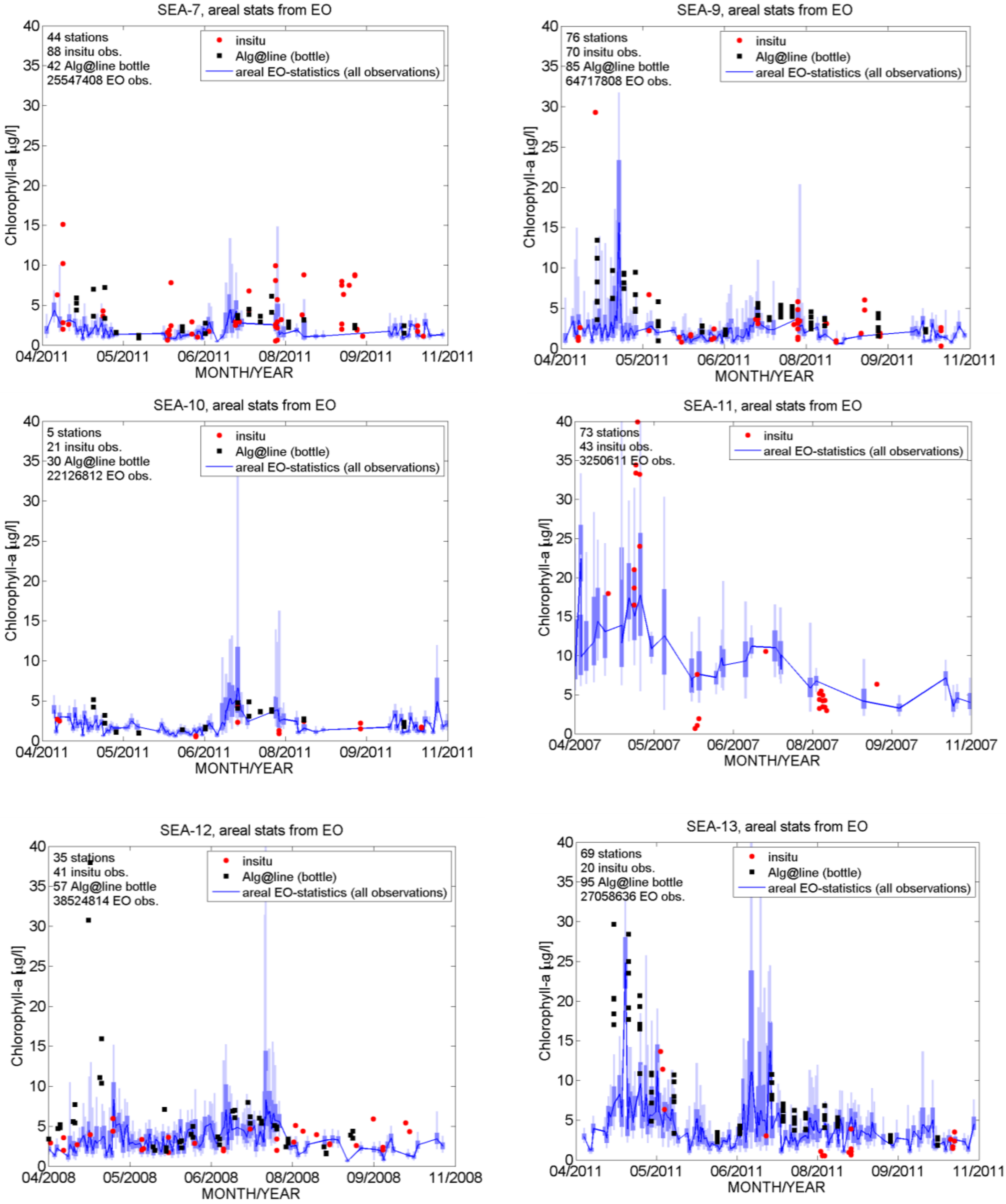


Figure 4.5. Examples of time series of chlorophyll-a [µg/l] observations using monitoring station measurements (red dots) Alg@line bottled samples (black squares), EO (blue) bars (daily percentiles). Assessment areas from the top left to bottom right: a) SEA-7, year 2011 b) SEA-9, year 2011 c) SEA-10, year 2011 d) SEA-11, year 2007, e) SEA-12, year 2008, f) SEA-13, year 2011. See Figure 4.2 for assessment area numbers. The EO data represents the whole assessment area.

The differences between EO and ICES (hereinafter MS) chlorophyll-*a* concentrations for the assessment period are mainly due to very different magnitude of sample sizes. Depending on the size of assessment area, EO data observations (individual pixels) typically amount up to several million within one year's assessment period. Thus, EO and MS data should not be expected to result in identical statistics.

The EO and MS datasets were further compared by first analyzing the shapes of the histograms using the match-up datasets that comprise similar amount of samples for both EO and MS data (Figure 4.6). The histograms clearly show that both EO and MS data are not normally distributed but skewed. Histograms produced by both datasets show good fit with Burr distribution (1942) that is a log-logistic distribution. Figure 4.6a and 4.6b show the probability density functions (PDF) fitted to both EO and MS datasets using Burr distribution (Rodriguez, 1977). The similarity of EO and MS distributions in the match-up dataset shows that with same amount of observations EO and MS data would result in similar statistics for the assessment period.

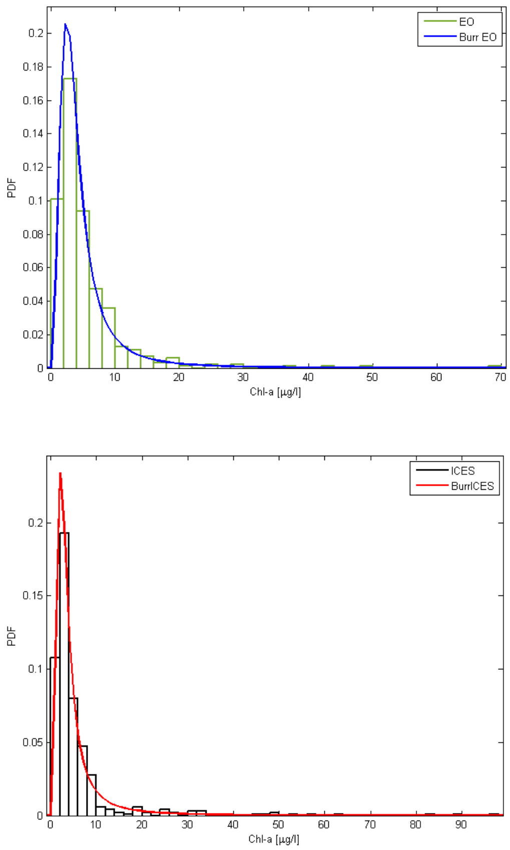


Figure 4.6. Histogram of a) EO data and b) MS data on station locations. Probability density function (PDF) for Burr distribution is fitted to both datasets.

Table 4.1 shows statistical measures calculated for the assessment period using both EO and MS datasets. For MS data, Table 1 presents arithmetic mean and median. For EO data, Table 4.1 presents median, geometric and arithmetic mean. In addition, the mode values of EO data, i.e. the most frequently occurring concentrations of EO chlorophyll-*a* are shown in Table 4.1 for example years of assessment period 2007-2011. Statistics for all years within period 2007-2011 are given in Appendix.

Table 4.1. Statistics of chlorophyll-a [µg/l] measured on monitoring stations (ST), and by EO using areal median, geometric and arithmetic mean and mode of EO observations. EO data represents the whole assessment area. Annual period: 1.6.-31.9. HELCOM assessment areas: SEA-007 - SEA-017.

Name	Bornholm Basin	Gdansk Basin	Eastern Gotland Basin	Western Gotland Basin	Gulf of Riga	Northern Baltic Proper	Gulf of Finland	Åland Sea	Bothnian Sea	The Quark	Bothnian Bay
ID	SEA-007	SEA-008	SEA-009	SEA-010	SEA-011	SEA-012	SEA-013	SEA-014	SEA-015	SEA-016	SEA-017
2007-2011											
ST_{MED}	2,77	3,70	2,90	2,70	3,03	2,72	2,91	2,90	2,52	2,34	2,30
ST_{MEAN}	**3,74**	**4,27**	**3,26**	**2,84**	**3,13**	**2,75**	**2,93**	**3,03**	**2,55**	**2,34**	**2,36**
EO_{AMEAN}	1,85	4,32	2,65	2,67	4,88	3,01	4,44	2,43	2,08	2,28	2,37
EO_{GMEAN}	**1,62**	**3,39**	**2,28**	**2,23**	**4,47**	**2,58**	**3,81**	**2,17**	**1,92**	**2,06**	**2,16**
EO_{MED}	1,60	3,23	2,42	2,41	4,69	2,67	3,86	2,37	1,96	2,11	2,19
EO_{MODE}	1,59	1,93	1,73	1,04	4,75	2,48	2,83	2,85	1,65	1,97	1,40

In most cases, the arithmetic mean of EO data (EO_{AMEAN} in Table 4.1) has the highest concentration. Unlike mode and geometric mean, arithmetic mean is sensitive to high (extreme) concentrations, such as the cyanobacteria period, which is often observed via EO data. Figure 4.7 gives an example of this by showing histogram of EO data and different statistical measures calculated from it. For assessment, it is relevant to use EO statistics that indicate where most of the observations lie within the assessment period. Thus, either geometric mean or mode values should be used in the assessment for the case of EO data. For EO data this is more relevant than MS due to the large amount of cyanobacteria observations.

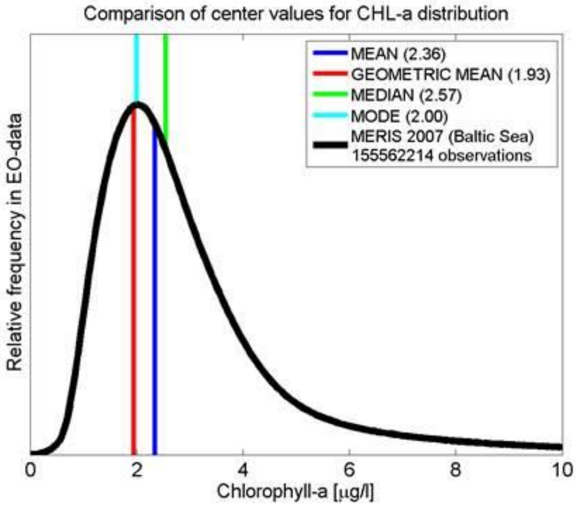
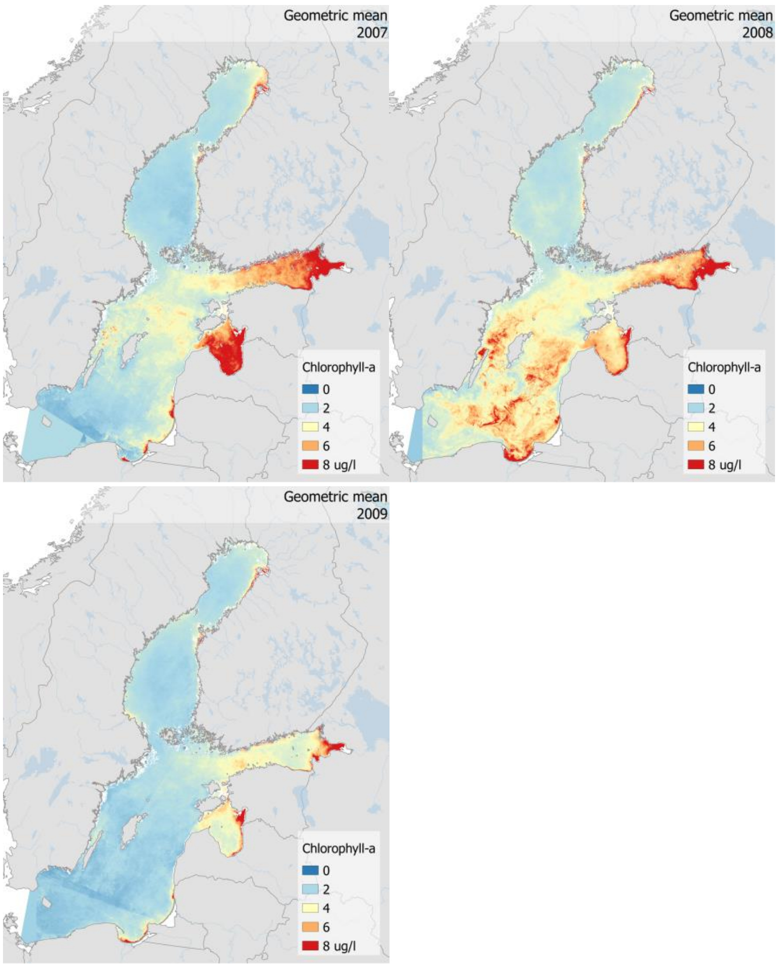


Figure 4.7. Histogram of EO data (Baltic Sea, 2007) and statistical measures derived from the dataset. Typically EO data represents skewed distribution. Skewness depends on the observed area and how much high concentrations (cyanobacteria surface blooms) are observed. Geometric mean and mode are the most representative statistical measures to be used in assessment.

The annual geometric mean for the assessment months varied substantially within the testing period 2007-2011 (Figure 4.8). This was the case especially in the Baltic Proper, Gulf of Finland, Gulf of Riga and Gdansk Basin, where the highest chlorophyll-a levels were found each year.



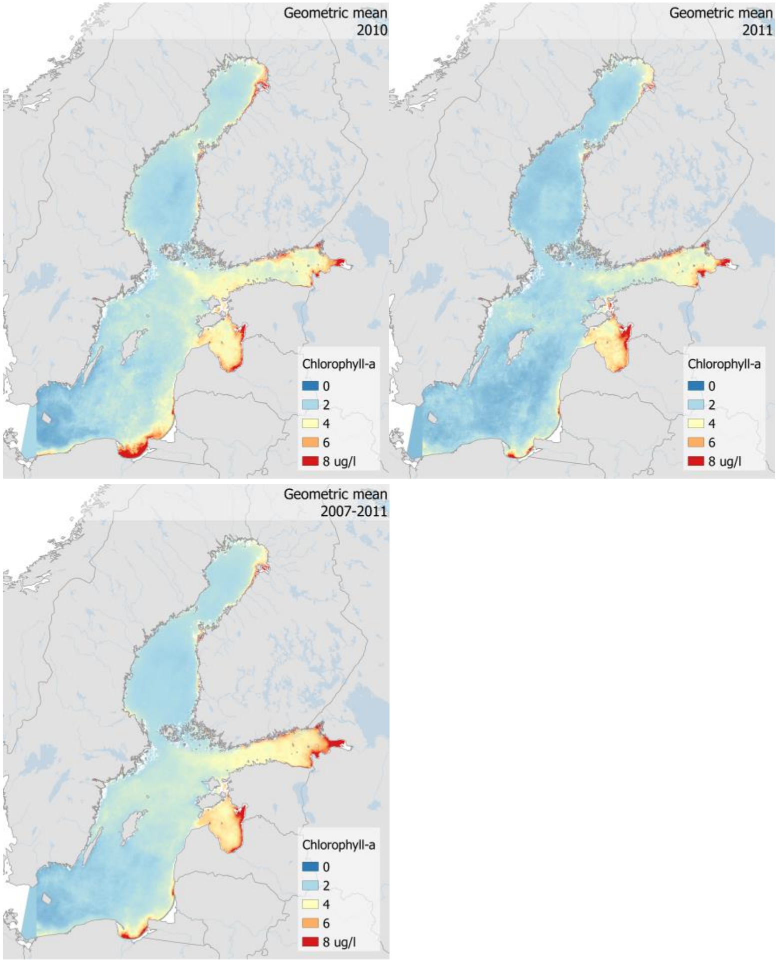


Figure 4.8. Annual geometric mean maps of chlorophyll-*a* [µg/l] derived from EO data (period: 1.6.-31.9., years 2007 -2011. Last map is a summary map of the assessment period 2007-2011.

4.4 Subdivision of EO data on HELCOM assessment areas using HELCOM grids

The use of HELCOM grids (10 and 20km grid sizes) were examined as calculation units for EO data statistics. This was a practical study to see how aggregation of EO data effects on the use of EO to the assessment. Both spatial and temporal aggregations were studied with altogether 10 discretization cases: 2 spatial and 5 temporal aggregation levels. The study started with a pilot area consisting of assessment areas SEA-12 - SEA-14 (see Figure 4.9 for all assessment areas).

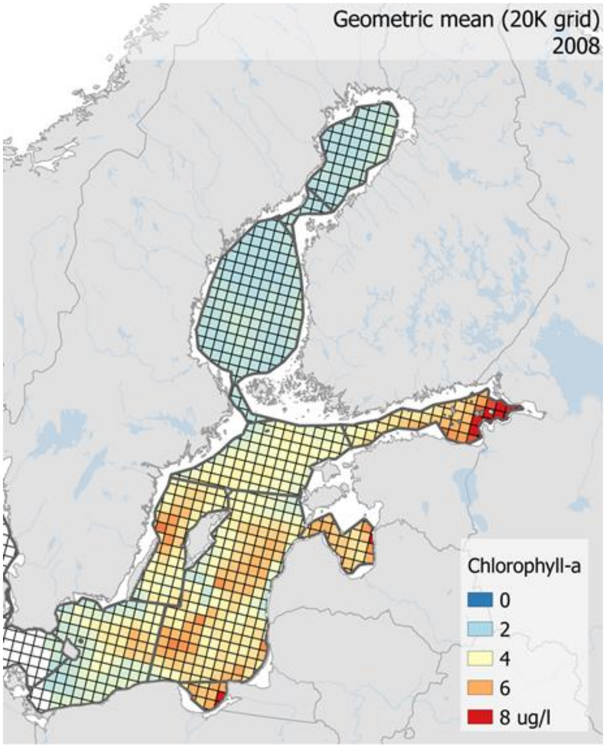


Figure 4.9. HELCOM 20 km grid division overlaid on EO geometric mean concentrations for year 2008.

There were no clear differences in the results when using 10k and 20 k grid sizes, thus examples are given with 20 km grid. The division of EO data with 20km grid proved to be sufficient for maintaining the spatial variation in EO data and reducing the amount of individual EO observations. The division of assessment areas to gridded data enables accounting for spatial variation within assessment areas. This is especially relevant for large, dynamic or spatially segmented assessment areas such as Eastern Gotland Basin or Gulf of Finland (see Figure 4.9).

In principle, it is possible to read all individual EO observations (pixels) to HELCOM Assessment database. However, temporal and spatial aggregation of the data eases the adaptation and utilization of this notably large dataset. Figure 4.10 shows example of statistics derived from cell grid of chlorophyll-*a* values for HELCOM SEA-12 area (Northern Baltic Proper). It shows that the influence of different aggregation time steps is not very relevant for median concentrations and percentiles of chlorophyll-*a* for different years. Similar behavior was observed for arithmetic and geometric mean. However, occasionally the aggregation in time smoothens out the highest concentrations, i.e. 95 percentiles in Figure 4.10 (especially for years 2009-2011). The aggregated datasets using 20 km grid have been calculated for the period 2003-2011 for assessment areas SEA-7 – SEA-17.

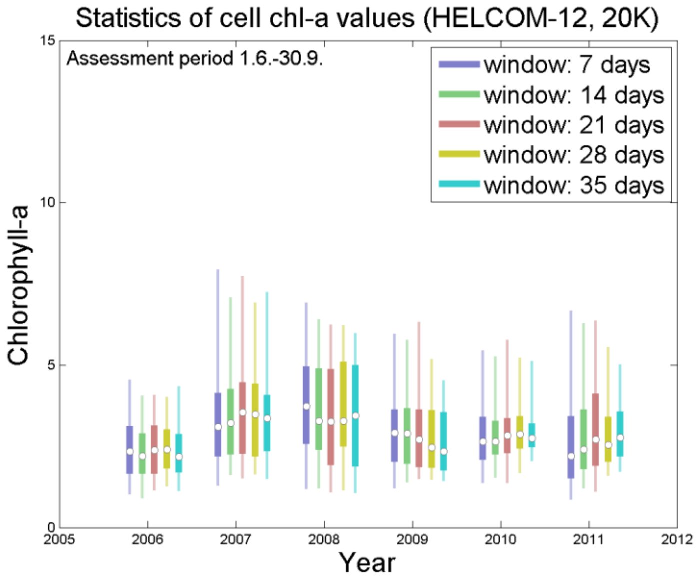


Figure 4.10. The influence of different time aggregation steps to the calculation of statistics for HELCOM assessment area 12 (Northern Baltic Proper). Thin bars represent 5/95 percentile limits and bold bars 25/75 percentile limits, median are shown as white dots for data for different years.

4.5 Approaches for combining different data types to update a single indicator

Methods and specifications

We tested different approaches for combining data types to produce a chlorophyll-*a* status estimate. Testing was done using information from both traditional *in-situ* data and Earth Observation data (EO data, from satellite remote sensing) bearing in mind that a similar methodology should enable the use of a third data type (eg. Ferrybox data) as well. The following approaches were tested (using a daily grid cell estimate to represent one observation when determining *n* for EO-data, see chapter 4.2.2).

Approach 1: Choose for each sub-basin the method with most available data (higher *n*).

- use ES-score (and number of obs if ES-scores are equal) for choosing

Approach 2: Averaging the ES values achieved using the two methods, where possible.

- where both data types exist, average the 2007-2011 estimates

Approach 3: Calculating weighted average of the two estimates.

- Confidence score: Setting weights according to number of observations or status confidence.
- Methodological correction factor: Setting correction factors were based on station-wise validations. This resulted in EO-estimates being weighted by 45% against 55% for in-situ observations in the Gulf of Riga, and 30% for EO data against 70% for in-situ observations in other basins).

The approaches were tested for the present assessment period (2007-2011). In-situ chlorophyll-*a* assessment data from HELCOM 2014 were used. For the EO-estimate, the data presented in Table 4.1 and ANNEX 4A of this document were used. The indicator methodology reported in the 'Eutrophication status of the Baltic Sea 2007-2011' (HELCOM 2014, Fleming-Lehtinen et al. 2015) was used, except for the following:

- Geometric means were used as annual or periodic (2007-2011) estimates for both *in-situ* and EO-data (as justified in chapter 4.1).
- When using ES-Scores as confidence estimates, the numerical scale was slightly adjusted to make a difference between situations with no observations as opposed to those with a small number of observations available. ES-scores were set as *High* = 100%, *Moderate* = 50%, *Low* = 10% and *no data* = 0% (used in approaches 1 and 3).
- For EO-data, the number of 20 x 20 km grid cells containing data, multiplied by the number of observation days, was used to describe *n*. This is in line with the proposed approach for the data format, as described below and used in approaches 1 and 3.

Results

In sub-basins where EO-based estimates and *in-situ* -based estimates differ substantially, the choice of combination methodology may affect the estimated level by up to 1.5 µg l^{-1}.

Approach 1: Choosing the estimate with the most data

Due to the vast data numbers, approach 1 leads to the use of EO-data in all sub-basins where this data type was available (SEA 07-17). Only the sub-basins lacking EO-data were estimated using *in-situ* data alone. At the present situation, this lead to a segregation between the approaches used in the southwest from the one used in the northern sub-basins. This should however be overcome when satellite-images from the southwestern areas become available. After that, using this approach would lead to *in-situ* data in the future having only a role in the validation of EO algorithms.

Approach 2: Averaging of estimates

In this approach, the two data types were used equally regardless of the amount of the data. This was also the case in sub-basins suffering from low confidence in the previous assessment due to small amounts of *in-situ* data (SEA 11 & 13-17).

Approach 3.1: Weighted average, using methodological correction factor and confidence scores

When methodological correction factors and confidence scores (ES-SCORE from HEAT 3.0) were used for weighting, both data types were used more or less equally in five (SEA 7-9 & 11) out of the sub-basins covered by EO-data. This increased the role of conventional in-situ data where sufficient observations were available. In basins lacking *in-situ* data however (SEA 11 & 13-17), EO-data was used compensated, though not completely.

Approach 3.2: Weighted average, using methodological correction factor and observation numbers

When observation numbers instead of confidence scores were used for weighing, EO-data dominated the final status estimate in all cases where it was available. The result was observed to be the same when replacing *n* with the *CV* (a statistical value combining standard error and *n*), and when a periodic weight estimate was used instead of annual weight estimates.

Choosing the most suitable approach

When deciding upon the approach to use when combining data types, one should keep in mind the following aspects: 1) The process to compute the final status estimate should be data-driven, in order for us to be able to use it in the EUTRO-OPER work flow, 2) we should use the approach we believe produces the most confident estimate, 3) the comparability to targets (GES boundaries) should be as good as possible, 4) harmonization between sub-basins should be optimal and 5) harmonization with previous assessment should be optimal (but not though sacrificing points 2-4). Table 2 presents a summary on how the different approaches take these points into account.

All three of the approaches are data driven, to the extent that they can be repeated by algorithms in the EUTRO-OPER work flow. Appr3.1 and Appr3.2 apply a methodological correction factor that might be complicated to produce in the work flow, but the estimates are not expected to change in time, and can thus be given as constant factors that are checked at regular intervals.

Of the approaches used, Appr3.1 and Appr3.1 provide the most confident final status estimates, since they take into account the data availability as well as, robustly, the uncertainty of the method used. The two approaches can even be developed further. Appr1 also takes the confidence into account, but where confidences are both good, the two data types are not taken advantage of together.

The targets (GES boundaries) have been estimated using spatial normalization of data points (see HELCOM 2013), in attempt to provide true average of the sub-basin in question. The HELCOM COMBINE monitoring program has also been developed to provide an optimal coverage of the sub-basins. In practice, when monitoring is not ambient and the number of observations is low, this is not always achieved. Thus, *in-situ* data, when in low numbers, does not provide a good spatial coverage. In addition, it does not take into account the high natural variability of the data. This leads to the conclusion, that Appr2 does not necessarily provide a confident final status estimate in all cases.

If all data types are not equally available for the different sub-basins, the approach providing highest harmony between them would be one combining the data types in relation to data availability and/or confidence. In the present case, where EO-data is unavailable from the southern sub-basins Appr1 causes a clear-cut methodological difference to appear at the boundary of these areas, and cannot thus be considered to optimize harmony across sub-basins. In practice, this applies also to Appr3.2, which has high dominance of EO-data wherever present. Additionally, *in-situ* observation numbers are very low in the northern sub-basins, causing high variation in uncertainty of *in-situ* data between northern and southern sub-basins, implying that Appr2 could not be considered optimal either. It can be suggested, that Appr3.1 combines the two data types in the most conservative way, in the present situation maximizing harmony between sub-basins.

Table 4.2. Summary on how the four approaches take into account the requirements set upon them (see text above).

Aspect	Appr1	Appr2	Appr3.1	Appr3.2
1) Data driven	Yes	Yes	Yes	Yes
2) Confident estimate	Moderately	No	Yes	Yes
3) Comparability to targets	Yes	Moderately	Yes	Yes
4) Sub-basin harmony	No	Moderately	Yes	Moderately
5) Previous assessment harmony	Moderately	Moderately	Moderately	Moderately

5 Input to core indicator web reports and monitoring manual

5.1 Improving core indicator web reports

5.1.1 Background of HELCOM core indicators of eutrophication

The HELCOM EUTRO project (2005) began investigating and developing methodology for an integrated thematic assessment. The project reported sub-basin specific sets of eutrophication indicators, such as nutrient concentrations (inorganic and total N and P), nutrient ratios (N, P, Si), chlorophyll-*a*, phytoplankton biomass, primary production, cyanobacteria, Secchi depth, oxygen concentration/depletion, H_2S concentration, zooplankton biomass and a variety of macrovegetation and zoobenthos indicators. They were published in 'Development of tools for assessment of eutrophication in the Baltic Sea' (HELCOM 2006).

The HELCOM EUTRO-PRO project (2006-2009) reduced the set of indicators. The set of eutrophication indicators used in the 2001-2006 assessment consisted of the following: nitrogen (DIN and/or totN), phosphorus (DIP and/or totP), chlorophyll-*a*, Secchi depth, zoobenthos (presented by alternative indicators) and submerged aquatic vegetation (presented by several indicators). The project published a final report 'Eutrophication in the Baltic Sea' (HELCOM 2009).

After publication of the first eutrophication assessment, HELCOM MONAS 11/2008 endorsed a set of prioritized eutrophication indicators for further development under inter-sessional workshops. This list was scrutinized in the workshops CORE EUTRO 1/2009 and 2/2010, resulting in the selection of the following core eutrophication state indicators: nutrient concentrations (nitrogen and phosphorus), water transparency, chlorophyll-*a*, phytoplankton biomass and species, macrophytobenthos, zoobenthos and oxygen. Other indicators found to be relevant but not developed further at that stage were primary production, spring bloom and cyanobacterial blooms.

By CORE EUTRO 4/2011, Secchi depth, chlorophyll-*a*, DIN and DIP indicators were operational (in that they could be updated with monitoring data). The phytoplankton species, macrophytobenthos and oxygen indicators have been under development under the CORE EUTRO activity, but have not been finalized. Meanwhile, the TARGREV project began developing an oxygen indicator based on the concept of oxygen debt below the halocline, and finalized the indicator for the sub-basins connected to the Baltic Proper by 2011. The zoobenthos indicator (Villnäs & Norkko, 2011) was also developed further under the TARGREV project, but was not finalized; it was left out of the eutrophication assessment also as a response to the requirements for assessing eutrophication under the MSFD (Anon. 2008)

GES boundaries (or targets) for core indicators

The HELCOM EUTRO project (2005) developed tentative reference conditions with acceptable deviations (generally set at 50%) for sub-basin specific sets of eutrophication indicators. The reference conditions were estimated through data mining, modelling and/or expert judgement. The work of HELCOM EUTRO was published in the final report 'Development of tools for assessment of eutrophication in the Baltic Sea' (HELCOM 2006).

The HELCOM EUTRO-PRO (2006-2009) revised the reference conditions where necessary. The project published a final report 'Eutrophication in the Baltic Sea' (HELCOM 2009).

The HELCOM TARGREV project (2010-2011) developed new scientifically-based target levels for the DIN, DIP, chlorophyll-*a*, Secchi depth and oxygen debt indicators in the open sea basins. The target levels, estimated through data mining using a GAM-GLM model to eliminate spatial and temporal bias together with ensemble hindcast modeling, were not based on reference conditions but described a state of good environmental status, and were published in the final report 'Approaches and methods for eutrophication target setting in the Baltic Sea region' (HELCOM 2013).

To determine final eutrophication targets, CORE EUTRO 7/2012 scrutinized the TARGREV target levels, producing a list of eutrophication status targets. Generally, the TARGREV targets were accepted as such, except where not found justified in light of published literature or in relation to the WFD targets in the neighboring coastal areas, taking into account the precautionary approach (in such cases, the tentative target from EUTRO-PRO remained valid). The eutrophication targets were thereafter accepted by HELCOM HOD 39/2012, and listed in the meeting minutes together with justifications provided by CORE EUTRO. The targets are published in 'Eutrophication status of the Baltic Sea 2007-2011' (HELCOM 2014).

5.1.2 Improving web reports

EUTRO-OPER updated the core indicator reports for eutrophication, based on the information used in the HELCOM eutrophication status assessment 2007-2011 for open-sea areas (HELCOM 2014). Indicator reports for DIN, DIP, chlorophyll-*a*, Secchi depth and oxygen debt were placed on the HELCOM web site alongside with other HELCOM core indicator reports (http://www.helcom.fi/baltic-sea-trends/indicators/, Figure 5.1).

The structure of the indicator reports was defined in collaboration with the CORESET II project, with the aim of harmonizing all HELCOM core indicator reports. The indicator reports were to have a hierarchical structure, with highest level expressing key message, and the next level, directed to experts, expressing results and information on confidence, good environmental status, indicator relevance, monitoring requirements, data, updating and contributors. The structure was built in a way that during indicator update, updating the results and confidence section together with indicator data would be sufficient, while other parts of the indicator report could remain more or less as they are.

The indicator results were embedded as interactive map and chart elements, using the HELCOM data and map service and interactive charts.

Figure 5.1. Indicator report in HELCOM web site.

5.2 Input to the HELCOM Monitoring manual

The project was tasked to develop a manual for monitoring each eutrophication state core indicator. Through work done under the MORE project, HELCOM developed a monitoring manual concept, with the aim that through reporting the monitoring sheets for the manual, Contracting Parties who are EU member states will simultaneously fill the requirements of Article 11 (3) of the MSFD. The monitoring program consists of program topics and sub-programs.

EUTRO-OPER contributed to the eutrophication monitoring program, by providing information to the programme topic sheets and sub-programmes for hydrography (oxygen and Secchi depth), hydrochemistry (nutrients) and Phytoplankton (pigments). The HELCOM monitoring manual is found at the HELCOM web site: http://www.helcom.fi/action-areas/monitoring-and-assessment/monitoring-manual/ .

6 Developing and testing potential new eutrophication indicators

The projects on operationalization of HELCOM core indicators (HELCOM CORESET and CORESET II) identified gaps in the present set of HELCOM core indicators in 2014, and began indicator development based on the outcome. Some of the indicators under development were also relevant for eutrophication (Table 6.1).

EUTRO-OPER identified six potential new core indicators for eutrophication to be developed for use in open-sea areas: total nitrogen, total phosphorus, spring bloom chlorophyll-*a*, cyanobacterial blooms, oxygen consumption and nutrient ratios. The four first named were developed to the stage that they could be given Pre-CORE status in June 2015 (STATE & CONSERVATION 2-2015), whereas oxygen consumption still remains as a candidate indicator due to it's developmental stage. After preliminary testing, nutrient ratios were found to be unsuitable as an indicator, and the indicator was not proposed to be developed further.

Table 6.1. HELCOM core- pre-core and candidate indicators of eutrophication eutrophication, their links to BSAP objectives (CN = concentrations of nutrients close to natural levels, AB = natural levels of algal blooms, CW = clear water, NO = natural oxygen levels, NPA = natural distribution and occurrence of plants and animals, TBC = thriving and balanced communities of plants and animals, MCL = natural marine and coastal landscapes) and MSFD criteria (EU 477/2010), information on GES boundary and developmental stage. (*Note the study reservations outlined above by Denmark, Germany and Finland)

Indicator name	S-status P-pressure	BSAP obj.	EU MSFD criterion primary	secondary	GES-boundary	**Developmental stage of indicator**
Core indicators of eutrophication						
Winter DIN concentration	S	CN	5.1.	1.6	Agreed for 17 open-sea sub-basins (HELCOM 2014)	**Fully operational**
Winter DIP concentration	S	CN	5.1.	1.6	Agreed for 17 open-sea sub-basins (HELCOM 2014)	**Fully operational**
Summer Chlorophyll-a concentration	S	AB	5.2	1.6	Agreed for 17 open-sea sub-basins (HELCOM 2014)	**Fully operational**

Indicator name	S-status P-pressure	BSAP obj.	EU MSFD criterion primary	EU MSFD criterion secondary	GES-boundary	**Developmental stage of indicator**
Summer Secchi depth	S	CW	5.2	1.6	Agreed for 17 open-sea sub-basins (HELCOM 2014)	**Fully operational**
Deep bottom oxygen debt	S	NO	5.3		Agreed for 7 open-sea sub-basins (HELCOM 2014)	**Fully operational**
Other core indicators						
State of the soft-bottom macrofauna community	S	TBC	6.2	1.6, 5.3	Open sea: not yet proposed Coast: agreed to use national boundaries with intercalibration	**CORE indicator of biodiversity. Development of high priority.**
Pre-core indicators						
Total nitrogen concentration	S	CN	5.1.	1.6	Not established	**Pre-core indicator of eutrophication, under development**
Total phosphorous concentration	S	CN	5.1.	1.6	Not established	**Pre-core indicator of eutrophication, under development**
Cyanobacterial surface accumulations	S	AB	5.2	1.6	Not established	**Pre-core indicator of eutrophication, under development**
Phytoplankton spring bloom intensity based on chl-a	S	AB	5.2	1.6	Not established	**Pre-core indicator of eutrophication, under development**
Lower depth limit distribution of the macrophyte community	S	TBC, NPA	1.5	6.2, 5.3	Not established	**Pre-core indicator, not used for HELCOM eutrophication assessment**
Diatoms/dinoflagellates ratio	S	TBC	4.3	1.6, 1.7, 5.2	Not established	**Pre-core indicator, not used for HELCOM eutrophication assessment**
Candidate, supplementary and other indicators						
Oxygen consumption	S	NO	5.3		Not established	**Candidate indicator under development**
Shallow bottom oxygen concentration	S	NO	5.3		Not established	**Candidate indicator under development**
Biomass ratio of opportunistic and perennial macroalgae	S	TBC, MCL	5.3	1.6, 1.7	Not established	**Candidate indicator, not relevant for eutrophication in HELCOM assessment**
Stateof the soft-bottom macrofauna communities	S	NPA	1.6, 6.2	5.3	Not established	**Candidate indicator, not relevant for eutrophication in HELCOM assessment**
Benthic diversity indicator	S	NPA	5.3	6.2	Tentative boundaries for open-sea assessment units	**Previous use in eutrophication assessment, presently**

Indicator name	S-status P-pressure	BSAP obj.	EU MSFD criterion primary	secondary	GES-boundary	**Developmental stage of indicator**
					under earlierdivision would need to be updated	**not used, not operational**

6.1 New Pre-CORE indicators on total nutrients

EUTRO-OPER 1-2014 recognized a need for developing indicators on total nutrients, and an indicator on total nitrogen as one of them, to support the present core indicators on winter inorganic nutrients, that might however overlook nutrients possibly bound to biological matter even during winter time, especially during warm winters. Germany was welcomed to take lead of the development work.

At present, the indicators are under PRE-CORE status. The indicator report is presented below.

6.1.1 Total nitrogen

Policy relevance

	Primary importance	**Secondary importance**
BSAP Segment and Objective	A Baltic Sea unaffected by eutrophication PRE-CORE INDICATOR	none stated
MSFD Descriptors and Criteria	5.1 Nutrient levels	none stated
Other relevant legislation: (e.g. WFD)	Water Framework Directive, ecological status, QE4	none stated

Role of total nitrogen in the ecosystem

Marine eutrophication is mainly caused by nutrient enrichment leading to increased production of organic matter supplied to the Baltic Sea with subsequent effects on water transparency, phytoplankton communities, benthic fauna and vegetation as well as oxygen conditions. Phytoplankton need nutrients, mainly nitrogen and phosphorus, for growth.

Adding total nutrients alongside inorganic nutrients as core indicators strengthens the link from nutrient concentrations in the sea to nutrient enrichment. In particular these parameters allow to take account of climate change in the eutrophication assessment since higher temperatures will lead to year-round phytoplankton proliferation and / or possible changes in zooplankton communities. To illustrate this point, the concentration of the total and the dissolved inorganic fractions of nutrients have been compared, and diverging trends have been observed in some sub-basins. For example, a decrease in winter DIN concentrations has been identified in the Bornholm Basin since the 1990's, but TN concentrations have remained high (see Figure below). A possible reason for this observation could be that in winter more nutrients are bound in the phytoplankton due to the higher water temperatures. In such a situation assessing only dissolved inorganic concentrations gives the wrong impression that nutrient concentrations seem to be declining, while, in fact, they are stable or increasing as can be seen when also assessing total concentrations. In conclusion, to get a good understanding of the trend in nutrient concentrations in the marine environment monitoring and assessing both, total and dissolved nutrients, is important. Furthermore, total nitrogen is often monitored and assessed all year round and annual averages are based on more data compared to the dissolved nitrogen, that is only monitored in winter. Assessment results for total nitrogen might therefore be more robust. Lastly, total nitrogen is required to calculate nitrogen budgets that allow for an investigation of the amount of nitorgen imported or exported from an area.

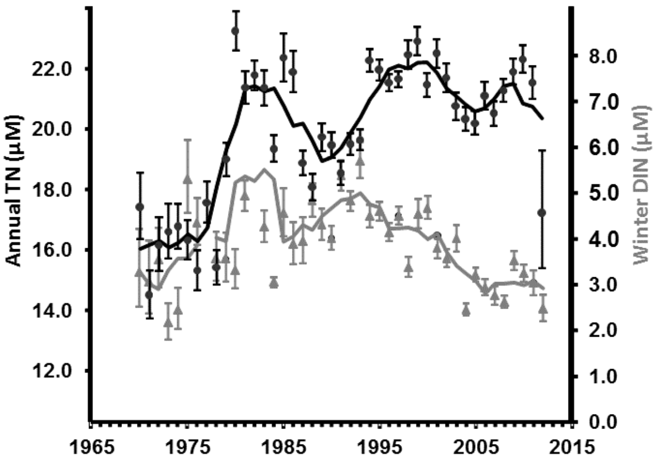


Figure 6.1. Time series of annual TN (black line and dots) and winter DIN (gray line and dots) in the Bornholm Basin. The decrease in winter DIN since the 1990's is not expressed by annual TN. The figure is modified from HELCOM 2013.

Estimation of good Environmental Status

As TN and TP were not simulated in the TARGREV modeling exercise only upper limits of annual means of TN and TP are proposed as GES targets (see TARGREV report page 84). These upper levels already represent a eutrophied Baltic Sea in the early 1970s and are therefore not suitable as GES targets since they are not in agreement with the target levels of the other eutrophication indicators (e.g. DIN, DIP, secchi depth). Nevertheless, some CPs have derived target levels for total nutrients.

Ecological modelling is planned to be used in estimating GES-boundaries in the open-sea-areas. In Germany, a new modeling approach has recently provided revised target concentrations for total nutrients in the Kiel Bay, Mecklenburg Bay, Arkona Basin and Bornholm Basin. The approach is based on historic nutrient inputs around 1880 and modelling of resulting total nutrient concentrations with ERGOM (Schernewski et al. 2015). Other ecological models, eg. BALTSEM or ERGOM, are planned to be used for setting targets for the remaining open-sea sub-basins, however, they currently are not able to deliver trustworthy target levels for total nutrients. One reason is that the ecosystem models applied can currently only resolve the fraction of total nitrogen that is dissolved or bound in phyto- and zooplankton or detritus (labile fraction), while the refractory nitrogen cannot be reproduced by the models. In coastal waters this is not a problem since the labile fraction of nitrogen dominates, but in the open sea refractory nitrogen cannot be neglected.

For coastal assessment units, national boundaries used for estimating Good Environmental Status under WFD may be used.

Anthropogenic pressures relevant to the indicator

	Strong connection	Secondary connection
General	Nutrient concentrations in the water column are affected by anthropogenic nutrient loads from land and air.	
MSFD Annex III, Table 2	Nutrient and organic matter enrichment	

Description of metadata and updating

Data source: The average for 2007-2011 was estimated using monitoring data provided by the HELCOM Contracting Parties, and kept in the HELCOM COMBINE database, hosted by ICES (www.ices.dk).

Description of data: The data includes total nitrogen observations, determined as explained in the HELCOM COMBINE manual. Measurements made at the depth of 0 – 10 m from the surface were used in the assessment.

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

Temporal coverage: The raw data includes observations throughout the year, during the assessment period 2007-2011. For the summer average, observations taken during June-September were included only.

Data aggregation: The 2007-2011 averages for each sub-basin were produced as an inter-annual estimates using observations from all months / June-September.

6.1.2 Total phosphorus

Policy relevance

	Primary importance	**Secondary importance**
BSAP Segment and Objective	A Baltic Sea unaffected by eutrophication PRE-CORE INDICATOR	none stated
MSFD Descriptors and Criteria	5.1 Nutrient levels	none stated
Other relevant legislation: (e.g. WFD)	Water Framework Directive, ecological status, QE4	none stated

Role of total phosphorus in the ecosystem

Marine eutrophication is mainly caused by nutrient enrichment leading to increased production of organic matter supplied to the Baltic Sea with subsequent effects on water transparency, phytoplankton communities, benthic fauna and vegetation as well as oxygen conditions. Phytoplankton need nutrients, mainly nitrogen and phosphorus, for growth.

Adding total nutrients alongside inorganic nutrients as core indicators strengthens the link from nutrient concentrations in the sea to nutrient enrichment. In particular these parameters allow to take account of climate change in the eutrophication assessment since higher temperatures will lead to year-round phytoplankton proliferation and / or possible changes in zooplankton communities. To illustrate this point, the concentration of the total and the dissolved inorganic fractions of nutrients have been compared, and diverging trends have been observed in some sub-basins. For example, an indication of decrease in winter DIP concentrations has been identified in the Arkona Basin during the last five years, but TP concentrations have remained somewhat unchanged (see Figure below). A possible reason for this observation could be that in winter more nutrients are bound in the phytoplankton due to the higher water temperatures. In such a situation assessing only dissolved inorganic concentrations gives the wrong impression that nutrient concentrations seem to be declining, while, in fact, they are stable or increasing as can be seen when also assessing total concentrations. In conclusion, to get a good understanding of the trend in nutrient concentrations in the marine environment monitoring and assessing both, total and dissolved nutrients, is important. Furthermore, total phosphorus is often monitored and assessed all year round and annual averages are based on more data compared to the dissolved phosphorus, which is only monitored in winter. Assessment results for total phosphorus might therefore be more robust. Lastly, total phosphorus is required to calculate phosphorus budgets that allow for an investigation of the amount of phosphorus imported or exported from an area.

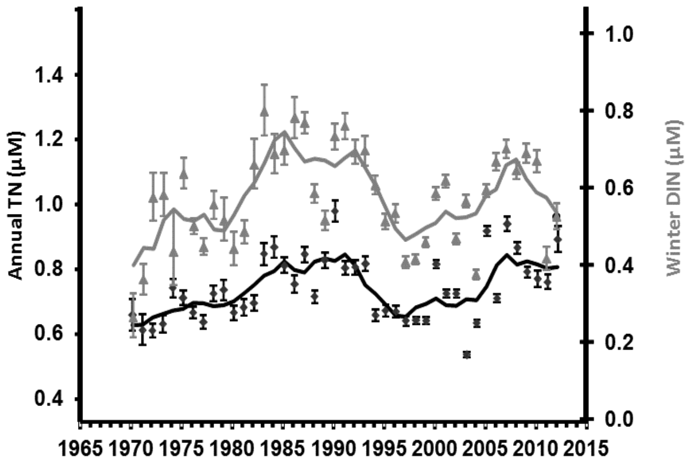


Figure 6.2. Time series of annual TP (black line and dots) and winter DIP (gray line and dots) in the Arkona Basin. The late (since 2008) decrease in winter DIP is not expressed by annual TP. The figure is modified from HELCOM 2013.

Estimation of good Environmental Status

As TN and TP were not simulated in the TARGREV modeling exercise only upper limits of annual means of TN and TP are proposed as GES targets (see TARGREV report page 84). These upper levels already represent a eutrophied Baltic Sea in the early 1970s and are therefore not suitable as GES targets since they are not in agreement with the target levels of the other eutrophication indicators (e.g. DIN, DIP, secchi depth). Nevertheless, some CPs have derived target levels for total nutrients.

Ecological modelling is planned to be used in estimating GES-boundaries in the open-sea-areas. In Germany, a new modeling approach has recently provided revised target concentrations for total nutrients in the Kiel Bay, Mecklenburg Bay, Arkona Basin and Bornholm Basin. Other ecological models, eg. BALTSEM, are planned to be used for setting targets for the remaining open-sea sub-basins. The approach is based on historic nutrient inputs around 1880 and modelling of resulting total nutrient concentrations with ERGOM (Schernewski et al. 2015).

For coastal assessment units, national boundaries used for estimating Good Environmental Status under WFD may be used.

Anthropogenic pressures relevant to the indicator

	Strong connection	**Secondary connection**
General	Nutrient concentrations in the water column are affected by anthropogenic nutrient loads from land and air.	
MSFD Annex III, Table 2	Nutrient and organic matter enrichment	

Description of metadata and updating

Data source: The average for 2007-2011 was estimated using monitoring data provided by the HELCOM Contracting Parties, and kept in the HELCOM COMBINE database, hosted by ICES (www.ices.dk).

Description of data: The data includes total nitrogen observations, determined as explained in the HELCOM COMBINE manual. Measurements made at the depth of 0 – 10 m from the surface were used in the assessment.

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

Temporal coverage: The raw data includes observations throughout the year, during the assessment period 2007-2011. For the summer average, observations taken during June-September were included only.

Data aggregation: The 2007-2011 averages for each sub-basin were produced as an inter-annual estimates using observations from all months / June-September.

6.2 New pre-core indicators on phytoplankton

EUTRO-OPER 1-2014 identified a need for including several indicators to describe phytoplankton increase, to fulfil the need for estimating distance to the BSAP ecological objective on natural level of algal blooms. Development work was initiated with the aim of developing an indicator with GES boundaries for the HELCOM open-sea sub-basins. Finland was welcomed to take the lead.

6.2.1 Chlorophyll-*a*, spring bloom intensity

The spring bloom chlorophyll-*a* indicator complements the present core indicator on summer chlorophyll-a in that it provides information on the most intensive but short-lasting phytoplankton growth period. The environmental fact sheet 'Spring bloom index', updated 2005-2008 (Fleming & Kaitala, 2006), that was later developed in the MARMONI (Innovative approaches for marine biodiversity monitoring and assessment of conservation status of nature values in the Baltic Sea, LIFE09 NAT/LV/000238) project to take advantage of high-resolution EO-data (Verlin et al. 2014), was developed further by EUTRO-OPER.

At present, the indicator is under PRE-CORE status. The indicator report is presented below.

Policy relevance

	Primary importance	Secondary importance
BSAP Segment and Objective	Eutrophication: natural level of algal blooms PRE-CORE INDICATOR	Biodiversity: thriving and balanced communities of plants and animals
MSFD Descriptors and Criteria	5.2	1.6
Other relevant legislation: (e.g. WFD)	QE1	none stated

Role of the spring bloom in the ecosystem

The indicator estimates the annual total biomass of the phytoplankton spring bloom. The spring is a period of extensive and rapid phytoplankton growth, during which the main part of the annual phytoplankton production occurs. Phytoplankton quantity is a direct proxy of eutrophication, through the increase of nutrient concentration. The nutrient load is in some areas added by internal nutrient loading from the bottom, accelerated by oxygen depletion. Phytoplankton increase in turn adds to the oxygen depletion, when sedimented 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.

Good Environmental Status

The boundary for Good Environmental Status for spring bloom is currently being defined based on ecosystem modelling.

Anthropogenic pressures relevant to the indicator

	Strong connection	Secondary connection
General	Phytoplankton concentration in the water column are affected by anthropogenic nutrient loads from land and air.	
MSFD Annex III, Table 2	Nutrient and organic matter enrichment	

Assessment protocol

The indicator estimates the total biomass of the phytoplankton spring bloom. The spring is a period of extensive and rapid phytoplankton growth, during which the main part of the annual phytoplankton production occurs. Quantifying the bloom biomass is not easy using traditional methods, which do not react at a high spatial or temporal scale. The biomass can be estimated through combining EO and ship-of-opportunity data, in order to obtain maximum spatial and temporal coverage, and is further developed to a spring bloom index as described by Fleming and Kaitala (2006). At present, EO and Alg@line data on part of the transects are utilized.

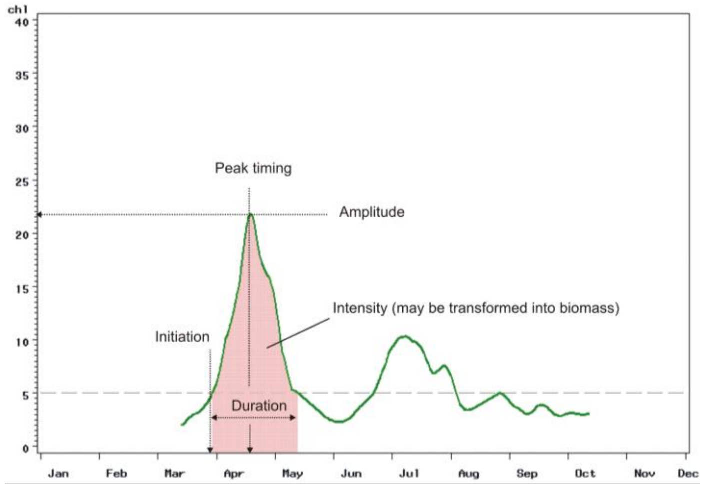


Figure 6.3. The properties of the spring phytoplankton bloom in the western Gulf of Finland in 2009, characterized from a time series of chlorophyll-a concentration. The intensity is defined as integral of the chl-a concentrations during the spring bloom period (Fleming and Kaitala, 2006).

The spring bloom indicator method was originally developed for the MARMONI project study areas (Verlin et al. 2014) and for the coastal WFD-areas of Finland. During the last year, it has been developed further for HELCOM assessment areas. As spring bloom period is short, intensive and often spatially 'limited', the spring bloom tends to average out using HELCOM assessment areas. Thus, HELCOM 20km grids have been utilized to determine sub-indicator indexes. These sub-indicators are then combined to represent the whole assessment areas.

The method utilizes time series of non-cloudy EO chlorophyll-*a* concentrations observed on each HELCOM grid (see Figure 4.1 for example of grid division). The start and end of the spring bloom is defined based on a threshold (chlorophyll-*a* concentration above 5 µg/l). For the period between the annual start and end of the spring bloom, EO observations are complemented to daily chlorophyll-*a* concentrations by using spline interpolation method. The spring bloom index for each grid is defined as an integral of the spline. Finally, grid based sub-indicators are combined (averaged) to represent the whole assessment areas.

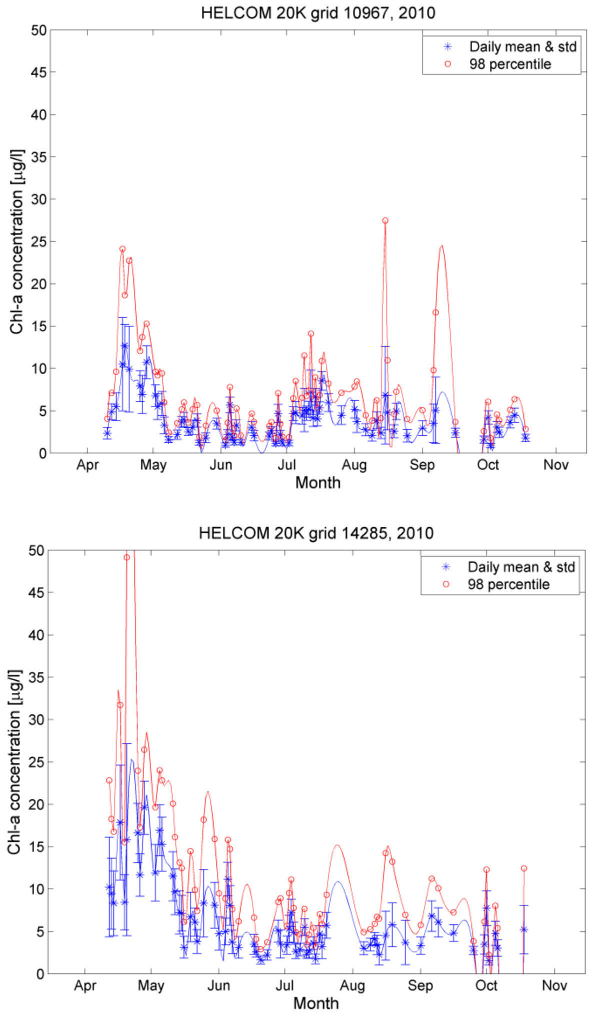


Figure 6.4. Example of time series of mean, standard deviation (blue stars and bars) and 98 percentile (red dots) chl-a observations by MERIS (years 2010) produced for HELCOM 20km grids, 10967 and 14285. Both grids represent Gulf of Finland. The lines are interpolated daily values obtained using non-cloudy EO observations. The start of the spring bloom is often extrapolated.

The assessments of the open sea areas were based on an integration of state data from core set indicators. The indicators were grouped under the following three "criteria" as described in the Commission Decision (2010/477/EU): 1. Nutrient levels, 2. Direct Effects, 3. Indirect Effects. The spring bloom indicator is proposed to be included under Criteria 2 (direct effects), along with the core indicators summer 'chlorophyll-*a* concentration' and 'water transparency'.

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 water bodies.

Results

To increase the accuracy of the spring bloom indicator, the method was adjusted to HELCOM 20 km gridded data. These sub-areas are used to define spring bloom accurately on different parts of the assessment areas.

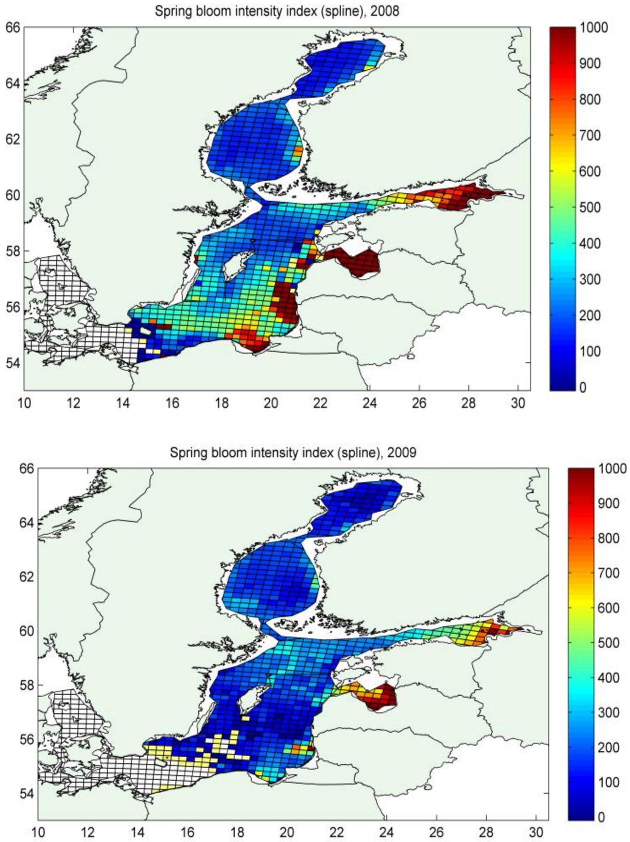


Figure 6.5. Example of spring bloom indicator values calculated for HELCOM 20 km grids, years a) 2008 and b) 2009.

Table 6.1. GES targets, present concentration.

HELCOM_ID	**Sub-basin**	**Target (µg l^{-1})**	**Average index 2007-2011**	**STATUS**
SEA-007	Bornholm Sea	Under progress	89,89	Under progress
SEA-008	Gdansk Basin	Under progress	493,72	Under progress
SEA-009	Eastern Gotland Basin	Under progress	341,71	Under progress
SEA-010	Western Gotland Basin	Under progress	1217,37	Under progress
SEA-011	Gulf of Riga	Under progress	1680,82	Under progress
SEA-012	Northern Baltic Proper	Under progress	418,75	Under progress
SEA-013	Gulf of Finland	Under progress	1383,15	Under progress
SEA-014	Åland Sea	Under progress	651,41	Under progress

SEA-015	Bothnian Sea	Under progress	800,32	Under progress
SEA-016	The Quark	Under progress	344,05	Under progress
SEA-017	Bothnian Bay	Under progress	525,74	Under progress

Long-term development

The longest time series on spring bloom intensity index can be derived from Alg@line data (Figure 6.6) for the Gulf of Finland (Fleming & Kaitala, 2006). In addition, there is modelling work under progress to hindcast spring bloom for the 20th century. The determination of chl-a concentrations during spring bloom period using EO data is possible from year 2003 on. Using the data from years 2003-2011, the trends and status based on the trend canl be defined for HELCOM assessment areas (SEA-7 – SEA-17). During initial study in the framework of MARMONI project, the status (trend) was defined increasing for the Gulf of Riga, and decreasing/no trend for the Gulf of Finland.

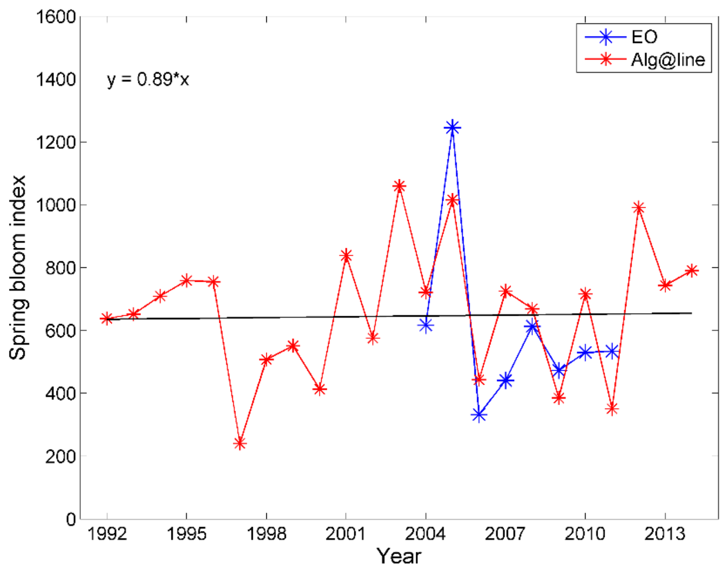


Figure 6.6. The development of spring bloom indicator on the Gulf of Finland using EO and Alg@line measured chl-a concentrations during 1992-2014. Red line represents Alg@line intensity index and blue line EO (MERIS data) intensity index.

Requirements

Spring bloom indicator requires sufficient amount of data during the spring period, so that the start, end and intensity of the bloom can be defined. It does not require daily observations, as caps can be filled using spline interpolation. In principle, the method can be used for any data that observes chl-a concentrations with sufficient frequency, such as Alg@line (Fleming and Kaitala 2006) or EO data.

The satellite instrument for the development of the spring bloom indicator method was MERIS (Medium resolution imaging spectrometer) onboard ENVISAT satellite. MERIS instrument overpasses are daily, thus daily observations are available for all non-cloudy areas and periods. Typically non-cloudy observations cover the whole Baltic Sea weekly. The ground resolution of the instrument is 300 m, i.e. one pixel on the image corresponds to 300m x 300m acreage on water.

Historical MERIS data will serve as basis for method development. The method is directly applicable for the forthcoming OLCI (Ocean and Land Colour Instrument) that is the most prominent instrument for Baltic Sea water quality detection after its launch (estimated during early 2016) onboard Sentinel 3A satellite.

Gaps

The current EO dataset starts from the beginning of April. Thus, spring bloom period in the southern Baltic Sea is not yet present in the study data. The method itself is applicable to any sea area in the future. MERIS instrument has not been operating after April 2012. Forthcoming instrument OLCI onboard Sentinel 3a satellite will replace MERIS data approximately during 2016. Thus, during years 2012-2015 similar data is not available.

6.2.2 Cyanobacterial surface accumulations

The chosen approach was to combine and develop further two existing indicators: the candidate indicator 'Cyanobacterial bloom index', developed originally under the project MARMONI (Innovative approaches for marine biodiversity monitoring and assessment of conservation status of nature values in the Baltic Sea, LIFE09 NAT/LV/000238) project to take advantage of high-resolution EO-data (Verlin et al. 2014), was developed further by EUTRO-OPER and the environmental fact sheet on 'Cyanobacteria biomass', developed by the PEG group (http://www.helcom.fi/baltic-sea-trends/environment-fact-sheets/eutrophication/cyanobacteria-biomass/).

At present, the indicator is under PRE-CORE status. The indicator report is presented below.

Policy relevance

	Primary importance	**Secondary importance**
BSAP Segment and Objective	Eutrophication: natural level of algal blooms PRE-CORE INDICATOR	Biodiversity: thriving and balanced communities of plants and animals
MSFD Descriptors and Criteria	5.2	1.6
Other relevant legislation: (e.g. WFD)	none stated	none stated

Role of cyanobacterial surface accumulations 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 1990's (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. 2007). Thus extensive cyanobacterial blooms potentially have a negative impact on the biodiversity of both the pelagic and the benthic communities.

Good Environmental Status

The target values for the assessment areas were derived by using independent satellite based time series on algae accumulations from the Baltic Sea by Kahru and Elmgren (2014). This data set covers years 1979-2014. The periods with highest status in the target value data set were identified and transformed to CSA values by using a linear model defined between these two. GES is reached, when the current status is higher than the identified target. Results presented here include Gulf of Finland (GoF), Northern Baltic Proper (NBP), Eastern Gotland Basin (EGB) and Western Gotland Basin (WGB), but its geographical relevance is Baltic Sea wide. The indicator may be extended to cover all the Baltic open sea and outer coastal assessment units; its GES boundaries are set region-specifically.

Anthropogenic pressures relevant to the indicator

	Strong connection	Secondary connection
General	Nutrient concentrations in the water column are affected by anthropogenic nutrient loads from land and air.	
MSFD Annex III, Table 2	Nutrient and organic matter enrichment	

Assessment protocol

The method combines different types of bloom information into the CSA-index by taking an average from the normalized time series of the indicative variables. The indicative variables can be weighted depending on the information value they are giving on the bloom event. Thus, the method can be applied with various observations types.

For the combination and comparison of different observations, all the indicative variables describing the bloom characteristics are normalized.

The CSA indicator value responds negatively to increasing eutrophication, i.e. low values in the present concentration indicate increased eutrophication.

Earth observation (EO) based assessment presented here

The main data source used in the development was the daily EO based product estimating the potentiality of surface algae accumulations in four classes [0-3 i.e. no, potential, likely and evident] (www.syke.fi/surfacealgalblooms). Data set used in the development included daily EO observations from years 2003-2014 during the summer seasons (20.6.-31.8.).

Spatial aggregation of daily EO observations from the assessment areas were 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).

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

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 (i.e. indicative variables) were estimated by using an empirical cumulative distribution function (ECDF) drawn from seasonal observations of daily algae barometer values from each assessment area (Annex 1). ECDF gives the cumulative proportion of the seasonal algae barometer values. The bloom characteristics were defined for each sub-basin as follows: 1) seasonal volume (intensity), 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, 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 (Figure 6.7).

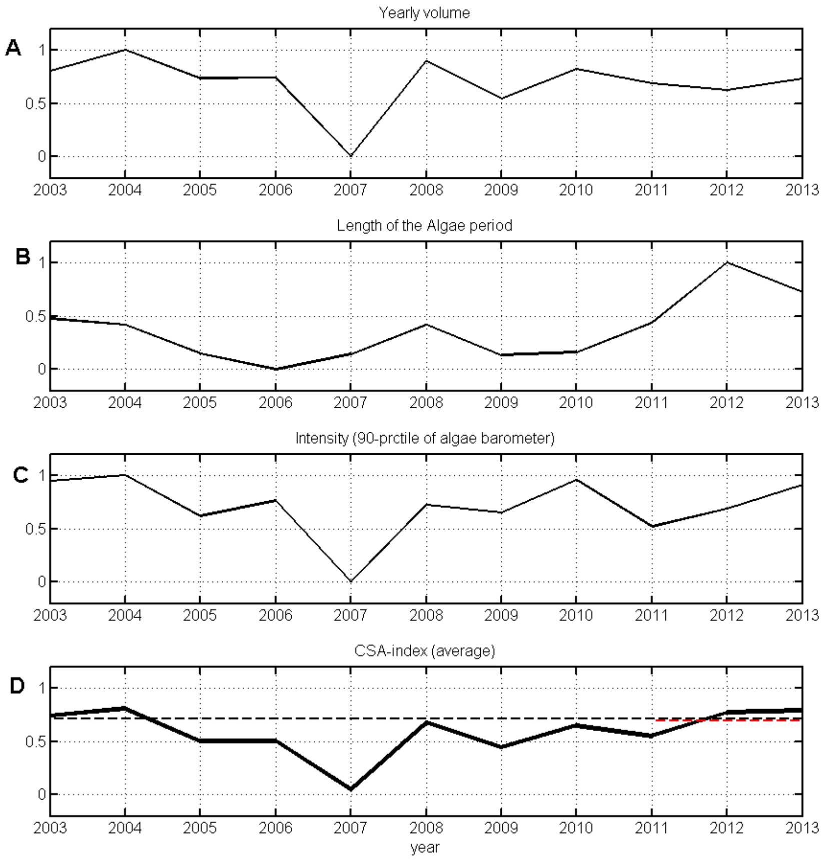


Figure 6.7. An example of deriving the CSA-index in the Western Gulf of Finland (from MARMONI project, indicator description http://marmoni.balticseaportal.net/wp/category/biodiversity-indicators/). Normalized indicative variable time series derived from the ECDF-functions (A-C) and combined to the CSA-index (D) when only remote sensing data are used. Value 1 represents the best conditions and 0 the worst. Black dashed horizontal line in (D) indicates the target condition and red the current status.

Area specific targets were first identified from the Fraction of Cyanobacteria Accumulations –data (FCA) by Kahru & Elmgren (2014) and then transformed into CSA-index by using a linear model between these two data sets. A break point detection method by in Rodionov (2004) and Rodionov & Overland (2005) were used to detect periods in time series with the highest FCA-values, which were used as target values.

For the status, CSAs of years 2007-2011 were calculated. GES is reached when the status exceeds the target.

Further work is anticipated on the inclusion of other data sources for the indicator as well as on the possibility to use modeling to derive the target conditions. Such data sources could include ie. phycocyanine observations measured by Ferrybox-systems, information on cyanobacteria cell numbers / biomass at the surface layer or citizen observations on algae blooms. Also information derived from the new remote sensing instruments (e.g. Sentinel 3 satellite instrument by European Space Agency to be launched on late 2015) requires careful harmonization of the derived information on the algae accumulations from other instruments

Description of metadata and updating

Data source: The data source was the daily EO based 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 chl-a product (www.syke.fi/chl-a). 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. Remote sensing instruments used in deriving the chl-a information were MERIS for the years 2003-2011 and MODIS for 2012-2013. All available raw data for the areas of interest were downloaded by using EOLI-SA service by ESA (https://earth.esa.int/web/guest/eoli) and from NASA's Ocean color near real time data service (see http://oceancolor.gsfc.nasa.gov/) for the MERIS and MODIS instruments, respectively. Chl-a concentrations were derived for the MERIS observations according to Schroeder et al. (2007a, 2007b) and for the MODIS data according to Maritorena et al. (2002, 2010) and O'Reilly et al. (1998, 2000). In the case of MODIS data, the algorithm showing the best performance when compared against in situ data were used.

The Fraction with Cyanobacterial Accumulations (FCA) data for the years 1979-2013 by Kahru and Elmgren (2014), were used to test the performance of the CSA-index and to derive the indicator target values. FCA is defined as the ratio between the number of turbid (detected surface accumulations) and valid (no surface accumulations detected) pixels during a two month period (July-August) from satellite sensors with daily or multiple overpasses per day. The satellite instruments used in FCA estimation were AVHRR, SeaWiFS, MODIS Aqua, MODIS Terra and VIIRS. The method for retrieving FCA and the data used in the comparison presented here are described in detail in Kahru and Elmgren (2014).

6.3 New candidate indicator on oxygen consumption

The need for development of an additional indicator on oxygen conditions in open-sea sub-basins was identified by EUTRO-OPER 1-2014. Sweden was welcomed to take lead in the work, leading to a candidate indicator still under development.

Background

This assignment is an attempt to develop an oxygen indicator for the HELCOM region, within the HELCOM project EUTRO-OPER. The indicator should be applicable in the HELCOM-region, there should be a link to eutrophication and it should be straight-forward to update annually. The previously, within the TARGREV-project, developed indicator for oxygen, the "Oxygen Debt-indicator", has some limitations in its application (HELCOM 2013). It is restricted to deep basins and an update of the indicator demand special resources such as specific programming and statistical skills.

The basic idea in this study is to estimate the oxygen consumption in the stagnant layer below the productive surface layer during summer (Figure 6.8) and see if and how this can be linked to eutrophication.

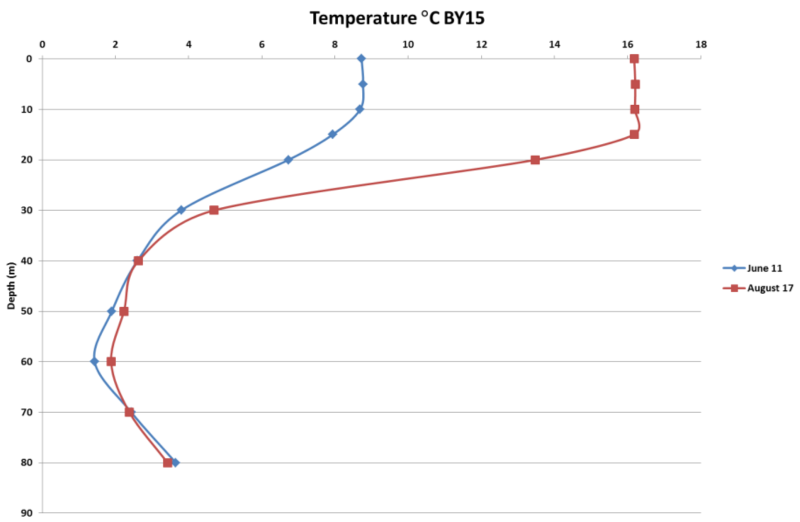


Figure 6.8. Temperature in June and August (1986) in the central Baltic Proper at station By15.

Method

Oxygen budget for the summer season for horizontal water layer below the euphotic zone is calculated in accordance with Eilola (1998). The amount of organic matter broken down in the layer is directly related to the oxygen consumption (*CONS*) described as:

$$CONS_{(u,d)} = DEPL_{(u,d)} + DIFF_{(u,d)} + ADV_{(u,d)}$$

Here *DEPL* is the oxygen depletion in the horizontal water layer between the upper (u) and deeper (d) boundary. *DIFF* is the vertical diffusion and *ADV* is the advection of oxygen. Due to small temporal differences in salinity and temperature within the layer, advection is neglected in this attempt. Figure 6.9 is an illustration of the different processes.

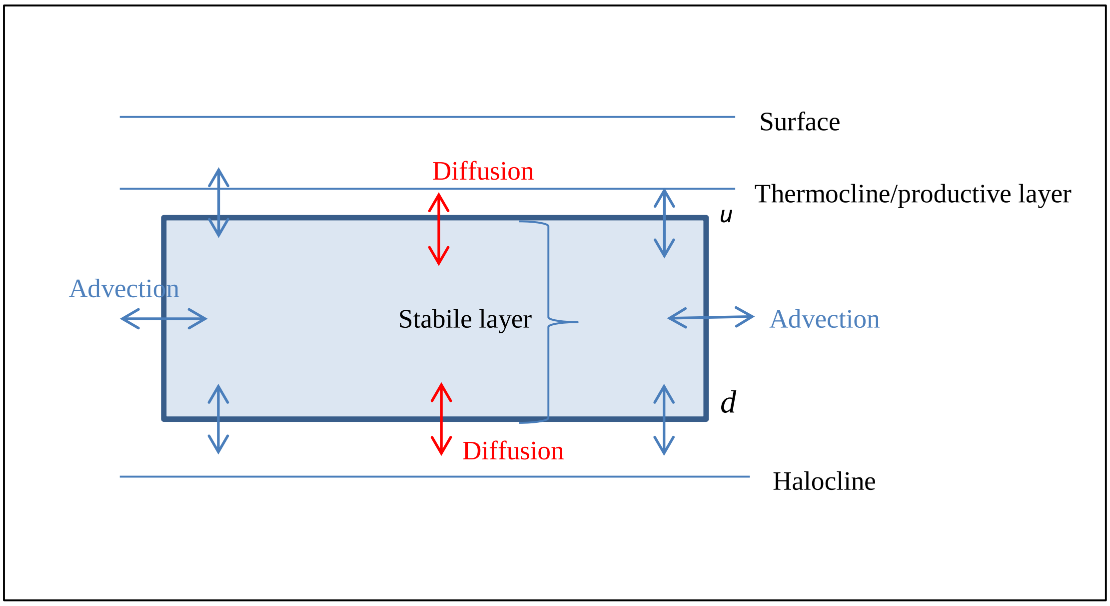


Figure 6.9. Conceptual sketch of the different processes.

The oxygen depletion and diffusion are computed from observations as:

$$DEPL_{(u,d)} = -\int_{u}^{d} A(z)\frac{\partial O_2(z)}{\partial t}dz$$

$$DIFF_{(u,d)} = -A(u)\left(\kappa(u)\frac{\partial O_2(u)}{\partial z} - \frac{A(d)}{A(u)}\kappa(d)\frac{\partial O_2(d)}{\partial z}\right)$$

A(z) is the horizontal area at depth z and $\frac{\partial O_2(z)}{\partial t}$ is the rate of oxygen change with time. The term $\frac{\partial O_2(z)}{\partial z}$ is the vertical gradient of oxygen concentration and κ(z) is the vertical diffusivity coefficient at depth z calculated as:

$$\kappa_{(u,d)} = \frac{\alpha_{(u,d)}}{N_{(u,d)}}$$

where α is an empirical intensity factor accounting for the mean mixing activity of turbulence. N is the Brunt-Väisälä frequency defined as:

$$N^2_{(u,d)} = \frac{g}{\rho_0}\frac{\partial \rho(u,d)}{\partial z}$$

g is the acceleration of gravity and ρ_0 the reference density.

Calculations were performed in the free available R, a software programming language. Data used was observations reported to the HELCOM COMBINE database**.** The station Gotland deep (BY15) was selected for the calculations due to large amount of in-situ measurements.

Result and discussion

To calculate the oxygen consumption for the summer season, a stabile depth interval as well as the months with the largest decrease in the oxygen concentration were identified (Figure 6.10). The stabile layer below the thermocline, but above the halocline was determined from comparing temperature and salinity from different depth interval and was established as the depth between 30-50 m. One may note the quite small changes in mean salinity (Figure 6.10a) and temperature (Figure 6.10b) in this depth interval. The temperature in the surface layer may, however, change by several degrees between June, July and August (e.g. Figure 6.8) indicating that vertical transports are indeed very small below the thermocline. The relatively large spread between individual years, shown by the whiskers and boxes (Figs. 6.10a and 6.10b), indicates that there may also be years when the layer seem less stagnant. In figures 6.10c and 6.10d, the largest oxygen reduction as well as an increase in phosphate concentration indicates that the largest decomposition of organic matter would occur between June and July.

In Figure 6.11, the results of the yearly mean oxygen consumption, depletion and diffusion between July and June is shown (left y-axis), together with the upper 10 m January-February mean of phosphate concentration in the station BY15 (right y-axis, grey dots). The ranges in the annual calculations have large variations for the consumption, depletion and diffusion, which imply that there are uncertainties in calculations performed from in-situ measurements. One reservation is that we have used the monthly mean when several observations exist and by this has the actual number of days between measurements not been taken into account in the calculation, which may influence the results.

An attempt to calculate the empirical intensity factor α of the vertical diffusion from in-situ measurements of salinity and temperature was performed. The computed values for the α-parameter were scattered with unrealistic numbers found in several years. This can be due to missing observations on the particular depths but also due to advective processes, which we have neglected, that affects the water mass and are difficult to estimate. Thus, a constant value for this parameter was chosen in the calculations (α=1.5 x 10^{-7} m^2 s^{-2}), which is a constant used in modern circulation models for the Baltic Proper (Meier, 2001; Gustafsson, 2003; Omstedt, 2011; Stigebrandt and Kalen, 2013).

However, despite the uncertainties a comparison of the oxygen consumption (*CONS*) with the upper 10 m mean phosphate winter concentration was made to investigate a possible link between increasing nutrient concentrations in wintertime with increasing oxygen consumption during summer. This test gave a small negative correlation coefficient (r~ -0.2) which would imply no significant link. The result is similar if the 10 m mean phosphate concentration is compared with oxygen consumption, depletion and diffusion for the whole Eastern Gotland Basin.

If we go a bit deeper in the analyses and divide the data set into two periods, 1990-1999 and 2000-2009, and calculate oxygen depletion between June and August we get different results. In Figure 6.12 we see the two periods differ from each other. The mean oxygen depletion is larger in the second period that also has a positive mean phosphate production. The winter concentration of nutrients is also larger in this second period, though, none of the changes observed in Figure 6.12 are statistically significant at the 95 % confidence level. This is of course a smoothed result since we are dealing with averages based on several years of data, but it still implies that it has to be more clear how to aggregate the data from observations.

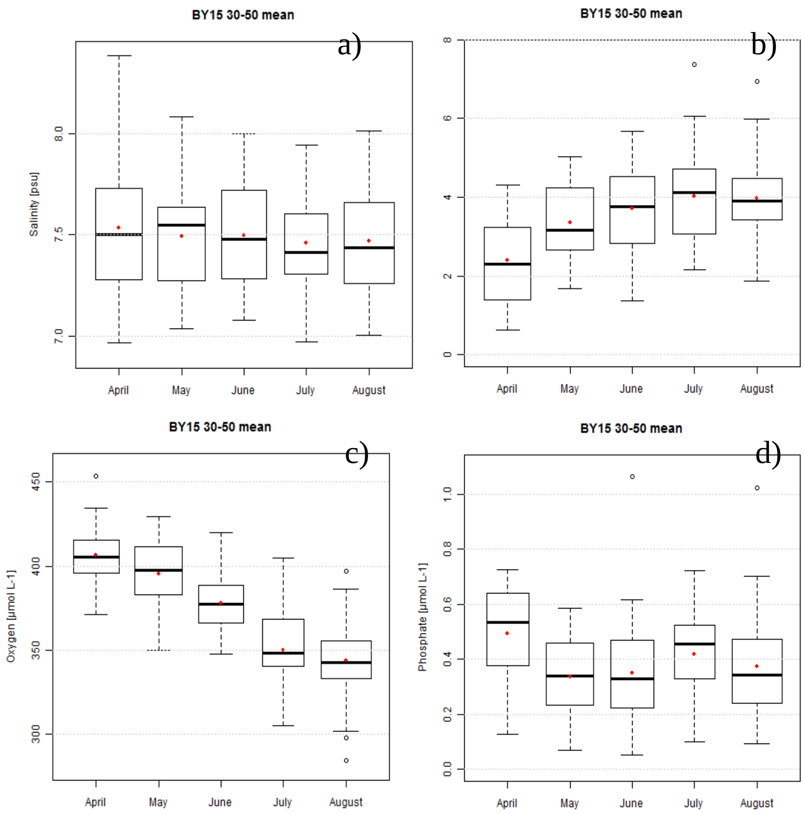


Figure 6.10. Boxplots of a) salinity, b) temperature, c) oxygen concentration and d) phosphate concentration for 30-50 m at the Gotland deep for April-August. The box's lower and upper limits are the first and third quartiles respectively, the thick horizontal line is the median, the red dot is the mean, black open circle outliers and the whiskers represent min and max without outliers.

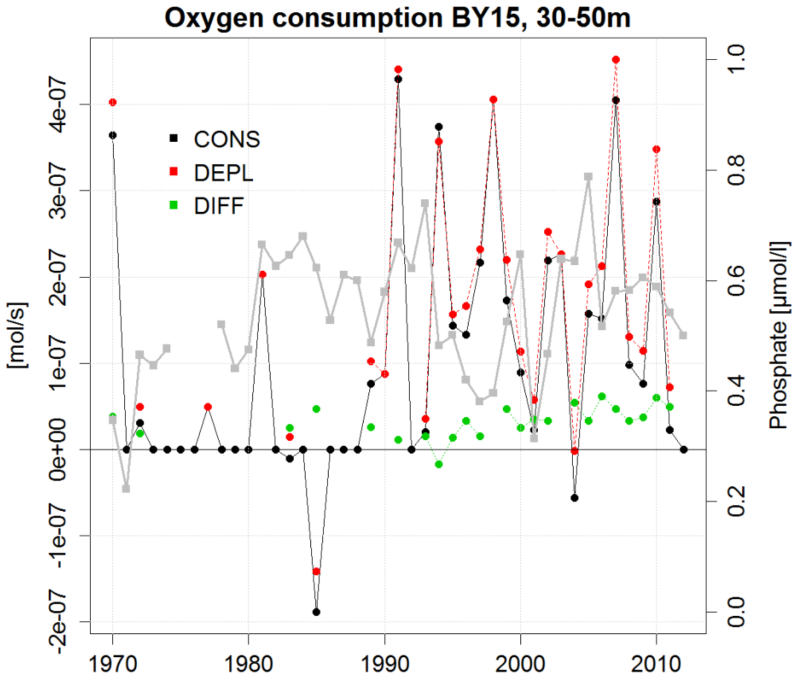


Figure 6.11. The June-July consumption (black dots), depletion (red dots) and diffusion (green dots) for oxygen in BY15 between 30-50 m depth. The right y-axis is the upper 10 m mean phosphate concentration (grey dots) in BY15 during winter (January-February).

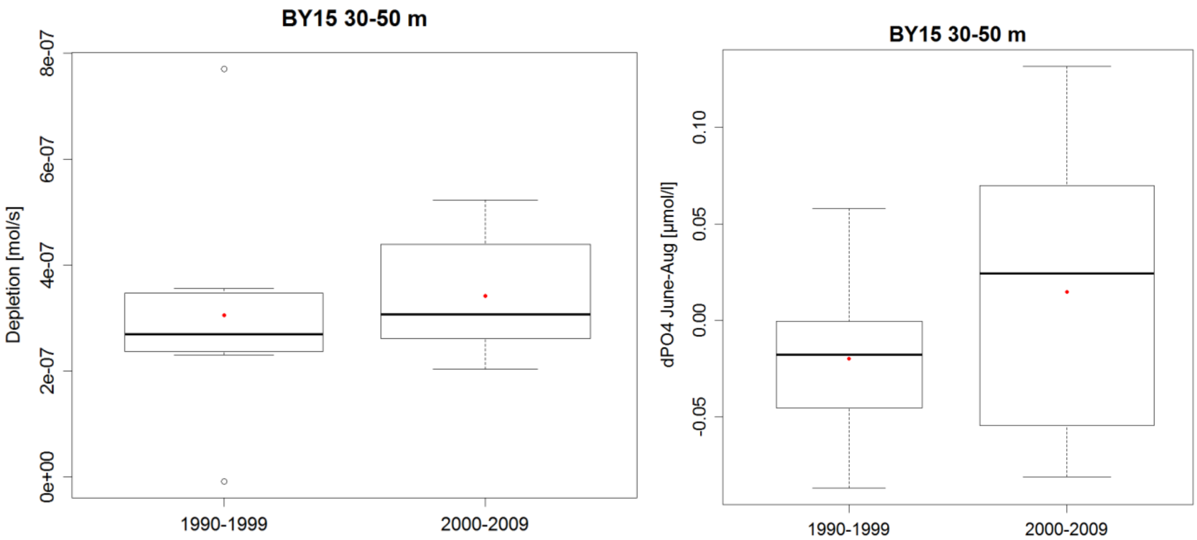


Figure 6.12. Boxplots of oxygen depletion 30-50m June-August, difference in phosphate 30-50m June-August and the 0-10m winter mean phosphate for two time periods, 1990-1999 and 2000-2009.

When the oxygen depletion between June and August is compared with winter values of phosphate concentration, the correlation is positive even though the correlation is still small (Figure 6.11 and 6.12). To understand fully the result that certain congeniality arises with winter phosphate if oxygen consumption between June-August is used instead of June-July, i.e. a longer time period is adopted during summer, require further investigations that are out of reach for the present study. This might indicate that the temporal development of the oxygen consumption diverges between years and one explanation arises from different conditions for algal blooms. The June-August distribution of calculated oxygen change is still large (R^2=0.21) but that is also the case for the phosphate winter values (R^2=0.28). Notice a negative value for the oxygen depletion (< -100%) implying an oxygen production. A probable explanation for this negative value is an effect from adjacent water masses that has influenced the oxygen concentration through the transport and mixing of the water masses. One may also mention that the first available observations in June and in August, respectively, were used for the compilation in Figure 6.12. The number of days for which oxygen depletion was computed varied fairly randomly between 48 and 81 days between the years (there was no trend in the number of days during the period).

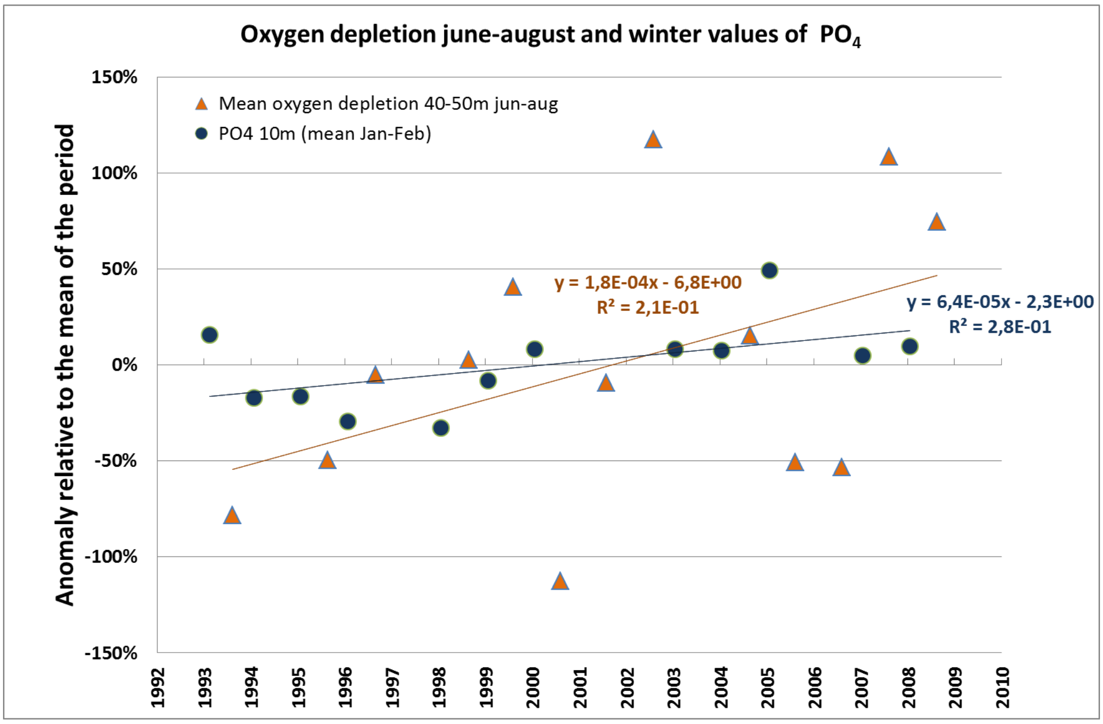


Figure 6.13. Calculated anomalies in percent (%) relative the periods mean of oxygen change between observations in June and August (triangle) for years with data at 40 to 50 m depth during 1993-2009. The values are integrated over a 20 m depth interval and areas of 1m².The calculations here also consider the number of days between measurements. Note, positive depletion corresponds to a decrease in oxygen consumption from June to August. Circles show the mean winter phosphate concentration (January-February) at 10 m depth. Linear regression lines for the two datasets and its equations and regression coefficient (R^2) are drawn in the same color next to the line. Data is from the SHARK-database at SMHI.

To finalize the study we also investigated if a possible candidate to use as a more simple oxygen depletion indicator could be the use of oxygen saturation at 50 meter depth at BY 15. If we assume that the temperature has not changed much since the establishment of stratification (see Figure6.8) we may expect that changes in oxygen saturation observed in August at this depth would be caused by the biological oxygen consumption occurring during late spring and summer. In Figure 7 we show the mean 50 meter depth oxygen saturation at BY15 in August and the winter concentration of PO4 in the preceding winter. The results are fairly similar to Figure 6.12 but the correlations coefficient of oxygen depletion (i.e. the R^2 of oxygen saturation) is slightly improved in this case.

To get a rough estimate of the correlation between the mean changes of winter phosphate and oxygen depletion we calculate some numbers for comparison. The increase in mean PO_4 between the periods was 0.17 mmol PO_4 m^{-3} which would cause a potential increase of export production of 3.43 mmol m^{-2} (=20m x0.17 mmol P m^{-3}) if we assume that the production takes place in the upper 20 m. The export of this matter would require increased oxygen consumption below 20 m depth of about 3.43x138=473 mmolO_2 m^{-2} if we assume complete oxidation of typical Redfield plankton with O_2:P ratio of 138.

The corresponding change in mean oxygen saturation between the two periods was -2.527% which corresponds to about -10.15 mmol O_2 m^{-3} when we use the initial concentration of 401 mmol O_2 m^{-3}. Hence, if we assume that the change in oxygen consumption is similar in the layer 20m-60m, the increased oxygen consumption between 20m and 60m depth becomes 406 mmol O_2 m^{-2} (=40m x 10.15 mmol O_2 m^{-3}) which would indicate that a large fraction of the increased production (473 mmolO_2 m^{-2}) may cause an increased organic matter decomposition above the halocline during summer. There is of course an uncertainty in this estimate because of the assumptions of the amount of exported matter, the Redfield ratio and other factors caused by the large variability in observations. The results indicate, however, that there may be some correlation between the increased winter DIP and oxygen consumption at 50 m depth.

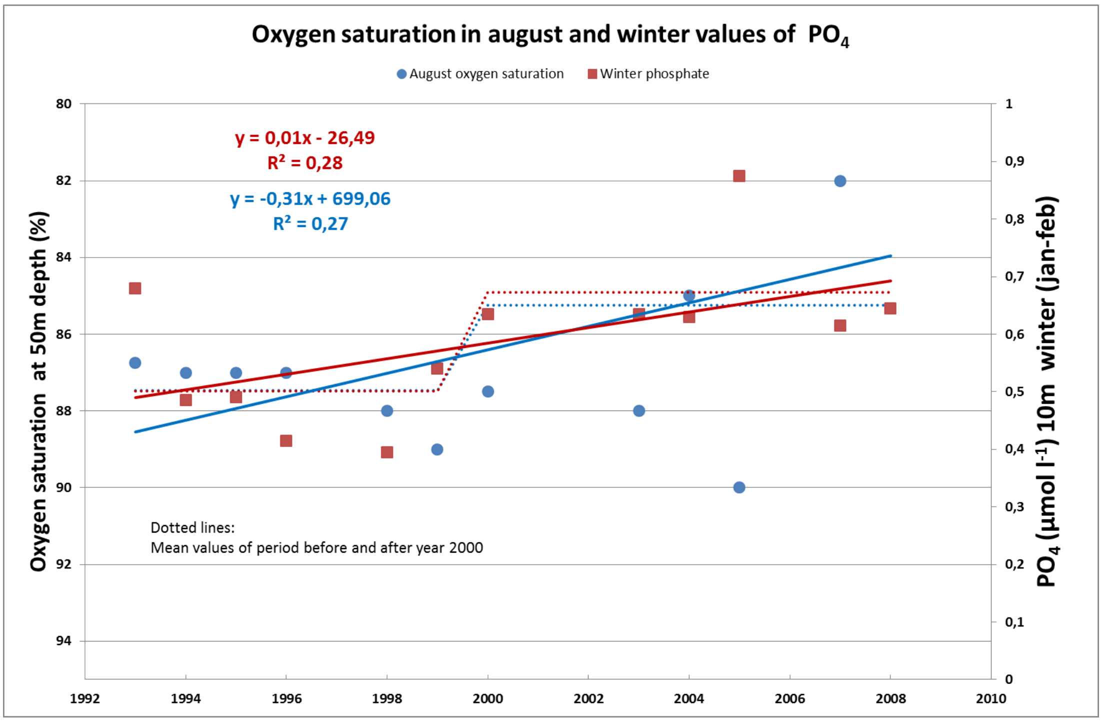


Figure 6.14. Mean 50 m depth oxygen saturation (%) at BY15 in August (left axes), and the winter (Jan-Feb) mean phosphate concentration at 10 m depth (right axes) from years with simultaneous measurements. The dashed lines show mean values for the years before 2000 and the years from 2000 and forward. The average oxygen concentration at 50 meter depth in April was 9 ml O_2 l^{-1} (= 401 mmol O_2 m^{-3}) and the mean oxygen saturation was 100% (SHARK data). Linear regression lines for the two datasets and its equations and regression coefficient (R^2) are drawn in the same color next to the line. Data is from the SHARK-database at SMHI.

Conclusions

A possible continuation of this study of the oxygen consumption as an indicator for eutrophication is to calculate different time periods as well as include a model to identify and quantify the effect of diffusion and advection and by that try to understand the annual spreading of the calculations. Another necessity is to identify representative stagnant layers in other parts of the Baltic Sea in addition the Gotland Deep. The layers are plausibly different due to stratification conditions as well as if the region is affected of, for instance, inflows and/or other water mass transports with different properties. The model can also be used to try to investigate which link to envisage between, for example, winter dissolved inorganic phosphorus and oxygen consumption below the thermocline. The correlations among these two indicators might not be 100 % due to biological effects, such as different onset of the spring bloom, the sinking rates and decomposition capacity, which influence the inter annual magnitude of oxygen consumption.

6.4 Alternatives for finding a common oxygen indicator in shallow waters

In the HELCOM eutrophication core set of indicators, a method has been established to assess the oxygen status (in terms of oxygen debt) of the deep basins of the Baltic Sea. This method was successfully applied to the Northern Baltic Proper, Gotland Basin, Gdansk Basin and Gulf of Finland. EUTRO-OPER, with Sweden in lead, has established development on an oxygen consumption indicator for open sea basins that are divided by deep water sills.

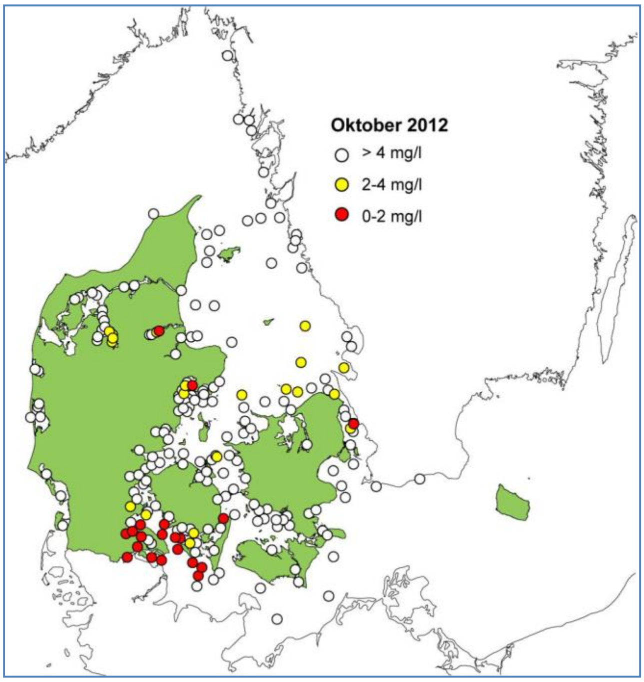
For shallower waters, such as the WFD coastal waters and other areas in HELCOM open waters for which the oxygen debt approach does not apply, there is no commonly agreed method yet to assess the quality of the oxygen conditions. HELCOM EUTRO-OPER has gone through approaches that are or have been used in the Baltic Sea, initiating a discussion on finding a common bottom oxygen indicator for shallow water areas, to be used in the open-sea sub-basins.

6.4.1 Danish Reports on oxygen conditions in the western Baltic Sea area

Since many years, oxygen reports have been published by DMU(Danish Environmental Research Institute) and in recent years by DCE (Danish Center for Environment and Energy, Aarhus University) on a regular basis. Often, Swedish and German data have been included as well. In the period 1997-2001 three reports and since 2002 four reports have been produced per year to cover the season where low oxygen values are likely to occur in order to follow the development of oxygen conditions (all years: July/August, September, October, since 2002: plus November) and assess the harmful effects. The results are presented in a three-class system:

- no oxygen depletion (>4 mg/l oxygen)
- oxygen depletion (2-4 mg/l oxygen)
- severe oxygen depletion (0-2 mg/l oxygen)

Examples are given in Figure 6.15. The reports are available online.



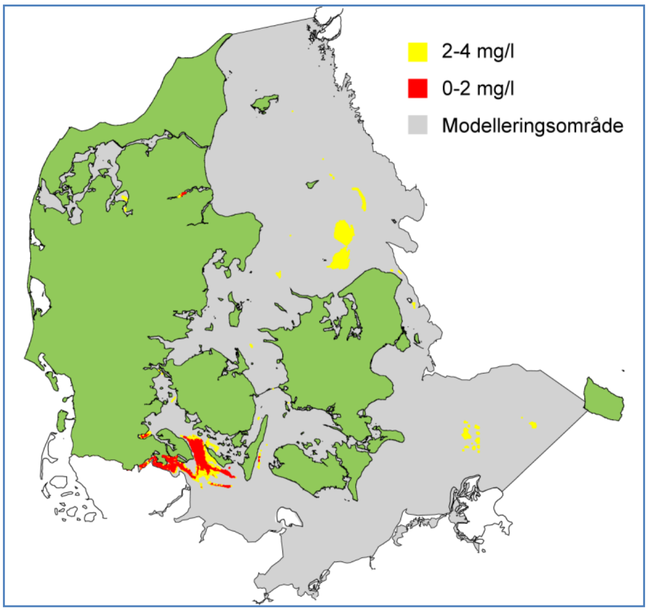


Figure 6.15. Oxygen conditions in October 2012 depicting stations visited (top) and modelling results (bottom). Source: J. W. Hansen et al. 2012, Iltsvind i de danske farvande i oktober 2012. Available online: http://bios.au.dk/fileadmin/bioscience/Fagdatacentre/MarintFagdatacenter/Publikationer/Iltsvindsrapport_oktober_2012.pdf

6.4.2 German approach 1: The oxygen concentrations in near-bottom waters (abt. 1 m from bottom)

These waters are classified according to the following scheme:

> 6 mg/l	=	good status
6 - > 4 mg/l	=	moderate status
4 - > 2 mg/l	=	poor status
2 - > 1 mg/l	=	bad status

1 mg/l and less = very bad status (H_2S-production)

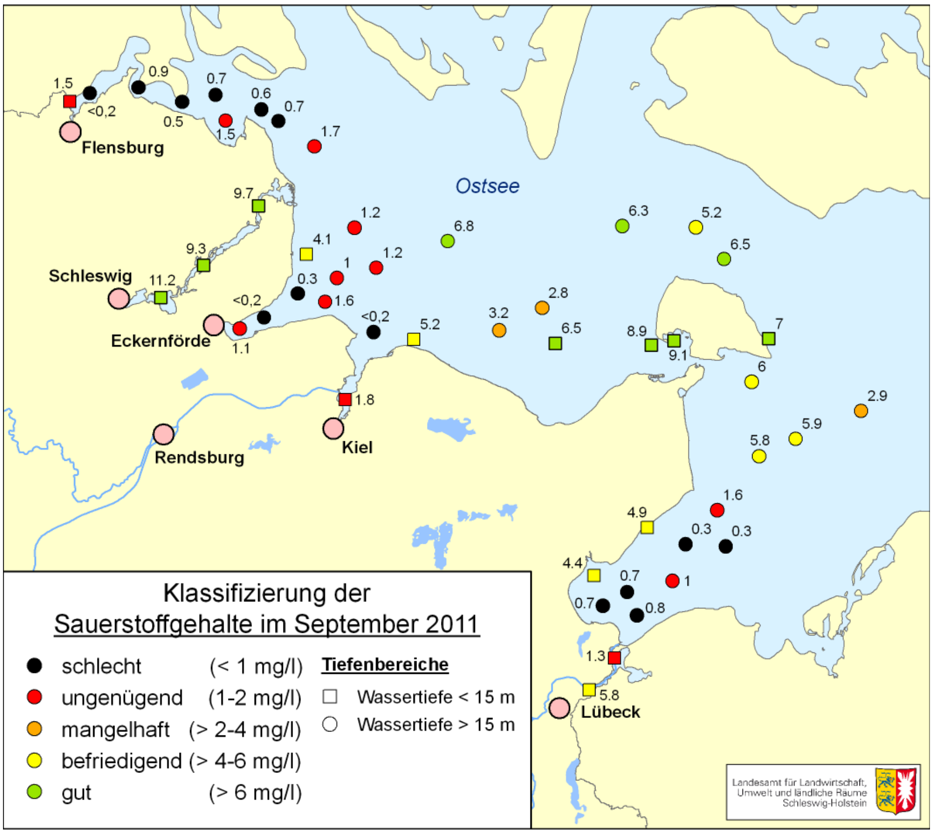
Measurements are taken from August to Oktober/November with focus on September. If there are several measurements per station from this period, the worst of the measurement results is used for oxygen classification. The classification system is still in use, but a final decision regarding its use for MSFD purposes has not been taken yet. Some examples of how results are presented are given in Figure 6.16. The reports are available online.

6.4.3 German approach 2: Classification according to trophic status and organic matter.

This classification scheme was used in Mecklenburg-Vorpommern coastal waters from 1983 until about 2005 and builds on 3 sets of criteria which are assessed equally (no weighing):

nutrients (o-PO_4-P, total phosphorus, DIN)
level of productivity (phytoplankton biovolume, chlorophyll a, Secchi depth)
oxygen regime and organic matter (oxygen saturation at surface, oxygen concentration near bottom and biochemical oxygen demand)

This classification comprised 6 status classes depicting different trophic stages from oligo- to hypertrophic (see Table 6.2) and was based on at least monthly measurements in surface and bottom waters throughout the year. In case of shallow, well mixed water bodies without stratification, classification was based on surface measurements only (the worst of the values was used for classification). In stratified waters, near-bottom oxygen concentration was used in addition. The classification was given up in the end because of differing demands coming with the Water Framework Directive.



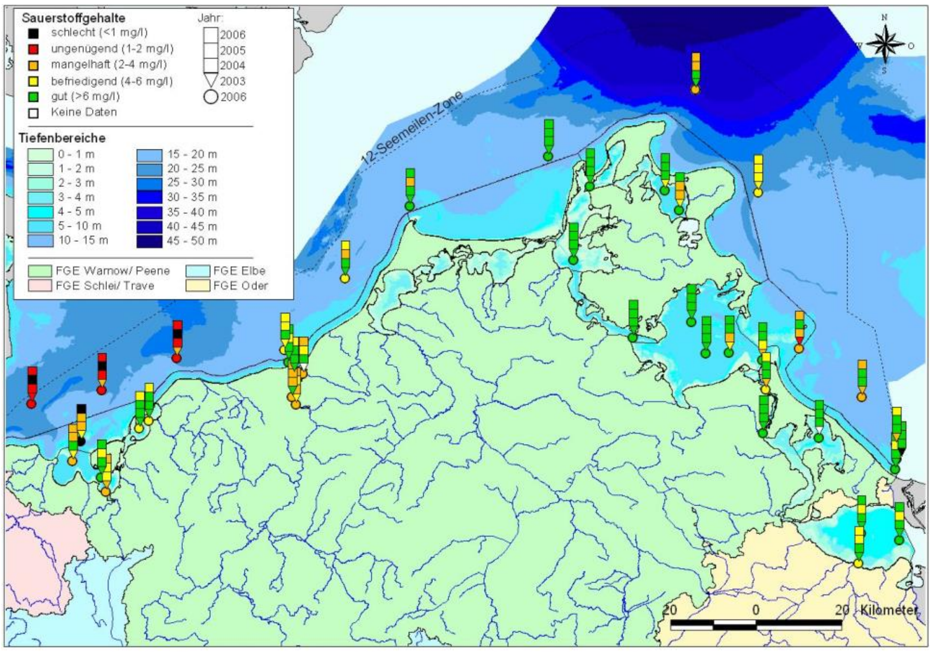


Figure 6.16. Classification of oxygen concentrations in the bottom-near water layer of Schleswig-Holstein for 2011 (top) and for 2003-2006 in Mecklenburg-Vorpommern waters (bottom). Sources: T. Petenati/LLUR, report available online: http://www.bsh.de/de/Meeresdaten/Beobachtungen/MURSYS-Umweltreportsystem/Mursys_031/seiten/oso27_01.jsp LUNG Water Quality Report 2003-2006, available online: http://www.lung.mv-regierung.de/dateien/a3_pub_ggb_2003_2006.pdf

Table 6.2. Classification according to trophic status and organic matter in Mecklenburg-Vorpommern coastal areas until about 2005. Note: o-PO_4-P not to be assessed in shallow sea areas with considerable interaction between phosphorous and sediment (sorption/desorption-equilibrium)

Status class		1	2	3	4	5	6
Trophic level		oligotrophic	mesotrophic	eutrophic	highly eutrophic	polytrophic	hypertrophic
Set of criteria/ criterion	*unit*						
Nutrient conditions							
o-PO_4-P	µmol/l	≤ 0,5	≤1,5	≤ 3	≤ 5	≤ 10	>10
Total P	µmol/l	≤ 1	≤ 3	≤ 6	≤ 10	≤ 20	>20
DIN (NO_3+NO_2+NH_4)	µmol/l	≤ 10	≤ 30	≤ 60	≤ 100	≤ 200	>200
Productivity level							
Phytoplankton biovolume	cm^3/m^3	≤ 1	≤ 5	≤ 10	≤ 20	≤ 40	>40
Chlorophyll a-concentration	mg/m^3	≤ 2	≤ 10	≤ 25	≤ 50	≤ 100	>100
Secchi depth	m	≥ 6	≥ 4	≥ 2	≥1	≥0,5	<0,5
Oxygen and organic matter							
Range of oxygen saturation (min. – max.)	% O_2	90-110	80-130	60-150	40-200	20-250	0-300
Near-bottom oxygen concen-tration	mg/l O_2	≥ 8	≥ 6	≥ 4	≥ 2	< 2	anaerob

BOD_5	mg/l O_2	≤ 2	≤ 4	≤ 6	≤ 8	≤ 10	>10

6.4.4 Polish system of oxygen conditions assessment in the southern Baltic Sea

Until the implementation of WFD (2005) oxygen conditions were assessed only in off-shore areas of the Polish EEZ, mainly in deep sea areas Gdańsk Deep, SE Gotland Basin and Bornholm Deep as well as in the deeper parts of the Gulf of Gdańsk, adjoining to Gdańsk Deep. The assessment took form of the statement of oxygen or hydrogen sulphide concentrations.

With the implementation of WFD a system of oxygen conditions assessment was developed based on minimal oxygen concentration in near bottom water in summer (VI-IX). The same indicator (min. O_2 concentration in summer (VI-IX) was then applied for the MSFD implementation and initial assessment (2012).

Oxygen concentrations are measured (ca. 0.5 m above bottom in the shallow areas and 2 m above bottom in the off-shore zone) at each station on each sampling/measurement occasion throughout the year; i.e. about 4 times within the WFD monitoring system and 3 times within the monitoring of off-shore areas [re. HELCOM COMBINE monitoring]. The minimal oxygen concentration from the months June-September is taken for the classification both in shallow and deep sea areas.

The following classification scheme is applied in the shallow water areas (MOŚ 2014):

> 6.0 O_2 mg/l = high status
6.0-4.2 O_2 mg/l = good status

No class limits are assigned for poor and bad quality statuses. [It is very rare that the minimal oxygen concentration is <4.2 mg/l in coastal waters, infrequently it was measured in the Vistula Lagoon and Szczecin Lagoon between 2000-2006 (IMGW-PIB 2012a)].

In the Initial Assessment for the MSFD implementation (IMGW-PIB 2012b) the classification system for transitional and coastal waters was applied as presented above and for the deep water areas the system was developed basing on concentrations expressed in volume units [cm^3/dm^3].

> 4.0 O_2 cm^3/dm^3 (5.7 mg/l) = good status
4.0-3.0 O_2 cm^3/dm^3 (5.7-2.1 mg/l) = moderate status
3.0-2.0 O_2 cm^3/dm^3 (2.1-1.4 mg/l) = poor status
< 2.0 O_2 cm^3/dm^3 (1.4 mg/l) = bad status.

6.4.5 Information from Estonia

At the moment there is no O_2 indicator used in Estonia. At the end of last year the new monitoring programme and assessment needs were proposed to the Ministry and one suggestion also involved O_2 measurements and development of an indicator in the near future.

6.4.6 Information from Latvia

Currently Latvia does not have oxygen indicators with formalized class boundaries. In assessments, usually two boundaries are used: 4 and 2 mg/l. These boundaries are not used in order to classify status (GES / SubGES), but to characterize the level of oxygen depletion.

6.4.7 Information from Finland

In Finland there is no coastal oxygen indicator or oxygen assessment criteria in place.

6.4.8 Swedish approaches for the assessment of oxygen conditions

For the Swedish coastal oxygen-indicator, the classification boundaries are expressed as either an oxygen concentration or as the proportion of bottom areas where oxygen concentrations are below the critical limit.

The causes of oxygen deficit, except from eutrophication, can be very different depending on area and physical characteristics of the water body which decides which one of the methods above to use.

The oxygen data is run through a set of tests that place the water body into one of the following categories: 1) Seasonal hypoxia, 2) Perennial oxygen deficiency, 3) Permanent oxygen deficiency, 4) Oxygenated deep waters or 5) Data missing.

Water bodies within category 1) shall be classified with the mean of the lowest quartile using bottom oxygen data January-December, GES value is 2.1 ml/l. Water bodies within categories 2) and 3) shall be classified using the proportion of affected bottom areas and data shall be based on the mean of oxygen concentration June-December expressed as proportion of total bottom area exposed for this concentration. GES values are area dependent.

6.4.9 GES-boundaries for oxygen in shallow waters reported nationally under the MSFD

In **Denmark**, a specific MSFD target has been set for the oxygen concentration in Danish Baltic Sea waters which is to be 2 mg/l (Miljöministeriet 2012, in HOD 39/2012, Doc. 2-7/Rev.1) at any time or place, except some areas, e.g. certain fjords, that are considered to be naturally hypoxic.

In **Sweden**, a specific MSFD target has been set for the oxygen concentration in Swedish Kattegat waters which is 3,5 ml/l (in HOD 39/2012, Doc. 2-7/Rev.1), corresponding to 5 mg/l. For more information on the Swedish method see information above.

In **Germany**, currently >4mg/l (July to October) is used as a target for oxygen concentration in Kiel Bay. The applicability of this target for the MSFD is under scrutiny (HOD 39/2012, Doc. 2-7/Rev.1).

6.4.10 New tentative approach for near-bottom oxygen classification in German shallow waters

In the light of the Swedish approach for coastal waters (WFD), the idea of taking the oxygen characteristics of water bodies into account when setting target values for near-bottom oxygen concentration was discussed by German experts. It was proposed to set the good/moderate boundary for stratified waterbodies with seasonal (June-Nov.) oxygen deficiency at 4 mg/l (values <4 mg/l being sub-GES). For non-stratified waterbodies the good/moderate boundary should be set at 6 mg/l (values <6 mg/l being sub-GES) because these waterbodies usually do not show oxygen deficiency so that low near-bottom oxygen concentrations are alarming. Stations in the German territorial waters (up to 12 nm) could be classified similarly according to their stratification characteristics. As in the classification used until now (see 6.4.2), the worst value out of a series of measurements between June and November would be used for classification. This approach is still under discussion but might be applied testwise in 2016.

6.5 The relevance of indicators developed under other HELCOM projects

In addition to the present core eutrophication indicators and the indicators developed under EUTRO-OPER, other indicators potentially relevant to the eutrophication assessment are developed by nominated task groups under the HELCOM CORESET II project.

A joint session of the HELCOM CORESET II and EUTRO-OPER projects was initiated in conjunction with EUTRO-OPER 4-2011 (11 February 2015, Gdynia, Poland). The aim of the session was to discuss core indicators that have been identified as relevant to several descriptors of the Marine Strategy Framework Directive (MSFD) or objectives of the Baltic Sea Action Plan (BSAP), and to specifically consider the applicability of the core indicators currently under development. Focus was placed on indicators developed for benthic and pelagic biodiversity indicators and eutrophication indicators. The session was attended by representatives from Denmark, Estonia, EU, Germany, Finland, Latvia, Poland and Sweden and an Observer from OSPAR as well as Invited Guests (meeting outcome: https://portal.helcom.fi/meetings/EUTRO-OPER%204-2015-217/MeetingDocuments/EUTRO-OPER%204-2015_9-1%20Final%20outcome.pdf)

The participants of the meeting were of the general view that:

- whenever possible, core indicators should be developed to reflect specific rather than multiple anthropogenic pressures,
- GES for pelagic indicators should be in line with the agreed targets for nutrient reduction in the Baltic Sea and GES as regards eutrophication parameters,
- the same indicator can be used in the assessment of several descriptors when found relevant.

The indicators developed under other HELCOM projects (eg. EUTRO PRO, CORESET, CORESET II) and potentially relevant for the eutrophication assessment are presented below.

6.5.1 Ratio of diatoms and dinoflagellates

The relative biomass of diatoms has decreased in the Baltic Proper since the 1980s, tentatively through zooplankton control of diatom blooms. It is an indicator that points out to the shift in biodiversity and food web structure. The link to eutrophication is currently weak and the meeting was of the view that it is not suitable or needed as an indicator of eutrophication.

The indicator is suitable for assessment of biodiversity (MSFD criteria 1.6) and food webs (MSFD criteria 4.3).

6.5.2 Lower depth distribution limit of macrophyte species

Different views were expressed by the participants. It is currently the only biodiversity core indicator that reflects the status of hard bottom communities, thus considered as relevant and required for assessment of biodiversity. It was also felt as a relevant indicator for eutrophication assessments due to the link to nutrients/water transparency in some areas.

The indicator is suitable for both biodiversity (MSFD criteria 1.4, 1.5) and eutrophication (MSFD indicator 5.3.1) assessments.

Aim: to involve eutrophication experts in the development of the indicator in CORESET II to ensure that the indicator concept takes eutrophication aspects into consideration sufficiently.

6.5.3 Biomass ratio of opportunistic and perennial macroalgae

Currently a candidate indicator with ongoing development mainly in Estonia. The indicator includes also soft-bottom communities and would complement the indicator on depth distribution limit as hard substrate does not extend deep enough in all areas.

Suitable as biodiversity indicator in addition to the indicator on depth distribution limit. Established links to eutrophication also supports the possible use of the indicator under Descriptor 5.

Further development is needed before concluding on the most suitable application of the indicator.

6.5.4 State of the soft-bottom macrofauna communities

The indicator is relevant for biodiversity (MSFD criteria 1.6) and seafloor integrity (MSFD criteria 6.2). Regarding its use for assessment of eutrophication, different view were expressed. It has been shown to reflect eutrophication in some areas but it also reflects e.g. physical disturbance.

For the assessment of biodiversity, benthic indices are suitable in both coastal and offshore areas. National indicators for coastal waters developed under the WFD are proposed to be used in coastal assessments. The new offshore BQI developed in CORESET II is proposed to be used in offshore assessment units.

Harmonization of indicators through assessment units is a long-term priority also for eutrophication, at present it is proposed to use intercalibrated national benthic indices for coastal assessments in order to ensure compatibility with WFD. If a benthic index is to be used in open sea areas (i.e. if required under Descriptor 5 in the tentative revision of the EC GES decision) some validation of the BQI developed in CORESET II is likely required to assess its suitability as an indicator of eutrophication.

6.5.5 Benthic diversity indicator

The indicator (Villnäs & Norkko, 2011) was used in the HELCOM eutrophication assessment 2001-2006 (HELCOM 2009). In Finland the indicator is still used and found as a robust indicator for offshore areas. In Germany the indicator is not considered as suitable under the MSFD.

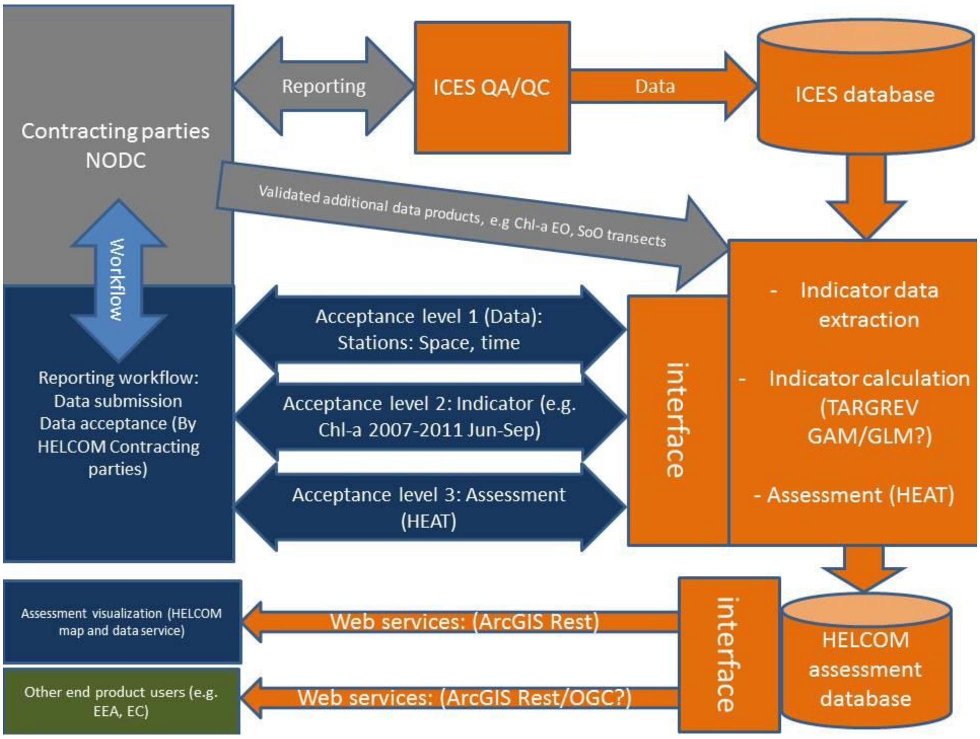
The indicator could be considered for use for eutrophication assessment in offshore areas (if required by the revised EC GES decision).

7 Developing assessment data and work flow

One of the main tasks of EUTRO-OPER is to streamline the assessment process, in collaboration with the HELCOM COMBINE database host ICES. The aim is to set-up a system that is as far as possible automatized but with regular steps of expert review, to ensure both quality and transparency. The system will significantly improve and simplify regular updates of core indicators and the thematic assessment of eutrophication as well as serve the upcoming 2nd HELCOM holistic assessment. The development process can be seen as pioneer work for other thematic assessments, as it is envisioned that a similar process can also be set up for other components of the HELCOM assessment system.

A plan for the data and information flow was made by EUTRO-OPER 1-2014 (Figure 7.1). The data flow is described in more detail below.

Figure 7.1. Proposal for data and information flow. The color of the items indicate the actor/host: Gray = Contracting Parties, Blue = HELCOM portal (hosted at the Secretariat), Orange = ICES, Green = Other end-users.



In the proposed model, **Contracting Parties** are responsible of reporting monitoring data to ICES, to begin with through regular reporting procedures, but in the future possibly through providing an interface to a distributed database. After receiving the data, ICES performs QA/QC checking procedures to the data and takes it into the **ICES database**. For each eutrophication assessment period, a subset of the ICES database is drawn to produce a separate **HELCOM assessment database**, also hosted by ICES. Additional data, such as validated and pre-aggregated EO- or ship-of-opportunity data, is taken directly from the provider to the HELCOM assessment database, without entrance to the ICES database. At this stage, aggregation products, such as indicator averages and HEAT assessment results, are produced automatically by algorithms and stored into the HELCOM assessment database. Visualized data products are subsequently brought through a review and acceptance procedure, using workflows in **HELCOM Eutrophication workspace**. The workflow is to be established on a Sharepoint-based Workspace, where it is possible task actors taking part in the assessment process, as well as documenting the progress. The HELCOM assessment database is produced repeatedly until the acceptance at data-, indicator- and assessment -levels has been achieved, through the HELCOM work flow, from named experts of the Contracting Parties.

Once acceptance at all three levels has been confirmed and the final HELCOM assessment is produced, the assessment dataset is locked for changes and archived to the HELCOM assessment database in order to preserve the original dataset used in the assessment. Final assessment products, such as indicator maps, are then produced and visualized from the database and made available through an interface hosted and maintained by ICES. The HELCOM web portal consists of the indicator and assessment web pages and the HELCOM Map and Data service. The chart type data visualizations would be read from the database using similar Highcharts based solution than the current ICES IROC portal and visualized in the indicator and assessment web pages. The spatial data (indicator maps) would be read from an interface produced with ArcGIS server rest interface, possibly also OGC WMS/WFS compatible web service. The documented interface would be open and could provide data products to be visualized in data portals and visualization end-points hosted by other actors, e.g. HELCOM Contracting Parties national institutions, EEA and EC.

The actual work began by defining the assessment data and work flow, datasets, data reporting, end-products and the roles of organizations in 2014. The actual implementation was done in 2015. After developing algorithms for extraction of data and calculation of updated core indicators for open-sea areas, algorithms for the coastal areas (using WFD indicator data) and the overall eutrophication (HEAT 3.0) assessment were developed (Figures 7.2 and 7.3).

Figure 7.2. The 'Indicator' view, presenting a status map and status data of a chosen core-indicator produced using algorithms connected to the eutrophication assessment database at ICES. The indicator is updated for open-sea areas using monitoring data reported to the HELCOM COMBINE database, while the coastal status is updated using WFD data reported by the contracting parties in the EUTRO-OPER project. All data used in the indicators is collected to the eutrophication assessment database at ICES. Please note that the indicator values are preliminary, as expert review is still to be done.

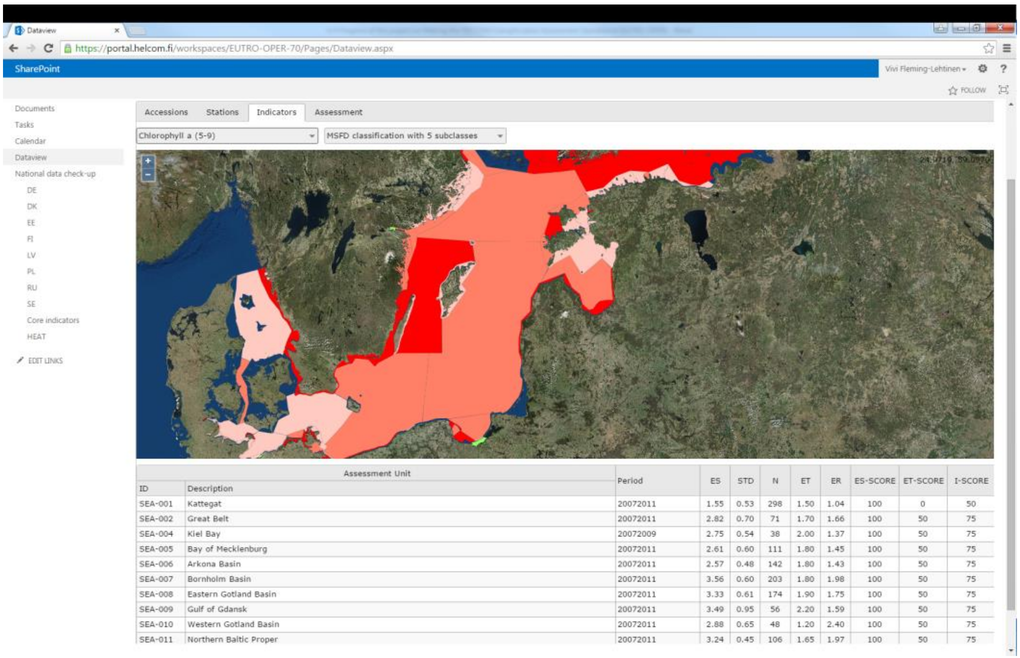
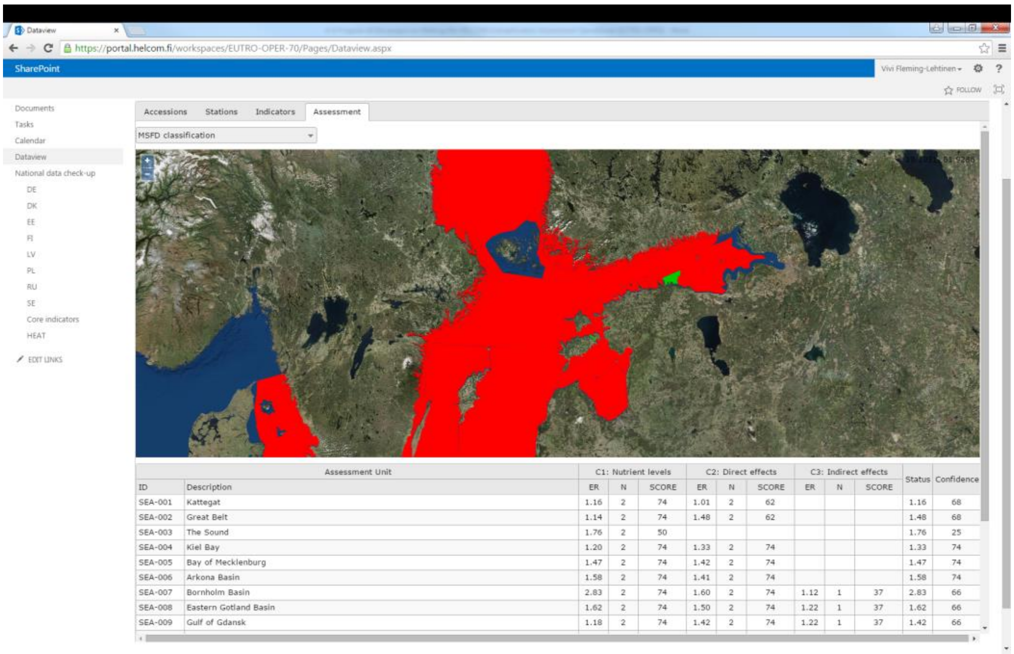
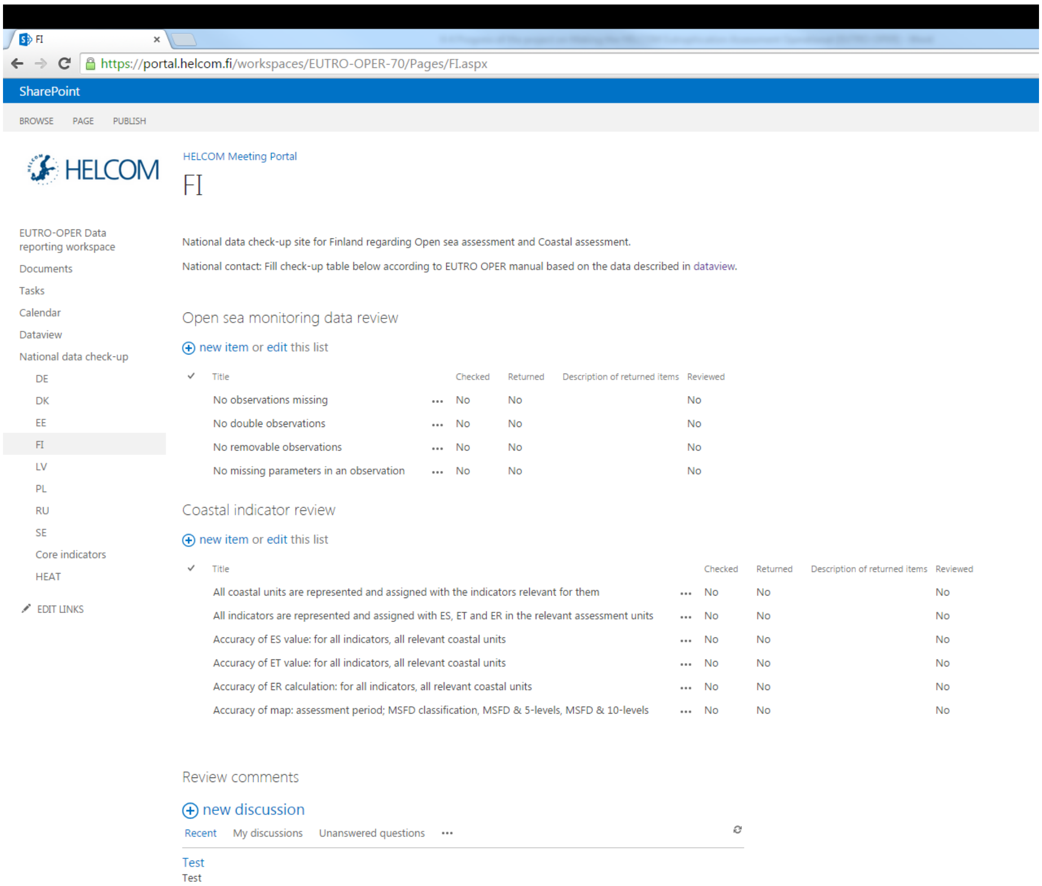


Figure 7.3. The "assessment" view, presenting status map and status data of the overall eutrophication. The overall assessment is produced using HEAT 3.0 algorithms on the indicator values produced as described in Figure 7.1. Please note that the values are preliminary, as expert review is still to be done.



Indicator values are transferred as tables in a specific work-space in the HELCOM Meeting Portal, at present accessible by EUTRO-OPER participants, but planned to be used in the future as a platform for accepting intermediate assessment products by assigned experts of the contracting parties. To facilitate the review process, ensure equal quality and fulfill the needs for transparency, a checking procedure with instructions was developed (Figure 7.4).

Figure 7.4. A "national data check-up site", presenting a check-list for the expert to go through while reviewing assessment data and products. A similar site is produced for each contracting party, with access by assigned experts in charge of the review. This site will be tested and developed through the comments received by EUTRO-OPER participants.



Assessment data on coastal indicators was requested from all contracting parties being EU member states.

Eutrophication manual

To facilitate future eutrophication assessments and make replication possible the EUTRO-OPER produced, as one of its final outcomes, an eutrophication assessment manual. This manual works both as an instruction hand book for experts in charge of updating the eutrophication assessment and as a document that describes the full methodology of the eutrophication assessment, from monitoring (through links to the monitoring manual) and data handling to indicators and the HEAT 3.0 assessment.

8 Test assessment

8.1 General

The purpose of the test assessment was to test the eutrophication assessment protocol and information flow developed under EUTRO-OPER. The focus was not in producing an accurate assessment, in the sense of making sure that all data is included and correct, but to find possible weaknesses in the assessment process. The experiences from the test assessment are either used to make instant improvements, or embedded in the anticipated future needs (Chapter 9).

This chapter presents the test assessment results. This information is also found in the EUTRO-OPER Data reporting workspace (https://portal.helcom.fi/workspaces/EUTRO-OPER-70/default.aspx). We emphasize, that it is a test, and the results may not be used to indicate the status of the Baltic Sea.

8.2 Data and reporting

The test assessment was produced according to the protocol proposed by EUTRO-OPER and described in the Eutrophication Assessment Manual (http://www.helcom.fi/Documents/Eutrophication%20assessment%20manual.pdf). Core indicator data was retrieved from the HELCOM Eutrophication assessment database for the test assessment.

The data retrieved from the HELCOM COMBINE database had mainly been reported according to the HELCOM COMBINE programme already earlier. Additional data was reported to the eutrophication assessment database by EUTRO-OPER participants (table 8.1).

Table 8.1. Data types, their sources and use in the test assessment. Detailed information may be found in the Eutrophication Assessment Manual.

Data type(s)	Data reported by /received from	Used in indicators	Used in assessment units
in-situ monitoring data	HELCOM contracting parties as part of HELCOM COMBINE programme	HELCOM CORE indicators DIN, DIP, chlorophyll-*a*, Secchi depth	SEA-001…SEA-017
EO-data product, 20K daily grid	SYKE, Finland	HELCOM CORE indicator chlorophyll-*a*	SEA-007…017
Oxygen debt indicator results	CORE EUTRO, as part of the 2007-2011 eutrophication assessment (HELCOM 2014)	HELCOM CORE indicator oxygen debt	SEA-007…010, SEA-012, SEA-013
National indicator results	EUTRO-OPER participants (EE, DE, DK, FI, LV, PL)	All coastal indicators	EST-001…016 GER-011…044 DEN-001…014 FIN-001…014 LAT-001…005 POL-001…019 SWE-001…025

8.3 Documentation of expert review

8.3.1 Overview and summary

The test assessment was reviewed by the participants of EUTRO-OPER (table 8.2). For open-sea areas, the review was conducted at data-, indicator- and assessment level. In the coastal areas, where only ready indicator results were reported, the review was conducted only at the indicator- and assessment level.

The responsibilities of reviewing were divided among Contracting Parties, so, that each contracting party was responsible for reviewing all information reported by them, or evaluating their coastal assessment units. In addition, selected Contracting Parties were responsible for the review of specific open-sea core indicators. Other participants were given the opportunity to comment on these results as well (see Eutrophication Assessment Manual for more detailed information). Due to practical restraints, the test assessment was only partly reviewed and accepted (table 8.2).

The test showed exceptions at all three levels (1. data, 2. indicator, 3. assessment), both at open sea and coast. It was concluded, that the review is an elementary part of producing a high quality assessment. The use of the eutrophication assessment dataview was found to be extremely useful in the review process. The interactive workspace for data checking and acceptance increased transparency and speeded up the assessment process, but it did not remove completely the need for additional e-mail communication and expert meetings.

Table 8.2. An overview of the review, with information on whether the review items were checked and accepted by the responsible Contracting Party, and whether exceptions were found. Detailed review results are shown in Annex 8A.

Task	Task details	Accepted (yes/no)	Checked (yes/no)	Responsible party	Exceptions (yes/no)	Comments
Open sea monitoring data review	Danish waters	no	no	Denmark		
	Estonian waters	yes	yes	Estonia	yes	parly accepted
	Finnish waters	yes	yes	Finland		
	German waters	no	no	Germany	yes	partly checked & accepted
	Latvian waters	no	no	Latvia		
	Lithuanian waters	no	no	Lithuania		
	Polish waters	yes	yes	Poland	yes	
	Russian waters	no	no	Russia		
	Swedish waters	yes	yes	Sweden	no	
Coastal indicator review	Danish waters	no	no	Denmark		
	Estonian waters	yes	yes	Estonia	yes	partly accepted
	Finnish waters	yes	yes	Finland	no	
	German waters	no	yes	Germany	yes	partly accepted
	Latvian waters	no	no	Latvia		
	Lithuanian waters			Lithuania		no coastal indicators reported

	Polish waters	yes	yes	Poland	no	
	Russian waters			Russia		no coastal indicators reported
	Swedish waters	yes	yes	Sweden	yes	
Coastal HEAT review	Danish waters	no	no	Denmark		
	Estonian waters	yes	yes	Estonia	yes	partly accepted
	Finnish waters	yes	yes	Finland	no	
	German waters	yes	yes	Germany	no	
	Latvian waters	no	no	Latvia		
	Lithuanian waters			Lithuania		no coastal indicators reported
	Polish waters	yes	yes	Poland	no	
	Russian waters			Russia		no coastal indicators reported
	Swedish waters	yes	yes	Sweden	yes	
Review of core indicator	Chla (in situ)	yes	yes	Finland	yes	Commented by the Secretariat
	Chla (EO)	yes	yes	Finland	no	
	Chla	yes	yes	Finland	no	
	DIN	yes	yes	Germany	yes	
	DIP	yes	yes	Germany	no	
	Oxygen debt	yes	yes	Sweden	no	Commented by the Secretariat
	Secchi depth	no	yes	Finland	no	Commented by the Secretariat
open HEAT	Review of HEAT	yes	yes	Secretariat	yes	

The open-sea data was accepted only by four Contracting parties. This was mainly due to the fact that checking the data nationally would have had to involve numerous experts, which was not seen to be reasonable within the time frame, especially in a test. For some Contracting Parties, this part of the review was however found extremely useful, and ended up in additional data being reported to ICES (Table 8.2, Annex 8A).

The coastal indicators were checked by five Contracting Parties. Despite the fact that the indicator results had been reported by the same instances, a number of exceptions were found in review. Most of these were not actual mistakes in importing the information into the eutrophication assessment database, but instead finding variability and subsequent faults in the reporting of the indicator results. Some exceptions were a result of the variability in the reporting between Contracting Parties, which lead to compromises in the overall assessment that had not been anticipated at the stage of reporting.

The assessment review for coastal areas was completed by five Contracting Parties. Some exceptions were found, but they were related to exceptions found at the indicator level.

The open-sea core indicator review was completed for all core indicators, and accepted for DIN, DIP, chlorophyll-*a* and oxygen debt. Exceptions were found only for chlorophyll-*a* (*in-situ*) and oxygen debt, though part of them were based on problems at data level. The remaining exceptions were corrected, and the indicators were subsequently accepted.

The open-sea review at assessment level was completed. Some exceptions were found, part of which were related to problems at data level. The remaining exceptions were corrected, and the assessment level was subsequently accepted for all open-sea areas.

8.4 Test assessment results

8.4.1 Overall assessment

In open-sea areas, the test (using 2007-2011 data) produced a similar result regarding overall eutrophication status: the entire Baltic Sea was estimated to be below GES (Figure 1). The result differed slightly in the intensity of eutrophication status when compared to the eutrophication status assessment 2007-2011 (Annex 8A, HELCOM 2014, hereafter 2007-2011 assessment). In the test, the Bornholm Basin was the most affected area, whereas in the 2007-2011 assessment the most affected sub-basins were the Western Gotland Basin and Gulf of Finland. This was most likely a subsequence of differences in the *in-situ* datasets especially regarding nutrients, or in the way this data was used in indicator update.

For coastal areas, the test (using mainly data from period 2007-2012, but in some cases years close to this) resulted in eutrophication status above GES in the Kattegat-Sound area. Additional selected coastal assessment units in the Bothnian Bay, Bothnian Sea, Gulf of Finland and Gulf of Riga were assessed to be above GES. The test result differed considerably from the 2007-2011 assessment, in which GES was achieved only in a number of coastal assessment units in the Bothnian Bay – Bothnian Sea area and one site in Germany. This is however not surprising, since both a different time-period and a different assessment tool was used in the test than in the 2007-2011 assessment.

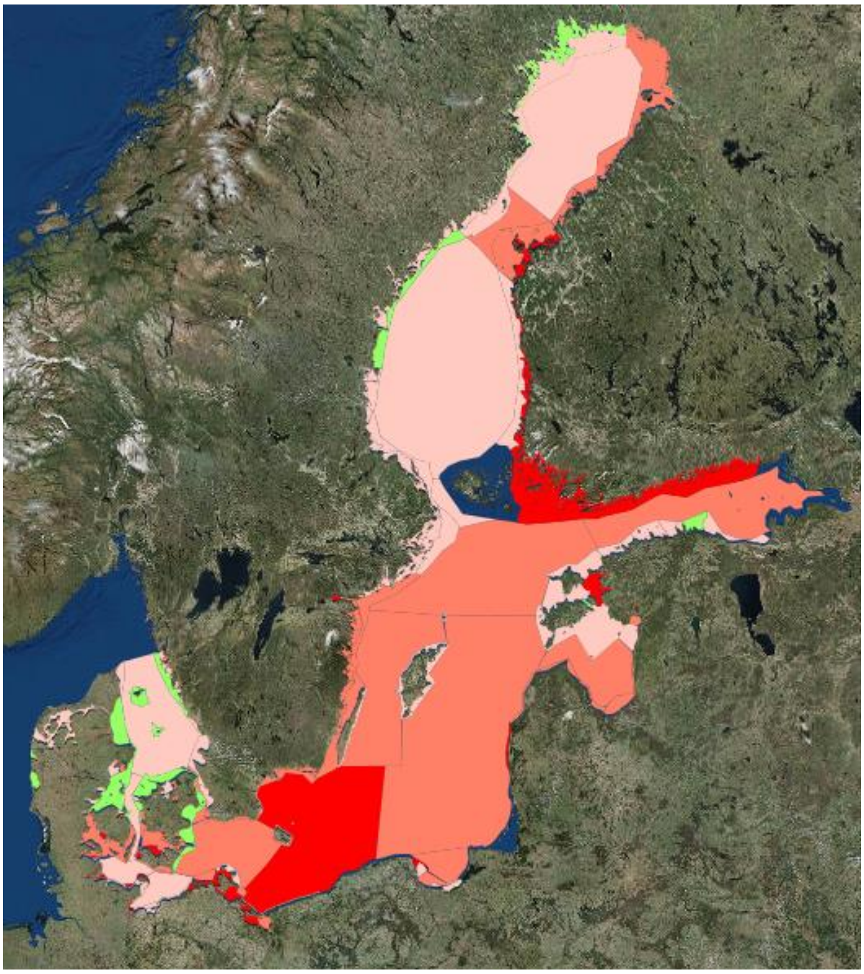


Figure 8.1. Test assessment: overall eutrophication status.

8.4.2 Core indicators in open-sea areas

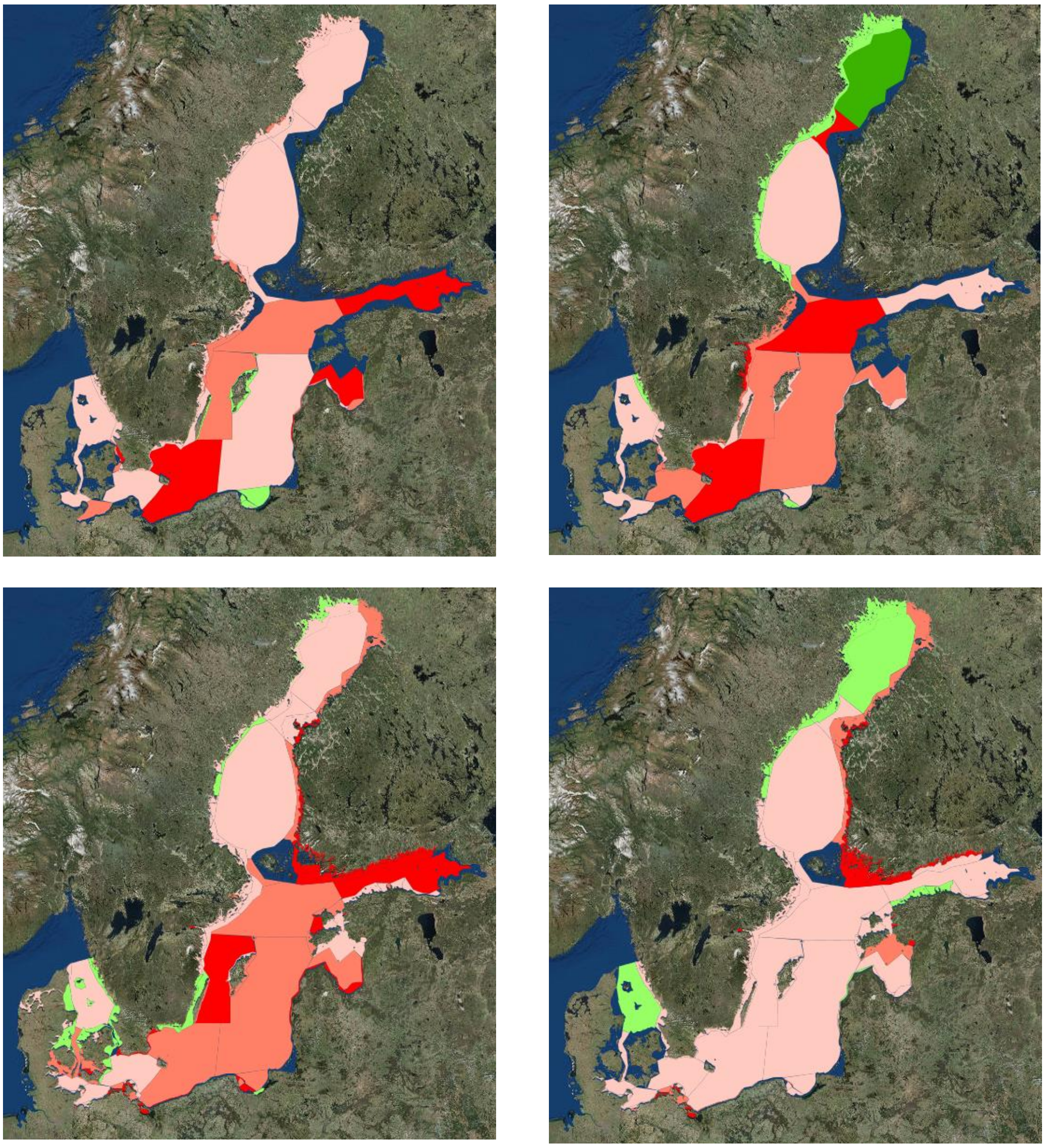
The results of the test indicator evaluations differed to some extent from the 2007-2011 indicator evaluations (HELCOM 2014, http://www.helcom.fi/baltic-sea-trends/indicators/), assumedly due to changes in both update data and methodology. The test assessment data was not thoroughly checked and approved by contracting parties (see chapter 8.2), and may therefor lack some data that was included into the 2007-2011 assessment but not reported to ICES. On the other hand, data has been also reported after 2013, and was subsequently included only in the test assessment. The most substantial methodological changes are the inclusion of EO-data in chlorophyll-*a* update and omitting the use of spatiotemporal normalization of nutrient data (HELCOM 2013, 2014).

The test evaluated DIN to be below GES in all open-sea areas except the Gdansk Basin (figure 8.2, upper left pane). The areas most affected were the Gulf of Finland, Gulf of Riga and Bornholm Basin. The difference to the 2007-2011 assessment was considerable especially in the Gulf of Riga, which was there evaluated to be above GES. The test showed considerably worse results also in the Gdansk Basin and Bornholm Basin (Annex 8A).

DIP was evaluated to be below GES in all open sub-basins except the Bothnian Bay (figure 8.2, upper right pane). The only distinct difference to the 2007-2011 evaluation was found in the Quark, where the test assessment result has fallen into SubGES with a high marginal. This result seems slightly suspicious, taking into account that the neighbouring open Bothnian Bay was in good status.

Chlorophyll-*a* was evaluated, combining information from both *in-situ* and EO-data, to be in SubGES status in all open-sea areas (figure 8.2, center right pane). The test results were considerably worse in the Gulf of Riga and Gulf of Finland in the test than in the 2007-2011 assessment. The evaluation in the latter was based on low status-confidence (HELCOM 2014). The status confidence in these areas was high in the test assessment, partly due to the inclusion of EO-data results. The classification for Kattegat differed between the test (SubGES) and the 2007-2011 evaluation (GES, Annex 8A).

Oxygen debt was evaluated only for seven sub-basins, relying completely on the results of the 2007-2011 assessment (figure 8.2, bottom left pane). It was classified into SubGES in all these areas.



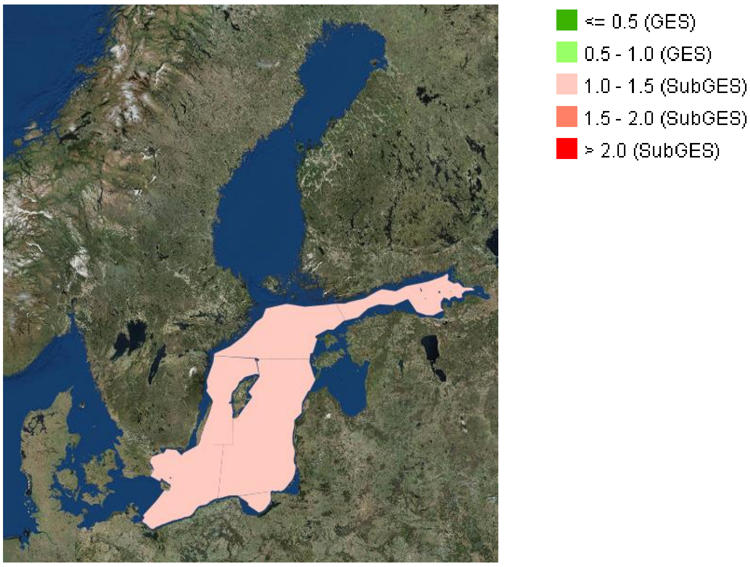


Figure 8.2. The evaluations of the open-sea core indicators DIN (upper left), DIP (upper right), chlorophyll-*a* (center left), Secchi depth (center right) and oxygen debt (bottom left). GES is indicated in green and SubGES in red, with colour shade indicating eutrophication ratio (scale bar bottom right).

8.4.3 Coastal indicators

The set of coastal indicators used in the test assessment varied substantially based on the Contracting Party reporting the indicators. Altogether 37 coastal indicators were reported and used. The main conclusion of the test assessment in coastal areas was, that the great variation in indicators dicreases the harmony and comparability between the results achieved in different assessment units.

Some of the indicators reported by different Contracting Parties were aggregated in the assessment dataview into quality elements, trusting that they indicate a similar change (eg. zoobenthos quality element), but as they were from different assessment units, this had no effect on how they were used in the overall HEAT assessment.

The most important differences in the reporting of coastal indicators could be grouped into differences in the following:

1. Different indicators for same function. This was the case especially regarding indicators of macrovegetation, macrozoobenthos and nutrients, but to some extent also bottom oxygen and phytoplankton. Some contracting parties reported multiparametric indicators (in practice WFD quality elements), whereas others reported single indicators.
2. In principle same indicator, but with distinctly different assessment season. Using the same indicator in summer, winter or annually could change the function completely. In some cases the difference was more subtle, in differing only by a month or two. This was common in nutrient, chlorophyll-*a* and Secchi depth indicators.
3. Same indicator with different statistic approach. For example, the bottom oxygen indicator could be salinity normalized in some areas but not in others.
4. Same indicator, but differences in target-setting principles. This seemed to be common especially among indicators that were not intercalibrated under WFD, such as bottom oxygen.
5. Different reporting period. The assessment period was mostly 2007-2012, determined by the requirements of WFD. Some Contracting Parties were however not able to report this period, but used another period as close as possible.

As a result of the variability of the coastal indicators, general Baltic-wide indicator evaluations were not made for coastal indicators. The indicator results are presented in Annex 8.

8.5 Metadata and confidence

8.5.1 Open-sea assessment and core indicators

In the test, open-sea core indicators were updated using data reported to the HELCOM COMBINE database by the contracting parties. The only exception to this was oxygen debt, which was included into the overall assessment using results from the previous eutrophication assessment for the test period 2007-2011 (BSEP 143).

The number of *in-situ* observations available for indicator update varied considerably between indicator parameters and assessment units (Table 8.8). Overall, the number of observations during the five-year test period varied between 0 – 298 observations per assessment unit. Most data was found in the large southern sub-basins: the Kattegat, Arkona Basin, Bornholm Basin and the Eastern Gotland Basin. The small basins were often insufficiently monitored: for certain indicator parameters, the total number of observations were below 5. Least data was reported in the Sound, where chlorophyll-*a* and Secchi depth could not be updated, and high-confidence updates could not be made for nutrients either.

Table 8.8. Number of monitoring observations used for update of indicators in each assessment unit. For chlorophyll-*a* (EO), the daily average in each grid cell was interpreted as an observation. Only observations from the assessment season are included, averaging measurements between 0 – 10 m depths.

ID	Assessment unit	DIN	DIP	Chl-a (insitu)	Chl-a (EO)	Secchi
SEA-001	Kattegat	271	271	298	*not used*	128
SEA-002	Great Belt	46	46	71	*not used*	6
SEA-003	The Sound	6	6	0	*not used*	0
SEA-004	Kiel Bay	31	31	38	*not used*	45
SEA-005	Bay of Mecklenburg	97	97	111	*not used*	103
SEA-006	Arkona Basin	147	142	142	*not used*	60
SEA-007	Bornholm Basin	119	118	203	604912	243
SEA-008	Gulf of Gdansk	28	28	56	11466	54
SEA-009	Eastern Gotland Basin	133	133	184	3482300	198
SEA-010	Western Gotland Basin	46	46	48	456960	19
SEA-011	Gulf of Riga	22	22	47	150746	77
SEA-012	Northern Baltic Proper	85	85	128	1584219	110
SEA-013	Gulf of Finland	90	90	67	897532	113
SEA-014	Åland Sea	13	13	4	28281	10
SEA-015	Bothnian Sea	166	164	12	5264508	71
SEA-016	The Quark	17	17	1	47250	12
SEA-017	Bothnian Bay	96	96	11	1312875	31

In the northern sub-basins (Åland Sea, Bothnian Sea, Quark and Bothnian Bay), *in-situ* chlorophyll-*a* data was more scarce than the other parameters. In the smallest basins, data was not sufficient for reliable indicator updating based on in-situ data alone. In the southern and central sub-basins, this was not a problem; chlorophyll-*a* data was often more numerous than nutrient data. This was most likely due to lower monitoring activity in winter than during summer.

EO-data products, daily averages in 20K grids, were combined with *in-situ* data for chlorophyll-*a* update in the Bornholm Basin and assessment units north from it. In these areas, 11 000 – 5 million daily grid cell averages were reported per assessment unit.

Indicator status confidence, a score indicating the availability of monitoring data for indicator update, was estimated to be high for most indicators and sub-basins (Table 8.9). The scarcity of chlorophyll-*a* *in-situ* data was compensated in the northern areas by introducing EO-data. As a result, only the Sound (all indicators), Åland Sea (nutrients and Secchi depth), Quark (Secchi depth) and Great Belt (Secchi depth) were problematic in terms of monitoring data availability.

Table 8.9. Status confidence for indicators in the open-sea assessment units. Status confidence is based on the number of observations used for indicator update (BSEP 143).

ID	Assessment unit	DIN	DIP	Chl-a	Secchi
SEA-001	Kattegat	HIGH	HIGH	HIGH	HIGH
SEA-002	Great Belt	HIGH	HIGH	HIGH	MOD
SEA-003	The Sound	MOD	MOD		
SEA-004	Kiel Bay	HIGH	HIGH	HIGH	HIGH
SEA-005	Bay of Mecklenburg	HIGH	HIGH	HIGH	HIGH
SEA-006	Arkona Basin	HIGH	HIGH	HIGH	HIGH
SEA-007	Bornholm Basin	HIGH	HIGH	HIGH	HIGH
SEA-008	Gulf of Gdansk	HIGH	HIGH	HIGH	HIGH
SEA-009	Eastern Gotland Basin	HIGH	HIGH	HIGH	HIGH
SEA-010	Western Gotland Basin	HIGH	HIGH	HIGH	HIGH
SEA-011	Gulf of Riga	HIGH	HIGH	HIGH	HIGH
SEA-012	Northern Baltic Proper	HIGH	HIGH	HIGH	HIGH
SEA-013	Gulf of Finland	HIGH	HIGH	HIGH	HIGH
SEA-014	Åland Sea	MOD	MOD	HIGH	MOD
SEA-015	Bothnian Sea	HIGH	HIGH	HIGH	HIGH
SEA-016	The Quark	HIGH	HIGH	HIGH	MOD
SEA-017	Bothnian Bay	HIGH	HIGH	HIGH	HIGH

The eutrophication assessment in open-sea areas was based on 2-5 indicators, depending on sub-basin (Table 8.10). In all open-sea areas except the Sound, two indicators under both criteria 1 (nutrient levels) and 2 (direct effects) could be updated. Under criterium 3 (indirect effects), only one core indicator has been developed, and it is applicable only in six assessment units.

Table 8.10. Number of indicators used (N) in Criterium 1 (C1, nutrient levels), Criterium 2 (C2, direct effects), Criterium 3 (C3, indirect effects) and altogether (overall) in the eutrophication assessment in the open-sea assessment units.

ID	Assessment unit	N C1	N C2	N C3	N overall
SEA-001	Kattegat	2	2	0	4
SEA-002	Great Belt	2	2	0	4
SEA-003	The Sound	2	0	0	2

SEA-004	Kiel Bay	2	2	0	4
SEA-005	Bay of Mecklenburg	2	2	0	4
SEA-006	Arkona Basin	2	2	0	4
SEA-007	Bornholm Basin	2	2	1	5
SEA-008	Gulf of Gdansk	2	2	1	5
SEA-009	Eastern Gotland Basin	2	2	1	5
SEA-010	Western Gotland Basin	2	2	1	5
SEA-011	Gulf of Riga	2	2	0	4
SEA-012	Northern Baltic Proper	2	2	1	5
SEA-013	Gulf of Finland	2	2	1	5
SEA-014	Åland Sea	2	2	0	4
SEA-015	Bothnian Sea	2	2	0	4
SEA-016	The Quark	2	2	0	4
SEA-017	Bothnian Bay	2	2	0	4

8.5.2 Coastal assessment: overall eutrophication

The coastal assessment was based on national indicators developed under the WFD process, and thus the set of indicators varied country by country. Also the number of indicators used in the assessment varied, ranging from 1 to 11. Generally, 1-6 indicators were used for each of the three criteria, though exceptions were found (ANNEX 8A).

German coastal areas were well represented by indicators. The coast was divided into 45 coastal assessment units. In all of them, 4-7 indicators were used to produce the overall assessment. Criterium 1 and 2 consisted always of two indicators, while the number of indicators varied in criteria 3 between 0 and 3. In summary,

The Danish coast was divided into 16 assessment units, part of which were located close to the western coast of Denmark. The overall eutrophication assessment was based on 1-2 indicators, representing Criteria 2 and/or 3. No indicators representing Criteria 1 were reported. In summary, the number of reported indicators was considered too low for producing a reliable eutrophication assessment for the Danish coasts (Fleming-Lehtinen et al. 2015).

Estonian coastal waters were extremely well represented by indicators. The coast was divided into 16 assessment units. The overall eutrophication assessment was usually based on 9-11 indicators, with the exception of EST-015 with 3 indicators. in 13 assessment units, all three criteria were represented by indicators. Criterium 1 was usually represented by two indicators (apart from three exceptions) and Criterium 2 by 4 indicators (apart from 2 exceptions). Criterium 3 consisted always of 3-5 indicators.

Finnish coastal areas were well represented by indicators. The coast was divided into 11 assessment units, representing either the outer or inner coastal areas. Apart from one exception, the assessment was based on 5-8 indicators, divided evenly between the tree criteria. Criterium 1 was based always on two indicators, while the number of indicators in criteria 2 and 3 varied between 1-3 indicators (with the exception of no C3 indicators in FIN-005).

Latvian coastal areas were well represented by indicators. The coast was divided into 5 assessment units, and the assessment was based on 5-7 indicators. Apart from one exception (LAT-002 lacking C3 indicator), the indicators represented evenly the three criteria.

The Polish coastal areas were well represented by indicators. The eutrophication assessment was produced for 14 coastal assessment units, based mainly on 5-8 indicators. There were exceptions to this: POL-004 and POL-003 with 10 and 9 indicators, and on the other hand, POL-011 with only one indicator. Criterium 1 was best represented, usually with 2-4 indicators. Criterium 2 and 3 consisted regularly of 1-3 indicators.

The Swedish coast was extremely well represented by indicators. The coastal areas were divided into 24 assessment units, using 7-11 indicators to assess eutrophication. Criterium 1 was usually based on 5-6 indicators, Criterium 2 of 2-3 indicators and Criterium 3 of 1-2 indicators.

9 Anticipated needs of the HELCOM eutrophication assessment work

9.1 Routines involved with assessment update

After an operational eutrophication assessment work flow, including a chain of actions from data reporting to indicator and assessment update, the experts assigned by contracting parties no longer need to be involved in the tasks of collating datasets, filtering data, updating indicators and integrating assessments. The work flow has however been designed to fulfill the requirements of high quality and transparency through involving the experts at specific stages of the process. Specifically, the routines include eg. the following:

Initializing the assessment work flow. This includes first and foremost setting an assessment period, and verifying the roles of contracting parties and institutions, as presented in the eutrophication assessment manual. A detailed time-table for the assessment update must be set, and ICES shall be contacted in order to set up a new assessment database and dataview for the update.

Organizing separate update of the oxygen debt core indicator. As long as the update of oxygen debt from monitoring data is not included into the eutrophication database algorithms, oxygen debt must be updated separately.

Update of coastal indicator data and revisiting coastal targets. As long as the update of coastal indicators from monitoring data is not included into the eutrophication database algorithms, the coastal indicators must be updated separately. The contracting parties are expected to inform of possible changes in coastal indicators rising from the national processes, and updating these into the assessment shall be agreed upon.

Setting specifications for coastal and open-sea HEAT assessment. Eg. indicator weights and methodological correction factors need to be agreed upon.

The **assessment products are to be reviewed**. This includes review of data (1st level), indicators (2nd level) and assessment (3rd level), and might require more than one iteration round, with additional monitoring data reporting from the contracting parties.

The **indicator and assessment reports shall be updated**. This includes mainly analyzing the assessment products in the indicator web reports as well as possible updated thematic assessment reports.

9.2 Development of assessment methods

The assessment method can be further developed. The assessment would benefit from development in the items listed below, though some of them might have to wait for achievements in the sciengific field of expertise, or some further investments.

Finalizing indicators of eutrophication, namely the pre-core indicators of total nitrogen, total phosphorus, spring bloom chlorophyll-*a* and cyanobacterial bloom index and the candidate indicator oxygen consumption as well as an oxygen indicator for shallow water areas. In addition to these, the possible future use of macrozoobenthos in the open-sea areas would require adjustments to the existing core indicators used in the 2003-2007 assessment. In practice, the work required would be:

- GES-boundaries for nutrient and spring bloom indicators should be estimated with the help of ecological models
- updating spring bloom for southern Baltic areas
- combining the cyanobacterial bloom index and the cyanobacteria biomass estimate (developed by the PEG group)
- testing further whether the oxygen consumption approach is suitable, and proceed with subsequent indicator development
- further development of shallow area oxygen indicator for open-sea areas combining oxygen concentration and salinity data, based on the Swedish approach
- GES-boundaries for the existing open-sea macrozoobenthos indicators (used in the 2003-2007) should be updated to suit the present sub-basin division for open-sea areas

Further harmonization of the coastal and open-sea assessment. At present, the coastal assessment is based on various indicators and time-periods, depending the national waters in question. Increased harmony could be achieved through unifying a core set of indicators used both at open-sea and coasts, and further harmonizing the GES boundaries.

Including further new data types to the update of core indicators. The alignments made during EUTRO-OPER on adding spatially or temporally high resolution data into the assessment allows further inclusion of potential new data types. For example:

- Including and evaluating EO-datasets for chlorophyll-a indicator update also for southern Baltic regions
- Ferrybox flow through data to the update of core indicator chlorophyll-*a*
- EO-data for the update of core indicator Secchi depth
- DIVA nutrient analysis to the update of core indicators DIN and DIP

Possible update of HEAT 3.0. The aggregation principles might have to be adjusted after the revision of the commission decision is finalized in 2016. Also other updates, such as developments in the confidence scoring, would improve the tool.

9.3 Further improvement of assessment work flow

The eutrophication assessment work flow may always be developed further. The anticipated next items for development are listed below. The development would require contributions from the data host.

Operationalizing the oxygen debt core indicator. Since the data for updating the indicator already is reported to the ICES database, the operationalizing would require developing the update algorithms, using indicator development work done during the HELCOM Targrev project. Since oxygen debt indicator involves complicated statistic procedures, developing these algorithms is not a simple task.

Adjusting the assessment work flow during possible uptake of new indicators. For some indicators (total nitrogen, total phosphorus, oxygen consumption, shallow water oxygen) algorithms for update using data already reported to ICES are required. Indicators using other data types (cyanobacterial bloom index, spring bloom chlorophyll-*a*, macrozoobenthos), data is reported in aggregated form, and the assessment work flow should be updated to include these.

Adjusting the HEAT algorithms after possible update of assessment tool.

Transferring into **data-driven coastal indicator updates**, once agreed upon by eutrophication experts.

Enabling remote access to distant databases, specifically when including datatypes not taken into the ICES quality checking procedure. Of the present datasets, especially the EO-data would come into consideration.

Developing sophisticated chart components, to be embedded both into the HELCOM workspace and later into the HELCOM web site.

Include algorithms for producing the eutrophication assessment according to OSPAR COMP in the Kattegat area. This would enable Sweden and Denmark to use products created in the eutrophication assessment work flow in their reporting in Kattegat, where OPSPAR methodology has been agreed to be used.

Including an option for contracting parties to receive a **comparison of cruise report data** and eutrophication monitoring data, upon request. For some contracting parties, the review process would be simplified if gaps in reported data could be shown.

Including **minor but possibly laborious details** in the present dataview

- possibility to download filtered datasets
- possibility of filtering using station name
- filtering for HELCOM sub-basins also for coastal areas, to facilitate eg. producing plots based on the number of coastal unit per HELCOM sub-basin achieving GES
- submission enquiry name into the stations sheet as a filtering option (to find out who submitted the data)
- show also other parameters besides ER in the map view

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ANNEX 1A: Project proposal HELCOM EUTRO-OPER

Project proposal for "Making HELCOM eutrophication assesssments operational (HELCOM EUTRO-OPER)"

1. Title of Project

"Making HELCOM Eutrophication assessments operational (HELCOM EUTRO-OPER)"

Project number 11.51

2. Project Manager

[Ms. Vivi Fleming-Lehtinen]

3. Proposing Party

Contracting Party _____

Commission _____

Subsidiary body __HELCOM CORE EUTRO 8/2013, supported by HELCOM MONAS 18/2013

Heads of Delegation _HELCOM HOD 41/2013 and HOD 42/2013 in principle supported [LD 108 and LD59, respectively]___

Executive Secretary _____

4. The body supervising the Project

HELCOM MONAS and HELCOM GEAR

5. Background, target and activities

Background

HELCOM Moscow 2010 Ministerial Declaration laid out the following:

"*DECIDE that this work will continue to be based on*

- *... jointly constructed quantitative targets and associated indicators as initiated with the HELCOM Baltic Sea Action Plan;*
- *joint coordinated monitoring providing the necessary data for regular assessment of the status of the Baltic Sea and of pressures and impacts affecting the status, adapted to support the assessing of progress towards the achievement of the environmental objectives and targets, using indicators developed under the Baltic Sea Action Plan, enabling the assessment and evaluation of the implementation of the jointly agreed measures;*

ALSO DECIDE, as a practical implementation of the above common principles:

- *that core set of indicators with quantitative targets shall be developed for each of the segments of the HELCOM Baltic Sea Action Plan, while ensuring that the indicators can also be used for the other international monitoring and reporting requirements inter alia the EU Marine Strategy Framework Directive, and that a full indicator-based follow-up system for the implementation of the HELCOM Baltic Sea Action Plan be further developed and placed on the HELCOM website by 2013;*[2]
- *that the already initiated revision of the HELCOM monitoring programmes be finalized by 2013 and that it results in cost-effective joint monitoring, which fully supports the indicator-based assessment approach and monitoring of the*

implementation of the HELCOM Baltic Sea Action Plan, and is in line with other international monitoring and reporting requirements."

The HELCOM TARGREV project on eutrophication target setting, CORE EUTRO process on core eutrophication indicators and assessment, the CORESET project on development of the first set of core indicators for biodiversity and hazardous substances, as well as the MORE project on monitoring revision have delivered the basic components of an operational regional monitoring and assessment system during 2010-2013. The components include an agreement on eutrophication status targets and core parameters that are to be addressed by indicators, the first set of core indicators for biodiversity and hazardous substances, as well as the revised Monitoring and Assessment Strategy underpinning the core indicators.

HELCOM Monitoring and Assessment Strategy endorsed by HELCOM HOD 41/2013 [and to be adopted by HELCOM 2013 Ministerial Meeting] is the basis for this project and the project will implement the Strategy.

Target

The target of this project is to make operational the production of regional assessments of eutrophication for the Baltic Sea.

The thematic assessment is planned to be a pilot to test a new cost-efficient approach to produce a HELCOM regional assessment which also takes into account the spatial and temporal scales needed for national assessment and reporting under other international obligations. Specifically, the project will produce regionally coordinated assessment products for the HELCOM Baltic Sea Action Plan and for those Contracting Parties being also EU Member States for reporting under the Marine Strategy Framework Directive.

There are developments within European frameworks to establish a mechanism for data management and assessments and that the European Environment Agency (EEA) and ICES have expressed interest in cooperating in the proposed eutrophication activity, with the view that it will contribute also to these greater development objectives.

The project also aims to develop the work process to increase the confidence and quality of the whole assessment chain.

Activities

1. Defining assessment methods (WP1)

    a. Eutrophication core indicators and indicator reports

        i. Description of parameters and data used for the set of core eutrophication indicators;
        ii. Development of a manual for monitoring of each core indicator, including QA/QC requirements and procedures.

    b. Aggregation of data for core indicators

        i. Identification of data aggregation products needed for regular updating of indicators;
        ii. Scrutiny and specification of methods and scripts for modelling (e.g. spatial, seasonal and long-term aspects) for data aggregation; and
        iii. Development of a manual for data aggregation for core eutrophication indicators, including a description for making graphs and maps of single indicator reports.

    c. HELCOM eutrophication assessment tool HEAT

i. Further scrutinising of specifics of the HEAT tool, e.g. class boundaries, use of indicators with linear and non-linear response under same criteria, etc.;
ii. Creating a user manual for HEAT 3.0.

d. Setting up the web-based eutrophication assessment report structure and functioning

i. Defining the data products needed for MSFD reporting by the Contracting Parties being also EU Member States, taking into account the outcomes form Working Groups on Good environmental status (WG GES) and Data, Information and Knowledge (WG DIKE), as well as developments with regard to Marine-WISE, including their spatial and temporal scales;
ii. Defining the web-page structure (cf. existing integrated eutrophication assessment web page and core indicator reports);
iii. Defining and making operational the interactive parts of the indicator reports and linkages to HELCOM GIS systems (cf. HELCOM Map and Data Service).

2. Setting up the data streams and a process for operationalizing the assessment system (WP2)

a. Setting up data streams for continuous/regular updating of the Baltic Sea pool of eutrophication data

i. e.g. continuation of reporting by the Contracting Parties to ICES or starting a process towards the use of distributed databases (Marine WISE).

b. HELCOM and ICES cooperation

i. Defining the roles of the institutions and setting up the necessary agreements to ensure a longer term practice.

c. HELCOM Eutrophication Expert Group (HELCOM EUTRO EG) to ensure HELCOM ownership

i. Setting up a process for regular review of the data and assessment products;
ii. Responsibility for QA/QC guidance of the full eutrophication assessment process from monitoring to assessment products;
iii. Identifying relevant institutes from the Contracting Parties, creating Terms of Reference for HELCOM EUTRO EG and agreement on the Group with ToR.

3. Development work for eutrophication assessment (WP3)

a. Eutrophication targets

i. Setting up a process for the regular review of the agreed targets to take account of e.g. new scientific knowledge;
ii. Development of GES targets for new core indicators (see below).

b. New Core indicators for eutrophication

i. Development of a core indicator for e.g. benthic invertebrates, phytoplankton, phytobenthos and coastal seasonal hypoxia based on indicator development carried out nationally or in international projects.

c. Work towards coordination of harmonisation of coastal and open sea assessments

i. Evaluation and development of proposals for further development of methods used for eutrophication assessment in the coastal zone (inter alia WFD indicators) as well as open sea (Baltic Sea Action Plan and Marine Strategy Framework Directive).

6. Expected results

The project will make operational regional assessments of eutrophication for the Baltic Sea. It will set up the coordination and cooperation between HELCOM and ICES to define and streamline the full process that leads from data to assessment products. Operationalization will encompass development of a system within which data from the Contracting Parties will be channeled to a common data pool, used for predefined data aggregation, production of core eutrophication indicator reports and finally eutrophication assessments for the Baltic Sea.

The project will update the HELCOM core set of eutrophication indicators and suggestion on indicator weighing.

The data products, i.e. core indicator reports and eutrophication assessments for the Baltic Sea will be designed so as to serve the follow-up of the implementation of the HELCOM Baltic Sea Action Plan, and for those Contracting Parties being also EU Member States, the reporting needs for the Marine Strategy Framework Directive, especially Qualitative Descriptor 5 for good environmental status. HELCOM Map and Data service will be developed to fully support the production of assessment products also needed by the CPs for their national reporting purposes, as well as to allow access to the data behind them.

HELCOM EUTRO-OPER will be a pilot project for setting up a full assessment system leading to regular holistic assessments and a functional GIS-based HELCOM data and information service linked to them. The project will also produce regionally coordinated assessment products for the HELCOM Baltic Sea Action Plan and for those Contracting Parties being also EU Member States also for reporting under the Marine Strategy Framework Directive. In this way the project will develop an assessment process which will minimise double-work to produce Baltic-wide and national assessment products and guarantee the regionally coordinated approach assessing the state of the Baltic Sea.

7. Consistency with HELCOM priorities _X_ yes ___ no

8. Timetable

The project duration will be from beginning of 2014 to the end of 2015.

A more detailed timetable will be created by the project members in cooperation with the possible project partners (e.g. ICES).

ANNEX 2A: Detailed results of comparing assessment tools

Detailed results from comparing WFD, HEAT 1.0 and HEAT 3.0 in coastal areas

Table ANNEX_2A.1. Assessment results from national WFD compared with HEAT 1.0 and HEAT 3.0. QE1-QE4 refers to the WFD quality elements; QE1-Plankton, QE2-Makrophytes, QE3-Bottomfauna and QE4-Physical-Chemical parameters. C1-C3 refers to the MSFD criteria; C1-Nutrient levels, C2-Direct effects and C3-Indirect effects. Status is presented as color according to the top color bar for each indicator sub group and per water body. Right column includes comments about data, result etc.

Country	Assessment			
Water type/ water body	National WFD	HEAT 1.0	HEAT 3.0	Comment
ESTONIA				
EST 005	National *	1.0	3.0	One coastal unit were tested, EST 005 in the Gulf of Finland. The national assessment was made with (*) and without inter calibrated class boundaries that resulted in different national WFD results. The relative large difference in class boundary setting between the WFD and the HEAT assessment is probably the main reason for the difference in status; HEAT 1.0 gives a bad status compared to the national WFD. For example, the moderate status class is much larger in the WFD, 0.67–0.33, than in HEAT 1.0 where it is 0.67-0.53.
	QE1	QE1	C1	
	QE2	QE2	C2	
	QE3	QE3	C3	
	QE4	QE4		
FINLAND				
Outer coastal waters of the Bothnian Bay				
6 Pu 001	National	1.0	3.0	Acceptable deviation for the HEAT assessment was not in the information sheet provided and therefore calculated from the EQR boundary values.
	QE1	QE1	C1	
	QE2	QE2	C2	
	QE3	QE3	C3	
	QE4	QE4		HEAT status assessment for Finnish coastal waters is mostly lower than the WFD assessment.
5 Pu 001	National	1.0	3.0	The main reason is the expert judgment of the supportive element, QE4. For some water bodies, the overall status is set to good even if the biological indicators are moderate. This gives in four cases the effect that status is changed to sub-GES from GES when HEAT is applied.
	QE1	QE1	C1	
	QE2	QE2	C2	
	QE3	QE3	C3	
	QE4	QE4		E.g **6Pu 001**: biological elements are overruled by supporting elements based on information on water
4 Pu 010	National	1.0	3.0	quality and pressures, Swedish classification results has also been taken into account.
	QE1	QE1	C1	
	QE2	QE2	C2	
	QE3	QE3	C3	
	QE4	QE4		
4 Pu 040	National	1.0	3.0	
	QE1	QE1	C1	
	QE2	QE2	C2	
	QE3	QE3	C3	
	QE4	QE4		
4 Pu 050	National	1.0	3.0	
	QE1	QE1	C1	

	QE2	QE2	C2		
	QE3	QE3	C3		
	QE4	QE4			
Quark					
3 Mu 110	National	1.0	3.0		
	QE1	QE1	C1		
	QE2	QE2	C2		
	QE3	QE3	C3		
	QE4	QE4			
Archipelago & western GoF					
3 Lu 030	National	1.0	3.0		
	QE1	QE1	C1		
	QE2	QE2	C2		
	QE3	QE3	C3		
	QE4	QE4			
3 Lu 050	National	1.0	3.0		
	QE1	QE1	C1		
	QE2	QE2	C2		
	QE3	QE3	C3		
	QE4	QE4			
3 Lu 070	National	1.0	3.0		
	QE1	QE1	C1		
	QE2	QE2	C2		
	QE3	QE3	C3		
	QE4	QE4			
2 Lu 020	National	1.0	3.0		National vs HEAT 1.0: Large difference because of difference in EQR for parameters. National EQR ≠ Ref/status, which is how it is calculated in HEAT 1.0.
	QE1	QE1	C1		
	QE2	QE2	C2		
	QE3	QE3	C3		
	QE4	QE4			
LATVIA					
LAT001	National	1.0	3.0		No overall or sub-group specified status classification for the WFD was in the information sheet provided, and therefore the test only included the comparison between the HEAT tools that showed equal results. Each parameter is assessed as; Chl-bad, biovolume-moderate, DIN-bad, DIP-moderate and Secchi-moderate.
	QE1	QE1	C1		
	QE2	QE2	C2		
	QE3	QE3	C3		
	QE4	QE4			
POLAND					
Gdańsk Basin (SEA - 009)					
1. Vistula Lagoon (PL TW I WB 1)	National	1.0	3.0*	3.0**	The national overall WFD assessment was not given and the test therefore only includes the comparison between HEAT tools. The test in HEAT 3.0 included assessment with target* vs. assessment with RefCon and AcDev**. From the classification schemes provided: chl: M, Secchi:M.
	QE1	QE1	C1	C1	
	QE2	QE2	C2	C2	
	QE3	QE3	C3	C3	
	QE4	QE4			
2.Puck Lagoon (PL TW II WB 2)	National	1.0	3.0*	3.0**	For the HEAT 1.0 test max Acdev = 53% (76% reported) for Secchi. WFD; From the classification schemes provided: chl: B, Secchi:B.
	QE1	QE1	C1	C1	
	QE2	QE2	C2	C2	
	QE3	QE3	C3	C3	

	QE4	QE4			
3.internal Gulf of Gdańsk (PL TW IV WB 4)	National	1.0	3.0*	3.0**	WFD; From the classification schemes provided: chl: M, Secchi:G, DIN:H, DIP:H. Of the three water bodies two got one class lower when target was used and two were the same. There were no major different between HEAT 1.0 and HEAT 3.0 in this test.
	QE1	QE1	C1	C1	
	QE2	QE2	C2	C2	
	QE3	QE3	C3	C3	
	QE4	QE4			

SWEDEN				
A) Water type 7: Arkona - Hanö Bukt				
1 V.Hanöbuktens kustvatten	National	1.0	3.0	National poor status based on expert judgment such as reports from fishermen. BQI have a national AcDev=71% but this is changed to 53% in HEAT 1.0 because of the tool's limitations.
	QE1	QE1	C1	
	QE2	QE2	C2	
	QE3	QE3	C3	
	QE4	QE4		
3 Valjeviken	National	1.0	3.0	Expert judgment due to high uncertainties in satellite data for chlorophyll.
	QE1	QE1	C1	
	QE2	QE2	C2	
	QE3	QE3	C3	
	QE4	QE4		
4 Tostebergabukt.	National	1.0	3.0	National poor status based on expert judgment such as reports from fishermen.
	QE1	QE1	C1	
	QE2	QE2	C2	
	QE3	QE3	C3	
	QE4	QE4		
5 Landöbukten	National	1.0	3.0	National poor status based on expert judgment such as reports from fishermen.
	QE1	QE1	C1	
	QE2	QE2	C2	
	QE3	QE3	C3	
	QE4	QE4		
6 Sandhammaren-Simrishamn	National	1.0	3.0	
	QE1	QE1	C1	
	QE2	QE2	C2	
	QE3	QE3	C3	
	QE4	QE4		
7 Östra Sydkustens kustvatten	National	1.0	3.0	
	QE1	QE1	C1	
	QE2	QE2	C2	
	QE3	QE3	C3	
	QE4	QE4		
8 Västra sydkustens kustvatten	National	1.0	3.0	WFD status is moderate even if biological QE has status high. This is based on nutrients that have moderate status.
	QE1	QE1	C1	
	QE2	QE2	C2	
	QE3	QE3	C3	
	QE4	QE4		
9 Södra Öresunds kustvatten	National	1.0	3.0	WFD status is moderate even if biological QE has status good. This is based on nutrients that have moderate status since the biological QE are assessed from expert judgment.
	QE1	QE1	C1	
	QE2	QE2	C2	
	QE3	QE3	C3	
	QE4	QE4		

10 Höllviken	National	1.0	3.0	WFD status is moderate even if biological QE has status good. This is based on nutrients that have moderate status since the biological QE are assessed from very little data.
	QE1	QE1	C1	
	QE2	QE2	C2	
	QE3	QE3	C3	
	QE4	QE4		
B) Water type 23: Outer Bothnian Bay				
1 Knivskärsfj.	National	1.0	3.0	2013. EQR but no status value are found and therefore is status calculated from EQR (to use in HEAT). AcDev for Secchi set to 53% in HEAT 1.0 (56%).
	QE1	QE1	C1	
	QE2	QE2	C2	
	QE3	QE3	C3	Biological QE are overruled by the supporting factors. This is because of few in situ data. Satellite and model data are used instead.
	QE4	QE4		
2 Hamnskärsfj.	National	1.0	3.0	2013. EQR but no status value are found and therefore is status calculated from EQR (to use in HEAT). AcDev for Secchi set to 53% in HEAT 1.0 (56%).
	QE1	QE1	C1	
	QE2	QE2	C2	
	QE3	QE3	C3	Expert judgment because of few in situ data. Satellite and model data are used instead.
	QE4	QE4		
3 Enskärsfj.	National	1.0	3.0	2013. EQR but no status value are found and therefore is status calculated from EQR (to use in HEAT). AcDev for Secchi set to 53% in HEAT 1.0 (56%).
	QE1	QE1	C1	
	QE2	QE2	C2	
	QE3	QE3	C3	Biological QE are overruled by the supporting factors. This is because of few in situ data. Satellite and model data are used instead.
	QE4	QE4		
4 S Seskaröfj.	National	1.0	3.0	2013. EQR but no status value are found and therefore is status calculated from EQR (to use in HEAT). AcDev for Secchi set to 53% in HEAT 1.0 (56%).
	QE1	QE1	C1	
	QE2	QE2	C2	
	QE3	QE3	C3	Biological QE are overruled by the supporting factors. This is because of few in situ data. Satellite and model data are used instead.
	QE4	QE4		
5 Norrbotten	National	1.0	3.0	2013. . EQR but no status value are found and therefore is status calculated from EQR (to use in HEAT). AcDev for Secchi set to 53% in HEAT 1.0 (56%).
	QE1	QE1	C1	
	QE2	QE2	C2	
	QE3	QE3	C3	Chlorophyll is based on satellite data and has high uncertainty.
	QE4	QE4		
6 M Bottenviken	National	1.0	3.0	2013. AcDev for Secchi set to 53% in HEAT 1.0 (56%). AcDev for biovolume set to 110% in HEAT 1.0 (163%).
	QE1	QE1	C1	
	QE2	QE2	C2	
	QE3	QE3	C3	
	QE4	QE4		
8 S Bottenviken	National	1.0	3.0	2013. Status in HEAT is calculated from EQR. AcDev for Secchi depth set to 53% in HEAT 1.0 (56%).
	QE1	QE1	C1	
	QE2	QE2	C2	
	QE3	QE3	C3	
	QE4	QE4		
C) Water type 4: Kattegat				
4 Onsala kustvatten	National	1.0	3.0	2013. Good status in HEAT 1 if not oxygen is included
	QE1	QE1	C1	
	QE2	QE2	C2	
	QE3	QE3	C3	
	QE4	QE4		

5 N m Hallands kustvatten	National	1.0	3.0	2013. Good status in HEAT 1 if not oxygen is included
	QE1	QE1	C1	
	QE2	QE2	C2	
	QE3	QE3	C3	
	QE4	QE4		

ANNEX 2B: Testing assessment tools in Swedish coastal areas

High	Good	Moderate	Poor	Bad

Testsites from Sweden and information of class boundaries

National data used in the test is from VISS (http://www.viss.lansstyrelsen.se/) and SMHI.

Table ANNEX_2B.1. Water type 7: Skånes kustvatten Arkona - Hanö Bukt. Class boundaries: EQR (WFD, HEAT1.0), EUT_ratios (HEAT3.0) with parameter values. Nutrients have a salinity relationship and here is an example of salinity > 7 presented.																	
WFD Cat.	MSFD Crit.	Indicator	AcDev % Resp. +/-	National WFD					HEAT 1.0				HEAT 3.0				
				R	H/G	G/M	M/P	P/B	H/G	G/M	M/P	P/B	H/G	G/M	M/P	P/B
1	2	Chl-a (VI-VIII)	50 (+)	1	0,8	0,67	0,35	0,15	0,8	0,67	0,53	0,38	0,5	1,0	1,5	>2,0
		µgL^{-1}		1,2	1,5	1,8	3,4	8,0	1.5	1.8	2.26	3.15	0,9	1,8	2,7	>3,6
1	2	Biovolume (VI-VIII)	79 (+)	1	0,72	0,56	0,24	0,08	0,75	0,56	0,36	0,17	0,5	1,0	1,5	>2,0
		mm^{3}L^{-1}		0,18	0,25	0,32	0,74	2,26	0.24	0.32	0.5	1.05	0,16	0,32	0,48	>0,64
2	2	Macroveg.	40 (-)	1	0,80	0,60	0,40	0,21	0,78	0,6	0,43	0,25	0,5	1,0	1,5	>2,0
		points		5	4	3	2	1	3,9	3	2,15	1,25	6	3	2	<1,5
3	3	BQI	71 (-) *	1	0,76	0,29	0,19	0,10	0,71	0,47	0,23	0,01	0,5	1,0	1,5	>2,0
				14	10,7	4,06	2,7	1,3	9,94	6,58	3.22	0.14	8,12	4,06	2,71	<2,03
4	1	DIN (XII,I,II)	50 (+)	1	0,80	0,67	0,45	0,29	0,81	0,67	0,53	0,38	0,5	1,0	1,5	>2,0
		µmolL^{-1}		2,5	3,1	3,8	5,6	8,8	3,1	3,8	4,7	6,58	1,9	3,8	5,7	>7,6
4	1	DIP (XII,I,II)	52 (+)	1	0,81	0,66	0,45	0,29	0,80	0,66	0,51	0,37	0,5	1,0	1,5	>2,0
		µmolL^{-1}		0,25	0,31	0,38	0,56	0,88	0,31	0,38	0,49	0,68	0,19	0,38	0,57	>0,76
4	1	TN (XII,I,II)	19 (+)	1	0,91	0,84	0,67	0,50	0,90	0,84	0,79	0,73	0,5	1,0	1,5	>2,0
		µmolL^{-1}		17	19	20	26	34	19	20	21,52	23,29	8,5	20	25,5	>34
4	1	TP (XII,I,II)	45 (+)	1	0,82	0,69	0,47	0,31	0,82	0,69	0,56	0,43	0,5	1,0	1,5	>2,0
		µmolL^{-1}		0,5	0,61	0,72	1,05	1,6	0,61	0,72	0,89	1,16	0,36	0,72	1,08	>1,44
4	1	TN (VI-VIII)	30 (+)	1	0,86	0,77	0,55	0,38	0,86	0,77	0,68	0,59	0,5	1,0	1,5	>2,0
		µmolL^{-1}		15	17	19	27	39	17	19	22	25	7,5	19	22,5	>30
4	1	TP (VI-VIII)	35 (+)	1	0,85	0,74	0,53	0,36	0,85	0,74	0,64	0,53	0,5	1,0	1,5	>2,0
		µmolL^{-1}		0,3	0,35	0,41	0,56	0,83	0,35	0,41	0,47	0,56	0,21	0,41	0,62	>0,82
4	2	Secchi (VI-VIII)	30 (-)	1	0,83	0,70	0,40	0,20	0,83	0,7	0,58	0,45	0,5	1,0	1,5	>2,0
		m		10	8,3	7,0	4,0	2,0	8,3	7,0	5,8	4,5	14	7	4,7	<3,5
4	3	Oxygen		-	-	-	-	-	-	-	-	-	-	-	-	-
		mlL^{-1}		-	-	-	-	-	-	-	-	-	-	-	-	-

*Max AcDev in HEAT 1.0 for indicators with positive response is 110% and for negative response 53%.

Water Type 23

Outer Bothnian Bay

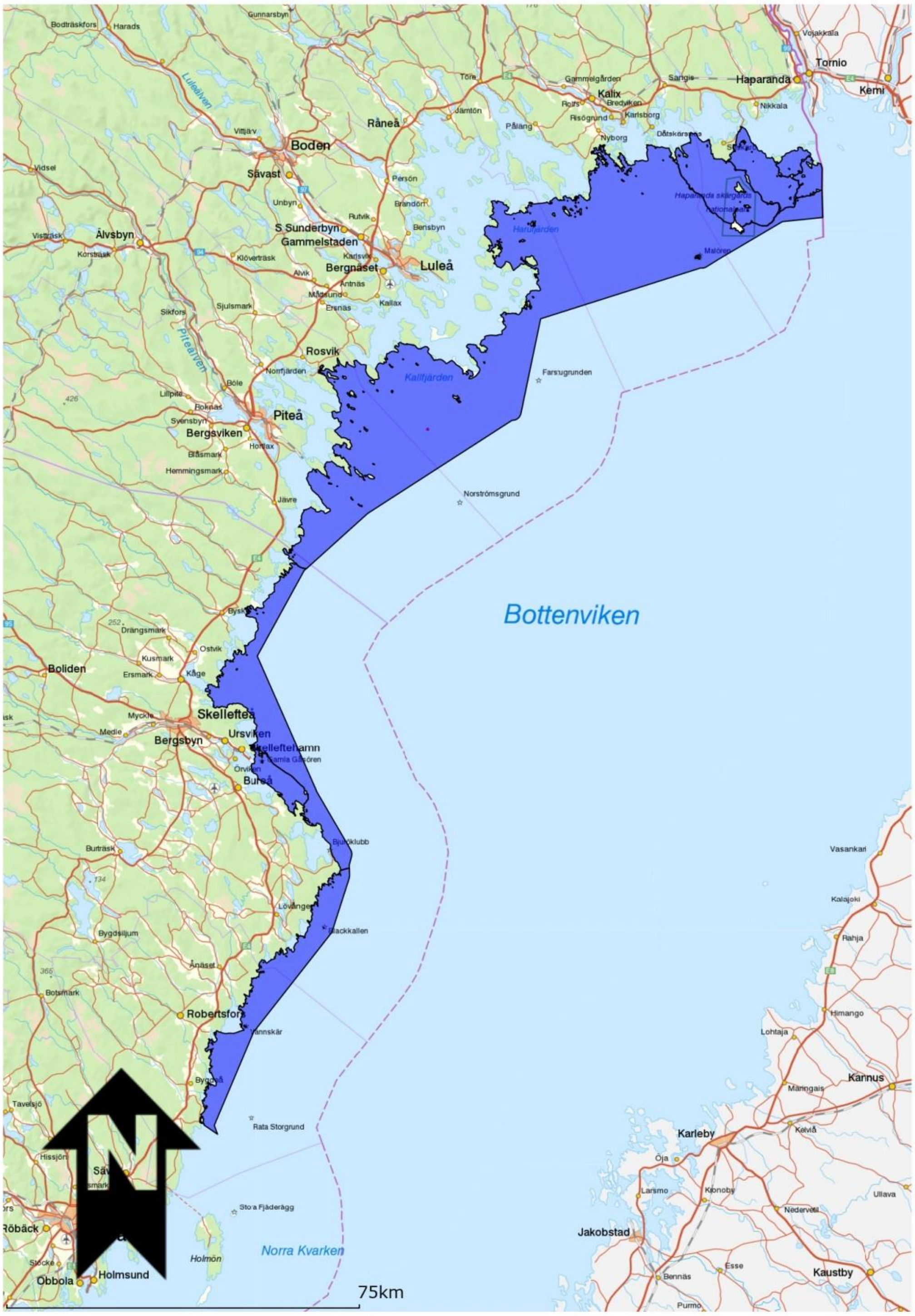


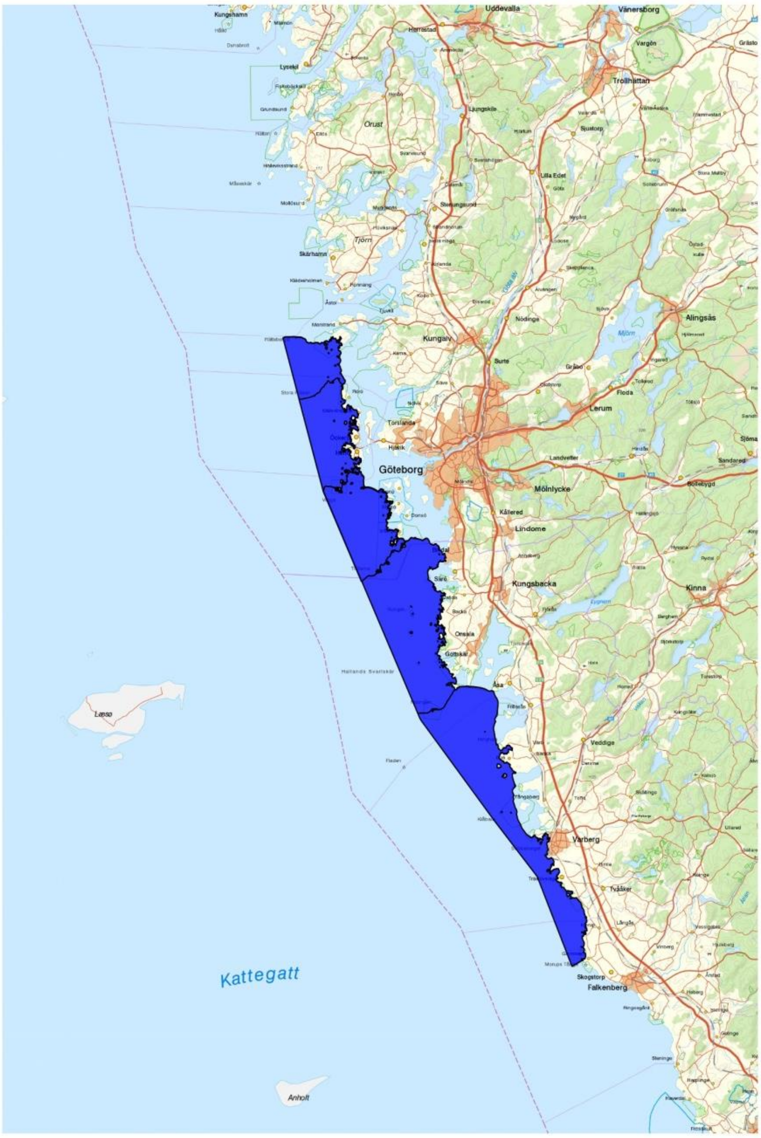
Table ANNEX_2B.2. Water type 23: Bothnian outer bay. Class boundaries: EQR (WFD, HEAT1.0), EUT_ratios (HEAT3.0) with parameter values.
Nutrients have a salinity relationship and here is an example of salinity > 3 presented.

WFD Cat.	MSFD Crit.	Indicator	AcDev % Resp. +/-	National WFD					HEAT 1.0				HEAT 3.0			
				R	H/G	G/M	M/P	P/B	H/G	G/M	M/P	P/B	H/G	G/M	M/P	P/B
1	2	Chl-a (VI-VIII)	82 (+)	1	0,73	0,55	0,30	0,13	0,75	0,55	0,35	0,15	0,5	1,0	1,5	>2,0
		µgL^{-1}		1,1	1,5	2,0	3,7	8,7	1.5	2,0	3,14	7,33	1	2,0	3	>4
1	2	Biovolume (VI-VIII)	163 (+)*	1	0,56	0,38	0,2	0,07	0,71	0,48	0,24	0,01	0,5	1,0	1,5	>2,0
		mm^{3}L^{-1}		0,15	0,27	0,4	0,74	2,26	0.21	0.32	0.63	15	0,2	0,4	0,6	>0,8
2	2	Macroveg.	40 (-)	1	0,80	0,60	0,40	0,21	0,78	0,6	0,43	0,25	0,5	1,0	1,5	>2,0
		points		5	4	3	2	1	3,9	3	2,15	1,25	6	3	2	<1,5
3	3	BQI	86 (-) *	1	0,57	0,14	0,09	0,05	0,71	0,47	0,23	0,01	0,5	1,0	1,5	>2,0
				11	6,3	1,5	1,0	0,5	7,81	5,17	2,53	0.11	3	1,5	1	<0,75
4	1	DIN (XII,I,II)	50 (+)	1	0,8	0,67	0,44	0,29	0,81	0,67	0,53	0,38	0,5	1,0	1,5	>2,0
		µmolL^{-1}		5	6,3	7,5	11,3	17,5	6,2	7,5	9,4	13,2	3,75	7,5	11,25	>15
4	1	DIP (XII,I,II)	50 (+)	1	0,8	0,67	0,44	0,29	0,81	0,67	0,53	0,38	0,5	1,0	1,5	>2,0
		µmolL^{-1}		0,10	0,13	0,15	0,23	0,35	0,12	0,15	0,19	0,27	0,08	0,15	0,225	>0,3
4	1	TN (XII,I,II)	18 (+)	1	0,93	0,85	0,68	0,51	0,90	0,85	0,80	0,74	0,5	1,0	1,5	>2,0
		µmolL^{-1}		18	20	22	27	36	20	22	22,5	24,32	11	22	33	>44
4	1	TP (XII,I,II)	56 (+)	1	0,78	0,64	0,42	0,26	0,80	0,64	0,49	0,33	0,5	1,0	1,5	>2,0
		µmolL^{-1}		0,2	0,26	0,31	0,48	0,76	0,25	0,31	0,41	0,61	0,16	0,31	0,46	>0,62
4	1	TN (VI-VIII)	32 (+)	1	0,83	0,69	0,47	0,31	0,85	0,76	0,66	0,57	0,5	1,0	1,5	>2,0
		µmolL^{-1}		17	20	22	31	44	20	22,4	25,8	29,8	11,2	22,4	33,6	>44,8
4	1	TP (VI-VIII)	45 (+)	1	0,85	0,74	0,53	0,36	0,82	0,69	0,56	0,43	0,5	1,0	1,5	>2,0
		µmolL^{-1}		0,15	0,18	0,22	0,32	0,49	0,18	0,22	0,27	0,35	0,11	0,22	0,33	>0,44
4	2	Secchi (VI-VIII)	56 (-)*	1	0,67	0,44	0,29	0,20	0,71	0,47	0,23	0,01	0,5	1,0	1,5	>2,0
		m		7,5	5,0	3,3	2,2	1,5	5,3	3,5	1,72	0,075	6,6	3,3	2,2	<1,65
4	3	Oxygen		-	-	-	-	-	-	-	-	-	-	-	-	-
		mlL^{-1}		-	-	-	-	-	-	-	-	-	-	-	-	-

*Max AcDev in HEAT 1.0 for indicators with positive response is 110% and for negative response 53%. Maximum used in HEAT calculation

water type 4

kattegat



, RAÄ, SGU, Sjöfartsverket, SMHI, SVO, SCB, SJV, FM, Bergsstaten, SLU, DIRNAT Skala 1:1074174

Table ANNEX_2B.3. Water type 4: Kattegat. Class boundaries: EQR (WFD, HEAT1.0), EUT_ratios (HEAT3.0) with parameter values. Nutrients have a salinity relationship and here is an example of salinity > 20 presented.

WFD Cat.	MSFD Crit.	Indicator	AcDev % Resp. +/-	National WFD					HEAT 1.0				HEAT 3.0			
				R	H/G	G/M	M/P	P/B	H/G	G/M	M/P	P/B	H/G	G/M	M/P	P/B
1	2	Chl-a (VI-VIII)	50 (+)	1	0,83	0,67	0,33	0,17	0,81	0,67	0,53	0,38	0,5	1,0	1,5	>2,0
		μgL^{-1}		1	1,2	1,5	3,0	6,0	1,23	1,5	1,9	2,63	0,5	1,5	2,25	>3
1	2	Biovolume (VI-VIII)	122 (+)*	1	0,67	0,45	0,22	0,08	0,71	0,48	0,24	0,01	0,5	1,0	1,5	>2,0
		mm^3L^{-1}		0,5	0,75	1,1	2,25	6,1	0,7	1,04	2,08		0,55	1,1	1,65	>2,2
2	2	Macroveg.	40 (-)	1	0,80	0,60	0,40	0,21	0,78	0,6	0,43	0,25	0,5	1,0	1,5	>2,0
		points		5	4	3	2	1	3,9	3	2,15	1,25	6	3	2	<1,5
3	3	BQI	34 (-)	1	0,89	0,66	0,44	0,22	0,81	0,66	0,52	0,37	0,5	1,0	1,5	>2,0
		index		15,7	13,9	10,3	6,9	3,4	12,7	10,3	8,16	5,8	20,6	10,3	6,9	<5,2
4	1	DIN (XII,I,II)	50 (+)	1	0,8	0,67	0,44	0,29	0,81	0,67	0,53	0,38	0,5	1,0	1,5	>2,0
		$\mu molL^{-1}$		4,5	5,6	6,8	10,1	15,8	5,6	6,8	8,5	11,8	3,4	6,8	10,3	>13,6
4	1	DIP (XII,I,II)	47 (+)	1	0,81	0,68	0,45	0,29	0,82	0,68	0,55	0,41	0,5	1,0	1,5	>2,0
		$\mu molL^{-1}$		0,4	0,5	0,6	0,9	1,4	0,49	0,6	0,73	0,98	0,3	0,6	0,9	>1,2
4	1	TN (XII,I,II)	27 (+)	1	0,88	0,79	0,60	0,43	0,87	0,79	0,71	0,62	0,5	1,0	1,5	>2,0
		$\mu molL^{-1}$		17	19	22	28	40	19,5	22	23,9	27,4	11	22	33	>44
4	1	TP (XII,I,II)	28 (+)	1	0,87	0,78	0,58	0,41	0,87	0,78	0,70	0,61	0,5	1,0	1,5	>2,0
		$\mu molL^{-1}$		0,7	0,8	0,9	1,21	1,72	0,8	0,9	1	1,14	0,5	0,9	1,4	>1,8
4	1	TN (VI-VIII)	30 (+)	1	0,87	0,77	0,57	0,40	0,86	0,77	0,68	0,59	0,5	1,0	1,5	>2,0
		$\mu molL^{-1}$		12	14	16	21	30	14	16	17,6	20,33	8	16	24	>32
4	1	TP (VI-VIII)	41 (+)	1	0,83	0,71	0,50	0,33	0,83	0,71	0,59	0,47	0,5	1,0	1,5	>2,0
		$\mu molL^{-1}$		0,4	0,48	0,56	0,8	1,2	0,48	0,56	0,68	0,85	0,28	0,56	0,84	>1,12
4	2	Secchi (VI-VIII)	24 (-)	1	0,90	0,76	0,48	0,33	0,86	0,76	0,67	0,57	0,5	1,0	1,5	>2,0
		m		10,5	9,5	8,0	5,0	3,5	9	8	7	6,0	16	8	5,33	<4
4	3	Oxygen		-	-	-	-	-	-	-	-	-	-	-	-	-
		mlL^{-1}		-	-	-	-	-	-	-	-	-	-	-	-	-

*Max AcDev in HEAT 1.0 for indicators with positive response is 110% and for negative response 53%. Maximum used in HEAT calculation

ANNEX 4A: Results from validation of EO-data

Before using EO chl-a data for the interpretation of the chl-a concentrations on HELCOM assessment areas, their validity in comparison to the MS measurements was analyzed for the period of 2007 - 2011.

The comparison analysis between EO and ICES was made using 3x3 pixel median values of EO data around the monitoring station locations. Non-cloudy EO observations that occur on the same day as ICES measurements were included in comparison.

Table ANNEX_4A.1. Statistics of chlorophyll-a [µg/l] measured on monitoring stations (ST), and by EO using areal median, geometric and arithmetic mean and mode of EO observations. EO data represents the whole assessment area. All years for assessment period 2007-2011 are presented separately. Annual period: 1.6.-31.9. HELCOM assessment areas: SEA-007 - SEA-017.

Name	Born-holm Basin	Gdansk Basin	Eastern Gotland Basin	Western Gotland Basin	**Gulf of Riga**	Northern Baltic Proper	Gulf of Finland	Åland Sea	Bothnian Sea	The Quark	Bothnian Bay
ID	SEA-007	SEA-008	SEA-009	SEA-010	SEA-011	SEA-012	SEA-013	SEA-014	SEA-015	SEA-016	SEA-017
2007											
ST_{MED}	2,60	1,73	2,55	3,35	4,23	2,45	1,17	2,90	2,10		3,37
ST_{AMEAN}	**2,97**	**1,81**	**3,12**	**3,26**	**4,36**	**2,33**	**2,50**	**2,90**	**2,10**		**3,37**
EO_{AMEAN}	1,73	3,61	3,05	2,91	7,65	3,21	6,43	2,60	1,98	2,24	2,53
EO_{GMEAN}	**1,70**	**2,83**	**2,92**	**2,75**	**7,22**	**2,84**	**5,42**	**2,35**	**1,87**	**2,08**	**2,37**
EO_{MED}	1,61	2,70	3,11	2,84	7,58	2,94	5,85	2,47	1,91	2,13	2,38
EO_{MODE}	1,53	1,24	4,04	2,14	7,23	2,35	6,47	1,65	1,68	2,15	2,05
2008											
ST_{MED}	3,13	4,37	4,20	2,75		2,82	3,52	1,57	1,82		1,60
ST_{MEAN}	**3,61**	**4,14**	**4,35**	**2,99**		**3,18**	**3,78**	**1,57**	**1,82**		**1,61**
EO_{AMEAN}	3,64	6,50	4,11	3,99	5,11	3,87	5,26	2,71	2,49	2,38	2,50
EO_{GMEAN}	**3,62**	**6,03**	**3,71**	**3,64**	**4,87**	**3,51**	**4,54**	**2,49**	2,36	**2,21**	**2,33**
EO_{MED}	3,67	6,80	4,08	3,81	5,02	3,59	5,28	2,81	2,47	2,49	2,41
EO_{MODE}	3,14	3,48	3,92	3,83	5,88	4,67	6,98	2,81	2,34	2,58	2,94
2009											
ST_{MED}	2,60	3,51	2,90	2,75	1,01	2,66	3,07	2,48	3,28		1,51

ST_{MEAN}	**3,45**	**3,68**	**3,18**	**2,83**	**1,12**	**2,73**	**2,48**	**2,48**	**2,94**		**1,51**
EO_{AMEAN}	1,85	3,78	2,02	2,08	3,87	2,86	3,71	2,36	2,18	2,42	2,40
EO_{GMEAN}	**1,55**	**3,12**	**1,73**	**1,69**	**3,57**	**2,35**	**3,53**	**2,04**	**1,95**	**2,21**	**2,12**
EO_{MED}	1,56	2,84	2,06	2,16	3,83	2,77	3,72	2,50	2,16	2,39	2,36
EO_{MODE}	1,82	1,83	1,84	2,26	3,97	3,29	2,45	2,81	2,25	1,32	1,50
2010											
ST_{MED}	2,30	5,04	2,76	3,40	3,09	2,82	5,24	4,62	2,16		2,76
ST_{MEAN}	**4,65**	**6,19**	**3,06**	**3,24**	**3,41**	**3,07**	**5,17**	**4,62**	**2,39**		**2,76**
EO_{AMEAN}	1,67	6,21	2,59	2,36	4,91	2,84	3,82	2,48	2,16	2,60	2,50
EO_{GMEAN}	**1,50**	**4,82**	**2,45**	**2,22**	**4,57**	**2,53**	**3,44**	**2,31**	**1,99**	**2,32**	**2,29**
EO_{MED}	1,61	3,99	2,48	2,24	4,69	2,61	3,44	2,34	1,92	2,37	2,34
EO_{MODE}	1,65	3,07	2,09	1,93	4,42	2,76	2,69	2,07	2,46	1,37	1,37
2011											
ST_{MED}	2,78	3,71	2,40	1,50	0,95	2,74	1,02	3,58	3,22	2,34	2,49
ST_{MEAN}	**3,92**	**4,37**	**2,60**	**1,77**	**0,92**	**2,66**	**1,31**	**3,58**	**3,22**	**2,34**	**2,49**
EO_{AMEAN}	1,73	2,93	1,83	2,06	4,37	2,64	3,65	2,13	1,79	1,91	2,01
EO_{GMEAN}	**1,54**	**2,52**	**1,65**	**1,69**	**4,02**	**2,20**	**3,16**	**1,84**	**1,68**	**1,74**	**1,84**
EO_{MED}	1,51	2,22	1,62	1,53	4,27	2,01	3,00	1,85	1,74	1,88	1,76
EO_{MODE}	1,23	1,66	1,35	0,91	2,85	1,15	2,76	0,94	1,13	2,01	1,30
2007-2011											
ST_{MED}	2,77	3,70	2,90	2,70	3,03	2,72	2,91	2,90	2,52	2,34	2,30
ST_{MEAN}	**3,74**	**4,27**	**3,26**	**2,84**	**3,13**	**2,75**	**2,93**	**3,03**	**2,55**	**2,34**	**2,36**
EO_{AMEAN}	1,85	4,32	2,65	2,67	4,88	3,01	4,44	2,43	2,08	2,28	2,37
EO_{GMEAN}	**1,62**	**3,39**	**2,28**	**2,23**	**4,47**	**2,58**	**3,81**	**2,17**	**1,92**	**2,06**	**2,16**
EO_{MED}	1,60	3,23	2,42	2,41	4,69	2,67	3,86	2,37	1,96	2,11	2,19
EO_{MODE}	1,59	1,93	1,73	1,04	4,75	2,48	2,83	2,85	1,65	1,97	1,40

Methods to describe the data processing and matching of EO and monitoring station data

Examples of EO data comparisons with monitoring station data are given for the test period of 2007-2011. The image pixels that are covered by clouds or cloud shadows have been removed from each EO-image through a combined automatic and manual screening process, leaving a final product with only the pixels which have an undisturbed visibility to the satellite instrument.

Statistics for the HELCOM-area

The areal statistics for each HELCOM-area were computed from the clear pixels for each day for which an EO-image is available within the annual assessment period (1.6.-30.9.). The statistics comprise arithmetic and geometric means of EO-observation of all clear pixels, median and mode values, percentiles of the distribution (5..95 % in 5 % increments, and 2/98%).

Sampling the EO-observations to match the monitoring station measurements

To complement the areal statistics, sampling of EO-data at each monitoring station was computed. For each day within the annual assessment period, the EO-observations that match to each monitoring station were extracted, which produced a dataset of daily EO-observations for each measurement station.

To reduce the effect of the small noise present in EO-observations and to smooth out the spatial variability of chlorophyll-*a* nearby the measurement station a sampling algorithm was used. The windowed sampling algorithm finds the closest EO-observation pixel to match each monitoring station and extracts the EO-observations for the 3 x 3 pixel window centred at the monitoring station (spatial coverage 900 m x 900 m). The median value from the window was used to represent the EO-observation for the monitoring station. The 5/95% and 25/75% percentiles of the values from the 3 x 3 pixel window were used to estimate the confidence limits for the observation.

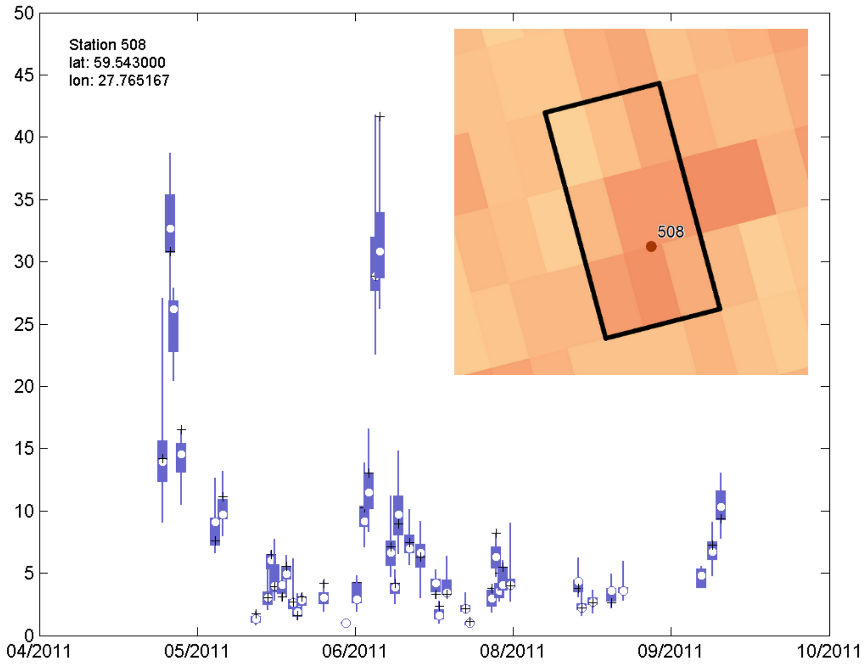


Figure ANNEX_4A.1. An example of the 3 x 3 pixel sampling window used to sample the EO-observations for monitoring station no. 508, and a graph of the produced samplings that represent the observations at that monitoring station. Each pixel has a spatial coverage of 300 m x 300 m (image is distorted due to the used map projection).

Sampled statistics of the EO-observations for the HELCOM-areas

The sampled EO-observations for each monitoring station were used to compute daily statistics for each HELCOM-area. For each day within the assessment period, the algorithm collects the monitoring stations that fall inside the particular HELCOM-area, and uses the sampled EO-observations to compute a representative statistics for the whole area (arithmetic and geometric mean, median and percentiles with 5% increments). The distribution of the sampled values is visualized by the 5/95% percentiles and 25/75% percentiles.

ANNEX 6A: Overview of shallow water bottom oxygen indicators.

Contracting Party	Method	Assessment period	coastal (< baseline + 1 nm)	shallow open (>basel. + 1 nm, but outside of deep basins)	deep basins	Classification system	Classification Method	GES-boundary	WFD	MSFD	BSAP	other national purpose	Remarks
Denmark	oxygen concentration in bottom water	July-November, 4 separate reports (July/Aug., Sept., Okt.,Nov.)	X	X	-	3 classes (>4 mg/l, 2-4 mg/l, 0-2 mg/l)	descriptive method without specific target	-				X	Reports produced by DMU/DCE, often including Swedish and German data http://naturstyrelsen.dk/vandmiljoe/havet/havmiljoe/iltsvind/
Denmark	oxygen concentration in bottom water	whole year	?	X	-	2 classes (GES/sub-GES)	Target must be met at any time or place	2 mg/l		X			Exception: target not valid for some fjords with naturally occurring hypoxia (see HOD 39, Doc. 2-7 Rev.1)
Estonia	none at the moment												Oxygen measurements and indicator development have recently been proposed to the Ministry, decision pending
Finland	no coastal oxygen indicator or assessment criteria in place												

Germany	oxygen concentration in bottom water	Aug.-Oct./Nov. with focus on Sept.	X	X	-	5 classes (>6 mg/l, 6->4 mg/l, 4->2 mg/l, 2->1 mg/l, 1 mg/l and less)	worst measurement result per station within the assessment period is used for classification	>6 mg/l				X	Method used in both parts of the German Baltic Sea. In Schleswig-Holstein waters, a special oxygen survey is carried out in September, covering more stations than those routinely investigated throughout the year. Target value may be too ambitious and is under discussion (Kiel Bay: >4 mg/l proposed as MSFD target) Reports may be found: https://www.schleswig-holstein.de/DE/Fachinhalte/M/meeresschutz/chemMonitoring.html
Germany	oxygen concentration in surface and bottom water	whole year	X		-	6 classes for each of the 9 parameters used	worst measurement result was used for classification; bottom oxygen only considered in stratified waters, classification system comprised 3 sets of criteria with a total of 9 parameters. Descriptive method without specific target	-				X	Formerly applied in Mecklenburg-Vorpommern waters to describe the trophic status (oligo- to hypertrophic) based on nutrient conditions, produc-tivity level, oxygen and organic matter, no longer in use. Note: o-PO4 not to be assessed in shallow areas (e.g. some inner coastal waters) with conserable interaction between P and sediment (sorption/desorption equilibrium)

Latvia	oxygen concentration in bottom water	?	(-)	X		3 classes (boundaries 4 and 2 mg/l)	descriptive method without specific target or formalized class boundaries	-				X	The term "coastal" probably needs some further consideration. It is so because we consider coastal up to 10-12 m depth. In this case there is no need for oxygen indicators because water is mostly well mixed and any oxygen consumption is balanced by water mixing. So if the whole Gulf of Riga can be looked on as "coastal" then we probably should start to think about oxygen indicators
Lithuania	no information available												
Poland	oxygen and hydrogen sulphide concentrations in offshore areas						descriptive method without specific target or formalized class boundaries	-				X	Until 2005 (WFD implementation) oxygen and H_2S-conditions only assessed in offshore-areas of Polish EEZ (deep basins/areas like Gdansk Deep, SE Gotland Basin, Bornholm Deep) and deep areas of Gulf of Gdansk)
Poland	oxygen concentration in bottom water of shallow areas	June-November	X	X		3 classes (>6.0 mg/l = high status, 6.0 - 4.2 mg/l = good status, <4.2 mg/l = no GES)	minimal oxygen concentration in assessment period is used for classification	4.2 mg/l (good status)	X	X			no class limits assigned for poor and bad status as it is very rare that the minimal oxygen concentration is <4.2 mg/l in coastal waters, infrequently it was measured in Vistula Lagoon and Szczecin Lagoon between 2000-2006. In the MSFD Initial Assessment transitional and coastal waters were classified this way.

Poland	oxygen concentrations in deep water areas	June-November			X	4 classes (good: >4.0 cm^3/dm^3 = 5.7 mg/l; moderate: 4.0-3.0 cm^3/dm^3 = 5.7-2.1 mg/l; poor: 3.0-2.0 cm^3/dm^3 = 2.1-1.4 mg/l; bad: <2.0 cm^3/dm^3 = <1.4 mg/l)	minimal oxygen concentration in assessment period is used for classification	>5.7 mg/l (= >4.0 cm^3/dm^3)					In the MSFD Initial Assessment the classification system for deep water areas was developed basing on concentrations expressed in cm^3/dm^3.
Sweden	Hypoxia testing and classification of oxygen conditions in coastal waters	whole year for checking type of hypoxia	X	?	-	5 classes (different class boundary values based on type of hypoxia prevailing in water body)	no hypoxia if station average Jan-Dec in the lower quartile of Boxplot exceeds the reference value of 3.5 ml/l. Water bodies with seasonal hypoxia: good status at <3,5 ml/l-2.1 ml/l. Perennial or permanent: water-body specific boundaries.	(target would be good status if used for WFD purposes)	?			?	Hypoxia in Swedish coastal waters has greatest distribution during growing season (Jun-Dec); while oxygen concentrations Jan-May reflect a form of background value. 4 types of hypoxia defined: No hypoxia, seasonal, perennial and permanent hypoxia. Details see main part of document
Sweden	oxygen consumption indicator			X	?								under development, needs waters with stable layer at abt. 30-50 m; see description in Doc. 5-1
Russia	no information available												

ANNEX 8A: Detailed results of test assessment

Scales

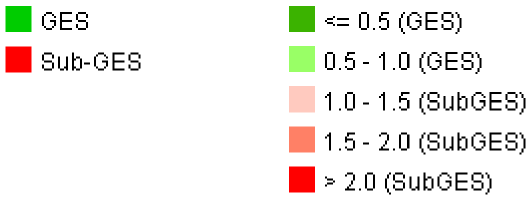


Figure 8A.1. Scales used in eutrophication maps: MSFD classification into GES / SubGES (left) and MSFD classification with 5 additional levels based on eutrophication ratio, indicating distance to GES (right).

Detailed review results (annex to chapter 8.3)

Table 8A.1. Description of exceptions found during review at data level, together with following actions.

Contracting party	Item to be checked at '*Stations*'-page for core indicator in question	Description of Exceptions	Reviewed by	Actions
EE	No observations missing	Most of the Estonian monitoring observations, besides open sea stations in February and June 2007, are missing. There are more data for 2007 and definitely there are data for years 2008-2012. The problem is that these data are not reported to the HELCOM-ICES database by data provider: Estonian Marine Institute. So far the reason for not updating the data have been due to the ICES data formats... The collected data for years 2008-2012 are available in the EIONET database – could ICES download the data and include these to the ICES database by themselves?	Inga Lips	Estonia will report the data, and it will be included into the assessment if reported by 12 Dec
PL	No observations missing	67BC, Eastern Gotland Basin, 2007	Elzbieta Łysiak-Pastuszak	Poland will contact ICES, with the aim of including the data to the test
DE	No observations missing	DE was only able to check the national database but since data are reported from there to ICES we assume that gaps in the national database will be the same as in ICES. For the period 2007 to 2011 there are large gaps in the national database concerning DIN, DIP, TN, TP, Chla, Secchi and oxygen. Data are in particular missing from IOW and LUNG, LLUR data seem to be complete. Given these large gaps the further steps in testing cannot be carried out.	Wera Leujak	There is currently no process foreseen to fill the datagaps. DE will focus resources on the upcoming HOLAS II assessment and the period 2011-2016 and will aim at reporting all relevant eutropication data to ICES for that period.

Table 8A.2. Description of exceptions found during review at indicator level for coastal assessment, together with following actions.

Contracting party	Item to be checked at '*Indicators*'-page for core indicator in question	Description of Exceptions	Reviewed by	Actions
EE	All coastal units are represented and assigned with the indicators relevant for them	Phytoplankton biomass 6-9: EST_8 and EST_9 do not have enough data for the period 2007-2012 - according to the map these areas are coloured.	Inga Lips	In the basins where no value for 2007-2012 was provided, the period 2001-2006 was used. No changes made.
EE	Accuracy of ES value: for all indicators, all relevant coastal units	TN 6-9: EST_014 should not have value as there aren't enough data for period 2007-2012, the value used at the present is for period 2001-2006 TP 6-9: EST_014 should not have value as there aren't enough data for period 2007-2012, the value used at the present is for period 2001-2006 Phyto BM 6-9: EST_003, EST_008 and EST_009 should not have values as there aren't enough data for period 2007-2012, the values used at the present are for period 2001-2006	Inga Lips	In the basins where no value for 2007-2012 was provided, the period 2001-2006 was used. No changes made.
EE	Accuracy of ER calculation: for all indicators, all relevant coastal units	TN 6-9: EST_014 should not have value as there aren't enough data for ES value for period 2007-2012, the value used at the resent is for period 2001-2006 TP 6-9: EST_014 should not have value as there aren't enough data for ES value for period 2007-2012, the value used at the present is for period 2001-2006	Inga Lips	In the basins where no value for 2007-2012 was provided, the period 2001-2006 was used. No changes made.
SE	All coastal units are represented and assigned with the indicators relevant for them	TP winter is missing for water type 12n	Karin Wesslander	Has been corrected trilaterally between ICES-SWE-Secretariat
SE	Accuracy of ES value: for all indicators, all relevant coastal units	I think this is wrong. It looks like the calculated ER values, the mean values Vivi calculated from the data I sent. I have sent you status expressed as EQR from the mid of the nationally reported status class which I think should be in this column instead.	Karin Wesslander	Corrected by ICES according to new ER values provided by SE.
SE	Accuracy of ER calculation: for all indicators, all relevant coastal units	If ES is wrong than ER is wrong too. I think ER should be what ES is now.	Karin Wesslander	Corrected by ICES according to new ER values provided by SE.
DE	All coastal units are represented and assigned with the indicators relevant for them	Some water bodies in the coastal waters of Schleswig-Holstein have been wrongly numbered; this concerns GER 21-26, GER 27 and 28, GER 30-36 and GER 38-41; the corrected information can be found in the re-submitted excel file	Wera Leujak	ICES has corrected the numbering according to re-submitted file
DE	All indicators are represented and assigned with ES, ET and ER in the relevant assessment units	Indicator Chlorophyll a is missing although DE provided data in the questionnaire; indicator Secchi is still lacking targets but these will be provided; indicator oxygen lacks status and targets - indicator is still under national revision and data can only be provided at a later stage; indicators macrophytes and macrozoobenthos lack data and targets from LLUR (Schleswig-Holstein) but these can be provided	Wera Leujak	ICES has corrected the missing information on chla and secchi according to re-submitted file; corretions on oxygen, macrophytes and macrozoobenthos will be corrected once the data is submitted by DE
DE	Accuracy of ES value: for all indicators, all relevant coastal units	For macrophytes and macrozoobenthos ES has been wrongly calculated; excel file with corrected calculations will be submitted; for Secchi there was a mistake in the targets provided by DE and an excel-file with new targets will be submitted that now contaisn target values for all WFD water bodies	Wera Leujak	DE has submitted new calculated values and ICES has corrected them accordingly.
DE	Accuracy of ET value: for all indicators, all relevant coastal units	For Secchi depth the provided targets will be updated by submitting a revised excel file	Wera Leujak	ICES has corrected Secchi depth targets according to resubmitted file.
DE	Accuracy of ER calculation: for all indicators, all relevant coastal units	Calculation of ER for macrophytes and macrozoobenthos is wrong; it cannot be done by dividing ES by ET because ES is not the status value but the calculated EQR of the WFD complex macrophyte/macrozoobethos index; Swedish formula needs to be applied also to enable aggregation of these parameters in the HEAT assessment	Wera Leujak	DE has submitted new calculated values and ICES has corrected them accordingly.

Table 8A.3. Description of exceptions found during review at assessment level for coastal assessment, together with following actions.

Contracting party	Item to be checked at '*Assessment*'-page	Description of Exceptions	Reviewed by	Actions
EE	Accuracy of N value	EST_003: Direct effects should have 3 indicators – there aren't enough data of phytoplankton BM for the period 2007-2012 . EST_008: Direct effects should be 3 indicators – there aren't enough data of phytoplankton BM for the period 2007-2012. EST_009: Direct effects should be 3 indicators – there aren't enough data of phytoplankton BM for the period 2007-2012. EST_014: Nutrient levels shouldn't have indicators (for TN and TP there aren't enough data for the period 2007-2012).	Inga Lips	In the basins where no value for 2007-2012 was provided, the period 2001-2006 was used. No changes made.
EE	Accuracy of ER value	EST_003: Direct effects ER value should be 1,23 as Direct effects should have 3 indicators – there aren't enough data of phytoplankton BM for the period 2007-2012 . EST_008: Direct effects ER value should be 2,34 as Direct effects should have 3 indicators – there aren't enough data of phytoplankton BM for the period 2007-2012. EST_009: Direct effects ER value should be 2,45 as Direct effects should have 3 indicators – there aren't enough data of phytoplankton BM for the period 2007-2012.	Inga Lips	In the basins where no value for 2007-2012 was provided, the period 2001-2006 was used. No changes made.
EE	Accuracy of Status value	EST_003: Status value should be 1,23 as the Direct effects ER value should be 1,23 as Direct effects should have 3 indicators – there aren't enough data of phytoplankton BM for the period 2007-2012. EST_008: Status value should be 3,06 as the Direct effects ER value should be 2,34 as Direct effects should have 3 indicators – there aren't enough data of phytoplankton BM for the period 2007-2012. EST_009: Status value should be 2,45 as the Direct effects ER value should be 2,45 as Direct effects should have 3 indicators – there aren't enough data of phytoplankton BM for the period 2007-2012.	Inga Lips	In the basins where no value for 2007-2012 was provided, the period 2001-2006 was used. No changes made.

Table 8.A.4. Description of exceptions found during review at indicator level for open sea, together with following actions.

CORE indicator	Item to be checked at '*Indicators*'-page for core indicator in question	Description of Exceptions	Reviewed by	Actions
Chla, in-situ	Accuracy of N: single years	the Quark only has one observation for the	Hermanni Kaartokallio	Data has not been checked by Finland. No changes made due to
Chla, in-situ	Accuracy of ET value: assessment period	ET for Northern Baltic Proper in 1.65 in the dataview and 1.7 in BSEP 143	Hermanni Kaartokallio	Secretariat and ICES have corrected
Chla, in-situ	Accuracy of ET-Score: assessment period	ET-score for Kattegat is 0, shouldn't it be 50 as for the others	Hermanni Kaartokallio	Secretariat and ICES have corrected
Chla, in-situ	Review comments by other experts	SEA-003 is not given a value, all though according to BSEP143 status (for 2007, 2008) and target weres assigned.	Vivi Fleming-Lehtinen	Data is missing, will not be corrected unless data is submitted
Secchi depth	Review comments by other experts	SEA-003 is not given a value, all though according to BSEP143 status (for 2007, 2008, 2009, 2010, 2011) and target weres assigned.	Vivi Fleming-Lehtinen	Data is missing, will not be corrected unless data is submitted
Oxygen debt	Review comments by other experts	ES-Score missing for all assessment units.	Vivi Fleming-Lehtinen	Secretariat and ICES have corrected

Table 8A.5. Description of exceptions found during review at assessment level for open sea, together with following actions.

Item to be checked at '*Assessment*'-page	Description of Exceptions	Reviewed by	Action
Accuracy of N value	SEA-003: for C1, n=0 even though in BSEP143 it was 2, meaning that both Secchi and chla did have data	Vivi Fleming-Lehtinen	Data is missing, will not be corrected unless data is submitted
Accuracy of ER value	missing for C2 in SEA-003 all though did have value in BSEP143	Vivi Fleming-Lehtinen	Data is missing, will not be corrected unless data is submitted
Accuracy of SCORE value	Score for C3 wrong in SEA-007...010, 012...013, due to missing ES Score for oxygen debt; Score missingg for C2 in SEA-003	Vivi Fleming-Lehtinen	Secretariat and ICES have corrected
Accuracy for Confidence value	Mistakes where C3 along, eg. SEA-013 should be 62, SEA-12 should be 66 (might be due to mistakes in score values, see above?)	Vivi Fleming-Lehtinen	Secretariat and ICES have corrected

Overall assessment (annex to chapter 8.3.1)

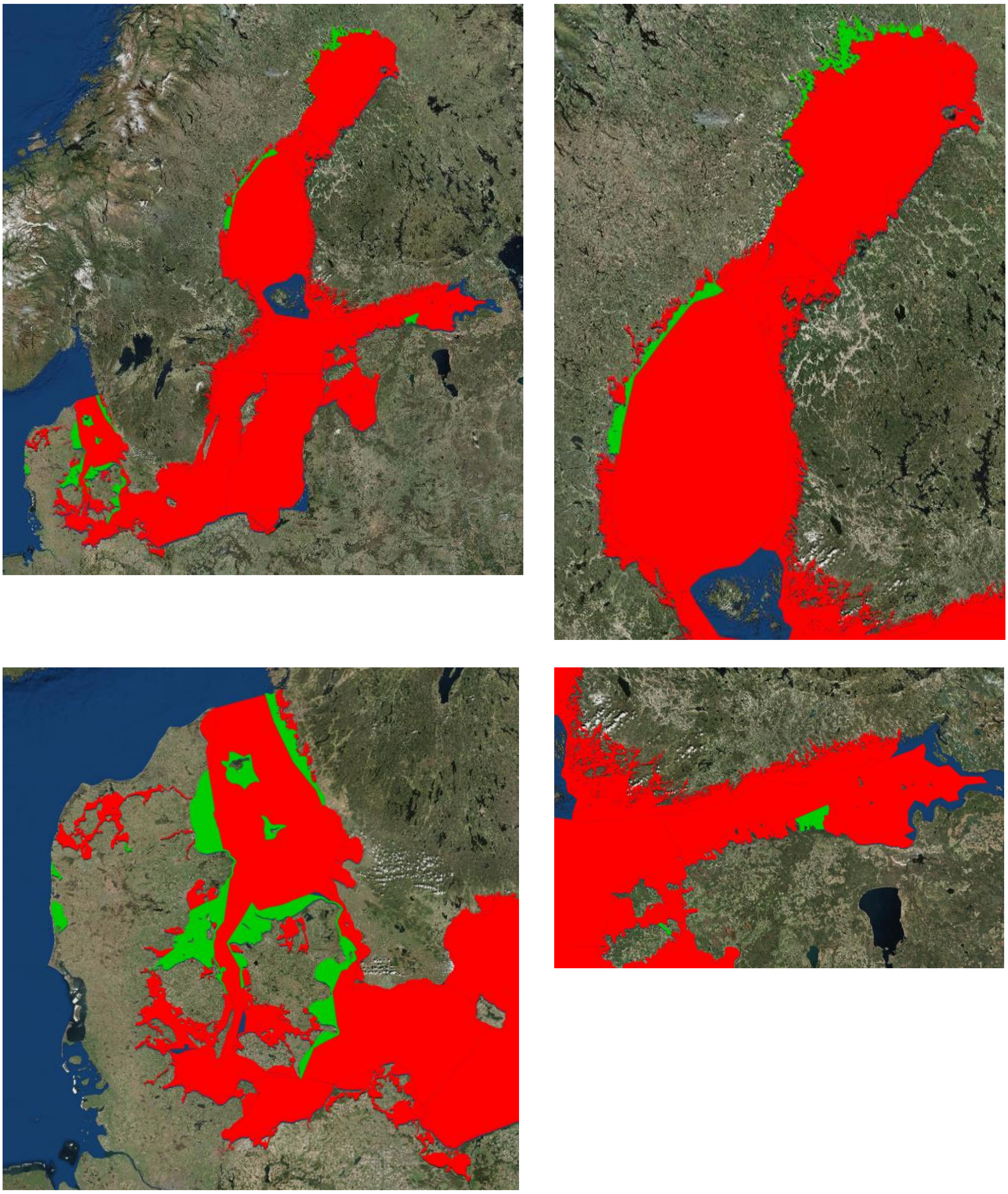
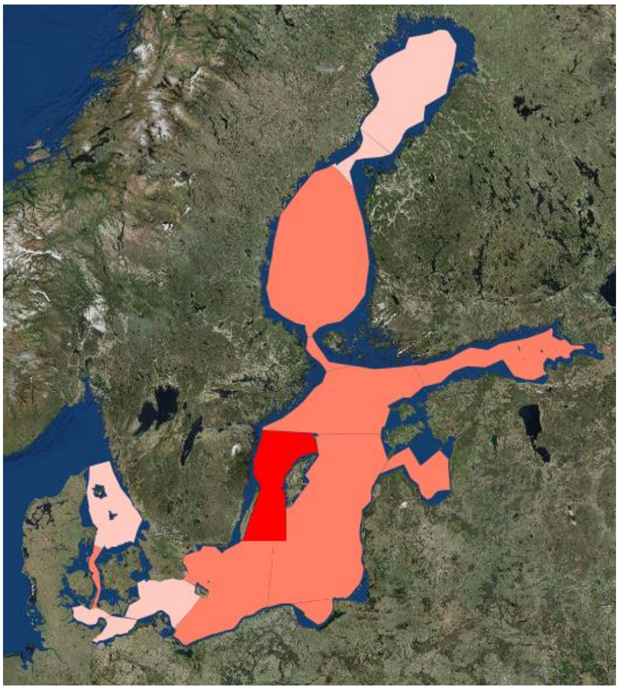


Figure 8A.2. Test assessment: overall eutrophication status for open-sea and coastal sub-basins, classified into GES (green) or SubGES (red). Above left entire Baltic Sea; top right Bothnian Sea, Quark and Bothnian Bay; bottom left Arkona Basin, Bay of Meclenburg, Great Belt, the Sound and Kattegat.

Core indicators in open-sea areas (annex to chapter 8.3.2)



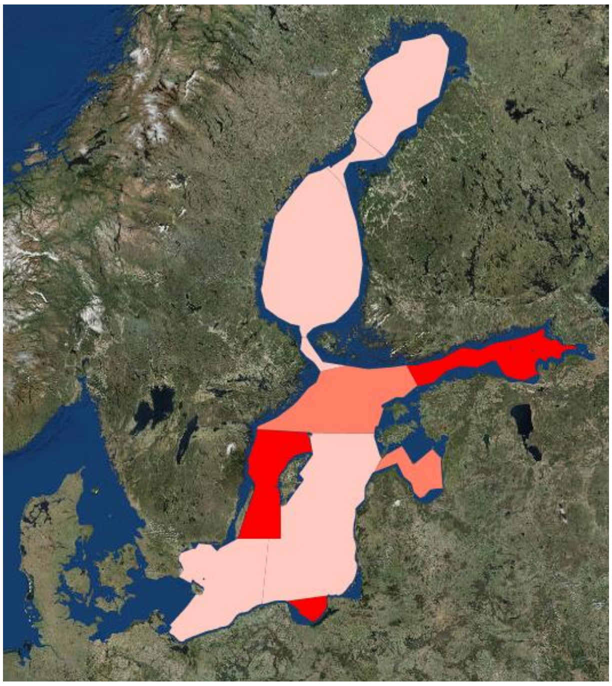
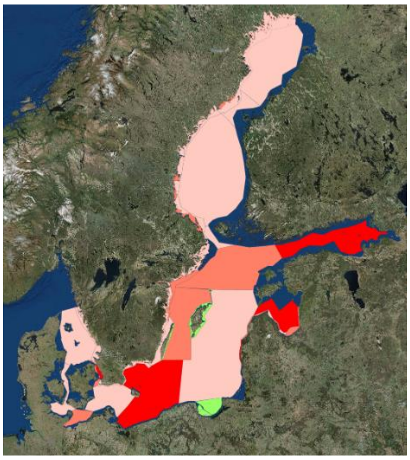
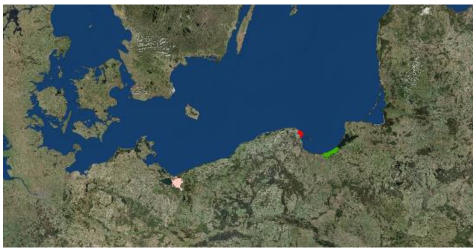


Figure 8A.2. The status of the open-sea chlorophyll-a indicator, updated only using in-situ observations (left) or EO-observations (right). Red colour indicates status below GES (see scales in Figure 8A.1)

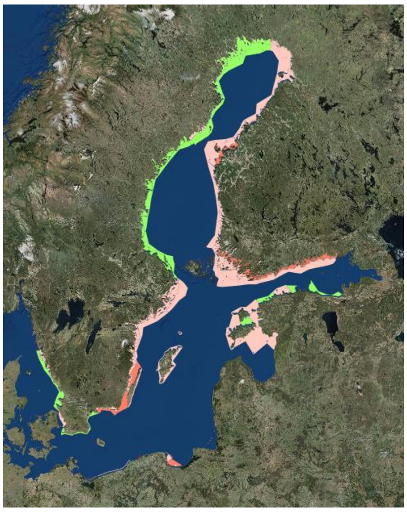
Coastal indicators (annex to chapter 8.3.3)

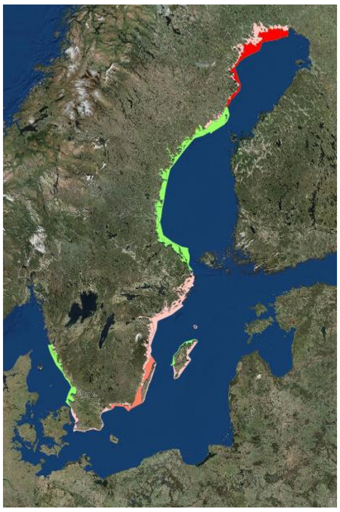


DIN (winter)

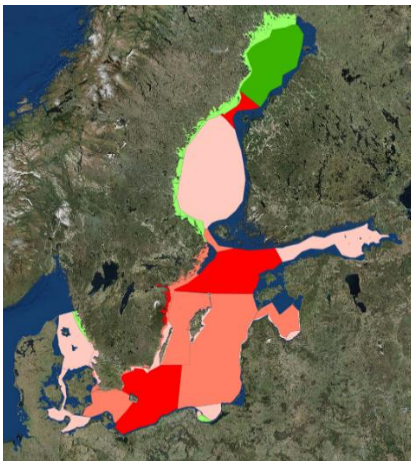


DIN (annual)

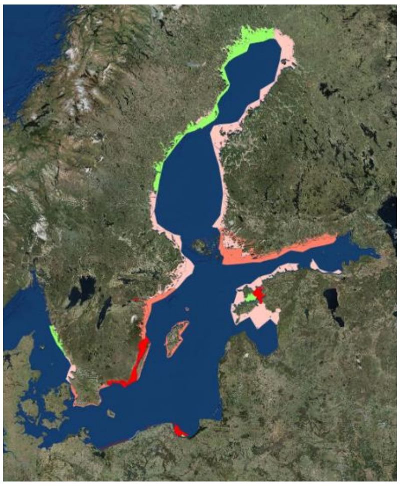

Ntot (summer)


Ntot (winter)


Ntot (annual)


DIP (winter)


DIP (annual)


Ptot (summer)


Ptot (winter)

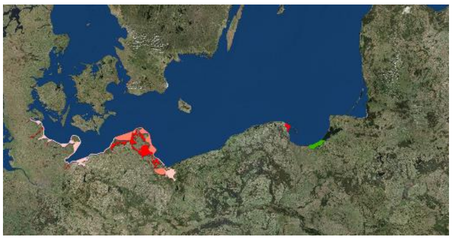
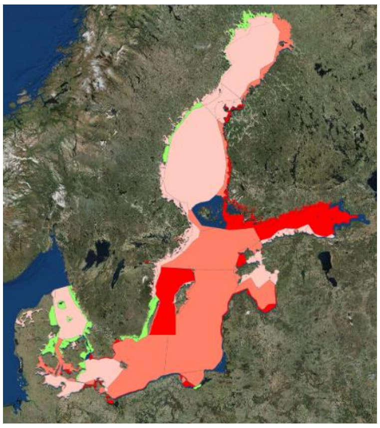
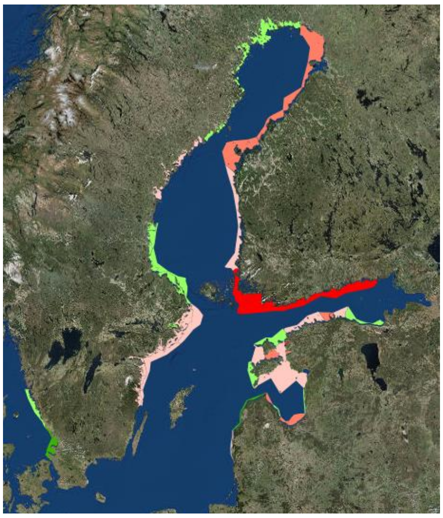

Ptot (winter)

Figure 8A.3. Test assessment: Status of coastal nutrients. Names of indicators / quality elements are given below each map. Green = GES, red = SubGES (see scales in Figure 8A.1).



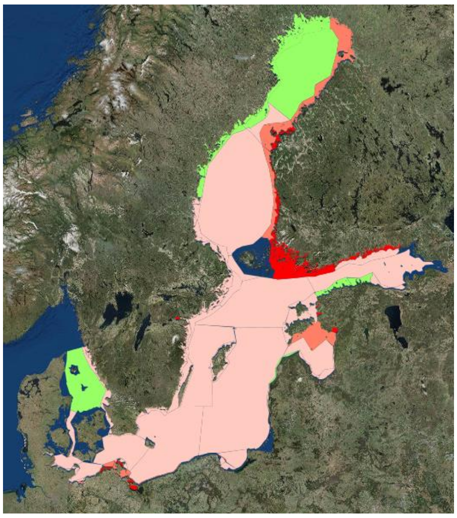
Chla (summer)

Chla (winter)



Phytoplankton biovolume (summer)

Figure 8A.4. Test assessment: Status of coastal phytoplankton. Names of indicators / quality elements are given below each map. Green = GES, red = SubGES (see scales in Figure 8A.1).

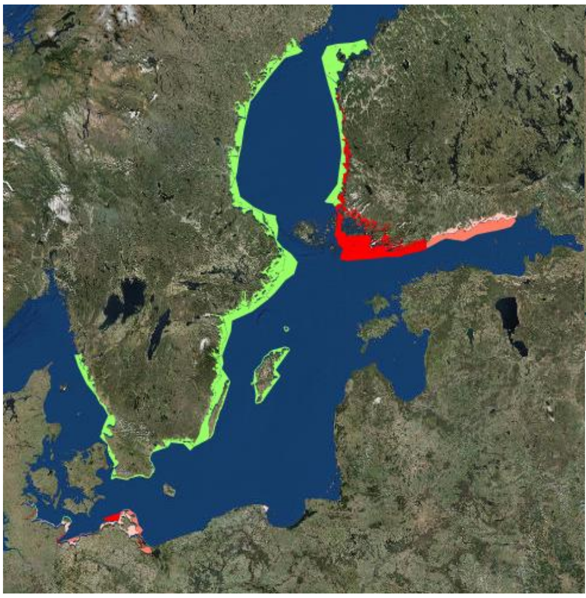


Secchi depth (summer)

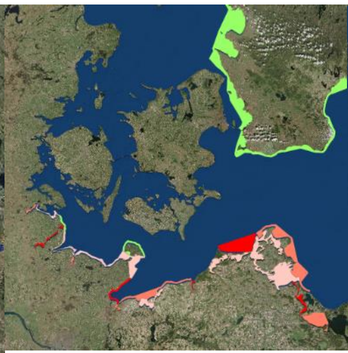
Secchi depth (annual)

Figure 8A.5. Test assessment: Status of coastal Secchi depth. Names of indicators / quality elements are given below each map. Green = GES, red = SubGES (see scales in Figure 8A.1).

Figure 8A.6. Test assessment: Status of coastal bottom oxygen. Green = GES, red = SubGES (see scales in Figure 8A.1).

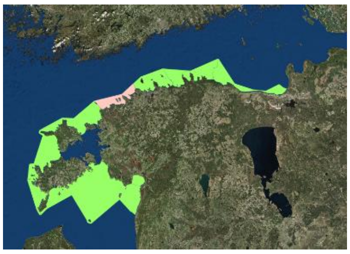


Macrovegetation Quality Element

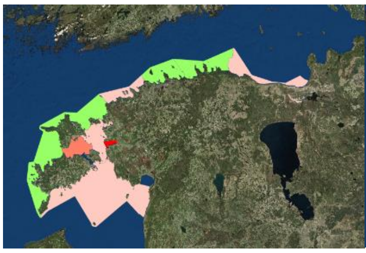


Macrovegetation Quality Element (zoom)

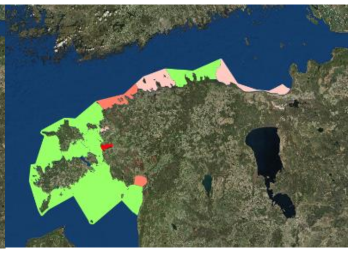
macrophytes sheltered



Benthic macroflora depth distribution



F. vesiculosus depth distribution

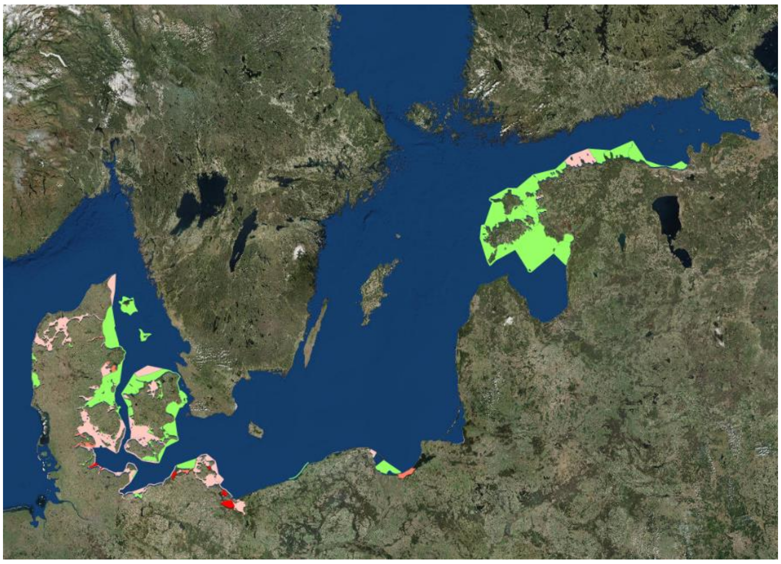


Proportion of perennial species

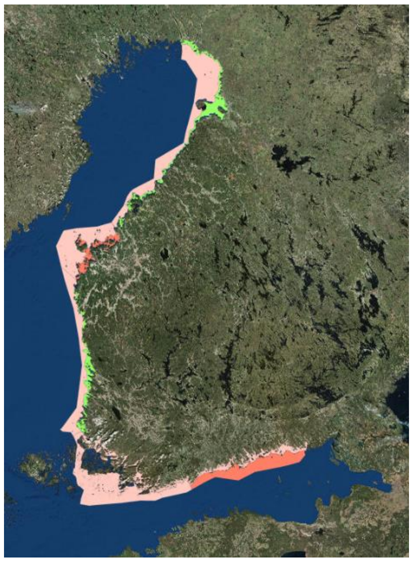
Furcellaria depth distribution

Phytobenthos ecological quality index

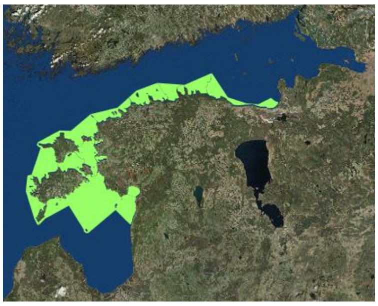
Figure 8A.7. Test assessment: Status of coastal macrovegetation. Names of indicators / quality elements are given below each map. Green = GES, red = SubGES (see scales in Figure 8A.1).



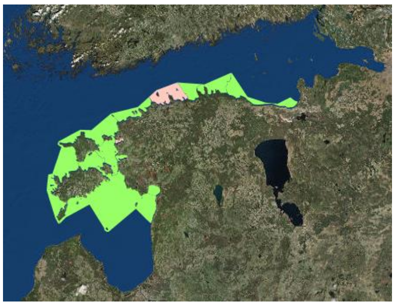
Zoobenthos Quality Element



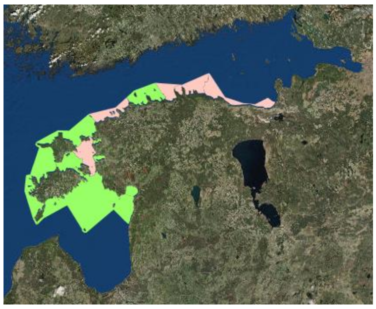
BBI



KPI



BQI



FDI

Figure 8A.8. Test assessment: Status of coastal zoobenthos. Names of indicators / quality elements are given below each map. Green = GES, red = SubGES (see scales in Figure 8A.1).

Metadata of coastal assessments (annex to chapter 8.4.2)

Table 8A.6. Number of indicators used (N) in Criterium 1 (C1, nutrient levels), Criterium 2 (C2, direct effects), Criterium 3 (C3, indirect effects) and altogether (overall) in the eutrophication assessment in the German coastal assessment units.

ID	Assessment Unit	C1_N	C2_N	C3_N	N overall
GER-001	mesohaline inner coastal waters, Wismarbucht, Suedteil	2	2	1	5
GER-002	mesohaline inner coastal waters, Wismarbucht, Nordteil	2	2	2	6
GER-003	mesohaline inner coastal waters, Wismarbucht, Salzhaff	2	2	2	6
GER-004	mesohaline open coastal waters, Suedliche Mecklenburger Bucht/ Travemuende bis Warnemünde	2	2	2	6
GER-005	mesohaline inner coastal waters, Unterwarnow	2	2	2	6
GER-006	mesohaline open coastal waters, Suedliche Mecklenburger Bucht/ Warnemünde bis Darss	2	2	1	5
GER-007	oligohaline inner coastal waters, Ribnitzer See / Saaler Bodden	2	2	2	6

GER-008	oligohaline inner coastal waters, Koppelstrom / Bodstedter Bodden	2	2	2	6
GER-009	mesohaline inner coastal waters, Barther Bodden, Grabow	2	2	2	6
GER-010	mesohaline open coastal waters, Prerowbucht/ Darsser Ort bis Dornbusch	2	2	2	6
GER-011	mesohaline inner coastal waters, Nord- und Westruegensche Bodden	2	2	2	6
GER-012	mesohaline inner coastal waters, Strelasund	2	2	2	6
GER-013	mesohaline inner coastal waters, Greifswalder Bodden	2	2	2	6
GER-014	mesohaline inner coastal waters, Kleiner Jasmunder Bodden	2	2	2	6
GER-015	mesohaline open coastal waters, Nord- und Ostruegensche Gewaesser	2	2	2	6
GER-016	oligohaline inner coastal waters, Peenestrom	2	2	1	5
GER-017	oligohaline inner coastal waters, Achterwasser	2	2	1	5
GER-018	mesohaline open coastal waters, Pommersche Bucht, Nordteil	2	2	2	6
GER-019	mesohaline open coastal waters, Pommersche Bucht, Südteil	2	2	1	5
GER-020	oligohaline inner coastal waters, Kleines Haff	2	2	2	6
GER-021	mesohaline inner coastal waters, Flensburg Innenfoerde	2	2	3	7
GER-022	mesohaline open coastal waters, Geltinger Bucht	2	2	2	6
GER-023	meso- to polyhaline open coastal waters, seasonally stratified, Flensburger Aussenfoerde	2	2	2	6
GER-024	mesohaline open coastal waters, Aussenschlei	2	2	2	6
GER-025	mesohaline inner coastal waters, Schleimuende	2	2	2	6
GER-026	mesohaline inner coastal waters, Mittlere Schlei	2	2	2	6
GER-027	mesohaline inner coastal waters, Innere Schlei	2	2	2	6
GER-028	mesohaline open coastal waters, Eckerfoerder Bucht, Rand	2	2	2	6
GER-029	meso- to polyhaline open coastal waters, seasonally stratified, Eckerfoerderbucht, Tiefe	2	2	2	6
GER-030	mesohaline open coastal waters, Buelk	2	2	2	6
GER-031	meso- to polyhaline open coastal waters, seasonally stratified, Kieler Aussenfoerde	2	2	2	6
GER-032	mesohaline inner coastal waters, Kieler Innenfoerde	2	2	3	7
GER-033	mesohaline open coastal waters, Probstei	2	2	2	6
GER-034	mesohaline open coastal waters, Putlos	2	2	2	6
GER-035	meso- to polyhaline open coastal waters, seasonally stratified, Hohwachter Bucht	2	2	1	5
GER-036	mesohaline open coastal waters, Fehmarnsund	2	2	2	6
GER-037	mesohaline inner coastal waters, Orther Bucht	2	2	2	6
GER-038	mesohaline open coastal waters, Fehmarnbelt	2	2	2	6
GER-039	meso- to polyhaline open coastal waters, seasonally stratified, Fehmarn Sund Ost	2	2	1	5
GER-040	mesohaline open coastal waters, Groemitz	2	2	2	6

GER-041	mesohaline open coastal waters, Neustaedter Bucht	2	2	3	7
GER-042	mesohaline inner coastal waters, Travemuende	2	2		4
GER-043	mesohaline inner coastal waters, Poetenitzer Wiek	2	2	2	6
GER-044	mesohaline inner coastal waters, Untere Trave	2	2		4
GER-111	mesohaline inner coastal waters, Nordruegensche Bodden	2	2	2	6

Table 8A.7. Number of indicators used (N) in Criterium 1 (C1, nutrient levels), Criterium 2 (C2, direct effects), Criterium 3 (C3, indirect effects) and altogether (overall) in the eutrophication assessment in the Danish coastal assessment units.

ID	Assessment Unit	C1_N	C2_N	C3_N	N overall
DEN-001	M1		1	1	2
DEN-002	M2		1	1	2
DEN-003	M3		1	1	2
DEN-004	M4		1	1	2
DEN-005	O3		1	1	2
DEN-006	O4		1		1
DEN-007	OW1		1	1	2
DEN-008	OW2		1	1	2
DEN-009	OW3a		1	1	2
DEN-010	OW3b		1	1	2
DEN-011	OW3c		1		1
DEN-012	P1		1	1	2
DEN-013	P2		1	1	2
DEN-014	P3		1	1	2
DEN-015	P4		1	1	2
DEN-016	Slusefjord			1	1

Table 8A.8. Number of indicators used (N) in Criterium 1 (C1, nutrient levels), Criterium 2 (C2, direct effects), Criterium 3 (C3, indirect effects) and altogether (overall) in the eutrophication assessment in the Estonian coastal assessment units.

ID	Assessment Unit	C1_N	C2_N	C3_N	N overall
EST-001	Narva-Kunda lahe rannikuvesi	2	4	5	11
EST-002	Eru-Käsmu lahe rannikuvesi		4	5	9
EST-003	Hara lahe rannikuvesi		4	5	9
EST-004	Kolga lahe rannikuvesi	2	4	5	11

EST-005	Muuga-Tallinna-Kakumäe lahe rannikuvesi	2	4	5	11
EST-006	Pakri lahe rannikuvesi	2	4	5	11
EST-007	Hiiu madala rannikuvesi	2	4	5	11
EST-008	Haapsalu lahe rannikuvesi	2	4	4	10
EST-009	Matsalu lahe rannikuvesi	2	4	4	10
EST-010	Soela väina rannikuvesi	2	4	5	11
EST-011	Kihelkonna lahe rannikuvesi	2	4	5	11
EST-012	Liivi lahe rannikuvesi	2	4	5	11
EST-013	Pärnu lahe rannikuvesi	2	3	4	9
EST-014	Kassari-Õunaku lahe rannikuvesi	2	4	4	10
EST-015	Väikse väina rannikuvesi			3	3
EST-016	Väinamere rannikuvesi	2	4	4	10

Table 8A.9. Number of indicators used (N) in Criterium 1 (C1, nutrient levels), Criterium 2 (C2, direct effects), Criterium 3 (C3, indirect effects) and altogether (overall) in the eutrophication assessment in the Finnish coastal assessment units.

ID	Assessment Unit	C1_N	C2_N	C3_N	N overall
FIN-001	Lounainen sisäsaaristo	2	2	3	7
FIN-002	Lounainen ulkosaaristo	2	3	3	8
FIN-003	Suomenlahden sisäsaaristo	2	2	3	7
FIN-004	Suomenlahden ulkosaaristo	2	3	3	8
FIN-005	Lounainen välisaaristo	2	1		3
FIN-006	Merenkurkun sisäsaaristo	2	2	1	5
FIN-007	Merenkurkun ulkosaaristo	2	3	2	7
FIN-008	Selkämeren sisemmät rannikkovedet	2	2	2	6
FIN-009	Selkämeren ulommat rannikkovedet	2	3	2	7
FIN-010	Perämeren sisemmät rannikkovedet	2	2	1	5
FIN-011	Perämeren ulommat rannikkovedet	2	3	1	6

Table 8A.10. Number of indicators used (N) in Criterium 1 (C1, nutrient levels), Criterium 2 (C2, direct effects), Criterium 3 (C3, indirect effects) and altogether (overall) in the eutrophication assessment in the Latvian coastal assessment units.

ID	Assessment Unit	C1_N	C2_N	C3_N	N overall
LAT-001	South-eastern exposed stony coast, waterbody A	2	3	2	7
LAT-002	South-eastern exposed sandy coast, waterbody B	2	3		5
LAT-003	Gulf of Riga sandy coast, waterbodies C&E	2	3	1	6
LAT-004	Gulf of Riga stony coast, waterbodies D&F	2	3	2	7

LAT-005	Gulf of Riga transitional waters	2	3	1	6

Table 8A.11. Number of indicators used (N) in Criterium 1 (C1, nutrient levels), Criterium 2 (C2, direct effects), Criterium 3 (C3, indirect effects) and altogether (overall) in the eutrophication assessment in the Polish coastal assessment units.

ID	Assessment Unit	C1_N	C2_N	C3_N	N overall
POL-002	PL TW I WB 8 very sheltered, fully mixed...	4	2	2	8
POL-003	PL TW I WB 1 very sheltered, fully mixed...	4	3	2	9
POL-004	PL TW II WB 2 very sheltered, fully mixed...	4	3	3	10
POL-005	PL TW III WB 3 partly protected, partly str...	4	2	1	7
POL-006	PL TW IV WB 4 partly stratified, moderate...	4	2	2	8
POL-007	PL TW V WB 6 river mouth, partly stratifi...	2	2	1	5
POL-008	PL TW V WB 5 river mouth, partly stratifi...	4		1	5
POL-009	PL TW V WB 7 river mouth, partly stratifi...	4	2	1	7
POL-010	PL CWI WB2 coastal waters, moderately...	2	2	1	5
POL-011	PL CWI WB1 coastal waters, moderately...		1		1
POL-013	PL CW II WB 8 central Polish coast, coastal...	2	2	1	5
POL-015	PL CW II WB 6E central Polish coast, coast...	2	2	1	5
POL-018	PL CW III WB 9 central Polish coast, coasta...	2	2	1	5
POL-019	PL CW III WB 7 central Polish coast, coasta...	2	2	2	6

Table 8A.12. Number of indicators used (N) in Criterium 1 (C1, nutrient levels), Criterium 2 (C2, direct effects), Criterium 3 (C3, indirect effects) and altogether (overall) in the eutrophication assessment in the Swedish coastal assessment units.

ID	Assessment Unit	C1_N	C2_N	C3_N	N overall
SWE-001	1s: West Coast inner coastal water	6	2	2	10
SWE-003	4. West Coast outer coastal water, Kattegat	6	3	2	11
SWE-004	5. South Halland and north Öresund coastal...	6	3	2	11
SWE-005	6. Öresund coastal water	6	2	2	10
SWE-006	7. Skåne coastal water	6	2	2	10
SWE-007	8. Blekinge archipelago and Kalmarsund, inner...	6	2	2	10
SWE-008	9. Blekinge archipelago and Kalmarsund, outer...	6	2	2	10
SWE-009	10. Öland and Gotland coastal water	6	2	2	10
SWE-010	11. Gotland north-west coastal water	6	2	2	10
SWE-011	12n: Östergötland and Stockholm archipelago...	5	3	2	10
SWE-012	12s: Östergötland and Stockholm archipelago...	6	3	2	11
SWE-013	13. Östergötland inner coastal water	6	3	2	11
SWE-014	14. Östergötland outer coastal water	6	3	2	11

SWE-015	15. Stockholm archipelago, outer coastal water	2	3	2	7
SWE-016	16. South Bothnian Sea,inner coastal water	6	3	2	11
SWE-017	17. South Bothnian Sea, outer coastal water	6	3	2	11
SWE-018	18. North Bothnian Sea, Höga kusten, inner...	6	3	2	11
SWE-019	19. North Bothnian Sea, Höga kusten, outer...	6	2	2	10
SWE-020	20. North Quark inner coastal water	6	3	1	10
SWE-021	21. North Quark outer coastal water	6	2	1	9
SWE-022	22. North Bothnian Bay, inner coastal water	6	3	1	10
SWE-023	23. North Bothnian Bay, outer coastal water	6	2	1	9
SWE-024	24. Stockholm inner archipelago	4	3	1	8
SWE-025	25. Göta and Nordre älv estuary	6	2	1	9

Eutrophication status assessment 2007-2011 (annex to chapter 8.5)

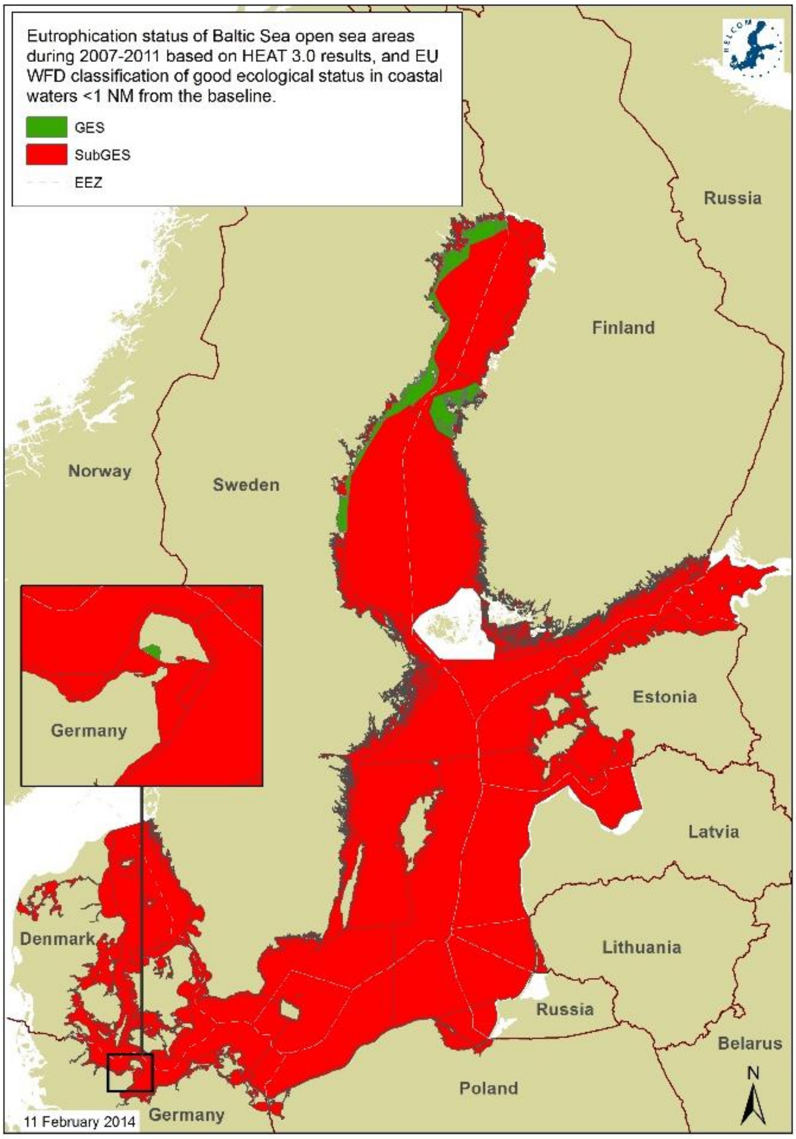


Figure 8A.9. Overall eutrophication status in 2007-2011 (BSEP 143). Green = GES, red = SubGES.

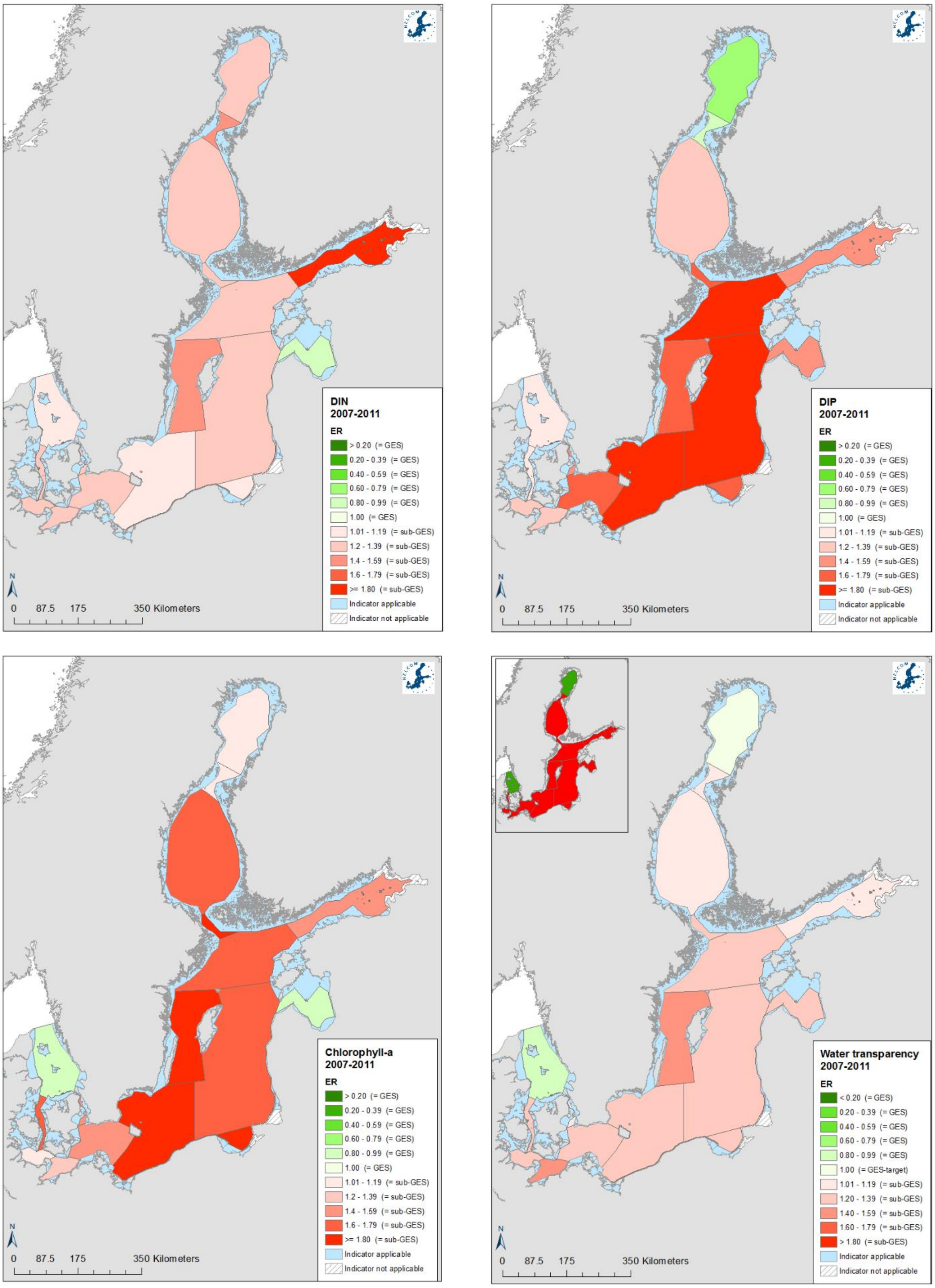


Figure 8.A.10. Status of open-sea core indicators in 2007-2011: DIN (above left), DIP (above right), chlorophyll-a (below left) and Secchi depth (below right). Indicators were updated for update of overall eutrophication status of the Baltic Sea, and published as web reports (http://www.helcom.fi/baltic-sea-trends/indicators/). Green = GES, red = SubGES. Colour scales indicate overall eutrophication ratio (BSEP 143).

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