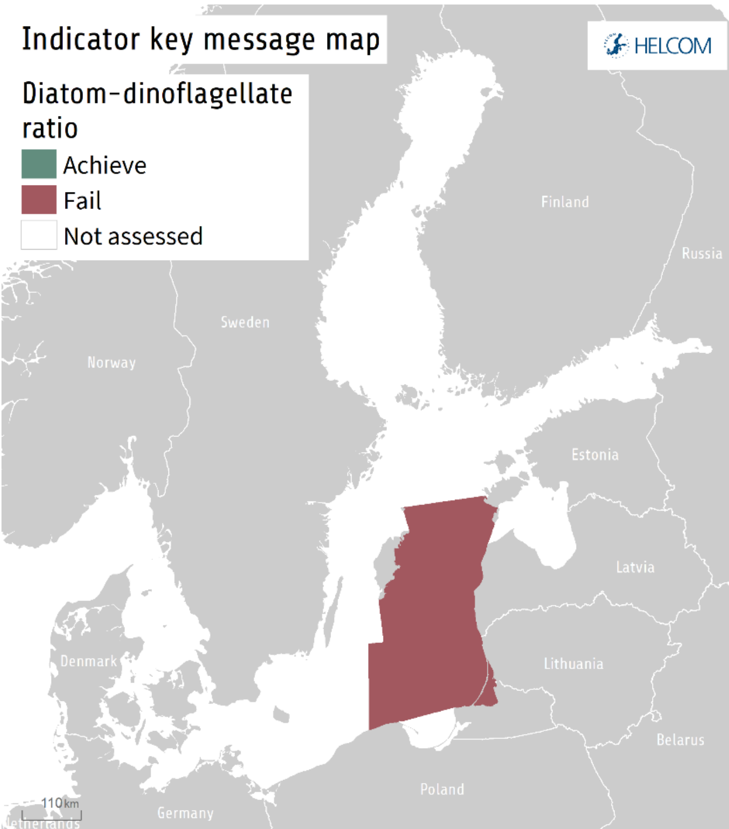
HELCOM pre-core indicator report
July 2018

Diatom/Dinoflagellate index

Key Message

This pre-core indicator and its threshold values are yet to be commonly agreed in HELCOM.
The indictor is included as a test indicator for the purposes of the 'State of the Baltic Sea' report, and the results are to be considered as intermediate.

The Diatom/Dinoflagellate index (Dia/Dino index) reflects the dominance patterns in the phytoplankton spring bloom. It has high relevance for the pathway of the food into the pelagic or benthic food web. In principle, the indicator is applicable in all coastal and open sea assessment units, except lagoons, large river plumes and the Bothnian Bay; however, thresholds for the good status are defined only for the southern and central Baltic Sea up to now.



Key message figure 1. Preliminary status assessment of the Eastern Gotland Basin based on the ratio of diatoms and dinoflagellate biomass for spring during the assessment period 2011-2016. This current test evaluation is carried out at HELCOM assessment scale 2 (HELCOM Monitoring and Assessment Strategy Attachment 4). **Click here to access interactive maps at the HELCOM Map and Data Service:** Diatom-Dinoflagellate index**.**

The indicator is not yet agreed as a HELCOM core indicator but is currently being tested in the HOLAS II project for the Eastern Gotland Basin only. In this assessment unit, good status was just missed, that means the average Dia/Dino index of the years 2011-2016 was below the threshold value of 0.5.

The confidence of the indicator evaluation depends on the data frequency. The data have to represent the diatom and dinoflagellate blooms adequately. If the diatom bloom is not sufficiently represented in the data, an alternative Dia/Dino index may be applied, based on silicate consumption data. This indicator is robust; its calculation is simple and traceable. The phytoplankton monitoring is operational in the whole Baltic Sea using methods prescribed in the COMBINE manual. Currently, a high quality of the data is assured by the experts of the HELCOM Phytoplankton Expert Group (PEG).

Relevance of the core indicator

Phytoplankton is the key primary producer in marine ecosystems, and diatoms and dinoflagellates are dominating groups in spring. They play a decisive role as food for higher trophic levels. Shifts in the diatom/dinoflagellate ratio may have high relevance for the nutrition of zooplankton and the following trophic levels. They influence even the benthos as diatom blooms sink quickly down and contribute more food to zoobenthos than dinoflagellates, which stay longer in the water column. The Dia/Dino index is primarily a descriptive trend indicator for changes in the food web. Moreover it may indicate silicate limitation which is an effect of eutrophication.

Policy relevance of the pre-core indicator

	BSAP Segment and Objectives	MSFD Descriptors and Criteria
Primary link	Eutrophication and biodiversity segment. Thriving and balanced communities of plants and animals	D4 - Food webs D4C1 The diversity (species composition and their relative abundance) of the trophic guild is not adversely affected due to anthropogenic pressures.
Secondary link	Natural Distribution and occurrence of plants and animals.	D1 - Food webs D1C6 The conditions of the habitat type, including its biotic and abiotic structure and its functions (e.g. its typical species composition and their relative abundance, absence of particularly sensitive or fragile species or species providing a key function, size structure of species), is not adversely affected due to anthropogenic pressures.
Other relevant legislation: In some coastal waters also Water Framework Directive		

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Diatom-Dinoflagellate index HELCOM pre-core indicator 2018 (pdf)

Results and Confidence

This pre-core indicator and its threshold values are yet to be commonly agreed in HELCOM.
The indictor is included as a test indicator for the purposes of the 'State of the Baltic Sea' report, and the results are to be considered as intermediate.

The evaluation is based on phytoplankton data of the spring period (March-May) from the upper mixed layer (Results table 1). Precondition for a valid calculation is a check whether the spring bloom is sufficiently represented in the data. The biomass of diatoms or dinoflagellates has to exceed a threshold of 1000 µg/L at least once. If this is not achieved, the calculation of an “alternative” Dia/Dino index, based on silicate consumption, may be applied, as described by Wasmund et al. (2017). As seen from Results table 1, the bloom was always sufficiently represented during the assessment period from 2011 to 2016.

Results table 1. Maximum and mean biomass of diatoms and dinoflagellates in the years of the assessment period.

Year	Seasonal maximum of diatoms (µg/L)	Seasonal maximum of dinoflagellates (µg/L)	Seasonal mean of diatoms (µg/L)	Seasonal mean of dinoflagellates (µg/L)
2011	3182.2	540.5	785.6	184.6
2012	756.9	1500.1	126.2	356.5
2013	1410.0	1537.6	276.0	405.6
2014	2778.5	835.7	355.1	206.1
2015	1232.6	4446.9	107.7	538.8
2016	4587.6	1886.4	463.2	469.9

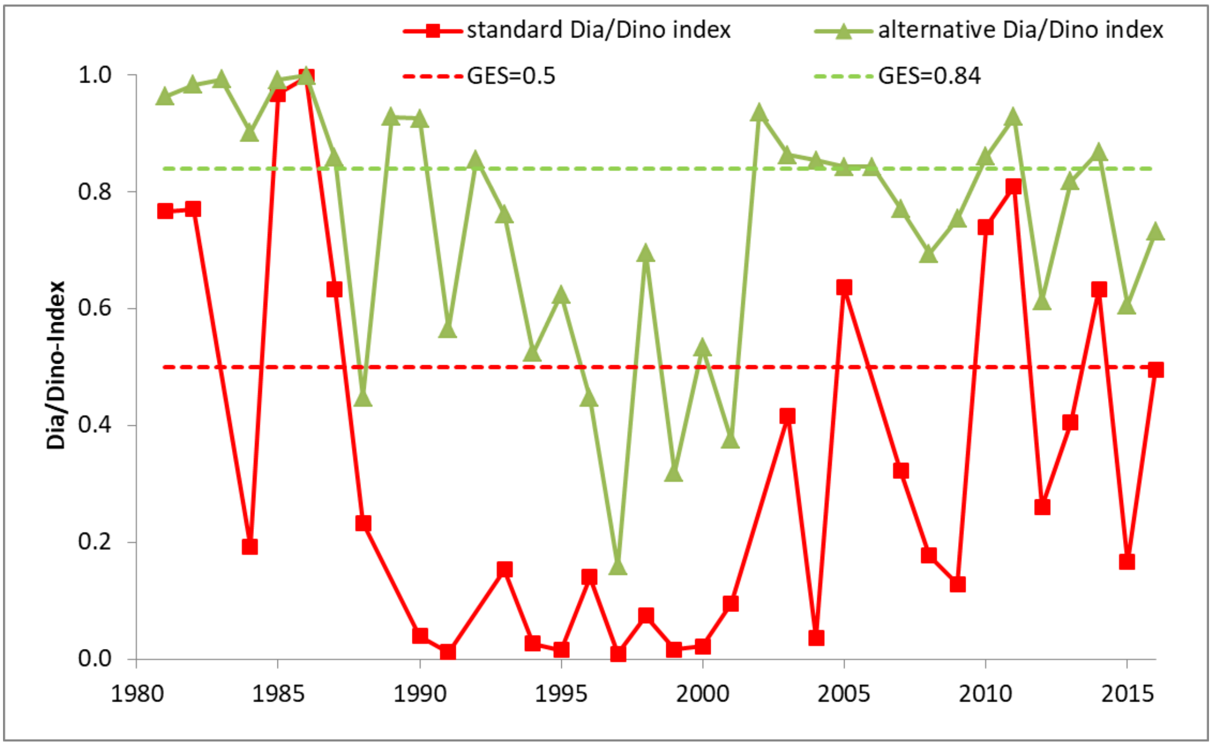
The good status is defined at a Dia/Dino index > 0.5. It was failed in 2012, 2013, 2015, 2016, and in the total average over the assessment period (Results table 2.)

Results table 2. Dia/Dino index in the Eastern Gotland Basin, separated for the years of the assessment period. Number of data points per season are given as “n”.

Year	n	Indicator value	Status
2011	12	0.81	achieve
2012	23	0.26	fail
2013	17	0.40	fail
2014	17	0.63	achieve
2015	21	0.17	fail
2016	21	0.50	fail
Average 2011-2016		**0.46**	**fail**

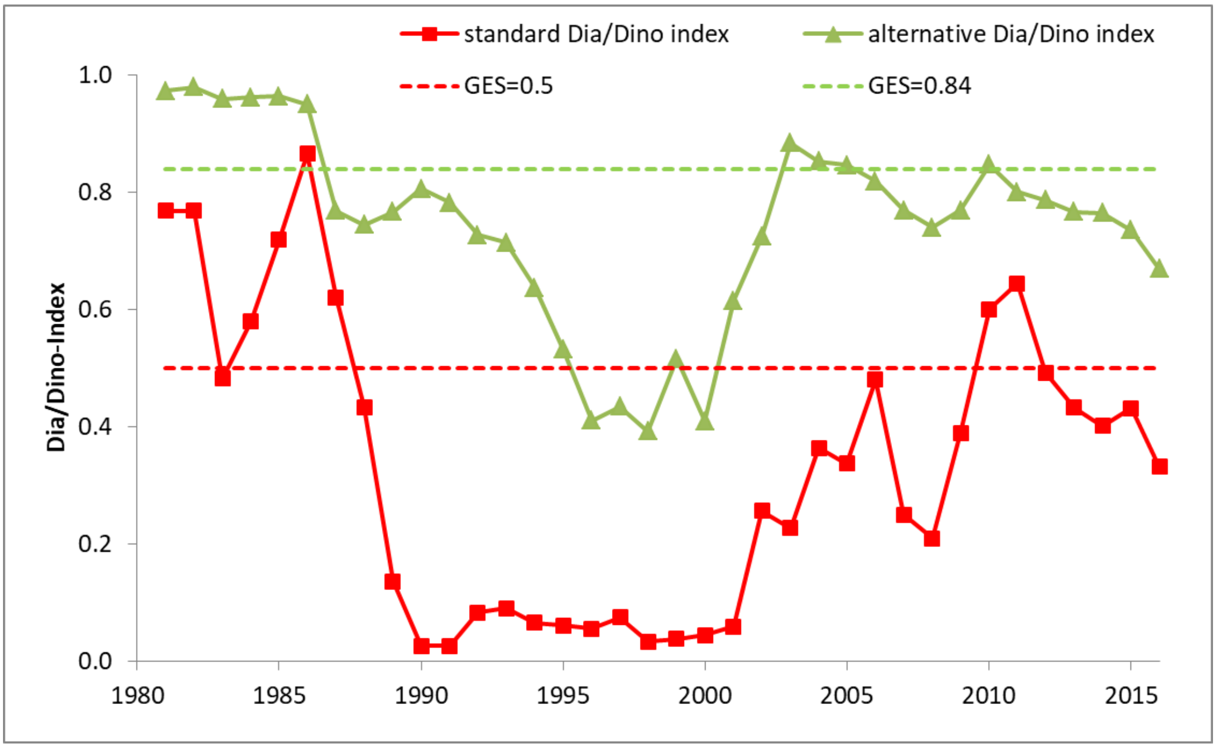
Additional information on temporal trends

Temporal trends provide additional information on the spread and variability of the Dia/Dino index. The original data for each year from 1981 to 2016 is shown in Results figure 1 (red line). It reveals a high variability. The spread over the entire potential range from 0 to 1 indicates the high sensitivity of this indicator. If the spring bloom was missed by the routine sampling, i.e. biomass of diatoms or dinoflagellates was smaller than 1000 µg/L, the use of the standard Dia/Dino index was not allowed. In that case, the alternative Dia/Dino index (green line) may be tried. It has to be noted, that its threshold for the good status is higher (in this case at 0.84). Also in years of extreme outliers that failed the good status, the alternative Dia/Dino index may be checked. This applies, for example, to the year 1984, when the standard Dia/Dino index indicated a bad status whereas the status may be still good according to the alternative Dia/Dino index. The alternative Dia/Dino index should only be used in exceptional and justified cases.



Results figure 1. Annual values of the standard Dia/Dino index and the alternative Dia/Dino index from 1981 to 2016. Dashed lines indicate the thresholds for the good status. GES = Good status.

For trend analyses, the curves should be smoothed, for example by using the 3-year moving average as shown in Results figure 2. By this processing, the strong decline of diatom blooms, as discovered by Wasmund et al. (1998), becomes obvious. After the very bad status in the 1990s concerning the diatom blooms (cf. also Klais et al. 2011), the system recovered under high fluctuations. On average, it still did not reach the good status.



Results figure 2. 3-year moving average of the standard Dia/Dino index and the alternative Dia/Dino index from 1981 to 2016. Dashed lines indicate the thresholds for the good status. GES = Good status.

Confidence of the indicator status evaluation

The indicator confidence depends on the data basis. The Dia/Dino index is based on data of the dominating phytoplankton groups, diatoms and dinoflagellates, that are more robust than those of rare phytoplankton groups. Moreover, these groups are easily to identify even without specific expert knowledge. This makes the original phytoplankton data robust.

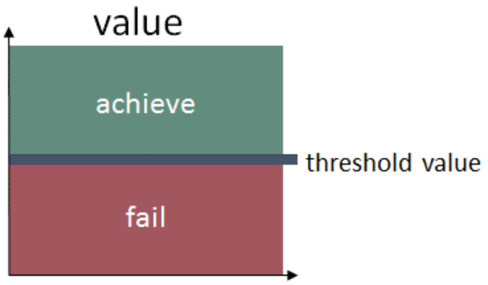
As seen from Results table 1, the bloom was always sufficiently represented during the assessment period from 2011 to 2016. The number of data points in each year is sufficient (see Results table 2). The standard Dia/Dino index can additionally be checked by an alternative method based on silicate data. As both methods result in the same evaluation for each year and show the same trends during the assessment period, the confidence of the assessment is considered to be **high**.

Thresholds and Status evaluation

This pre-core indicator and its threshold values are yet to be commonly agreed in HELCOM.
The indictor is included as a test indicator for the purposes of the 'State of the Baltic Sea' report, and the results are to be considered as intermediate.

The Working Group on Good Environmental Status (European Commission, 2015) recommended a common approach, based on the reference condition plus acceptable deviation, for determining environmental status. According to them, "reference state can be defined using a variety of methods, including historic conditions, based on various evidence about conditions before there was significant anthropogenic activity."

The Dia/Dino index belongs to the few indicators that can be calculated already for the early 20th century, when anthropogenic impact was low. Quantitative phytoplankton analyses date back to that time and were compiled by Wasmund (2017). The derivation of threshold values from historical data was explained by Wasmund et al. (2017). A deviation of 20% from the historical Dia/Dino index was allowed and therefore suggested as threshold. In that paper, a threshold value for the Eastern Gotland Basin of 0.5 was suggested, which marks just the value of balanced (1:1) diatom and dinoflagellate biomass. Suggestions for thresholds values in other assessment units of the southern Baltic Sea were already made by Wasmund et al. (2016). These threshold values have already been accepted by HELCOM (2016).



Thresholds figure 1. Schematic representation of the threshold value for the indictor "Dia/Dino index", that is just 0.5 in the Eastern Gotland Basin.

Diatom dominance over dinoflagellate dominance is typical in the spring blooms of the Baltic Sea according to historical data (Wasmund 2017). Therefore, diatom dominance, i.e. standard Dia/Dino index >0.5, is typical for a non-impacted ecosystem and considered as good status.

The derivation of the threshold value for the alternative Dia/Dino index is described by Wasmund et al. (2017).

Assessment Protocol

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The analysis required for the indicator evaluation is that the biomass of planktonic diatoms is divided by the biomass of autotrophic (+ mixotrophic) dinoflagellates. In order to let this indicator range from 0 to 1, the ratio is calculated as follows:

$$\text{Dia/Dino index} = \frac{\text{Biomass of diatoms}}{\text{Biomass of diatoms} + \text{Biomass of dinoflagellates}}$$

The following conditions have to be fulfilled for the analysis to be valid:

- The data must be based on a representative sample of the upper mixed water layer (see Note 1)
- Only the autotrophic (inclusive mixotrophic) part of the pelagic community has to be included (see Note 2)
- The biomass has to be given in wet weight (see Note 3)
- Seasonal mean values have to be inserted into the formula (see Note 4)
- The Dia/Dino index refers only to the spring season (see Note 5)
- The spring biomass maxima of diatoms or dinoflagellates have to exceed a threshold (see Note 6)

Note 1: For practical reasons, a representative sample from the upper mixed layer irrespective of the sampling depth should be sufficient. Only in spring, the upper mixed layer is rather deep and comprises the whole euphotic (trophogenic) layer. Deep chlorophyll maxima, frequently formed by dinoflagellates, seem to rarely occur in spring. The influence of day-time is low, and thus the time of day need not be considered in the sampling guidelines.

Note 2: Diatoms are always considered as autotrophic, but dinoflagellates may also be mixotrophic or heterotrophic. The mode of nutrition is difficult to identify. Pigmented dinoflagellates are considered as autotrophs. Even the chloroplasts are sometimes hard to recognize. The bloom-forming dinoflagellates of the spring (*Peridiniella catenata, Biecheleria baltica, Gymnodinium corollarium, Scrippsiella hangoei*; cf. Klais et al. 2013) are autotrophs. A minor error in a few doubtful dinoflagellates will not affect the index.

Note 3: The biomass in the numerator and denominator has to be given in the same units. Wet weight or carbon units can be used, but as carbon data are frequently lacking in older data, wet weight is preferred. If carbon units are used the Dia/Dino index is skewed. As large diatoms have a big vacuole that contains only little organic carbon, the Dia/Dino index will be lower in comparison with that based on wet weight. However, especially in spring, when small diatoms dominate, the deviation is not as large as in other seasons and may be acceptable.

Note 4: If sampling dates or numbers of samples are very irregularly distributed during the spring months, monthly means have to be calculated before seasonal means are calculated from the monthly means.

Note 5: The Dia/Dino index reflects the conditions during the spring bloom because this is the most prominent bloom in the annual cycle. The strongest effect of eutrophication (new nutrients) and global warming is expected in spring. Other arguments for using spring data are given in Note 3. Spring is defined as the period from March to May in the Baltic Proper.

Note 6: It has to be assured that the bloom was met. We suggest a biomass threshold of 1000 µg/L which has to be exceeded either by the diatoms or the dinoflagellates as a criterion. If this value is missed, the standard Dia/Dino index must not be calculated.

Note 7: Missing the diatom bloom may have two consequences: (1) The regular Dia/Dino index cannot be calculated because the threshold was missed (Note 6) or (2) the biomass threshold is just passed but the Dia/Dino index is unusually low nevertheless. In that case the diatom biomass can be calculated on the basis of silicate consumption as originally suggested by Wasmund et al. (2013). The resulting alternative Dia/Dino index is calculated as follows:

$$\text{Dia/Dino index} = \frac{[\text{Si(max)} - \text{Si(min)}] * 100\ [\mu\text{gC /L}]}{[\text{Si(max)} - \text{Si(min)}] * 100\ +\ \text{wet weight}\ [\mu\text{g /L}]\text{of dinoflagel.} * 0.13}$$

The alternative Dia/Dino index is normally higher than the standard Dia/Dino index because the silicate consumption estimates the maximal possible diatom biomass (cf. Results figure 1). Therefore, different good status values have to be derived.

Assessment unit

For the time being, this assessment is made only for the Eastern Gotland Basin.

Relevance of the Indicator

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Food web assessment

The Dia/Dino index is the only indicator that analyses the pathway of pelagic nutrients and biomass in the food web. Diatoms tend to sink quickly down after the bloom and feed the benthos whereas dinoflagellates stay in the pelagial for a longer time and contribute to the pelagic food web (see below). Changes in the Dia/Dino index indicate changes in the conditions for the nutrition of higher trophic levels. According to historical data, a high Dia/Dino index, i.e. diatom dominance, indicates a good status. While sinking, diatoms remove nutrients from the open water and therefore contribute to mitigation of eutrophication.

Policy relevance

Assessments on the structure and functioning of the marine food web are requested by the Baltic Sea Action Plan (BSAP) and the MSFD. This indicator may be applied to the Marine Strategy Framework Directive (MSFD), primarily for descriptor 4 (Food web). As it deals with the principal pelagic food basis in spring, it establishes a link to the higher trophic levels both in the pelagic and the benthic communities. A sort of diatom/dinoflagellate-ratio is already considered by OSPAR, as described in Results. It may have importance in the whole ICES area. The ICES-Working Group on Phytoplankton and Microbial Ecology (WGPME) discussed this ratio and will consider it in the planned "ICES phytoplankton and microbial plankton status report". The recent status report is available at http://wgpme.net/status-report-now.

This indicator may also contribute to descriptor 5 (Eutrophication) in the case on ongoing eutrophication that may lead to silicate limitation. It will react very sensitively to that limitation. Eutrophication is one of the four thematic segments of the HELCOM Baltic Sea Action Plan (BSAP) with the strategic goal of having a Baltic Sea unaffected by eutrophication.

Role of diatoms and dinoflagellates in the ecosystem

Phytoplankton are an important component of the food web in aquatic ecosystems and influences the global carbon cycle significantly (e.g. Smetacek 1999). Diatoms and dinoflagellates are the main components of the phytoplankton community not only in the Baltic Sea but also in the oceans. Their biomass can reach 6 g/m^3 or more in the Baltic Proper.

Strong changes in the diatom/dinoflagellate ratio in spring blooms in the southern Baltic Proper were discovered by Wasmund et al. (1998) and identified by Alheit et al. (2005) as regime shifts. Such regime shifts are of high concern as they impact the whole food web. A dinoflagellate to diatom ratio has already been suggested "to reflect ecosystem state and the quality of the phytoplankton community as food for zooplankton" in the GES-REG project final report on food web indicators, September 2013 (Uusitalo et al. 2013, p.9).

The phytoplankton spring bloom does not only feed the pelagic food web, but sinks partly to the bottom where it feeds the benthic food web. Diatoms are much more susceptible to sedimentation than dinoflagellates and therefore the main contributor of organic matter to the benthos (Heiskanen 1998). Thus the Dia/Dino index may indicate whether the food substances stay primarily in the pelagial or are exported to the benthal. An indicator of the pathway of the food is of high interest for assessing the status of the environment.

Phytoplankton reacts directly to eutrophication by biomass increase, reflected in an increase in chlorophyll-*a* concentrations, which is already approved as a core indicator. The search for indicator species for eutrophication was not successful. However, the Dia/Dino index may have an indicator function based on the silicate requirement of diatoms. Eutrophication is mainly caused by anthropogenic input of nitrogen and phosphorus but not silicate. As silicate concentrations decrease with eutrophication, this nutrient may become the limiting nutrient for diatom growth (Danielsson et al. 2008). The Dia/Dino index will be able to indicate severe silicate limitation provoked by eutrophication.

Human pressures linked to the indicator

	General	MSFD Annex III, Table 2a
Strong link	Eutrophication by phosphorus and nitrogen leads to relative silicate shortage that may limit diatom growth and support unwanted flagellates. However, recently no Si limitation is expected.	Inputs of fertilisers and other nitrogen and phosphorus-rich substances (e.g. from point and diffuse sources, including agriculture, aquaculture, atmospheric deposition).
Weak link	The Dia/Dino index is related to the minimum winter temperature: mild winters inhibit diatoms.	Significant changes in thermal regime (e.g. by outfalls from power stations).

Monitoring Requirements

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Monitoring methodology

Monitoring of phytoplankton biovolume according to the **HELCOM Monitoring Manual**.

Current monitoring

The monitoring activities relevant to the indicator, that are currently carried out by HELCOM Contracting Parties are described in the **HELCOM Monitoring Manual** 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**. For this indicator, only samples from the upper mixed layer from spring are necessary. For the alternative Dia/Dino index, also silicate data are required.

These data are already taken in the running COMBINE monitoring. Also additional data from research projects can be included if the methods prescribed in the **HELCOM Monitoring Manual** are used. Unfortunately, the open sea monitoring activities of many countries have been reduced during the last years.

The indicator is operational as:

- A monitoring programme 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 data banks (ICES)

Description of optimal monitoring

In fact, the Dia/Dino index has simply to reflect whether the spring bloom is dominated by diatoms or by dinoflagellates. The sampling schedule has to ensure that the duration and magnitude of the spring bloom has been captured adequately. Weekly sampling would be optimal, resulting in 12 samples per station during spring. This number is reached as shown in Results table 2. However, sampling occasions are frequently clustered, leading to gaps despite a high number of samples. Therefore, samples have to be evenly distributed over the time and to be taken at different stations that are representative for the area. Also samples from ships-of-opportunity and from research projects can be included if quantitatively analyzed according to the **HELCOM Monitoring Manual**. The contribution of data from all contracting parties is necessary to reach a sufficient data coverage.

Data and updating

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Access and use

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

HELCOM (2018) Diatom/Dinoflagellate index. HELCOM pre-core indicator report. Online. [Date Viewed], [Web link].

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Metadata

Result: Diatom-Dinoflagellate index

Data: Diatom-Dinoflagellate index

Data source: The data of the HELCOM Contracting Parties are kept in the HELCOM COMBINE database, hosted by ICES (www.ices.dk). However, it turned out that the data are incomplete. Therefore, the original data were directly received from the contributors (see below). The evaluation of the southern part of the Eastern Gotland data was supported by the National Marine Fisheries Research Institutes (NMFRI) statutory activity and Polish National Environmental Monitoring (PMŚ). Further data originated from the Leibniz Institute of Baltic Sea Research Warnemünde (IOW), Swedish Meteorological and Hydrological Institute, Västra Frölunda (SMHI), Estonian Marine Institute, University of Tartu (EMI), and Environmental Protection Agency, Department of Marine Research, Klaipeda.

Description of data: The basic data are phytoplankton biomass data, determined as explained in the HELCOM COMBINE manual, originating from the depth of 0 – 10 m. Also silicate data were used that were taken parallel to the phytoplankton sampling.

Temporal coverage: The assessment period comprised the years 2011-2016. From each year, spring data (March to May) were used. For silicate information, also data from February were considered.

Data aggregation: If original data were strongly skewed in temporal respect, monthly means were calculated first as a basis for seasonal means. The data from different stations were pooled.

Contributors and references

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Archive

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

Diatom-Dinoflagellate index HELCOM pre-core indicator 2018 (pdf)

Earlier versions of this indicator are available at:

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

References

Alheit,J., C. Möllmann, J. Dutz, G. Kornilovs, P. Loewe, V. Mohrholz and N. Wasmund (2005). Synchronous ecological regime shifts in the central Baltic and the North Sea in the late 1980s. ICES J. Mar. Sci. 62: 1205-1215.

European Commission (2015). Review of the GES Decision 2010/477/EU and MSFD Annex III – cross-cutting issues (version 4). GES_13-2015-02. Available online at: https://circabc.europa.eu/d/a/workspace/SpacesStore/53b2e4e2-2921-468a-941f-499811ee12f9/GES_13-2015-02_GESDecisionReview_Cross-cuttingIssues_v4.doc

Heiskanen, A.-S. (1998). Factors governing sedimentation and pelagic nutrient cycles in the northern Baltic Sea. Monographs of the Boreal Environmental Research 8, 1-80.

HELCOM (2016). Outcome of the fifth meeting of the Working Group on the State of the Environment and Nature Conservation (State & Conservation 5-2016). Available online at: https://portal.helcom.fi/meetings/STATE%20-%20CONSERVATION%205-2016-363/MeetingDocuments/Final%20Outcome%20State%20and%20Conservation%205-2016.pdf

Klais, R., T. Tamminen, A. Kremp, K. Spilling and K. Olli (2011). Decadal-Scale Changes of Dinoflagellates and Diatoms in the Anomalous Baltic Sea Spring Bloom. PLoS ONE 6(6): e21567. doi:10.1371/journal.pone.0021567

Klais, R., Tamminen, T., Kremp, A., Spilling, K., An, B.W., Hajdu, S., et al. (2013). Spring phytoplankton communities shaped by interannual weather variability and dispersal limitation: Mechanisms of climate change effects on key coastal primary producers. Limnol. Oceanogr. 58, 753-762.

Smetacek, V. (1999): Diatoms and the ocean carbon cycle. Protist 150: 25-32. Uusitalo, L., H. Hällfors, H. Peltonen, M. Kiljunen, P. Jounela and E. Aro (2013). Indicators of the Good Environmental Status of food webs in the Baltic Sea, GES-REG project final report on food web indicators, September 2013.

Uusitalo, L., H. Hällfors, H. Peltonen, M. Kiljunen, P. Jounela and E. Aro (2013). Indicators of the Good Environmental Status of food webs in the Baltic Sea, GES-REG project final report on food web indicators, September 2013.

Wasmund, N., G. Nausch and W. Matthäus (1998): Phytoplankton spring blooms in the southern Baltic Sea - spatio-temporal development and long-term trends. J. Plankton Research 20: 1099-1117.

Wasmund, N., Nausch G. and Feistel, R. (2013): Silicate consumption: an indicator for long-term trends in spring diatom development in the Baltic Sea. Journal of Plankton Research 35: 393-406; doi: 10.1093/plankt/fbs101

Wasmund, N., Göbel, J., Jaanus, A., Johansen, M., Jurgensone, I., Kownacka, J., et al. (2016). "Pre-core indicator 'Diatom-Dinoflagellate index' – proposal to shift status to core indicator". Document to the meeting of the HELCOM Working Group of the State of the Environment and Nature Conservation (STATE&CONSERVATION 5-2016), 7.-11.11.2016, Tallinn. Available online at: https://portal.helcom.fi/meetings/STATE%20-%20CONSERVATION%205-2016-363/MeetingDocuments/4J-6%20Pre-core%20indicator%20%E2%80%98Diatom-Dinoflagellate%20index%E2%80%99%20%E2%80%93%20proposal%20to%20shift%20status%20to%20core%20indicator.pdf

Wasmund, N., Kownacka, J., Göbel, J., Jaanus, A., Johansen, M., Jurgensone, I., Lehtinen, S., Powilleit, M. (2017): The diatom/dinoflagellate index as an indicator of ecosystem changes in the Baltic Sea. 1. Principle and handling instruction. Frontiers in Marine Science 4 (22): 1-13. doi: 10.3389/fmars.2017.00022 http://journal.frontiersin.org/article/10.3389/fmars.2017.00022/full?&utm_source=Email_to_authors_&utm_medium=Email&utm_content=T1_11.5e1_author&utm_campaign=Email_publication&field=&journalName=Frontiers_in_Marine_Science&id=235096

Wasmund, N. (2017): The diatom/dinoflagellate index as an indicator of ecosystem changes in the Baltic Sea. 2. Historical data for use in determination of good environmental status. Frontiers in Marine Science 4 (153): 1-12. doi: 10.3389/fmars.2017.00153 http://journal.frontiersin.org/article/10.3389/fmars.2017.00153/full?&utm_source=Email_to_authors_&utm_medium=Email&utm_content=T1_11.5e1_author&utm_campaign=Email_publication&field=&journalName=Frontiers_in_Marine_Science&id=247098

Additional relevant publications

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