Document title	Seasonal succession of functional phytoplankton groups – proposal to shift status to core indicator
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Category	DEC
Agenda Item	4J – HELCOM indicators and assessment
Submission date	17.10.2016
Submitted by	Lead Country Estonia
Reference	STATE & CONSERVATION 2-2015 (paragraph 4J.10 point 3 of the outcome)

Background

The indicator 'Seasonal succession of functional phytoplankton groups' was agreed to be shifted from candidate status to pre-core by STATE & CONSERVATION 2-2015 (paragraph 4J.10 point 3 of the outcome).

The HELCOM HOD 48-2015 agreed on a Lead Country approach for further development of core indicator (paragraph 3.64 of the outcome). For this pre-core indicator the Lead Country has been Estonia with Co-Lead Countries being Finland, Latvia and Sweden. Poland has also supported the indicator work by developing an R-script for the assessment protocol.

The indicator development was presented and discussed at HELCOM PEG 2016. The PEG group reached an expert level consensus that if further indicator development work does not lead to a stronger GES-boundary being defined, then it may be appropriate to consider developing the concept into a supporting parameter that describes trends instead of a core indicator. Alternatively a trend-based GES boundary could be developed.

The continued indicator development work during 2016 has focussed on defining assessment unit specific baselines defined by reference periods for the whole Baltic Sea taking the variable pelagic ecological conditions in the different sub-basins into account. For the Gulf of Riga, Gdansk Bay and coastal areas of the southern Gulf of Finland and parts of the Swedish coast a baseline value is available, however not considered to be fully verified as marking a relevant boundary defining GES. The analyses revealed it to be difficult to establish relevant reference periods throughout the region, in particular for the coastal assessment units.

The proposal by the Lead Country is to use this indicator to develop qualitative description of trends by using all available data as reference and compare the results to the status during the assessment period (2011-2016) for HOLAS II purposes. The indicator is considered relevant to be used in the holistic assessment of the Baltic Sea pelagic habitats. An R-script has been developed for calculating the indicator; however it has not yet been sufficiently tested. The Lead Country proposes to rename the indicator from the current 'functional phytoplankton groups' to 'dominating phytoplankton groups' since the groups may not be functionally homogenous (e.g. dinoflagellates contain both auto-, mixo- and heterotrophs).

This document presents the indicator report of the pre-core indicator 'Seasonal succession of functional phytoplankton groups'.

Action requested

The Meeting is invited to:

- agree on the new name 'Seasonal succession of dominating phytoplankton groups',
- endorse the assessment protocol and endorse the approach of assessing status through the means of trends against all available data
- endorse a shift in status of the indicator from pre-core to core.

Seasonal succession of phytoplankton groups – pre-core indicator proposal

Pre-core indicator report:

Seasonal succession of dominating phytoplankton groups

Contents

Key message

A provisional status evaluation has been done for the period 2008-2014. The GES-boundary (indicator value), based on the proportion of observations with acceptable deviations in monthly biomass indicating normal seasonal succession of phytoplankton, was preliminarily set at ≥0.67 for the tested areas in the Gulf of Gdansk, the Curonian lagoon, the Gulf of Riga and the southern Gulf of Finland. The five test areas represent mainly discrete coastal water bodies and a sub-basin (Gulf of Riga). The data is, however, provided for 18 assessment units, but not sufficiently tested in all areas of the Baltic Sea. The reference periods proposed in this report are still subjects of revision, which in turn hinders development of stronger GES boundaries. To overcome this problem, we propose a temporary solution to use all available data as reference and compare the results to the status during a certain period.

This indicator should be applicable in all coastal and open sea waters around the Baltic Sea.

Relevance of the core indicator

Phytoplankton is the key primary producer in marine ecosystems. Phytoplankton comprises several functionally diverse groups that dominate the community at different times of the year. A change in when a group of phytoplankton organisms dominates and becomes abundant may change ecosystem function since carbon settles on the sediment and becomes available to higher trophic levels at a different time of the year.

Deviations from the normal seasonal cycle (such as a too high or too low biomass, or absence of some dominating phytoplankton group(s)) indicate an impairment in environmental status. Phytoplankton species composition changes if the amount of nutrients or nutrient ratios change, and eutrophication has resulted in more intense and frequent phytoplankton blooms in the summer.

Policy relevance of the core indicator

	BSAP Segment and Objectives	**MSFD Descriptors and Criteria**
Primary link	• Thriving and balanced communities of plants and animals	D4 - Food webs 4.3.1. Abundance trends of functionally important selected groups/species (key trophic groups)
Secondary link	• Natural Distribution and occurrence of plans and animals	D5 - Eutrophication 5.2.4. Species shift in florisitic composition such as diatom to flagellate ratio etc
Other relevant legislation:		

Cite this indicator

Jaanus, A., Kownacka, J., Całkiewicz, J., Jurgensone, I., Lehtinen, S., Johansen, M. & Griniene, E. (2016). Seasonal succession of dominating phytoplankton groups**.** HELCOM core indicator report. Online. [Date Viewed], [Web link].

Download full indicator report

Core indicator report – web-based version [month year] (pdf)

Results and confidence

The results of preliminary evaluation are presented for the southern coastal Gulf of Finland (Tallinn and Muuga bays), Curonian Lagoon (estuarine and freshwater part), Gulf of Riga (coastal and open sea), Gulf of Gdansk (Sopot area) and the northern Baltic Proper (Askö archipelago). Additional data, provided for the 13 assessment units, will be tested immediately after the revision of reference periods (by the end of 2016).

The results of preliminary evaluation are summarized in Table 1. The reference period is defined separately for each sea area and depends on the availability of data. Time-series usually start from the beginning of the 1990s, while disturbances in the environment were evident already in the 1960s (Andersen et al., 2015). To start evaluating environmental status and to create reference growth curves, a regular data set of at least 10 years with monthly sampling is needed to comprise all natural variability. This is the reason why the tentative reference periods extend until the mid of 2000s. The test period includes most recent years (5−6) and may also vary dependinmg on the data available for the analysis. An example of reference growth curves with indicator values for a certain assessment period is given in Figure 1. The GES-boundary is still preliminary and has to be set separately for each assessment unit to account for the characteristics of environmental differences between the areas.

Table 1. Test results from different areas of the Baltic Sea. Indicator value lays between 0 and 1 and is the proportion of samples within the frame of seasonal reference growth curves and acceptable deviations. Indicator values for individual dominant groups are averaged. The GES-boundary is preliminarily set at ≥0.67.

Area	Dominant group	Test period	No. of obs.	No. of data points within acc. range	Indica-tor value	Refe-rence period	No. of obs.	No. of data points within acc. range	Indica-tor value	GES evaluation
Southern Gulf of Finland		2010-2014			0.61	1993-2006				sub-GES
	Cyanobacteria		34	23	0.68					
	Dinoflagellates		34	19	0.56		95	62	0.65	
	Diatoms		34	23	0.68					
	M. rubrum		34	17	0.50					
Curonian Lagoon, fresh		2009-2014			0.69	1994-2007				GES
	Cyanobacteria		50	33	0.66		146	93	0.64	
	Diatoms		50	36	0.72		148	94	0.64	
	Green algae		50	35	0.70		148	97	0.66	
Curonian Lagoon, estuarine		2008-20122 2012			0.50	1994-20070 7				sub-GES
	Cyanobacteria		52	29	0.56		133	69	0.56	
	Diatoms		52	17	0.33		133	60	0.45	
	Green algae		52	32	0.62		133	58	0.44	
Gulf of Gdansk, Sopot		2008-2014			0.69	1991-2007				GES
	Cyanobacteria		50	32	0.64		76	41	0.54	
	Dinoflagellates		50	37	0.74		76	31	0.41	
	Diatoms		50	32	0.64		76	42	0.55	
	M. rubrum		50	36	0.72		76	37	0.49	
Gulf of Riga, coastal		2010-2014			0.51	1992-2009				sub-GES
	Cyanobacteria		38	15	0.39					
	Dinoflagellates		38	24	0.63					
	Diatoms		36	22	0.61					
	M. rubrum		36	15	0.42					

Gulf of Riga, open		2010-2014			0.53	1992-2009				sub-GES
	Cyanobacteria		32	14	0.44					
	Dinoflagellates		32	28	0.88					
	Diatoms		32	17	0.53					
	M. rubrum		32	9	0.28					
Askö archi-pelago		2009-2013			0.85	1983-2005				GES
	Cyanobacteria		59	48	0.81					
	Dinoflagellates		59	50	0.85					
	Diatoms		59	54	0.92					
	M. rubrum		59	48	0.81					

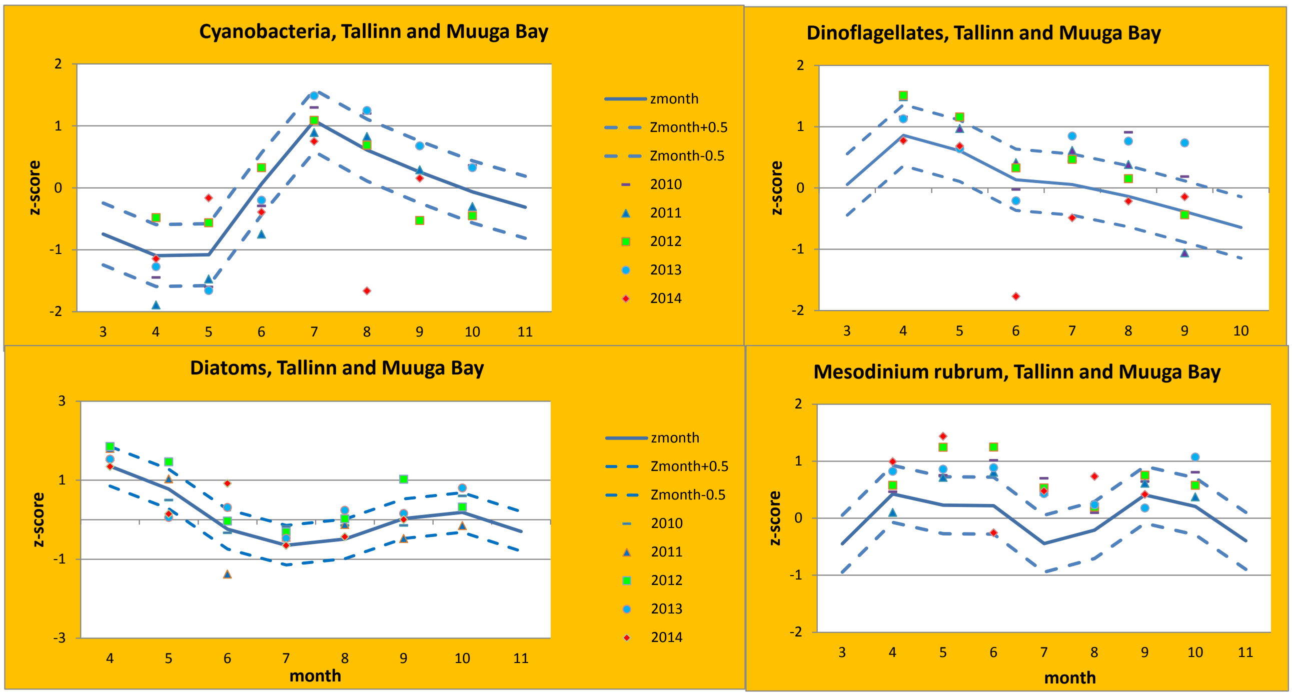

Figure 1. Reference growth curves with monthly averaged normalized biomass values (Z_{month}), acceptable deviations (Z_{month}±0.5) and data points from the test period (2010–2014) in the southern Gulf of Finland (Tallinn and Muuga Bay).

Confidence of the indicator status evaluation

Spatio-temporal coverage differs between the assessment units. For most of the test areas, the confidence of indicator status is **moderate**. Confidence level depends on the length of time-series and regularity of phytoplankton sampling during the vegetation period. Once the reference growth curves have been established, some compromises in the frequency of sampling and total number of samples used in the assessment are possible. The indicator value is the proportion of biomass values fitting into the reference growth envelope and the values for individual months are independent. It means that if some data points for some months during the assessment period are missing, the evaluation of status is still feasible.

Good Environmental Status

The concept for evaluating good environmental status using the succession of dominant groups in the phytoplankton community is structured around a reference status succession and acceptable deviation. The indicator evaluates the coincidence of seasonal succession of dominating phytoplankton groups over the assessment period (5−6 years) with regionally established reference seasonal growth curves using wet weight biomass data. The indictor value is based on the number of data points which fall within the acceptable deviation range set for each monthly point of the reference growth curve and expressed as the percentage to the total number of observations. Strong deviations from the reference growth curves indicate impairment in the environmental status.

The GES-boundary was preliminarily set at the indicator value ≥0.67 for tested sea areas – the gulfs of Finland, Gdansk and Riga and the Curonian Lagoon. The final evaluation may be based either on the score(s) of single dominant group(s) or on a multimetric index, where the individual indicator values are averaged.

The GES-boundary ≥0.67 is rather arbitrary value and based only on expert judgement. If further indicator development work does not lead to a stronger value being defined, then it may be appropriate to consider developing trend-based GES-boundaries. This indicator may also be used as background data for development a modified lifeform approach would be tested in the HELCOM area in monitoring and environmental assessments. Lifeform approach has been considered to be taken into use in the MSFD assessments by OSPAR (Tett et al. 2008, Gowen et al. 2011).

Background information on deriving the GES boundary

The confidence of GES-boundary is currently being considered low and requires further validation for more assessment units in the Baltic Sea. However, most areas in the Baltic Sea have been heavily influenced by anthropogenic pressures already before the regular monitoring started and it may be difficult to determine the reference conditions for the succession. Due to the lack of high status waterbodies and historical datasets, the reference seasonal growth curves have been set through observations made after the 1980’s and the threshold between GES and sub-GES is based on expert judgement. The test results revealed that in some areas (Polish coastal waters and Estonian coastal waters of the Gulf of Finland, offshore waters in the Eastern Gotland, Arkona and Bornholm basins and the Mecklenburg Bight) the indicator values calculated for the test period (mainly 2008−2014) showed higher status than during the preliminary set reference period (1990s and the beginning of the 2000s) (Table 1). Further analysis with data from mostly offshore areas also seemed to indicate that in several cases, the deviations from the long-term mean reference growth curves have become less frequent during the last decade than in the 1990s and the early 2000s. This may refer to the improvement in the current environmental status.

The latter was the reason to revise reference periods for all assessment units where data was available. There are two principles of choice. The first one was to use all available data as reference and compare the results to the status during a certain period. The second option was to define unit-specific reference conditions by ascertaining the periods of stability in long-time biomass data. This has been tested in two ways. One way is to calculate 3- or 5-years moving averages of standard deviations in yearly total biomass values (Fig. 2). Another way is to use multiplicative decomposition model, where the values are seasonally adjusted and trends can be seen more clearly (Fig. 3). The example based on biomass data from the Northern Baltic Proper. The two methods resulted in partly different periods of stability, which may be used as reference periods in the evaluation of environmental status. Analysis with datasets from other sea areas will be continued.

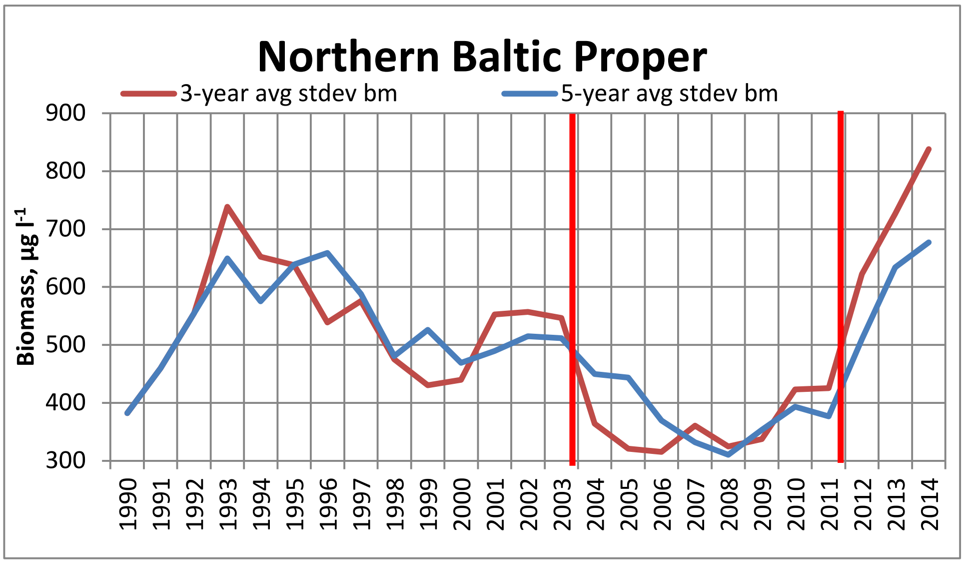

Figure 2. Selection of reference period by calculting 3- or 5-years moving averages of standard deviations in yearly total biomass (µg l^{-1}) values. The period with lowest variability is indicated between red bars.

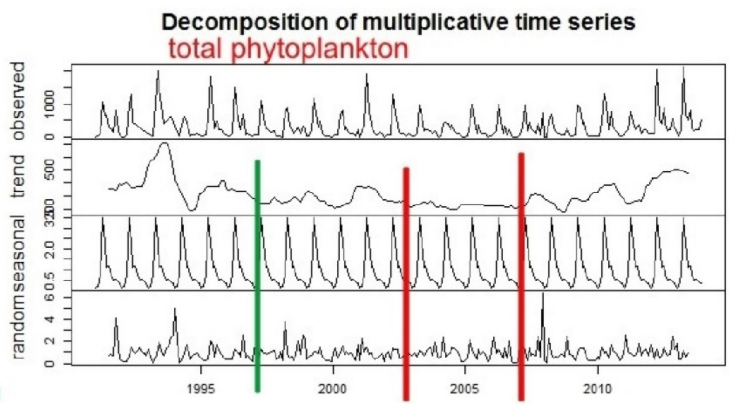

Figure 3. Selection of reference period by decomposition of multiplicative time series. Observed – raw fluctuations in total biomass; seasonal – seasonality effect; random – irregular component in dataset. Trend shows seasonally adjusted periods of stability (within red bars, possible extension of the period is marked with green bar), where the fluctuations are smoothed. This example is based on the data collected from the northern Baltic Proper.

Assessment protocol

Calculations and data requirements

The data required by this indicator is attained by quantitative phytoplankton analysis (cf. HELCOM 2014). The analysis requires wet weight biomasses of major functional or dominating groups over a sampling year. Sampling frequency should be at least once per month. The selection of groups may be different in different sub-basins of the Baltic Sea, and is needed to decide based on expert judgement on long-term monitoring data. In most test areas cyanobacteria, dinoflagellates, diatoms and the autotrophic ciliate *Mesodinium rubrum* were selected, except in the Curonian Lagoon where green algae were included in the analysis instead of dinoflagellates and *M.rubrum*.

The process of establishing phytoplankton group reference growth curves for marine water bodies was originally described by Devlin et al. (2007). Type- or site-specific seasonal growth curves can be designed for each dominating phytoplankton group:

1) Skewed data is accounted for by the transformation of phytoplankton biomass on a natural log scale (ln x+1 bm);
2) Monthly mean and standard deviations are calculated for each functional group over a reference period;
3) Monthly Z scores are calculated as follows:

$$\mathbf{Z}_{\,month} = \frac{(\textbf{Monthly mean} - \textbf{Overall mean})_{reference\ period}}{\textbf{Overall standard deviation}_{reference\ period}}$$

A positive z-score implies that the observed type and site specific growth curve for a certain month is greater than the mean. And this in turn indicates that the phytoplankton group has grown more in that month than average. A negative score indicates that the observation is less than the mean and the phytoplankton group is missing or constitutes only minor part of biomass in the whole community.

4) Acceptable deviations for monthly means (reference envelopes) are calculated ($z_{month}\pm0.5$).
The indicator value is calculated:

$$\mathbf{Z}_{\,score} = \frac{\textbf{Monthly mean}_{year} - \textbf{Overall mean}_{reference\ period}}{\textbf{Overall standard deviation}_{reference\ period}}$$

The indicator value is based on the number of data points from the test area which fall within the acceptable deviation range that has been set for each monthly point of the reference growth curve. Percentage-based thresholds are established for each dominating group to determine index values for the assessment of the ecological status:

$$\textbf{Index value}_{\,assessment\ period} = \frac{\textbf{No. of data points within the reference envelope}}{\textbf{Overall no. of observations}}$$

An R-script has been developed for calculating the indicator; however it has not yet been sufficiently tested.

Assessment units

The indicator should be applicable for the entire Baltic Sea. The set of dominating algal groups may vary between different sub-basins. For example cyanobacteria do not belong to the dominants in high salinity areas.

The characteristics for this indicator are different in different sea areas of the Baltic Sea, and require derivation of assessment unit specific reference conditions and GES-boundaries. The indicator values may also differ between the coastal and open sea zone within the same sub-basin. The intention is to make the assessment unit areas as large as possible without including areas of completely different characteristics. Tentatively, HELCOM assessment unit Level 3 dividing the Baltic Sea into 17 sub-basins and further into coastal areas is used.

Data of the southern Gulf of Finland and estuarine part of the Curonian Lagoon are obtained from different stations within one coastal water body. Data of the Gulf of Riga are pooled from different stations belonging to 3 coastal water bodies. Data from the open Gulf of Riga are also aggregated from several stations. In the Gulf of Gdansk, in the freshwater part of the Curonian Lagoon and in Stockholm archipelago, data from single stations are used. The sampling covered all vegetation period. Data from the Baltic Proper are not yet tested, but available for at least three HELCOM assessment units. There are coastal data available from two stations in the northern Gulf of Finland, from one station in the Archipelago Sea, and from two stations in the Gulf of Bothnia, but these monitoring data sets have not been tested yet. The assessment units are defined in the HELCOM Monitoring and Assessment Strategy Annex 4.

Relevance of the indicator

Biodiversity assessment

The status of the food webs is assessed using several core indicators. Each indicator focuses on one important aspect of the complex issue. In addition to providing an indicator-based evaluation of the "Seasonal succession of dominating phytoplankton groups", this indicator will also contribute to the next overall food webs assessment to be completed in 2018 along with the other biodiversity core indicators.

Policy Relevance

The proposed core indicator is among the few indicators able to evaluate the structure of the Baltic Sea food web with known links to lower and higher trophic levels. Assessments on the structure and functioning of the marine food web are requested by the Baltic Sea Action Plan (BSAP) and the EU Marine Strategy Framework Directive (MSFD).

The BSAP ecological objective 'Thriving and balanced communities of plants and animals' calls for balanced communities, which has a direct connection to the food web structure. The background document to the Biodiversity segment of the BSAP describes a target for this ecological objective as 'By 2021 all elements of the marine food webs, to the extent that they are known, occur at natural and robust abundance and diversity'.

The EU MSFD lists a specific qualitative descriptor for the food webs: 'All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity.'

Role of phytoplankton in the ecosystem

In aquatic ecosystems, a hierarchical response across trophic levels is commonly observed; that is, higher trophic levels may show a more delayed response or a weaker response to eutrophication than lower ones. Measurements of biomass (rather than abundance) were used to develop this indicator, since they can readily be translated into understanding biogeochemical cycles, they link to eutrophication, and are considered to give a more accurate depiction of the phytoplankton community.The succession of phytoplankton has a rather regular pattern and the initial events like vernal blooms may also influence the formation of summer communities. Firstly, the dominance of either diatoms or dinoflagellates in spring period determines the rate of sinking organic matter and subsequent oxygen consumption in bottom sediments. The diatoms settle out quickly and cause oxygen depletion, which may in turn launch the release of phosphorus from sediments and favour the phytoplankton, which benefits by excessive P, especially diazotrophic cyanobacteria blooms (e. g. Eilola et al., 2009).

The succession of functional groups can provide an index that represents a healthy planktonic system, with a natural succession of dominant functional groups throughout the seasonal cycle. Deviations from the normal seasonal cycle, such as a too high or too low biomass, absence or appearance of some dominating groups at unusual time period of the year may indicate an impairment in environmental status.

Human pressures linked to the indicator

	General	MSFD Annex III, Table 2
Strong link	"the most important anthropogenic threat to phytoplankton is eutrophication"	Nutrient and organic matter enrichment - inputs of fertilizers and other nitrogen and phosphorous-rich substances - inputs of organic matter
Weak link	Biological disturbance (introduction of non-native species)	

The shift in the plankton community is most probably due to complex interactions between warming, eutrophication and increased top-down pressure due to overexploitation of resources, and the resulting trophic cascades. A shift in functional groups may affect ecosystem function in terms of the carbon available to higher trophic levels or settling to the sediments. The examination of seasonality shows the broad temporal variability of phytoplankton populations. Succession of dominant groups can potentially provide an index that represents a healthy planktonic system, with a natural progression of dominant functional groups throughout the seasonal cycle. Alterations in the seasonal cycle may be related to nutrient enrichment. Expert judgement must be used when alterations in the seasonal cycle, and their causes, are interpreted.

Monitoring requirements

Monitoring methodology

HELCOM common monitoring of the phytoplankton community is described in general terms in the HELCOM Monitoring Manual in the programme topic: Phytoplankton. The methods for sampling, sample analysis and calculation of carbon biomass are described in the COMBINE manual. The COMBINE manual guidelines are under review for inclusion in the HELCOM Monitoring Manual during 2015.

For time-series calculations, it is important to have as regular datasets as possible. At least monthly sampling during the vegetation period is needed to design reference growth curves. If sampling dates or numbers of samples are very irregularly distributed, monthly means have to be calculated before further analysis. If historical datasets are not available, time-series data should be collected during at least 10 years to include natural interannual variability. The data must represent the upper mixed layer. Ferrybox data can be additionally used assuming that that the sampling depth (usually 4–5 m) represents the upper surface layer as the ship creates turbulence when moving.

Current monitoring

Sufficiently frequent sampling is seldom available through monitoring programmes (see also Heiskanen et al., 2016). Moreover, the open sea monitoring activities of many countries have been reduced during the last years. This is in some areas (Gulf of Finland, Northern Baltic Proper) compensated by increasing activities of sampling by ferrybox systems. A detailed scheme of stations and sampling times of recent monitoring activities cannot be given at the moment.

The indicator is operational as:

- A monitoring program for getting the samples is established (HELCOM COMBINE)

- Samples are taken and processed according to guidelines (COMBINE manual)
- Data are delivered by experts belonging to the HELCOM Phytoplankton Expert Group (PEG) and are therefore of high quality
- The data are regularly reported and stored in national and international databases (ICES)

Description of optimal monitoring

The interval of sampling should be regular and the frequency at least once a month during the vegetation period. In some areas, especially offshore, it can be reached also by ferrybox sampling. The time-scale for data sets should be at least 10 years to create type- or site-specific reference growth curves. No recommendations for spatial resolution have been given at the moment.

Data and updating

Access and use

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

HELCOM (2016) Seasonal succession of dominating phytoplankton groups**.** HELCOM core indicator report. Online. [Date Viewed], [Web link].

ISSN 2343-2543

Metadata

The methods of collection, counting and identification should be unified between all laboratories sharing the same assessment area. Data has been collected directly from the persons responsible for phytoplankton monitoring, no common database was used. The ICES database is not comfortable to use for this task as it does not contain biomass values of dominating groups. To extract and calculate 3 or 4 values for each sample using the ICES database requires a lot of extra work. Probably it will be more efficient to contact the partners (TMa and HELCOM Phytoplankton Expert Group – PEG) directly for the original data.

The indicator can be updated either annually or after every 5–6 years to detect reliable trends in seasonal dynamics on phytoplankton dominant group level.

Contributors and references

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