Name of indicator	## 3.3 Cyanobacterial surface accumulations - the CSA-index
Type of Indicator	State indicator
Author(s)	Saku Anttila, Jenni Attila and Vivi Fleming-Lehtinen
Description of the indicator	The indicator compares the recent (current) cyanobacterial surface accumulation characteristics with past observations. It is based on information on the yearly intensity, duration and temporal volume of cyanobacterial blooms in the Baltic Sea. Information from these indicative variables is normalized and combined to produce a Cyanobacterial Surface Accumulation index (CSA-index). The CSA-index time series is used to provide the indicator target condition (2003-2010) and the current status (years 2011-2013). The principal data source for the indicator is satellite remote sensing, but the indicator can be complemented with observations obtained using other monitoring methods. An example of this combination of different data sources is provided for the MARMONI FIN-EST study area (central and western Gulf of Finland), where Alg@line phycocyanin fluorescence measurements are utilized as an additional data source for the indicator.
Relationship of the indicator to marine biodiversity	The indicator reflects changes in the phytoplankton community. These changes are related to changes in nutrient composition and climate, and have direct impact on sea-use and ecosystem services. 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, Schmidt & Jónasdóttir 1997, 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*. 2007a). Thus extensive cyanobacterial blooms potentially have a negative impact on the biodiversity of both the pelagic and the benthic communities.
Relevance of the indicator to different policy instruments	The indicator has been listed as a Supplementary Indicator in the HELCOM CORESET of Biodiversity indicators (HELCOM 2012). Marine Strategy Framework Directive (MSFD) descriptors 1, 5. HELCOM Baltic Sea Action Plan (BSAP)
Relevance to commission decision criteria and indicator	1.6. Habitat condition 1.6.2. Relative abundance and/or biomass, as appropriate
Method(s) for obtaining indicator values	The main data source for the indicator is the time series of daily algal surface accumulation remote sensing products of the Finnish Environment Institute SYKE. It is based on chlorophyll *a* estimation product by SYKE. The remote sensing instruments used in the development of the indicator were MERIS (MEdium Resolution Imaging Spectrometer) and MODIS (MODerate Resolution Imaging Spectroradiometer). For the method development, we used MERIS data archives consisting of years 2003-2011 and MODIS data archives of years 2012-2013. The dataset was processed and is archived at the Finnish Environment Institute (SYKE). Chlorophyll *a* concentrations are derived from MERIS observations, i.e. measured reflectances, using a neural network-based bio-optical processor (FUB) that is developed at the Free University of Berlin (Schroeder *et al.* 2007a-b). Chlorophyll *a* concentrations from MODIS observations were derived using SeaDAS-software by NASA. During the period 2012-2013, the algorithm to derive chlorophyll *a* was both GSM (Maritorena *et al*. 2002, 2010) and standard OC4 algorithm (O'Reilly et al 1998, 2000). Annually, for each day during July-August period, the algal surface accumulation product is derived by first generalizing the original daily chlorophyll *a* estimation with three consequent moving window filtering procedures with differing filter sizes (minimum, median and maximum) and then categorizing the result into four classes (from no algal surface accumulations [0] to evident accumulations [3]; see Fig. 1). A similar classification is used in other algal accumulation observation approaches, including observations made on coast guard flights and by citizens. Examples on SYKE's standard remote sensing product of estimated algal surface accumulations can be found on (www.syke.fi/surfacealgalblooms).To describe and analyse the characteristics of annual algal surface accumulations, an algae barometer is calculated for each day where algae observations exist. The developed algae barometer value is a weighted sum of the proportion of algae observations in different

	classes in an assessment area (Eq 1; Rapala *et al*. 2012). $$AB = \frac{1}{n_{tot}} (n_{\#cl1} + n_{\#cl2} \times 2 + n_{\#cl3} \times 3) \quad \text{(Eq. 1)}$$ where n_{tot} is the total number of algae observations, and $n_{\#cl1}$, $n_{\#cl2}$, and $n_{\#cl3}$ are the number of observations in each class (class zero indicates no algae, and is thus not included in equation). Algae barometer values were calculated from the daily algal surface accumulation observations for the assessment areas (Fig. 2). The indicative variables i.e. yearly intensity, duration and temporal volume of cyanobacterial blooms are derived from the empirical cumulative distribution function (ECDF) of yearly observations of algae barometer values. ECDF gives the cumulative proportion for the yearly algae barometer values. From the yearly ECDFs, the indicative variables are derived as described in Fig. 3. - *Duration* of the accumulation period is defined as the percentage of observations with algae barometer values above zero (1-proportion value, horizontal line in Fig. 3). - *Intensity* as the 90-percentile of the algae barometer observations (vertical line in Fig. 3). - *Temporal volume* as the area above of the ECDF function. Each of the time series of annual indicative variables are normalized to an index by using the minimum and maximum observations in respective time series (e.g. Hering *et al.* 2006). Finally, normalized indexes are combined to the CSA-index by taking the yearly average (Fig. 4). The combination of different data sources can be performed in two ways. If complementary data are similarly classified algae observations as remote sensing algae observations, these can be added as such into the calculation of daily algae barometer values. In the case of a different type of observations, such as FerryBox fluorometer observations of phycocyanin, the data source can be combined in the calculation of the joint CSA-index by using specific weights for each data source. At the moment, expert judgment is used to specify weights for the data sources, but more quantitative methods are under development. In the MARMONI FIN-EST assessment area (central and western Gulf of Finland), normalized Alg@line phycocyanin yearly averages were included by using 50% weight when compared to remote sensing derived indicative variables. An example of this is provided in Fig. 5. The resulting CSA-index is a value between 0 and 1, where 1 represents the best conditions (i.e. few cyanophyte surface accumulations) and 0 the worst (i.e. extensive cyanophyte surface accumulations).
Documentation of relationship between indicator and pressure	Growth of nitrogen-fixing cyanobacteria gains advantage of excess phosphorus in the water column (Niemi 1979, Vahtera *et al*. 2007b, Raateoja *et al*. 2011). Thus phosphorus load, especially in a dominantly nitrogen-limiting environment, is estimated as the main pressure to the indicator.
Geographical relevance of indicator	2. Regional
How Reference Conditions (target values/thresholds) for the indicator were obtained?	The target value for each assessment area was derived from the time series of the CSA-index from the years 2003-2010. The target was simply the 75-percentile of the reference period's CSA-index values. In the case of the CSA-index where different types of cyanobacteria information were combined, the target setting required assumptions. Alg@line phycocyanin observations were available only from the year 2007 onwards. Therefore, the phycocyanin yearly averages of Alg@line data were assumed to have a generalized extreme value distribution. This distribution was found most suitable for the existing Alg@line yearly observations and can be rationalized also with expert judgment. The Alg@line target was thus the 75-percentile of the general extreme value distribution expected from the observations. Therefore, in the combined index case, the target was set as a weighted average, where the 75-percentile of remote sensing derived indicative variables were given equal weight, and the Alg@line target value contributed 50% weight compared to the remote sensing derived indicative variables. New method for the target setting based on historical observations is currently under development.
Method for determining GES	The current status of the indicator was calculated as the average CSA-index using the remote sensing data for the period of 2011-2013. This value was compared to the 75-

	percentile of CSA-index time series (2003-2010). GES is reached, if the current status is higher than the set target. The indicator may be extended to cover all the Baltic open sea and outer coastal assessment units.
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Illustrative material for indicator documentation

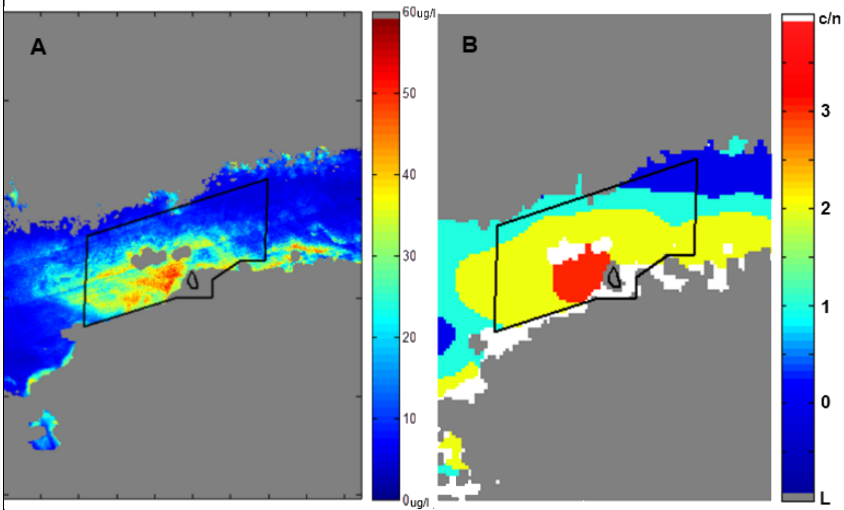

Figure 1. Examples of SYKE's remote sensing based chlorophyll *a* and surface floating algae accumulation products calculated from the MODIS/Aqua satellite data (NASA) on 19.7.2012.

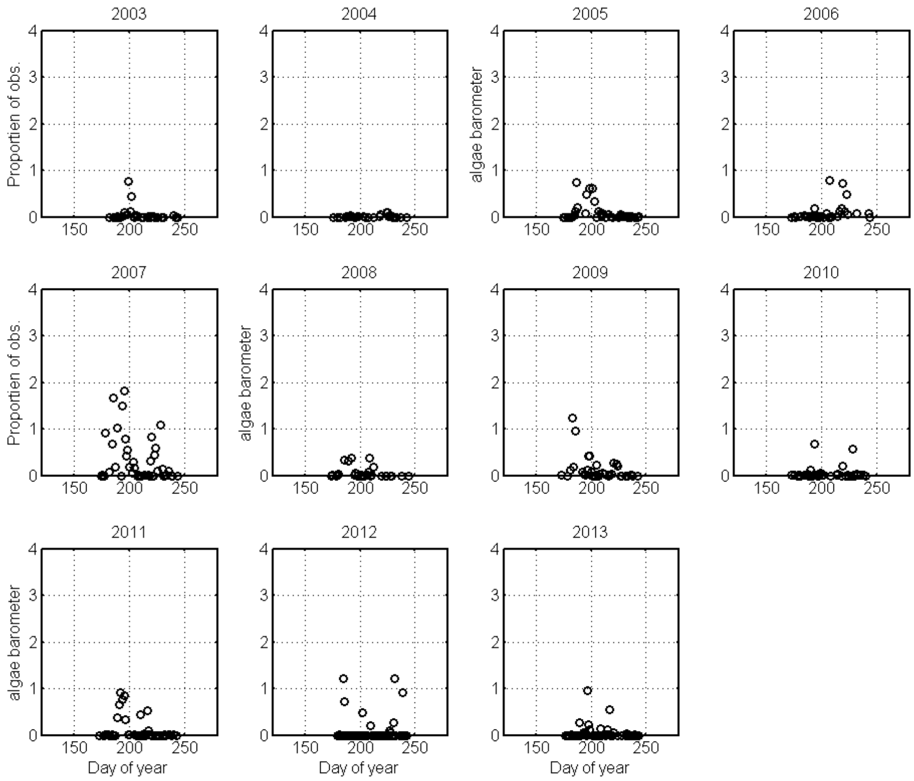

Figure 2. Algae barometer time series for the MARMONI FIN-EST area derived from the daily remote sensing observations.

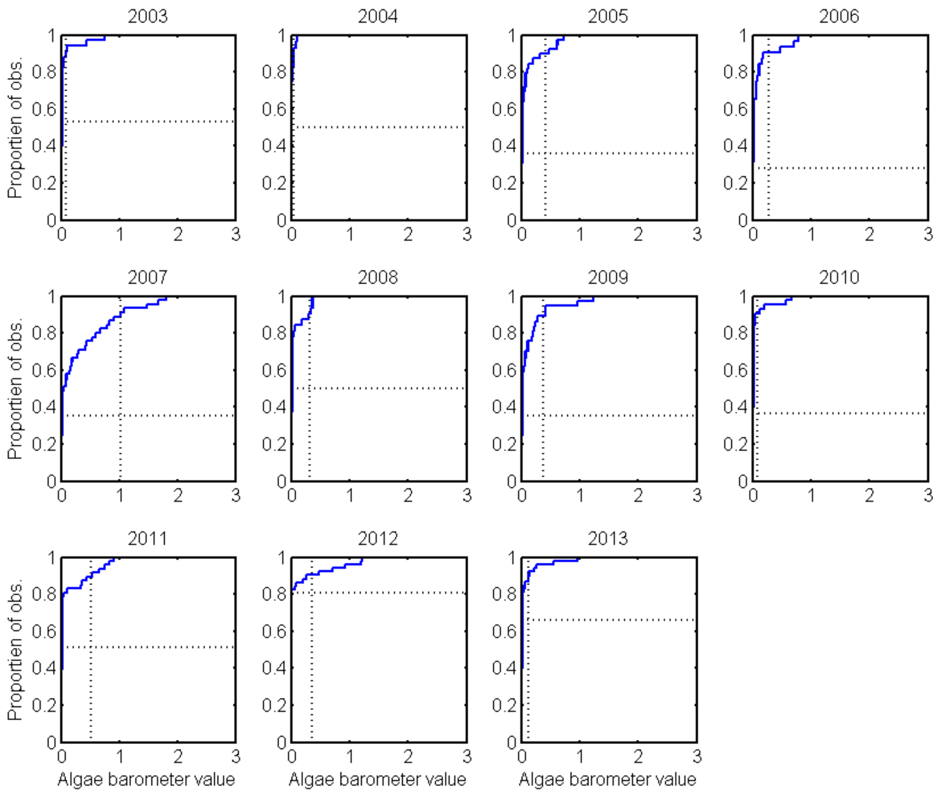

Figure 3. ECDFs derived from the algae barometer values of the years 2003-2013. Horizontal lines indicate the length of the algal surface accumulation periods and vertical

lines the 90-percentile of the algae barometer observations. The yearly volumes are derived from the areas above the ECDF function.

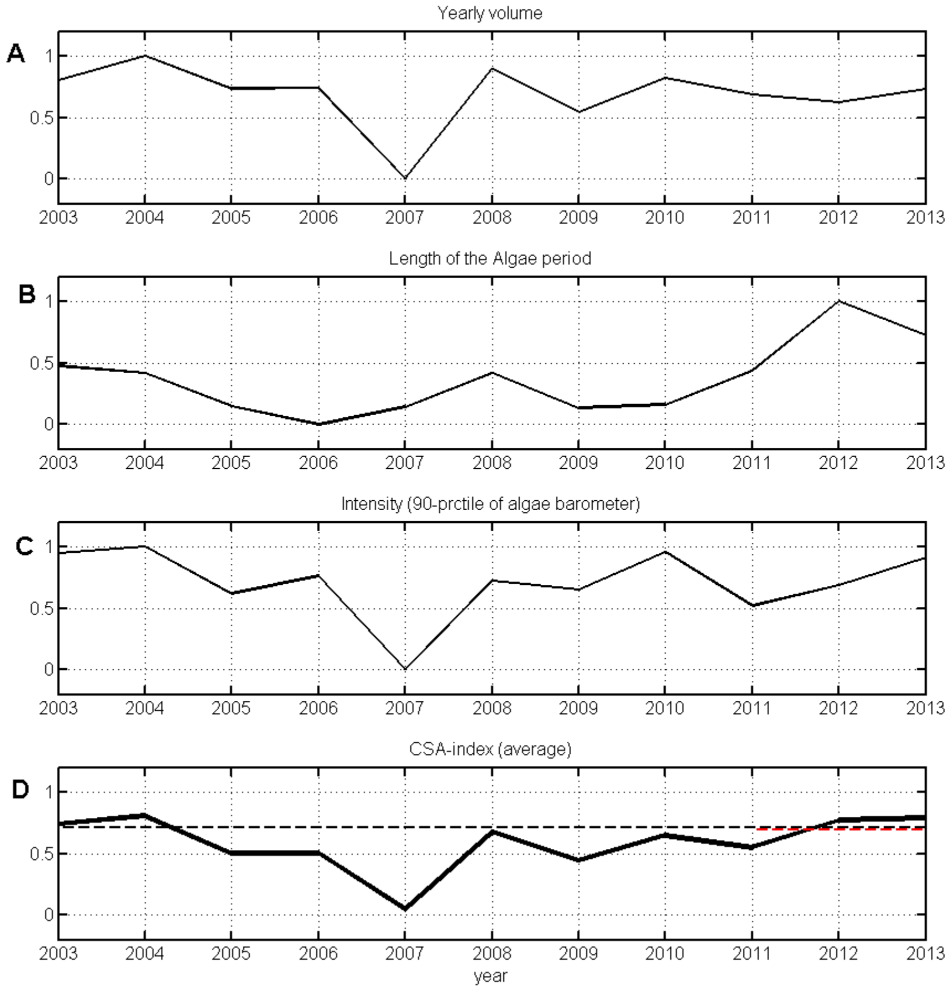

Figure 4. Normalized indicative variable time series derived from the ECDF-functions (A-C) and combined to the CSA-index (D) when only remote sensing data are used. Value 1 represents the best conditions and 0 the worst. Black dashed horizontal line in (D) indicates the target condition and red the current status. The data are from the MARMONI FIN-EST area.

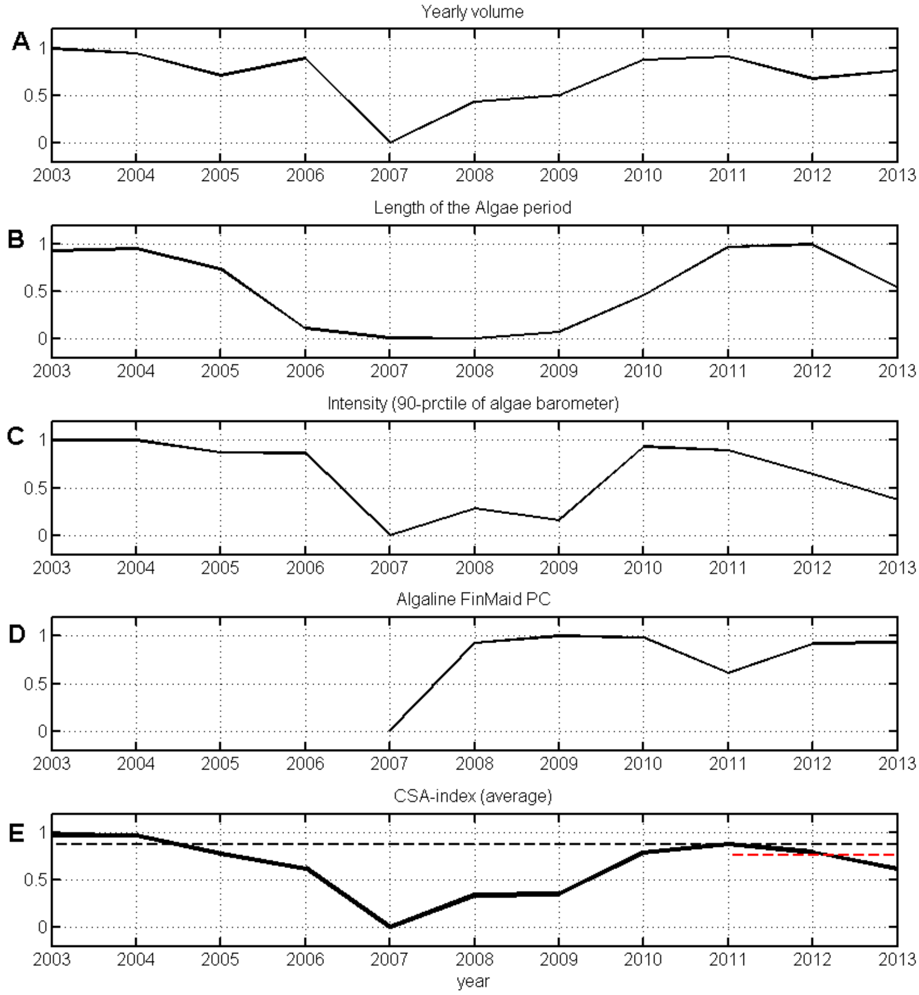

Figure 5. Normalized indicative variable time series derived from the ECDF-functions (A-C), normalized Alg@line yearly phycocyanin observations (D) and combined CSA-index (E). Value 1 represents the best conditions and 0 the worst. Black dashed horizontal line in (E) indicates the target condition and red the current status. Alg@line-data are given 50% weight in CSA-index when compared to remote sensing derived indicative variables. The data are from the MARMONI FIN-EST area.