Document title	Chlorophyll-a spring bloom
Code	3J-52
Category	DEC
Agenda Item	3J-Progress of relevant HELCOM expert groups and projects
Submission date	13.9.2021
Submitted by	Secretariat

Background

The document below provides a template filled by indicator leads to provide an overview of progress to STATE & CONSERVATION 15-2021. Key aspects such as methodologies, spatial extent changes, assessment scales and threshold values are presented, identifying ongoing work and other relevant issues towards HOLAS III. This process builds on the prior review of indicator development carried out under STATE & CONSERVATION 14-2021 (summarised in document 4J-16 Rev.1, and detailed within numerous documents under agenda item 4J). The focus of these development works is the completion of indicator development and adjustment work for HOLAS III by the end of 2021, as previously agreed under HOD 57-2019 (document 4-20, Outcomes paragraph 4.51).

The aspect of threshold values in particular is a key issue as threshold value approval will be carried out at HOD 61-2021, with these same templates being submitted to HOD at the same stage as submission to State and Conservation 15-2021 (to allow for the longer national processes required that culminate in approval at HOD).

The document below addresses a single indicator and as well as the generic 'action requests' relating to endorsement of the proposed application in HOLAS III (and the threshold values proposals, where relevant), specific additional requests or statements are also indicated within the separate sections of the document to help guide where further input/discussion/guidance may be needed.

This template aims to report the indicator development for HOLAS III, allowing for technical guidance and endorsement by STATE & CONSERVATION 15-2021 and also simultaneously to facilitate the threshold value approval process by HOD 61-2021.

Action requested

The Meeting is invited to:

- provide further technical guidance to the indicator leads and experts, including specific requests defined within the document;
- consider and endorse the proposed developments of the indicator for use in the HOLAS III assessment.

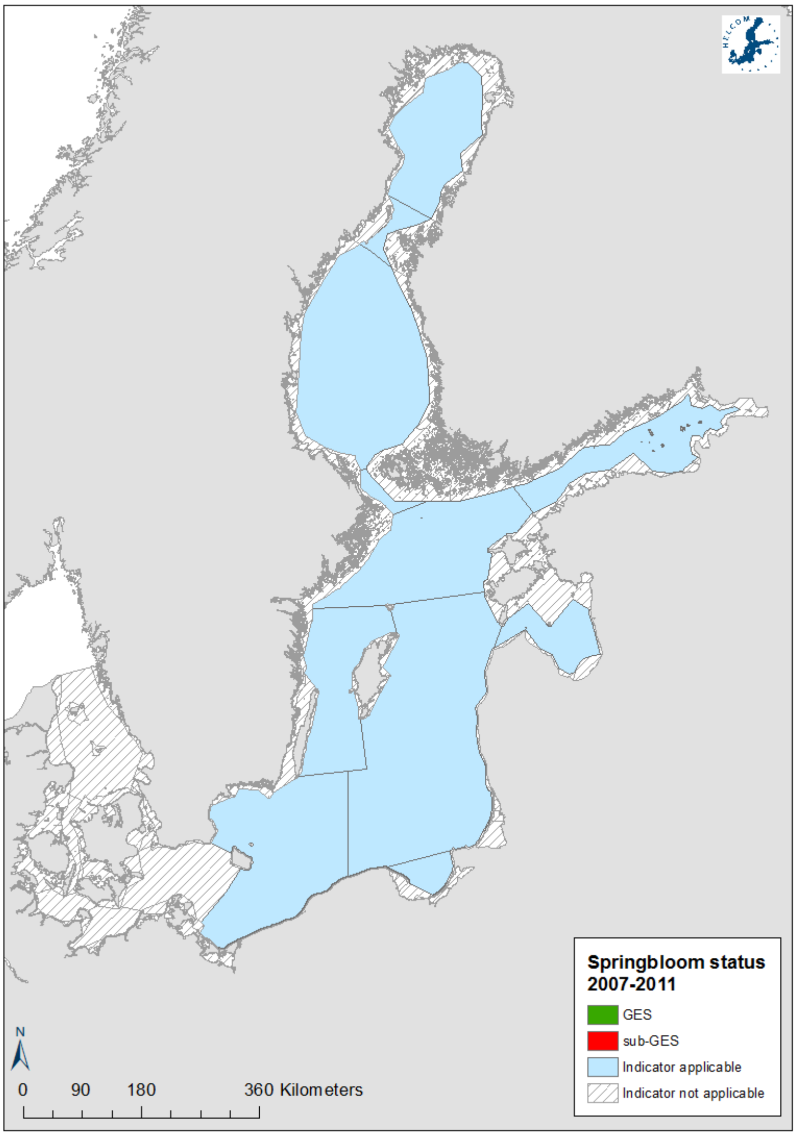
Chlorophyll-a spring bloom

Indicator name
Chlorophyll-a spring bloom. Proposed as pre-CORE indicator, potentially to be tested in HOLAS III. Indicator lead: Finland.
Scale of assessment for HOLAS III and rational
Assessment scale 4, applied for eutrophication indicators.
Spatial coverage of the indicator for HOLAS III
SEA-007 Bornholm Sea SEA-008 Gdansk Basin SEA-009 Eastern Gotland Basin SEA-010 Western Gotland Basin SEA-011 Gulf of Riga SEA-012 Northern Baltic Proper SEA-013A Gulf of Finland West SEA-013B Gulf of Finland East SEA-014 Åland Sea SEA-015 Bothnian Sea SEA-016 The Quark SEA-017 Bothnian Bay The possibilities for extending the spatial coverage to assessment units SEA-001…006 can be investigated.
Methodology to be applied for HOLAS III and rational
The spring bloom indicator is an attempt to describe the total biomass of the phytoplankton spring bloom. It is the function of the extent and duration of the spring bloom. The extent is defined as the daily level of chlorophyll-*a* concentration; in monitoring data this is approximated as a seven-day moving average. The duration is the time between the day when the average chlorophyll-a concentration exceeds 5 μgL^{-1} and the day when it descends below it for the last time during the spring months. When updating the indicator with monitoring data, results from HELCOM 20K grid cells have to be averaged, since the timing of the bloom varies considerably within the assessment units. See indicator report for more information.
Threshold value setting logic and rational
The will be determined through model simulations, investigating the following approaches: 1) Hindcast estimates of the total biomass of the phytoplankton spring bloom as a function of time, extending to 1920-40. This provides information on what the level of spring bloom was during a pre-eutrophied period. 2) Estimate of the total biomass of the phytoplankton spring bloom as a function of the dissolved inorganic phosphorus- and nitrogen concentrations at the surface (0-10 m) during the preceding winter months (Dec-Feb). If such information is not available, hindcast estimates of the winter nutrient concentrations as a function of time. This information is used to investigate what the chlorophyll-a spring bloom was when the nutrient indicators are at the levels of their thresholds of Good Environmental Status.
Threshold value(s)
Possible - underway

Other significant issues that need to be addressed or presented to State and Conservation
Dataflows are in place at the eutrophication assessment database hosted by ICES, and will be further improved by the Baltic Data Flow project
Latest indicator report or (for new indicators) initially completed indicator template
Please sea Annex 1 for the indicator report.

Spring bloom intensity based on chlorophyll-*a*

Key message



The indicator is applicable in open sea sub-basins, but still under development (light blue). In principle, the indicator can be developed for all areas where satellite data during the spring season is achieved. However, at its present stage, the indicator development does not cover the Kattegat, the Danish Sounds or coastal areas (striped).

The target for the spring bloom intensity is still under development. It is planned to be derived through ecosystem modelling.

The confidence of the spring bloom status estimate is generally high due to the large amount of satellite observations.

Relevance of the pre-core indicator

Spring bloom indicator is used as a proxy of phytoplankton total biomass during the spring period. Phytoplankton increases along with increased eutrophication, as a result of increased nutrient concentrations. The indicator also reflects changes in the phytoplankton annual succession as a result of changes in food web, hydrography and climate change affect the indicator.

Policy relevance of the pre-core indicator

	Primary importance	**Secondary importance**
BSAP Segment and Objective	Eutrophication: natural level of algal blooms	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

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Cite this indicator

[Author's name(s)], [2015]. [Indicator name]**.** HELCOM core indicator report. Online. [Date Viewed], [Web link].

Indicator concept

Good Environmental Status

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

Table 1. Summary table of assessment unit specific GES-boundaries in the open-sea areas (to be developed further)

HELCOM_ID	Basin	Target (µg l−1)
SEA-001	Kattegat	NA
SEA-002	Great Belt	NA
SEA-003	The Sound	NA
SEA-004	Kiel Bay	NA
SEA-005	Bay of Mecklenburg	NA
SEA-006	Arkona Sea	NA
SEA-007	Bornholm Sea	Under progress
SEA-008	Gdansk Basin	Under progress
SEA-009	Eastern Gotland Basin	Under progress
SEA-010	Western Gotland Basin	Under progress
SEA-011	Gulf of Riga	Under progress
SEA-012	Northern Baltic Proper	Under progress
SEA-013	Gulf of Finland	Under progress
SEA-014	Åland Sea	Under progress
SEA-015	Bothnian Sea	Under progress
SEA-016	The Quark	Under progress
SEA-017	Bothnian Bay	Under progress

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 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. 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 development of the spring bloom index developed by Fleming and Kaitala (2006). At present, EO data is utilized but work on updating spring bloom index utilizing Alg@line data is under progress.

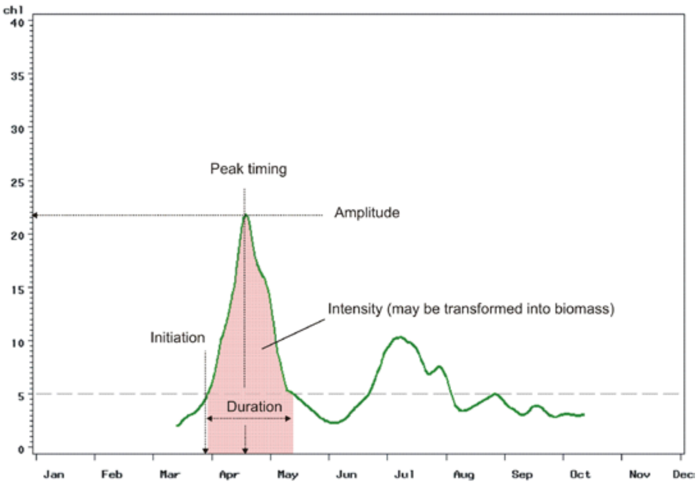

Figure 2. The properties of the spring phytoplankton bloom in the western Gulf of Finland in 2009, characterized from a time series of chlorophyll-a concentration. The intensity is defined as integral of the chl-a concentrations during the spring bloom period (Fleming and Kaitala, 2006).

The spring bloom indicator method was originally developed for MARMONI project study areas 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 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.

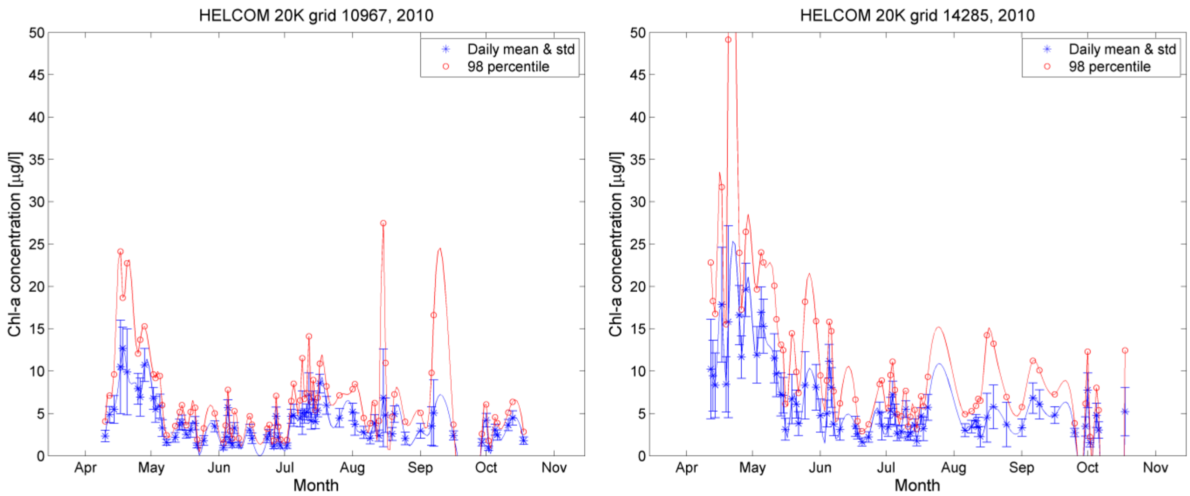

Figure 3. Example of time series of mean, standard deviation (blue stars and bars) and 98 percentile (red dots) chl-a observations by MERIS (years 2010) produced for HELCOM 20km grids, 10967 and 14285. Both grids represent Gulf of Finland. The lines are interpolated daily values obtained using non-cloudy 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 bodies.

Figure: HELCOM assessment areas.

Relevance of the indicator

Policy Relevance

Eutrophication is one of the four thematic segments of the HELCOM Baltic Sea Action Plan (BSAP) with the strategic goal of having a Baltic Sea unaffected by eutrophication (HELCOM 2007). Eutrophication is defined in the BSAP as a condition in an aquatic ecosystem where high nutrient concentrations stimulate the growth of algae which leads to imbalanced functioning of the system. The goal for eutrophication is broken down into five ecological objectives, of which one is "natural levels of algal blooms". Increase in phytoplankton can be assessed using chlorophyll-a depth as a proxy. The spring bloom indicator integrates the spring bloom period chl-a concentrations to index values that are comparable for different years.

The EU Marine Strategy Framework Directive (Anonymous 2008) requires that "human-induced eutrophication is minimized, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algal blooms and oxygen deficiency in bottom waters" (Descriptor 5). "Chlorophyll concentration in the water column" is listed as an indicator for assessing the criterion for "direct effects of nutrient enrichment" (5.2).

The EU Water Framework Directive (Anonymous 2000) requires good ecological status in the European coastal waters. Good ecological status is defined in Annex V of the Water Framework Proposal, in terms of the quality of the biological community, the hydrological characteristics and the chemical characteristics, including chlorophyll-a. For the time being, spring bloom period is not taken into account in WFD reporting, but the use of EO data enables this in the future.

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.

Results and confidence

Spring bloom intensity was estimated for the following sub-besins: Bornholm Sea, Gdansk Basin, Eastern Gotland Basin, Western Gotland Basin, Gulf of Riga, Northern Baltic Proper, Gulf of Finland, Åland Sea, Bothnian Sea, the Quark and Bothnian Bay. At present, the GES boundary has not yet been estimated, and thus indicator status is not comparable between sub-basins. The results will be updated once the GES-boundaries are estimated.

The work continues with complementing calculations to cover the HELCOM grid based spring bloom indicator for the periods 2003-2005 and 2010-2011. In addition, Alg@line data can be used as complementary data source in areas where EO data is not available (mostly cloudy periods). There is on-going study for using modelling approach to determine GES.

The indicator can utilize observations of the forthcoming EO instruments (e.g. OLCI instrument onboard Sentinel 3a satellite by European Space Agency, estimated to be launched on late 2015). After OLCI data becomes operationally available, the spring bloom indicators can be calculated for years 2016 on.

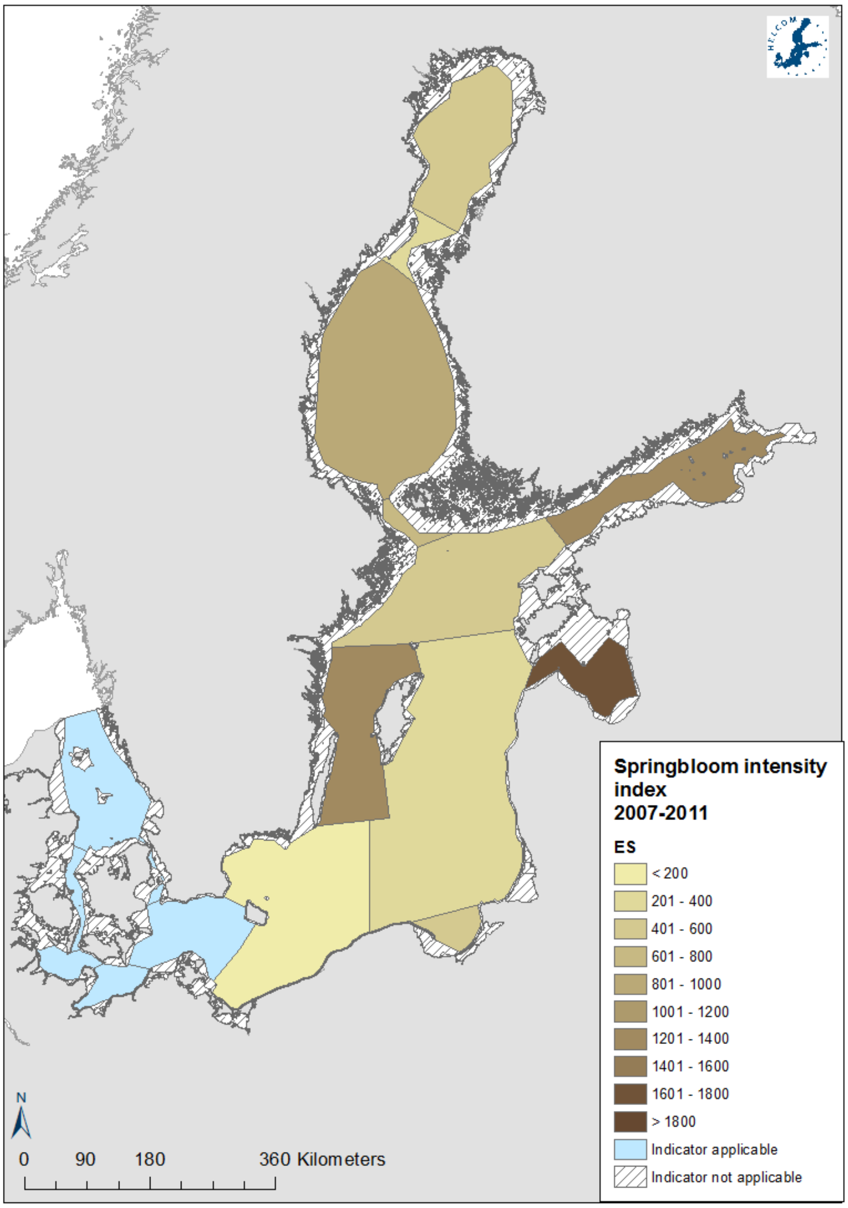

Table 2: Information on GES targets, present concentration and status (GES / Sub-GES). The information will be updated once targets have been estimated and agreed.

HELCOM_ID	Sub-basin	Target (μg l^{-1})	Average 2007-2011 (μg l^{-1})	Eutrophication ratio, ER	STATUS
SEA-001	Kattegat	no suitable data	-	-	-
SEA-002	Great Belt	no suitable data	-	-	-
SEA-003	The Sound	no suitable data	-	-	-

SEA-004	Kiel Bay	no suitable data	-	-	-
SEA-005	Bay of Mecklenburg	no suitable data	-	-	-
SEA-006	Arkona Sea	no suitable data	-	-	-
SEA-007	Bornholm Sea	under progress	89,89	under progress	under progress
SEA-008	Gdansk Basin	under progress	493,72	under progress	under progress
SEA-009	Eastern Gotland Basin	under progress	341,71	under progress	under progress
SEA-010	Western Gotland Basin	under progress	1217,37	under progress	under progress
SEA-011	Gulf of Riga	under progress	1680,82	under progress	under progress
SEA-012	Northern Baltic Proper	under progress	418,75	under progress	under progress
SEA-013	Gulf of Finland	under progress	1383,15	under progress	under progress
SEA-014	Åland Sea	under progress	651,41	under progress	under progress
SEA-015	Bothnian Sea	under progress	800,32	under progress	under progress
SEA-016	The Quark	under progress	344,05	under progress	under progress
SEA-017	Bothnian Bay	under progress	525,74	under progress	under progress

Temporal trends

The longest time series on spring bloom intensity index can be derived from Alg@line data (Figure 2) 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 reliable determination of chl-a concentrations during spring bloom period using EO data is possible from year 2003 on. Once the time series of 2003-2011 are ready, the trends and status based on the trend will 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.

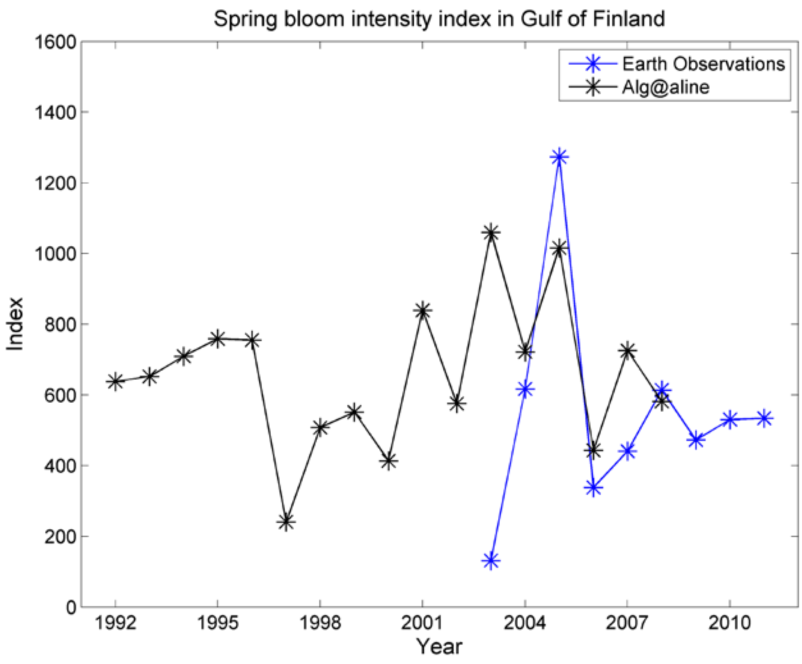

Figure. The development of spring bloom indicator on the Gulf of Finland using EO and Alg@line measured chl-a concentrations during 1992-2011. Black line represents Alg@line intensity index and blue line EO (MERIS data) intensity index. Figure represents the earlier version of spring bloom indicator (MARMONI project).

Confidence of the indicator status evaluation

[confidence map will be inserted]

The indicator confidence was estimated through confidence scoring of the target (ET-Score) and the indicator data (ES-Score). The ET-Score was rated based on the uncertainty of the target setting procedure. The ES-Score is based on the number as well as spatial and temporal coverage of the observations for the assessment period 2007-2011. To estimate the overall indicator confidence, the ET- and ES-Scores were combined. See Andersen et al. 2010 and Fleming-Lehtinen et al. 2015 for further details.

Monitoring requirements

Monitoring methodology

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 late 2015) onboard Sentinel 3A satellite.

Optimal monitoring

For assessment purposes, at least 15 observations should be conducted during the period December-February made every winter in each assessment unit. The compilation of observations is expected to be distributed spatially within the assessment unit in a non-biased way.

Current monitoring

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. In principle, MODIS instrument data can be used for the period 2012-2015, but has not been tested for the time being.

Description of data and updating

Metadata

Data source: The EO dataset used for deriving spring bloom intensity indexes is based on MERIS time series (years 2003-2011). The dataset is available, processed and archived at SYKE. MERIS L1A reprocessing version 3 was used as input data (available from EOLI-SA service by ESA (https://earth.esa.int/web/guest/eoli). MERIS L1A reflectances were processed to chl-a concentrations using a BEAM blug-in processor MERIS Case-2 Water Properties Processor, FUB (version beam-wew-water-1.2.10, Schroeder et al., 2007). The original geo-location information of MERIS data was complemented with AMORGOS 3.0 (Accurate MERIS Ortho-Rectified Geo-location Operational Software, by ACRI). Images are available in EUREF (WGS84) coordinates system. Cloud masking was performed semi-automatically by first using Beam MERIS cloud processor (v1.5.203), modified to use only "ocean" neural network type on the Baltic Sea. The cloud mask was quality-checked and complemented manually when necessary. The ground resolution of the instrument is 300 m.

Description of data: Spring bloom intensities can be calculated annually for each HELCOM 20 km grid and jointly for the assessment area. In addition to the intensity index indicator value, also annual mean chl-a concentration for the spring bloom period is suggested to be added to the database.

Geographical coverage: Baltic Sea, most of the observations are on the northern Baltic Sea. Geographic coordinates (WGS84) Latitude [58.747 66.020] Longitude [15.465 30.986]

Temporal coverage: The EO data includes observations made between April - October, during the period 2003 - 2011.

Data aggregation: Spring bloom estimate has been calculated using daily MERIS data. The daily observations (pixels) have been aggregated to daily statistics for each HELCOM 20 km grid. Spring bloom indicator is defined for each grid. In addition, the annual indicator value is aggregated from the grid based indexes for each assessment area.

Arrangements for updating the indicator

For update of future eutrophication assessments, the HELCOM EUTRO-OPER is concentrating in streamlining the process from data reporting to indicator and assessment update. The indicator can be updated annually after the spring bloom period.

Publications and archive

(Archive)

- pdf of this and older versions of the indicator

Publications used in the indicator

Ferreira, J.G., Andersen, J.H., Borja, A., Bricker, S.B., Camp, J., Da Silva, M.C., Garcés, E., Heiskanen, A.S., Humborg, C., Ignatiades, L. 2011. Overview of eutrophication indicators to assess environmental status within the European Marine Strategy Framework Directive. Estuar. Coast. Shelf Sci. 93,117-131

Fleming and Kaitala 2006. Phytoplankton spring bloom intensity index for the Baltic Sea estimated for the years 1992 to 2004. Hydrobiologia 554:57-65.

Gohin, F., Saulquin, B., Oger-Jeanneret, H., Lozac'h, L., Lampert, L., Lefebvre, A., Riou, P., Bruchon, F., 2008. Towards a better assessment of the ecological status of coastal waters using satellite-derived chlorophyll-a concentrations. Remote Sensing of Environment, 112, 3329-3340.

Platt T., Sathyendranath S., (2008). Ecological indicators for the pelagic zone of the ocean from remote sensing, Remote Sensing of Environment 112 (2008), 3426–3436.

Platt T., Sathyendranath S., Forget M.-H., White III G. N., Caverhill C., Bouman H., Devred E., Son SH., (2008).Operational estimation of primary production at large geographical scales, Remote Sensing of Environment, 112, 3437–3448.

Schroeder T., Schaale M., Fischer J., (2007). Retrieval of atmospheric and oceanic properties from MERIS measurements: A new Case-2 water processor for BEAM. International Journal of Remote Sensing, 28 (24), 5627–5632. http://dx.doi.org/10.1080/01431160701601774.

Verliin, A., Auniņš, A., Jaanus, A., Kuresoo, A., Stīpniece, A., Lappalainen, A., Ruuskanen, A., Minde, A., Müller-Karulis, B., Amid, C., Kokkonen, E., Gorokhova, Ē., Krūze, E., Martin, G., Sundblad, G., Piepponen, H., Hällfors, H., Nygard, H., Bārda, I., Jurgensone, I., Attila, J., Näslund, J., Kotta, J., Lesutiene, J., Kaljurand, K., Torn, K., Kostamo, K., Jürgens, K., Herkül, K., Uusitalo, L., London, L., Saks, L., Luigujoe, L., Nilsson, L., Rostin, L., Alberte, M., Lehtiniemi, M., Anttila, M., Vetemaa, M., Ogonowski, M., Kallasvuo, M., Koskelainen, M., Pärnoja, M., Kurkilahti, M., Demereckiene, N., Wijkmark, N., Heikinheimo, O., Klais, R., Svirgsden, R., Anttila, S., Hällfors, S., Lehtinen, S., Junttila, S., Strake, S., Möller, T., Talvik, Ü., Jermakovs, V., Fleming-Lehtinen, V. 2015. List of developed and proposed indicators for the assessment of marine biodiversity in the Baltic Sea. In: Martin, G., Fammler, H., Veidemane, K., Wijkmark, N., Auniņš, A., Hällfors, H., Lappalainen, A. (eds.) The MARMONI approach to marine biodiversity indicators : Volume II : List of indicators for assessing marine biodiversity in the Baltic Sea developed by the LIFE MARMONI Project. Tallinn, University of Tarto. P. 23-51. Estonian Marine Institute Report Series; 2014, 16. ISBN 978-9985-4-0873-5 (print), 978-9985-4-0874-2 (pdf), ISSN 1406-023X