Name of indicator	3.4 Phytoplankton taxonomic diversity (Shannon95)
Type of Indicator	State indicator
Author(s)	Laura Uusitalo, Vivi Fleming-Lehtinen, Heidi Hällfors, Andres Jaanus, Lauri London and Seija Hällfors
Description of the indicator	The indicator utilises the novel robust approach for detecting changes in the alpha diversity of phytoplankton described by Uusitalo *et al.* (2013). The biodiversity of phytoplankton, the key primary producers in the marine ecosystem, is often very difficult to estimate since the phytoplankton assemblage includes a vast number of taxa, many of which occur in so small quantities that they may not be recorded in routine sampling. Moreover, even a skilled taxonomist cannot identify all taxa to species level by the methods available within routine phytoplankton monitoring, i.e. light microscopy of preserved samples. This means that we will not, by routine phytoplankton monitoring methods, attain a complete list of phytoplankton species in the ecosystem at any given point in time. The Shannon95 method introduced by Uusitalo *et al*. (2013) circumvents the problem of rare (and thus unreliably recorded) taxa by computing the Shannon biodiversity index (Shannon 1948) from the taxa that cumulatively constitute 95% of the total phytoplankton biomass. The Shannon95 metric responds to the extent by which the community is dominated by just one or few taxa. The metric was originally developed for the open Gulf of Finland, and its applicability for other sea areas should be tested.
Relationship of the indicator to marine biodiversity	The indicator reflects the taxonomic diversity of the phytoplankton community. It has been shown that the more diverse the phytoplankton community, the more resistant it is to the changes caused by different pressures (Ptacnik *et al*. 2008).
Relevance of the indicator to different policy instruments	Through collaboration between MARMONI and the HELCOM CORESET project, the indicator has been agreed as a Candidate Indicator in the HELCOM CORESET of Biodiversity indicators (4.22 Phytoplankton diversity, HELCOM 2012). The Water Framework Directive (EU 2000), the Marine Strategy Framework Directive (EU 2008) and the HELCOM Baltic Sea Action Plan (HELCOM 2007) specifically mention phytoplankton as an ecological component to be addressed in the assessment of the ecological status of the sea. Marine Strategy Framework Directive descriptor 1, criterion 1.6 Habitat condition, 1.6.1. Condition of the typical species and communities.
Relevance to commission decision criteria and indicator	1.6. Habitat condition 1.6.1. Condition of the typical species and communities
Method(s) for obtaining indicator values	Principle: The alpha diversity of phytoplankton is estimated using an applied Shannon's index, called the Shannon95, where the Shannon biodiversity index is computed for each sample based on the main body of phytoplankton biomass, i.e. the taxa that cumulatively constitute 95% of the total phytoplankton biomass (Uusitalo *et al.* 2013). The Shannon95 metric responds to the extent by which the community is dominated by just one or few taxa. Indicator value: The 75-percentile of all the Shannon95 observations during each summer (June–September) was used as the annual indicator value (Figure 1). The higher fractions of Shannon95 associated better to low total biomass than the average or median value (Uusitalo *et al*. 2013, see also section 'Documentation of relationship between indicator and pressure', below). The 75-quantile was chosen as best estimate, since it did not differ substantially from higher percentiles in its value or relationship to total biomass, yet could be achieved reliably also from smaller datasets. The upper percentile is justified by the reasoning that while theory suggests that biodiversity should have a unimodal, dome-shaped, relationship with productivity, i.e. biodiversity should peak at intermediate levels of productivity (Grime 1973, Irigoien *et al*. 2004), Spatharis *et al.* (2011) pointed out that while this theory of a unimodal relationship is strong, the area below the unimodal curve is often filled with data points. Therefore, an upper percentile should reliably approximate the response in relation to biodiversity pressure. It has to be noted that Baltic Sea data can be assumed to include only the right-hand side of the expected dome shape: eutrophication has been identified as a problem in the Baltic Sea since the 1980s (e.g. Larsson *et al*. 1985, Elmgren 1989), and hence the current data do not cover non-eutrophied, low-productivity conditions. Indicator present status: The present status of the indicator was calculated for the years 2011-2013, based on quantitative analysis of phytoplankton samples from ship-of-opportunity monitoring data (m/s *Baltic Princess* and m/s *Silja Europa* operating between Helsinki and Tallinn).

	Sample analysis and data preparation: The data required by this indicator is attained by quantitative phytoplankton analysis (cf. HELCOM 2014a). Measurements of biomass (rather than abundance) were used, 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 (Paasche 1960, Olenina *et al*. 2006). In sample analysis, the greatest possible taxonomical accuracy should be used; however, since all specimens cannot be determined to species or even genus level, by necessity the analysis includes different taxonomic units (species, genera, and higher; Uusitalo *et al*. 2013). When deemed relevant, a distinction between autotrophic and heterotrophic individuals in genus or higher level taxa should be made (Uusitalo *et al*. 2013). All size classes within genus- and higher-level taxonomic units should be aggregated, unless there is a particular reason to keep them separated. Quality assurance: When preparing the phytoplankton data for data analysis, it is very important to consult the person or persons who have performed the actual phytoplankton species analysis. A profound understanding of phytoplankton taxonomy and nomenclature is essential. Sampling: In developing the Shannon95 approach, sampling was performed in summer (June–September) approximately every other week (Uusitalo *et al*. 2013); however a data set with less regular sampling interval (such as the 2011–2013 data used to determine present status) will produce good results, providing a sufficient number of samples have been analysed. The lowest possible number of samples based on which the indicator can safely be calculated has not been tested.
Documentation of relationship between indicator and pressure	Eutrophication has been identified as the most important factor causing degradation of the Baltic Sea ecosystem (HELCOM 2009). The phytoplankton species composition is sensitive to changes in nutrient levels and ratios (Gasiūnaitė *et al*. 2005, Carstensen and Heiskanen 2007, Suikkanen *et al*. 2007, Jurgensone *et al*. 2011), and eutrophication has resulted in increases in summer phytoplankton abundance and biomass (Carstensen and Heiskanen 2007, Fleming-Lehtinen *et al*. 2008, Jaanus *et al*. 2011) and more intense and frequent blooms (Finni *et al*. 2001, Carstensen *et al*. 2007). The sensitivity of phytoplankton diversity to eutrophication has been demonstrated both in the Baltic Sea (Uusitalo *et al*. 2013) and elsewhere (Gilmartin and Revelante 1980, Moncheva *et al*. 2002, Chalar 2009). Analyses of the ship-of-opportunity monitoring data in the open Gulf of Finland demonstrated that under circumstances with high phytoplankton biomass only low Shannon95 values occurred, and even more importantly, that high Shannon95 values were always associated with low total phytoplankton biomass (Uusitalo *et al*. 2013). On the other hand, low Shannon95 values were observed both at high and low biomasses. These results were consistent both using data based on individual samples and using yearly sampling station averages (Uusitalo *et al*. 2013).
Geographical relevance of indicator	2. Regional
How Reference Conditions (target values/thresholds) for the indicator were obtained?	The indicator target (i.e. GES boundary) was estimated through harmonization to the HELCOM summer (June–September) phytoplankton target for the open Gulf of Finland, where average chlorophyll *a* (chl) in the surface layer (0–10 m) is used as a proxy. When doing so, the HELCOM target of 2 µg l^{-1} (HELCOM 2014b) was converted into total phytoplankton biomass (BM) using the conversion factor $BM = 0.15 \times chl^{1.2}$ (Kuusisto *et al*. 1998), resulting in a total biomass value of 0.34 mg l^{-1} (i.e. 340 mg m^{-3}, expressed as more conventional units; Figure 2). The indicator target (i.e. GES boundary) was calculated from ship-of-opportunity data (m/s *Wasa Queen*, 1997-2002, presented in Uusitalo *et al*. 2013), as the 0.75-percentile of the Shannon95 values where biomass was at or below the HELCOM phytoplankton target (Figure 2).
Method for determining GES	GES is estimated as a target value (lower limit). The indicator has been developed for the open Gulf of Finland, but it is likely applicable in other Baltic Sea areas also, where sufficiently frequent sampling is conducted. The target (i.e. GES boundary) has to be set separately for each area to account for the characteristic differences in the areas.
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Illustrative material for indicator documentation

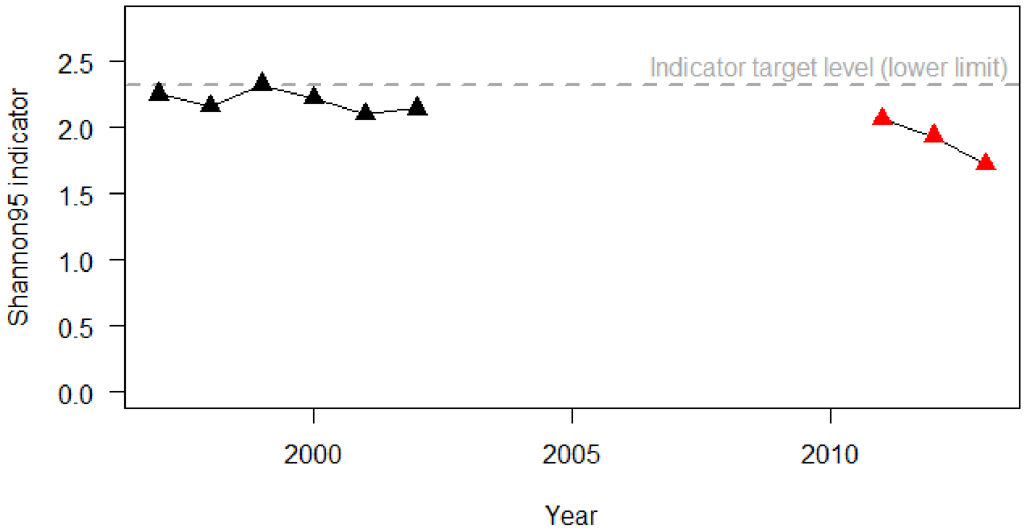

Figure 1. The annual summertime phytoplankton taxonomic diversity (Shannon95) indicator values in 1997–2002 (black triangles) and during the status period 2011–2013 (red triangles) in the central Gulf of Finland, on the Helsinki–Tallinn ship-of-opportunity transect. Note that the sampling stations used during the later period do not cover the northern part of the transect. The lower limit of the indicator target (i.e. the GES boundary) is indicated by a broken grey line.

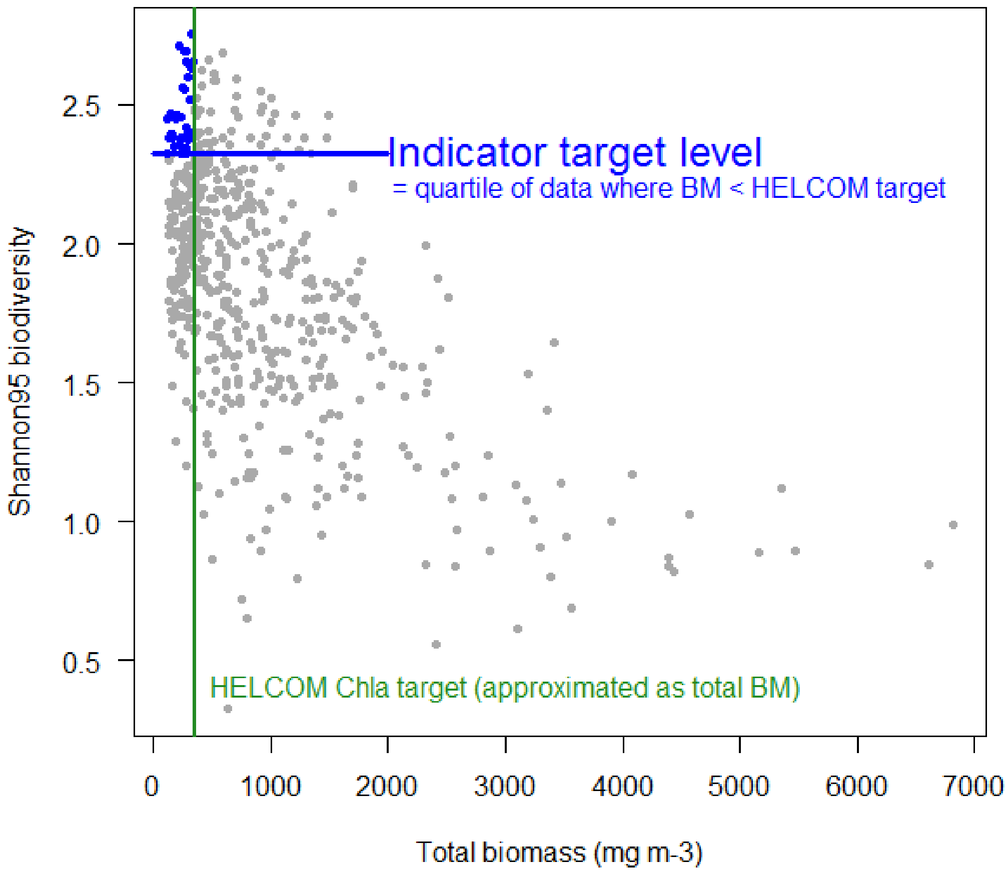

Figure 2. Shannon95 diversity plotted against total biomass (mg m^{-3}) in the central Gulf of Finland on the Helsinki–Tallinn ship-of-opportunity transect (described in Uusitalo *et al.* 2013). The green line indicates the biomass at the HELCOM phytoplankton (i.e. chlorophyll *a*) target level, converted into total biomass (as described above). The blue line indicates the indicator target level (i.e. GES boundary), as the 75-percentile of the data fraction where total biomass is below or at the HELCOM target level, and the blue dots indicate the data points above the target level.