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LIST OF INDICATORS FOR ASSESSING THE STATE OF MARINE BIODIVERSITY IN THE BALTIC SEA DEVELOPED BY THE LIFE MARMONI PROJECT

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The report is produced in the frame of the LIFE+ Nature & Biodiversity project "Innovative approaches for marine biodiversity monitoring and assessment of conservation status of nature values in the Baltic Sea" (Project acronym -MARMONI). The content of this publication is the sole responsibility of the authors and can in no way be taken to reflect the views of the European Union.

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Contents

Background

The implementation of several national and international environmental regulations requires assessment of the status of components of marine biodiversity. One such recent regulation is the EU Marine Strategy Framework Directive (MSFD) but also several other regulations require reporting on the state and trends of marine biodiversity (Habitats Directive, the Water Framework Directive, the Birds Directive, the UN Convention of Biodiversity and the HELCOM Baltic Sea Action Plan).

Assessing the status of Baltic Sea biodiversity is a very complex issue. The marine environment has its peculiarities in comparison with the terrestrial world but many things are common also. Especially on ecosystem level we can recognize several common features and processes, which can be described using similar tools in both environments. “Biodiversity” is a term describing all variety of structure and organization of living matter and the environment around it. Biodiversity is the basis for the evolutionary process itself enabling the continuous development of species and habitats providing valuable ecosystem services. That is why we are very concerned about the loss and degradation of biodiversity caused by different human-induced local pressures but also by global processes such as climate change.

The first step in managing the pressures causing degradation of natural biodiversity is to assess the current state of biodiversity on different levels. This is a very difficult task because of the complexity and, in many cases, poor understanding of nature of the processes. In this task we can use certain metrics, which respond to the processes and changes we are interested in but are easy to measure and understand. These metrics are called “indicators”. A good indicator is easy to measure, reflects the changes in state of a certain element of biodiversity, is predictably correlated with pressures and is applicable on different geographical scales. Of course, there are many exceptions from these rules and for certain purposes indicators with other features can be used.

The biodiversity indicator itself can be either a single measurable parameter (e.g. concentration of chlorophyll a, number of species in one sample, depth distribution of vegetation), aggregation of a parameter over time or space (e.g. mean summer chlorophyll a concentration in sea water, average number of species in samples in a certain area, share of biomass of certain species in the area) or it can be a complex index calculated using several different parameters or measurements. All these can be used to reflect the status of and trends in biodiversity, and the applicability of each may differ in different circumstances.

So far, most marine environmental monitoring programmes in the Baltic Sea have been designed for measuring different parameters reflecting water quality. Until recently, in the northern Baltic Sea, no programme existed for evaluating the status of marine biodiversity, although many components of biodiversity have been monitored as indicators of water quality and eutrophication. At the same time, "Biodiversity” is the one of the 11 descriptors of Good Environmental Status used by the MSFD. Developing new monitoring programmes fulfilling the requirements of the MSFD and other directives generates a need for establishing new methods and indicators for the assessment of marine biodiversity. Development of suitable indicators reflecting the status and trends of different components and levels of biodiversity is a very important step in the implementation of the MSFD. Indicator development includes a huge amount of intellectual work on a conceptual level – thinking about possible elements and measures of biodiversity that could be measured and monitored and also testing of those possible indicator candidates against existing pressure gradients. The final set of biodiversity indicators proposed for the monitoring and assessment of marine biodiversity should include features enabling assessment of many different levels of marine biodiversity in a complex manner. They should also facilitate evaluation of the measures taken to reduce the pressures on different geographical scales.

This report presents results of the MARMONI project, within the framework of which a number of new, cost-effective and innovative indicators for the assessment of marine biodiversity in the Baltic Sea was developed as a proposal for inclusion in national monitoring programmes. The indicators were developed and tested on data specially collected for this purpose, often collected in a targeted manner in four project areas (Gulf of Riga, central part of Gulf of Finland, Hanö Bight and Archipelago Sea) representing different natural conditions occurring in the Baltic Sea.

1 Fish indicators

Name of indicator	1.1 Abundance and distribution of juvenile flounder
Type of Indicator	State indicator
Author(s)	Meri Kallasvuo, Eevi Kokkonen & Antti Lappalainen
Description of the indicator	The indicator illustrates the abundance and distribution of juvenile flounders in shallow coastal sandy nursery habitats. Flounder is a fish species, which lives at the northern edge of its distributional range in the northern Baltic Sea (Nissling *et al*. 2002) and, thus, is sensitive to changes in the environment. Therefore, the abundance and distribution of juvenile flounders in shallow sandy habitats can be used as an indicator linked to fish reproduction and environmental status of coastal waters. In the northern Baltic Sea, flounder spawning is strongly determined by salinity (Nissling *et al*. 2002) and occurs in late spring (Florin 2005). After hatching, larvae are pelagic for a few months (Bagge 1981), until they undergo metamorphosis to attain asymmetric body shape and settle to shallow (< 1 m) sandy nursery areas in late summer (Florin *et al*. 2009, Martinsson and Nissling 2011).
Relationship of the indicator to marine biodiversity	The indicator describes the environmental status of coastal habitats i.e. shallow sandy bottoms and the pelagial part of the archipelago during the larval phase. The increase in filamentous algae observed in recent years potentially reduces the quality and quantity of suitable shallow sandy bottoms used as flounder nursery areas (Pihl *et al.* 2005, Wennhage and Pihl 2007, Carl *et al*. 2008). The environmental conditions (and changes) occurring in the pelagial and their effects on larval flounders are still unknown.
Relevance of the indicator to different policy instruments	MSFD descriptor 1 (especially 1.6. Habitat condition): environmental status of the coastal shallow sandy bottoms (juveniles) and the pelagial part of the archipelago area during midsummer (larvae).
Relevance to commission decision criteria and indicator	1.1.1. Distributional range 1.2.1. Population abundance and/or biomass 1.6.1. Condition of the typical species and communities
Method(s) for obtaining indicator values	The abundance and distribution of juvenile flounders in shallow coastal sandy habitats is monitored with beach seine in autumn (young-of-the-year juveniles) or spring (1+ overwintered juveniles) combined with environmental variable measurements. Indicator is based on average numbers and occurrence of juvenile flounder (≤ 70 mm) in fixed coastal monitoring areas. Data analysis from field inventories to optimize the sampling size and time for future indicator monitoring continues.
Documentation of relationship between indicator and pressure	The habitat requirements of fish are known to be most strict during the early life stages and, thus, the quality and quantity of reproduction habitats lays the basis for fish production (Houde 1989, Urho 2002). This also implies that environmental changes affect fish populations in many cases most heavily during the reproductive phase. A considerable number of fish species in the northern Baltic Sea reproduce in the shallow coastal areas, which are the most heavily exploited parts and also affected by large scale environmental changes. Flounders are naturally not associated with vegetated areas (Florin et al 2009) and avoid vegetation, such as algal mats, if possible (Carl *et al*. 2008). In the Finnish coastal area, flounders also live on the edge of their reproductive range determined by low salinity (5-6 psu) and, therefore, are susceptible to declining salinity (Nissling *et al*. 2002). Thus, main pressures potentially affecting juvenile flounders are eutrophication and climate change. By the time of sampling, juvenile flounders have already been exposed to varying environmental conditions and passed critical periods (pelagic larval stage, metamorphosis, settling, possibly also overwintering).
Geographical relevance of indicator	2. Regional
How Reference Conditions (target values/ thresholds) for the indicator were obtained?	Some baseline data is available from last few decades from Finland (Aro and Sjöblom 1982) and new field data was gathered within MARMONI in Finland still in spring 2014. In spring 2013, data was gathered also in Estonia. Preliminary description of data is shown in figures 1-4. The annual variation appears relatively high.

Method for determining GES	The preliminary GES-target is that the abundance and distribution range of juvenile flounder do not decrease. A more precise target value for GES will be determined later if the indicator will be adopted to use and new data will be available. More data and analysis is needed to understand the causes of annual variation.
References	Aro E. & Sjöblom V. 1982. The abundance of 0-group 1-year-old flounder off the coast of Finland in 1978-81 according to exploratory fishing with a beach seine. ICES International Council for the Exploration of the Sea, Council Meeting documents, Baltic Fish Committee J:26. Bagge O. 1981. Demersal fishes. In: Voipio A. (ed.), The Baltic Sea. Elsevier Oceanographic Series 30 ed., Elsevier Scientific Company, Amsterdam, pp. 331-333. Carl J.D., Sparrevohn C.R., Nicolajsen H. & Støttrup J.G. 2008. Substratum selection by juvenile flounder *Platichthys flesus (L.)*: effect of ephemeral filamentous macroalgae. J Fish Biol 72: 2570-2578. Florin A. 2005. Flatfishes in the Baltic Sea - a review of biology and fishery with a focus on Swedish conditions. Finfo 2005:14: 1-56. Florin A., Sundblad G. & Bergström U. 2009. Characterisation of juvenile flatfish habitats in the Baltic Sea. Estuar Coast Shelf Sci 82: 294-300. Houde E.D. 1989. Subtleties and episodes in the early life of fishes. J Fish Biol 35: 29-38. Martinsson J. & Nissling A. 2011. Nursery area utilization by turbot (Psetta maxima) and flounder (*Platichthys flesus*) at Gotland, central Baltic Sea. Boreal Env Res 16: 60-70. Nissling A., Westin L. & Hjerne O. 2002. Reproductive success in relation to salinity for three flatfish species, dab (*Limanda limanda*), plaice (*Pleuronectes platessa*), and flounder (*Pleuronectes flesus*), in the brackish water Baltic Sea. ICES Journal of Marine Science: Journal du Conseil 59: 93-108. Pihl L., Modin J. & Wennhage H. 2005. Relating plaice (*Pleuronectes platessa*) recruitment to deteriorating habitat quality: effects of macroalgal blooms in coastal nursery grounds. Can J Fish Aquat Sci 62: 1184-1193. Urho L. 2002. The importance of larvae and nursery areas for fish production. PhD thesis, University of Helsinki and Finnish Game and Fisheries Research Institute: 1-118. Wennhage H. & Pihl L. 2007. From flatfish to sticklebacks: assemblage structure of epibenthic fauna in relation to macroalgal blooms. Mar Ecol Prog Ser 335: 187-198.

Illustrative material for indicator documentation

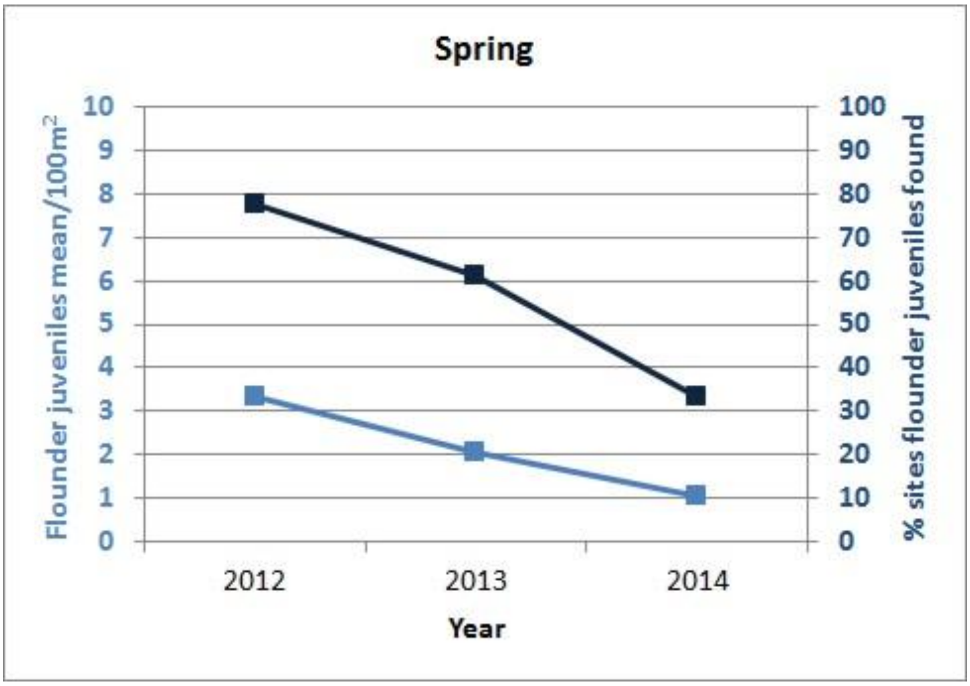


Figure 1. Flounder juveniles abundance and occurrence in the spring. Mean of flounder juveniles in 100 square meters is presented in light blue lines. In calculation minimum haul area was used. Dark blue color describes the percent of sites where flounder juveniles were found. From Finland 18 sites which have been visited every spring are included.

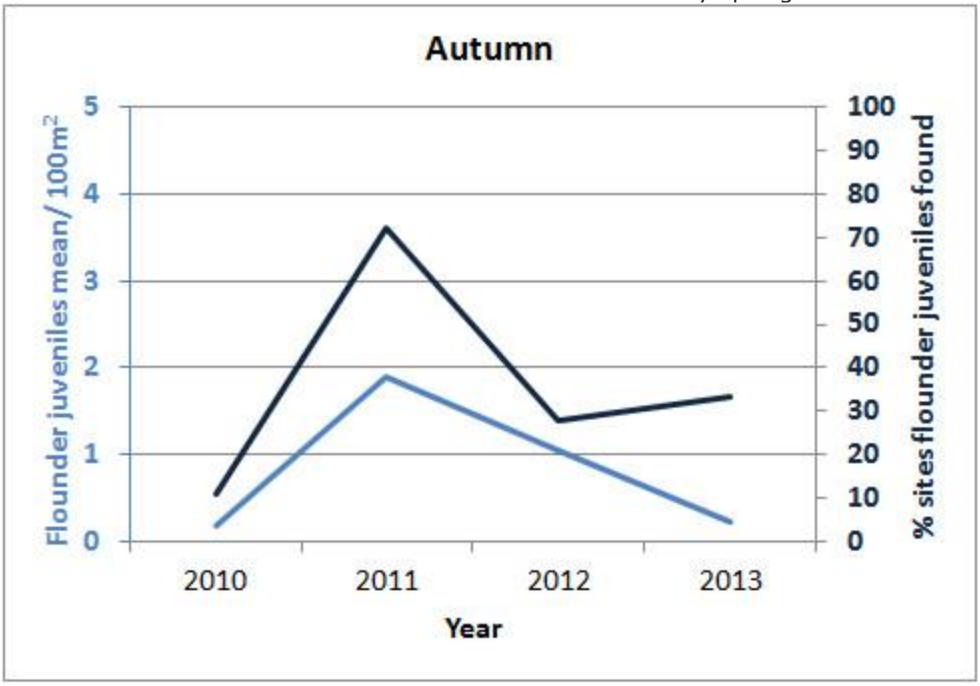


Figure 2. Flounder juveniles abundance and occurrence in the autumn. Mean of flounder juveniles in 100 square meters is presented in light blue lines. In calculation minimum haul area was used. Dark blue color describes the percent of sites where flounder juveniles were found. 18 sites visited every autumn are included.

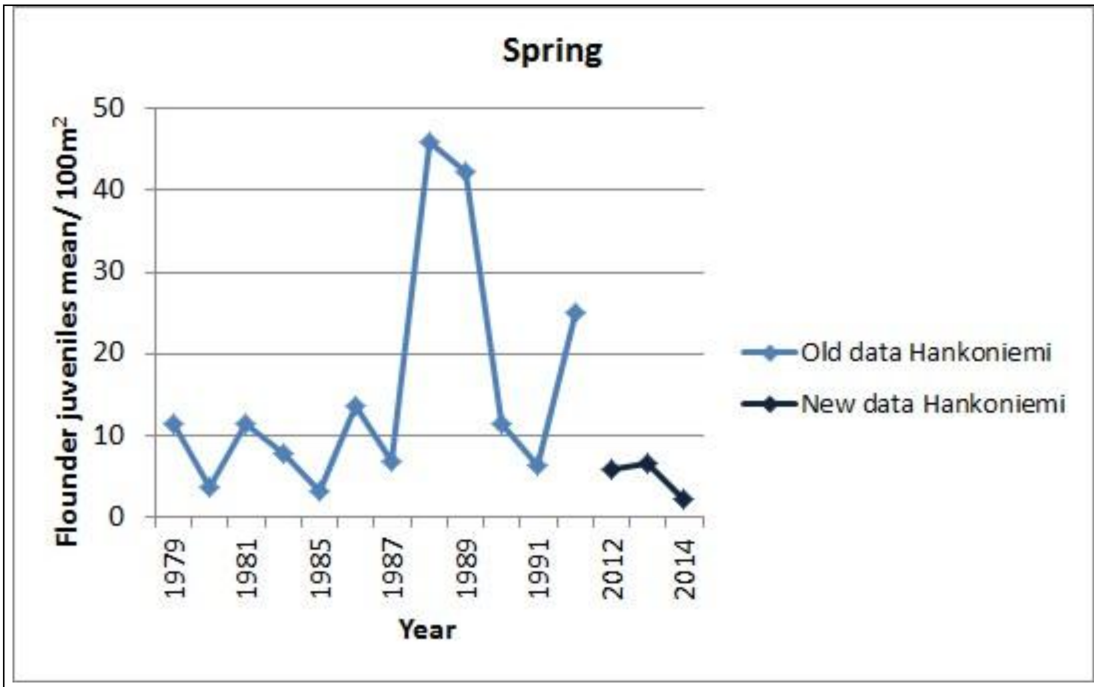


Figure 3. Comparison of old and new data. Flounder juveniles mean per 100 square meters in the spring. Old data is from years 1979 to 1992 (no data from years 1982 and 1984) and new data from years 2012 to 2014.

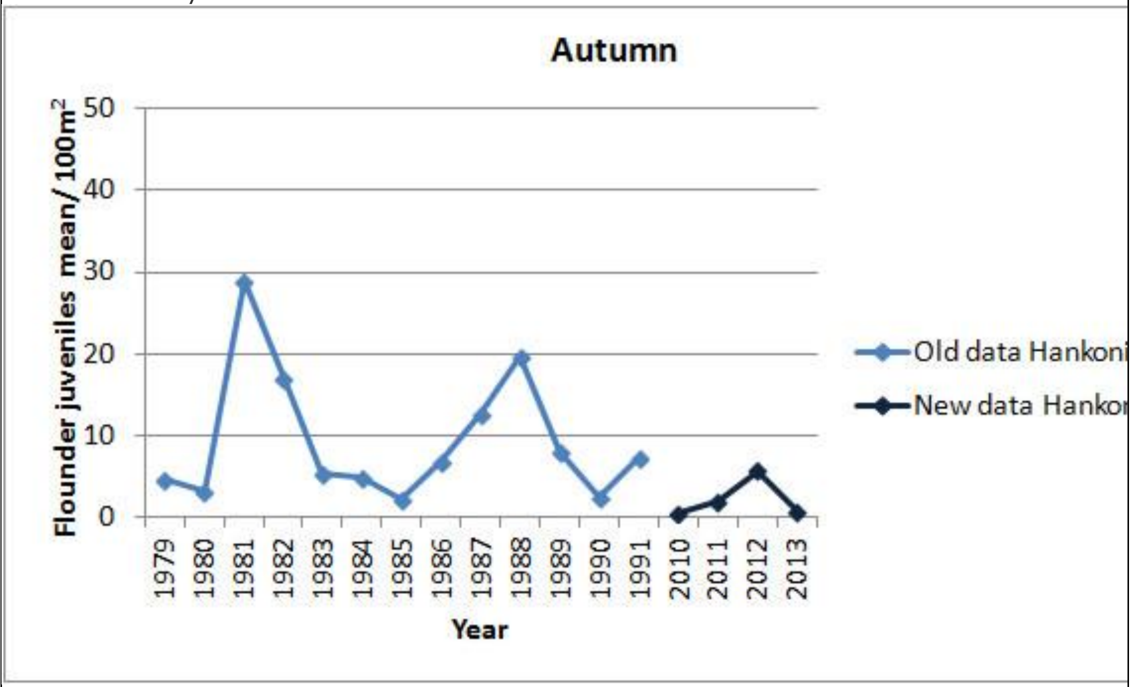
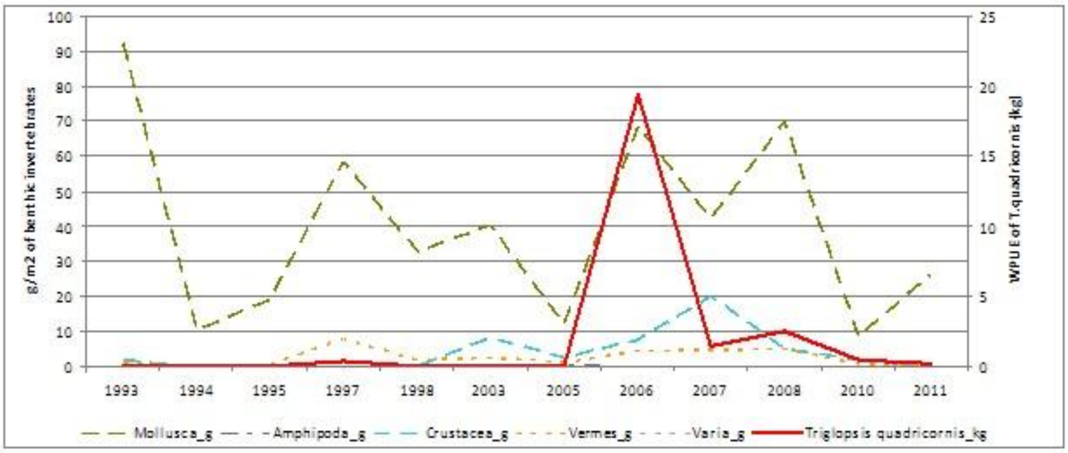


Figure 4. Comparison of old and new data. Flounder juveniles mean per 100 square meters in the autumn. Old data is from years 1979 to 1991 and new data from years 2010 to 2013.

Name of indicator	1.2 Long term abundance and distribution of demersal fish in relation to benthic communities (fourhorn sculpin *Myoxocephalus quadricornis* and eelpout *Zoarces viviparous* example)
Type of Indicator	State indicator
Author(s)	Ēriks Krūze, Atis Minde
Description of the indicator	The indicator demonstrates trophic relationships between demersal fish and benthic fauna. Biomass of fourhorn sculpin (*Myoxocephalus quadricornis*) and eelpout (*Zoarces viviparous*) plotted against biomass of benthic invertebrates. Fourhorn sculpin is thought to be the first fish species that occupied Baltic Sea waters after its forming. Fourhorn sculpin occupies cold brackish and moderately saline water and thus can be an indicator of change in hydrological state of the sea, climate change and increase of eutrophication. For example increased eutrophication can result in lower oxygen concentration that affects food availability for fourhorn sculpin and have direct impact as well. Climate change can alter water temperature and fourhorn sculpin being preferably cold water species can be affected by that. Besides, also increase of salinity and predation by cod can have negative impact on abundance of four-horn sculpin. Also high concentrations of heavy metals often observed in the tissue of four-horn sculpins can have negative effects on population level. Therefore distinction of the main factors responsible for particular chages in four-horn sculpin abundance is very important. The indicator is appropriate to use in the Gulf of Riga and other Baltic Sea areas where eelpout is dominant species in the benthic fish community. In the Gulf of Riga there is little fishing pressure on eelpout population because it is targeted only by coastal fishery and fishing intensity is very low. Therefore changes in eelpout abundance are related mostly to environmental factors like food availability and predation by cod and fish eating birds, especially cormorants. To distinguish between effects of decline of habitat quality and other environmental factors, eelpout abundance is plotted against benthic invertebrate biomass. For example low oxygen concentration can decrease the biomass of benthic invertebrates and also fish.
Relationship of the indicator to marine biodiversity	The indicator describes abundance of the key benthic fish species in the Gulf of Riga in relation to benthic invertebrate community. Thus this species could serve as an indicator of good quality of sea environment and is an element of natural biodiversity.
Relevance of the indicator to different policy instruments	Indicator can be applied for reporting on MSFD descriptors 1 and 4. Indicator is related to HELCOM BSAP ecological objective: that habitats, including associated species, show a distribution, abundance and quality in line with prevailing physiographic, geographic and climatic conditions.
Relevance to commission decision criteria and indicator	1.1.1. Distributional range 1.2.1. Population abundance and/or biomass 1.6.1. Condition of the typical species and communities
Method(s) for obtaining indicator values	Sampling of the fish is carried out annually in the Gulf of Riga and Irbe Strait using benthic trawl in fixed survey stations. Biomass of each fish species per m² is calculated for each trawling station and an average value from several stations within a geographical region and depth stratum is calculated. The same procedure is applied for biomass data of benthic invertebrates. Benthic invertebrate data come from the National Baltic Sea monitoring programme.
Documentation of relationship between indicator and pressure	Fourhorn sculpin is clearly regarded as a post-glacial relict (Ekman 1940), coldwater species living in brackish waters of the Baltic Sea (http://www.rktl.fi). Although there are no papers documenting direct link between four-horn sculpin abundance and eutrophication level in marine environment, such connection exists regarding closely related species *Myoxocephalus thompsonii* (often considered as a sibling species of fourhorn sculpin) in freshwater lakes in North America (Sheldon *et al*. 2008). In several non-scientific articles eutrophication is mentioned as a threat also for fourhorn sculpin freshwater populations in Sweden. Indicator is related mainly to changes of eutrophication and anoxia in the bottom of the sea. However it could be sensitive to the effects of predation by cod and cormorants. Eelpouts are widely used as a bioindicator of local pollution due to their stationary behavior, but there is little known about links between eelpouts abundance and environmental quality (Hedman *et al*. 2011). As a cold water species abundance and growth rate of eelpouts could indicate rising water temperatures due to climatic changes (Portner *et al*. 2001, Portner and Knust 2007).

Geographical relevance of indicator	2. Regional 3. National waters
How Reference Conditions (target values/thresholds) for the indicator were obtained?	According to literature, there have been at least three systemic regime shifts in the Baltic Sea ecosystem including such subsystems as the Gulf of Riga. Therefore it is still unclear which environmental state can serve as a reference condition. The last ecosystem shift in the Gulf of Riga occured around 1995-1996 and the return of the ecosystem in previous states is discutable. If the current conditions are taken as a reference, then an average abundance of fourhorn sculpin and eelpout since 1995/1996 can be taken as reference value.
Method for determining GES	Indicator can be applicable for Gulf of Riga ecosystem or similar Baltic Sea region. Indicator values need to be calculated preferably for smaller scale geographic regions (for example: West, East, South, Central part of the Gulf of Riga). Ecosystem can be considered being in GES when abundance of fourhorn sculpin and eelpout are within limits of natural yearly variation and there is no decreasing trend of WPUE values coinciding with decrease of benthic invertebrate biomass. Current amount of available data does not allow to properly test this indicator! Precise method for estimation of GES can not be elaborated at this stage.
References	Ekman S. Die Swedishe Verbreitung der glazial-marinen Relikte. Verhandlungen des Internationalen Verein Limnologie. 9:37-58 Commercially exploited fish species in Finland, internet resource http://www.rktl.fi/printview/english/fish/fish_atlas/fourhorn_sculpin/fourhorn_sculpin.html H.O. Portner, B. Berdal, R. Blust, O. Brix, A. Colosimo, B. De Wachter, A. Guiliani, T. Johansen, T. Fischer, R. Knust, G. Lanning, G. Naevdal, A. Nedenes, G. Nyhammer, F. J. Sartoris, I. Serendero, P. Sirabella, S. Thorkildsen, M. Zakhartsev Climate induced temperature effects on growth performance, fecundity and recruitment in marine fish: developing a hypothesis for cause and effect relationships in Atlantic cod (*Gadus morhua*) and common eelpout (*Zoarces viviparus*). Continental Shelf Research. Volume 21, Issues 18-19, December 2001, Pages 1975-1997 Hans O. Portner, Rainer Knust. Climate Change Affects Marine Fishes Through The Oxygen Limitation of Tolerance. Science 5 January 2007: Vol. 315 no. 5808 pp. 95-97 Jenny E. Hedman, Heinz Rudel, Jens Gercken, Sara Bergek, Jakob Strand, Marcus Quack, Magnus Appelberg, Lars Forling, Arvo Tuvikene, Anders Bignert Eelpout (*Zoarces viviparus*) in marine environmental monitoring. Marine Pollution Bulletin. 62(2011)2015-2029 Sheldon, T. A, Mandrak, N. E., Lovejoy, N. R. 2008. Biogeography of the deepwater sculpin (*Myoxocephalus thompsonii*), a Nearctic glacial relict. Canadian Journal of Zoology, Vol.86/2:108-115
Illustrative material for indicator documentation	 Figure 1. Changes in fourthorn sculpin (*Myoxocephalus quadricornis*) abundance in relation to benthic communities.

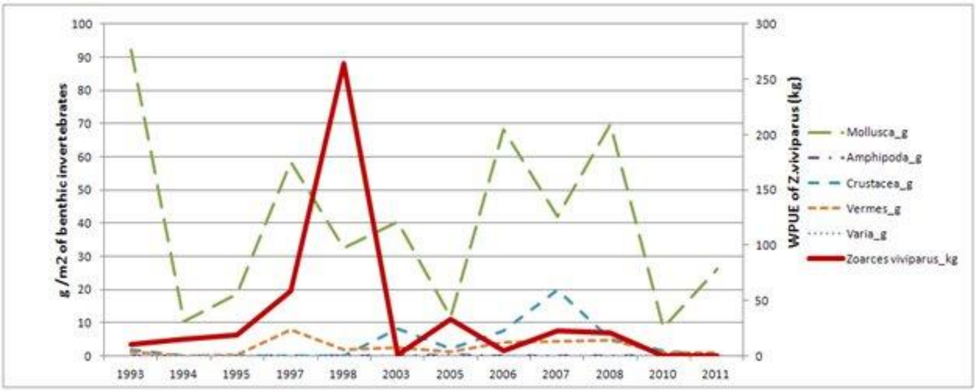
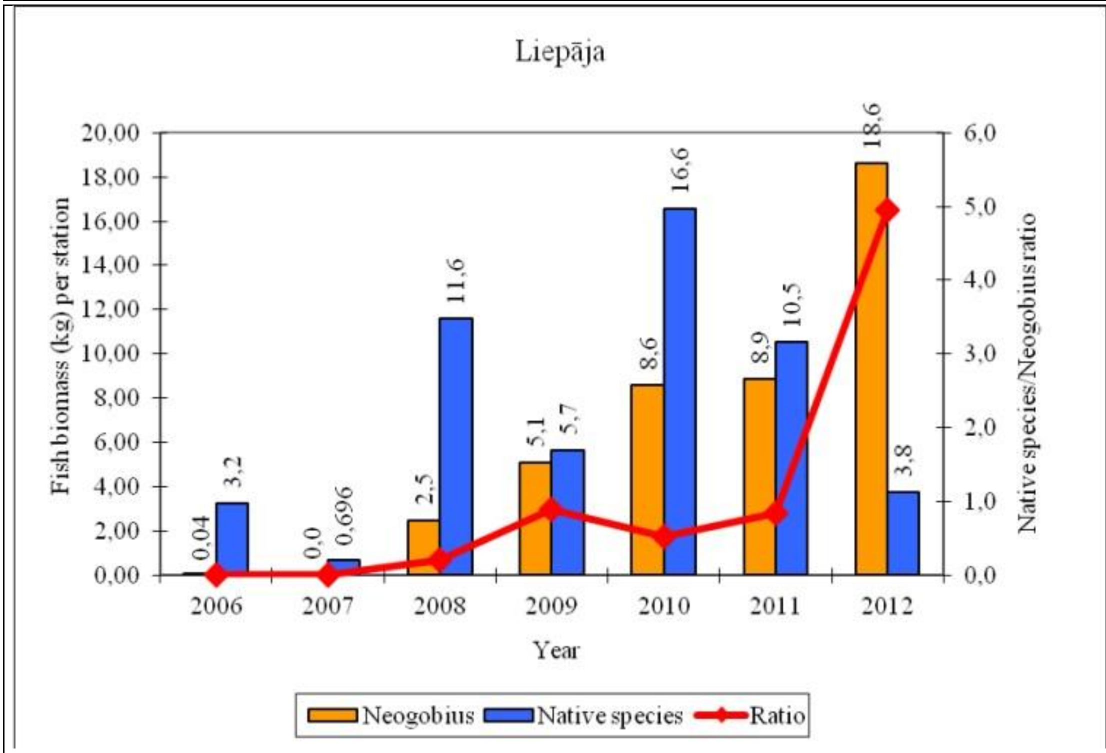


Figure 2. Changes in eelpout (*Zoarces viviparous*) abundance in relation to benthic communities.

Name of indicator	1.3 Abundance and impact of non-native fish species (round goby

	example)
Type of Indicator	State indicator
Author(s)	Atis Minde, Eriks Kruze
Description of the indicator	Indicator reflects primary and secondary invasions of non-native species and is related to various pressures like shipping, ballast water discharge, climate change depending on introduction route of particular non-native species. Degree of impact of the non-native species on the native fish communities can be very different. Alien species can integrate in the native fauna without causing significant changes in the ecosystem or they can be ecologically aggressive and cause major changes in the natural food web structure and biodiversity in general. For example population of round goby can significantly decrease biomass of benthic mussels and other benthic invertebrates thus limiting food supply for other benthic fish in the Baltic like flounder and also competing with benthic feeding waterbirds. Thus, the increase of biomass of non-native species at the cost of decreasing abundance of local species shows loss of biodiversity and structural changes in the food webs.
Relationship of the indicator to marine biodiversity	The indicator describes relative abundance of particular non-native species within an area of concern and its impact on the biodiversity and food web at habitat/ecosystem level.
Relevance of the indicator to different policy instruments	Indicator can be applied for reporting on MSFD descriptors 1, 2 and 4. Indicator is related to HELCOM BSAP ecological objective: that habitats, including associated species, show a distribution, abundance and quality in line with prevailing physiographic, geographic and climatic conditions.
Relevance to commission decision criteria and indicator	1.1.1. Distributional range 1.2.1. Population abundance and/or biomass
Method(s) for obtaining indicator values	The values for this indicator are obtained from coastal fish monitoring using "coastal net series" -survey nets. WPUE (mean biomass per one sampling station in May and June) of round goby and native benthic fish species (in this case: flounder) are calculated. Only May and June data are used because it is the period of peak activity of round goby and catches of passive sampling gears (in this case bottom gillnets) are reflecting true abundance of the species. Ratio between biomass of round goby and flounder is calculated by dividing WPUE of round goby by WPUE of flounder.
Documentation of relationship between indicator and pressure	Invasion of round goby can have a great variety of both negative and positive effects on the marine habitat (Corkum *et al.* 2004). There are several articles that describe existing and possible competition between round goby and native fish species occurring in the same habitat and decrease of native species occurrence where strong populations of round goby have been established. Round goby can have a negative effect on native fish populations by feeding on their eggs (Chotkowski and Marsden 1999), feeding competition (Karlson et al 2007) and aggressive behaviour (Dubs and Corkum 1996). We can expect that populations of fish species that occupy the same habitat or have similar diet preferences will have an impact of increasing round goby population and their numbers and/or biomass will decrease. It is indicated that at least in one occasion abundance of round goby and flounder are negatively correlated (Karlson et al 2007).
Geographical relevance of indicator	2. Regional
How Reference Conditions (target values/thresholds) for the indicator were obtained?	Reference conditions for this indicator is a state of coastal ecosystem before establishment of round goby population. In Latvian case it is the natural state of coastal fish community before 2007.
Method for determining GES	This indicator could be used in various geographical regions. However, for calculation of this indicator, it is important to use only those native species that are historically characteristic and abundant in the habitat/ecosystem of concern and which occupy the same or similar ecological niche as the invasive fish species. One has to follow two steps to determine GES using this indicator. Step 1. It needs to be established whether or not there is a relationship between changes of

	invasive species and native fish biomass evident. If no relationship between invasive species and native fish species biomass can be seen we consider habitat or ecosystem to be in GES. If this is the case there is no need to follow with step 2. Step 2. There is a likely relationship between invasive and native fish species. In this case if the correlation between invasive and native fish species is positive we also could consider the habitat/ecosystem to be in GES. However if the correlation is negative (and there is a clear biological explanation of that process) and we can see the values of invasive species/native species ratio increasing, we have to consider the habitat/ecosystem not in GES. In the current example we can see significant increase of round goby biomass in both areas – Liepāja and Pape. There is also clear decrease of flounder biomass within the period of round goby invasion and most possibly feeding competition is behind these changes. Thus we cannot consider that both areas are in GES.
References	Chotkowski, M.A. and Marsden, J.E. (1999). Round goby and mottled sculpin predation on trout eggs and fry: field predictions from laboratory experiments. Journal of Great Lakes Research 25: 26–35 Corkum L.D., Sapota M.R., Skóra K.E., 2004. The round goby, *Neogobius melanostomus*, a fish invader on both sides of the Atlantic Ocean, Biological Invasions 6: 173-181 Dubs, D.O.L. and Corkum, L.D. (1996). Behavioral interactions between round gobies (*Neogobius melanostomus*) and mottled sculpins (*Cottus bairdi*). Journal of Great Lakes Research 22: 838–844 Karlson, A. M. L., Almqvist, G., Skóra, K. E., and Appelberg, M. 2007. Indications of competition between non-indigenous round goby and native flounder in the Baltic Sea. ICES Journal of Marine Science, 64: 479–486
Illustrative material for indicator documentation	 Figure 1. Ratio between native species and round goby biomass (WPUE).

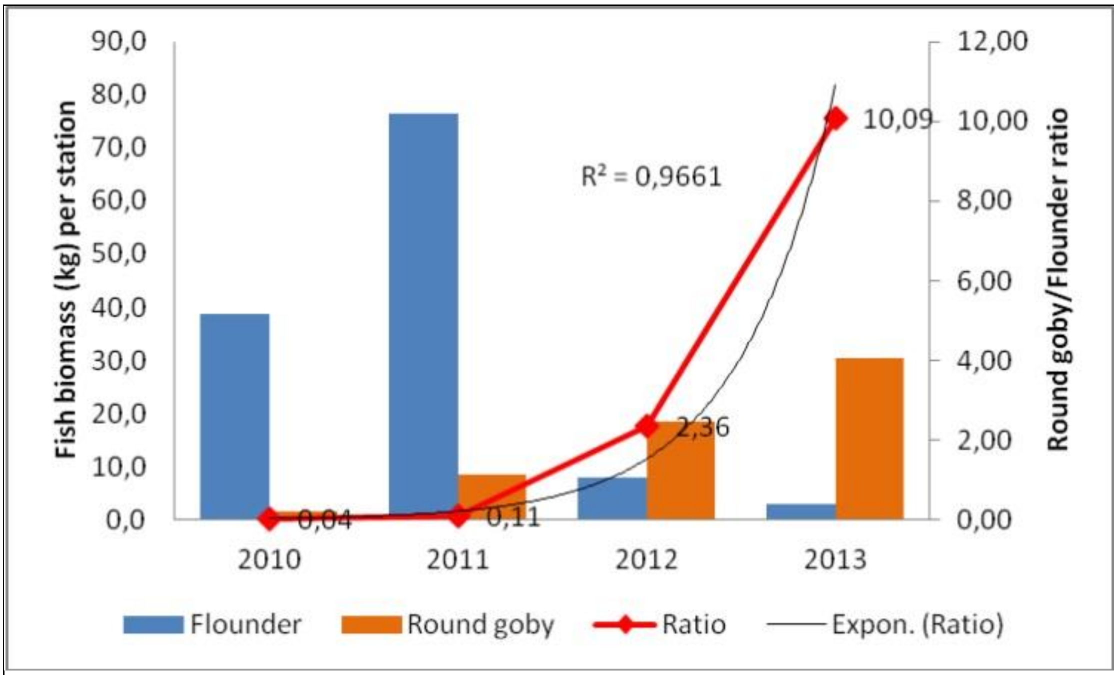


Figure 2. Ratio between round goby and flounder biomass (WPUE).

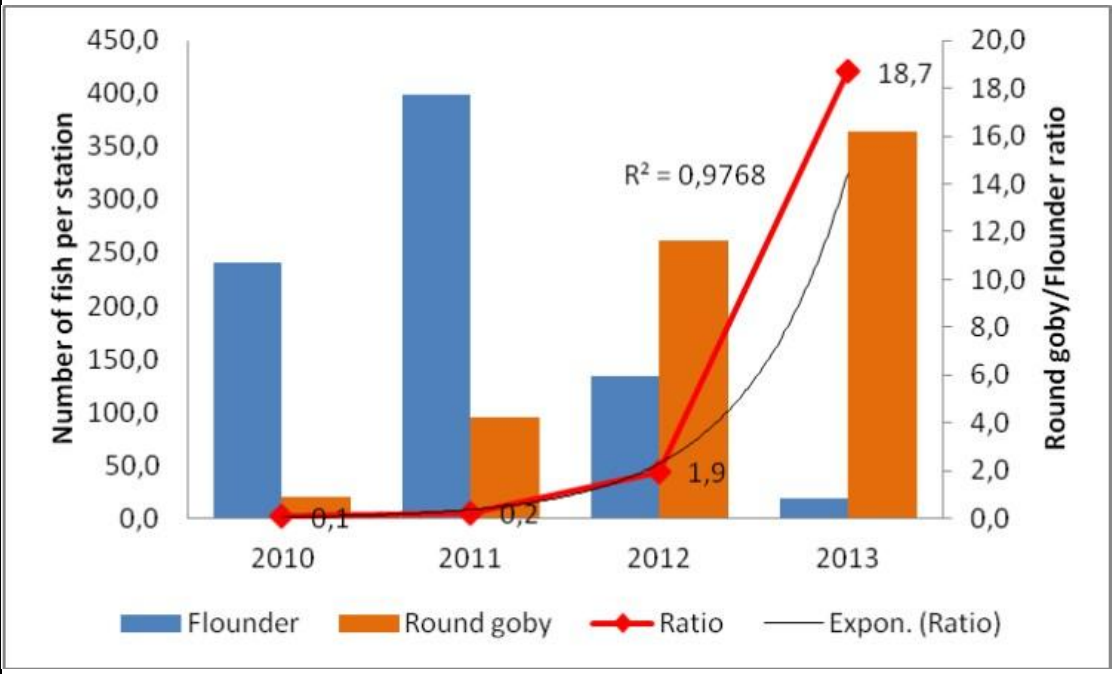


Figure 3. Ratio between total number of round goby and flounder (CPUE).

Name of indicator	**1.4 Abundance index of large (TL>250 mm) perch (*Perca fluviatilis*) in monitoring catches**
Type of Indicator	State indicator
Author(s)	Lauri Saks, Roland Svirgsden, Kristiina Jürgens, Aare Verliin, Markus Vetemaa
Description of the indicator	The indicator describes the abundance of large perch (TL>250mm) in the local community. Thus, this indicator should be considered as index describing the age and size structure of the local perch population and fishing (both commercial and recreational) pressure on local fish communities. Decrease in the values of this index may be symptoms for heavy fishing pressure which may result in decrease of the mean trophic level of the community, which in turn may be associated with decline in local biodiversity (Fig 1).
Relationship of the indicator to marine biodiversity	Generally, higher frequencies of older and larger individuals are considered to be in correlation with the health of fish stocks (Piet *et al*. 2010). Larger individuals have a more specific role in the ecosystem if compared to smaller individuals. Besides occupying higher trophic level, larger individuals contribute disproportionately more to the reproductive potential of a population than smaller fish (see e.g. Beldade, 2012 and Olin *et al*. 2012 for example on perch). At the same time, commercial fisheries are targeting specifically larger individuals (e.g. HELCOM, 2012a). It is proposed that the proportion of larger individuals in a population is very sensitive to exploitation and starts to decrease in case of strong fishing pressure (see. e.g. Olsen *et al*. 2005, HELCOM, 2012a and Pukk *et al*. 2013 for example on perch, Fig 2).
Relevance of the indicator to different policy instruments	This indicator is included to the MSFD descriptors 1 (D1.3.1: Population condition, demographic characteristics) and 3 (D3.3.1: Commercially exploited fish and shellfish, Population age and size distribution, Proportion of fish larger than the mean size of first sexual maturation). In case of perch, this indicator ("Abundance index of large (TL>250 mm) individuals in monitoring catches") was used instead of proportion of fish larger than the mean size of first sexual maturation as suggested by ICES (2012). This decision was made, as perch achieves sexual maturation already at relatively small size (♀♀ TL> 157, ♂♂ TL>101; Pihu *et al*., 2003 transformed according to Saat *et al*., 2007). However, the rationale of this indicator (D3.3.1.1) is to describe the abundance of larger individuals in the catches and thus this indicator was preferred.
Relevance to commission decision criteria and indicator	1.3.1. Population demographic characteristics (e .g. body size or age class structure, sex ratio, fecundity rates, survival/ mortality rates)
Method(s) for obtaining indicator values	Data on the abundance of large perch (TL>250mm) in the local communities was gathered during annual monitoring catches according to Thoresson (1993). The abundance of large perch is calculated as number of larger than 250 mm (TL) perch individuals per one monitoring station (catch per unit effort - CPUE) (Eschbaum *et al*., 2012).
Documentation of relationship between indicator and pressure	The values of this indicator have been shown to relate with selective (recreational) fishing pressure (HELCOM 2012a). However, it is likely that in circumstances of heavy (selective) fishing pressure, the proportion of large individuals (especially predatory fish species) will decrease in the community (see e.g. Pukk *et al*. 2013). Thus, decrease in the values of this index may be symptoms for decrease in the mean trophic level of the community, which in turn may be associated with decline in local biodiversity (Fig 1). Associations between indicator values and fishing pressure were tested by comparing monitoring areas near Kihnu and Vilsandi islands (Fig 3) with different commercial fishing pressures (Table 1). Evidently, indicator values were considerably lower (U-test: Z=5,22; p<0,00001; n=30) for Kihnu (stronger fishing pressure) than for Vilsandi monitoring area in 2013 (Fig 4).
Geographical relevance of indicator	1. Local
How Reference Conditions (target values/thresholds) for the indicator were obtained?	As no data on quantitative historic reference conditions (target values/threshold values) is available, qualitative criteria are used at the moment. Relatively long data series from different monitoring areas (see. e.g. Martin 2013) tend to be collected during the period when perch populations in these areas were suffering from overfishing (Ådjers *et al*. 2006). Thus future data collection and analysis is required to determine the quantitative reference conditions of this indicator.
Method for determining GES	Trend-based approach is used to determine GES. GES can be considered when no decreasing trend is evident from time series. However stable trend of low indicator values should not always be considered as GES because strong fishing pressure may have affected the population structure before the beginning of data collection (see e.g. Ådjers *et al*. 2006,

	Martin 2013 pp. 269-270).
References	Beldade, R., Holbrook, S.J., Schmitt, R.J., Planes, S., Malone, D. & Bernardi, G. (2012) Larger female fish contribute disproportionately more to self-replenishment. *Proc. R. Soc. B.,* 279, 2116-2121. Eschbaum, M., Hubel, K., Jürgens, K., Piirisalu, U., Rohtla, M., Saks, L., Špilev, H., Talvik, Ü. & Verliin, A. 2012. *Riikliku kalanduse andmekogumise programmi täitmine. Osa: Rannikumere kalad* Tartu Ülikool, Eesti Mereinstituut. Tallinn. HELCOM, 2012a. Indicator-based assessment of coastal fish community status in the Baltic Sea 2005-2009. Balt. Sea Environ. Proc. No. 131. HELCOM, 2012b. Development of a set of core indicators: Interim report of HELCOM CORESET project. PART A. Description of the selection process. Balt. Sea Environ. Proc. No. XXX A (http://www.helcom.fi/BSAP_assessment/ifs/ifs2012/en_GB/CoastalFish/ ICES. 2012. Marine Strategy Framework Directive – Descriptor 3+, ICES CM 2012/ACOM:62. 169pp. Martin, G., (editor). 2013 Eesti mereala Hea Keskkonnaseisundi indikaatorid ja keskkonnasihtide kogum. Aruanne MSFD artikkel 9 ja 10 nõuete täitmiseks. Eesti Mereinstituut. Tallinn. Olin, M., Jutila, J., Lehtonen, H., Vinni, M., Ruuhijärvi, J., Estlander, S., Rask, M., Kuparinen, A. & Lappalainen, J. 2012 Importance of maternal size on the reproductive success of perch, *Perca fluviatilis*, in small forest lakes: implications for fisheries management. Fisheries Manag. Ecol., 19, 363-374 Olsen, E.M., Lilly, G.R., Heino, M., Morgan, M.J., Brattley, J. & Dieckmann, U. 2005. Assessing changes in age and size at maturation in collapsing populations of Atlantic cod (*Cadus morhua*). Can. J. Fisheries Aquatic Sci. 62, 811-823. Piet, G.J., Albella, A.J., Aro, E., Farrugio, H., Lleonart, J., Lordan, C., Mesnil, G., Petrakis, G., Pusch, C., Radu, G. & Rätz, H.-J. 2010. Marine Strategy Framework Directive. Task Group 3 Report. Commercially exploited fish and shellfish. (Doerner, H. & Scott, R., eds). EU and ICES, Luxembourg. Pihu, E., Järv, L., Vetemaa, M. & Turovski, A. 2003. Ahven, *Perca fluviatilis L*. In *Fishes of Estonia* (Ojaveer, E., Pihu, E. & Saat, T. eds), pp289-296. Estonian Academy Publishers, Tallinn. Pukk, L., Kuparinen, A., Järv, L., Gross, R. & Vasemägi, A. 2013. Genetic and life-history changes associated with fisheries-induced population collapse. Evol. Appl. 6, 749-760. Saat, T., Saat, T. & Nursi, A. 2007. Total length – standard length relationship in Estonian fishes. In Book of abstracts of the XII european congress of ichthyology (Buj, I., Zanella, L. & Mrakovicic, M., eds), p 141. European Ichthyological Society. Thoresson, G. (1993). Guidelines for coastal monitoring. Kustrapport, 1993: 35 pp Ådjers, K., Appelberg, M., Eschbaum, R., Lappalainen, A., Minde, A., Repecka, R. & Thoresson, G. 2006. Trends in the coastal fish stocks in the Baltic Sea. *Boreal. Env. Res.*, 11, 13-25.

Illustrative material for indicator documentation

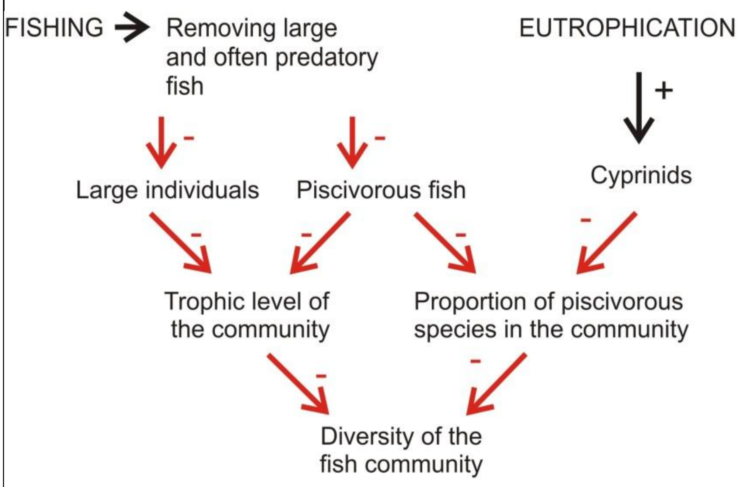


Figure 1. Relationship between biodiversity of the fish community and anthropogenic pressures (modified from HELCOM 2012b)

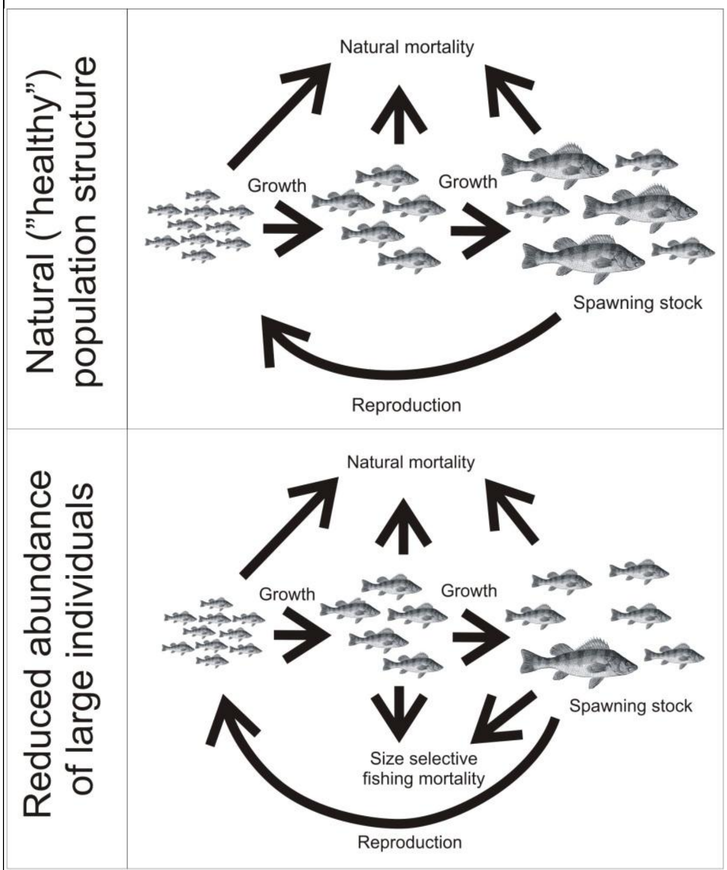


Figure 2. Strong fishing effort can shift the natural population structure. The individuals which grow faster are removed from the spawning stock by size-selective fisheries and thus alternative life-history strategies (slow growth and/or early maturation) prevail.

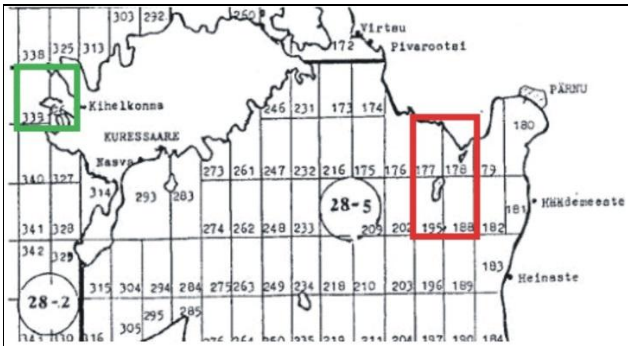


Figure 3. The areas (green box denotes Vilsandi and red box Kihnu area) used for testing the relationship between indicator and pressure

Table 1. Commercial fisheries statistics from Vilsandi and Kihnu area

Area	Section	Nr. of gillnet nights	Perch landings (kg)
Kihnu	177	5 380	12 857
	178	25 162	133 879
	188	6 668	39 728
	195	3 247	11 630
	total	**40 457**	**198 094**
Vilsandi	326	654	448
	339	146	29
	total	**800**	**477**

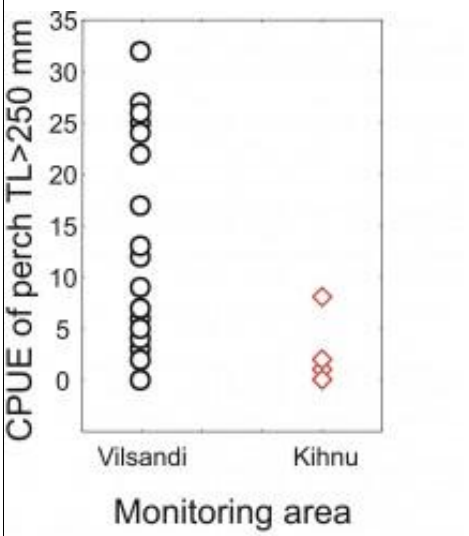


Figure 4. Comparison of indicator values in monitoring stations in areas with different fishing pressure.

Name of indicator	**1.5 The length at sexual maturation of female pikeperch (*Sander lucioperca*) in monitoring catches**
Type of Indicator	State indicator
Author(s)	Lauri Saks, Kristiina Jürgens, Antti Lappalainen, Eevi Kokkonen, Outi Heikinheimo, Aare Verliin, Markus Vetemaa, Ülle Talvik
Description of the indicator	The indicator describes the average size (TL) at which female pikeperch of monitored populations reach maturity. This indicator should be considered as index of the population's size and age distribution and should be associated to fishing pressure (both commercial and recreational) on local fish communities. Decrease in the values of this indicator may be symptom of strong fishing pressure which may have lead to life-history shift in local pikeperch populations. The latter can further lead to decrease in the mean trophic level of the community, which in turn may lead to decline in local biodiversity (Fig 1).
Relationship of the indicator to marine biodiversity	Generally, higher frequencies of sexually mature (older and larger) individuals are considered to be in correlation with the health of fish stocks (Piet *et al*. 2010). At the same time fishing effort (especially recreational but also commercial) is often targeted at large predatory fish and in circumstances of heavy (size-selective) fishing pressure, the proportion of large, sexually mature piscivores will decrease in the community (e.g. Allendorf 2009). It is known that the size at sexual maturation is under strong evolutionary pressure in fish (e.g. Stearns 1992). At the same time earlier maturation is often associated with slower growth (e.g. Vainikka & Hyvärinen 2012). As fast growing individuals which reach sexual maturity in relatively large size are removed from the spawning stock by selective fishing, life-history shifts are prone to occur in local populations towards the strategies of slower growth and/or maturation in smaller size (Fig 2; see e.g. Hutchings & Reynolds 2004, Olesen *et al*. 2005, Conover 2007; Enberg *et al*. 2012, Pukk *et al*. 2013). Larger individuals have a more specific role in the ecosystem than smaller individuals as they usually occupy higher trophic level than smaller fish. Such shifts in the structure of local fish communities may, however, be symptomatic for decrease in the mean trophic level of the community, which in turn may lead to decline in local biodiversity (Fig 1).
Relevance of the indicator to different policy instruments	Similar indicators (e.g. Mean size of perch (*Perca fluviatilis*) at their first sexual maturation in monitoring catches) are used as indicators for fishing pressure under the descriptor 3 of MSFD by Estonia (Martin 2013). This indicator can be used as for MSFD D1 and D3.
Relevance to commission decision criteria and indicator	1.3.1. Population demographic characteristics (e .g. body size or age class structure, sex ratio, fecundity rates, survival/ mortality rates)
Method(s) for obtaining indicator values	Data on local mean size of female pikeperch at first sexual maturation (L50) is gathered during annual monitoring (trawl or fyke-net) catches. Monitoring is carried out during spring, before the spawning season of the pikeperch. Level of maturation is determined by visual inspection of dissected fish. L50 is determined using logistic regression model (Fig. 3; results in Table 1) where individual total length (TL) is an independent variable and the level of sexual maturity is a dependent variable (Chen & Paloheimo 1994).
Documentation of relationship between indicator and pressure	Evolutionary life-history shift towards reduction in size at first maturation as response to heavy fishing has been reported for several fish species (see e.g. Hutchings & Reynolds 2004, Olesen *et al*. 2005, Conover 2007; Enberg *et al*. 2012, Pukk *et al*. 2013). Determining L50 has been successfully used for such studies at the population level (e.g. Chen & Paloheimo, 1994; O'Brien, 1999). Associations between indicator values and fishing pressure were tested by comparing monitoring areas with different pikeperch fishery regulations. In Pärnu area (Gulf of Riga) the minimum catchable size limit is TL=44 cm and only gillnets with minimum mesh size of 48 mm (knot to knot = 96 mm streched mesh) are allowed. Gillnet fisheries in the Helsinki area have mesh size limitations at 50 mm (knot to knot = 100 mm streched mesh). In the Archipelago Sea, there are mesh size limitations or recommendations at 43 mm or 45 mm (knot to knot = 86 mm or 90 mm streched mesh). The minimum catchable size limit for pikeperch is TL=40 cm in the Helsinki area, and TL=37 cm in the Archipelago Sea. Evidently, L50 values for monitoring areas with alternative pikeperch fishery regulations differed markedly (Table 1, Fig 4). The lowest indicator values were recorded from Archipelago Sea with long history of strong size-selective fishing pressure. The indicator values for Helsinki and Pärnu area were considerably higher. Still, only one measurement was higher than estimated target value (and also in this case only in the comparison with conservative

	target value). Thus, if compared to historic data, indicator values (for at least Pärnu area) during recent years were lower than recorded in the past (Fig. 4). These results indicate that that size-selective fishing pressure may have played a role in the development of the current size structure of these pikeperch populations (similarly with several documented cases; see e.g. Hutchings & Reynolds 2004, Olesen *et al*. 2005, Conover 2007; Enberg *et al*. 2012, Pukk *et al*. 2013).
Geographical relevance of indicator	2. Regional
How Reference Conditions (target values/thresholds) for the indicator were obtained?	The target values were selected on the basis of historical data on Pärnu area (Erm, 1981). The size at which approximately 50% of females individuals were mature was between (conservative estimate) TL=40.3 cm and (optimistic estimate) TL=41.4 cm (Erm 1981, transformed according to Saat *et al*. 2007). However, as pikeperch growth rate is dependent on several environmental factors (temperature, food availability) substantial inter-location variability in L50 reference conditions may be expected to occur. Thus, if possible, the indicator baseline values should be adjusted to local conditions.
Method for determining GES	The situation is considered to be subGES if the indicator values are lower than locally determined reference conditions (e.g. L50 lower than 40.3 cm in Pärnu area; Fig 4).
References	Allendorf, F.W. & Hard, J.J. 2009.Human-induced evolution caused by unnatural selection through harvest of wild animals.Proc. Natl Acad. Sci. USA 106: 9987–9994 Chen, Y. & Paloheimo, J.E. 1994. Estimating fish length and age at 50% maturity using a logistic type model. Aquat. Sci., 56, 206-219. Conover, D.O. 2007. Fisheries: Nets versus nature. Nature, 450, 179-180. Enberg, K., Jørgensen, K., Dunlop, E.S., Varpe, Ø., Boukal, D.S., Baulier, L., Eliassen, S. & Heino, M. 2012. Fishing-induced evolution of growth: concepts, mechanisms and the empirical evidence. Marine Ecol., 33, 1–25. Erm, V. 1981. Koha. Valgus, Tallinn. HELCOM, 2012. Development of a set of core indicators: Interim report of HELCOM CORESET project. PART A. Description of the selection process. Balt. Sea Environ. Proc. No. XXX A (http://www.helcom.fi/BSAP_assessment/ifs/ifs2012/en_GB/CoastalFish/ Hutchings, J.A. & Reynolds, J.D. 2004. Marine fish population collapse: consequences for recovery and extinction risk. BioScience 54, 297-309. Martin, G., (ed). 2013 Eesti mereala Hea Keskkonnaseisundi indikaatorid ja keskkonnasihtide kogum. Aruanne MSFD artikkel 9 ja 10 nõuete täitmiseks. Eesti Mereinstituut. Tallinn. Olsen, E.M., Lilly, G.R., Heino, M., Morgan, M.J., Brattley, J. & Dieckmann, U. 2005. Assessing changes in age and size at maturation in collapsing populations of Atlantic cod (*Cadus morhua*). Can. J. Fisheries Aquatic Sci. 62, 811-823. Piet, G.J., Albella, A.J., Aro, E., Farrugio, H., Lleonart, J., Lordan, C., Mesnil, G., Petrakis, G., Pusch, C., Radu, G. & Rätz, H.-J. 2010. Marine Strategy Framework Directive. Task Group 3 Report. Commertially exploited fish and shellfish. (Doerner, H. & Scott, R., eds). EU and ICES, Luxembourg. Pukk, L., Kuparinen, A., Järv, L., Gross, R. & Vasemägi, A. 2013. Genetic and life-history changes associated with fisheries-induced population collapse. Evol. Appl. 6, 749-760. Saat, T., Saat, T. & Nursi, A. 2007. Total length – standard length relationship in Estonian fishes. In Book of abstracts of the XII European congress of ichthyology (Buj, I., Zanella, L. & Mrakovicic, M., eds), p 141. European Ichthyological Society. Stearns, S.C. 1992. The evolution of life histories. Oxford University Press, Oxford. Vainikka, A. & Hyvärinen, P. 2012. Ecologically and evolutionarily sustainable fishing of the pikeperch *Sander lucioperca*: Lake Oulujärvi as an example. Fisheries Res. 113, 8–20.

Illustrative material for indicator documentation

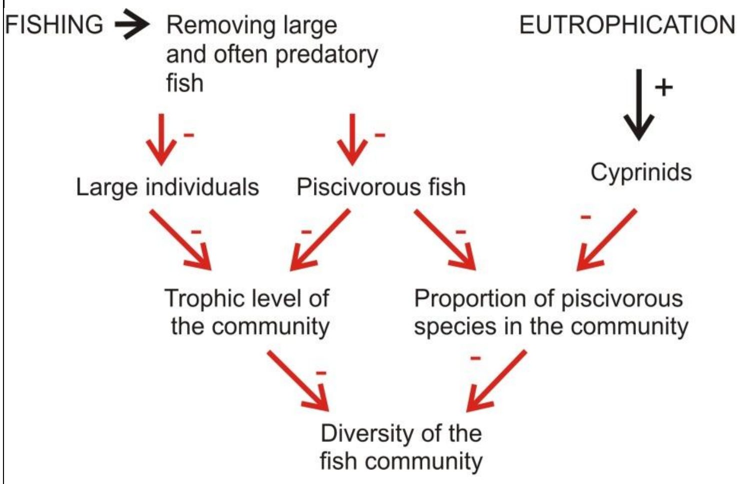


Figure 1. Relationship between biodiversity of the fish community and anthropogenic pressures (modified from HELCOM 2012b)

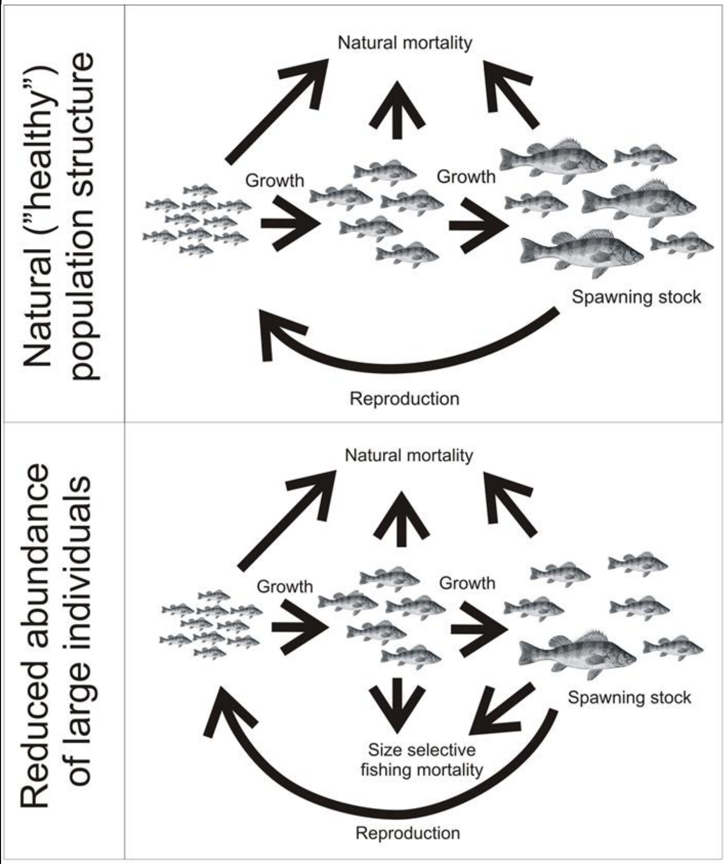


Figure 2. Strong fishing effort can shift the natural population structure. The individuals which grow faster are removed from the spawning stock by size-selective fisheries and thus alternative life-history strategies (slow growth and/or early maturation) prevail.

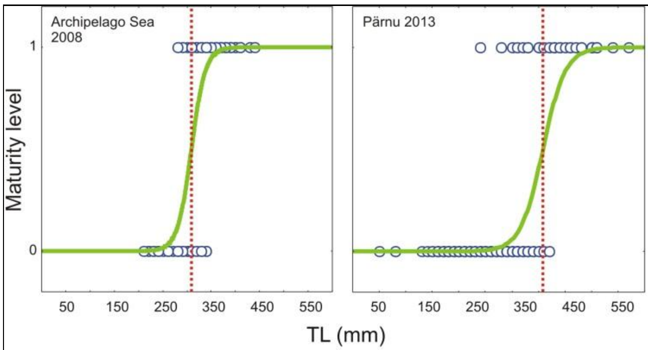


Figure 3. L50 is determined using logistic regression model where individual total length (TL) is independent and the level of sexual maturity is dependent variable (Chen & Paloheimo 1994). Red dashed line denotes respective L50 values.

Table 1. Indicator values in areas with different pikeperch fishery regulations.

Location	Year	L50	Model χ^2	p	N (0's; 1's)
Helsinki	2012	35.1	101.25	<0.00001	42; 76
	2013	35.3	62.33	<0.00001	30; 53
Pärnu	2011	38.4	106.86	<0.00001	153; 31
	2012	36.3	59.24	<0.00001	56; 17
	2013	40.8	122.41	<0.00001	245; 32
Archipelago Sea	2004	31.2	36.85	<0.00001	60; 152
	2005	31.2	27.48	<0.00001	23; 76
	2006	31.6	26.90	<0.00001	17; 37
	2008	30.9	65.29	<0.00001	33; 67
	2009	27.4	26.86	<0.00001	17; 154

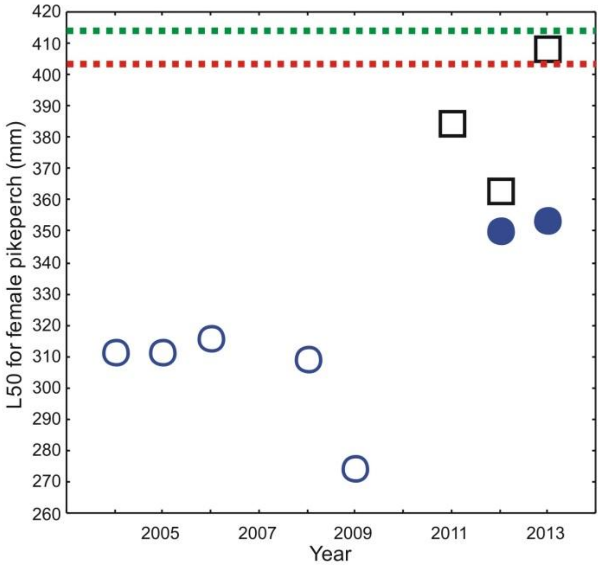
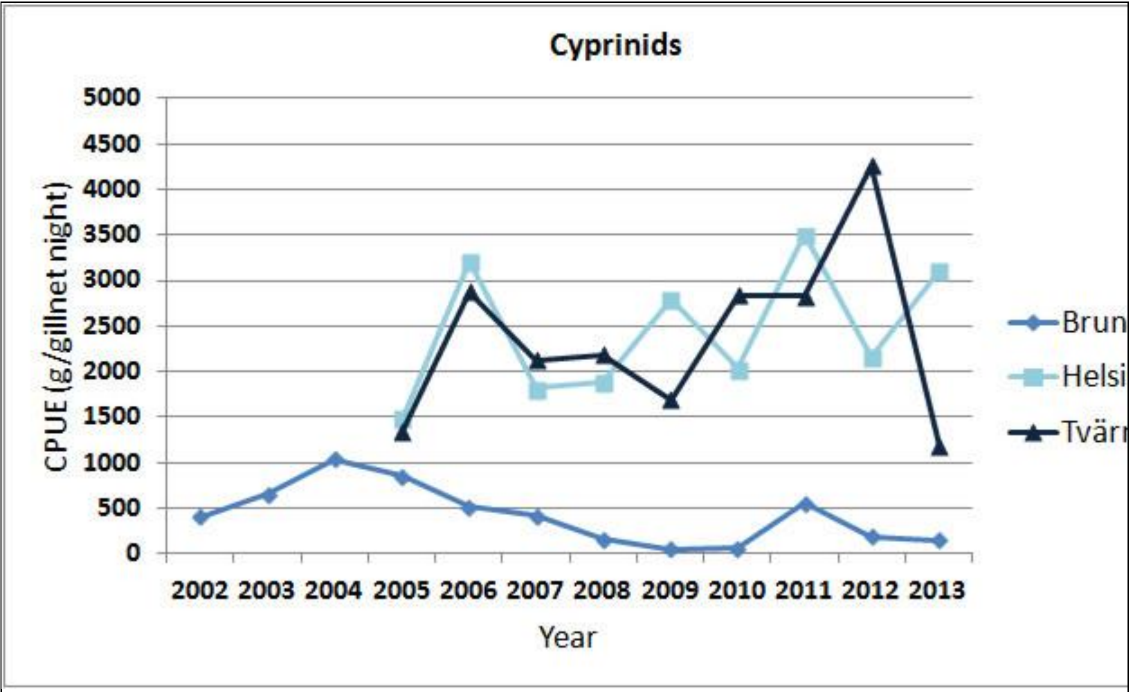


Figure 4. Indicator values in areas with different pikeperch fishery regulations. Empty circles denote Archipelago Sea, filled circles denote Helsinki and empty squares denote Pärnu area. Green dashed line marks the upper (optimistic, TL=41.4 cm) and red dashed line the lower (conservative, TL=40.3 cm) target values for Pärnu area.

Name of indicator	**1.6 Abundance of Cyprinids**
Type of Indicator	State indicator
Author(s)	Antti Lappalainen
Description of the indicator	This indicator measures the abundance of Cyprinids (group of freshwater fish species) in archipelago areas. The primary indicator is the average abundance (kg/gill-net/night) of Cyprinids (all togeteher) in coastal gill-net monitoring. A potential secondary indicator is the average catch (kg/trap net /day) of bream (*Abramis brama*) during the spring season in the commercial fishery targeted to Cyprinids and other coastal species. Abundance of roach (*Rutilus rutilus*) in gill-net monitoring, measured as individuals/gill-net/night, has already been used in the assessment of coastal fish communities (HELCOM 2006). The power analyses of Cyprinid gill-net data carried out in MARMONI-project have, however, revealed that the variation is lower and power higher if abundance is measured as weight than as numbers of individuals.
Relationship of the indicator to marine biodiversity	This indicator reflects the biodiversity of coastal fish communities. Cyprinids, such as roach and breams (*Abramis brama* and *Blicca bjoerkna*), have an important role in the food-webs of shallow archipelago areas in the northern Baltic Sea. They feed mainly on molluscs (e.g. Rask 1989). Predation by Cyprinids might even affect the structure of local blue mussel (*Mytilus edulis*) populations in the Gulf of Finland, where blue mussels live at the edge of their range (Lappalainen *et al*. 2005)
Relevance of the indicator to different policy instruments	This indicator can be applied for MSFD descriptor 1 (Biodiversity / 1.2. population size) and especially for MSFD descriptor 4 (Food webs / 4.3 abundance or distribution of key trophic groups/species). The indicator has been agreed as a Candicate indicator in the HELCOM CORESET of Biodiversity indicators (2.11. Abundance of fish key trpohic groups, HELCOM 2012).
Relevance to commission decision criteria and indicator	1.2.1. Population abundance and/or biomass
Method(s) for obtaining indicator values	The primary indicator is the average abundance (kg/gill-net/night) of Cyprinids (all togeteher) in coastal gill-net monitoring. In Finland, the recently started commercial fishery targeted for Cyprinids offers new valuable data source for estimating the abundance of Cyprinids, if this type of fishery continues in future. Here the average catch (kg/trap net /day) of bream (*Abramis brama*) during the spring season could be used as an indicator. Some attempts to estimate the biomasses of cyprinids by hydroacoustic surveys in the shallow archipelago areas have recently carried out in Finland, too, but these attempts have failed. Finland has the longest time series of catch data of small-scale commercial fishery in the Baltic Sea region. The data is available from year 1980 onwards. Our analysis has, however, revealed that this long data set can not be properly used here, the basic reason being the fact that the fishermen's interest for Cyprinids has not been stable. During the early years, there was demand and targeted fishery for bream, and as a consequence, the catches were high and well reported. During the 1990s and 2000s, fishermen mostly tried to avoid breams and other cyprinids and did not report them properly, but after 2009-2010, some commercial fishermen started effective fishery on cyprinids. According to some old samples, the growth of bream in the Finnish coast used to be higher 20-30 years ago than now. It is possible that scarcity of food might restrict the growth of cyprinids now because the densities are evidently high. Thus, the growth of bream (corrected by a temperature factor) might reflect the abundance and be used as an indicator in the future. A prerequisite is that the effects of the targeted commercial fishery for bream should be seen on the growth during the next few years.
Documentation of relationship between indicator and pressure	Large cyprinid fish, such as breams and roach, have become increasingly abundant e.g. in the archipelago waters of Finnish coast and the main reason for this development is coastal eutrophication (Lappalainen 2002). Bonsdorff *et. al*. (1997) has reported similar results from the Archipelago Sea. Results of gill-net monitoring data from the Archipelago Sea and Åland Sea also shows increase in the abundance of certain Cyprinids, the possible reason being the coastal eutrophication (Ådjers *et al*. 2006). In lakes, the increase in total catches and in cyprinid populations caused by strong eutrophication is a well documented phenomenon (e.g. Svärdson and Molin 1981, Persson *et al*. 1991)

	In addition to this, the high abundance of cyprinids probably tends to maintain the eutrophic conditions also in the archipelago area as has been reported from several eutrophic lakes.
Geographical relevance of indicator	1. Local
How Reference Conditions (target values/thresholds) for the indicator were obtained?	No proper long-term data sets of reference conditions are available from the Finnish coast. A few coastal gill-net surveys have been carried out in the 1970s and 1990s, but the gill-nets and sampling designs used were not similar as nowadays. The "Nordic" multi-mesh gill-nets have commonly been used in Finland and Sweden since the early 2000s, when several new monitoring areas where established. Gill-net series are still used in Estonia and there the possibilities to find suitable reference data could be better. There are, however, high and even contradictory variaton in abundance of cyprinids between monitoring areas. Thus, it might be problematic to extrapolate the results outside the monitoring areas.
Method for determining GES	The preliminary GES-target is a decreasing trend in the abuncance of Cyprinids in the archipelago areas, where increase in abundance has been observed (e.g. Finnish coast of the Gulf of Finland, Archipelago Sea, Archipelago of the Åland Sea).
References	Bonsdorff, E., Blomqvist, E.M., Mattila, J. and Norkko, A. 1997. Long-term changes and coastal eutrophication. Examples from the Åland Islands and the Archipelago Sea, northern Baltic Sea. Oceanol. Acta 20:319-329. HELCOM 2006. Assessment of coastal fish in the Baltic Sea. Baltic Sea Environment Proceedings No. 103 A. HELCOM 2012: Development of a set of core indicators: Interim report of the HELCOM CORESET project, part B: Descriptions of the indicators. – Baltic Sea Environmental Proceedings 129B: 1–219. Lappalainen. A. 2002. The effects of recent eutrophication on freshwater fish communities and fishery on the northern coast of the Gulf of Finland, Baltic Sea. PhD-Thesis, University of Helsinki. Lappalainen, A., Westerbom, M. and Heikinheimo, O. 2005. Roach (*Rutilus rutilus*) as an important predator on blue mussel (*Mytilus edulis*) populations in a brackish water environment, the northern Baltic Sea. Marine Biology 147:323-330. Persson, L., Diehl, S., Johansson, L., Andersson, G. and Hamrin, S. 1991. Shifts in fish communities along the productivity gradient in temperate lakes – patterns and the importance of the size-streuctured interactions. J. Fish Biol. 38:281-293. Rask, M. 1989. A note of the diet of roach, *Rutilus rutilus, L.*, and other cyprinids at Tvärminne, northern Baltic Sea. Aqua Fennica 19:19-27. Svärdson, G. and Molin, G. 1981. The impact of eutrophication and climate change on a warmwater fish community. Rep. Inst. Freshw. Res., Drottningholm 59:142-151. Ådjers, K., Appelberg, M., Eschbaum, R., Lappalainen, A., Minde, A., Rpecka, R. and Thoresson, G. 2006. Trends in coastal fish stocks of the Baltic Sea. Boreal Environment Research 11:13-25.

Illustrative material for indicator documentation	 Figure 1. Catch per unit effort (CPUE) cyprinids in the Archipelago Sea (Brunskär) and in the Gulf of Finland (Helsinki, Tvärminne).

Name of indicator	**1.7 Trophic diversity index of juvenile fish**

Type of Indicator	State indicator
Author(s)	Martin Ogonowski, Göran Sundblad, AquaBiota Water Research
Description of the indicator	This indicator reflects the diversity of juvenile fish weighted by the mean community trophic level of adults. A high value of the indicator should reflect an overall high diversity in terms of juvenile fish and favorable nursery habitats for key predatory fish species such as pike (*Esox lucius*), perch (*Perca fluviatilis*) and pikeperch (*Sander lucioperca*), which are important for the maintenance of food web integrity (Eriksson *et al.* 2009). The indicator will currently be of relevance for Swedish waters as the method of using underwater detonations is restricted to a national level.
Relationship of the indicator to marine biodiversity	The indicator directly indicates the biodiversity of juvenile fish species in relation to the mean trophic level of the community and this diversity should in turn also indicate the fish production potential of the habitats. The indicator is directly comparable to metrics used in gillnet monitoring (Helcom 2012, D1.7.1), where it is used to reflect the general trophic structure at the community level. Low values may indicate domination of species favoured by eutrophic conditions and vice versa. Unlike Helcom (2012) fishing is expected to be of less direct relevance (indirectly via potential reduction of SSB), and a comparison of the two methods should be made.
Relevance of the indicator to different policy instruments	MSFD descriptors: Mainly relevant for MSFD descriptor 1 "Biological diversity is maintained", and also 3 "Populations of all commercially exploited fish and shellfish are within safe biological limits" and descriptor 5 "Eutrophication". HELCOM BSAP: Relevant for BSAP segment 1: „Towards a Baltic Sea unaffected by eutrophication" and 4: "Towards favourable conservations status of Baltic Sea biodiversity" by providing data on important fish communities and nursery habitats. Habitats Directive: The indicator may be used to indicate structure and function of a selected set of Natura 2000 habitat types which may serve as important nursery habitats (Sundblad *et al*. 2011).
Relevance to commission decision criteria and indicator	1.6.1. Condition of the typical species and communities 1.6.2. Relative abundance and/or biomass, as appropriate
Method(s) for obtaining indicator values	The distribution and abundance of 0-group fish is sampled by the use of small (1g or 10 g explosive) underwater detonations (e.g. Sundblad *et al*. 2011). This active sampling method, which is non-destructive with respect to other biota than fish, is used by Scandinavian fisheries researchers to obtain point abundance samples in heterogeneous environments where other methods such as beach seines, small trawls and drop-samplers are difficult to use (Snickars *et al*. 2007). The method captures all species with gas-filled cavities within approximately a 5 m radius of the detonation and yields representative length distributions of fish between 3 and 20 cm total length. Indicator values will be calculated as the Shannon-Wiener index of 0-group fish (juveniles) weighted by the mean community trophic level of adults (trophic level set by Fishbase www.fishbase.org). The index is primarily intended to be calculated on coastal bay-basis but other geographical scales should also be evaluated.
Documentation of relationship between indicator and pressure	Eutrophication and habitat loss, due to e.g. dredging, constructions or boating activities, are suggested to be the main anthropogenic pressures for this indicator but relationships between the indicator and pressures still have to be tested and determined (Sandström *et al*. 2005, Bergström *et al*. 2013). A comparison of the indicator obtained with underwater detonations and with gillnet monitoring is also recommended.
Geographical relevance of indicator	3. National waters
How Reference Conditions (target values/thresholds) for the indicator were obtained?	Reference conditions need to be established. Reference conditions could be examined by spatial modelling in relation to both environmental and pressure variables in order to delineate natural and anthropogenic influence on the indicator. Also, comparing across different regional settings could help separate low from high estimates suggesting suitable targets. Simultaneously high and low indicator values may be further investigated in relation to other organisms and trophic levels, primarily macrovegetation and gillnet monitoring.
Method for determining GES	GES-levels have not yet been established. In order to reach recommendations on levels, similar analyses as for Reference Conditions should be applied. Including, where available, the use of time series.

References	Bergström, U., Sundblad, G., Downie, A.-L., Snickars, M., Boström, C., and Lindegarth, M. 2013. Evaluating eutrophication management scenarios in the Baltic Sea using species distribution modelling. Journal of Applied Ecology 50: 680-690. Eriksson, B. K., L. Ljunggren, A. Sandström, G. Johansson, J. Mattila, A. Rubach, S. Råberg, and M. Snickars. 2009. Declines in predatory fish promote bloom-forming macroalgae. Ecological Applications 19:1975–1988. HELCOM, 2012. Development of a set of core indicators: Interim report of the HELCOM CORESET project. PART B: Descriptions of the indicators. Baltic Sea Environment Proceedings No. 129 B. Sandström, A., Eriksson, B. K., Karås, P., Isæus, M., and Schreiber, H. 2005. Boating and navigation activities influence the recruitment of fish in a Baltic Sea archipelago area. Ambio, 34: 125-130. Snickars, M., Sandström, A., Lappalainen, A., and Mattila, J. 2007. Evaluation of low impact pressure waves as a quantitative sampling method for small fish in shallow water. Journal of Experimental Marine Biology and Ecology, 343: 138-147. Sundblad, G., Bergström, U., and Sandström, A. 2011. Ecological coherence of marine protected area networks: a spatial assessment using species distribution models. Journal of Applied Ecology 48: 112-120.

Name of indicator	**1.8 Habitat-related functional diversity of juvenile fish**
Type of Indicator	State indicator

Author(s)	Martin Ogonowski, Göran Sundblad, AquaBiota Water Research
Description of the indicator	This indicator reflects the functional biodiversity of 0-group (juvenile) fish species in terms of habitat preference and is based on the diversity of species that have a preference for high temperatures and a strong affinity for vegetation. The classification of preference follows Sandström *et al.* (2005, Table 1). A high value of the indicator should reflect a high diversity of species within the defined functional group as well as warm and vegetated areas functioning as nursery areas for both pike (*Esox lucius*), perch (*Perca fluviatilis*) and many cyprinids. The indicator will primarily be of relevance for Swedish waters as the method of using underwater detonations is restricted to a national level.
Relationship of the indicator to marine biodiversity	The indicator directly indicates the biodiversity of juvenile fish within a habitat based functional group and this diversity should in turn also indicate to what extent the habitat functions as spawning and nursery areas, i.e. fish production, if the number of species is complemented with densities (cpue). The indicator is to some extent comparable to metrics used in gillnet monitoring (HELCOM 2012) where it is used to reflect fishing pressure and eutrophication. However, the juvenile stages are less directly responding to fishing pressure and are likely more related to eutrophication and coastal development. A comparison between detonation (juvenile) and gillnet monitoring is recommended for the future.
Relevance of the indicator to different policy instruments	MSFD descriptors: Mainly relevant for MSFD descriptor 1 "Biological diversity is maintained", and also 3 "Populations of all commercially exploited fish and shellfish are within safe biological limits" and descriptor 5 "Eutrophication" HELCOM BSAP: Relevant for BSAP segment 1: „Towards a Baltic Sea unaffected by eutrophication" and 4: "Towards favourable conservations status of Baltic Sea biodiversity" by providing data on important fish communities and nursery habitats. Habitats Directive: The indicator may be used to indicate structure and function of a selected set of Natura 2000 habitat types which may serve as important nursery habitats (Sundblad *et al.* 2011).
Relevance to commission decision criteria and indicator	1.6.1. Condition of the typical species and communities 1.6.2. Relative abundance and/or biomass, as appropriate
Method(s) for obtaining indicator values	The distribution and abundance of 0-group fish is sampled by the use of small (1g or 10 g explosive) underwater detonations (e.g. Sundblad *et al*.2011). This active sampling method, which is non-destructive with respect to other biota than fish, is used by Scandinavian fish researchers to obtain point abundance samples in heterogeneous environments where other methods such as beach seines, small trawls and drop-samplers are difficult to use (Snickars *et al.* 2007). The method captures all species with gas-filled cavities within approximately a 5 m radius of the detonation and yields representative length distributions of fish between 3 and 20 cm total length. Indicator values will be calculated as the Shannon-Wiener index of fish species with a preference for warm and vegetated areas *sensu* Sandström *et al.* (2005). The index is primarily intended to be calculated on coastal bay-basis but other geographical scales will also be evaluated. In addition to the biodiversity index evaluations using densities (cpue) is also recommended.
Documentation of relationship between indicator and pressure	Eutrophication and habitat loss, due to e.g. dredging, constructions or boating activities, are suggested to be the main anthropogenic pressures for this indicator (Sandström *et al*. 2005, Bergström *et al.* 2013) but relationships between the indicator and pressures still have to be tested and determined.
Geographical relevance of indicator	3. National waters
How Reference Conditions (target values/thresholds) for the indicator were obtained?	Reference conditions need to be established. Reference conditions could be examined by spatial modelling in relation to both environmental and pressure variables in order to delineate natural and anthropogenic influence on the indicator. Also, comparing across different regional settings could help separate low from high estimates suggesting suitable targets. Simultaneously high and low indicator values may be further investigated in relation to other organisms and trophic levels, primarily macrovegetation and gillnet monitoring.
Method for determining GES	GES-levels have not yet been established. In order to reach recommendations on levels, similar analyses as for Reference Conditions should be applied. Including, where available, the use of time series.
References	Bergström, U., Sundblad, G., Downie, A.-L., Snickars, M., Boström, C., and Lindegarth, M.

	2013. Evaluating eutrophication management scenarios in the Baltic Sea using species distribution modelling. Journal of Applied Ecology, 50: 680-690. HELCOM, 2012. Development of a set of core indicators: Interim report of the HELCOM CORESET project. PART B: Descriptions of the indicators. Baltic Sea Environment Proceedings No. 129 B. Sandström, A., Eriksson, B. K., Karås, P., Isæus, M., and Schreiber, H. 2005. Boating and navigation activities influence the recruitment of fish in a Baltic Sea archipelago area. Ambio, 34: 125-130. Snickars, M., Sandström, A., Lappalainen, A., and Mattila, J. 2007. Evaluation of low impact pressure waves as a quantitative sampling method for small fish in shallow water. Journal of Experimental Marine Biology and Ecology, 343: 138-147 Sundblad, G., Bergström, U., and Sandström, A. 2011. Ecological coherence of marine protected area networks: a spatial assessment using species distribution models. Journal of Applied Ecology 48: 112-120.

2 Benthic indicators

Name of indicator	**2.1 Accumulated cover of perennial macroalgae**
Type of Indicator	State indicator
Author(s)	Nicklas Wijkmark
Description of the indicator	This indicator reflects quantity of the perennial macroalgae community measured as accumulated cover, thus indicating biodiversity quantity as the amount of a diverse community of algae and species living on and among the algae. It indicates biodiversity quantity on shallow hard bottoms and may be used simultaneously with a vascular plant indicator for shallow soft bottoms. The measured unit is accumulated % cover and the assessment unit is the total aggregated accumulated cover within a predefined monitoring area. Since the abundance of ephemeral species varies considerably both seasonally and between years (e.g. Kiirikki and Lehvo 1997), only perennial species are included in this indicator. It is similar to the indicator "Total cover of erect macroalgae" developed as an indicator of water quality for the WFD in Denmark (Carstensen *et al*. 2005), but in accumulated cover the cover of each species are summed including all layers and overlapping species. The indicator is intended for use in the entire Baltic Sea, but establishment of new reference values are needed when using the indicator in a new area. The indicator may also be used in the Gulf of Bothnia by including bryophytes when calculating accumulated cover.
Relationship of the indicator to marine biodiversity	This indicator reflects the amount of the perennial macroalgae community, thus indicating biodiversity quantity of perennial macroalgae and associated species. Macroalgae form habitats for a range of other species in the Baltic Sea (e.g. Bucas 2009; Råberg and Kautsky, 2006; Wikström and Kautsky, 2007; Salovius and Kraufvelin, 2004).
Relevance of the indicator to different policy instruments	MSFD descriptors: Mainly relevant for MSFD descriptor 1 "Biological diversity is maintained". May also be of relevance for descriptor 5 "Eutrophication" HELCOM BSAP: Relevant for BSAP segment 4: "Towards favourable conservations status of Baltic Sea biodiversity" by providing data of important communities and habitat building species. Habitats Directive**:** May provide relevant data for habitats such as 1170 (reefs).
Relevance to commission decision criteria and indicator	1.5.2. Habitat volume 1.6. Habitat condition 1.6.1. Condition of the typical species and communities 1.6.2. Relative abundance and/or biomass, as appropriate
Method(s) for obtaining indicator values	Suggested sampling method is drop-video which is a time efficient method for covering large areas (Svensson *et al*. 2011). Methods such as diving may also be used. Geographical aggregation – Sampling may be performed in different ways. An example applicable to drop-video is a randomized stratified sampling in monitoring areas in order to cover important gradients such as depth and wave exposure. Both soft and hard substrates can be sampled, thus also providing data for the vascular plant indicator within the same survey. However, indicator values for this indicator are only calculated for hard bottoms. Stations with both soft and hard substrates can provide data for both indicators. Monitoring areas can be natural such as coastal basins, or artificial such as administrative units. Temporal aggregation – Repeated sampling and modelling of perennial macroalgae cover in monitoring areas within a monitoring programme provides temporal trends of the quantity of this community. Sampling is performed once during a monitoring year. This is typically performed in summer or early autumn.
Documentation of relationship between indicator and pressure	Eutrophication is suggested as the main anthropogenic pressure for this indicator. Accumulated cover of perennial macroalgae was negatively related to mean CHLa in a random Forest analysis of the data from the Hanö Bight study area, supporting eutrophication and the resulting reduced transparency as main "anthropogenic" pressure. Mixed pollutants from environmentally hazardous activities also had a negative effect on the indicator values. The similar indicator "Total cover of erect macroalgae" (Carstensen *et al*. 2005) is related to water transparency and eutrophication in offshore areas, a higher cover indicating better water quality and clearer water.
Geographical relevance of indicator	4. Baltic Sea wide

How Reference Conditions (target values/thresholds) for the indicator were obtained?

Reference conditions were established by spatial modelling and prediction with environmental layers adjusted to reference conditions (e.g. adjusted predictor layers where effects of anthropogenic pressures have been removed). Adjusted environmental layers were CHLa, Secchi depth, proximity to environmentally hazardous activities, marine traffic and urban developments. This was performed with data from the Hanö Bight study area in Sweden.

Predicted reference values accumulated cover were higher than actual accumulated cover at depths below 3 meters and lower at shallower depths.

Method for determining GES

GES-levels were set as 25 % acceptable deviation from the modelled reference conditions in 2 m depth intervals.

See Table 1 for values.

References

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Kiirikki, M. and Lehvo, A. 1997. Life strategies of filamentous algae in the northern Baltic Proper. Sarsia 82, 259-267.

Råberg, S., Kautsky L., 2006. A comparative biodiversity study of the associated fauna of perennial fucoids and filamentous algae. Estuarine, Coastal and Shelf Science 73, 249-258.

Salovius, S. and Kraufvelin, P., 2004. The filamentous green alga *Cladophora glomerata* as a habitat for littoral macro-fauna in the Northern Baltic Sea, Ophelia,Vol. 58, Iss. 2, 2004.

Sandén, P. and Håkansson, B. 1996. Long-term trends in Secchi depth in the Baltic Sea. Limnol. Oceanogr. 31: 909-926.

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Wikström, S. A. and Kautsky, L. 2007. Structure and diversity of invertebrate communities in the presence and absence of canopy-forming *Fucus vesiculosus* in the Baltic Sea. Estuarine, Coastal and Shelf Science 72, 168-172.

Illustrative material for indicator documentation

Table 1. Reference conditions and GES for accumulated cover of perennial macroalgae in depth intervals suggested. The first meter below the surface should be excluded from the assessment.

Predicted RefCond and GES-levels (mean % acc. cover)		
Depth (m)	**GES value**	**Reference condition**
1-3	42	56
3-5	39	52
5-7	36	48
7-9	34	45
9-11	22	30
11-15	21	28

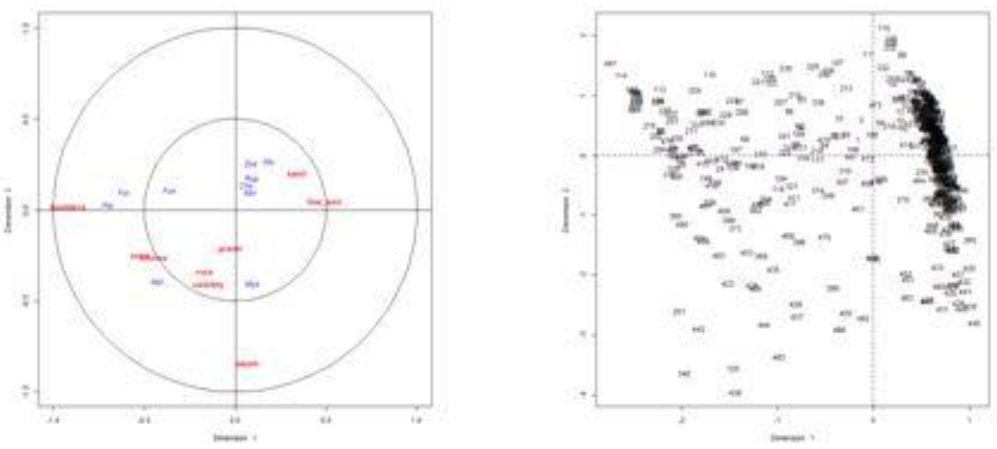

Figure 1. CCA-plot illustrating abundant macroalgae and vascular plant species in the Hanö Bight in relation to natural environmental variables. Accumulated cover of perennial macro-algae and Accumulated cover of vascular plants will together indicate biodiversity quantity in two important coastal communities.

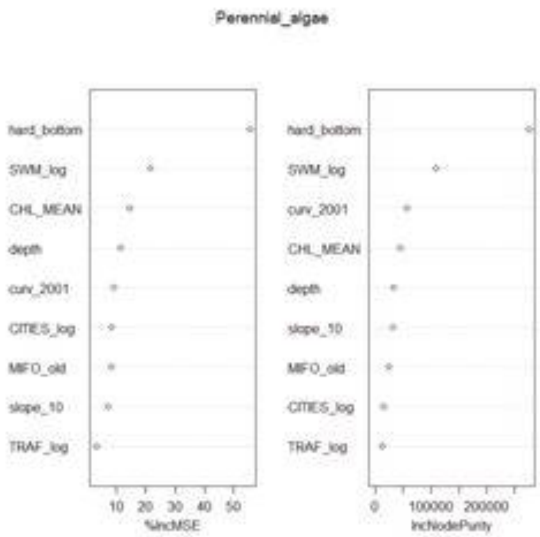

Figure 2. rF variable importance measures for accumulated cover of perennial macroalgae. Mean chlorophyll is the most important of the four "anthropogenic" or "semi-anthropogenic" environmental variables included in the analysis. (MIFO is the density of environmentally hazardous activities, CITIES is the density of populated places and TRAF is shipping).

Name of indicator	**2.2 Accumulated cover of submerged vascular plants**
Type of Indicator	State indicator
Author(s)	Nicklas Wijkmark
Description of the indicator	This indicator reflects quantity of the submerged vascular plant community measured as accumulated cover, thus indicating biodiversity quantity as the amount of the vascular plant community and associated species. It indicates biodiversity quantity on shallow soft bottoms in more sheltered areas and can be used simultaneously with the macroalgae indicator for shallow hard bottoms. All species of submerged vascular plants are included in this indicator, both eelgrass meadows and mixed stands of taxa such as *Stuckenia, Potamogeton, Myriophyllum* etc. Most studies on submerged vascular plants focus on seagrasses (e.g. Boström and Bonsdorff 1997, Hemminga and Duarte 2000,), but two studies by Hansen *et al.* (2010) on other vascular plants and charophytes show that invertebrate abundance is higher on structurally complex species.
Relationship of the indicator to marine biodiversity	This indicator reflects the amount of the submerged vascular plant community, thus indicating biodiversity quantity of submerged vascular plants and associated species. Submerged vascular plant meadows are habitats for a range of other species in the Baltic Sea (e.g. Boström and Bonsdorff, 1997) and it is known both animal abundance and species richness are higher when vascular plants are present (Orth *et al*. 1984, Hemminga and Duarte 2000).
Relevance of the indicator to different policy instruments	MSFD descriptors: Mainly relevant for MSFD descriptor 1 "Biological diversity is maintained". May also be of relevance for descriptor 5 "Eutrophication". HELCOM BSAP: Relevant for BSAP segment 4: "Towards favourable conservations status of Baltic Sea biodiversity" by providing data on community level for one aspect of Baltic Sea biodiversity as well as habitat building species. Habitats Directive: May provide relevant data for habitats such as 1110 (sublittoral sandbanks).
Relevance to commission decision criteria and indicator	1.5.2. Habitat volume 1.6. Habitat condition 1.6.1. Condition of the typical species and communities 1.6.2. Relative abundance and/or biomass, as appropriate
Method(s) for obtaining indicator values	Suggested sampling method is drop-video, which is a time efficient method for covering large areas (Svensson *et al*. 2011). Methods such as diving may also be used. Geographical aggregation – Sampling may be performed in different ways. Example using drop-video: sampling performed in a randomized stratified way within monitoring areas. Both soft and hard substrates may be sampled, thus also providing data for the macroalgae indicator within the same survey. However, only soft bottoms are included in this indicator. Monitoring areas can be natural such as coastal basins, or artificial such as administrative units. Temporal aggregation – Repeated sampling and modelling of submerged vascular plant cover in monitoring areas within a monitoring program provides temporal trends of the quantity of this community. Within a monitoring year sampling is performed once, typically in late summer or early autumn.
Documentation of relationship between indicator and pressure	Eutrophication is the main anthropogenic pressure affecting values of this indicator. CHL a, Secchi depth and N and P concentrations had negative effects on accumulated cover in a random Forest analysis performed on data from the Hanö Bight, CHL a being the most important of these predictors (Fig. 2).
Geographical relevance of indicator	4. Baltic Sea wide
How Reference Conditions (target values/thresholds) for the indicator were obtained?	Reference conditions were established by spatial modelling and prediction with environmental layers adjusted to reference conditions (e.g. adjusted predictor layers where effects of anthropogenic pressures have been removed). Adjusted environmental layers were CHL a, Secchi depth, proximity to environmentally hazardous activities, marine traffic and urban developments. The analysis was performed with data from the Hanö Bight study area in Sweden.

Method for determining GES

GES-levels were set as 25 % acceptable deviation below modelled reference conditions in 2 m depth intervals. Suggested depth interval for determining GES is 1-9 meters.

See Table 1 for GES-values.

References

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Hemminga, M. A., Duarte, C. M. 2000. Seagrass Ecology. Cambridge University Press, Cambridge, UK.

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Sandén, P. and Håkansson, B. 1996. Long-term trends in Secchi depth in the Baltic Sea. Limnol. Oceanogr. 31: 909-926.

Orth, R. J., Heck, K.L., van Monfrans, J. 1984. Faunal communities in seagrass beds: a review of the influence of plant structure and prey characteristics on predator-prey relationships. Estuaries 7:339-350.

Illustrative material for indicator documentation

Table 1. Predicted reference conditions and GES-levels for the Hanö Bight in suggested 2 m intervals.

Predicted RefCond and GES-levels (mean % acc. Cover)		
Depth	GES level	Reference condition
1-3 m	30	40
03-5 m	30	40
05-7 m	20	27
07-9 m	6	8

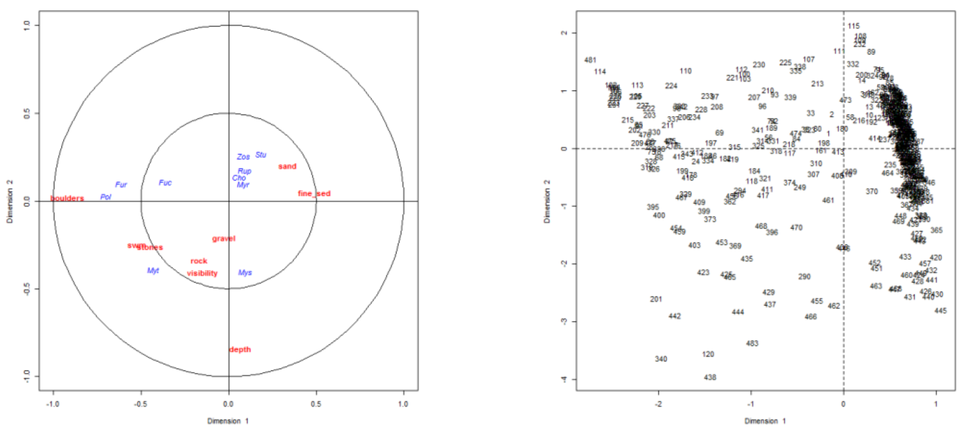


Figure 1. CCA-plot showing the vascular plant community in relation to some other abundant species and environmental variables. Accumulated cover of vascular plants and Accumulated cover of perennial macroalgae will together indicate biodiversity quantity in two important coastal communities.

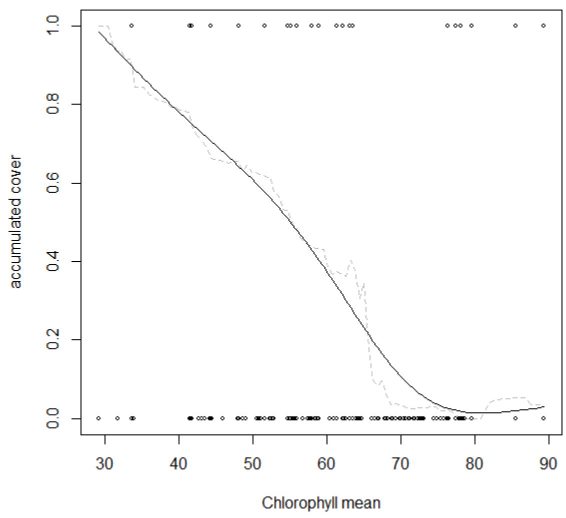


Figure 2. rF partial dependence of CHL a for accumulated cover of submerged vascular plants.

Name of indicator	**2.3 Beach wrack Macrovegetation Index (BMI)**
Type of Indicator	State indicator
Author(s)	Kaire Torn, Georg Martin, Madara Alberte
Description of the indicator	Indicator is based on the structure of macrovegetation of beach wrack. Representativeness of beach wrack data reflecting the biodiversity of macrovegetation in coastal area was tested during the study. Differences between submerged macrovegetation in coastal area and beach wrack samples were the smallest in July (table 1, Suursaar *et al.,* 2014). Compared to commonly used monitoring methods (Torn & Martin, 2011), BMI is easy to use and cost-effective. BMI was developed during a case study on data collected from northern Gulf of Riga (Baltic Sea) and tested in southern part of the Gulf of Riga. Indicator is based on relationship between eutrophication and species diversity in benthic vegetation. Index was developed based on presumptions: 1) key species (*Fucus vesiculosus, Furcellaria lumbricalis, Zostera marina, Charophyceae)* of the area were considered as valuable species for forming healthy communities, and 2) species richness of the community will shift toward increase in species number of filamentous algae due to disturbance e.g. eutrophication impact. This method can be recommended for the areas which are not affected by strong tides and currents or frequent extreme storm events.
Relationship of the indicator to marine biodiversity	Indicator reflects the diversity of macrovegetation species and abundance of community forming species.
Relevance of the indicator to different policy instruments	MSFD descriptor 1
Relevance to commission decision criteria and indicator	1.6. Habitat condition 1.6.2. Relative abundance and/or biomass, as appropriate 1.7. Ecosystem structure 1.7.1. Composition and relative proportions of ecosystem components (habitats and species)
Method(s) for obtaining indicator values	Beach wrack samples were collected from three transects parallel to the shoreline in each study area during July 2011-2013. The samples were collected using a 20 cm × 20 cm metal frame at a distance of 1 m from each other. The freshest beach wrack (i.e., the closest wrack band to the water edge) was always chosen for sampling. The collected material was packed and kept frozen. In the laboratory, the species composition of the sample was determined. In laboratory occurrence of all species, abundance of key species *(Fucus vesiculosus, Furcellaria lumbricalis, Zostera marina*, charophytes) and total biomass of the sample were determined. As wrack specimens were often fragmented and detailed identification was impossible, the morphologically very similar species were treated as one group. Based on formula (1) index was calculated for all samples. Average index value is used. The equation for calculation of BMI is: $$BMI= (1-P_{ks})/(1+P_{ks})x(N_f/N), \quad (1)$$ where P_{ks} is the proportion of key species (expressed as part per hundred), N_f means species number of filamentous algae, and N means total number of macrophyte taxa.
Documentation of relationship between indicator and pressure	The index value can vary between 0 and 1, lower values show higher status of benthic biodiversity (better condition of valuable species). In the northern Gulf of Riga, lower index values (higher status of biodiversity) were detected in areas were water transparency was higher and nutrient concentrations were lower. Pearson correlations between the index values and pressure indicators were computed. Statistically significant relationships between index and water transparency (Secchi depth), BSPI (Baltic Sea Pressure Index) and total nitrogen were found in the northern Gulf of Riga (table 2, figure 1), whereas chlorophyll *a* showed a significant relationship with index values in the southern part of the Gulf (table 3, figure 2).
Geographical relevance of indicator	2. Regional
How Reference Conditions (target values/thresholds) for the indicator were obtained?	The reference conditions for the BMI, required for establishing GES boundary, were determined based on expert judgement and current data (index values determined in the MARMONI pilot area). The index value can vary between 0 and 1, lower values show higher status of benthic biodiversity (better condition of valuable species). The best possible BMI value (BMI=0) was set as reference condition. In case of reference conditions, the majority of vegetation biomass belongs to the valuable key species and the species number of filamen-

	tous algae is negligible.
Method for determining GES	GES (Good Environment Status) level was set by using concept of acceptable deviation from the reference conditions (European Commission, 2000). Quite a similar approach has been used in assessment method for the ecological status of Estonian coastal waters, using submerged aquatic vegetation and following the requirements of EU Water Framework Directive (WFD) (Torn and Martin, 2011, 2012). According to OSPAR Common Procedure for Identification of the Eutrophication Status of the Maritime Area, the acceptable deviation from reference conditions can be restrictive (15%), intermediate (25%) or non-restrictive (50%) (Andersen *et al*., 2006). In the current study, intermediate (25%) deviation from the reference conditions was used as GES boundary (BMI values 0.25).
References	Andersen, J.H., Schlüter, L., Ærtebjerg, G. 2006. Coastal eutrophication: recent developments in definitions and implications for monitoring strategies. Journal of Plankton Research, 28 (7): 621-628. European Commission, 2000. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. Off. J. Eur. Communities L372/1. Suursaar, Ü.; Torn, K.; Martin, G.; Herkül, K.; Kullas, T. (2014). Formation and species composition of stormcast beach wrack in the Gulf of Riga, Baltic Sea. Oceanologia, 56(4), 673 - 695. Torn, K., Martin, G. 2011. Assessment method for the ecological status of Estonian coastal waters based on submerged aquatic vegetation. Brebbia, C.A.; Beriatos, E. (Toim.). Sustainable Development and Planning V (443 - 452). Southampton: WIT Press. Torn, K., Martin, G. 2012. Response of submerged aquatic vegetation to eutrophication-related environment descriptors in coastal waters of the NE Baltic Sea. Estonian Journal of Ecology, 61(2), 106 - 118.
Illustrative material for indicator documentation	Table 1. Differences of species occurrence and abundance between submerged vegetation in coastal area and data from beach wrack in three studied areas, ANOSIM test R values are shown. The R value of less than 0.25 indicates that the separation between groups is negligible; the R value of 0.5 to 0.75 shows overlapping but clearly differentiable groups, and the R value over 0.75 indicates well separated groups.

Month	Area	R	p %
May	Kõiguste	0.150	1.50
May	Orajõe	0.469	0.01
May	Sõmeri	0.356	0.03
July	Kõiguste	0.127	2.20
July	Orajõe	0.300	0.05
July	Sõmeri	0.214	0.30
Sept.	Kõiguste	0.332	0.01
Sept.	Orajõe	0.444	0.01
Sept.	Sõmeri	0.270	0.02

Table 2. Results of Pearson correlation analysis between BMI (Beach wrack Macrovegetation Index) and selected eutrophication variables, data from northern Gulf of Riga. Statistically significant relationships (p < 0.05) are in bold.

Environmental variables	R
BSPI	**0,78**
Secchi (m)	**-0,87**
Ntot (µmolN/l)	**0,63**
Ptot (µmolP/l)	0,04

Table 3. Results of Pearson correlation analysis between BMI (Beach wrack Macrovegetation Index) and selected eutrophication variables, southern Gulf of Riga. Statistically significant relationships (p < 0.05) are in bold.

Environmental variables	R
Chl *a*	**0,83**
Secchi	-0,69
Ntot	0,48
Ptot	0,32

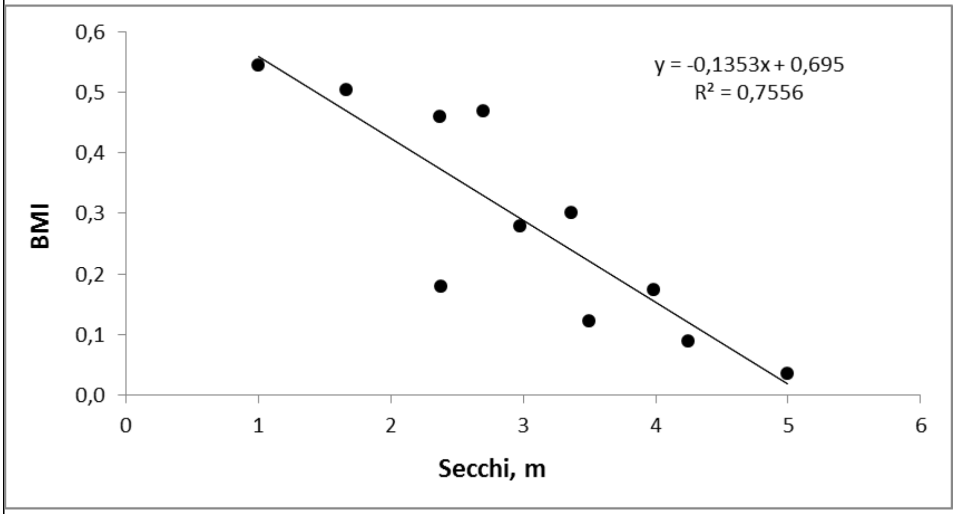


Figure 1. Relation between BMI and water transparency (Secchi depth) based on data from northern Gulf of Riga, 2011-2013.

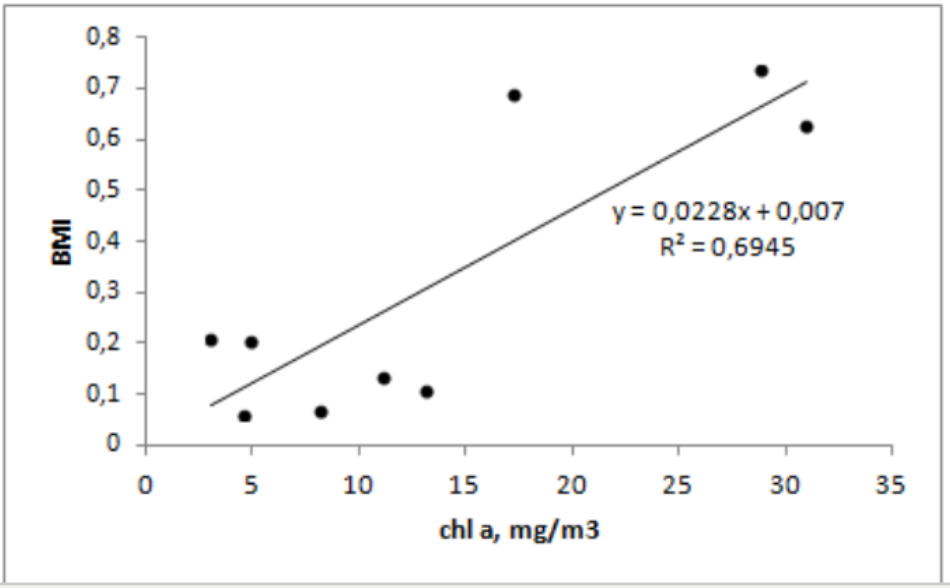


Figure 2. Relation between BMI and chlorophyll *a* based on data from southern Gulf of Riga, 2012-2013.

Name of indicator	**2.4 Indicator of macroalgal community structure (MCS)**
Type of Indicator	State indicator
Author(s)	Tiia Möller, Georg Martin
Description of the indicator	The indicator focuses on the phytobenthic community and its structural features. The macrophytes function both as a habitat and a food source for macrofauana and it is known that macrofaunal composition depends mainly on habitat architecture at a spatial micro-scale. Also that most faunal species show high mobility and dispersal rates and they colonize available habitats rapidly. Thus, though focusing only on plants, the indicator illustrates the macrofaunal community as well both in soht and hard substrates. During last years the focus on studying macroalgal communities has moved towards biological traits including structure and structural complexity (e.g. Christie *et al.* 2009), but only few indicators are based on macroalgal community structure so far (Blomqvist *et al.* 2012 and references therein). To our knowledge, this specific indicator has not been described before at least in such formula.
Relationship of the indicator to marine biodiversity	The indicator reflects the structural diversity of macroalgal community and through that composition of accompanying fauna.
Relevance of the indicator to different policy instruments	MSFD - indicator can be used under qualitative descriptors 1 (Biological diversity) as it reflects the structural diversity of macroalgal community and illustrates the possible suitable habitats for benthic fauna. Habitats Directive - indicator can be used to illustrate the variability within valuable habitat types and evaluate the temporal and spatial changes within habitat. Birds Directive – not applicable. HELCOM BSAP – indicator can be used to illustrate the variability within habitats that belong to the HELCOM Red list of Baltic habitats. Indicator can also be used in detailed landscape/habitat maps as a descriptive unit of biodiversity.
Relevance to commission decision criteria and indicator	1.7. Ecosystem structure 1.7.1. Composition and relative proportions of ecosystem components (habitats and species)
Method(s) for obtaining indicator values	The indicator values are based on coverage data of different functional and structural groups of macroalgae. Sampling is performed and coverage estimations of all distinguishable species are gained via diving or remote underwater video analysis. In the Baltic Sea area, sampling should be conducted in late summer, when all the communities have evolved. The indicator values are based on coverage data of different functional and structural groups of macroalgae, for that 3 different macroalgal groups are defined based on literature (Kotta and Orav, 2001; Salovius and Kraufvelin 2004; Råberg and Kautsky 2007; Kersen *et al*. 2007; Christie *et al*. 2009; Hansen *et al.* 2010) and available datasets: Group 1) all filamentous algae, *Chorda sp, Potamogeton perfoliatus,* Group 2) higher plants (excl. *Zostera marina* and *P. perfoliatus*, incl. *Potamogeton sp, Ruppia sp, Zannichellia sp, Myriophyllum sp, Ceratophyllum sp, Myriophyllum sp), Chara sp., Tolypella nidifica, Furcellaria sp., Phyllophora sp., Fucus radicans* 3) *Zostera marina, Fucus vesiculosus, Furcellaria lumbricalis* (loose). The coverage of species within different structural groups is summarized and the exact formula for calculations is given in illustrative materials.
Documentation of relationship between indicator and pressure	The indicator varies between 0-1. Low indicator values indicate on dominance of filamentous algae and higher values reflect the dominance of structurally more diverse community. Due to eutrophication the general tendency of the macroalgal community is the replacement of structurally more diverse perennials (key-species) with ephemeral fast-growing filamentous algae (e.g. Valiela *et al.* 1997, Kraufvelin 2006; Burkholder *et al.* 2007). The indicator is expected to mirror the change in environmental conditions also when minor changes occur.
Geographical relevance of indicator	3. Baltic sea wide

How Reference Conditions (target values/thresholds) for the indicator were obtained?	Reference conditions are not available and need to be developed.
Method for determining GES	Methods for determining GES are not available and need to be developed.
References	Blomqvist, M., Krause-Jensen, D., Olsson, P., Susanne Qvarfordt, Wikström, S.A. (2012) Potential eutrophication indicators based on Swedish coastal macrophytes. WATERS Report no. 2012:2. 72 pp. Burkholder, J.A., Tomasko, D.A. and Touchette, B.W. (2007) Seagrasses and eutrophication. Journal of Experimental Marine Biology and Ecology 350:46-72 Christie, H., Norderhaug, K.M. and Fredriksen, S. (2009) Macrophytes as habitat for fauna. Marine Ecology Progress Series, 396:221-233 Hansen, J.P., Sagerman, J. and Wikström, S. (2010) Effects of plant morphology on small-scale distribution of invertebrates. Marine Biology 157:2143-2155 Kersen, P., Kotta, J., Bučas, M., Kolesova, N. and Dekere, Z. (2011) Epiphytes and associated fauna on the brown alga *Fucus vesiculosus* in the Baltic and the North Seas in relation to different abiotic and biotic variables. Marine Ecology 32:87-95 Kotta, J. and Orav, H. (2001) Role of benthic macroalgae in regulating macrozoobenthic assemblages in the Väinameri (north-eastern Baltic Sea). Annales Zoologici Fennici 38: 163–171 Kraufvelin, P., Moy, F.E., Christie, H. and Bokn, T.L. (2006) Nutrient addition to experimental rocky shore communities revisited: delayed responses, rapid recovery. Ecosystems 9:1076-7093 Råberg, S. and Kautsky, L. (2007) A comparative biodiversity study of the associated fauna of perennial fucoids and filamentous algae. Estuarine, Coastal and Shelf Science 73:249-258 Salovius, S. and Kraufvelin, P. (2004) The filamentous green alga *Cladophora glomerata* as a habitat for littoral macro-fauna in the Northern Baltic Sea. Ophelia 58: 65-78 Valiela I., McClelland J., Hauxwell J., Behr P.J. and Hersh D. (1997) Macroalgal blooms in shallow estuaries: Controls and ecophysiological and ecosystem consequences. Limnology and Oceanography, 42:1105–1118
Illustrative material for indicator documentation	A – total summarized coverage of taxa belonging to the group 1. (can be over 100) B – total summarized coverage of taxa belonging to the group 2. (can be over 100) C – total summarized coverage of taxa belonging to the group 3. (can be over 100) D – total summarized coverage (can be over 100) E – total summarized cover with maximum value 100 (in case of exceeding 100, value 100 is used in the formula) $MCS = \left(\frac{(1xA + 2xB + 3xC)}{D} / 300\right) x E$

Name of indicator	2.5 Habitat diversity index
Type of Indicator	State indicator
Author(s)	Kristjan Herkül
Description of the indicator	Diversity of benthic habitats is one of the many aspects of marine biodiversity. High diversity of benthic habitats is important in order to maintain species diversity and ecosystem processes. Habitat diversity index indicates the level of diversity of marine benthic habitats by counting the number of different habitats in a predefined grid.
Relationship of the indicator to marine biodiversity	Habitat diversity index reflects biodiversity on the level of marine benthic habitats.
Relevance of the indicator to different policy instruments	1.6. Habitat condition 1.6.1. Condition of the typical species and communities
Method(s) for obtaining indicator values	The general process of obtaining indicator value is as follows: 1. Benthic habitat map is overlaid by a grid with predefined cell size in a geographical information system (GIS) (see an example in Figure 1). Different sources and classifications of benthic habitat maps can be potentially used. To ensure comparability of calculations between different areas and dates, the habitat data must be collected and processed in a uniform way. Coverage layers (rasters or polygons) are preferred as an input but sampling-point-wise input data can be used alternatively. 2. The number of different habitat types is counted in each grid cell (see an example in Figure 2). 3. The average number of different habitats over all grid cells in a given area serves as the value of habitat diversity index. For the purposes of biodiversity monitoring, the method is more suitable for trend analysis based on a time-series of habitat maps than for episodic state assessments.
Documentation of relationship between indicator and pressure	The relationships between indicator value and pressures have not been tested. However, it is known that anthropogenic pressures lead to the loss of biodiversity (Worm et al. 2006). The impoverishment of marine benthic habitats due to anthropogenic pressures is expected to be reflected by the habitat diversity index.
How Reference Conditions (target values/thresholds) for the indicator were obtained?	Reference conditions have not been set due to the lack of time series of habitat maps
Geographical relevance of indicator	3. Baltic sea wide
How Reference Conditions (target values/thresholds) for the indicator were obtained?	Not available. Trend of environmental status can be assessed based on time series of the index.
Method for determining GES	Not available. Trend-based determination of GES can be done: stable or increasing values of the index can be considered as GES while decrease indicates non-GES.
References	Worm B, Barbier EB, Beaumont N, Duffy JE, Folke C, Halpern BS, Jackson JB, Lotze HK, Micheli F, Palumbi SR, Sala E, Selkoe KA, Stachowicz JJ, Watson R. 2006. Impacts of Biodiversity Loss on Ocean Ecosystem Services. Science, 3: 787-790.

Illustrative material for indicator documentation

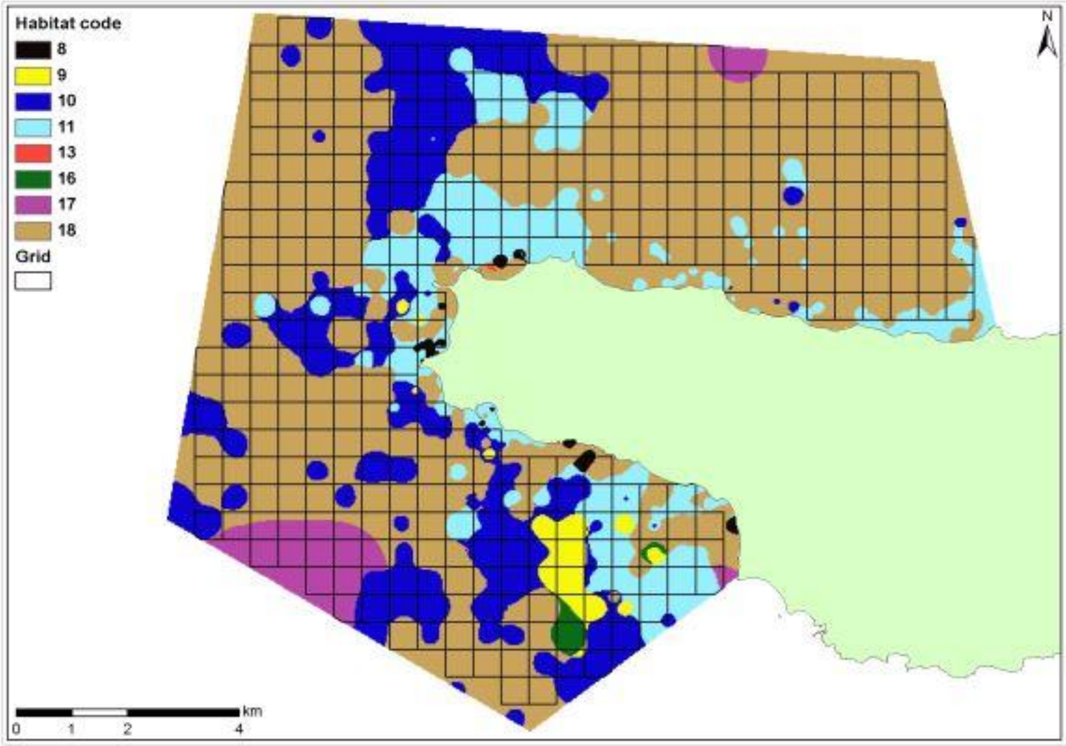


Figure 1. An example of a benthic habitat map overlaid by a grid with a cell size of 500 m.

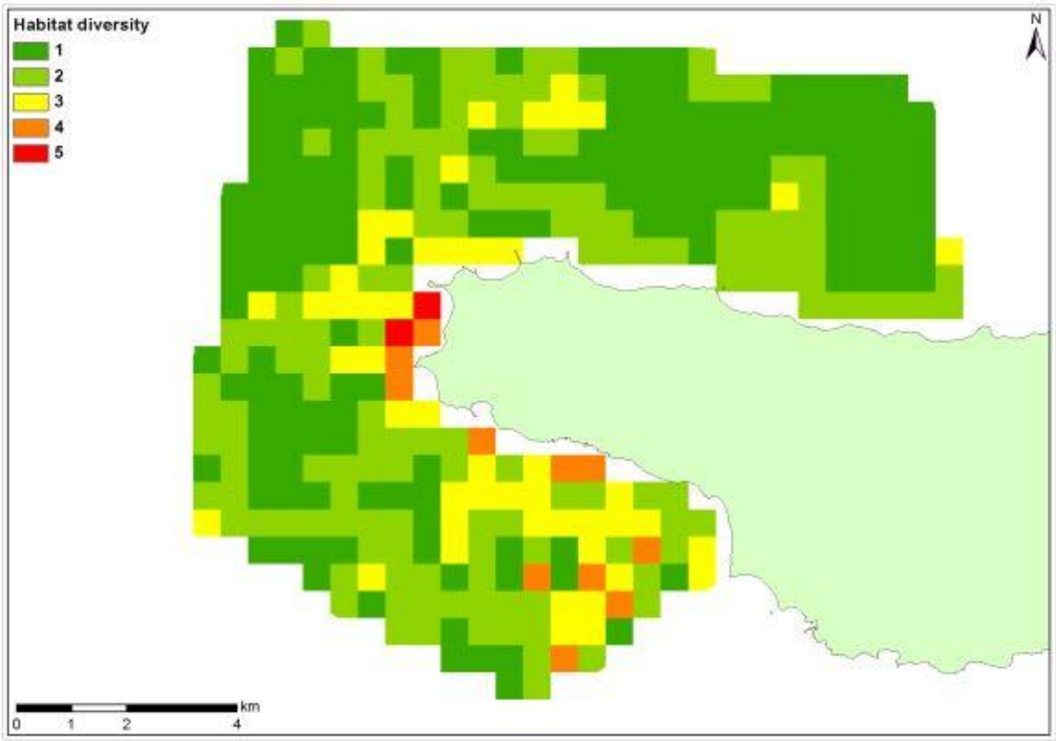
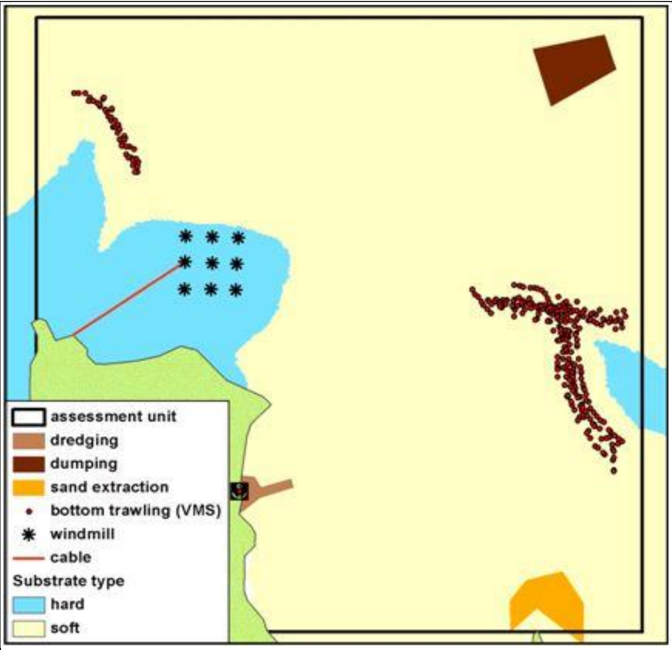
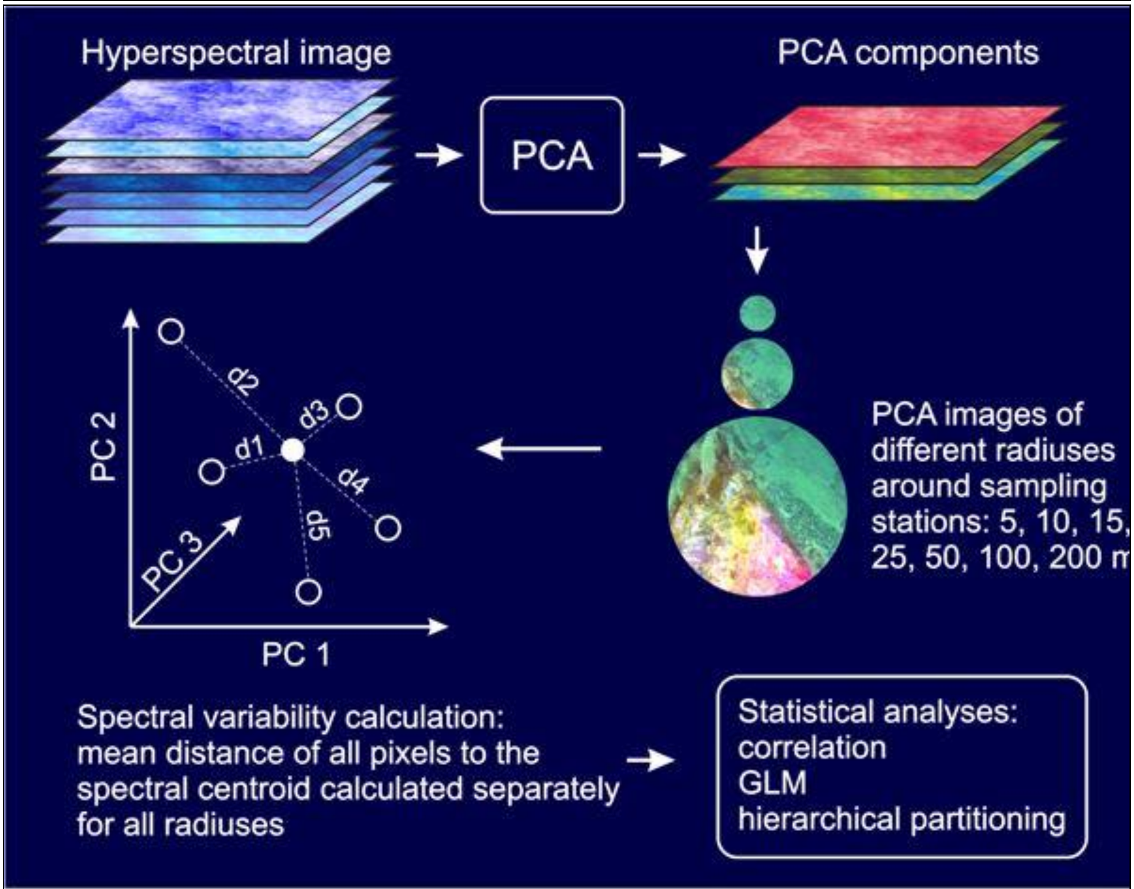


Figure 2. An example of the number of different benthic habitats (i.e. habitat diversity) in the cells of a predefined grid.

Name of indicator	**2.6 Seafloor exploitation index**
Type of Indicator	Pressure indicator
Author(s)	Kristjan Herkül
Description of the indicator	Seafloor exploitation index measures the extent (area) of seabed that is impacted by direct physical anthropogenic disturbances. These disturbances can be divided as follows (Foden et al. 2011). - Smothering: covering the seabed with a layer of material. This activity includes disposal of dredged material. - Obstruction: permanent structures fixed on the seabed. This activity includes pipelines, cables, wrecks, wind turbines, oil and gas platforms and other constructions. - Abrasion: scouring and ploughing of the seabed. Abrasion activities include benthic fishing using trawl gear, burying activity during cable laying. - Extraction: exploitation by removal of seabed resources. This activity includes dredging and aggregate extraction. Seafloor exploitation index quantifies the spatial extent of these disturbances in regard to different seabed substrate types.
Relationship of the indicator to marine biodiversity	Seafloor exploitation index is a pressure indicator that directly measures the extent of anthropogenic pressure on seabed. The negative effects of direct anthropogenic disturbances of seabed on marine benthic biodiversity have been shown in many studies, e. g. Dayton *et al*. 1995, Thrush *et al*. 2001, Simonini *et al*. 2005, Bolam *et al.* 2006.
Relevance of the indicator to different policy instruments	MSFD descriptor 6.
Relevance to commission decision criteria and indicator	1.6. Habitat condition
Method(s) for obtaining indicator values	In order to obtain the value of indicator, all relevant information on direct anthropogenic physical disturbances of seabed must be gathered in a georeferenced manner and compiled into a database of a geographical information system (GIS). The relevant georeferenced data include locations of seabed dredging and dumping of dredged material, bottom trawling fishery (VMS, Vessel Monitoring System), resource extraction (e.g. mining of sand and gravel), building and exploitation of marine constructions (cables, pipelines, windmills etc.). Data on direct anthropogenic disturbances can be acquired from different sources, for example authorities responsible for management of natural resources and environmental conservation, fisheries authorities, maritime and shipping authorities, companies involved in offshore development (pipelines, cables, windmills). The proportion of area of different seabed substrate types, which are directly affected by human activities, will be assessed by the means of overlay analysis in GIS (see Figure 1 for a schematic example of overlay analysis in GIS). The average proportion of directly impacted seabed over all substrate types serves as the overall index value in a given area.
Documentation of relationship between indicator and pressure	Not relevant: the indicator directly reflects anthropogenic pressure itself.
Geographical relevance of indicator	3. Baltic Sea wide
How Reference Conditions (target values/thresholds) for the indicator were obtained?	Conditions, in which direct anthropogenic disturbances to the seabed are totally lacking, could be considered as reference conditions. Specially dedicated research is needed in order to develop explicit determination of reference conditions.
Method for determining GES	Not available. Specially dedicated research is needed in order to develop methods for assessment of environmental status. Conceptually, the seabed exploitation must be on a level that enables long-term sustainability of natural biodiversity and ecosystem processes.

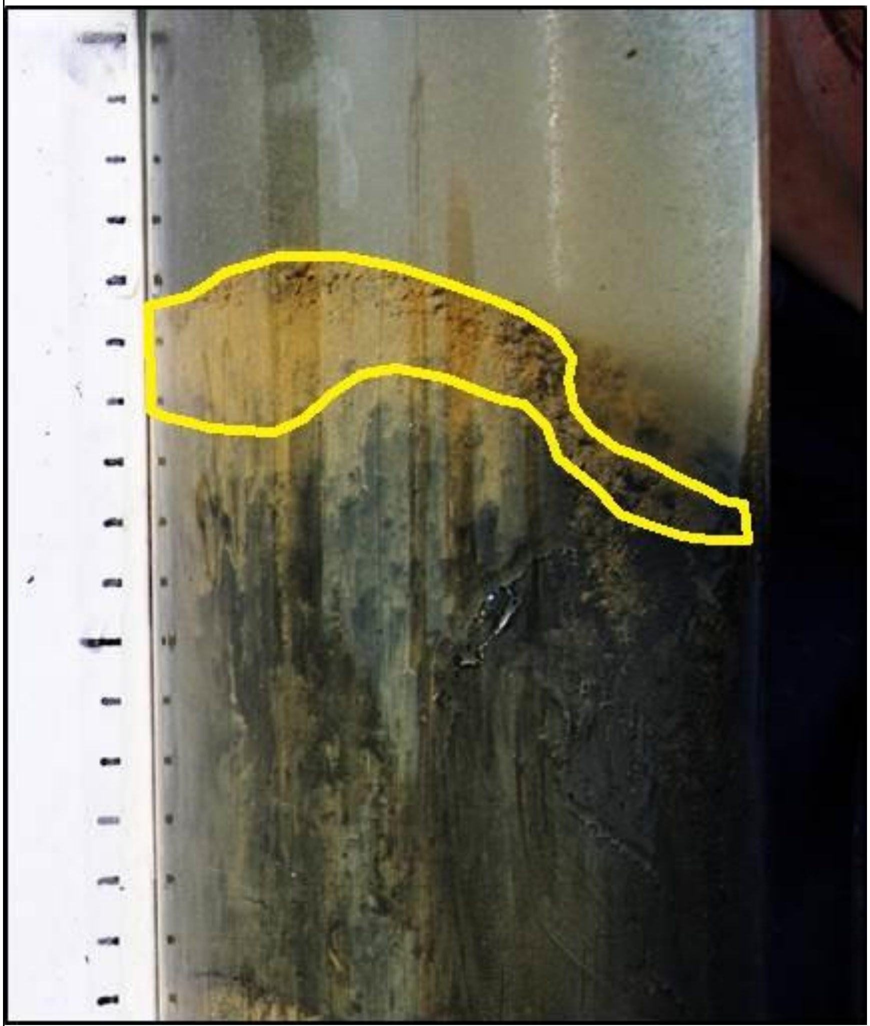
References	Bolam SG, Rees HL, Somerfield P, Smith R, Clarke KR, Warwick RM, Atkins M, Garnacho E. 2006. Ecological consequences of dredged material disposal in the marine environment: A holistic assessment of activities around the England and Wales coastline. Marine Pollution Bulletin, 52: 415-426. Dayton PK, Thrush SF, Agardy MT, Hoffman RJ. 1995. Environmental effects of marine fishing. Aquatic Conservation: Marine and Freshwater Ecosystems, 5: 205-232. Foden J, Rogers SI, Jones AP. 2011. Human pressures on UK seabed habitats: a cumulative impact assessment. Marine Ecology Progress Series, 428: 33-47. Simonini R, Ansaloni I, Cavallini F, Graziosi F, Iotti M, Massamba N'Siala G, Mauri M, Montanari G, Preti M, Prevedelli D. 2005. Effects of long-term dumping of harbor-dredged material on macrozoobenthos at four disposal sites along the Emilia-Romagna coast (Northern Adriatic Sea, Italy). Marine Pollution Bulletin, 50: 1595-1605. Thrush SF, Hewitt JE, Funnell GA, Cummings VJ, Ellis J, Schultz D, Talley D, Norkko A. 2001. Fishing disturbance and marine biodiversity: the role of habitat structure in simple soft-sediment systems. Marine Ecology Progress Series, 223: 277-286.
Illustrative material for indicator documentation	 Figure 1. A schematic example of a geographical overlay analysis of direct anthropogenic seabed disturbances.

Name of indicator	**2.7 Spectral variability index**
Type of Indicator	State indicator
Author(s)	Kristjan Herkül
Description of the indicator	Spectral variability index is based on the spectral variation hypothesis that predicts a positive correlation between spectral heterogeneity of a remotely sensed image and biodiversity. Based on the results of a recent study (Herkül *et al*. 2013), the variability of air-borne hyperspectral imagery is positively correlated with benthic biodiversity variables. Spectral variability index quantifies the variability in a remotely sensed (air-borne or space-borne) imagery that, in turn, indicates benthic biodiversity. The method is potentially useful in extensive shallow water areas that are difficult to reach with a vessel.
Relationship of the indicator to marine biodiversity	A positive correlation between spectral variability of remotely sensed imagery and biodiversity has been shown in terrestrial plant communities (e.g. Rocchini 2007, Oldeland *et al*. 2010, White *et al*. 2010). Recent study (Herkül *et al.* 2013) revealed that spectral variability of a remotely sensed hyperspectral imagery also reflects the biodiversity of shallow water benthic habitats.
Relevance of the indicator to different policy instruments	Potentially relevant for MSFD descriptor 1.
Relevance to commission decision criteria and indicator	1.6.1. Condition of the typical species and communities 1.7.1. Composition and relative proportions of ecosystem components (habitats and species)
Method(s) for obtaining indicator values	Georeferenced remotely sensed imagery of a sea area is needed for the calculation of spectral variability index. High resolution multispectral or hyperspectral imagery is preferred input for the calculation. The imagery must reflect seabed properties i.e. the method can be used only in shallow and very clear waters. Principal component analysis can be used to reduce the redundant information in hyperspectral data prior to calculating values of spectral variability. The values of spectral variability are calculated in each cell of a predefined grid. The suitable cell size depends on the extent of the area to be assessed and the spatial resolution of the remotely sensed imagery. Spectral variability is measured as a mean distance from spectral centroid of a given cell. Spectral centroid is calculated as the mean value of each band or principal component in a given cell. The distance (difference) of each pixel from the spectral centroid is then determined within each cell. The mean distance of all pixels from the spectral centroid in a given cell is considered as the mean spectral variability of that cell (see Figure 1). The mean value of spectral variability over all cells in a given area serves as the value of spectral variability index. See Rocchini (2007), Oldeland *et al*. (2010), and Herkül *et al.* (2013) for more detailed description of the calculation of spectral variability. For the purposes of biodiversity monitoring, the method is more suitable for trend analysis based on a time-series of hyperspectral imagery than for episodic state assessments.
Documentation of relationship between indicator and pressure	The relationships between the indicator and pressures have not been tested, because there are no time-series of high-resolution remotely sensed imagery available for empirical testing. However, it is known that anthropogenic pressures lead to the loss of biodiversity (Worm *et al.* 2006). The impoverishment of marine benthic biodiversity due to anthropogenic pressures is expected to be reflected by the spectral variability index, but this must be quantified in further specific studies.
Geographical relevance of indicator	2. Regional
How Reference Conditions (target values/thresholds) for the indicator were obtained?	Not available. As the method is more suitable for trend analysis based on time-series of remotely sensed imagery than for episodic state assessments, trend-based assessment of the environmental status rather than comparison with reference conditions is recommended. Specially dedicated research is needed in order to develop methods for assessment of the environmental status.
Method for determining GES	Not available. Trend-based assessment of GES can be considered – stable or increasing values of the index can be considered as GES while decrease indicates non-GES. Specially dedicated research is needed in order to develop methods for assessment of the environmental status.
References	Herkül K, Kotta J, Kutser T, Vahtmäe E. 2013. Relating remotely sensed optical variability to marine benthic biodiversity. PLoS ONE, 8(2), e55624

	Oldeland J, Wesuls D, Rocchini D, Schmidt M, Jürgens N. 2010. Does using species abundance data improve estimates of species diversity from remotely sensed spectral heterogeneity? Ecological Indicators, 10: 390-396 Rocchini D. 2007. Effects of spatial and spectral resolution in estimating ecosystem α-diversity by satellite imagery. Remote Sensing of Environment, 111: 423-434. White JC, Gómez C, Wulder MA, Coops NC. 2010. Characterizing temperate forest structural and spectral diversity with Hyperion EO-1 data. Remote Sensing of Environment, 114: 1576-1589 Worm B, Barbier EB, Beaumont N, Duffy JE, Folke C, Halpern BS, Jackson JB, Lotze HK, Micheli F, Palumbi SR, Sala E, Selkoe KA, Stachowicz JJ, Watson R. 2006. Impacts of Biodiversity Loss on Ocean Ecosystem Services. Science, 3: 787-790.
Illustrative material for indicator documentation	 Figure 1. Principal illustration of data processing and spectral variability calculation.

Name of indicator	2.8 Condition of soft sediment habitats – the aRPD approach
Type of Indicator	State indicator
Author(s)	Henrik Nygård
Description of the indicator	A soft bottom habitat in good condition can support a zoobenthic community able to sustain a favourable living environment e.g. through bioturbation processes and recirculation of organic material. The condition of the habitats is ultimately determined by oxygen conditions, which are as well pivotal in structuring the benthic communities (Cicchetti *et al*. 2006). The oxygen conditions in the sediment can be demonstrated by the redox potential discontinuity depth (RPD), which is the depth where oxidizing processes are replaced by reducing processes. A deep RPD depth indicates good oxygen conditions in the sediment and in the near-bottom water. This indicator shows the condition of soft bottom habitats through an estimation of the RPD depth, thus being a proxy for conditions suitable for a diverse community (Birchenough et al. 2012). As well, it describes the successional stage and functionality of the benthic community as long-lived and deep-burrowing species maintain sediment mixing and nutrient regeneration processes, thus increasing resilience (Pearson & Rosenberg 1978, Nilsson & Rosenberg 2000, Bonsdorff et al. 1996, Birchenough *et al*. 2012, Villnäs *et al*. 2012). An index based on RPD depth and the activity of zoobenthos (Benthic Habitat Quality; BHQ), retrieved by sediment profile imagery, has been developed in western Sweden (Nilsson & Rosenberg 1997, 2000). The aim here was to, with the starting point in BHQ, modify and test the applicability of this indicator in Baltic Sea conditions. The indicator was tested in MARMONI area FIN, i.e. the coastal areas of south-western Finland.
Relationship of the indicator to marine biodiversity	The indicator relates to the condition of the soft sediment habitat and reflects the state of the habitat and functional diversity of the community. Poor oxygen conditions in the benthic habitats, leading to shallow RPD depth in soft sediments, sustain only tolerant and opportunistic species resulting in a community with low diversity and reduced functionality (e.g. Villnäs *et al*. 2013). In good conditions, the benthic community can develop and become more diverse. Long-lived and deep-burrowing species add functionality to the community, thus also sustaining the favourable conditions through bioturbation processes and nutrient regeneration (Pearson & Rosenberg 1978, Nilsson & Rosenberg 1997, Norkko *et al.* 2013).
Relevance of the indicator to different policy instruments	This indicator responds to the following descriptors in the EU Marine Strategy Framework Directive: 1.6 Habitat condition; 5.3 Indirect effects of nutrient enrichment; 6.1 Physical damage, having regard to substrate characteristics; 7.2 Impact of permanent hydrological changes. The indicator also reflects the HELCOM Baltic Sea Action Plan ecological objectives for "natural marine and coastal landscapes" and "natural oxygen levels".
Relevance to commission decision criteria and indicator	1.6. Habitat condition 1.6.3. Physical, hydrological and chemical conditions
Method(s) for obtaining indicator values	The measure of RPD depth can be retrieved by several methods. Sediment profile imagery (SPI) has been widely used to assess the RPD depth (e.g. in BHQ; Nilsson & Rosenberg 1997, 2000), offering an *in situ* characterization of the soft sediment habitat. In short, a camera is lowered to the sea-floor, where it first takes a photograph of the sediment surface. Then the camera penetrates into the sediment and like an up-side-down periscope takes a vertical photograph of the sediment profile. In the sediment profile, the shift from brownish sediment where particles are covered by ferric hydroxide, to greyish-black sulphidic sediments, is used to identify the RPD depth and is referred to as the apparent redox potential discontinuity (aRPD; Nilsson & Rosenberg 1997). Our approach is to use sediment cores (e.g. GEMAX cores), which are photographed, and the oxidized sediment layer is measured from the photographs of the sediment core. Using for example ImageJ, the area of the oxidized sediment can be measured. To get the depth, the area has to be divided by the width of the sediment core (Fig. 1). The aRPD measured by our approach cannot be directly compared to the aRPD measured by sediment profile imagery, as the quality and interpretation of the pictures differ. However, the principles of interpreting the results remain the same.

Documentation of relationship between indicator and pressure	This indicator can be used to monitor the effects of eutrophication. Eutrophication has led to an increase in pelagic primary production, resulting in a higher input of organic material to the bottom, Oxygen is consumed in the decomposing processes of this material, resulting in hypoxic, or even anoxic, conditions in the near-bottom water (see Diaz & Rosenberg 1995 for a review). aRPD has successfully been shown to reflect the hypoxic conditions in the sediment (Nilsson & Rosenberg 1997, 2000, Schumchenia & King 2010). Additionally, sediment profiles have successfully been used to study effects of trawling (Nilsson & Rosenberg 2003, Rosenberg et al. 2003), fish farming (Karakassis et al. 2002), and to assess water quality (Schumchenia & King 2010), as well as to characterize the soft sediment habitat (Bonsdorff *et al.* 1996).
Geographical relevance of indicator	1. Local
How Reference Conditions (target values/thresholds) for the indicator were obtained?	The target value for the indicator in the coastal area of SW Finland was obtained through calibration against the EU Water Framework Directive (WFD) indicator Brackish water Benthic Index (BBI; Perus *et al*. 2007). Van Veen-grab samples were taken from the same locations as the sediment cores and based on the benthic macrofauna community BBI was calculated. The WFD Good-Moderate border for BBI in the study area varies between 0.34 and 0.44 depending on water type and depth, and 0.4 was chosen as the border against which the EU Marine Strategy Framework Directive target value for this indicator was set. The target value was set through linear regression (r^2=0.443, p<0.001) to 2.17 cm. Target values need to be set area specifically, so that local conditions are taken into account.
Method for determining GES	GES is determined through the target value.
References	Birchenough SNR, Parker RE, McManus E, Barry J (2012) Combining bioturbation and redox metrics: Potential tool for assessing seabed function. Ecol Indic 12:8-16 Bonsdorff E, Diaz RJ, Rosenberg R, Norkko A, Cutter GR Jr (1996) Characterization of soft-bottom benthic habitats of the Åland Islands, northern Baltic Sea. Mar Ecol Prog Ser 142:235-245 Cicchetti G, Latimer JS, Rego SA, Nelson WG, Bergen BJ, Coiro LL (2006) Relationships between near-bottom dissolved oxygen and sediment profile camera measures. J Mar Syst 62:124-141 Diaz RJ, Rosenberg R. Marine benthic hypoxia: A review of its ecological effects and the behavioural responses of benthic macrofauna. Oceanogr Mar Biol Annu Rev 33:245-303 Karakassis I, Tsapakis M, Smith CJ, Rumohr H (2002) Fish farming impacts in the Mediterranean studied through sediment profiling imagery. Mar Ecol Prog Ser 227:125-133 Nilsson HC, Rosenberg R (1997) Benthic habitat quality assessment of an oxygen stressed fjord by surface and sediment profile images. J Mar Syst 11:249-264 Nilsson HC, Rosenberg R (2000) Succession in marine benthic habitats and fauna in response to oxygen deficiency: analysed by sediment profile-imaging and by grab samples. Mar Ecol Prog Ser 197:139-149 Nilsson HC, Rosenberg R (2003) Effects on marine sedimentary habitats of experimental trawling analysed by sediment profile imagery. J Exp Mar Biol Ecol 285-286:453-463 Norkko A, Villnäs A, Norkko J, Valanko S & Pilditch C (2013) Size matters: implications of the loss of large individuals for ecosystem function. Sci Rep 3:2646. Pearson TH, Rosenberg R (1978) Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanogr Mar Biol Annu Rev 16:229-311 Perus J, Bonsdorff E, Bäck S, Lax H-G, Villnäs A, Westberg V (2007) Zoobenthos as Indicators of Ecological Status in Coastal Brackish Waters: A Comparative Study from the Baltic Sea. AMBIO 36:250-256 Rosenberg R, Nilsson HC, Grémare A, Amouroux J-M (2003) Effects of demersal trawling on marine sedimentary habitats analysed by sediment profile imagery. J Exp Mar Biol Ecol 285-286:465-477 Shumchenia EJ, King JW (2010) Evaluation of sediment profile imagery as a tool for assess-

	ing water quality in Greenwich Bay, Rhode Island, USA. Ecol Indic 10:818-825 Villnäs A, Norkko J, Lukkari K, Hewitt J, Norkko A (2012) Consequences of increasing hypoxic disturbance on benthic communities and ecosystem functioning. PLos ONE 7(10):e44920 Villnäs A, Norkko J, Hietanen S, Josefson AB, Lukkari K, Norkko A (2013) The role of recurrent disturbances for ecosystem multifunctionality. Ecology 94:2275-2287
Illustrative material for indicator documentation	 Figure 1. Measuring the oxidized sediment depth from a sediment core photograph. The area within the yellow borders need to be divided by the width of the core to get the mean depth of the oxidized layer. The scale on left is in centimetres. Photograph by Henrik Nygård.

Name of indicator	**2.9 Population structure of *Macoma balthica***
Type of Indicator	State indicator
Author(s)	Henrik Nygård and Vadims Jermakovs
Description of the indicator	Deviation from the natural size distribution within the population of a species can be used as an indicator of disturbance in reproduction and/or survival, thus indicating the state of the population. Moreover, size structure can indicate the availability and quality of prey for predators on the species. Long-lived benthic species are suitable as indicators of population structure since they integrate changes in the environment over several years. Different life stages can vary in their sensitivity and response to disturbances, responding with low survival or impaired reproduction (Jahn *et al*. 1997). This indicator describes the size distribution of *Macoma balthica*, the dominant, long-lived bivalve species on soft bottoms in the northern Baltic Sea. Occurrence of new recruits, juveniles as well as adults in all year classes in a population of *M. balthica* indicate that no severe disturbance has taken place and that the population is in a good state. Lack of juveniles or a year class of adults demonstrates adverse conditions. As the natural size distribution of *M. balthica* varies geographically and also by depth due to variation in growth rates (Segerstråle 1960, Gilbert 1973), targets have to be adjusted to local conditions.
Relationship of the indicator to marine biodiversity	This indicator describes the complexity of benthic habitats and reflects the population condition and abundance/biomass of a dominant long-living benthic species. Large specimens have an important impact on the functioning of the ecosystem and ecosystem services such as energy flow and nutrient cycles (Norkko *et al*. 2013), thus this indicator also relates to the functional diversity of soft sediment habitats. Additionally, when the indicator value is within the GES limits the *M. balthica*-population can provide preferred prey-size for predators like common scooter, velvet scooter, flounder and roach (Dunrick *et al*. 1993, Karlson et al. 2007, Lappalainen *et al*. 2005).
Relevance of the indicator to different policy instruments	Size distribution of *Macoma balthica* could be used in describing the following descriptors under the EU Marine Strategy Framework Directive: 1.3 Population condition; 1.6 Habitat condition; 4.3 Abundance/distribution of key trophic groups/species; 6.2 Condition of benthic community. Size distribution of *M. balthica* also reflects the HELCOM Baltic Sea Action Plan biodiversity goal 'favourable conservation status of Baltic biodiversity' and the ecological objectives for 'thriving and balanced communities of plants and animals'.
Relevance to commission decision criteria and indicator	1.3. Population condition 1.3.1. Population demographic characteristics (e .g. body size or age class structure, sex ratio, fecundity rates, survival/ mortality rates)
Method(s) for obtaining indicator values	Data needed for this indicator can be obtained by length measurements of *Macoma balthica* in samples from e.g. regular monitoring programs. To avoid the high variation caused by variations in the number of settling recruits (Strasser *et al*. 2001, Beukema *et al*. 2010), only individuals larger than 5 mm are included in the indicator. This is also roughly the size when maturity occurs in *M. balthica*, thus all adult year classes are included in the indicator. The indicator value is the median length of *M. balthica* larger than 5 mm. Since it is typical that strong year classes are not produced every year in *M. balthica* populations (Strasser *et al.* 2001, Beukema *et al.* 2010), it is recommended that a 5-year average of the median length is used as the indicator value. Samples considered to be from the same *M. balthica* population can be pooled to obtain a more confident evaluation of the population condition and a greater spatial coverage. To obtain a reliable estimate of the population size distribution the density of adult *M. Balthica* should be at least 100 individuals per square meter.
Documentation of relationship between indicator and pressure	An undisturbed population of *Macoma balthica* consists of individuals spanning the whole size range (Leppäkoski 1975). Populations disturbed by e.g. eutrophication, harmful substances, or physical disturbance will deviate from this pattern as an effect of increased mortality and failure in recruitment leading to lacking year-classes (Jahn *et al.* 1997). An indicator value below the GES limit indicates lack of large individuals and occurrence of frequent disturbance, such as seasonal hypoxia, restricting the population to reach old age. On the other hand, an indicator value higher than the GES limit shows that the population consists of only old individuals and that the recruitment is impaired, i.e. not sustainable. Pressures that have an impact on the *M. balthica* population are illustrated in Fig. 1. Spatial distribu-

	tion of median length of *Macoma balthica* in the Gulf of Riga in recent data shows significant relationship with HELCOM Baltic Sea Impact Index (BSII) (Fig. 2).
Geographical relevance of indicator	2. Regional
How Reference Conditions (target values/thresholds) for the indicator were obtained?	Reference conditions can be obtained from undisturbed areas, historical data or theoretical population growth models. Reference conditions for MARMONI area FIN, i.e. the coastal area of southwestern Finland were obtained from historical data (Segerstråle 1960) covering a 10-year period (1926-1935) in Tvärminne, SW Finland (Fig. 3). The target value was set by first calculating 5-year mean size distributions for the 10-year period (see fig. 2 for an example). Using these distributions the mean median length and standard deviations of individuals >5 mm were calculated. The mean median length was 11.04 mm, which is considered as the target value. To assess the influence of more eutrophic conditions, the target was also tested by comparing more recent time-series with near-bottom oxygen conditions. Additionally, to serve as a food web indicator, the target was also checked against preferred prey size of predators (common scooter, velvet scooter, flounder and roach) on *M. balthica*. Preferred mussel prey size for these predators was found to be 10-15 mm (Dunrick *et al*. 1993, Karlson *et al.* 2007, Lappalainen *et al.* 2005), thus well complying with the target set by historical data. Reference conditions for MARMONI area Gulf of Riga were obtained from historical data (BaltNIIRH unpublished) covering a 3-year period (1958-1961) (Fig. 4). The mean length of individuals >5 mm from this data was determined to 11.44 mm, which is considered as the target value for the Gulf of Riga.
Method for determining GES	GES is determined through the target value determined through historical data; indicator values falling within two standard deviations of the target value indicate GES. For SW Finland indicator values within the interval 8.6-13.5 mm indicate GES. In turn, for the Gulf of Riga indicator values within the interval 8.6-14.5 mm indicate GES. Due to geographically varying growth rates target values need to be set according to local conditions.
References	Beukema JJ, Dekker R, Philippart CJM (2010) Long-term variability in bivalve recruitment, mortality, and growth and their contribution to fluctuations in food stocks of shellfish-eating birds. Mar Ecol Prog Ser 414:117-130 Dunrick J, Christensen KD, Skov H & Danielsen F (1993) Diet of the common scoter *Melanitta nigra* and velvet scoter *Melanitta fusca* wintering in the North Sea. Ornis Fennica 70:215-218. Gilbert MA (1973) Growth rate, longevity and maximum size of *Macoma balthica* (L.) Biol Bull 145:119:126 Jahn A, Janas U, Theede H, Szaniawska A (1997) Significance of body size in sulphide detoxification in the Baltic clam *Macoma balthica* (Bivalvia, Tellinidae) in the Gulf of Gdansk. Mar Ecol Prog Ser 154:175-183 Karlson AML, Almqvist G, Skora KE & Appelberg M (2007) Indications of competition between non-indigenous round goby and native flounder in the Baltic Sea. ICES Journal of Marine Science 64:479-486 Lappalainen A, Westerbom M & Heikinheimo O (2005) Roach (Rutilus rutilus) as an important predator on blue mussel (*Mytilus edulis*) populations in a brackish water environment, the northern Baltic Sea. Marine Biology 147:323-330 Leppäkoski E (1975). Assessment of degree of pollution on the basis of macrozoobenthos in marine and brackish-water environments. Acta Academiae Aboensis, Ser B, Vol 35(2), 90 p. Norkko A, Villnäs A, Norkko J, Valanko S & Pilditch C (2013) Size matters: implications of the loss of large individuals for ecosystem function. Scientific Reports 3:2646 Segerstråle SG (1960) Investigations on Baltic populations of the bivalve Macoma balthica (L.). Part I: Introduction; Studies on recruitment and its relation to depth in Finnish coastal waters during the period 1922-1959; Age and growth. Commentationes Biologicae Societas Scientiarum Fennica 23. 72 pp Strasser M, Hertlein A, Reise K (2001) Differential recruitment of bivalve species in the northern Wadden Sea after the severe winter of 1995/96 and of subsequent milder winters.

	Helgol Mar Res 55:182-189

Illustrative material for indicator documentation

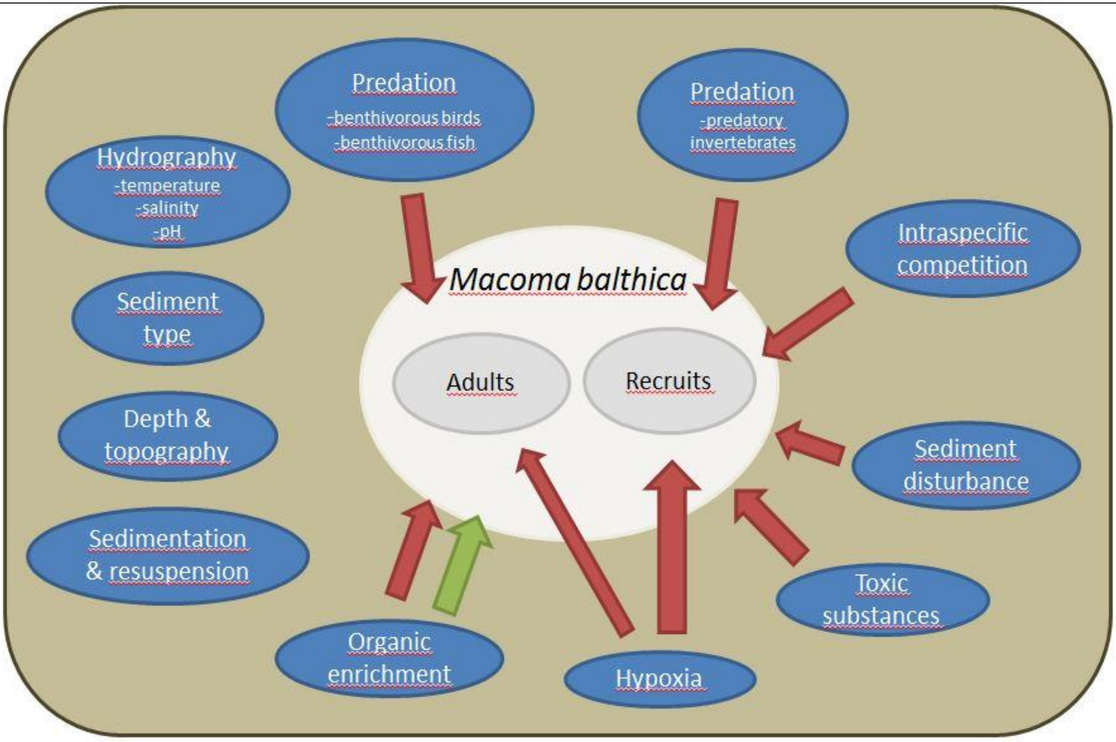


Figure 1. Factors influencing *Macoma balthica* and its population structure. Red arrows indicate a negative effect, whereas the green arrow indicates a positive effect. The abiotic factors on the left represent other habitat structuring factors influencing the occurrence and/or growth rates of *M. balthica*.

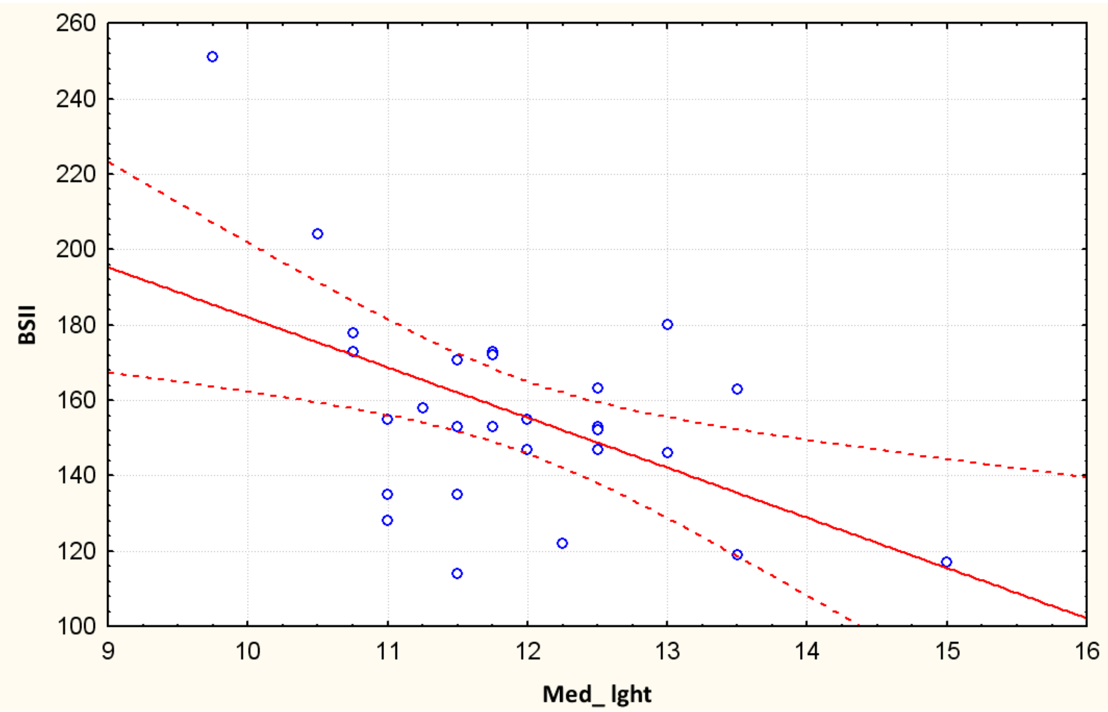


Figure 2. Relationships between Baltic Sea Impact Index (BSII) and median length of *Macoma balthica* >5 mm in the Gulf of Riga in 2010-2011 (r=0.5138, p=0.0052, n=28).

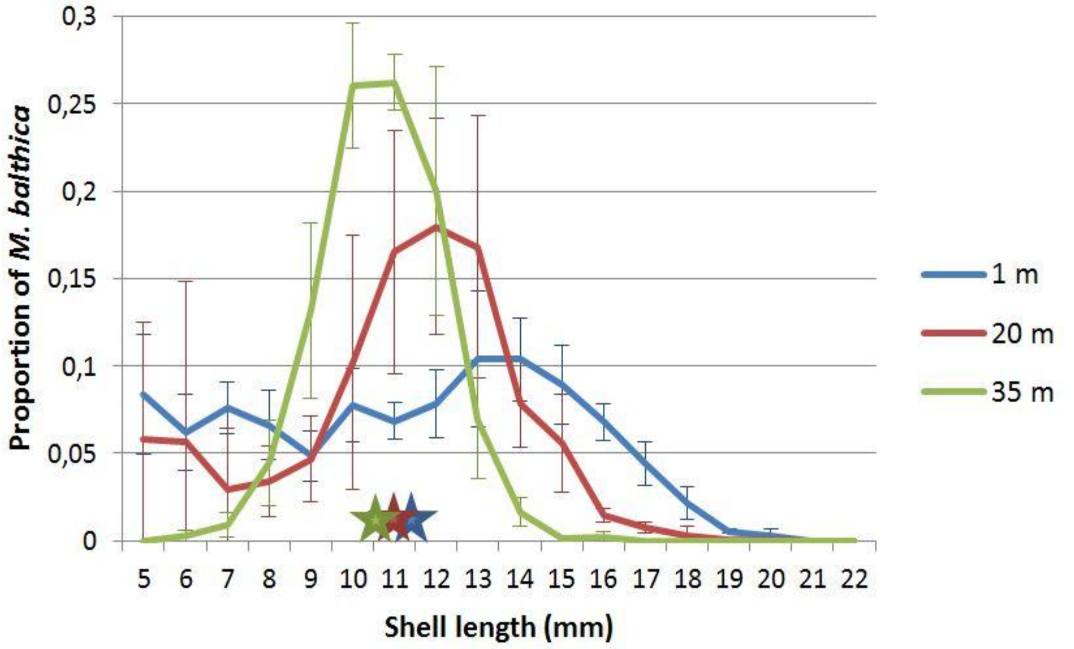


Figure 3. An example of obtaining the indicator value. The lines show historical (1926-1930) 5-year average length distributions (±standard deviation) of *M. balthica* at three different depths (based on Segerstråle 1960). The stars indicate the 5-year average median length of *M. balthica* larger than 5 mm at respective depth.

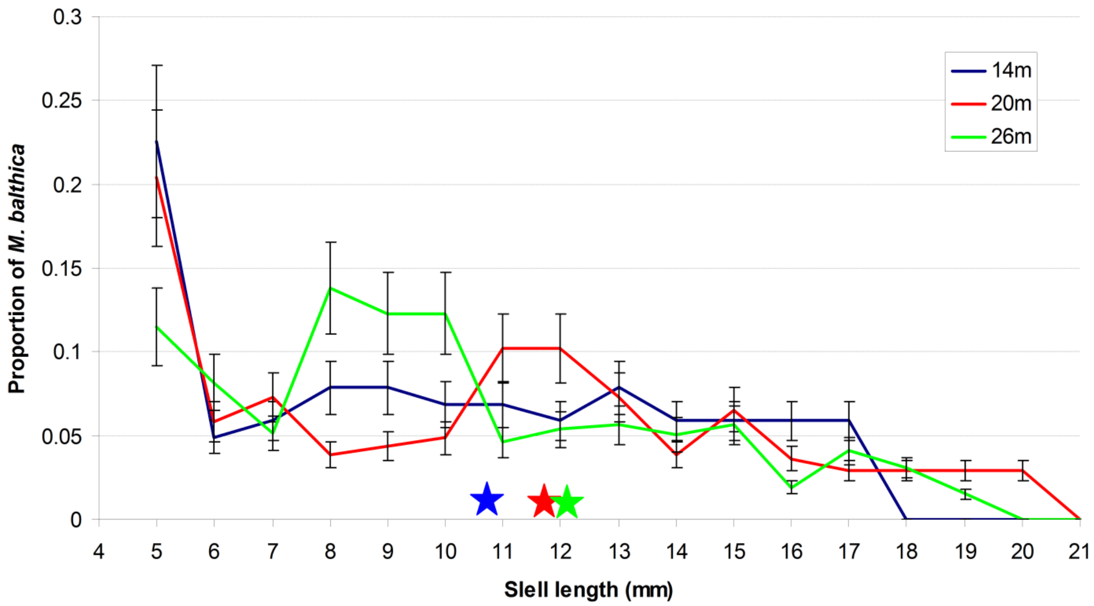


Figure 4. An example of obtaining the indicator value for Gulf of Riga. The lines show historical (1958-1961) 3-year average length distributions (±20%) of *Macoma balthica* at three different depths. The stars indicate the 3-year average median length of *M. balthica* >5 mm at respective depth.

Name of indicator	**2.10 *Cladophora glomerata* growth rate**
Type of Indicator	State indicator
Author(s)	Ari Ruuskanen
Description of the indicator	The indicator describes the abundance of *Cladophora glomerata* in an assessment unit. The abundance of the *C. glomerata* vegetation is expressed as growth rate, derived from information on frond length and the length of the growth period. The filamentous summertime green algae *C. glomerata* is the most common algae occupying shorelines along the Finnish coast line. Its seasonal occurrence and abundance is mainly determined by nutrient availability in the water column, as well as water temperature. Sources of natural variation in abundance are geographical location, wave exposure, and sea bottom structure. If the sources of natural variation are known, it is possible to assess responses of *C. glomerata* to anthropogenic pressure. In the present work, the pressure is nutrients and the response is expressed as *C. glomerata* growth rate. By excluding sources of natural variation, and comparing with the observed growth rates of *C. glomerata* when grown in laboratory conditions in different nutrient concentrations, we can, based on measurements of *C. glomerata* populations in the field, estimate the overall summertime nutrient status in the studied sea area. In traditional water quality monitoring, sampling takes place once a week or even less frequently. Nutrient concentrations fluctuate on a daily basis and by taking samples once a week or month this variation will not be observed (Figure 1). However, *C. glomerata* takes up available (fluctuating) nutrients from the water column continuously as it grows and this can be measured as an increase in frond length. Thus, frond length represents the total amount of nutrients present in water column during a given time period. This indicator species describes short term (1-4 months) direct human-based impacts of sea-use activities. The frond length of *C. glomerata* is a cost-efficient way to measure approximate nutrient concentrations in large areas where traditional sampling procedures or the use of measurement devices are not applicable. The indicator does not replace traditional nutrient sampling, but indicates the direction how nutrient levels are developing. The indicator was developed and tested for the coastal area of south-western Finland (MARMONI 3FIN) study area (MARMONI 3FIN).
Relationship of the indicator to marine biodiversity	The length of the frond of the indicator species is related to the nutrient concentrations in the water and reflects the state of the sea in the area. By excessive growth due to increased nutrient concentrations *C. glomerata* forms mass occurrences which in turn inhibit colonization success and later occurrence of perennial key species such as *Fucus vesiculosus* and associated fauna, decreasing total biodiversity.
Relevance of the indicator to different policy instruments	Through collaboration between MARMONI and the HELCOM CORESET project, the *Cladophora glomerata* length segment of the indicator has been agreed as a Candidate Indicator in the HELCOM CORESET of Biodiversity indicators (HELCOM 2012). Marine Strategy Framework Directive (MSFD) descriptor 1, criterion 1.2 Population size, 1.2.1 Population abundance and/or biomass MSFD descriptor 5, criterion 5.1 Direct effects of nutrient enrichment MSFD descriptor 6, criterion 6.1 Kind and size of relevant biogenic substrata HELCOM Baltic Sea Action Plan (BSAP): Ecological objectives "Natural distribution and occurrence of plants and animals" (Eutrophication) and "Thriving communities of plants and animals" (Nature conservation).
Relevance to commission decision criteria and indicator	1.2. Population size 1.2.1. Population abundance and/or biomass
Method(s) for obtaining indicator values	The growth of *C. glomerata* is approximated through measuring fronds of *C. glomerata* at a known time of its seasonal succession. Basically, sampling can take place at any time during the growth period of *C. glomerata* (May-August), but late summer is recommended. To exclude sources of natural variation in abundance, frond length or growth rate samples are collected from chosen sea marks located along ship routes (Figure 2). The sea marks are

	identical in terms of the microhabitat of the growth surface, construction material, etc. and their maintenance history is known. An important feature of sea marks is that the buoyancy effect of sea marks keeps C. glomerata canopy at steady depth all the growth season. From each sea mark at least eight fronds are collected, but a number of 20 - 30 fronds is recommended, and measured with the accuracy of one millimetre; thereafter their mean length is determined. At least eight sea marks should be included. It is recommended that the same sea marks are sampled each time (year). After the mean length or growth rate of *C. glomerata* has been determined from all sea marks at the given water site, the acquired values are compared to a reference growth rate value, which is also the GES border.
Documentation of relationship between indicator and pressure	The length and growth rate of *C. glomerata* fronds has been shown to be determined mainly by nutrient availability. We assume that the growth limiting nutrient in Finnish coastal waters is nitrogen (NO_3). In the present work, the relationship between *C. glomerata* frond length (growth rate) and pressure (nutrients) was tested in controlled laboratory experiments. *C. glomerata* fronds were cultivated in manipulated natural sea water by the water flow-thru method in different nutrient (NO_3) concentrations for approximately eight weeks (Figure 3). The change in frond length was measured and growth rates at different nutrient concentrations were determined. As a result we found that the average daily growth rate at 0,02 mg NO_3/L was 1,8 mm per day, and at a concentration of 0,05 mg/L the growth rate was 2,3 mm per day. The growth season starts when sea surface temperature reaches 5 ^{o}C.
Geographical relevance of indicator	2. Regional
How Reference Conditions (target values/thresholds) for the indicator were obtained?	The indicator reference value, i.e. the daily growth rate at pristine conditions, was determined as follows: first, we determined the overall growth rate of *C. glomerata* frond at manipulated nutrient conditions (see section "Documentation of relationship between indicator and pressure" above). The growth rate was linear in the beginning of the laboratory growth experiment period, but started to decrease at the end of the period, perhaps for natural reasons. By using pooled growth rates acquired from the laboratory experiment we concluded that a mean daily growth rate was 2,05 mm at 0.035 mg NO_3/ L. Second, we determined the reference level of NO_3 by field studies and expert judgment. This value is needed to estimate growth rate of *C. glomerata* frond in pristine conditions. In the field, the range of NO_3 levels was studied *in situ* with a high-frequency measurement device in 2010 and 2011. The monitoring was carried out for the duration of approximately 6 weeks during the growth season and the measurement frequency was 10 minutes. As a result we found that NO_3 ranged between 0,005 and 0,08 mg NO_3/L (see figure 1 for year 2010). We use the lower quarter of the data set as the reference nutrient conditions. The lower quarter was 0,01 mg/L. To conclude: when the mean growth rate was 2,05 mm at 0,035 mg NO_3/ L, then the estimated daily growth rate in pristine conditions (NO_3 0,01 mg per L) is 0,58 mm per day.
Method for determining GES	GES will be determined quantitatively through the target (i.e. reference condition value). Two examples of determining indicator status, both from the Hanko peninsula, Finland (MARMONI 3FIN study area): Example 1: In 2011, the growth season was 154 days and the observed mean length of *C. glomerata* was132 mm, yielding a growth rate of (132 mm / 154 days) 0,86 mm/day. To meet GES, the growth rate of *C. glomerata* may not exceed 0,58mm/day in the area; this mean that GES was not reached. Example 2: In 2012, the growth season was 91 days and the observed mean length of *C. glomerata* was182 mm, yielding a growth rate of (182 mm / 91 days) 2,0 mm/day. To meet GES, the growth rate of *C. glomerata* may not exceed 0,58 mm/day in the area; this mean that GES was not reached.
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Illustrative material for indicator documentation

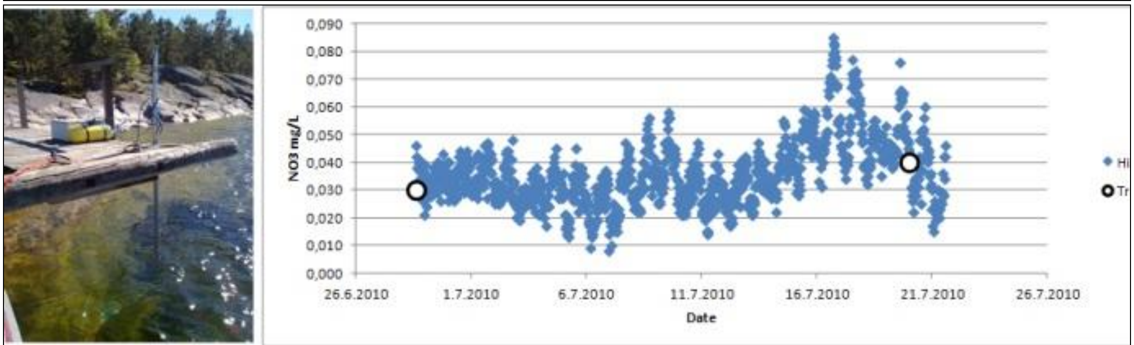


Figure 1. Left: a nutrient measurement device in action. Right: Daily fluctuations in NO_3 measured at 10 minutes intervals (diamonds) and by traditional sampling protocol data obtained from the database of the Finnish Environment Institute SYKE (open circles) in Finnish coastal waters in the summer of 2010. Photo by A. Ruuskanen.

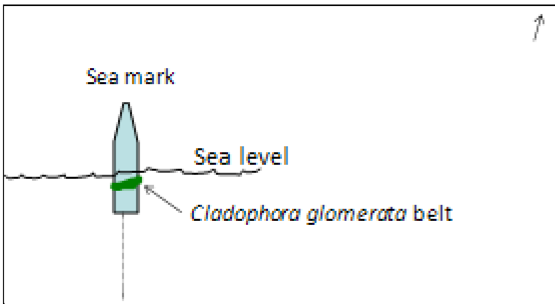


Figure 2. A sea mark and a diagrammatic illustration of the annual filamentous green algae *Cladophora glomerata* growing on it.

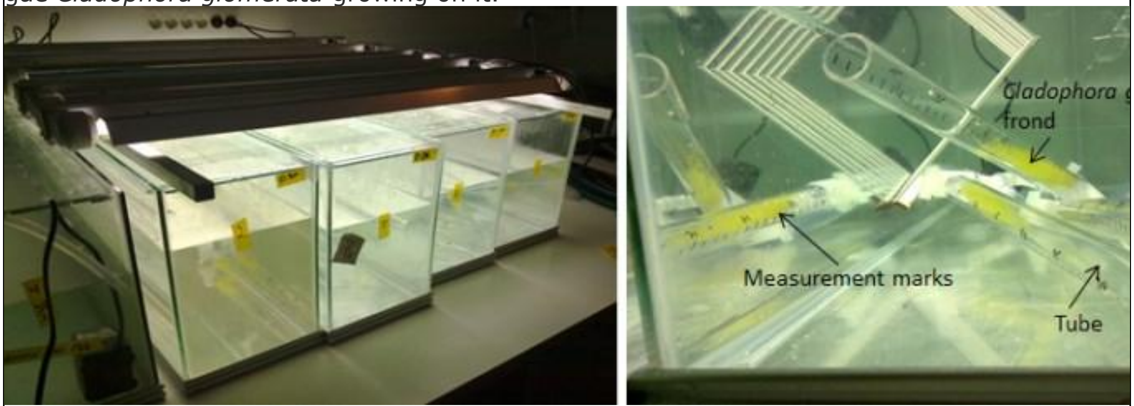


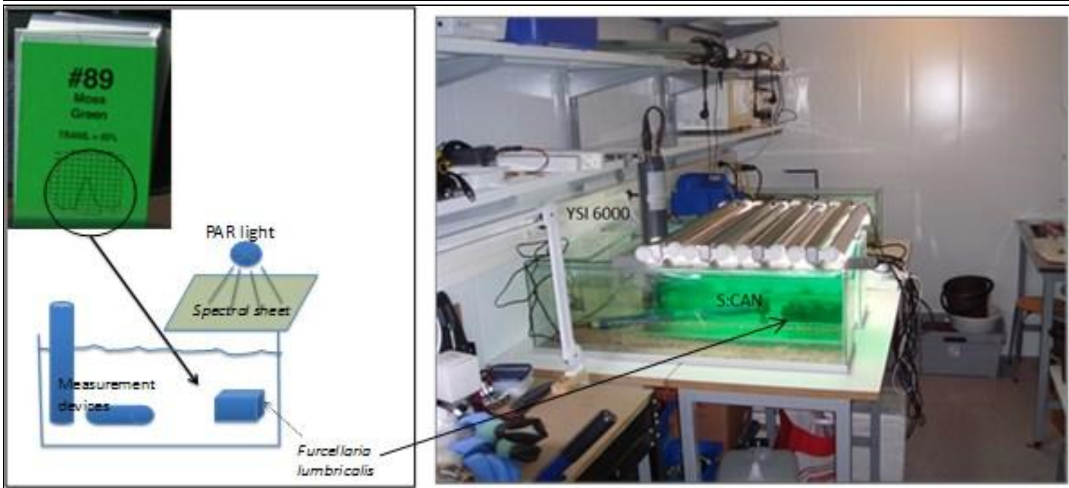
Figure 3. Laboratory experiment setup: *C. glomerata* cultivation in water flow-thru tubes in different nutrient concentrations. Changes in frond length were observed by measurement marks on the tube. Photos by A. Ruuskanen.

Name of indicator	**2.11 Depth distribution of selected perennial macroalgae**
Type of Indicator	State indicator
Author(s)	Ari Ruuskanen
Description of the indicator	The indicator is a multimetric indicator comprising of a set of four perennial macroalgae indicator species, the red algae *Furcellaria lumbricalis*, *Polysiphonia fucoides*, *Phyllophora pseudoceranoides* and *Rhodomela confervoides*. These species belong to the natural flora of the coastal area of south-western Finland MARMONI FIN3 study area and the indicator can be used in the whole study area except in the innermost bays. The indicator describes the long-term changes in water quality through measurements of the lower depth limit of a coverage of ≥ 0,1% of the indicator species. It has been shown that human-based eutrophication has an effect on the vertical depth distribution of macroalgae by decreasing water transparency and thus light penetration in the water column (Torn *et al*. 2006). Furthermore, the natural variation of the indicator species' occurrence and abundance are strongly related to the geographical location, sea bottom structure, and wave exposure (Rinne *et al*. 2011). When these sources of natural variation are known and taken into account, effects of human-based eutrophication can be detected.
Relationship of the indicator to marine biodiversity	The indicator red algae species *Furcellaria lumbricalis*, *Polysiphonia fucoides*, *Phyllophora pseudoceranoides* and *Rhodomela confervoides* are dominant in the sublittoral zones of Finnish coastal waters (SYKE macrophyte data base). They make up most of the diversity in terms the number of species and the number of individuals. The sublittoral invertebrate fauna is strongly associated to these species (Koivisto 2011). The most common zoobenthos taxa are blue mussel (*Mytilus trossulus*), gastropods (*Hydrobia* spp.) and gammarids (*Gammarus* spp). Thus, canopies of the indicator species maintain zoobenthos diversity in hard bottoms, and a decrease in the abundance of the indicator species means a decrease in total biodiversity (Koivisto 2011).
Relevance of the indicator to different policy instruments	The present indicator can be connected to the Water Framework Directive (EC 2000/60/EC) compliance Finnish Macrophyte Index. The indicator has been agreed as a Core Indicator in the HELCOM CORESET of Biodiversity indicators (HELCOM 2012). descriptor 1, criteria 1.1 Species distribution, 1.1.1 Distributional range descriptor 5, criterion 5.1 Direct effects of nutrient enrichment descriptor 6, criterion 6.1 Kind and size of relevant biogenic substrata HELCOM Baltic Sea Action Plan (BSAP): Ecological objectives "Natural distribution and occurrence of plants and animals" (Eutrophication) and "Thriving communities of plants and animals" (Nature conservation).
Relevance to commission decision criteria and indicator	1.1. Species distribution 1.1.1. Distributional range
Method(s) for obtaining indicator values	Data sampling is performed by a trained SCUBA diver. The diver measures the depth of the lower growth limit of a coverage of ≥0,1 % of the indicator species with an accuracy of 10 cm. At least four sites per studied water area must be sampled, and three of the four indicator species are needed for attaining a reliable indicator value; the use of too low number of species does not give a reliable result. The diver performing the investigation must have good species identification skills. The depth values measured for each indicator species is converted to EQR (Ecological Quality Ratio) values, by a method obtained from the WFD (EC 2000/60/EC). The EQR is a numerical expression of a function of observed values divided by the reference depth (Table 1). The EQR value is expressed as a number between zero and one, where one represents reference conditions and zero extremely bad conditions. Since each indicator species have different reference depths, the use of EQR makes it possible to compare values. For the calculation of the index, for a water body (or water type or given water site), the average of the EQRs of all indicator species found at the site is calculated.

Documentation of relationship between indicator and pressure	General eutrophication has an effect on the vertical depth distribution of macroalgae by decreasing water transparency and thus light penetration in the water column; the more eutrophied the area is, the lower (shallower) the depth distribution of macroalgae. The indicator species' occurrence and abundance, expressed here as their vertical depth distribution, are furthermore strongly related to the geographical location, sea bottom structure, and wave exposure. If we know the natural conditions mentioned above, and the minimum light requirements of a species for growth in pristine conditions, it is possible to determine the potential maximum growth depth of the indicator species, i.e. the reference value. If the indicator species do not meet this potential maximum growth depth, we can assume that water transparency has decreased, perhaps due to anthropogenic reason. By analysing existing data sets of maximum vertical depth limits of the percentage coverage of ≥ 0,1% of the indicator species, and data sets on Secchi depths, we found that there was a relationship between the vertical depth distribution of the indicator species and Secchi depth (i.e. water transparency). Secchi depth in turn has been shown to correspond with general eutrophication; a lower Secchi depth being indicative of eutrophication.
Geographical relevance of indicator	Regional
How Reference Conditions (target values/thresholds) for the indicator were obtained?	The expected lower growth depth values, i.e., reference values, were determined through laboratory experiments, by using published literature, by analysing data available in the data base of the Finnish Environment Institute SYKE, and by doing additional field works and laboratory experiment to fill gaps in knowledge. The laboratory experiment set up was as follows (Figure 1). As an example, specimens of *Furcellaria lumbricalis* were placed in a net basket so that they were situated in their natural position. The basket was placed in an aquarium containing autoclaved natural seawater and was exposed to various intensities of light. The light quality (wave length and colour) was adjusted according to the Rosco light conversion sheets (Kraufvelin *et al.* 2012) (#89 Moss green) to be equal to light prevailing at the depth of 15–20 meters (the estimated lower growth limit of given species). By increasing and decreasing the light intensity it was possible to determine a compensation point of photosynthesis activity, i.e. the production of the specimen, measured as the oxygen production. The change in oxygen production was measured from the aquarium water with a YSI 6000 sond at 10 minute intervals. To make ensure that plankton production did not affect oxygen production, a S:CAN fluorometer was included to detect the presence of plankton. The temperature was kept at 12 ºC, the mean temperature at approximately 15 meters depth during the growth season. As a result, the compensation point of light intensity, expressed as oxygen production, was for *Furcellaria lumbricalis* between 5–7 μE/m^2/sec (Figure 2). In other words, the compensation point equals the theoretical lower growth depth, i.e., the depth where the amount of light is 5–7 μE/m^2/sec. By using under water light measurement device in the field, the equivalent depth for a light amount of 5–7 μE/m^2/sec was determined to be 16–14 meters in the study area.
Method for determining GES	In the present work, we define GES as a deviation of 21% from the reference value. This means that GES is EQR = 0,79. To determine reference conditions, historical data, modelling and expert judgment was used. The reference depths or values of the indicator species are shown in table 1. In order to take natural variation in depth limit caused by wave action in to account, the archipelago is divided into more exposed and more sheltered parts. The final EQR is calculated as follow: After the sampling of a given water site (a water body, a water type or a given water site), the average of the EQRs of the all indicator species is calculated.

Table 1. The reference depths of the indicator species.

	More exposed archipelago	More sheltered archipelago
Indicator species	Reference depth (m)	Reference depth (m)
Furcellaria lumbricalis	18	15
Polysiphonia fucoides	15	13
Phyllophora pseudoceranoides	21	18
Rhodomela confervoides	15	13

	An example of the use of the present indicator is shown in Figure 3. The data from the coastal area of south-western Finland MARMONI study area (Hanko peninsula) from the years 2002-2013 was obtained from the data base of the Finnish Environment Institute SYKE. According to the indicator, the water quality does not meet GES during this period.
References	EC, 2000. DIRECTIVE 2000/60/EC of the European parliament and of the council, of 23 October 2000, establishing a framework for Community action in the field of water policy. Official Journal of the European Communities, G.U.C.E. 22/12/2000, L 327. HELCOM 2012. Development of a set of core indicators: Interim report of the HELCOM CORESET project PART B: Descriptions of the indicators. BSEP 129B:1-219. Koivisto, M. 2011: Blue mussel beds as biodiversity hotspots on the rocky shores of the northern Baltic Sea. – Academic dissertation, University of Helsinki. Kraufvelin, P., Ruuskanen A., Bäck S. & Russell G. 2012: Increased seawater temperature and light during early springs accelerate receptacle growth of *Fucus vesiculosus* in the northern Baltic proper. – Marine Biology 159:1795-1807. Krause-Jensen D., Carstensen J. & Dahl K. 2007: Total and opportunistic algal cover in relation to environmental variables. - Marine Pollution Bulletin 55:114–125. Krause-Jensen D., Carstensen, J., Dahl, K., Saara Bäck, S. & Neuvonen, S. 2009: Testing relationships between macroalgal cover and Secchi depth in the Baltic Sea. - Ecological Indicators 9:1284–1287. Rinne, H., Salovius-Laurén, S., & Mattila, J. 2011: The occurrence and depth penetration of macroalgae along environmental gradients in the northern Baltic Sea. - Estuarine, Coastal and Shelf Science 94:182-191. Torn, K., Krause-Jensen, D. & Martin, G., 2006: Present and past depth distribution of bladderwrack (*Fucus vesiculosus*) in the Baltic Sea. - Aquatic Botany 84: 53-62. Torn, K, & Martin, G. 2012: Response of submerged aquatic vegetation to eutrophication-related environment descriptors in coastal waters of the NE Baltic Sea. - Estonian Journal of Ecology 61(2):106-118.
Illustrative material for indicator documentation	 Figure 1. A schematic and authentic presentation of the laboratory experiment set up.

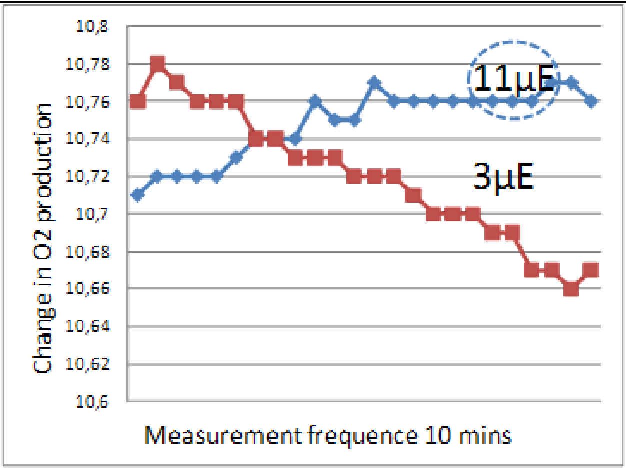


Figure 2. The change in oxygen production of *Furcellaria lumbricalis* at 11 µE/m^2/sec and 3 µE/m^2/sec light exposures. At the light exposure of 3 µE/m^2/sec there was no oxygen production, only respiration. At the light exposure of 11 µE/m^2/sec oxygen production took place. The measurement period (marks) was 10 minutes.

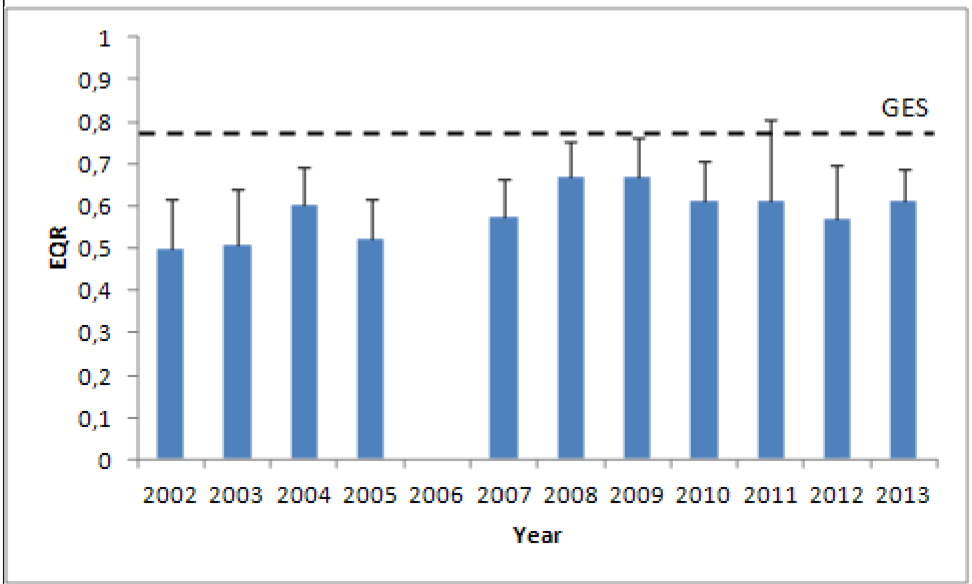
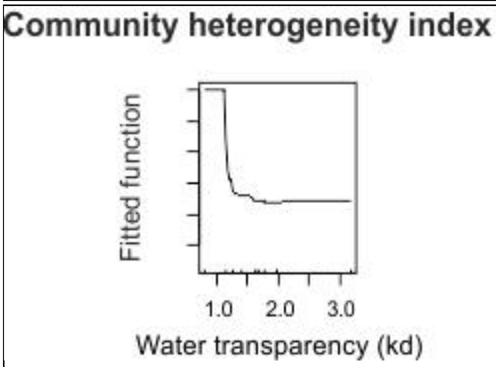
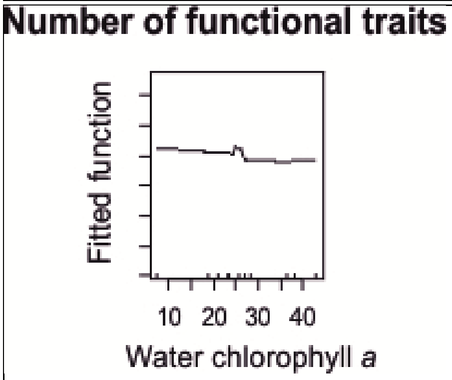


Figure 3. Changes in EQR of the present indicator species (average of all) in the coastal area of south-western Finland in 2002-2013. No sampling was performed in the year 2006. The GES limit is indicated as a dashed line; according to the indicator, the water quality does not meet GES.

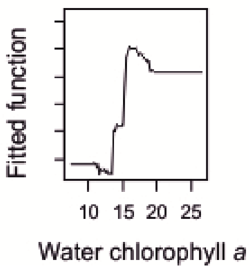
Name of indicator	**2.12 Community heterogeneity (CH)**
Type of Indicator	State indicator
Author(s)	Jonne Kotta, Merli Pärnoja
Description of the indicator	The index analyses heterogeneity of communities at the landscape scale. In order to do so we quantify the relative importance of scale-specific variability of macroalgal and benthic invertebrate communities. Using multivariate data analyses dissimilarities between pairs of samples are calculated using a zero-adjusted Bray-Curtis coefficient (e.g. using PRIMER software package). The coefficient is known to outperform most other similarity measures and enables samples containing no organisms at all to be included. Then the geographical distances between the studied sites are calculated and the distances are related to the dissimilarity matrices of biota. The ratio between the distance-based mean dissimilarities and its standard deviation is used as a proxy of the community heterogeneity at landscape scale. As such the index estimates the complexity of the spatial patterns of benthic communities with higher values of the statistic indicating more distinct and less variable (i.e. potentially less disturbed) communities at the studied spatial scale.
Relationship of the indicator to marine biodiversity	The development of this diversity index is based on the evidence that various stressors operate at different spatial scales. The index allows estimating simultaneously the relative contribution of different stressors operating at various spatial scales. The CH index quantifies the diversity of seascapes i.e. beta diversity.
Relevance of the indicator to different policy instruments	There is a potential to use the indicator for assessment of MSFD descriptors 1, 2, 4, 5, 6 and in the frame of the Habitats Directive.
Relevance to commission decision criteria and indicator	1.6. Habitat condition 1.7. Ecosystem structure 1.7.1. Composition and relative proportions of ecosystem components (habitats and species)
Method(s) for obtaining indicator values	The equation of a zero-adjusted Bray-Curtis coefficient is: $dBCC\ (i,j) = \frac{\sum_{k=0}^{n-1} \lvert yi,k - yj.k \rvert}{[2 + \sum_{k=0}^{n-1}(yi,k + yj,k)]}$ In the equation dBCC is the Bray-Curtis dissimilarity between the objects i and j; k is the index of a variable and n is the total number of variables y. A zero-adjusted Bray-Curtis coefficient includes a virtual dummy variable being 1 for all objects. Consequently, the result is not undefined, when the variables among two objects are entirely 0. In the numerator this variable subtracts to zero and in the denominator it sums to 2. The equation of the scale-specific community heterogeneity is: $CHi = \frac{mean(dBCCi)}{stdev(dBCCi)},$ where mean(dBCCi) is the mean zero-adjusted Bray-Curtis dissimilarity coefficient and stdev (dBCCi) is a standard deviation of this mean at a predefined spatial scale i. Although response variables can be manifold such as number of species, abundances, biomasses of species, functionality of community etc., in this study benthic species biomasses were used.
Documentation of relationship between indicator and pressure	The CH index responded differentially to the studied environmental variables. The links between environmental variables and index were always the strongest at 5 km spatial scale. At smaller spatial scales the index reflected changes to local ice conditions and/or coastal topography. At 5 km spatial scale, however, the index followed the variability in coastal eutrophication. Thus, this is the scale where eutrophication processes are likely to have the largest effects on coastal environment and at which the impacts of eutrophication on coastal biota should be assessed. The CH index decreased with elevating eutrophication i.e. kd values. However, the relationship was not very strong. An explanation of the observed relationship is as follows. The CH index reflects patchiness in the seascape. It is known that an increased eutrophication tends to homogenize the seascape patchiness by increasing the cover of filamentous algae irrespective of physical water properties and local topography. Besides, eutrophication impover-

	ishes underwater light conditions and therefore further reduces overall biological diversity as in such a low-light environment only a few algal and associated invertebrate species can be found. Consequently, an inverse relationship between eutrophication and CH is expected (Kotta *et al*. 2013).
Geographical relevance of indicator	2. Regional
How Reference Conditions (target values/thresholds) for the indicator were obtained?	Due to the lack of historical data of required spatial resolution and extent, the reference condition was set at the upper tail (95th percentile) of the natural variability of the index value in the MARMONI pilot area. This expert judgement is based on the current status of the marine coastal ecosystems and on the established probability distribution of the index value.According to these criteria the reference condition of CH index was set at 18.0.
Method for determining GES	GES was determined using the the European Union Water Framework Directive classification scheme for water quality in the Estonian coastal areas. Specifically, among the eutrophication related variables water transparency was best related to the CH index. Thus, in order to set GES value, a functional relationship between pressure levels (e.g. kd values) and index values was established (the BRT modelling). Then, the existing boundary of water transparency between moderate and good water quality class was used to define the GES boundary of CH index. According to the established criteria the GES value of CH index was 9.0.
References	Kotta, J., Orav-Kotta, H., Pärnoja, M. 2013. Role of physical water properties and environmental disturbances on the diversity of coastal macrophyte and invertebrate communities in a brackish water ecosystem. WIT Transactions on Ecology and the Environment, WIT Press, 77 – 88.
Illustrative material for indicator documentation	 Supplementary figure. The Boosted Regression Tree model on the functional relationship between eutrophication variable and the index calculated at 5 km spatial scale. As a proxy of eutrophication we used the MODIS satellite derived water transparency (kd). The frequency of satellite observations was generally weekly over the whole ice-free period, however, several observations were discarded due to cloudiness. The spatial resolution of satellite data was 1 km. In general, increasing eutrophication is associated with elevated Kd values in our study area.

Name of indicator	**2.13 Number of functional traits (NFT)**
Type of Indicator	State indicator
Author(s)	Jonne Kotta, Merli Pärnoja
Description of the indicator	One of the most promising of the recently proposed approaches to measure community functional diversity is Biological Traits Analysis. Biological traits analysis uses a series of life history, morphological and behavioural characteristics of species present in assemblages to indicate aspects of their ecological functioning. The roles performed by benthic species are important for regulating ecosystem processes and these roles are determined by the biological traits species exhibit. The approach aims to provide a description of multiple aspects of functioning based on features of the biological ecosystem component. It does this by utilising specific species traits as indicators of functioning and examining the occurrence of these traits over assemblages. Community structure is governed by habitat variability and the biological traits exhibited by organisms will provide information about how they behave and respond to stress, thereby indicating the state of the environment.
Relationship of the indicator to marine biodiversity	The development of this diversity index is based on the evidence that the presence of various functional groups in a community hints the functional diversity and ecosystem services performed by the community.
Relevance of the indicator to different policy instruments	There is a potential to use the indicator for assessment of MSFD descriptors 1, 2, 4, 5, 6 and in the frame of the Habitats Directive.
Relevance to commission decision criteria and indicator	1.6. Habitat condition 1.6.1. Condition of the typical species and communities 1.7. Ecosystem structure 1.7.1. Composition and relative proportions of ecosystem components (habitats and species)
Method(s) for obtaining indicator values	Biological Traits Analysis is based on habitat template theory, which states that species' characteristics evolve in response to habitat constrain. Community structure is governed by habitat variability and the biological traits exhibited by organisms will provide information about how they behave and respond to stress, thereby indicating the state of the environment. BTA uses a number of analyses to describe patterns of biological trait composition over entire assemblages (i.e. the types of trait present in assemblages and the relative frequency with which they occur). The NFT index counts the number of functions (biological traits) in the system. Higher number of such functions reflects elevated functional diversity and, thus, such communities are able to provide more ecosystem services compared to those having smaller number of functions. In the current index the observed benthic invertebrate species were classified according to their mobility (mobile and non-migratory) and feeding type (suspension feeders, herbivores, deposit-feeders, and carnivores) based on literature (Bonsdorff and Pearson, 1999) and field observations. Benthic macrophyte species were classified according to their growth form (coarsely branched, filamentous, sheet, thick leathery).
Documentation of relationship between indicator and pressure	The index responded differentially to the studied environmental variables. The links between environmental variables and index were always the strongest at 5 km spatial scale. At smaller spatial scales the index reflected changes to local ice conditions and/or coastal topography. At 5 km spatial scale, however, the index followed the variability in coastal eutrophication. Thus, this is the scale where eutrophication processes are likely to have the largest effects on coastal environment and at which the impacts of eutrophication on coastal biota should be assessed. The NFT index gradually decreased with elevating eutrophication i.e. mainly with increasing chl a values. However, the relationship was not very strong. An explanation of the observed relationship is as follows. The biomass of macrophyte biomass is a function of nutrient availability and that of benthic invertebrates by macrophytes. However, an increasing eutrophication of the Baltic Sea ecosystem favours fast growing species and decreases a chance of perennial benthic function to be observed. Consequently, species and functional diversity is expected to decrease with eutrophication (Kotta *et al.* 2013).
Geographical relevance of indicator	2. Regional

How Reference Conditions (target values/thresholds) for the indicator were obtained?	Due to the lack of historical data of required spatial resolution and extent, the reference condition was set at the upper tail (95th percentile) of the natural variability of the index value in the MARMONI pilot area. This expert judgement is based on the current status of the marine coastal ecosystems and on the established probability distribution of the index value. According to these criteria the reference condition of NFT index was set at 6.6.
Method for determining GES	GES was determined using the European Union Water Framework Directive classification scheme for water quality in the Estonian coastal areas. Specifically, among the eutrophication related variables water chlorophyll a was best related to the NFT index. Thus, in order to set GES value, a functional relationship between pressure levels (e.g. chl a values) and index values was established (the BRT modelling). Then, the existing boundary of chl a between moderate and good water quality class was used to define the GES boundary of NFT index. According to the established criteria the GES value of NFT index was 6.2.
References	Bonsdorff, E. & T. H. Pearson, 1999: Variation in the sublittoral macrozoobenthos of the Baltic Sea along environmental gradients; a functional-group approach. Aust. J. Ecol. 24: 312–326. Kotta, J., Orav-Kotta, H., Pärnoja, M. 2013. Role of physical water properties and environmental disturbances on the diversity of coastal macrophyte and invertebrate communities in a brackish water ecosystem. WIT Transactions on Ecology and the Environment, WIT Press, 77 – 88.
Illustrative material for indicator documentation	 **Supplementary figure**. The Boosted Regression Tree model on the functional relationship between eutrophication variable and the index calculated at 5 km spatial scale. As a proxy of eutrophication we used the MODIS satellite derived water chlorophyll a values. The frequency of satellite observations was generally weekly over the whole ice-free period, however, several observations were discarded due to cloudiness. The spatial resolution of satellite data was 1 km. In general, increasing eutrophication is associated with elevated Chl a and kd values in our study area.

Name of indicator	2.14 Macrozoobenthos community index (ZKI)
Type of Indicator	State indicator
Author(s)	Jonne Kotta
Description of the indicator	The structure of benthic assemblages responds diversely to many kinds of stresses because these assemblages typically include organisms with a wide range of physiological tolerances, feeding modes, and trophic interactions. In order to make this information usable for water quality assessment, the ZKI index divides the macrofauna into three distinct groups according to their sensitivity to an increasing stress (including eutrophication). Species belonging to class 1 are those that can be found at heavily eutrophicated conditions, species belonging to class 2 are those that gain biomass under moderate eutrophication conditions, and class 3 species are those typical to pristine conditions. The index also takes into account species number at station and compensates this diversity term for salinity gradients. The compensation term is based on waterbody-specific maximum values for species number calculated from the entire content of national database. The index is currently used when assessing the water quality in Estonia in the frame of the EU Water Framework Directive.
Relationship of the indicator to marine biodiversity	The index takes into account species number at survey station and compensates this diversity term for salinity gradients. Thus, the index has a potential to reflect spatial and temporal variability of diversity of benthic invertebrate communities related to changes in the intensity of various pressures.
Relevance of the indicator to different policy instruments	The index is currently used in the frame of the Water Framework Directive, there is a potential to use the indicator for assessment of MSFD descriptors 1, 2, 4, 5, 6 and in the frame of the Habitats Directive.
Relevance to commission decision criteria and indicator	1.6. Habitat condition 1.6.1. Condition of the typical species and communities 1.6.2. Relative abundance and/or biomass, as appropriate 1.7. Ecosystem structure 1.7.1. Composition and relative proportions of ecosystem components (habitats and species)
Method(s) for obtaining indicator values	The equation of the ZKI index is as follows: $$\mathrm{ZKI} = [0.5 \times (\mathrm{Class\ 1} + 2 \times \mathrm{Class\ 2} + 3 \times \mathrm{Class\ 3}) - 0.5] \times \left[\frac{S}{S_{\max}}\right]$$ where: Class i is a ratio of sum of dry weight of the species belonging to class i to total invertebrate biomass at station; S is number of species/taxa at station; S_{max} is a waterbody-specific value of maximum species number at station. The values of ZKI index vary locally between 0 and 1 i.e. 1 representing the healthy communities and 0 representing the most deteriorated communities (Kotta *et al.*, 2012). There are certain criteria that need to be fulfilled: (1) The index can be used for soft bottom communities including mixed sand sediments. (2) Sampling device is either a van Veen or Ekman type benthic grab. (3) Depth should be ≥ 5 m and ≤ 30 m.
Documentation of relationship between indicator and pressure	The index responded differentially to the studied environmental variables. The links between environmental variables and index were always the strongest at 5 km spatial scale. At smaller spatial scales the index reflected changes to local ice conditions and/or coastal topography. At 5 km spatial scale, however, the index followed the variability in coastal eutrophication. Thus, this is the scale where eutrophication processes are likely to have the largest effects on coastal environment and at which the impacts of eutrophication on coastal biota should be assessed. The ZKI index increased with elevating eutrophication i.e. chl a values. This can be ex-

	plained as follows. Locally, the biomass of macrophyte species is a function of nutrient availability and that of benthic invertebrates by macrophytes. Thus, an increasing eutrophication of the Baltic Sea ecosystem relaxes competitive interactions for food and increases a chance of any benthic species to be observed. Consequently, local species diversity increases with eutrophication. Too high a nutrient loading, however, is known to cause hypoxia and irreversible changes in communities. Nevertheless, such conditions are not met in the study area (Kotta *et al*. 2012).
Geographical relevance of indicator	2. Regional
How Reference Conditions (target values/thresholds) for the indicator were obtained?	Due to the lack of historical data of required spatial resolution and extent, the reference condition was set at the lower tail (5th percentile) of the natural variability of the index value in the MARMONI pilot area. This expert judgement is based on the current status of the marine coastal ecosystems and on the established probability distribution of the index value. According to these criteria the reference condition of ZKI index was set at 0.
Method for determining GES	GES was determined using the European *Union* Water Framework Directive classification scheme for water quality in the Estonian coastal areas. Specifically, among the eutrophication related variables water chlorophyll a was best related to the ZKI index. Thus, in order to set GES value, a functional relationship between pressure levels (e.g. chl a values) and index values was established (the BRT modelling). Then, the existing boundary of chl a between moderate and good water quality class was used to define the GES boundary of ZKI index. According to the established criteria the GES value of NFT index was 0.03.
References	Kotta, J., Lauringson, V., Kaasik, A., Kotta, I. 2012. Defining the coastal water quality in Estonia based on benthic invertebrate communities. Estonian Journal of Ecology, 61, 86–105. Lauringson, V., Kotta, J., Kersen, P., Leisk, Ü., Orav-Kotta, H., Kotta, I. 2012. Use case of biomass-based benthic invertebrate index for brackish waters in connection to climate and eutrophication. Ecological Indicators. 12, 123–132.
Illustrative material for indicator documentation	**Macrozoobenthos community index**  **Supplementary figure**. The Boosted Regression Tree model on the functional relationship between eutrophication variable and the index calculated at 5 km spatial scale. As a proxy of eutrophication we used the MODIS satellite derived water chlorophyll a values. The frequency of satellite observations was generally weekly over the whole ice-free period, however, several observations were discarded due to cloudiness. The spatial resolution of satellite data was 1 km. In general, increasing eutrophication is associated with elevated Chl a and Kd values in our study area.

Name of indicator	**2.15 Reed belt extent – the NDVI approach via high resolution satel-**

	lite images
Type of Indicator	State indicator
Author(s)	Hanna Piepponen, Meri Koskelainen and Kirsi Kostamo
Description of the indicator	The indicator expresses the extent of coastal reed belts, using information from remote sensing and exposition-depth data. The reed belt extent in the archipelago of South-western Finland, in the MARMONI 3FIN study area, was examined from high resolution satellite images dating from September 2009 (RapidEye, 5m by 5m resolution) and July 2013 (WorldView, 2m by 2m resolution). For verifying the results, data from Kotka located in South-eastern Finland was used. The Kotka satellite images dated from July 2011 (RapidEye, 5m by 5m resolution) and September 2012 (WorldView, 2m by 2m resolution). The indicator is a combination of Normalized Difference Vegetation Index (NDVI) and the exposition-depth data (Isaeus & Rygg 2005, Tolvanen 2010) that shows the optimum growing area for reed vegetation. The indicator demonstrates the local extent of reed communities very well in the two test areas. NDVI calculated from satellite images shows the actual extent and location of reed communities in sheltered areas. A temporal aspect is possible to attain by comparing seasonal changes in reed vegetation, provided that suitable satellite images are available. However, both the temporal and spatial coverage of the indicator is still fairly restricted due to a lack of available high resolution satellite images, and for a better coverage of reed vegetation information in the Gulf of Finland a higher number of high resolution satellite images are needed. Images of a coarser resolution are not useful for local scale reed belt extent studies because they do not provide reliable spatial information for the calculation of the size and shape of the reed belt by the NDVI. Coarse resolution Landsat (30m by 30m resolution) satellite images were tested but the results are too rough for closer examination of changes in reed belt extent. The lack of high resolution satellite images also prevents comparing temporal changes in coastal areas in a long time scale, so the development of the index requires further studies with upcoming satellite images. Availability of usable high resolution satellite images is not certain because the weather conditions and scanning time limit the use of all available images from a study area. Summarizing the above, high resolution satellite images of sufficient spatial and temporal frequency are requisite for the indicator.
Relationship of the indicator to marine biodiversity	Common reed, *Pharagmites australis* (Cav.) Trin. Ex Steudel, is an erect perennial grass growing in lakes, trenches, shore and bog meadows in Northern Europe (Hämet-Ahti *et al*. 1998). It often forms dense and more or less monospecific patches or areas consuming all available growing space. Both the number and coverage of reed patches has increased in many areas both in disturbed and forested sites in Northern America (McCormick *et al*. 2010). Common reed is a rapidly expanding species which can reproduce both clonally and sexually. Even though it forms very dense patches, negative effects of shading on plant biodiversity have not been established (Güsewell & Edwards 1999). Furthermore, it has been discovered that the species richness does not decrease as a result of an increase in reed biomass (Grime 1973, 1979, Güsewell & Edwards 1999), but changes from aquatic macrophytes towards species occurring in the geolittoral (Munsterhjelm 1997). Furthermore, high reed biomasses may alter the proportion of species so that the plant community will develop so that light-demanding species from nutrient-poor sites are replaced by more shade-tolerant and more nutrient-demanding species. In light of these results, it is also likely that an increase in eutrophication may affect the plant community composition (Tilman 1982, 1987, Olff 1992, Eek & Zobel 1997). Since the light interception by common reed follows a clear seasonal pattern and is negligible until June, its impacts on species developing in spring or early summer are likely to be strongly reduced by phenological separation (Güsewell & Edwards 1999). Therefore species, growing until the end of the summer, are more likely to be influenced by *P. australis* than species that complete their annual growth in early summer or which are at least capable of doing so if light conditions decline. The relationship between species richness and reed biomass is further complicated by the different types of wetland communities (Güsewell & Edwards 1999). Thus the coexistence of other wetland species and succession of species composition can increase the biodiversity of the reed communities.

Relevance of the indicator to different policy instruments	EU Marine Strategy Framework Directive: descriptor 1 Biodiversity, 1.5 Habitat extent, 1.5.1 Habitat area. HELCOM Baltic Sea Action Plan ecological objective for 'natural marine and coastal landscapes'. Habitats Directive: state of the coastal habitats and protected species.
Relevance to commission decision criteria and indicator	1.5. Habitat extent 1.5.1. Habitat area
Method(s) for obtaining indicator values	The coverage of common reed was estimated by using information provided by satellite remote sensing (RapidEye 5m by 5m resolution and WorldView-2 2m by 2m resolution). The reed vegetation presence was determined from the images by calculating the Normalized Difference Vegetation Index (NDVI), which was calculated from the band relations between red and infrared bands. NDVI areas were extracted to water areas by clipping the data by shoreline as we assumed that all the vegetation in water is reed vegetation. The threshold value of the NDVI was set in both summer and fall images to 0.2 to avoid errors caused by highly reflecting objects such as sailboats. In general, the reflection from vegetation was more moderate in fall compared to summer when the reflection intensity was the highest and shows the maximum vegetation cover. The indicator utilizes depth-exposition data to determine the potential growing area of reed belts. Used depth-exposition data covers the shoreline from 0 to 2m in depth (Luther 1951a, 1951b) and exposition of less than 100 000 (sheltered and moderately sheltered areas, Munsterhjelm 1997, 2005); these conditions were considered to be the optimum growing area for reed vegetation. Over 95% of NDVI areas were included in depth-exposition area showing that the optimum area for reed vegetation is coherent. Cloudy areas on each used data were removed for reducing errors and the pixel size of each data was resampled to the same size (4m by 4m). In addition to satellite remote sensing, the maximum extent of reed belts was confirmed by local field measurements during summer 2013 in Tammisaari. A comparison of summer and fall images revealed that it is possible to use both late summer and early fall satellite images for determining reed belt extent. Spring images (April, May) are not useful in Finnish coastal areas especially when growing season starts late due to elongated winter because the reed coverage reaches its maximum extent only in late June or July. Fall images (September) are usable but they underestimate the reed belt extent by about 10%. This was verified by calculations in Kotka, South-eastern Finland, from satellite images in July 2011 and in September 2012. The assumption was that reed vegetation has not changed during one year, and therefore, the reed extent in fall and summer images should be the same. As the reed extent in fall was smaller than in summer we derived a coefficient of 10% of underestimation for fall images. After adding 10% to reed vegetation data in fall 2009 in Tammisaari in the MARMONI 3FIN study area, we concluded that the reed belt extent has expanded by 1% during the period 2009–2013.
Documentation of relationship between indicator and pressure	The main pressures affecting the extent of the reed belts are land use and eutrophication. In the coastline of the Northern Baltic Sea, also land uplift influences the reed extent through a series of succession stages resulting from geological succession of the shoreline (Munsterhjelm 1997, 2005). Disturbance of upland habitats and eutrophication of estuaries have been shown to be positively correlated with the abundance of common reed (Bertness *et al*. 2002, Silliman & Bertness 2004, King *et al*. 2007, Chambers *et al*. 2008). A higher level of disturbance in developed watersheds can create open spaces for seedling emergence and rhizoid settlement and establishment and thus facilitate dispersal of this species (Kettenring et al. 2011). Offsite human activities, such as human alteration to surrounding uplands (Burdick *et al*. 2001, Bertness *et al.* 2002), atmospheric enrichment of nitrogen and carbon dioxide, and altered climate, may also enhance invasions (Minchington 2002, Burdick & Konisky 2003). The changes in land use can be analysed from, e.g.*,* CORINE-remote sensing data, but since this data exists currently only from 2000 and 2006, more data is needed to confirm this relationship. The effects of eutrophication are more complex in macrophyte communities than in plankton or annual macroalgal communities, because macrophytes take up nutrients with roots from the bottom sediments and not directly from the water. The effects of eutrophication are therefore accumulative and should be studied more in relation to a temporal aspect, *e.g.,* the nutrient content of the water column versus the nutrient content in the sediment. When considering grasses, including common reed, the increase in reproductive output resulting from eutrophication may enhance the invaders ability to establish new, genetically distinct populations and enhance the spatial dominance in already invaded areas. Furthermore, increased input of atmospheric nitrogen and carbon dioxide levels can alter the competitive balance of marsh plants in favour of common reed (Jaworski *et al*. 1997).

	Nutrient enrichment results in taller stems, increase in floret and inflorescence production and overall biomass, but also an increase in asexual reproduction (Minchinton & Bertness 2003, Rickey & Anderson 2004, Saltonsall *et al*. 2004, Saltonsall & Stevenson 2007, Mozdzer & Zieman 2010, Kettenring *et al*. 2011). On one hand, it has been discovered that if the reed colony is under high nitrogen levels, it may invest heavily on rhizome production (Rickey & Anderson 2004). This enables dispersal to areas, where low nitrogen content prevents population establishment by seeds (Bart & Hartman 2002). On the other hand, in high nutrient regime, seedling emergence and establishment benefit from eutrophication and increase the probability that population establishment occurs via seeds (Saltonsall & Stevenson 2007). Surprisingly, according to some studies, it has also been discovered that under high nutrient levels the below-ground biomass does not increase, although this is expected in populations where dispersal occurs by fragmented pieces of rhizoids (Haslam 1965, Rickey & Anderson 2004). Instead, the above-ground biomass increases (Minchinton & Bertness 2003, Rickey & Anderson 2004). It has also been discovered that under a high nutrient regime, the species spreads to deeper water than in oligotrophic conditions (Haslam 1965, 1972). The increase in nitrogen levels has been linked to the successful dispersal of common reed in a large number of areas (Haslam 1965, Marks *et al.* 1994). However, it has also been discovered that an increase in nitrogen increases also the growth of native species, so the eradicative effects of nutrients might not be as strong as assumed earlier (Rickey & Anderson 2004). All in all however, present knowledge suggests that eutrophication favours reed belt extent.
Geographical relevance of indicator	4. Baltic Sea wide
How Reference Conditions (target values/thresholds) for the indicator were obtained?	The target is trend-based, expecting no increase of area covered by reed belts, as indicated by the NDVI, in order to achieve Good Environmental Status.
Method for determining GES	The trend-based target for reed belt extent, as indicated by the NDVI, is estimated for the years 2002-2013, using medium resolution images for 2002-2009 and high resolution images for 2009-2013.
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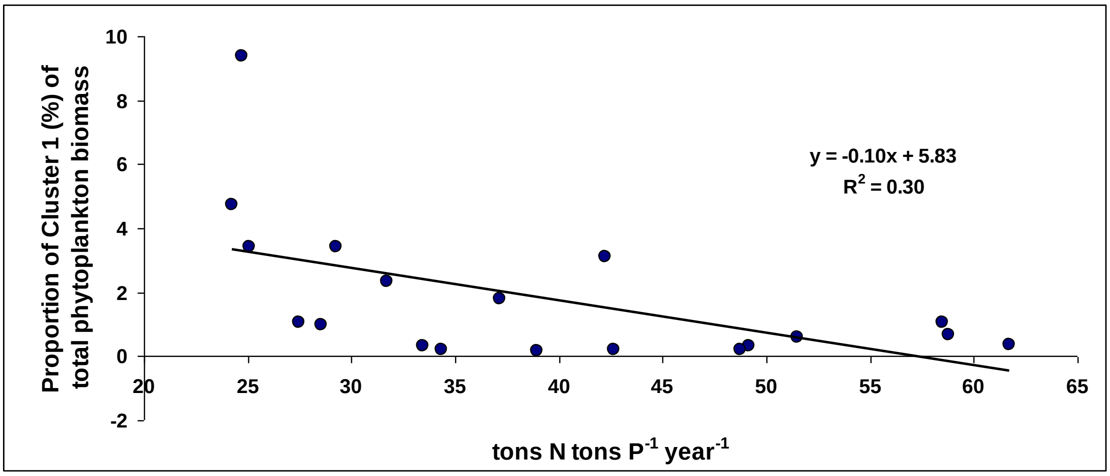
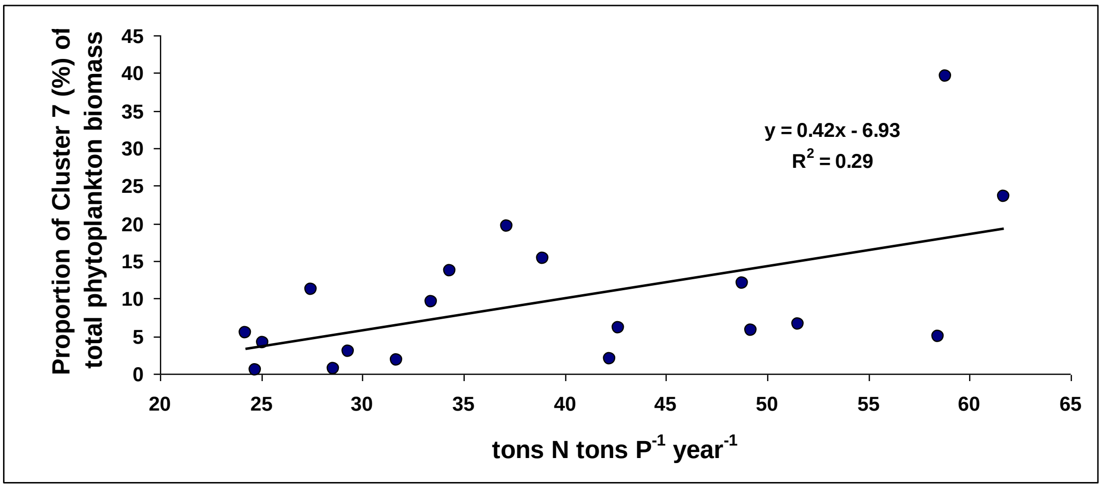
Illustrative material for indicator documentation	


Reed extent in July 2013 with depth-exposition data inTammisaari inner archipelago, SW Finland
0
0,3
0,6 Kilometers
Shoreline
July 2013
Depth-exposition

Reed extent in September 2009 with depth-exposition data inTammisaari inner archipelago, SW Finland

3 Pelagic indicators

Name of indicator	**3.1 Phytoplankton species assemblage clusters based on environmental factors**
Type of Indicator	State indicator
Author(s)	Bärbel Müller-Karulis, Iveta Jurgensone, Ieva Bārda
Description of the indicator	Indicator based on 7 summer phytoplankton species clusters obtained with a cluster analysis. Most clusters appeared at all stations at each sampling occasion, if a cluster was absent, it was assigned a biomass of 0. Relationships with environmental factors were tested with GAM models. Dominant species in each cluster and cluster dependencies on environmental factors are: Cluster 1 – wide range of species from different taxonomical groups representing high biodiversity, however in very low abundance Cluster 2 – cluster is more associated with stability of water column Cluster 3 – consists of tolerant species occurring all year around, including species *Aphanizomenon flos-aquae* Cluster 4 – consist of species complex, indicating high nutrient concentrations. One of included species is *Eutreptiella spp*., which could be indicator of bad environmental state Cluster 5 – included opportunistic species *Skeletonema costatum*, which might indicate eutrophication Cluster 6 – species complex is dominating by the flagellates characteristic in the Gulf of Riga during summer season Cluster 7 – cluster coherent with nutrient loads Within the framework of the MARMONI project, we tested existing clusters within the last 4 year data and their relation with nutrient loads. The clusters 1 and 7 were the only clusters showing significant link with nitrogen/phosphorus loads in perennial perspective.
Relationship of the indicator to marine biodiversity	Indicator reflects on eutrophication and indirectly on biodiversity.
Relevance of the indicator to different policy instruments	MSFD descriptors 1 and 5
Relevance to commission decision criteria and indicator	1.6.2. Relative abundance and/or biomass, as appropriate 1.6.3. Physical, hydrological and chemical conditions 1.7.1. Composition and relative proportions of ecosystem components (habitats and species)
Method(s) for obtaining indicator values	Species grouping into different clusters was done at genus level based on log (biomasses) of all genera found in 185 phytoplankton samples collected in June – September in the Gulf of Riga between 1993 and 2008. Similarities between samples were expressed as Euclidean distances between genera biomass. Ward's minimum variance method, an agglomeration method that aims to minimize the variance within clusters, was used to group species into clusters. Relationships with environmental factors were established for the log+1 transformed biomass of each cluster. Sampling month was included as a factor in the analysis. All statistical methods are part of the R libraries (clustering according to hclust, general additive models according to mgcv (Hastie & Tibshirani 1986)).
Documentation of relationship between indicator and pressure	Relationship between nutrient loads and clusters have been found. The Cluster 1 increases when N/P loads decrease (Fig.1), while the proportion of the Cluster 7 increases with an increase of N/P loads (Fig.2).

Geographical relevance of indicator	2. Regional
How Reference Conditions (target values/ thresholds) for the indicator were obtained?	Phytoplankton clusters reflect the influence of eutrophication (Cluster 7) and biodiversity (Cluster 1). The reference conditions were estimated taking into account the period of 1993-2012, when maximum biodiversity (Cluster 1) and at the same time minimum eutrophication (Cluster 7) were recorded. It was estimated during the period of 2007-2009 (Fig.3). Reference threshold was determined for Cluster 7, which should not exceed 2% of the total phytoplankton biomass.
Method for determining GES	GES value has been determined from reference threshold. Respectively, GES value for Cluster 7 is +50% of reference conditions, that is 3% from phytoplankton total biomass.
References	Hastie, Trevor, and Tibshirani, R. 1986. Generalized Additive Models (with discussion). Statistical Science Vol 1, No 3, 297-318
Illustrative material for indicator documentation	 Figure 1. Cluster 1 relation with N/P loads in the Gulf of Riga.  Figure 2. Cluster 7 relation with N/P loads in the Gulf of Riga.

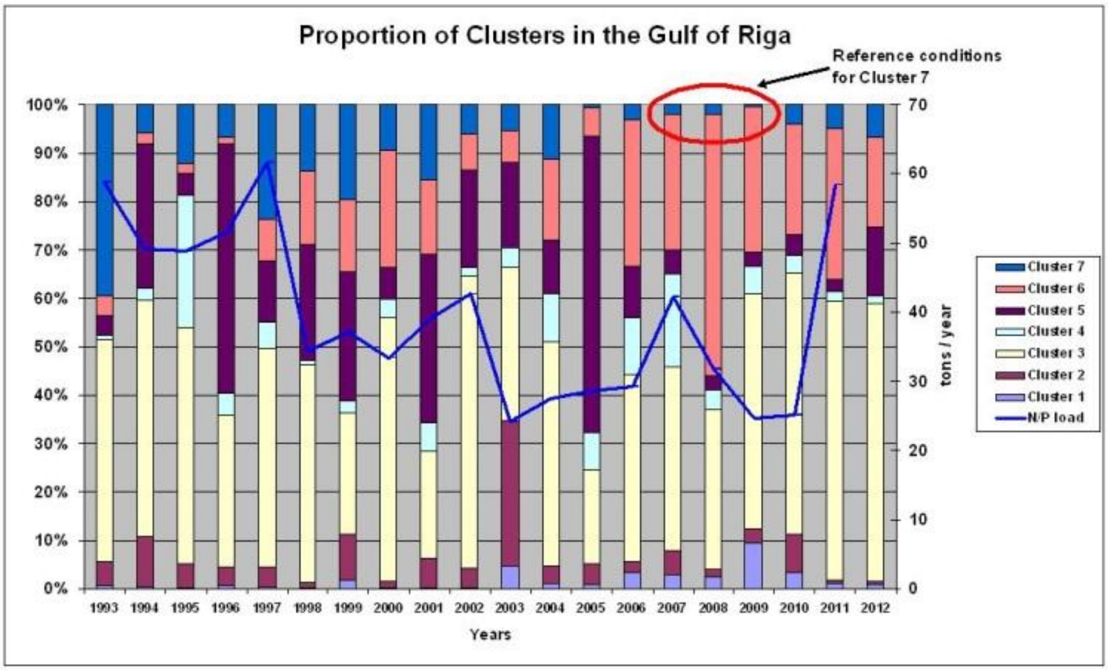


Figure 3. Clusters distribution in the Gulf of Riga.

Name of indicator	3.2 Seasonal progression of phytoplankton functional groups
Type of Indicator	State indicator
Author(s)	Andres Jaanus
Description of the indicator	A shift in phytoplankton functional groups may affect ecosystem function in terms of the carbon available to higher trophic levels or settling to the sediments. The succession of functional groups can provide an index that represents a healthy planktonic system, with a natural progression of dominant functional groups throughout the seasonal cycle. Deviations from the normal seasonal cycle (such as a too high or too low biomass, or the absence of some dominating phytoplankton group(s)) indicate an impairment in environmental status. This indicator has been originally proposed for British coastal waters (Devlin *et al*., 2007).
Relationship of the indicator to marine biodiversity	Phytoplankton encompasses a huge range of taxonomic and functional diversity linked closely to the health of marine ecosystems.
Relevance of the indicator to different policy instruments	Marine Strategy Framework Directive (MSFD) descriptors 1 (1.6.1., 1.6.2. and 1.7.1 according to the Commission Decision), 4 (4.3.1) and 5 (5.2.4). HELCOM Baltic Sea Action Plan (BSAP). Water Framework Directive (WFD).
Relevance to commission decision criteria and indicator	1.6. Habitat condition 1.6.1. Condition of the typical species and communities 1.6.2. Relative abundance and/or biomass, as appropriate 1.7. Ecosystem structure 1.7.1. Composition and relative proportions of ecosystem components (habitats and species
Method(s) for obtaining indicator values	Principle: 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 have been designed for each dominating phytoplankton group. Phytoplankton counts (wet weight biomass values) are averaged over months, and monthly mean and standard deviations (SD) are calculated for each functional group. A process of normalization, transformation and calculation of a monthly Z score (-2...+2) establishes comparable seasonal distributions for each functional group for a sampling year. A positive Z score indicates that the observation is greater than the mean and a negative score indicates that the observation is less than the mean. Indicator value: Data points are calculated by subtracting the long-term overall mean/SD value from the monthly mean value for a certain year. The score is based on the number of data points from the test area which fall within the acceptable deviation range set for each monthly point of the reference growth curve. Percentage-based thresholds are established for each functional group to determine class boundaries (EQR values) for the assessment of the ecological status. Indicator present status: The present status of the indicator was calculated for the years 2006–2011, based on monitoring data from Tallinn and Muuga bays (southern Gulf of Finland). Sample analysis and data preparation: The data required by this indicator is attained by quantitative phytoplankton analysis (cf. HELCOM 2014). 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. Wet weight biomasses of four major functional groups, including cyanobacteria, dinoflagellates, diatoms and the autotrophic ciliate *Mesodinium rubrum* are averaged for each month over a sampling year. Skewed data is accounted for by the transformation of phytoplankton biomass on a natural log scale (ln bm). Type-specific reference curves are established (mean and ±acceptable deviations). Quality assurance: The methods of collection, counting and identification should be unified between all laboratories sharing the same assessment area. Sampling: The time-scale for data sets should be at least 10 years to create type- or site-specific reference growth curves and the frequency of sampling at least once a month during the vegetation period.

Documentation of relationship between indicator and pressure	In the original publication (Devlin *et al*., 2007) a risk assessment of different water bodies was made based on nutrient availability, production and disturbance. As a result, a ´risk´ status was allocated to each coastal water type. The threshold values (reference curves) must be validated by testing them against a range of data from sites of different levels of impact. For that the data from different type areas representing waterbodies with pristine conditions to very disturbed ones should be collected with sufficient frequencies (at least once a month) throughout the vegetation period. After that the assessment could be made whether the reference growth curves for low, medium and high risk waterbodies are comparable in term of percentage counts falling within the predefined growth envelopes.
Geographical relevance of indicator	2. Regional
How Reference Conditions (target values/thresholds) for the indicator were obtained?	Generic reference curves were established for each coastal water type or open sea basin. Yearly and monthly means and standard deviations of phytoplankton counts (wet weight biomass values) were calculated for each functional group. The acceptable deviation from monthly mean values in Estonian marine areas is ±standard deviation. The same procedure was followed in testing sampling data from other areas of the Baltic Sea (Latvian, Finnish and Polish coastal waters). A process of normalization and calculation of Z scores makes the seasonal growth curves of different functional groups comparable. Z scores of zero illustrate that the monthly sample approaches the overall mean for that sampling period. Positive and negative values indicate greater and lower values than the overall mean, respectively. The score was based on the number of data points from the test waterbody which fell within the acceptable deviation range set for each monthly point of the reference growth curve.
Method for determining GES	GES is tentatively determined with 2/3 (EQR=0.67) values falling inside ±standard deviation from monthly mean log-normalized biomass values of each functional group. This index is applicable for coastal and open sea waters of the Gulf of Finland. The index has been preliminarily tested in the Gulf of Riga and in the southern Baltic Sea, with no conclusions as yet about the applicability in these sub-regions. Separate GES-boundaries might need to be set for different areas depending on the test results.
References	Devlin, M., Best, M., Coates, D., Bresnan, E., O'Boyle, S., Park, R., Silke, J., Cusack, C. & Skeats, J. 2007. Establishing boundary classes for the classification of UK marine waters using phytoplankton communities. Marine Pollution Bulletin 55, 91–103. HELCOM 2014. Manual for Marine Monitoring in the COMBINE Programme of HELCOM. Part C, Programme for monitoring of eutrophication and its effects. Annex C-6, Guidelines concerning phytoplankton species composition, abundance and biomass; pp. 285–300. Last updated: 17.1.2014. Available at http://helcom.fi/action-areas/monitoring-and-assessment/manuals-and-guidelines/combine-manual

<table>
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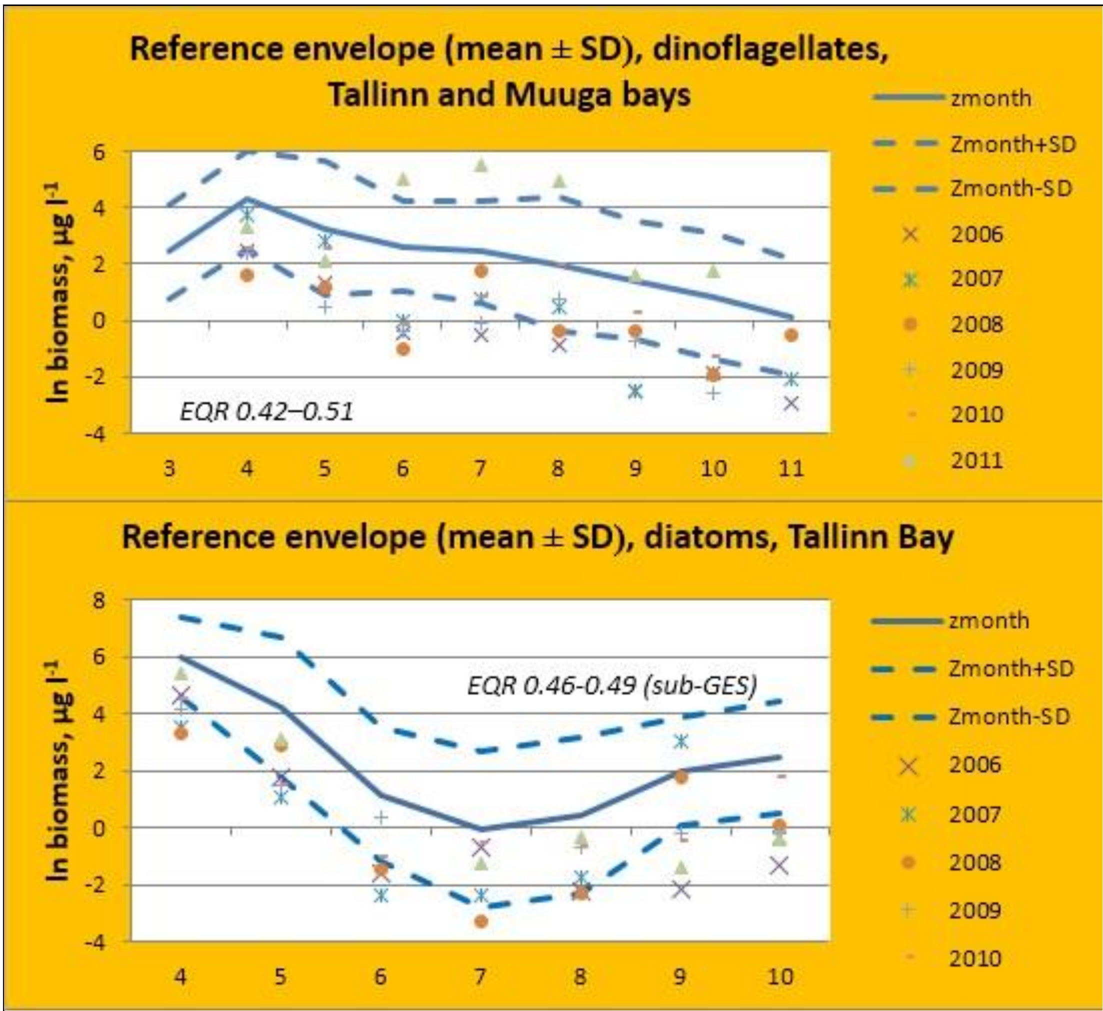

Examples of reference growth curves. Monthly averaged normalized biomass values (Z_{month}), acceptable deviations (Z_{month}±SD) and test values for the period 2006–2011 in the southern Gulf of Finland (Tallinn Bay). Using a 5-year moving average, the number of observations falling inside reference envelope (monthly mean ±SD) is 42–51 % depending on algal group and test period. Applying the GES boundary of 67%, this means that the area does not reach GES.
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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 devel-

	opment.
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

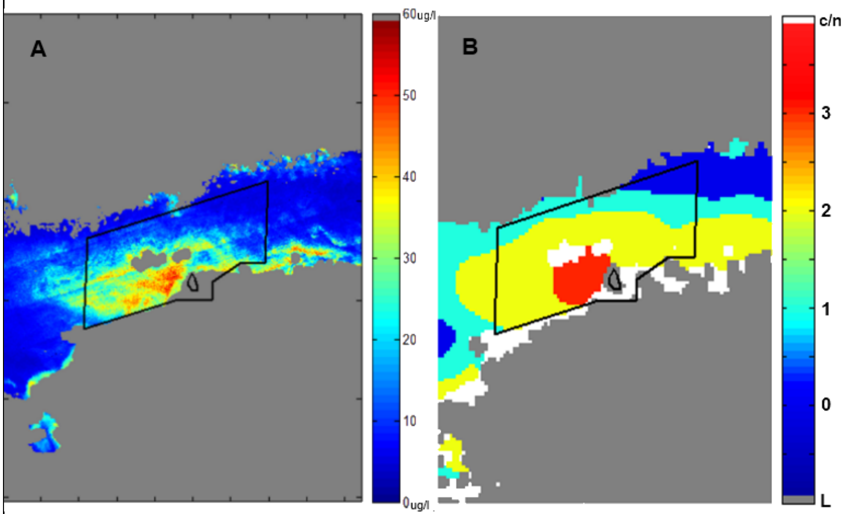

Figure 1. Examples of SYKE’s remote sensing based chlorophyll *a* and surface floating algae accumulation products calculated from the MODIS/Aqua satellite data (NASA) on 19.7.2012.

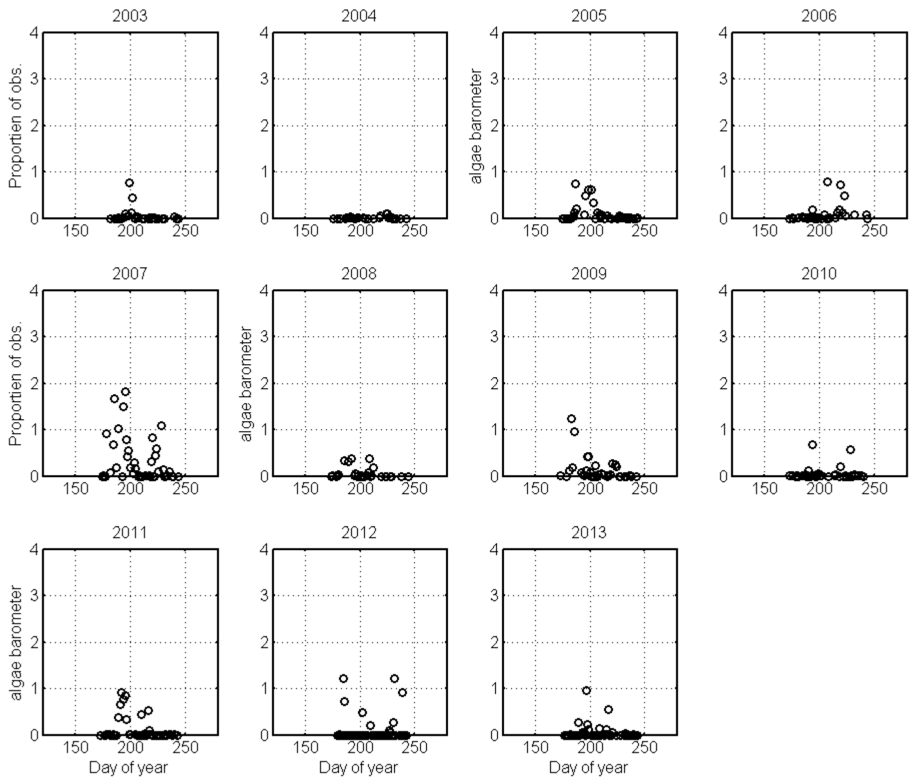

Figure 2. Algae barometer time series for the MARMONI FIN-EST area derived from the daily remote sensing observations.

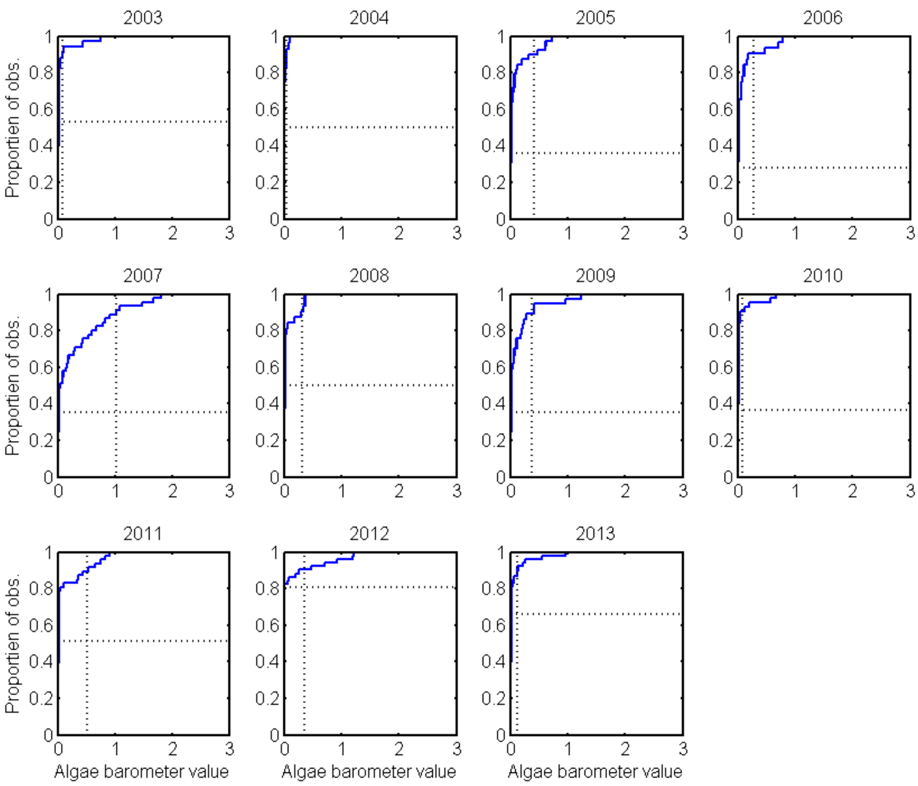

Figure 3. ECDFs derived from the algae barometer values of the years 2003-2013. Horizontal lines indicate the length of the algal surface accumulation periods and vertical lines the 90-percentile of the algae barometer observations. The yearly volumes are derived from the areas above the ECDF function.

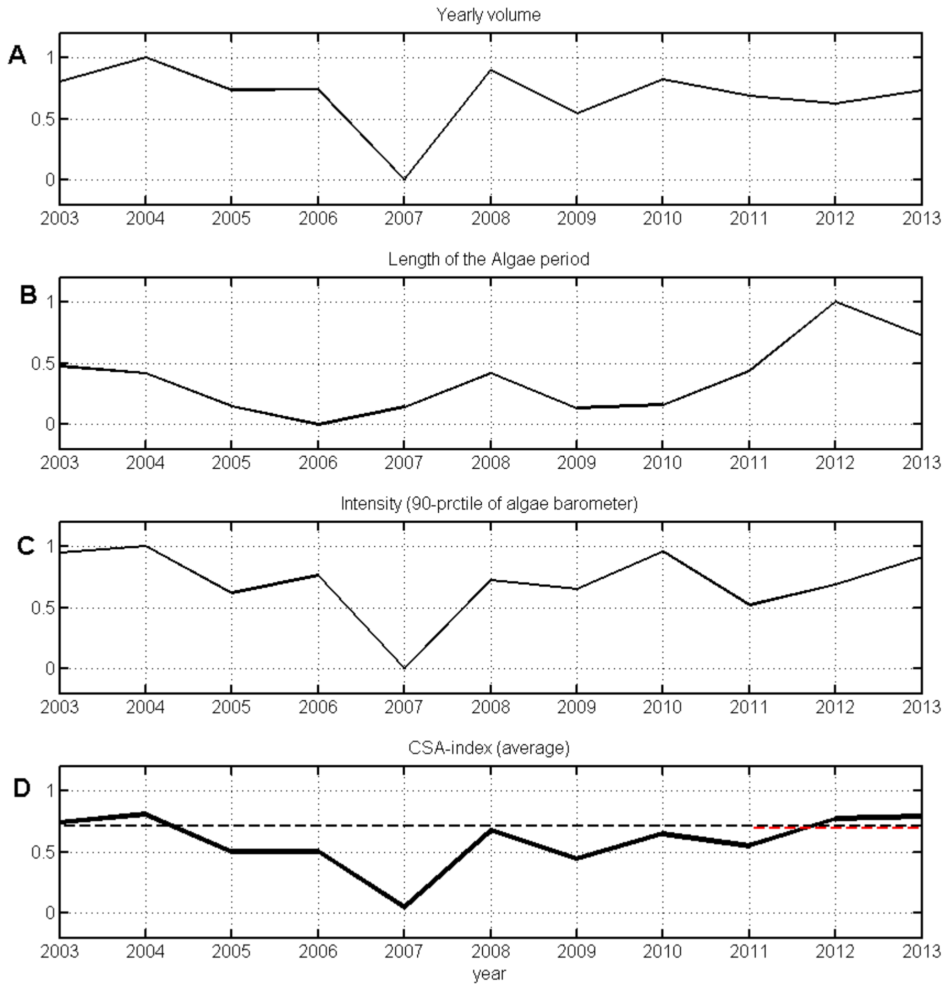

Figure 4. Normalized indicative variable time series derived from the ECDF-functions (A-C) and combined to the CSA-index (D) when only remote sensing data are used. Value 1 represents the best conditions and 0 the worst. Black dashed horizontal line in (D) indicates the target condition and red the current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

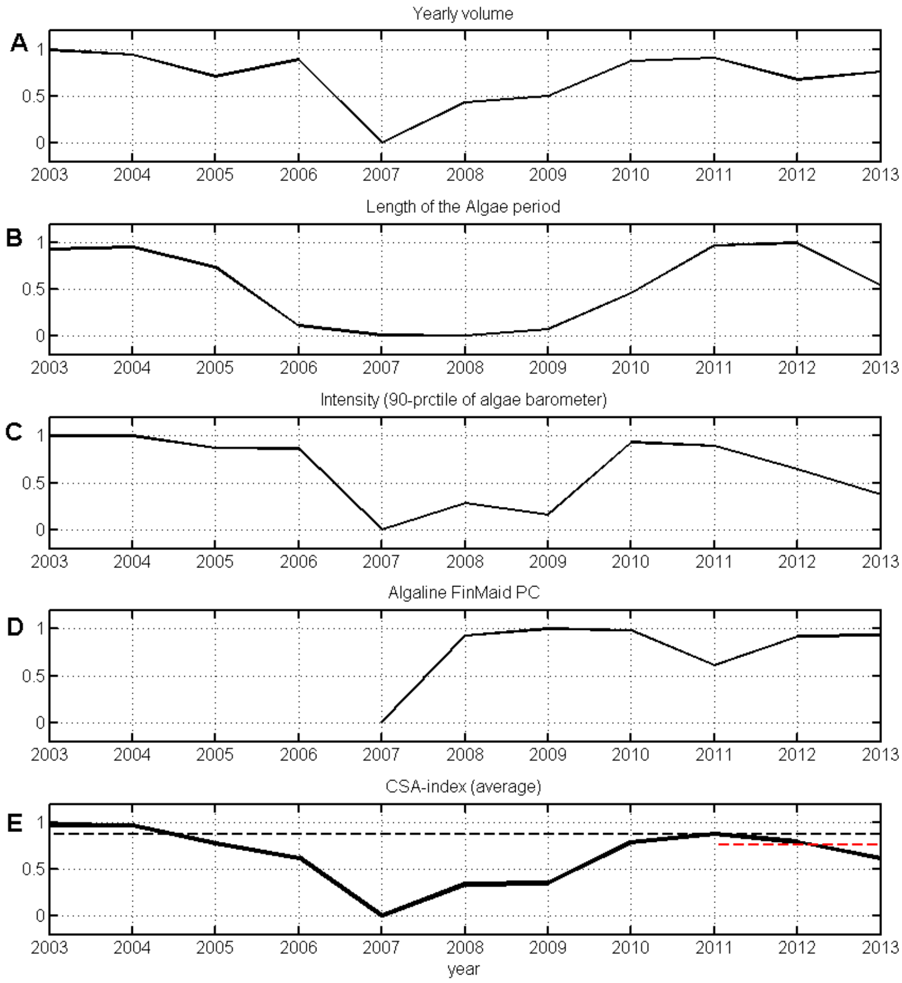

Figure 5. Normalized indicative variable time series derived from the ECDF-functions (A-C), normalized Alg@line yearly phycocyanin observations (D) and combined CSA-index (E). Value 1 represents the best conditions and 0 the worst. Black dashed horizontal line in (E) indicates the target condition and 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.

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

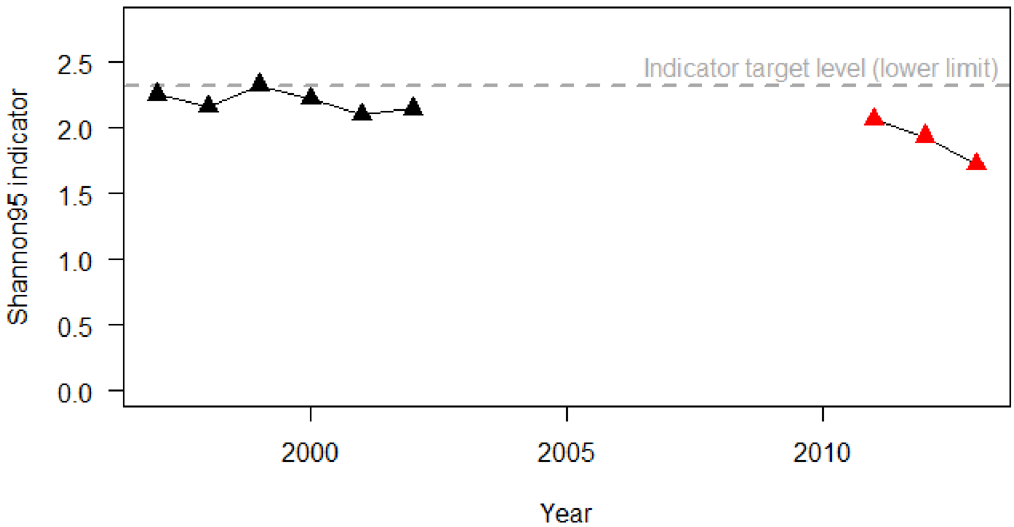


Figure 1. The annual summertime phytoplankton taxonomic diversity (Shannon95) indicator values in 1997–2002 (black triangles) and during the status period 2011–2013 (red triangles) in the central Gulf of Finland, on the Helsinki–Tallinn ship-of-opportunity transect. Note that the sampling stations used 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.

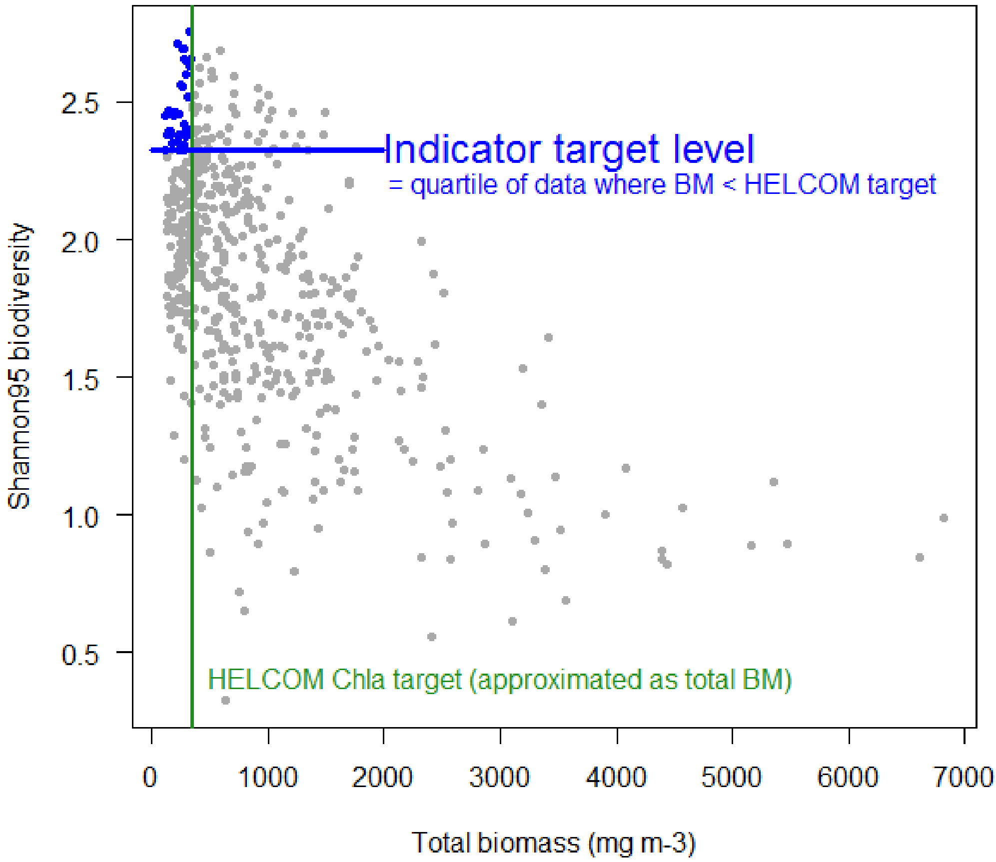


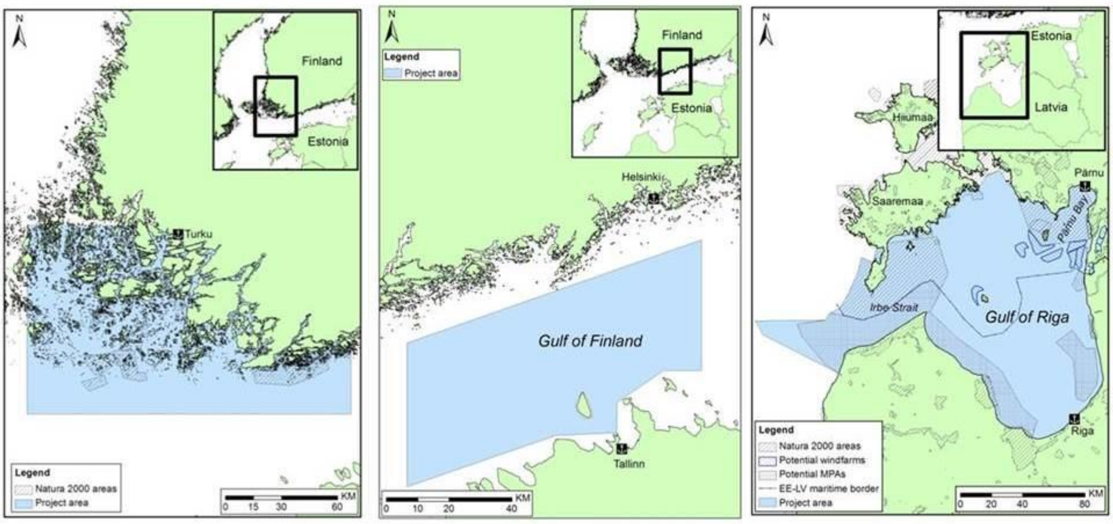
Figure 2. Shannon95 diversity plotted against total biomass (mg m^{-3}) in the central Gulf of Finland on the Helsinki–Tallinn ship-of-opportunity transect (described in Uusitalo *et al.* 2013). The green line indicates the biomass at the HELCOM phytoplankton (i.e. chlorophyll *a*) target level, converted 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.

Name of indicator	**3.5 Phytoplankton trait- and dendrogram based functional diversity index (FD)**
Type of Indicator	State indicator
Author(s)	Sirpa Lehtinen and Riina Klais
Description of the indicator	The indicator aims to describe the trait-based functional diversity of phytoplankton with a functional diversity index (FD), which is calculated based on the dendrogram method (Mouchet *et al*. 2008). The 11 functional traits considered here, including for example traits like motility and ability to fix nitrogen, are described in Klais *et al*. (in prep.). Within the framework of the MARMONI project, we tested the usability of this trait- and dendrogram-based index as a biodiversity indicator. This is not the only way to calculate a phytoplankton functional diversity index (see e.g. Mouchet *et al*. 2010), and there are also different possibilities to select traits. At present, the index is not ready to be utilized as an indicator. In order to get comparable FD index results, the microscopy methods and the level (accuracy) of species identification must be the same in all samples. To obtain a trait-based functional diversity index which could be used as a simple biodiversity indicator, further studies are needed to determine (1) which trait composition is the most useful for describing phytoplankton functional diversity, (2) which method is the most useful to calculate the functional diversity index, and (3) how functional diversity and various traits relate to different ecological processes.
Relationship of the indicator to marine biodiversity	The trait-based functional diversity index aims to describe the functional diversity of Baltic Sea phytoplankton. The hypothesis is that a more functionally diverse phytoplankton community is more stable and thus more resistant to different pressures. Previously it has been shown that taxonomic diversity predicts stability in natural phytoplankton communities (Ptacnik *et al*. 2008). The index was tested with natural phytoplankton community data from two stations (Seili and Längden, located in the coastal area of south-western Finland in the MARMONI FIN area) and by re-analysing an existing experimental data set (from six mesocosm experiments, performed also in the MARMONI FIN area). The aim of the testing was to obtain a target value above which FD would indicate a relatively stable phytoplankton community, and below which FD would indicate a relatively unstable community, if exposed to pressures. The re-analysis of the existing experimental data set supported somewhat the hypothesis by indicating stability in FD if the initial FD was high. However, the results from long-term data and re-analysis of experimental data showed non-comparable levels of the FD index. This was probably due to differences in analysing methods and changes in the accuracy of species identification. The conclusion is that the FD index is sensitive to changes relating to microscopy methods and the accuracy of species identification. Long-term data showed an increasing trend in the FD index which was difficult to interpret with current scientific knowledge. It is however worth noting that the observed increase in FD is in line with recent studies showing an increase in the Baltic Sea phytoplankton taxonomic diversity (Olli *et al*. 2014). Olli *et al*. (2014) found that phytoplankton taxonomic diversity has increased in the Baltic Sea, and concluded that this might indicate a long-term change in the species inventory of the Baltic Sea, potentially reflecting a delayed long-term response to the anthropogenic fertilization. We conclude that the tested method of calculating the FD index cannot be taken into use as a phytoplankton biodiversity indicator at the moment, since a complete ecological base study is needed to understand the ecosystem processes connected to phytoplankton functional diversity.
Relevance of the indicator to different policy instruments	MSFD descriptor 1: Biodiversity, 1.7. Ecosystem structure, 1.7.1. Composition and relative proportions of ecosystem components (habitats and species). HELCOM BSAP
Relevance to commission decision criteria and indicator	1.7. Ecosystem structure 1.7.1. Composition and relative proportions of ecosystem components (habitats and species)

Method(s) for obtaining indicator values	The functional diversity of a phytoplankton sample is calculated based on species specific microscopy results and a table, where each taxon is categorized based on the functional traits that it possesses. The microscopy results are obtained by quantitative analysis of conventional monitoring samples. A detailed phytoplankton species composition analysis requires good species identification skills. In order to get comparable FD index results, the microscopy methods and the accuracy of species identification must be the same in the whole investigated data set. For this functional diversity index, functional diversity is determined by using a clustering dendrogram method (Mouchet *et al.* 2008, Mouchet *et al*. 2010, Litchman *et al*. 2010).
Documentation of relationship between indicator and pressure	The index was tested as an ecosystem structure indicator, and thus the aim was not to find relationships between the index and pressures. Instead, the aim was to find a target value to indicate stability of the community when it is exposed to pressures. The relationship between phytoplankton community diversity and stability has been shown earlier by e.g. Ptacnik *et al*. (2008).
Geographical relevance of indicator	2. Regional
How Reference Conditions (target values/thresholds) for the indicator were obtained?	Long-term and experimental data were used in an attempt to obtain reference conditions and target values/thresholds. Based on this data and due to gaps in the current scientific knowledge it was not possible to obtain reference conditions and target values or thresholds.
Method for determining GES	A target value (lower limit) to indicate stability of the community when it is expressed to pressures (Ptacnik *et al*. 2008) was sought. Based on testing performed using long-term data and experimental data, we conclude that currently a target level for this index cannot be defined. In the future projects, further studies will be undertaken to determine which trait composition is the most useful for describing phytoplankton functional diversity, which method is the most useful to calculate the functional diversity index, and how functional diversity and various traits are connected to different ecological processes.
References	Klais, R., Lehtinen, S., Olli, K., Trikk, O., Tamminen, T. (In prep.). Functional diversity of Baltic Sea phytoplankton. Litchman, E., de Tezanos Pinto, P., Klausmeier, C.A., Thomas, M.K., Yoshiyama, K. (2010). Linking traits to species diversity and community structure in phytoplankton. Hydrobiologia 653: 15-28. Mouchet, M., Guilhaumon, F. Villéger, S., Mason, N.W.H. Tomasini, J.-A., Mouillot, D. (2008). Towards a consensus for calculating dendrogram-based functional diversity indices. Oikos 117: 794-800. Mouchet, M., Villéger, S., Mason, N.W.H., Mouillot, D. (2010). Functional diversity measures: an overview of their redundancy and their ability to discriminate community assembly rules. Functional Ecology 24: 867-876. Olli, K., Ptacnik, R, Andersen, T., Trikk, O., Klais, R., Lehtinen, S. & Tamminen, T. (2014). Against the tide: Recent diversity increase enhances resource use in coastal ecosystems. Limnol. Oceanogr. 59 (1): 267-274. Ptacnik, R. Solimini, A.G., Andersen, T., Tamminen, T., Brettum, P., Lepistö, L., Willén, E., Rekolainen, S. (2008). Diversity predicts stability and resource use efficiency in natural phytoplankton communities. PNAS vol. 15, no. 13: 5134-5136.

Name of indicator	**3.6 Spring bloom intensity index**
Type of Indicator	State indicator
Author(s)	Jenni Attila, Sofia Junttila, Saku Anttila and Vivi Fleming-Lehtinen
Description of the indicator	The indicator estimates the annual total biomass of the phytoplankton spring bloom. Spring is a period of extensive and rapid phytoplankton growth, during which the main part of the annual phytoplankton production occurs. Quantifying the spring bloom intensity, or the total biomass developed during a spring bloom, is not possible using monitoring station measurements, which do not produce data at a sufficiently high spatial or temporal frequency. This spring bloom intensity index -indicator is developed based on the method developed for Alg@line FerryBox data in Fleming and Kaitala (2006) and also for remote sensing data by Platt and Sathyendranath (2008) and Platt *et al.* (2008). The spring bloom intensity is estimated by combining remote sensing and ship-of-opportunity data in order to obtain maximum spatial and temporal coverage. The indicator is demonstrated for the MARMONI 3FIN, 4FIN-ESTand 1EST-LAT areas shown in Figure 1. In principle, the method is applicable to all Baltic Sea sub-basins. Nevertheless, it is recommended that the method is first validated against adequate *in situ* chlorophyll *a* measurements when the method is applied to a new sub-basin or water body.
Relationship of the indicator to marine biodiversity	The phytoplankton spring bloom provides a source of energy to the zooplankton community during its growth phase (Lignell *et al*. 1993). The annual peak of zooplankton biomass follows the peak of the spring bloom (Lignell *et al*. 1993), which thus indirectly affects the early development of communities at higher trophic levels as well (Platt *et al*. 2003). Despite grazing by zooplankton, most of the spring algal biomass eventually settles to the bottom (Lignell *et al*. 1993), thus potentially increasing oxygen depletion in stratified areas. However, since the spring bloom forms the major carbon flux to the bottom, it also provides the main annual input of food to the benthic communities (Kuparinen *et al.* 1984, Tallberg & Heiskanen 1998).
Relevance of the indicator to different policy instruments	Marine Strategy Framework Directive (MSFD) descriptors 1, 4, 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 spring bloom intensity index of Fleming and Kaitala (2006) was further developed using both ship-of-opportunity and remote sensing chlorophyll *a* data in order to produce an estimate of the total areal algal biomass produced during the spring bloom. From this data, we first defined parameters such as the initiation, amplitude, timing and duration of the spring bloom (Figure 2), based on frequent and spatially comprehensive remote sensing chlorophyll *a* measurements. This information was used to derive the spring bloom index. The remote sensing, or Earth Observation (EO), instrument used in the development of the indicator was MERIS (MEdium Resolution Imaging Spectrometer). For the method development, we used MERIS data archives consisting of years 2003-2011. The dataset was processed and is archived at the Finnish Environment Institute (SYKE). Chlorophyll *a* concentrations are derived from MERIS observations, i.e. from the measured reflectances, using a neural network-based bio-optical processor (FUB) developed at the Free University of Berlin (Schroeder *et al*. 2007a-b). The FUB processor performs atmospheric correction and solves chlorophyll *a* concentrations from the MERIS measurements. The preprocessing of the data consisted of rectification and cloud masking of the individual images. For the method development, the daily images were further combined to weekly composites. Figure 3 shows two examples of weekly composites for the assessment area 4FIN-EST in the Gulf of Finland. Each year, the dataset covered the period April-October (typically weeks between 13 and 44). In principle, spring bloom indicator does not require data after the summer minimum is reached, but data is available in time series (Figure 3) for other purposes, such as detecting cyanobacteria period during July-August. The developed indicator is directly applicable using other instruments, such as the forthcoming OLCI (Ocean and Land Colour Instrument), which after its launch in 2015 onboard the Sentinel 3A satellite will be the most prominent satellite instrument for detecting Baltic Sea water quality. While

	Sentinel 3 is not yet on mission, the gap-filling years between the optimal instruments MERIS and OLCI can be substituted with MODIS and VIIRS data. These instruments provide a chlorophyll *a* estimate with a more modest ground resolution. The method was developed using nine years of MERIS data. The available data showed that although satellite information is spatially and temporally very representative, clouds may hamper the accurate detection of the initiation of the spring bloom, as it this period tends to be cloudy. Thus, complementing data is often necessity for determining the start week of the spring bloom. For this purpose, Alg@line FerryBox data was applied. The Alg@line FerryBox system collects water quality data with automated equipment onboard eight merchant ships traversing the Baltic Sea. Water quality data, among them chlorophyll *a*, are recorded with a spatial resolution of 200 m. The system includes a sequence water sampler collecting up to 24 water samples along the ship route. Time series of weekly mean chlorophyll *a* concentrations were calculated from MERIS and Alg@line data (Figure 4 and Figure 5). The spring bloom intensity index calculated from MERIS and Alg@line data were combined to form one time series for each assessment area (see assessment areas in Figure 1). The limit for the spring bloom period chlorophyll *a* concentrations was set at 5 µg/l (Figure 4A) (Fleming and Kaitala 2006). The intensity index was calculated by a time-intensity integral for the weeks where weekly average exceeded the limit value. Figure 6 presents the intensity index for the assessment area 4FIN-EST using Alg@line data for the years 1992-2008 and MERIS data for the period 2003-2011. The trend line for the same assessment area is presented in Figure 6. The other characteristics (amplitude, initiation, duration, and timing of maximum) were also determined from time series of weekly mean chlorophyll *a* concentrations. Table 1 gives examples of these statistics calculated for each assessment area.
Documentation of relationship between indicator and pressure	The indicator reacts primarily to pressures such as changes in nutrient composition, hydrography and climate change. The start of the phytoplankton bloom is initiated by increase in light availability in the euphotic zone and the development of vertical stratification after the winter (Svedrup 1952). The course of the bloom is determined by nutrient availability in the upper water column (Lignell *et al*. 1992, Fleming & Kaitala 2006). Loading of nitrogen, phosphorus and silicate are thus identified as the main pressures of the indicator. Spring bloom intensity responds positively to pressures.
Geographical relevance of indicator	2. Regional
How Reference Conditions (target values/thresholds) for the indicator were obtained?	The target is trend-based, assuming that the spring bloom intensity index shows neither a decrease nor an increase from the level defined from Alga@line measurements during 1992-2008. The target level was derived using the time series of the spring bloom intensity index (Fleming and Kaitala 2006). Figure 6 presents the spring bloom intensity index and the trend line derived using Alg@line measurements for years 1992-2008 and using MERIS data for years 2003-2011 for the assessment area 4FIN-EST. The trend line implies changes in spring bloom intensity level that can be utilized to define the amount of biomass. If the trend is increasing, it means that the intensity of spring bloom (i.e. biomass) increases. If the trend is decreasing, the spring bloom intensity decreases.
Method for determining GES	GES is determined quantitatively using the target approach. The indicator is applicable for all areas where the spring bloom occurs in such intensity that it has importance for annual phytoplankton succession, zooplankton community and where it forms relevant carbon flux to the bottom. The method can be applied both in local and regional scale as well as on national waters, i.e. for example for each coastal water body (relevant for WFD reporting for example). At present, it has been tested for northern parts of the Baltic Sea.
References	Fleming, V, Kaitala S, 2006. Phytoplankton spring bloom intensity index for the Baltic Sea estimated for the years 1992 to 2004. Hydrobiologia 554:57-65. Klemas, V, 2012. Remote Sensing of Algal Blooms: An Overview with Case Studies. J.Coast.Res. 34-43. Kuparinen, J, Leppänen, J-M, Sarvala, J, Sundberg, A, Virtanen, A, 1984. Production and utilization of organic matter in a Baltic ecosystem off Tvärminne, southwest coast of Finland. – Rapp. P.-V. Reun. Cons. Int. Explor. Mar. 183:180–192. Lignell, R, Kaitala, S, Kuosa, H 1992. Factors controlling phyto- and bacterioplankton in late spring on a salinity gradient in the northern Baltic. Marine Ecology Progress Series 84:121-131. Lignell, R, Heiskanen, A-S, Kuosa, H, Gundersen, K, Kuuppo-Leinikki, P, Pajuniemi, R, Uitto,

	A, 1993. Fate of a phytoplankton spring bloom: sedimentation and carbon flow in the planktonic food web in the northern Baltic. Marine Ecology Progress Series 94:239-252. Platt T, Sathyendranath S, 2008. Ecological indicators for the pelagic zone of the ocean from remote sensing, Remote Sensing of Environment 112:3426–3436. Platt, T, Fuentes-Yaco, C and Frank, KT, 2003. Marine ecology: Spring algal bloom and larval fish survival. Nature 423:398-399. Platt T, Sathyendranath S, Forget M-H, White 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, TH, Schaale, M, Fisher, 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: 5627-5630. Schroeder, TH, Behnert, I, Schaale, M, Fisher, J, Doerffer, R, 2007. Atmospheric correction for MERIS above Case-2 waters. International Journal of Remote Sensing, 28, pp. 1469–1486. Svedrup, H U, 1952. On conditions for the vernal blooming of phytoplankton. Journal du Conseil 18: 287–295. Tallberg, P, Heiskanen, A-S 1998. Species-specific phytoplankton sedimentation in relation to primary production along an inshore-offshore gradient in the Baltic Sea. - J. Plankton Res.20:2053-2070.
Illustrative material for indicator documentation	 Figure 1. MARMONI areas for method development: 3FIN Coastal area of SW Finland (left), 4FIN-EST Gulf of Finland (middle) and 1EST-LAT Gulf of Riga (right).

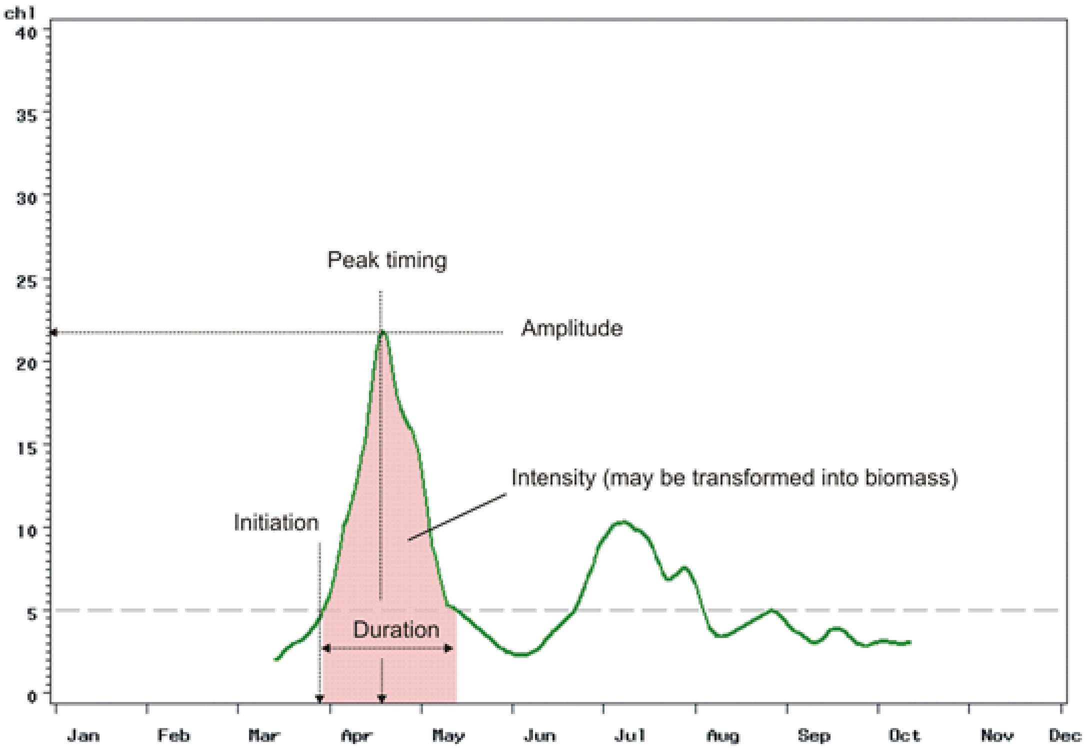


Figure 2. The properties of the spring phytoplankton bloom in the western Gulf of Finland in 2009, characterized from a time series of chlorophyll concentration. The characteristics that can be determined are amplitude, initiation, timing of maximum and duration.

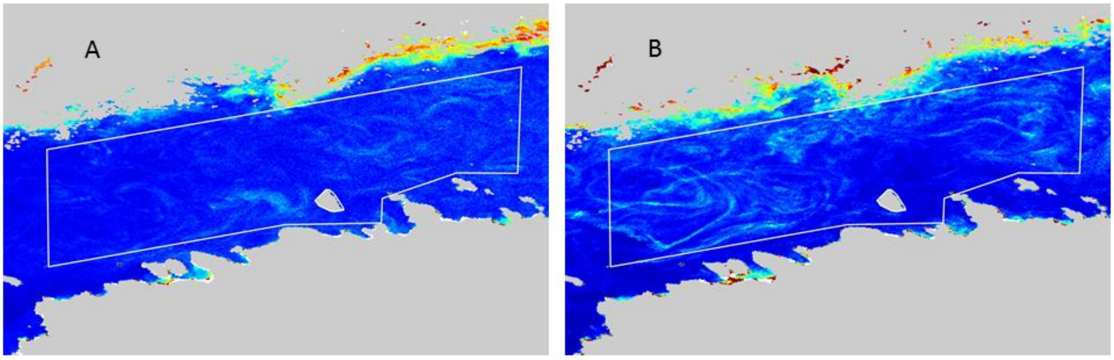


Figure 3. Two examples of EO interpretation of weekly chlorophyll *a* mean concentration [µg/l] during spring bloom 2005 in the MARMONI project area 4FIN-EST Gulf of Finland, A) week 17 (25.4.-1.5.) and B) week 18 (2.-8.5.).

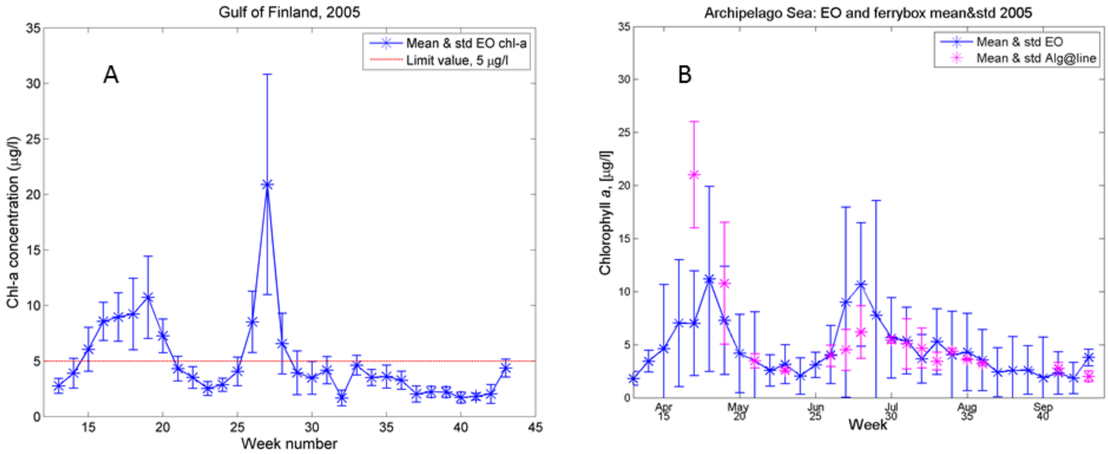
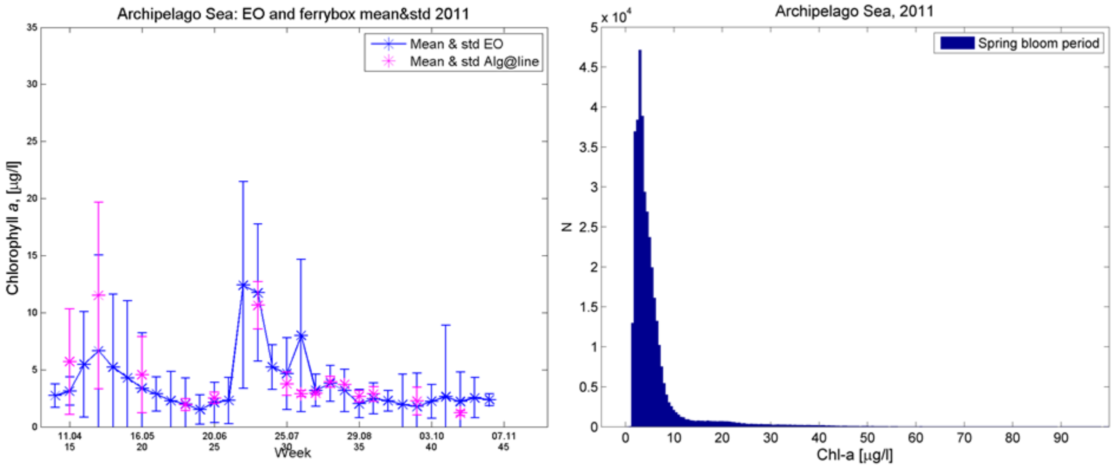
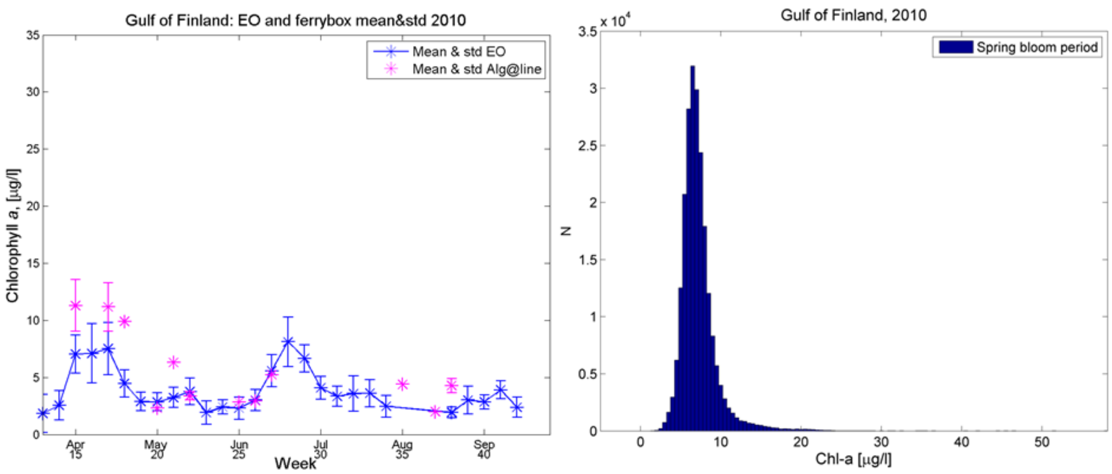


Figure 4. A) Time series of mean chlorophyll *a* concentrations and standard deviations derived from remote sensing data (EO, blue lines and bars). The red line indicates the spring bloom limit value, 5µg/l. This example is from the MARMONI project area 4FIN-EST Gulf of Finland in 2005. B) Similar time series using remote sensing data (blue lines and bars) and Alg@line FerryBox data (purple stars and bars). This example is from the MARMONI project area 3FIN Coastal area of SW Finland in 2005.



A



B

Figure 5. A) Left: Time series using remote sensing data (EO, blue lines and bars) and Alg@line FerryBox data (purple stars and bars) from the MARMONI project area 3FIN Coastal area of SW Finland in 2011. Right: Histogram describing the distribution of chlorophyll *a* concentrations during the spring bloom period. B) Left: Time series using remote sensing data (blue lines and bars) and Alg@line FerryBox data (purple stars and bars) from the MARMONI project area 4FIN-EST Gulf of Finland in 2010. Right: Histogram describing the distribution of chlorophyll *a* concentrations during the spring bloom period.

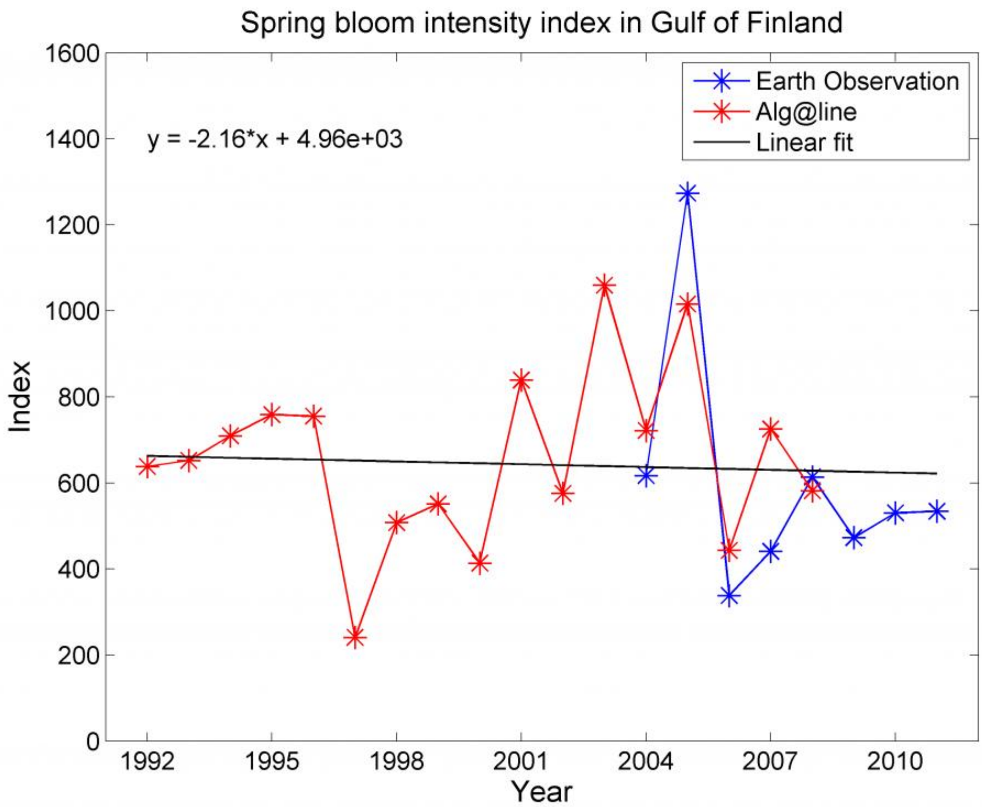


Figure 6. Time series of spring bloom intensity index in the project area 4FIN-EST Gulf of Finland. Blue stars and lines represent remote sensing data and red stars and lines Alg@line Ferry Box data. Black line is the linear fit for the data.

Table 1. The statistics describing the spring bloom: the mean chlorophyll *a* concentration during the spring bloom, maximum concentration (peak maximum in table, amplitude), length of the spring bloom in days and weeks (duration), the start (initiation) and end week for all the studied areas 3FIN Coastal area of SW Finland (Archipelago Sea), 4FIN-EST Gulf of Finland and 1EST-LAT Gulf of Riga for the years 2009-2011.

Sea area	Year	Intensity index	Mean(ug/l)	Peak (ug/l)	Peak wk	Peak's maximum (ug/l)	Length (days)	Length (wk)	Start (wk)	End (wk)
Archipelago Sea	2009	82,41	5,89	6,02	17	92,99	14	2	16	17
	2010	168,90	6,03	6,56	16	99,70	28	4	15	18
	2011	121,29	5,78	6,64	17	99,90	21	3	16	18
Gulf of Finland	2009	135,09	6,43	7,55	16	82,65	21	3	16	18
	2010	151,54	7,22	7,52	17	58,16	21	3	15	17
	2011	152,60	7,27	7,74	16	88,76	21	3	16	18
Gulf of Riga	2009	607,73	10,85	15,20	16	61,28	56	8	15	22
	2010	576,02	10,29	19,37	17	65,02	56	8	15	22
	2011	783,24	13,99	20,76	17	99,48	56	8	14	22

Name of indicator	**3.7 Copepod biomass**
Type of Indicator	State indicator
Author(s)	Elena Gorokhova, Maiju Lehtiniemi, Solvita Strake, Jurate Lesutiene, Natalja Demereckiene and Laura Uusitalo
Description of the indicator	The indicator is based on the idea that zooplankton with a high mean size, i.e. copepods, would indicate good feeding conditions for zooplanktivorous fish as well as a high potential grazing on phytoplankton (e.g. Cardinale *et al*.2002, Rönkkönen *et al*.2004). The data for the indicator is obtained through routine zooplankton monitoring programs carried out in several Baltic Sea countries. Annual (once a year) sampling provides sufficient data for the calculation of the indicator, but a higher sampling frequency would probably be better due to decreasing the variation in the data. The minimum requirement for the taxonomic resolution in the sample analysis is to group level, meaning that copepods have to be counted as their own group. The indicator has a solid scientific basis and it addresses the importance of zooplankton as the mediator of energy from primary producers to fish. This indicator presents the status of the part of the zooplankton community i.e. copepods, which is the most important for maintaining good growth conditions for pelagic fish stocks. The indicator 'mean size vs. total stock' has partly the same function indicating good feeding conditions for zooplanktivorous fish although it does not separate between large sized cladocerans and copepods as the present indicator does.
Relationship of the indicator to marine biodiversity	The indicator reflects changes in the zooplankton community. These changes are indirectly related to changes in nutrient composition and directly related to fish communities, climate and phytoplankton community composition, and have direct impact on both phytoplankton communities and fish growth. The zooplankton community, and its dominant members the copepods, have a crucial role in the pelagic food web dynamics in transferring energy from primary producers to a form utilizable by fish. Zooplankton is affected by changes in primary production, indicative of eutrophication, and by changes in the structure and abundance of the fish community, indicative of overfishing (e.g. Adrian *et al*. 1999, Yan *et al*. 2008). Therefore, zooplankton lives between top-down and bottom-up dynamics, and can potentially yield a lot of information on the state and dynamics of the aquatic ecosystem (Jeppesen *et al*. 2011). Copepods are selective feeders. Thus the copepods species composition affects directly both the phytoplankton and zooplankton species composition and have a potential to affect the biodiversity in these communities.
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 (HELCOM 2013). Marine Strategy Framework Directive (MSFD) descriptors 1 Biodiversity, 4 Food web. HELCOM Baltic Sea Action Plan (BSAP) Ecological Objective: Viable population of species, Target: By 2021 all elements of the marine food webs, to the extent that they are known, occur at natural and robust abundance and diversity.
Relevance to commission decision criteria and indicator	1.2. Population size 1.2.1. Population abundance and/or biomass 1.6. Habitat condition 1.6.2. Relative abundance and/or biomass, as appropriate
Method(s) for obtaining indicator values	The indicator is based on zooplankton data obtained from routine zooplankton sampling (e.g. HELCOM COMBINE; HELCOM 1988). Copepod abundance is determined by light microscopy, either by traditional "manual" counting, or by an automatic image analysis method using a scanner and suitable software. Copepod biomass can then be estimated based on length measurements of individuals (automatic image analysis does this), or by using species and stages specific pre-established weight values (if sample analysis is done with 'manual' counting by a microscope).
Documentation of relationship between indicator and pressure	Zooplankton biomass correlates positively with phytoplankton biomass and hence with eutrophication; in particular, small-bodied, filter-feeding (microphagous) zooplankters increase with increasing eutrophication (Gliwicz 1969, Pace 1986, Hsieh *et al*. 2011). On the other hand, the large-bodied zooplankters, especially copepods, constitute the best-quality food items for the zooplanktivorous fish (e.g. Cardinale *et al*. 2002, Rönkkönen *et al.* 2004). Rönkkönen *et al.* (2004) reported that in the Gulf of Finland, herring growth correlates positively with the abundance of the marine copepod species *Pseudocalanus minutus elongatus*.
Geographical relevance of indicator	4. Baltic Sea wide

How Reference Conditions (target values/thresholds) for the indicator were obtained?	Good Environmental Status is based on a reference period within existing time series that defines a reference state when the food web structure represented good fish feeding conditions. The reference period for the copepod indicator was selected when growth of zooplanktivorous fish (weight-at-age, WAA) and its population size were relatively high. Recently, Ljunggren et al. (2010) demonstrated that WAA could be used as a proxy for zooplankton food availability and related fish feeding conditions to fish recruitment in coastal areas of the northern and central Baltic Sea. GES boundaries are set region-specifically (e.g. Gulf of Finland, Gulf of Riga, Gulf of Bothnia etc.).
Method for determining GES	GES is met when – there is a high proportion of copepods, that efficiently graze on phytoplankton and provide good-quality food for zooplanktivorous fish, and – the abundance of zooplankton is at the level adequate to support fish growth and exert control over phytoplankton production. GES is determined for the copepod biomass in the zooplankton community. GES-boundary (lower limit) for the open Gulf of Finland (MARMONI 4FIN-EST area) is >70 mg/m^3. The status for the assessment period 2010-2012 for this area is in GES, indicator value is 160.8 mg/ m^3. The reference periods considered where 1979-1987.
References	Adrian, R., Hansson, S., Sandin, B., DeStasio, B., Larsson, U. (1999) Effects of food availability and predation on a marine zooplankton community—a study on copepods in the Baltic Sea. Int Rev Hydrobiol 84:609–626 Cardinale M., Casini M., Arrhenius F. (2002) The influence of biotic and abiotic factors on the growth of sprat (*Sprattus sprattus*) in the Baltic Sea. Aquat. Liv. Res.: 273-281. Gliwicz, Z.M. (1969) Studies on the feeding of pelagic zooplankton in lakes with varying trophy. Ekol. Pol., 17, 663–708. HELCOM (1988) Guidelines for the Baltic monitoring programme for the third stage. Part D. Biological determinants. Baltic Sea Environment Proceedings 27D: 1-161. HELCOM (2013). MSTS indicator description sheet. Downloadable from HELCOM web site:http://meeting.helcom.fi/c/document_library/get_file?p_l_id=80219&folderId=2289395&name=DLFE-54128.docx Hsieh CH, *et al*. (2011) Eutrophication and warming effects on long-term variation of zooplankton in Lake Biwa. Biogeosciences 8: 593-629. Jeppesen E, *et a.l* (2011) Zooplankton as indicators in lakes: a scientific-based plea for including zooplankton in the ecological quality assessment of lakes according to the European Water Framework Directive (WFD). Hydrobiologia 676: 279-297. Ljunggren, L., Sandström, A., Bergström, U., Mattila, J., Lappalainen, A., Johansson, G., Sundblad, G., Casini, M., Kaljuste, O., and Eriksson, B. K. (2010). Recruitment failure of coastal predatory fish in the Baltic Sea coincident with an offshore ecosystem regime shift. ICES Journal of Marine Science, 67: 1587-1595. Pace, M.L. (1986). An empirical analysis of zooplankton community size structure across lake trophic gradients. Limnol. Oceanogr. 31: 45-55. Rönkkönen, S., Ojaveer, E., Raid T., Viitasalo, M. (2004) Long-term changes in Baltic herring (*Clupea harengus membras*) growth in the Gulf of Finland. Canadian Journal of Fisheries and Aquatic Sciences 61: 219-229. Yan ND, *et al*. (2008) Long-term trends in zooplankton of Dorset, Ontario, lakes: the probable interactive effects of changes in pH, total phosphorus, dissolved organic carbon, and predators. Can. J. Fish. Aquat. Sci. 65: 862-877.

Name of indicator	**3.8 Zooplankton diversity**
Type of Indicator	State indicator
Author(s)	Laura Uusitalo and Maiju Lehtiniemi
Description of the indicator	The indicator aims to describe the species diversity of zooplankton in the Baltic Sea by applying Shannon's diversity index (Shannon 1948). The index was calculated from routine zooplankton monitoring data for each year (1979-2008) and sub-basin around Finland (Gulf of Finland, Bothnian Sea, Bothnian Bay) including the MARMONI study area 4FIN-EST in the Gulf of Finland. Within the framework of the MARMONI project, we tested the usability of this diversity index as a biodiversity indicator. At present, the index is not ready to be utilized as an indicator. To obtain a species diversity index which could be used as a simple biodiversity indicator, further studies are needed to determine how species diversity is related to ecological processes and pressures.
Relationship of the indicator to marine biodiversity	The Shannon index provides information about the rarity and commonness of species in a community. The ability to quantify diversity in this way would be an important tool to describe zooplankton community structure. The index was tested with natural zooplankton community data from routine monitoring, collected from the northern Baltic Sea, including also the MARMONI 4FIN-EST area. The aim of the testing was to see how well the index relates to ecological processes and pressures. However, the results from our testing showed no relationship between Shannon index values, changes in the long-term data, and pressures. We conclude that the tested method, Shannon's diversity index, cannot be taken into use as a zooplankton biodiversity indicator at the moment.
Relevance of the indicator to different policy instruments	Marine Strategy Framework Directive (MSFD) descriptor 1 Biodiversity, 1.6 Habitat condition, 1.6.1. Condition of the typical species and communities. HELCOM Baltic Sea Action Plan
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	The indicator is based on zooplankton data obtained from routine zooplankton sampling (e.g. HELCOM COMBINE; HELCOM 1988). Individual numbers of species are counted using a microscope and biomass can then be estimated based on length measurements of individuals or by using species and stages specific pre-established weight values. The indicator value is attained by calculating Shannon's diversity index on zooplankton species abundance data. It is important that the zooplankton species composition in the samples is analysed to the highest taxonomic resolution possible (preferably to species(sub-species) level).
Documentation of relationship between indicator and pressure	Taxonomic diversity, as computed by Shannon's index, constitutes of two components: the number of species present in the system, and the evenness of those species. Hence, the biodiversity of zooplankton is expected to decrease in two cases: a) If the number of species decreases, e.g. due to deteriorating environmental conditions so that the most sensitive species do not survive. b) If the evenness of the species decreases, i.e. some species increase in abundance. This can be caused by introduction on invasive species, or if environmental conditions favour some species so that their abundance strongly increases.
Geographical relevance of indicator	4. Baltic Sea wide
How Reference Conditions (target values/thresholds) for the indicator were obtained?	Trend based targets could be used with the target: no decline in zooplankton biodiversity over time. Long-term data were used in an attempt to obtain reference conditions and target values/thresholds. Trends in index values were tested using the Mann-Kendall nonparametric trend test. Based on this data and due to gaps in the current scientific knowledge it was not possible to obtain reference conditions and target values or thresholds.
Method for determining GES	Based on testing performed using long-term data we conclude that currently a target level for this index cannot be defined.

References	HELCOM (1988) Guidelines for the Baltic monitoring programme for the third stage. Part D. Biological determinants. Baltic Sea Environment Proceedings 27D: 1-161. Shannon, C.E. 1948. A mathematical theory of communication. – The Bell System Technical Journal 27:379–423, 623–656.

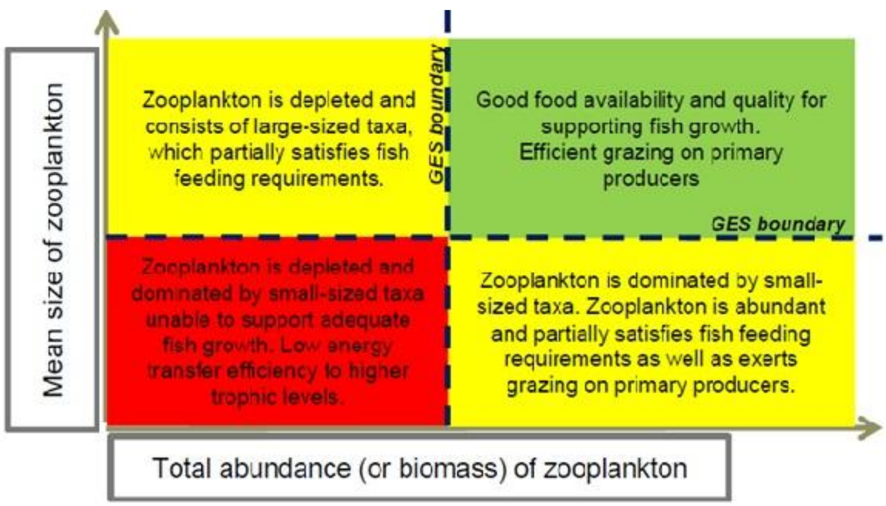
Name of indicator	**3.9 Microphagous mesozooplankton biomass**
Type of Indicator	State indicator
Author(s)	Elena Gorokhova, Maiju Lehtiniemi, Solvita Strake, Jurate Lesutiene, Natalja Demereckiene and Laura Uusitalo
Description of the indicator	The indicator is based on the idea that small-sized herbivorous zooplankton indicate a limitation in the ability of the zooplankton community to transfer energy from primary producers to higher trophic levels (HELCOM 2013, Gorokhova *et al*. in prep.). These small-sized zooplankters, i.e. microphagous mesozooplankton, include rotifers, non-predatory cladocerans, copepod nauplii, rotifers, tintinnids and protozoans. This indicator shows the changes in the zooplankton community structure related to eutrophication and gives a more detailed picture of the change in the species diversity in the zooplankton community compared to mean size vs. total stock indicator. The data for the indicator is obtained through routine zooplankton monitoring programs carried out in several Baltic Sea countries. Annual (once a year) sampling provides sufficient data for the calculation of the indicator, but a higher sampling frequency would probably be better due to decreasing the variation in the data. It is important that the zooplankton species composition in the samples is analysed to the highest taxonomic resolution possible (preferably to species level). The indicator has a solid scientific basis and it addresses the importance of zooplankton as the mediator of energy from primary producers to fish.
Relationship of the indicator to marine biodiversity	The indicator reflects changes in the zooplankton community. These changes are indirectly related to changes in nutrient composition and directly related to climate and phytoplankton community composition, and have direct impact on phytoplankton communities. Zooplankton has a crucial role in the pelagic food web dynamics: it transfers energy from primary producers to a form utilizable by fish. Zooplankton is affected by changes in primary production, indicative of eutrophication, and by changes in the structure and abundance of the fish community, indicative of overfishing (e.g. Adrian *et* al. 1999, Yan *et al*. 2008). Therefore, zooplankton lives between top-down and bottom-up dynamics, and can potentially yield a lot of information on the state and dynamics of the aquatic ecosystem (Jeppesen *et al*. 2011). Small-sized microphagous zooplankton feed mainly on phytoplankton, bacteria and detritus. Many of these organisms can reproduce rapidly due to parthenogenetic reproduction and will in optimal environmental conditions potentially reduce zooplankton biodiversity and evenness of the community. The species composition in the zooplankton community affects directly both the phytoplankton and zooplankton species composition and have a potential to affect the biodiversity in these communities.
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 (HELCOM 2013). Marine Strategy Framework Directive (MSFD) descriptors 1 Biodiversity, 5 Eutrophication. HELCOM Baltic Sea Action Plan (BSAP) Ecological Objective: Viable population of species, Target: By 2021 all elements of the marine food webs, to the extent that they are known, occur at natural and robust abundance and diversity.
Relevance to commission decision criteria and indicator	1.2. Population size 1.2.1. Population abundance and/or biomass 1.6. Habitat condition 1.6.2. Relative abundance and/or biomass, as appropriate
Method(s) for obtaining indicator values	The indicator is based on zooplankton data obtained from routine zooplankton sampling (e.g. HELCOM COMBINE; HELCOM 1988). Individual numbers of species and life stages are counted using a microscope. Microphagous mesozooplankton biomass can then be estimated based on length measurements of individuals, or by using species and stages specific pre-established weight values.
Documentation of relationship between indicator and pressure	Eutrophication favours small-sized, filter-feeding phytoplankton and detritus production, which in turn favours microphagous zooplankton (Gliwicz 1969, Pace 1986, Hsieh *et al*. 2011). Climate change will increase the water temperature which will favour most of the microphagous zooplankters due to rapid parthenogenetic reproduction in optimal conditions (often warm water).
Geographical relevance of indicator	4. Baltic Sea wide

How Reference Conditions (target values/thresholds) for the indicator were obtained?	Good Environmental Status is based on a reference period within existing time series that defines a reference state when the food web structure was not measurably affected by eutrophication. The reference period for the microphagous zooplankton indicator was selected when GES for chlorophyll *a* concentrations and water transparency that have been specifically defined for the sub-basins of the Baltic Sea (HELCOM 2009) are met. GES boundaries are set region-specifically (e.g. Gulf of Finland, Gulf of Riga, Gulf of Bothnia etc.). GES-boundary (upper limit) for the open Gulf of Finland (MARMONI 4FIN-EST area) is < 143 mg/m^3. The status for the assessment period 2010-2012 for this area is GES, indicator value is 14,80 mg/ m^3. The reference periods considered where 1979-1982.
Method for determining GES	The reference period for the microphagous zooplankton biomass reflects a time period when effects of eutrophication are low, defined as 'acceptable' chlorophyll *a* concentration and hence eutrophication-related food web changes are negligible.
References	Adrian, R., Hansson, S., Sandin, B., DeStasio, B., Larsson, U. (1999) Effects of food availability and predation on a marine zooplankton community—a study on copepods in the Baltic Sea. Int Rev Hydrobiol 84:609–626. Gliwicz, Z.M. (1969) Studies on the feeding of pelagic zooplankton in lakes with varying trophy. Ekol. Pol., 17, 663–708. HELCOM (1988) Guidelines for the Baltic monitoring programme for the third stage. Part D. Biological determinants. Baltic Sea Environment Proceedings 27D: 1-161. HELCOM (2013). MSTS indicator description sheet. Downloadable from HELCOM web site:http://meeting.helcom.fi/c/document_library/get_file?p_l_id=80219&folderId=2289395&name=DLFE-54128.docx Hsieh CH, *et al*. (2011) Eutrophication and warming effects on long-term variation of zooplankton in Lake Biwa. Biogeosciences 8: 593-629. Jeppesen E, *et al*. (2011) Zooplankton as indicators in lakes: a scientific-based plea for including zooplankton in the ecological quality assessment of lakes according to the European Water Framework Directive (WFD). Hydrobiologia 676: 279-297. Pace, M.L. 1986. An empirical analysis of zooplankton community size structure across lake trophic gradients. Limnol. Oceanogr. 31: 45-55. Yan ND, *et al*. (2008) Long-term trends in zooplankton of Dorset, Ontario, lakes: the probable interactive effects of changes in pH, total phosphorus, dissolved organic carbon, and predators. Can. J. Fish. Aquat. Sci. 65: 862-877.

Name of indicator	**3.10 Zooplankton mean size vs. total stock (MSTS)**

Type of Indicator	State indicator
Author(s)	Elena Gorokhova, Maiju Lehtiniemi, Jurate Lesutiene, Solvita Strake, Laura Uusitalo, Natalja Demereckiene, Callis Amid
Description of the indicator	The indicator is based on the idea that the mean size of zooplankton and the biomass or abundance, when examined together, provide more information than when the parameters are considered separately. Abundant zooplankton with a high mean size would indicate good feeding conditions for zooplanktivorous fish as well as high potential grazing on phytoplankton; while other combinations (small total stock, or small mean size, or both) would indicate limitations in the ability of the zooplankton community to transfer energy from primary producers to higher trophic levels (HELCOM 2013, Gorokhova *et al*. in prep.). The data for the indicator is obtained through routine zooplankton monitoring programs carried out in several Baltic Sea countries. Annual (once a year) sampling provides sufficient data for the calculation of the indicator, but a higher sampling frequency would probably be better due to decreasing the variation in the data. There is no minimum requirement for the taxonomic resolution in the sample analysis because the only required data is the number of individuals and the size of the individuals. The indicator has a solid scientific basis and it addresses the importance of zooplankton as the mediator of energy from primary producers to fish. However, the inherent noise in zooplankton data presents a challenge in setting the GES boundaries, as well as evaluating the indicator values from year to year.
Relationship of the indicator to marine biodiversity	The indicator reflects changes in the zooplankton community. These changes are indirectly related to changes in nutrient composition and directly related to fish communities, climate and phytoplankton community composition, and have direct impact on both phytoplankton communities and fish growth. Zooplankton has a crucial role in the pelagic food web dynamics: it transfers energy from primary producers to a form utilizable by fish. Zooplankton is affected by changes in primary production, indicative of eutrophication, and by changes in the structure and abundance of the fish community, indicative of overfishing (e.g. Adrian *et al*. 1999, Yan *et al*. 2008). Therefore, zooplankton lives between top-down and bottom-up dynamics, and can potentially yield a lot of information on the state and dynamics of the aquatic ecosystem (Jeppesen *et al*. 2011). Zooplankters are selective feeders. Some species eating solely herbivorously or carnivorously but many of the species are omnivorous utilising both phytoplankton and zooplankton species as prey. The size of zooplankters affects their prey selection. Thus the species composition in the zooplankton community affects directly both the phytoplankton and zooplankton species composition through size-selective feeding and have a potential to affect the biodiversity in these communities.
Relevance of the indicator to different policy instruments	Through collaboration between MARMONI and the HELCOM CORESET project. The indicator has been listed as a Core Indicator in the HELCOM CORESET of Biodiversity indicators (HELCOM 2013. Marine Strategy Framework Directive (MSFD) descriptors 1 Biodiversity, 4 Food webs. HELCOM Baltic Sea Action Plan.
Relevance to commission decision criteria and indicator	1.2. Population size 1.2.1. Population abundance and/or biomass 1.3. Population condition 1.3.1. Population demographic characteristics (e.g. body size or age class structure, sex ratio, fecundity rates, survival/ mortality rates) 1.6. Habitat condition 1.6.1. Condition of the typical species and communities
Method(s) for obtaining indicator values	The indicator is based on zooplankton data obtained from routine zooplankton sampling (e.g. HELCOM COMBINE; HELCOM 1988). The total stock (indicated as either biomass or abundance) means the number of zooplankton individuals. Abundance is determined by light microscopy, either by traditional "manual" counting, or by an automatic image analysis method using a scanner and suitable software. Biomass can be estimated based on length measurements of individuals (automatic image analysis does this), or by using species and stages specific pre-established weight values (if sample analysis is done with 'manual' counting by a microscope). The mean size of the zooplankton community is calculated by dividing the biomass of the whole community by the number of zooplankton individuals. The indicator is based on the combination of these two values (total stock and mean size).
Documentation of relationship between indicator	Zooplankton biomass correlates positively with phytoplankton biomass and hence with eutrophication; in particular, small-bodied, filter-feeding (microphagous) zooplankters increase with increasing eutrophication (Gliwicz 1969, Pace 1986, Hsieh *et al*. 2011). On the other

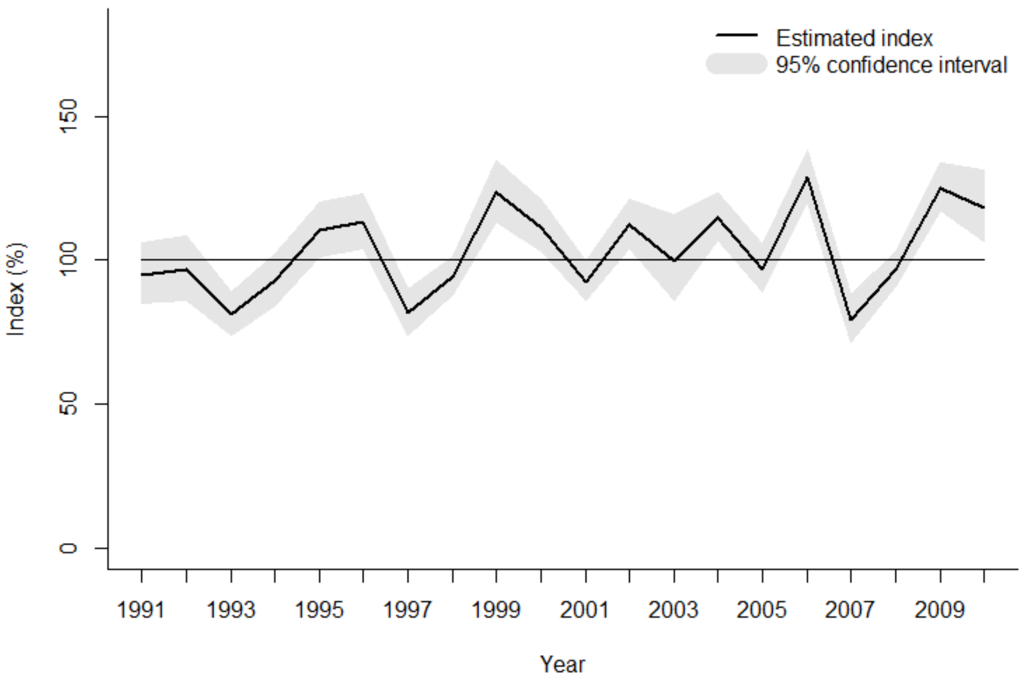
and pressure	hand, the large-bodied zooplankters, especially copepods, constitute the best-quality food items for the zooplanktivorous fish (e.g. Cardinale *et al*. 2002, Rönkkönen *et al*. 2004). Rönkkönen *et al.* (2004) reported that in the Gulf of Finland, herring growth correlates positively with the abundance of the marine zooplankton species *Pseudocalanus minutus elongatus*.
Geographical relevance of indicator	4. Baltic Sea wide
How Reference Conditions (target values/thresholds) for the indicator were obtained?	Good Environmental Status is based on a reference period within existing time series that defines a reference state when the food web structure was not measurably affected by eutrophication and/or representing good fish feeding conditions. The reference period for the zooplankton indicator was selected when 1. GES for chlorophyll *a* concentrations and water transparency, that have been specifically defined for the sub-basins of the Baltic Sea (HELCOM 2009), were in GES, and 2. Growth of zooplanktivorous fish (weight-at-age, WAA) and population size were relatively high. Recently, Ljunggren *et al*. (2010) have demonstrated that WAA could be used as a proxy for zooplankton food availability and related fish feeding conditions to fish recruitment in coastal areas of the northern and central Baltic Sea. GES boundaries are set region-specifically (e.g. Gulf of Finland, Gulf of Riga, Gulf of Bothnia etc.).
Method for determining GES	GES is met when – there is a high contribution of large-sized individuals (mostly copepods) in the zooplankton community that efficiently graze on phytoplankton and provide good-quality food for zooplanktivorous fish, and – the abundance of zooplankton is at the level adequate to support fish growth and exert control over phytoplankton production. GES will be determined for two parameters: the zooplankter mean size and the total abundance or biomass of the zooplankton community (Fig. 1). - The reference period for the mean size: the GES boundary is at lower 95% CI of the mean during a time period when zooplankton is adequate to support high growth of zooplanktivorous fish (measured as weight at age [WAA] and high stock size). The high WAA values in combination with relatively high stock abundance (to avoid density-dependent WAA) indicate good growth of the herring stock because of high abundance of high-quality food (usually large amount of copepods) and, thus, a good reference period with regard to the fish-feeding conditions. - The reference period for the total zooplankton abundance (or biomass) reflects a time period when effects of eutrophication are low, defined as ‘acceptable’ chlorophyll a concentration (i.e. EQR > 1) and hence eutrophication-related food web changes are negligible. - The obtained values (mean size and total zooplankton abundance) are placed to the schematic 4-square (Fig. 1), where the areas of the diagram get values from 1 to 3 (lower left corner = 1 = below GES, upper left and lower right corners = 2 = below GES and upper right corner = 3 = GES). Thus if both mean size and total zooplankton abundance values settle to the upper right corner, the GES is met and the indicator value is 3. GES-boundaries for the open Gulf of Finland (MARMONI 4FIN-EST area) are >0.0063 mg for the mean size and >9080 ind/m^3 for total abundance, indicator value is 3. The status for the assessment period 2010-2012 for this area is below GES, indicator value is 2 (mean size = 0.0056 mg and total abundance= 32671 ind/m3). The reference periods considered were 1979-1982 for mean size and 1979-1987 for total abundance. GES-boundaries for the Gulf of Riga (MARMONI 1EST-LAT area) are >0.0027 mg/ind for the mean size and >91722 ind/m^3 for total abundance, indicator value is 3.The status for the assessment period 2010-1012 for this area is below GES, indicator value is 2 (mean size = 0.0036 mg/ind and total abundance = 83853 ind/m^3). The reference periods considered were 1993-1997 for mean size and 1995-1999 for total abundance.
References	Adrian, R., Hansson, S., Sandin, B., DeStasio, B., Larsson, U. (1999) Effects of food avail-

	ability and predation on a marine zooplankton community—a study on copepods in the Baltic Sea. Int Rev Hydrobiol 84:609–626 Cardinale, M., Casini, M., Arrhenius, F. (2002) The influence of biotic and abiotic factors on the growth of sprat (*Sprattus sprattus*) in the Baltic Sea. Aquat. Liv. Res.: 273-281. Gliwicz, Z.M. (1969) Studies on the feeding of pelagic zooplankton in lakes with varying trophy. Ekol. Pol., 17, 663–708. HELCOM (1988) Guidelines for the Baltic monitoring programme for the third stage. Part D. Biological determinants. Baltic Sea Environment Proceedings 27D: 1-161. HELCOM (2013) MSTS indicator description sheet. Available at the HELCOM web site: http://meeting.helcom.fi/c/document_library/get_file?p_l_id=80219&folderId=2289395&name=DLFE-54128.docx Hsieh CH, *et a.l* (2011) Eutrophication and warming effects on long-term variation of zooplankton in Lake Biwa. Biogeosciences 8: 593-629. Jeppesen E, *et al.* (2011) Zooplankton as indicators in lakes: a scientific-based plea for including zooplankton in the ecological quality assessment of lakes according to the European Water Framework Directive (WFD). Hydrobiologia 676: 279-297. Ljunggren, L., Sandström, A., Bergström, U., Mattila, J., Lappalainen, A., Johansson, G., Sundblad, G., Casini, M., Kaljuste, O., and Eriksson, B. K. 2010. Recruitment failure of coastal predatory fish in the Baltic Sea coincident with an offshore ecosystem regime shift. ICES Journal of Marine Science, 67: 1587-1595. Pace, M.L. 1986. An empirical analysis of zooplankton community size structure across lake trophic gradients. Limnol. Oceanogr. 31: 45-55. Rönkkönen S, Ojaveer E, Raid T, Viitasalo M (2004) Long-term changes in Baltic herring (*Clupea harengus membras*) growth in the Gulf of Finland. Canadian Journal of Fisheries and Aquatic Sciences 61: 219-229. Yan ND, *et al*. (2008) Long-term trends in zooplankton of Dorset, Ontario, lakes: the probable interactive effects of changes in pH, total phosphorus, dissolved organic carbon, and predators. Can. J. Fish. Aquat. Sci. 65: 862-877.
Illustrative material for indicator documentation	 Figure 1. A schematic diagram of the use of the indicator. The green area represents GES condition, yellow areas represent sub-GES conditions where only one of the two parameters is adequate, and the red area represents sub-GES conditions where both parameters fail.

4 Bird indicators

Name of indicator	**4.1 Abundance index of wintering waterbird species**
Type of Indicator	State indicator
Author(s)	Ainars Auniņš, Leif Nilsson, Andres Kuresoo, Leho Luigujõe, Antra Stīpniece
Description of the indicator	This is a single species indicator and it reflects population level at wintering season of the particular species compared to reference level (population at base year or period). Index is calculated for all species that are regularly recorded at inshore and offshore areas of the Baltic Sea during wintering period. Indicator is calculated separately for inshore and offshore areas due to different data collection schemes. Baltic-wide indicators are calculated separately for each of the following species: *Cygnus olor, Cygnus cygnus, Fulica atra, Anas platyrhynchos, Clangula hyemalis, Melanitta nigra, Melanitta fusca, Somateria mollissima, Aythya marila, Aythya fuligula, Bucephala clangula, Aythya ferina, Mergus albellus, Gavia stellata, Gavia arctica, Mergus merganser, Mergus serrator, Podiceps cristatus, Alca torda, Uria aalge, Cepphus grylle, Larus minutus, Larus ridibundus, Larus canus, Larus argentatus, Larus marinus*. Species lists for national and subbasin versions of these indicators are country and subbasin specific.
Relationship of the indicator to marine biodiversity	The indicator reflects status of important components of the marine biodiversity. This indicator (population indices for each species) is further used for calculation of other indicators (e.g. Wintering waterbird index)
Relevance of the indicator to different policy instruments	MSFD descriptors 1 (species level/population size and habitat level/condition of typical species) and 4 (abundance trends of functionally important selected species). Habitats Directive (this indicator is needed for Article 17 reporting to report status of typical species of the habitat types 1110 and 1170; Anon 2007, Aunins 2010) Birds Directive (this indicator is needed for Article 12 reporting to report long-term and short-term population trend of all regularly occurring wintering marine waterbird species. HELCOM CORESET (in collaboration with MARMONI an inshore part of this indicator developed using inshore data collected during International Waterbird Census)
Relevance to commission decision criteria and indicator	1.2. Population size 1.2.1. Population abundance and/or biomass 1.6.1. Condition of the typical species and communities
Method(s) for obtaining indicator values	Field data collection: using any of the standard methods. For inshore part of the indicator coastal ground counts (such as International Waterbird Census; methods described in Wetlands International 2010) are used. This type of data has been collected in all Baltic Sea countries for decades. Data for offshore part of the indicator need to be collected using ships or planes (Komdeur *et al.* 1992, Petersen *et al.* 2005, Camphuisen *et al*. 2006, Nilsson 2012). Indicator calculation: The index gives species population abundance relative to population at base time (period). Average wintering population during 1991 - 2000 period is suggested as base level. To obtain the population index, site and year specific counts of individuals of particular species are related to site and year effects (factors) and missing values are imputed from the data of all surveyed sites. Freeware programme TRIM is available to produce annual indices based on loglinear models (Pannekoek & van Strien 1998). In addition to annual indices, TRIM allows the estimation of trends over the whole period. To separate true time effects from other impacts such as climate change, using models that include climate specific covariate has been suggested (Aunins *et al*. in prep). The suggested model includes mean air temperature during the week preceding bird counts as a covariate in addition to site and year and used GAM (generalised additive modelling) framework. The model accounts for serial correlation and overdispersion.
Documentation of relationship between indicator and pressure	Each of the species for which the indicator is calculated respond to different pressures. Important pressures and response patterns vary among the species. The indicator (depending on species) responds to: eutrophication oil pollution/shipping hazardous substances

	fishing pressure bycatch hunting fisheries discards coastal development wind energy sand and gravel extraction climate change Latest knowledge and summary of related studies are given in Skov *et al.* 2011 Contribution of each particular pressure on a given species can be controlled by including additional explanatory variables characterising the level of the pressure as covariates in the indicator calculation model.
Geographical relevance of indicator	2. Regional 3. National waters 4. Baltic Sea wide
How Reference Conditions (target values/ thresholds) for the indicator were obtained?	Reference conditions (GES thresholds) are set at 30% on both sides from base population level (i.e. mean population during 1991 - 2000 period). Thus indicator for each particular species can be considered being at GES if it falls between 70 and 130% (ICES 2013).
Method for determining GES	Currently GES levels have been set arbitrarily at 30% on both sides from base population level (i.e. mean population during 1991 - 2000 period). More ecological studies are needed to set species specific GES thresholds as well as to choose different and species specific time periods reflecting base population levels.
References	Anon. 2007. Interpretation manual of European Union Habitats. EUR 27. European Commission DG Environment. Aunins A. (ed.) 2010. [Protected habitats of European Union in Latvia. Identification Handbook]. Latvian Fund for Nature, Riga, 320 pp. Aunins A., Clausen P., Dagys M., Garthe S., Grishanov G., Korpinen S., Kuresoo A., Lehikoinen A., Luigujoe L., Meissner W., Mikkola-Roos M., Nilsson L., Petersen I.K., Stipniece A., Wahl J. (in prep) Development of Wintering Waterbird Indicators for the Baltic Sea. Camphuysen C.J., Fox A.D., Leopold M.F. & Petersen I.K. 2004. Towards standardised seabirds at sea census techniques in connection with environmental impact assessments for offshore wind farms in the U.K. Report commissioned by COWRIE for the Crown Estate, London. Royal Netherlands Institute for Sea Research, Texel, 38 pp. ICES. 2013. Report of the Joint ICES/OSPAR Ad hoc Group on Seabird Ecology (AGSE), 28-29 November 2012, Copenhagen, Denmark. ICES CM 2012/ACOM:82, 30 pp. Komdeur, J., Bertelsen, J. & Cracknell, G. (Eds.). 1992. Manual for Aeroplane and Ship Surveys of Waterfowl and Seabirds. IWRB Special Publication No. 1, Slimbridge, UK, 37 p. Nilsson, L. 2012. Distribution and numbers of wintering sea ducks in Swedish offshore waters. Ornis Svecica 22: 39-60. Petersen, I.K, Fox, A.D. 2005. An aerial survey technique for sampling and mapping distributions of waterbirds at sea. Department of Wildlife Ecology and Biodiversity, National Environmental Research Institute. 24 pp. Skov. H., Heinänen S., Žydelis R., Bellebaum J., Bzoma S., Dagys M., Durinck J., Garthe S., Grishanov G., Hario M., Kieckbusch J.J., Kube J., Kuresoo A., Larsson K., Luigujõe L., Meissner W., Nehls H.W., Nilsson L., Petersen I.K., Roos M.M., Pihl S., Sonntag N., Stock A., Stipniece A., Wahl J. 2011. Waterbird Populations and Pressures in the Baltic Sea. Nordic Council of Ministers, Copenhagen, 201 pp. Van Strien, A.J., Pannekoek, J. et Gibbons, D.W. (2001): Indexing European bird population

	trends using results of national monitoring schemes: a trial of a new method. Bird Study 48: 200-213. Wetlands International 2010. Guidance on waterbird monitoring methodology: Field Protocol for waterbird counting. Report prepared by Wetlands International.
Illustrative material for indicator documentation	 Figure 1. Example draft indicator for inshore part of the Baltic sea (currently only data from Sweden, Estonia, Latvia, Lithuania, Poland (only Gulf of Gdansk) and Germany used): Goldeneye *Bucephala clangula.*

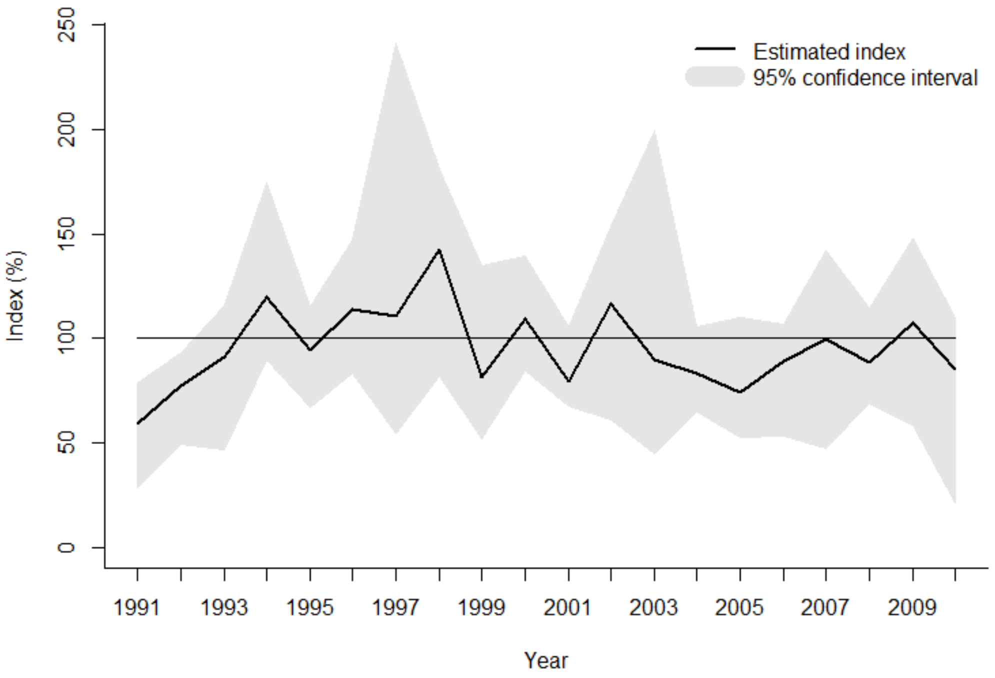
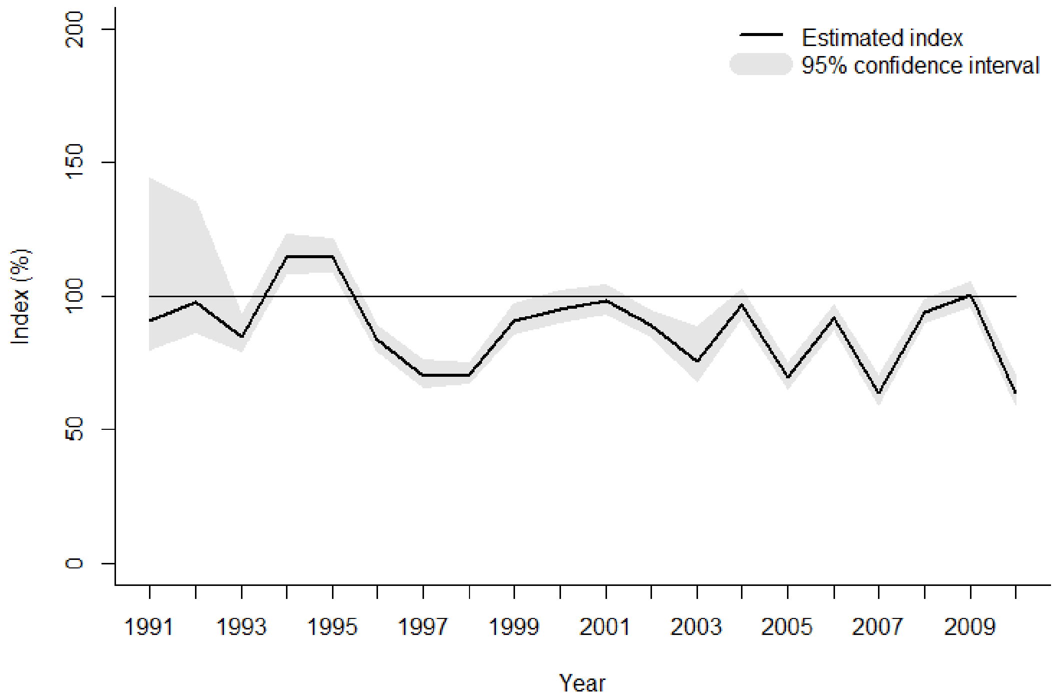


Figure 2. Example draft indicator for inshore part of the Baltic sea (currently only data from Sweden, Estonia, Latvia, Lithuania, Poland (only Gulf of Gdansk) and Germany used): Common Eider *Somateria mollissima.*

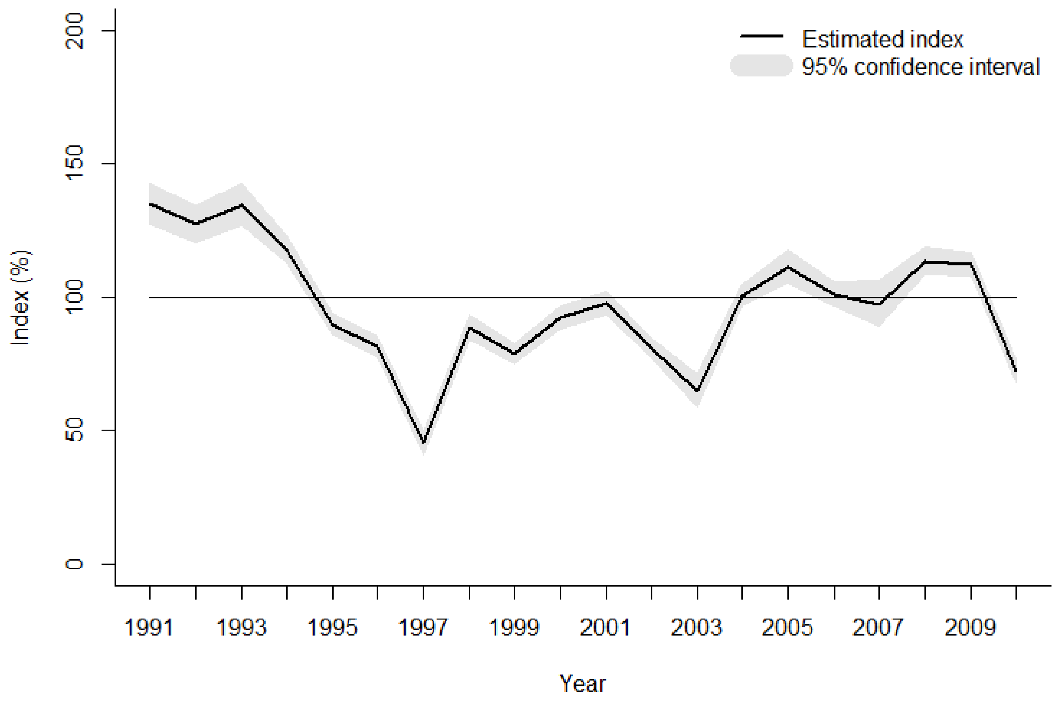
Name of indicator	**4.2 Wintering waterbird index (WWBI)**
Type of Indicator	State indicator
Author(s)	Ainars Auniņš, Leif Nilsson, Andres Kuresoo, Leho Luigujõe, Antra Stīpniece
Description of the indicator	This is a multi-species indicator and it reflects status of wintering waterbird community compared to base (reference) level. All regularly occurring species at inshore and offshore areas of the Baltic Sea during wintering period are included in calculation of the indicator. Indicator is calculated separately for inshore and offshore areas due to different data collection schemes. Computationally this indicator is similar to farmland bird index (one of the EU Sustainable development indicators) and other wild bird indices that are calculated for breeding land birds (Gregory *et al.* 2005, Gregory, van Strien 2010). The multi-species index is calculated from single species indices (the indicator "Abundance index of wintering waterbird species"). Species to be included in the calculation of the Baltic-wide version of this indicator are: *Cygnus olor, Cygnus cygnus, Fulica atra, Anas platyrhynchos, Clangula hyemalis, Melanitta nigra, Melanitta fusca, Somateria mollissima, Aythya marila, Aythya fuligula, Bucephala clangula, Aythya ferina, Mergus albellus, Gavia stellata, Gavia arctica, Mergus merganser, Mergus serrator, Podiceps cristatus, Alca torda, Uria aalge, Cepphus grylle, Larus minutus, Larus ridibundus, Larus canus, Larus argentatus, Larus marinus*. For subbasin or national versions of the indicator species lists are country and subbasin specific.
Relationship of the indicator to marine biodiversity	The indicator reflects health of waterbird communities of marine environment. In this type of single multi-species indicator (geometric mean of the single species indices) both abundance and diversity of its forming species is taken into account (Gregory, van Strien 2010).
Relevance of the indicator to different policy instruments	MSFD descriptors 1 (ecosystem level) and 4 (abundance trends of functionally important selected species). HELCOM CORESET (in collaboration with MARMONI an inshore part of this indicator developed using inshore data collected during International Waterbird Census).
Relevance to commission decision criteria and indicator	1.6.1. Condition of the typical species and communities 1.7. Ecosystem structure 1.7.1. Composition and relative proportions of ecosystem components (habitats and species)
Method(s) for obtaining indicator values	Field data collection: using any of the standard methods. For inshore part of the indicator coastal ground counts (such as International Waterbird Census; methods described in Wetlands International 2010) are used. This type of data has been collected in all Baltic Sea countries for decades. Data for offshore part of the indicator need to be collected using ships or planes (Komdeur *et al*. 1992, Petersen *et al.* 2005, Camphuisen *et al.* 2006, Nilsson 2012). Indicator calculation: The indicator is calculated from single species indices (see Abundance index of wintering waterbird species) using geometric mean. Every species is treated equally (no weighting). Standard errors are calculated using formula $\mathrm{var}(\bar{I}) \approx \left(\frac{\bar{I}}{T}\right)^2 \sum_t \left(\frac{\mathrm{var}(I_t)}{I_t^2}\right)$, where Ī – multi-species index value, T – number of indices (species), It – species abundance index value
Documentation of relationship between indicator and pressure	This multispecies indicator is affected by all pressures acting on species forming the indicator. Thus the indicator responds to ensemble of following pressures: eutrophication oil pollution/shipping hazardous substances fishing pressure bycatch hunting fisheries discards coastal development

	wind energy sand and gravel extraction climate change Latest knowledge and summary of related studies on response of marine waterbird species to important pressures are given in Skov *et al.* 2011 Contribution of each particular pressure can be controlled by including additional explanatory variables characterising the level of the pressure as covariates in the indicator calculation model.
Geographical relevance of indicator	2. Regional 3. National waters 4. Baltic Sea wide
How Reference Conditions (target values/thresholds) for the indicator were obtained?	Reference conditions (GES thresholds) are set at 30% on both sides from base population level (i.e. mean population during 1991 - 2000 period). Thus indicator can be considered being at GES if it falls between 70 and 130% (ICES 2013).
Method for determining GES	Currently GES levels have been set arbitrarily at 30% on both sides from base population level (ICES 2013). More ecological studies are needed to set more precise and better justified GES thresholds or to choose different time period to serve as base level.
References	Aunins A., Clausen P., Dagys M., Garthe S., Grishanov G., Korpinen S., Kuresoo A., Lehikoinen A., Luigujoe L., Meissner W., Mikkola-Roos M., Nilsson L., Petersen I.K., Stipniece A., Wahl J. (in prep) Development of Wintering Waterbird Indicators for the Baltic Sea. Camphuysen C.J., Fox A.D., Leopold M.F. & Petersen I.K. 2004. Towards standardised seabirds at sea census techniques in connection with environmental impact assessments for offshore wind farms in the U.K.. Report commissioned by COWRIE for the Crown Estate, London. Royal Netherlands Institute for Sea Research, Texel, 38 pp. Gregory R.D., van Strien A.J., Vorisek P., Gmelig Meyling A.W., Noble D.G., Foppen R.P.B. et Gibbons D.W. (2005): Developing indicators for European birds. Philosophical Transactions of the Royal Society B 360: 269-288. Gregory, R.D., van Strien, A. (2010): Wild bird indicators: using composite population trends of birds as measures of environmental health. Ornithological Science 9 (1): 3-22. ICES. 2013. Report of the Joint ICES/OSPAR Ad hoc Group on Seabird Ecology (AGSE), 28-29 November 2012, Copenhagen, Denmark. ICES CM 2012/ACOM:82, 30 pp. Komdeur, J., Bertelsen, J. & Cracknell, G. (Eds.). 1992. Manual for Aeroplane and Ship Surveys of Waterfowl and Seabirds. IWRB Special Publication No. 1, Slimbridge, UK, 37 p. Petersen, I.K, Fox, A.D. 2005. An aerial survey technique for sampling and mapping distributions of waterbirds at sea. Department of Wildlife Ecology and Biodiversity, National Environmental Research Institute. 24 pp. Skov. H., Heinänen S., Žydelis R., Bellebaum J., Bzoma S., Dagys M., Durinck J., Garthe S., Grishanov G., Hario M., Kieckbusch J.J., Kube J., Kuresoo A., Larsson K., Luigujõe L., Meissner W., Nehls H.W., Nilsson L., Petersen I.K., Roos M.M., Pihl S., Sonntag N., Stock A., Stipniece A., Wahl J. 2011. Waterbird Populations and Pressures in the Baltic Sea. Nordic Council of Ministers, Copenhagen, 201 pp. Wetlands International 2010. Guidance on waterbird monitoring methodology: Field Protocol for waterbird counting. Report prepared by Wetlands International.

Illustrative material for indicator documentation	Example draft indicator for inshore part of the Baltic Sea (data from all Baltic Sea countries except Russia used):  Figure 1. Wintering Waterbird Index (Aunins *et al*. in prep) Included species: *Gavia stellata, Gavia arctica, Podiceps cristatus, Phalacrocorax carbo, Cygnus olor, Anas platyrhynchos, Aythya ferina, Aythya fuligula, Aythya marila, Somateria mollissima, Clangula hyemalis, Melanitta nigra, Melanitta fusca, Bucephala clangula, Mergus albellus, Mergus serrator, Mergus albellus, Fulica atra.*

Name of indicator	**4.3 Wintering indices for waterbirds of different feeding guilds (WWBIFG)**
Type of Indicator	State indicator
Author(s)	Ainars Auniņš, Leif Nilsson, Andres Kuresoo, Leho Luigujõe, Antra Stīpniece
Description of the indicator	This is a set of multi species indicators reflecting status of specific feeding guilds in the wintering waterbird communities compared to base (reference) level. We suggest separate indices for herbivorous benthic feeders, invertebrate benthic feeders, fish feeders and gulls. All regularly occurring species with the specific feeding habits at inshore and offshore areas of the Baltic Sea during wintering period are included in calculation of the indicators. Indicator is calculated separately for inshore and offshore areas due to different data collection schemes. Computationally this indicator is similar to the suggested Wintering Waterbird index and other wild bird indices that are calculated for breeding land birds such as farmland bird index (Gregory *et al.* 2005, Gregory, van Strien 2010). The multi-species indices are calculated from single species indices (the indicator "*Abundance index of wintering waterbird species* "). Species to be included in the guild specific indices are as follows: Benthic herbivore index: *Cygnus olor, Cygnus cygnus, Fulica atra, Anas platyrhynchos* Benthic invertebrate feeder index*: Clangula hyemalis, Melanitta nigra, Melanitta fusca, Somateria mollissima, Polysticta stelleri, Aythya marila, Aythya fuligula, Bucephala clangula, Aythya ferina* Fish feeder index*: Gavia stellata, Gavia arctica, Mergus merganser, Mergus serrator, Podiceps cristatus, Alca torda, Uria aalge, Cepphus grylle* Gull index*: Larus minutus, Larus ridibundus, Larus canus, Larus argentatus, Larus fuscus, Larus marinus*
Relationship of the indicator to marine biodiversity	The indicator reflects health of specific feeding guilds in waterbird communities of marine environment. In this single multispecies-indicator indicator (geometric mean of the single species indices) both abundance and diversity of its forming species is taken into account (Gregory, van Strien 2010).
Relevance of the indicator to different policy instruments	MSFD descriptors 1 (ecosystem level) and 4 (abundance trends of functionally important selected species). HELCOM CORESET (in collaboration with MARMONI an inshore part of this indicator developed using inshore data collected during International Waterbird Census).
Relevance to commission decision criteria and indicator	1.6.1. Condition of the typical species and communities 1.7. Ecosystem structure 1.7.1. Composition and relative proportions of ecosystem components (habitats and species)
Method(s) for obtaining indicator values	Field data collection**:** using any of the standard methods. For inshore part of the indicator coastal ground counts (such as International Waterbird Census; methods described in Wetlands International 2010) are used. This type of data has been collected in all Baltic Sea countries for decades. Data for offshore part of the indicator need to be collected using ships or planes (Komdeur *et al*. 1992, Petersen *et al.* 2005, Camphuisen *et al.* 2006, Nilsson 2012). Indicator calculation**:** The indicator is calculated from single species indices (see Abundance index of wintering waterbird species) using geometric mean. Every species is treated equally (no weighting). Standard errors are calculated using formula $\mathrm{var}(\bar{I}) \approx \left(\frac{\bar{I}}{T}\right)^2 \sum_t \left(\frac{\mathrm{var}(I_t)}{I_t^2}\right)$, where Ī – multi-species index value, T – number of indices (species), It – species abundance index value
Documentation of relationship between indicator and pressure	These multispecies indicators are affected by all pressures acting on species forming the indicator of a particular feeding guild. Thus each indicator responds to ensemble of following pressures:

	eutrophication oil pollution/shipping hazardous substances fishing pressure bycatch hunting fisheries discards coastal development wind energy sand and gravel extraction climate change Latest knowledge and summary of related studies on response of marine waterbird species to important pressures are given in Skov *et al*. 2011 Contribution of each particular pressure to a given indicator can be controlled by including additional explanatory variables characterising the level of the pressure as covariates in the indicator calculation model.
Geographical relevance of indicator	2. Regional 3. National waters 4. Baltic Sea wide
How Reference Conditions (target values/thresholds) for the indicator were obtained?	Reference conditions (GES thresholds) are set at 30% on both sides from base population level (i.e. mean population during 1991 - 2000 period). Thus indicator can be considered being at GES if it falls between 70 and 130% (ICES 2013).
Method for determining GES	Currently GES levels have been set arbitrarily at 30% on both sides from base population level (ICES 2013). More ecological studies are needed to set more precise and better justified guild specific GES thresholds or to choose different guild specific time period to serve as base level.
References	Camphuysen C.J., Fox A.D., Leopold M.F. & Petersen I.K. 2004. Towards standardised seabirds at sea census techniques in connection with environmental impact assessments for offshore wind farms in the U.K.. Report commissioned by COWRIE for the Crown Estate, London. Royal Netherlands Institute for Sea Research, Texel, 38 pp. Gregory R.D., van Strien A.J., Vorisek P., Gmelig Meyling A.W., Noble D.G., Foppen R.P.B. et Gibbons D.W. (2005): Developing indicators for European birds. Philosophical Transactions of the Royal Society B 360: 269-288. Gregory, R.D., van Strien, A. (2010): Wild bird indicators: using composite population trends of birds as measures of environmental health. Ornithological Science 9 (1): 3-22. ICES. 2013. Report of the Joint ICES/OSPAR Ad hoc Group on Seabird Ecology (AGSE), 28-29 November 2012, Copenhagen, Denmark. ICES CM 2012/ACOM:82, 30 pp. Komdeur, J., Bertelsen, J. & Cracknell, G. (Eds.). 1992. Manual for Aeroplane and Ship Surveys of Waterfowl and Seabirds. IWRB Special Publication No. 1, Slimbridge, UK, 37 p. Petersen, I.K, Fox, A.D. 2005. An aerial survey technique for sampling and mapping distributions of waterbirds at sea. Department of Wildlife Ecology and Biodiversity, National Environmental Research Institute. 24 pp. Skov. H., Heinänen S., Žydelis R., Bellebaum J., Bzoma S., Dagys M., Durinck J., Garthe S., Grishanov G., Hario M., Kieckbusch J.J., Kube J., Kuresoo A., Larsson K., Luigujõe L., Meissner W., Nehls H.W., Nilsson L., Petersen I.K., Roos M.M., Pihl S., Sonntag N., Stock A., Stipniece A., Wahl J. 2011. Waterbird Populations and Pressures in the Baltic Sea. Nordic Council of Ministers, Copenhagen, 201 pp.

	Wetlands International 2010. Guidance on waterbird monitoring methodology: Field Protocol for waterbird counting. Report prepared by Wetlands International.
Illustrative material for indicator documentation	Example draft indicators for inshore part of the Baltic sea (data from International Waterbird Census from all Baltic sea countries are used):  Figure 1. Benthic herbivore Index. Included species: *Cygnus olor, Anas platyrhynchos, Fulica atra.*

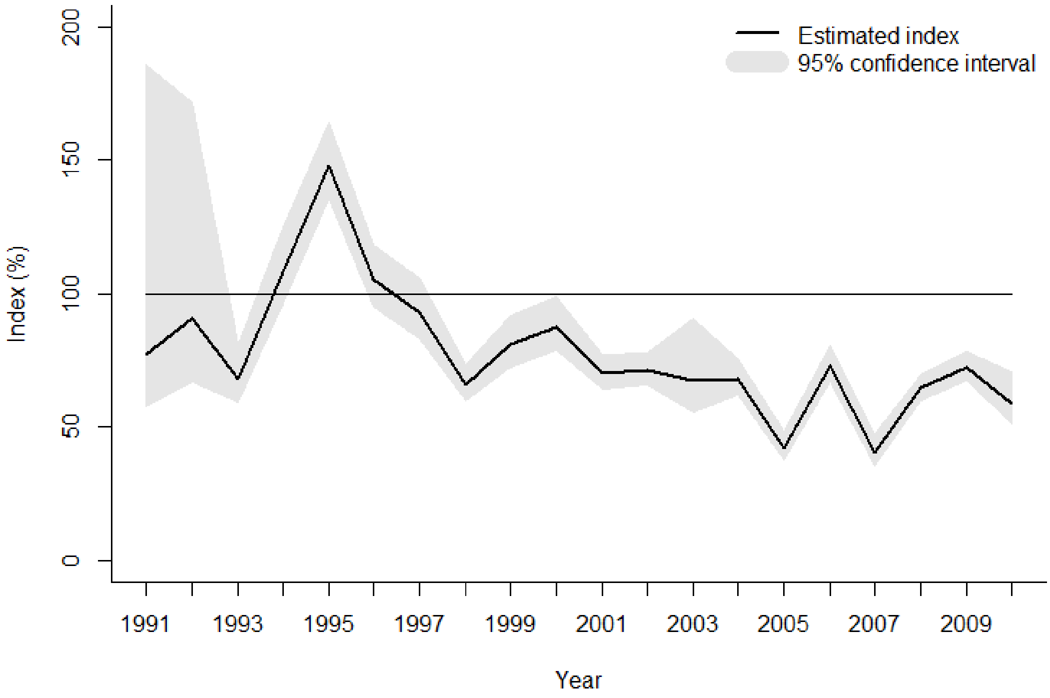


Figure 2. Benthic invertebrate feeder index. Included species: *Aythya ferina, Aythya fuligula, Aythya marila, Somateria mollissima, Polysticta stelleri, Clangula hyemalis, Melanitta nigra, Melanitta fusca, Bucephala clangula.*

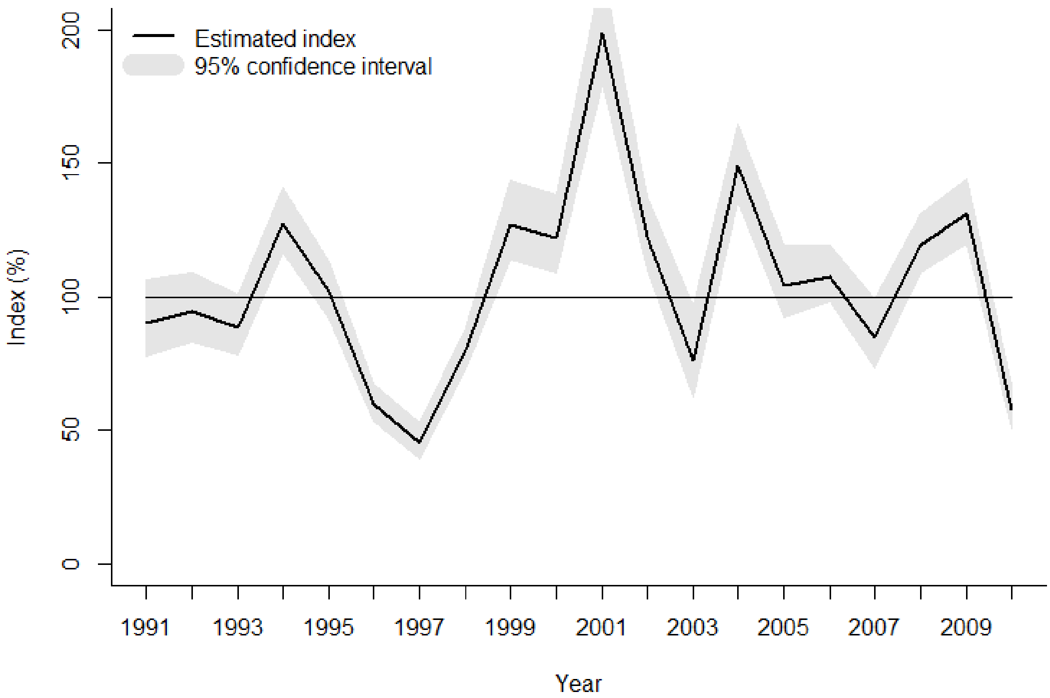
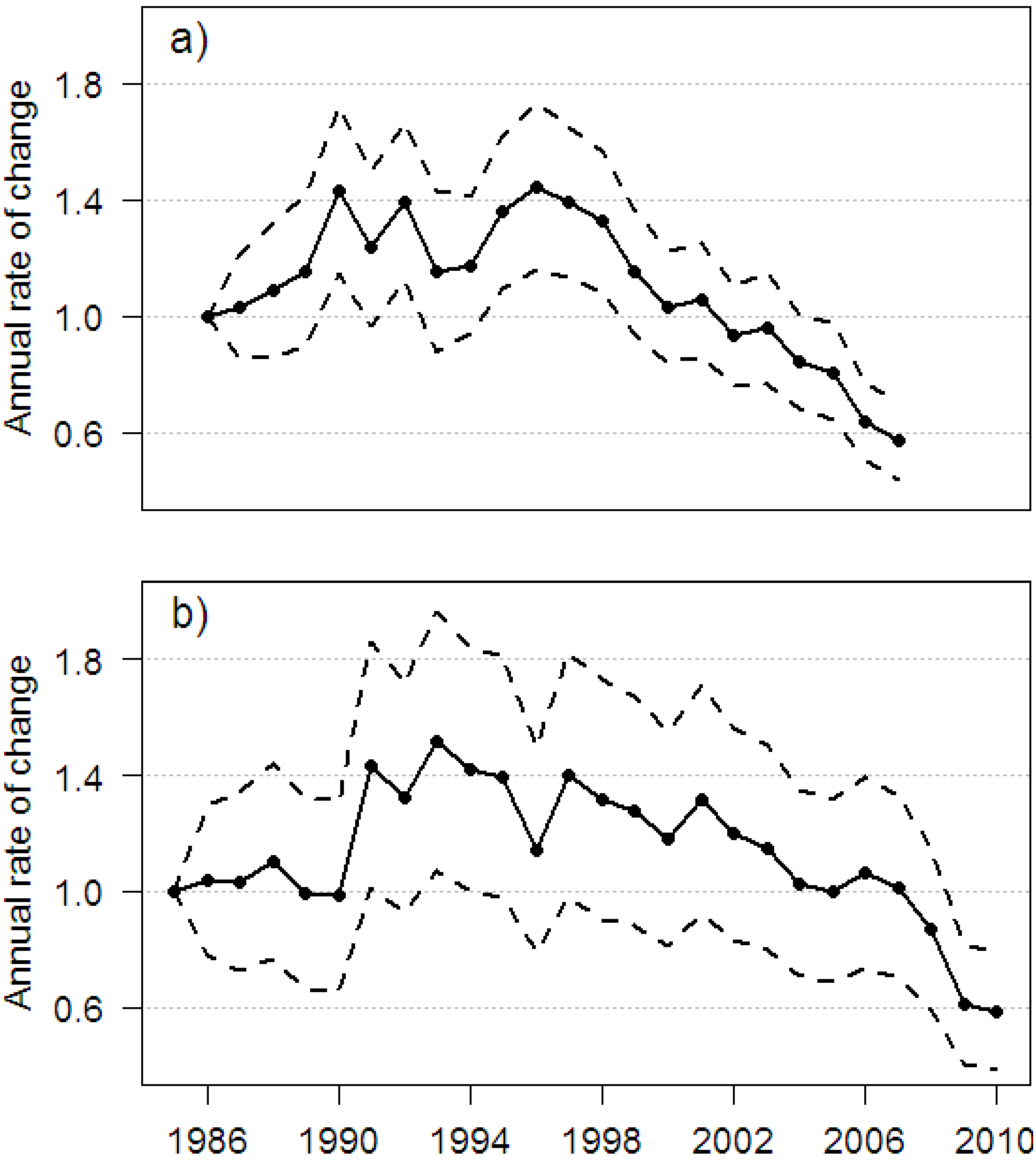


Figure 3. Fish feeder index. Included species: *Gavia stellata, Gavia arctica, Podiceps cristatus, Phalacrocorax carbo, Mergus serrator, Mergus merganser.*

Name of indicator	**4.4 Abundance index of breeding waterbird species**
Type of Indicator	State indicator
Author(s)	Ainars Auniņš, Leif Nilsson, Andres Kuresoo, Leho Luigujõe, Antra Stīpniece
Description of the indicator	This is a single species indicator and it reflects level of breeding population of particular species compared to base year (or reference level). Index is calculated for all species that are regularly recorded as breeders at coastal areas of the Baltic Sea and marine environment is important for them in this part of the season. Baltic-wide indicators are calculated separately for each of the following species: *Cygnus olor, Melanitta fusca, Somateria mollissima, Aythya marila, Tadorna tadorna, Alca torda, Uria aalge, Cepphus grylle, Larus canus, Larus argentatus, Larus marinus, Sterna caspia, Sterna hirundo, Sterna paradisaea, Sterna sandvicensis, Sterna albifrons, Phalacrocorax carbo*. Species lists for national and subbasin versions of these indicators are country and subbasin specific.
Relationship of the indicator to marine biodiversity	The indicator reflects status of important components of the marine biodiversity.
Relevance of the indicator to different policy instruments	MSFD descriptors 1 (species level/population size and habitat level/condition of typical species) and 4 (abundance trends of functionally important selected species). Birds Directive (this indicator is needed for Article 12 reporting to report long-term and short-term population trend of all regularly occurring breeding coastal and marine waterbird species. HELCOM CORESET (developed for several species using breeding data collected from national coordinators)
Relevance to commission decision criteria and indicator	1.2. Population size 1.2.1. Population abundance and/or biomass 1.6.1. Condition of the typical species and communities
Method(s) for obtaining indicator values	Field data collection: using any of the standard recording methods. Indicator calculation**:** The index gives species population abundance relative to population at base time (period). Average breeding population during 1991 - 2000 period is suggested as

	base level. To obtain the population index, site and year specific counts of individuals of particular species are related to site and year effects (factors) and missing values are imputed from the data of all surveyed sites. Freeware program TRIM is available to produce annual indices based on loglinear models (Pannekoek & van Strien 1998). In addition to annual indices, TRIM allows the estimation of trends over the whole period.
Documentation of relationship between indicator and pressure	This multispecies indicator is affected by all pressures acting on species forming the indicator. Thus the indicator responds to ensemble of following pressures: coastal development eutrophication hazardous substances predation by non-native species (e.g. American Mink) fisheries discards climate change To a lesser extent also: oil pollution/shipping by-catch wind energy sand and gravel extraction Latest knowledge and summary of related studies on response of marine waterbird species to important pressures are given in *Skov et al*. 2011.
Geographical relevance of indicator	2. Regional 3. National waters 4. Baltic Sea wide
How Reference Conditions (target values/thresholds) for the indicator were obtained?	Reference conditions (GES thresholds) are set at 30% on both sides from base population level (i.e. mean population during 1991 - 2000 period). Thus indicator for each particular species can be considered being at GES if it falls between 70 and 130% (ICES 2013).
Method for determining GES	Currently GES levels have been set arbitrarily at 30% on both sides from base population level ICES 2013). More ecological studies are needed to set species specific GES thresholds as well as to choose different and species specific time periods reflecting base population levels.
References	Ekroos J., Fox A.D., Christensen T.K., Petersen I.K., Kilpi M., Jonsson J.E., Green M., Laursen K., Cervencl A., de Boer P., Nilsson L., Meissner W., Garthe S., Öst M. 2012. Declines amongst breeding Eider *Somateria mollissima* numbers in the Baltic/Wadden Sea flyway. Ornis Fennica 89:81–90. ICES. 2013. Report of the Joint ICES/OSPAR Ad hoc Group on Seabird Ecology (AGSE), 28-29 November 2012, Copenhagen, Denmark. ICES CM 2012/ACOM:82, 30 pp. Skov. H., Heinänen S., Žydelis R., Bellebaum J., Bzoma S., Dagys M., Durinck J., Garthe S., Grishanov G., Hario M., Kieckbusch J.J., Kube J., Kuresoo A., Larsson K., Luigujõe L., Meissner W., Nehls H.W., Nilsson L., Petersen I.K., Roos M.M., Pihl S., Sonntag N., Stock A., Stipniece A., Wahl J. 2011. Waterbird Populations and Pressures in the Baltic Sea. Nordic Council of Ministers, Copenhagen, 201 pp. Van Strien, A.J., Pannekoek, J. et Gibbons, D.W. (2001): Indexing European bird population trends using results of national monitoring schemes: a trial of a new method. Bird Study 48: 200-213. Wetlands International 2010. Guidance on waterbird monitoring methodology: Field Protocol for waterbird counting. Report prepared by Wetlands International.

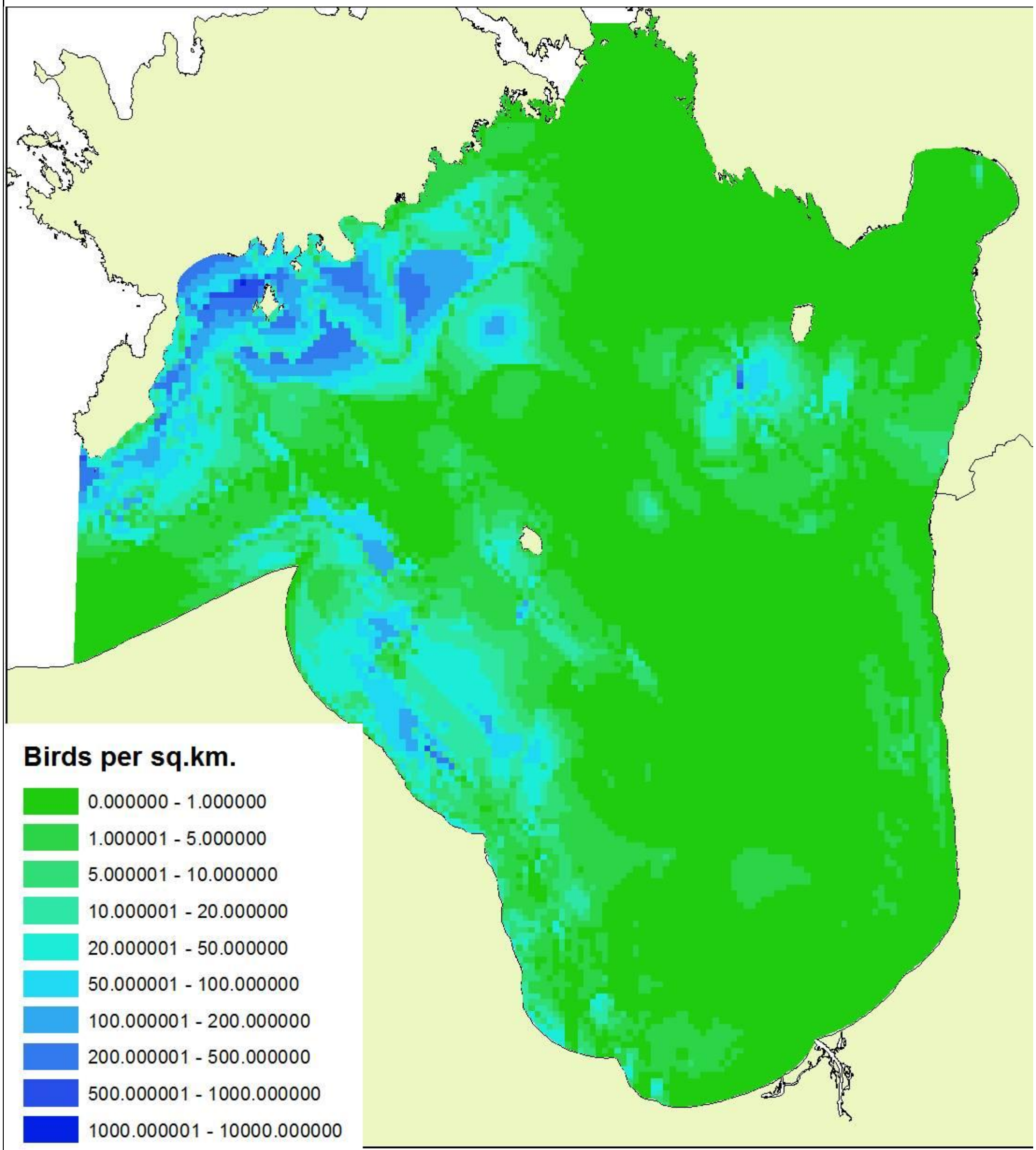
Illustrative material for indicator documentation	 Figure 1. Population development of the Eider in (a) Finland during 1986–2007 and (b) Sweden during 1985–2010 (Ekroos et al 2012).

Name of indicator	**4.5 Breeding waterbird index (BWBI)**
Type of Indicator	State indicator
Author(s)	Ainars Auniņš, Leif Nilsson, Andres Kuresoo, Leho Luigujõe, Antra Stīpniece
Description of the indicator	This is a multi-species indicator and it reflects status of breeding waterbird community compared to base (reference) level. All regularly breeding species ecologically connected with the Baltic Sea during breeding period are included in calculation of the indicator. Computationally this indicator is similar to farmland bird index (one of the EU Sustainable development indicators) and other wild bird indices that are calculated for breeding land birds (Gregory *et al*. 2005, Gregory, van Strien 2010). The multi-species index is calculated from single species indices (the indicator *Abundance index of breeding waterbird species*). Species to be included in the calculation of the Baltic-wide version of this indicator are: *Cygnus olor, Melanitta fusca, Somateria mollissima, Aythya marila, Tadorna tadorna, Alca torda, Uria aalge, Cepphus grylle, Larus canus, Larus argentatus, Larus marinus, Sterna caspia, Sterna hirundo, Sterna paradisaea, Sterna sandvicensis, Sterna albifrons, Phalacrocorax carbo*. For those species having populations breeding inland, Species lists for national and subbasin versions of this indicator are country and subbasin specific.
Relationship of the indicator to marine biodiversity	The indicator reflects health of breeding waterbird communities connected with marine environment. In this type of multi-species indicator (geometric mean of the single species indices) both abundance and diversity of its forming species is taken into account (Gregory, van Strien 2010).
Relevance of the indicator to different policy instruments	MSFD descriptor 1 (habitat level/Condition of the typical species and communities and ecosystem level/Composition and relative proportions of ecosystem components (habitats and species)
Relevance to commission decision criteria and indicator	1.6.1. Condition of the typical species and communities 1.7. Ecosystem structure 1.7.1. Composition and relative proportions of ecosystem components (habitats and species)
Method(s) for obtaining indicator values	Field data collection: using any of the standard recording methods for breeding birds. Indicator calculation**:** The indicator is calculated from single species indices (see Abundance index of breeding waterbird species) using geometric mean. Every species is treated equally (i.e. no weighting). Standard errors are calculated using formula $\mathrm{var}(\bar{I}) \approx \left(\frac{\bar{I}}{T}\right)^2 \sum_t \left(\frac{\mathrm{var}(I_t)}{I_t^2}\right)$, where Ī – multi-species index value, T – number of indices (species), It – species abundance index value
Documentation of relationship between indicator and pressure	This multispecies indicator is affected by all pressures acting on species forming the indicator. Thus the indicator responds to ensemble of following pressures: coastal development eutrophication hazardous substances predation by non-native species (e.g. American Mink) fisheries discards climate change To a lesser extent also: oil pollution/shipping by-catch wind energy sand and gravel extraction Latest knowledge and summary of related studies on response of marine waterbird species to important pressures are given in Skov *et al*. 2011.

Geographical relevance of indicator	2. Regional 3. National waters 4. Baltic Sea wide
How Reference Conditions (target values/thresholds) for the indicator were obtained?	Reference conditions (GES thresholds) are set at 30% on both sides from base population level (i.e. mean population during 1991 - 2000 period). Thus indicator can be considered being at GES if it falls between 70 and 130% (ICES 2013).
Method for determining GES	Currently GES levels have been set arbitrarily at 30% on both sides from base population level (ICES 2013). More ecological studies are needed to set more precise and better justified GES thresholds or to choose different time period to serve as base level.
References	Gregory R.D., van Strien A.J., Vorisek P., Gmelig Meyling A.W., Noble D.G., Foppen R.P.B. et Gibbons D.W. (2005): Developing indicators for European birds. Philosophical Transactions of the Royal Society B 360: 269-288. Gregory, R.D., van Strien, A. (2010): Wild bird indicators: using composite population trends of birds as measures of environmental health. Ornithological Science 9 (1): 3-22. ICES. 2013. Report of the Joint ICES/OSPAR Ad hoc Group on Seabird Ecology (AGSE), 28-29 November 2012, Copenhagen, Denmark. ICES CM 2012/ACOM: 82, 30 pp. Skov. H., Heinänen S., Žydelis R., Bellebaum J., Bzoma S., Dagys M., Durinck J., Garthe S., Grishanov G., Hario M., Kieckbusch J.J., Kube J., Kuresoo A., Larsson K., Luigujõe L., Meissner W., Nehls H.W., Nilsson L., Petersen I.K., Roos M.M., Pihl S., Sonntag N., Stock A., Stipniece A., Wahl J. 2011. Waterbird Populations and Pressures in the Baltic Sea. Nordic Council of Ministers, Copenhagen, 201 pp. Wetlands International 2010. Guidance on waterbird monitoring methodology: Field Protocol for waterbird counting. Report prepared by Wetlands International.

Name of indicator	4.6 Distribution of wintering waterbird species
Type of Indicator	State indicator
Author(s)	Ainars Auniņš, Leif Nilsson, Andres Kuresoo, Leho Luigujõe, Antra Stīpniece
Description of the indicator	This is a set of single species indicators that reflects distribution pattern of wintering populations of particular species. For each species the indicator is expressed as spatial grid with cell values expressing abundance or density of the species. Baltic-wide indicators are calculated separately for each of the following species: *Cygnus olor, Cygnus cygnus, Fulica atra, Anas platyrhynchos, Clangula hyemalis, Melanitta nigra, Melanitta fusca, Somateria mollissima, Aythya marila, Aythya fuligula, Bucephala clangula, Aythya ferina, Mergus albellus, Gavia stellata, Gavia arctica, Mergus merganser, Mergus serrator, Podiceps cristatus, Alca torda, Uria aalge, Cepphus grylle, Larus minutus, Larus ridibundus, Larus canus, Larus argentatus, Larus marinus*. Species lists for national and subbasin versions of these indicators are country and subbasin specific.
Relationship of the indicator to marine biodiversity	The indicator reflects status and distribution of important components of the marine biodiversity in spatially explicit way.
Relevance of the indicator to different policy instruments	MSFD descriptor 1 (species level/distribution range and distribution pattern within range) Habitats Directive (this indicator is needed for Article 17 reporting to report status of typical species of the habitat types 1110 and 1170; Anon 2007). Birds Directive (this indicator is needed for Article 12 reporting as distribution and range of all regularly occurring wintering marine waterbird species.
Relevance to commission decision criteria and indicator	1.1. Species distribution 1.1.1. Distributional range 1.1.2. Distributional pattern within the range
Method(s) for obtaining indicator values	Field data collection: using any of the standard methods designed for offshore counts using ships or planes (Komdeur *et al*. 1992, Petersen *et al*. 2005, Camphuisen *et al.* 2006, Nilsson 2012). Indicator calculation: using density surface modelling approach – GAM or machine learning models based on count data from line transects and spatial covariates (Hedley, Buckland 2004, Elith *et al.* 2011, Drew *et al*. 2011). The result of the computation is a grid where cell values represent estimated abundances or densities of the species in the particular location.
Documentation of relationship between indicator and pressure	Each of the species for which the indicator is calculated respond to different pressures and the indicator reflects these responses spatially. The important pressures and response patterns vary among the species. The indicator (depending on species) responds to an ensemble consisting of combinations of the following pressures: eutrophication oil pollution/shipping by-catch hazardous substances fishing pressure hunting fisheries discards coastal development wind energy sand and gravel extraction climate change Eutrophication has impacts on virtually all the species, also effects of bycatch and oil pollution are widespread among the species. Indicator is able to show local effects of these impacts. The indicator might be scale sensitive in this regard.

	Latest knowledge and summary of related studies are given in Skov *et al*. 2011 Contribution of each particular pressure on a given species can be assessed by including additional explanatory variables characterising the level of the pressure as covariates in the statistical model used for the indicator calculation.
Geographical relevance of indicator	1. Local 2. Regional 3. National waters 4. Baltic Sea wide
How Reference Conditions (target values/thresholds) for the indicator were obtained?	Reference conditions are based on proportion of occupied ecogeographically suitable grid cells. Target level is 100%. The actual GES threshold for each species still needs to be defined.
Method for determining GES	Currently GES levels have not been set. The method itself is based on proportion of ecologically, climatically and geographically suitable grid cells that are occupied by particular species. More ecological studies are needed to set species specific GES thresholds.
References	Anon. 2007. Interpretation manual of European Union Habitats. EUR 27. European Commission DG Environment. Aunins A. (ed.) 2010. [Protected habitats of European Union in Latvia. Identification Handbook]. Latvian Fund for Nature, Riga, 320 pp. Aunins A., Kuresoo A., Luigujoe L. 2012. Distribution and numbers of birds in the Gulf of Riga 2011. Deliverable 3.3. Gulf of Riga as a resource for wind energy –GORWIND. Riga and Tartu, Latvian Fund for Nature and Estonian University of Life Sciences. Camphuysen C.J., Fox A.D., Leopold M.F. & Petersen I.K. 2004. Towards standardised seabirds at sea census techniques in connection with environmental impact assessments for offshore wind farms in the U.K.. Report commissioned by COWRIE for the Crown Estate, London. Royal Netherlands Institute for Sea Research, Texel, 38 pp. Drew C.A., Wiersma Y.F., Huettmann (eds.) F. 2011. Predictive Species and Habitat Modeling in Landscape Ecology. Concepts and applications. 1st edition. Springer, 314 p. Elith. J., Phillips S.J., Hastie T., Dudik M., Chee Y.E., Yates C.J. 2011. A statistical explanation of MaxEnt for ecologists. Diversity and Distributions 17: 43 – 57. Komdeur, J., Bertelsen, J. & Cracknell, G. (Eds.). 1992. Manual for Aeroplane and Ship Surveys of Waterfowl and Seabirds. IWRB Special Publication No. 1, Slimbridge, UK, 37 p. Petersen, I.K, Fox, A.D. 2005. An aerial survey technique for sampling and mapping distributions of waterbirds at sea. Department of Wildlife Ecology and Biodiversity, National Environmental Research Institute. 24 pp. Skov. H., Heinänen S., Žydelis R., Bellebaum J., Bzoma S., Dagys M., Durinck J., Garthe S., Grishanov G., Hario M., Kieckbusch J.J., Kube J., Kuresoo A., Larsson K., Luigujõe L., Meissner W., Nehls H.W., Nilsson L., Petersen I.K., Roos M.M., Pihl S., Sonntag N., Stock A., Stipniece A., Wahl J. 2011. Waterbird Populations and Pressures in the Baltic Sea. Nordic Council of Ministers, Copenhagen, 201 pp.

Illustrative material for indicator documentation	 Figure 1. Example draft indicators for the Gulf of Riga (from Aunins *et al*. 2012): Long-tailed Duck *Clangula hyemalis.*

Name of indicator	**4.7 Distribution of wintering waterbirds (multi-species)**
Type of Indicator	State indicator
Author(s)	Ainars Auniņš, Leif Nilsson, Andres Kuresoo, Leho Luigujõe, Antra Stīpniece
Description of the indicator	This is a multispecies indicator that reflects distribution pattern of wintering waterfowl in the Baltic Sea, national waters or region of interest. The indicator is expressed as spatial grid with cell values expressing abundance or density of wintering waterbirds. For the calculation of the indicator all counts of divers, grebes, cormorants, swans, geese, ducks, mergansers, coots and auks are pooled.
Relationship of the indicator to marine biodiversity	The indicator reflects health of marine ecosystem and importance of its different parts for the marine biodiversity in spatially explicit way.
Relevance of the indicator to different policy instruments	MSFD descriptor 1 (habitat level/condition of the typical species and communities ecosystem level/composition and relative proportions of ecosystem components)
Relevance to commission decision criteria and indicator	1.6.1. Condition of the typical species and communities 1.7. Ecosystem structure 1.7.1. Composition and relative proportions of ecosystem components (habitats and species)
Method(s) for obtaining indicator values	Field data collection**:** using any of the standard methods designed for offshore counts using ships or planes (Komdeur *et al*. 1992, Petersen *et al*. 2005, Camphuisen *et al*. 2006, Nilsson 2012). Indicator calculation: using density surface modelling approach – GAM or machine learning models based on count data from line transects and spatial covariates (Hedley, Buckland 2004, Elith *et al*. 2011, Drew *et al*. 2011). Counts of all species included in this indicator (divers, grebes, cormorants, ducks, geese, swans, mergansers, coots, auks) are pooled. The result of the computation is a grid where each cell value represents estimated abundance/density of all wintering waterbirds in the particular location.
Documentation of relationship between indicator and pressure	Being a multi-species indicator it accumulates the impacts of pressures affecting each of the species used in indicator calculation. The indicator responds to an ensemble consisting of combinations of the following pressures: eutrophication oil pollution/shipping by-catch hazardous substances fishing pressure hunting fisheries discards coastal development wind energy sand and gravel extraction climate change The most pronounced are effects of eutrophication, bycatch and oil pollution. Indicator is able to show local effects of these impacts. The indicator might be scale sensitive in this regard. Latest knowledge and summary of related studies are given in Skov *et al*. 2011. Contribution of each particular pressure on the indicator can be assessed by including additional explanatory variables characterising the level of the pressure as covariates in the statistical model used for the indicator calculation.

Geographical relevance of indicator	1. Local 2. Regional 3. National waters 4. Baltic Sea wide
How Reference Conditions (target values/thresholds) for the indicator were obtained?	Reference conditions are based on proportion of occupied ecogeographically suitable grid cells. Target level is 100%. The actual GES threshold for each species still needs to be defined.
Method for determining GES	Currently GES levels have not been set. The method itself is based on proportion of ecologically, climatically and geographically suitable grid cells that are occupied by wintering waterbirds. More ecological studies are needed to set GES threshold.
References	Aunins A., Kuresoo A., Luigujoe L. 2012. Distribution and numbers of birds in the Gulf of Riga 2011. Deliverable 3.3. Gulf of Riga as a resource for wind energy –GORWIND. Riga and Tartu, Latvian Fund for Nature and Estonian University of Life Sciences. Camphuysen C.J., Fox A.D., Leopold M.F. & Petersen I.K. 2004. Towards standardised seabirds at sea census techniques in connection with environmental impact assessments for offshore wind farms in the U.K.. Report commissioned by COWRIE for the Crown Estate, London. Royal Netherlands Institute for Sea Research, Texel, 38 pp. Drew C.A., Wiersma Y.F., Huettmann (eds.) F. 2011. Predictive Species and Habitat Modeling in Landscape Ecology. Concepts and applications. 1st edition. Springer, 314 p. Elith. J., Phillips S.J., Hastie T., Dudik M., Chee Y.E., Yates C.J. 2011. A statistical explanation of MaxEnt for ecologists. Diversity and Distributions 17: 43 – 57. Komdeur, J., Bertelsen, J. & Cracknell, G. (Eds.). 1992. Manual for Aeroplane and Ship Surveys of Waterfowl and Seabirds. IWRB Special Publication No. 1, Slimbridge, UK, 37 p. Petersen, I.K, Fox, A.D. 2005. An aerial survey technique for sampling and mapping distributions of waterbirds at sea. Department of Wildlife Ecology and Biodiversity, National Environmental Research Institute. 24 pp. Skov. H., Heinänen S., Žydelis R., Bellebaum J., Bzoma S., Dagys M., Durinck J., Garthe S., Grishanov G., Hario M., Kieckbusch J.J., Kube J., Kuresoo A., Larsson K., Luigujõe L., Meissner W., Nehls H.W., Nilsson L., Petersen I.K., Roos M.M., Pihl S., Sonntag N., Stock A., Stipniece A., Wahl J. 2011. Waterbird Populations and Pressures in the Baltic Sea. Nordic Council of Ministers, Copenhagen, 201 pp.

Illustrative material for indicator documentation

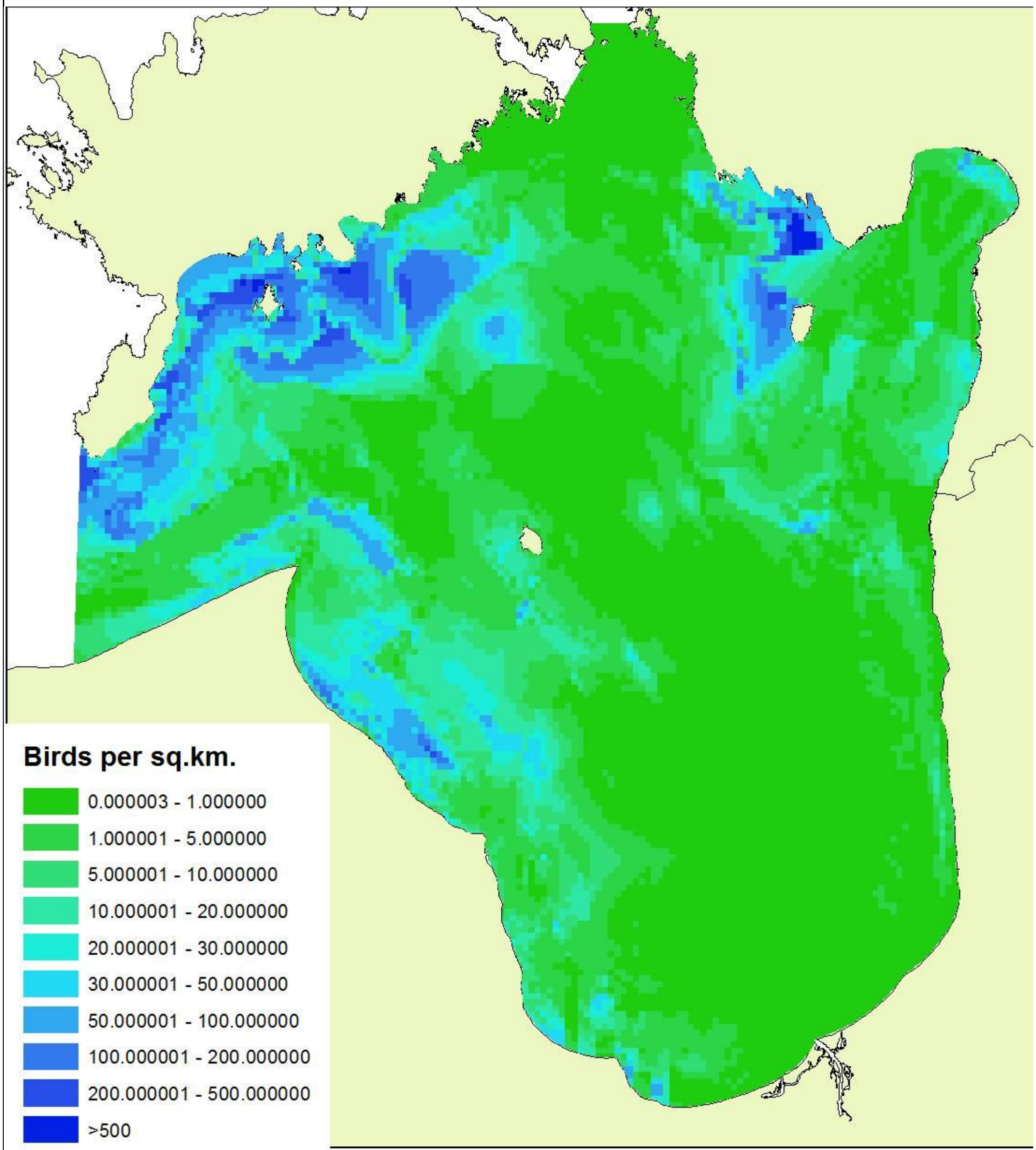
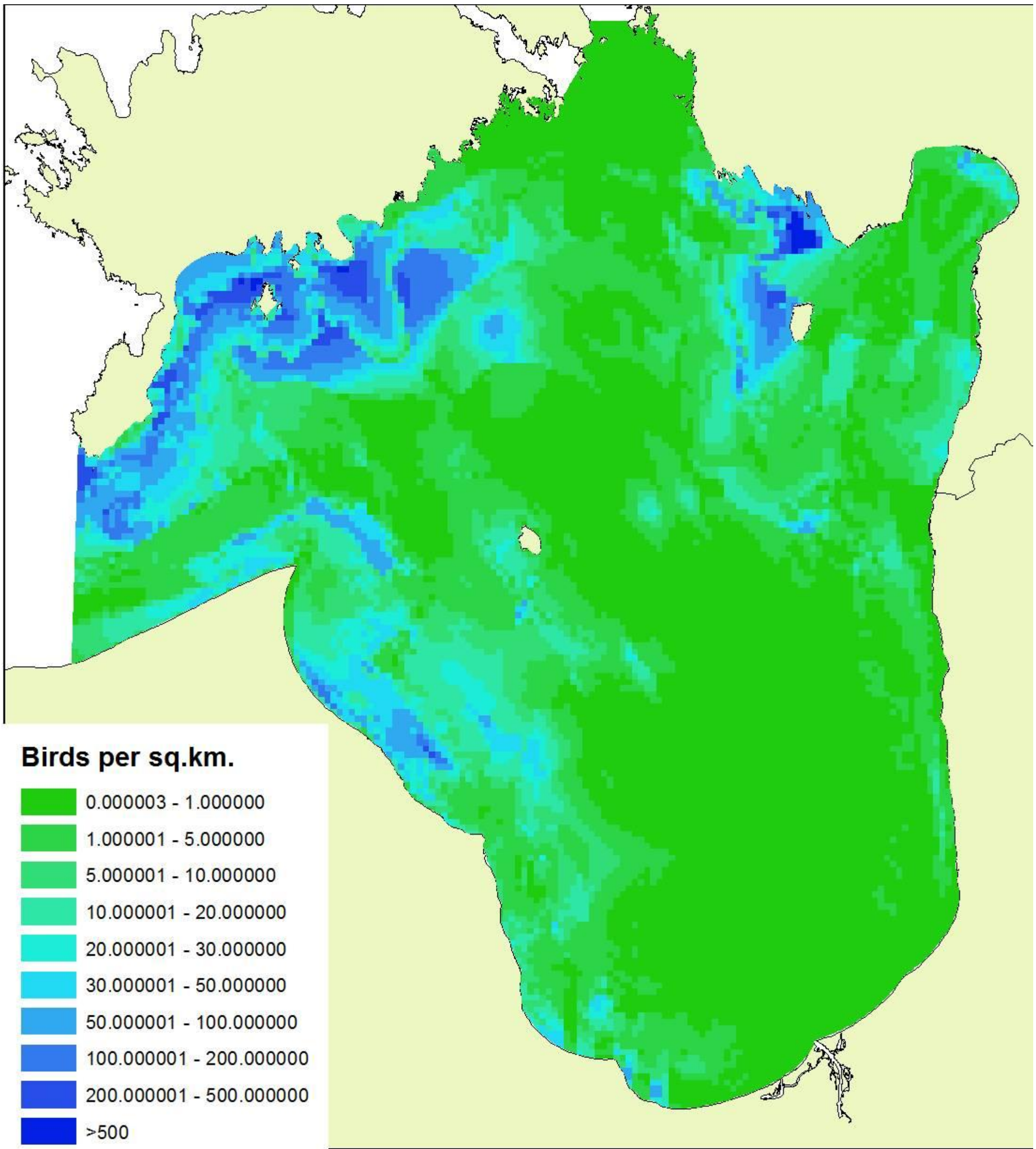


Figure 1. Example draft indicator for the Gulf of Riga in 2012 (from Aunins *et al.* 2012): All waterbirds (divers, grebes, cormorants, swans, geese, ducks, mergansers, coots, auks) in winter 2012.

Name of indicator	**4.8 Distribution of wintering waterbirds of different feeding guilds (multi-species)**
Type of Indicator	State indicator
Author(s)	Ainars Auniņš, Leif Nilsson, Andres Kuresoo, Leho Luigujõe, Antra Stīpniece
Description of the indicator	This is a set of multi-species indicators reflecting distribution pattern of wintering waterfowl belonging to different feeding guilds (niches) in the Baltic Sea. This is an abundance/density based indicator similar to „Distribution of wintering waterbird species" which includes all those waterbird species belonging to a particular feeding niche in the calculation of the each indicator. The indicator is expressed as spatial grid with cell values expressing abundance or density of wintering waterbirds. Following versions of the indicator are suggested: Distribution of benthic herbivores: *Cygnus sp., Fulica atra, Anas sp, Anser sp., Branta sp.* Distribution of benthic invertebrate feeders: *Clangula hyemalis, Melanitta nigra, Melanitta fusca, Somateria mollissima, Polysticta stelleri, Aythya marila, Aythya fuligula, Bucephala clangula, Aythya ferina* Distribution of fish feeders: *Gavia stellata, Gavia arctica, Mergus merganser, Mergus serrator, Podiceps cristatus, Alca torda, Uria aalge, Cepphus grylle* Distribution of gulls*: Larus minutus, Larus ridibundus, Larus canus, Larus argentatus, Larus fuscus, Larus marinus* For the calculation of the indicators all counts of corresponding species (species groups) are pooled.
Relationship of the indicator to marine biodiversity	The indicator reflects health of marine ecosystem and importance of its different parts for components of marine biodiversity (functional groups) in spatially explicit way.
Relevance of the indicator to different policy instruments	MSFD descriptors 1 (habitat level/condition of the typical species and communities and ecosystem level/proportions of ecosystem components, condition of typical species and communities) and 4 (abundance distribution of functionally important groups of species).
Relevance to commission decision criteria and indicator	1.6.1. Condition of the typical species and communities 1.7. Ecosystem structure 1.7.1. Composition and relative proportions of ecosystem components (habitats and species)
Method(s) for obtaining indicator values	Field data collection: using any of the standard methods designed for offshore counts using ships or planes (Komdeur *et al*. 1992, Petersen *et al*. 2005, Camphuisen *et al*. 2006, Nilsson 2012). Indicator calculation: using density surface modelling approach – GAM or machine learning models based on count data from line transects and spatial covariates (Hedley, Buckland 2004, Elith *et al.* 2011, Drew *et al.* 2011). Counts of all species belonging to the particular functional (feeding niche) group are pooled. The result of the computation is a grid where each cell value represent estimated abundance/density of waterbirds of the functional group in the particular location.
Documentation of relationship between indicator and pressure	Each functional (feeding niche) group of species respond to different pressures. Being multi-species indicators each of them accumulates the impacts of pressures affecting each of the species used in indicator calculation. The indicator responds to an ensemble consisting of combinations of the following pressures: eutrophication oil pollution/shipping by-catch hazardous substances fishing pressure hunting fisheries discards

	coastal development wind energy sand and gravel extraction climate change The most pronounced are effects of eutrophication, bycatch and oil pollution Indicator is able to show local effects of these impacts. The indicator might be scale sensitive in this regard. Latest knowledge and summary of related studies are given in Skov *et al.* 2011. Contribution of each particular pressure on the indicator can be assessed by including additional explanatory variables characterising the level of the pressure as covariates in the statistical model used for the indicator calculation. Responses of this indicator to different ecogeographical variables for the Gulf of Riga are provided in Aunins *et al*. 2012.
Geographical relevance of indicator	1. Local 2. Regional 3. National waters 4. Baltic Sea wide
How Reference Conditions (target values/thresholds) for the indicator were obtained?	Reference conditions are based on proportion of occupied ecogeographically suitable grid cells. Target level is 100%. The actual GES threshold for each species still needs to be defined.
Method for determining GES	Currently GES levels have not been set. The method itself is based on proportion of ecologically, climatically and geographically suitable grid cells that are occupied by wintering waterbirds of the particular functional (feeding niche) groups. More ecological studies are needed to set GES threshold.
References	Aunins A., Kuresoo A., Luigujoe L. 2012. Distribution and numbers of birds in the Gulf of Riga 2011. Deliverable 3.3. Gulf of Riga as a resource for wind energy –GORWIND. Riga and Tartu, Latvian Fund for Nature and Estonian University of Life Sciences. Camphuysen C.J., Fox A.D., Leopold M.F. & Petersen I.K. 2004. Towards standardised seabirds at sea census techniques in connection with environmental impact assessments for offshore wind farms in the U.K.. Report commissioned by COWRIE for the Crown Estate, London. Royal Netherlands Institute for Sea Research, Texel, 38 pp. Drew C.A., Wiersma Y.F., Huettmann (eds.) F. 2011. Predictive Species and Habitat Modeling in Landscape Ecology. Concepts and applications. 1st edition. Springer, 314 p. Elith. J., Phillips S.J., Hastie T., Dudik M., Chee Y.E., Yates C.J. 2011. A statistical explanation of MaxEnt for ecologists. Diversity and Distributions 17: 43 – 57. Komdeur, J., Bertelsen, J. & Cracknell, G. (Eds.). 1992. Manual for Aeroplane and Ship Surveys of Waterfowl and Seabirds. IWRB Special Publication No. 1, Slimbridge, UK,37 p. Petersen, I.K, Fox, A.D. 2005. An aerial survey technique for sampling and mapping distributions of waterbirds at sea. Department of Wildlife Ecology and Biodiversity, National Environmental Research Institute. 24 pp. Skov. H., Heinänen S., Žydelis R., Bellebaum J., Bzoma S., Dagys M., Durinck J., Garthe S., Grishanov G., Hario M., Kieckbusch J.J., Kube J., Kuresoo A., Larsson K., Luigujõe L., Meissner W., Nehls H.W., Nilsson L., Petersen I.K., Roos M.M., Pihl S., Sonntag N., Stock A., Stipniece A., Wahl J. 2011. Waterbird Populations and Pressures in the Baltic Sea. Nordic Council of Ministers, Copenhagen, 201 pp.

Illustrative material for indicator documentation	 Figure 1. Example draft indicator for the Gulf of Riga in 2012 (from Aunins *et al.* 2012): Distribution of benthic invertebrate feeders in winter 2012

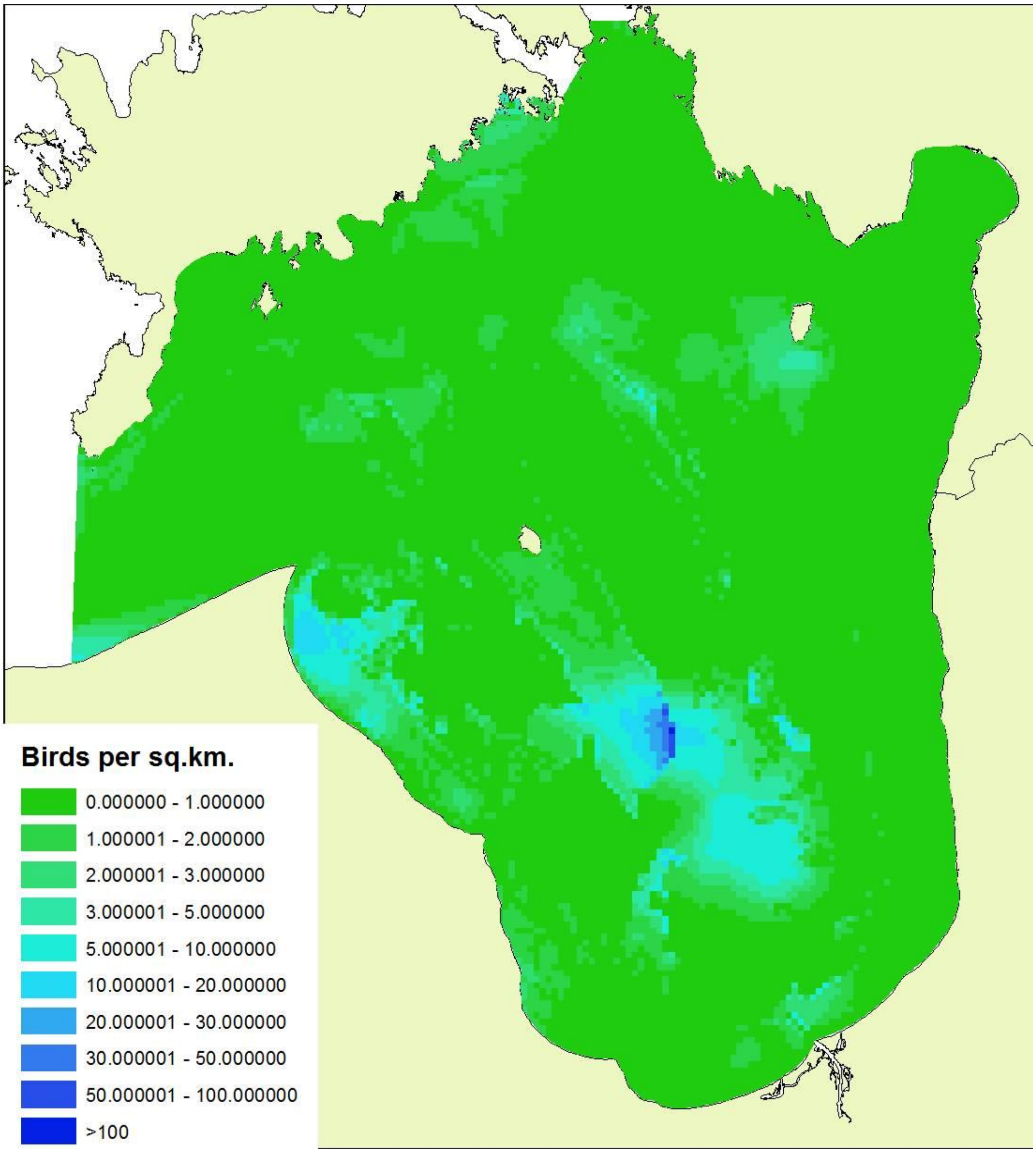


Figure 2. Example draft indicator for the Gulf of Riga in 2012 (from Aunins *et al.* 2012): Distribution of gulls (all *Larus* species) in winter 2012

Name of indicator	**4.9 Distribution of breeding waterbird species**
Type of Indicator	State indicator
Author(s)	Andres Kuresoo, Ainars Auniņš, Leif Nilsson, Leho Luigujõe, Antra Stīpniece
Description of the indicator	This set of single species indicators reflects distribution pattern of breeding populations of particular species. For each species the indicator is expressed as spatial grid with cell values expressing abundance or density of the species. Baltic-wide indicators are calculated separately for each of the following species: Great Cormorant, Common Shelduck, Common Eider, Scaup, Velvet Scoter, Sandwich Tern. Species lists for national and subbasin versions of these indicators are country and subbasin specific.
Relationship of the indicator to marine biodiversity	The indicator reflects status and distribution of important components of the marine biodiversity in spatially explicit way. Change of breeding distribution of population reflects the habitat changes, availability of food resources, and pressures related to climate change.
Relevance of the indicator to different policy instruments	The indicator addresses the population condition as required for assessments of the MSFD qualitative descriptor 1 (biodiversity) (Anon 2008) and stated in the EC Decision 477/2010/EU for the MSFD (Anon. 2010). The indicator can also be used for the assessment of the MSFD qualitative descriptor 4 (food webs) as recommended by the MSFD Task Group 4 (Rogers *et al.* 2010). The indicator addresses the HELCOM ecological objective 'Viable populations of species' which is part of the biodiversity goal 'Favourable conservation status of Baltic biodiversity' (HELCOM 2007). HELCOM CORESET: there is general agreement for the need of this indicator.' Birds Directive (this indicator is needed for Article 12 reporting as distribution and range of all regularly occurring breeding marine waterbird species.
Relevance to commission decision criteria and indicator	1.1. Species distribution 1.1.1. Distributional range 1.1.2. Distributional pattern within the range
Method(s) for obtaining indicator values	Field data collection**:** using any of the standard methods designed for breeding bird surveys such as bird count data (island birds), but also breeding bird atlases from large areas (presence–absence data). Indicator calculation: using density surface modelling approach – GAM or machine learning models based on count data from line transects and spatial covariates (Hedley, Buckland 2004, Elith *et al.* 2011, Drew *et al*. 2011). The result of the computation is a grid where cell values represent estimated abundances or densities of the species in the particular location. The centroids of the historical and present range are compared in range shift analyses, from which the geodesic distance (D) between the two centroids, and the initial azimuth (h) of the geodesic path from the centroids (historical/present range) are calculated Huntley *et al*. 2008).
Documentation of relationship between indicator and pressure	Each of the species for which the indicator is calculated is affected by all pressures acting on species forming the indicator. Thus the indicator responds to ensemble of following pressures: coastal development eutrophication hazardous substances predation by non-native species (e.g. American Mink) fisheries discards climate change To a lesser extent also: oil pollution/shipping by-catch wind energy

	sand and gravel extraction Latest knowledge and summary of related studies on response of marine waterbird species to important pressures are given in Skov *et al.* 2011. Contribution of each particular pressure on a given species can be assessed by including additional explanatory variables characterising the level of the pressure as covariates in the statistical model used for the indicator calculation.
Geographical relevance of indicator	1. Local 2. Regional 3. National waters 4. Baltic Sea wide
How Reference Conditions (target values/thresholds) for the indicator were obtained?	Reference conditions are based on proportion of occupied ecogeographically suitable grid cells. Target level is 100%. The actual GES threshold for each species still needs to be defined.
Method for determining GES	Currently GES levels have not been set. The method itself is based on proportion of ecologically, climatically and geographically suitable grid cells that are occupied by particular species. More ecological studies are needed to set species specific GES thresholds.
References	Anon. (2008a): Directive 2008/56/EC of the European Parliament and the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). Official Journal of the European Union, L 164/19, 25.06.2008. Anon. (2010): Commission decision of 1 September 2010 on criteria and methodological standards on good environmental status of marine waters (2010/477/EU). OJ L 232/14, 2.9.2010. Aunins A., Kuresoo A., Luigujoe L. 2012. Distribution and numbers of birds in the Gulf of Riga 2011. Deliverable 3.3. Gulf of Riga as a resource for wind energy –GORWIND. Riga and Tartu, Latvian Fund for Nature and Estonian University of Life Sciences. Bergman G (1980): Single-breeding versus colonial breeding in the Caspian Tern *Hydroprogne caspia*, the Common Tern *Sterna hirundo* and the Arctic Tern *Sterna paradisaea*. (Räyskän, kalatiiran ja lapintiiran pesimisestä yksittäispareina ja yhdyskunnittain). – Ornis Fennica 57: 141–152. Drew C.A., Wiersma Y.F., Huettmann (eds.) F. 2011. Predictive Species and Habitat Modeling in Landscape Ecology. Concepts and applications. 1st edition. Springer, 314 p. Edler L, Kononen K & Kuosa H (1996) Harmful algae. In: HELCOM (1996), Third periodic assessment of the state of the marine environment of the Baltic Sea, Chapter 8.1. Available at: http://www.baltic.vtt.fi/balticinfo/index.html Hario M, Kastepold T, Kilpi M, Staav R, & Stjernberg T (1987): Status of Caspian Terns *Sterna caspia* in the Baltic. – Ornis Fennica 64: 154–156. HELCOM (2012) Development of a set of core indicators: Interim report of the HELCOM CORESET project, PART A. Description of the selection process. Baltic Sea Environment Proceedings No. 129 A. Available at: www.helcom.fi/publications. Hokkanen T (2012) Eastern Gulf of Finland, seabird populations, ornithological surveys. Nature Protection Publications of Metsähallitus. Series A 195. [In Finnish, abstract in English and Swedish] Huntley B, Collingham YC, Willis SG, Green RE (2008) Potential Impacts of Climatic Change on European Breeding Birds. PLoS ONE 3(1): e1439. Nordström, M., Högmander, J., Laine, J., Nummelin, J., Laanetu, N., Korpimäki, E. 2003. Effects of feral mink removal on seabirds, waders and passerines on small islands in the Baltic Sea. Biological Conservation, 109: 359–368. Ottvall R, Edenius L, Elmberg J, Engström H, Green M, Holmqvist N, Lindström Å, Tjernberg M & Pärt T (2008) Populationstrender för fågelarter som häckar i Sverige. Naturvårdsverket

Rapport 5813. [In Swedish, summary in English]

Rogers, S., Casini, M., Cury, P., Heath, M., Irigoien, X., Kuosa, H. *et al.* (2010) MSFD, Task Group 4 Report, Food webs. European Commission Joint Research Center and ICES. Available at: http://www.ices.dk/projects/projects.asp.

Skov. H., Heinänen S., Žydelis R., Bellebaum J., Bzoma S., Dagys M., Durinck J., Garthe S., Grishanov G., Hario M., Kieckbusch J.J., Kube J., Kuresoo A., Larsson K., Luigujõe L., Meissner W., Nehls H.W., Nilsson L., Petersen I.K., Roos M.M., Pihl S., Sonntag N., Stock A., Stipniece A., Wahl J. 2011. Waterbird Populations and Pressures in the Baltic Sea. Nordic Council of Ministers, Copenhagen, 201 pp.

Illustrative material for indicator documentation

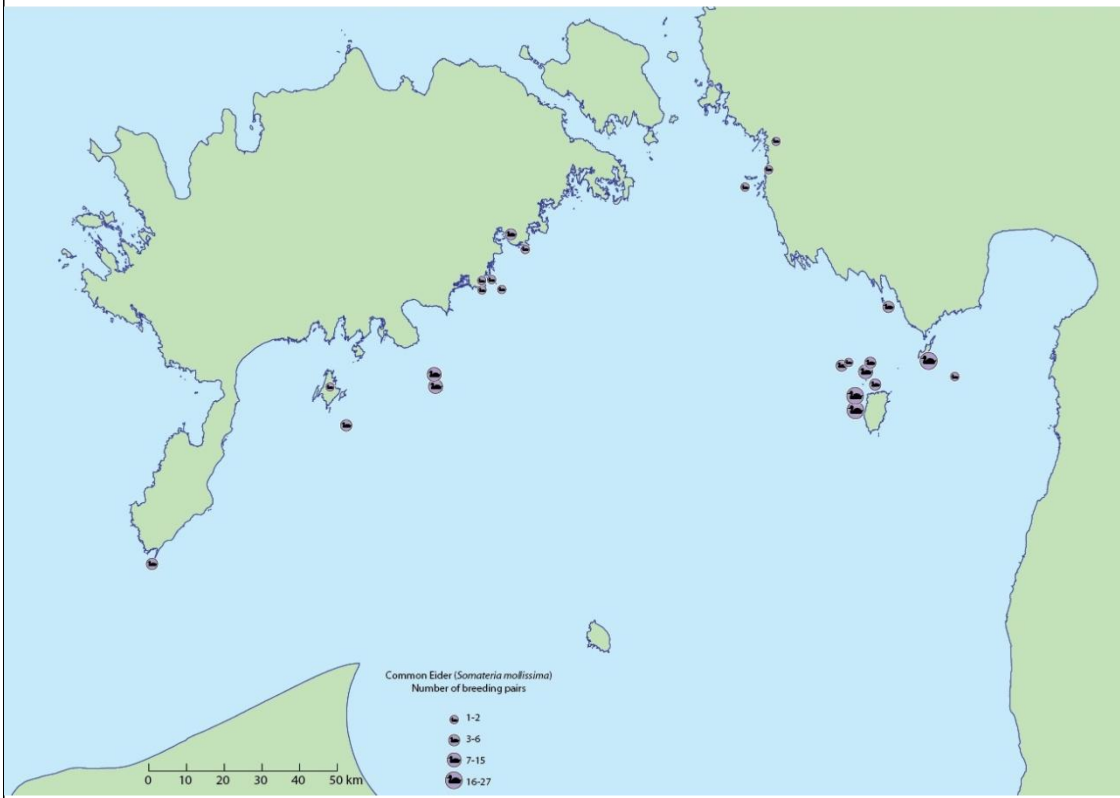


Figure 1. Distribution and numbers of breeding Common Eider *Somateria mollissima* in the Gulf of Riga (image from Aunins *et al*. 2012).

Name of indicator	**4.10 Breeding success: clutch and brood size of breeding species**
Type of Indicator	State indicator
Author(s)	Andres Kuresoo, Ainars Auniņš, Leif Nilsson, Leho Luigujõe, Antra Stīpniece, Martti Hario
Description of the indicator	This is a set of single species indicators and it reflects breeding success and productivity of the particular species. Indicator has two values: 1. clutch size or number of eggs per clutch laid 2. number of juveniles per breeding female. Breeding success reflects population condition of particular species - productivity, survival of nests, ability of population to re-estabilsh its population after losses. The breeding success data sets are still limited and more sites and species in more countries need to be monitored. Indicators are calculated separately for each of the following species: *Phalacrocorax carbo, Tadorna tadorna, Melanitta fusca, Somateria mollissima, Larus canus, Larus fuscus, Sterna caspia, Sterna hirundo, Sterna paradisaea, Sterna sandvicensis, Sterna albifrons*. Species lists for national and subbasin levels of these indicators are country and subbasin specific.
Relationship of the indicator to marine biodiversity	Breeding success reflects the availability of food resources, abundance of predators (incl. introduced species) and human disturbance, but also pressures related to climate change. Breeding success of the waterbirds is affected by bioaccumulated hazardous substances, particularly organochlorines and oil in the water.
Relevance of the indicator to different policy instruments	The indicator addresses the population condition as required for assessments of the MSFD qualitative descriptor 1 (biodiversity) (Anon. 2008) and stated in the EC Decision 477/2010/EU for the MSFD (Anon. 2010). The indicator can also be used for the assessment of the MSFD qualitative descriptor 4 (food webs) as recommended by the MSFD Task Group 4 (Rogers *et al.* 2010). The indicator addresses the HELCOM ecological objective 'Viable populations of species' which is part of the biodiversity goal 'Favourable conservation status of Baltic biodiversity' (HELCOM 2007). HELCOM CORESET: there is general agreement for the need of this indicator.
Relevance to commission decision criteria and indicator	1.3. Population condition 1.3.1. Population demographic characteristics (e .g. body size or age class structure, sex ratio, fecundity rates, survival/ mortality rates) 1.6.1. Condition of the typical species and communities
Method(s) for obtaining indicator values	Field data collection: to obtain clutch size of the species, searching for nests in sample plots and recording clutch size is needed. In case of larger colonies that cannot be taken whole as a sample plot (i.e. all nests found and clutch size recorded) a sampling within the colony is needed. Random or stratified random sampling design id needed to obtain reliable data. To obtain brood size (number of young per breeding female) for the species number of breeding pairs and number of young per brood (brood size) need to be recoded. Random or stratified random sampling design id needed to obtain reliable data. For game species the proportion juveniles can be estimated from game bags; - proportion of juvenile individuals Indicator calculation: The clutch size is calculated as the mean number of eggs per nest. The brood size is calculated as The measured parameter is defined as 'number of juveniles per breeding females'. Several field methods can be applied, for example: - number of fledglings per breeding females (field counts); - the proportion of Common Eider juveniles could be estimated from game bags; - proportion of juvenile individuals in the wintering population of Long-tailed Ducks could be assessed from photographs.
Documentation of relationship between indicator and pressure	This indicator is more sensitive to short term changes and processes within the population (such as problems with productivity or survival of nests) that will impact abundance of the population in longer term than abundance indicators (either in breeding or nonbreeding sea-

	sons). The pressures associated with this clutch size are those affecting body condition of female birds such as decreased food stocks or quality of food items and decline in area of suitable feeding habitats. The pressures associated with this clutch size are predation and disturbance during nesting period.
Geographical relevance of indicator	1. Local 2. Regional 3. National waters 4. Baltic Sea wide
How Reference Conditions (target values/thresholds) for the indicator were obtained?	Target indicator values both for clutch size and brood size are species specific. The actual GES targets and boundaries have not been set. Meanwhile a trend based GES reference conditions can be used - if the trend in the clutch size and brood size is negative, the indicator cannot be at GES.
Method for determining GES	More ecological studies are needed to set species specific GES targets and boundary values for age ratio. While precise GES targets and levels cannot be set, a negative trend in clutch and brood size suggest that the indicator can be considered as not being at GES.
References	Anon. (2008a): Directive 2008/56/EC of the European Parliament and the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). Official Journal of the European Union, L 164/19, 25.06.2008. Anon. (2010): Commission decision of 1 September 2010 on criteria and methodological standards on good environmental status of marine waters (2010/477/EU). OJ L 232/14, 2.9.2010. Bergman G (1980): Single-breeding versus colonial breeding in the Caspian Tern *Hydroprogne caspia*, the Common Tern *Sterna hirundo* and the Arctic Tern *Sterna paradisaea*. (Räyskän, kalatiiran ja lapintiiran pesimisestä yksittäispareina ja yhdyskunnittain). – Ornis Fennica 57: 141–152. Cury PM, Boyd IL, Bonhommeau S, Anker-Nielsen T *et al*. (2011) Global Seabird Response to Forage Fish Depletion—One-Third for the Birds. Science 334: 1703-1705. Edler L, Kononen K & Kuosa H (1996) Harmful algae. In: HELCOM (1996), Third periodic assessment of the state of the marine environment of the Baltic Sea, Chapter 8.1. Available at: http://www.baltic.vtt.fi/balticinfo/index.html Ekroos J, Fox AD, Christensen TK, Petersen IK, Kilpi M, Jónsson JE, Green M, Laursen K, Cervencl A, de Boer P, Nilsson L, Meissner W, Garthe S & Öst M (2012) Declines amongst breeding Eider *Somateria mollissima* numbers in the Baltic/Wadden Sea flyway. Ornis Fennica 89: 1-10. Hario M, Kastepold T, Kilpi M, Staav R, & Stjernberg T (1987): Status of Caspian Terns *Sterna caspia* in the Baltic. – Ornis Fennica 64: 154–156. HELCOM (2012) Development of a set of core indicators: Interim report of the HELCOM CORESET project, PART A. Description of the selection process. Baltic Sea Environment Proceedings No. 129 A. Available at: www.helcom.fi/publications. Hokkanen T (2012) Eastern Gulf of Finland, seabird populations, ornithological surveys. Nature Protection Publications of Metsähallitus. Series A 195. [In Finnish, abstract in English and Swedish] Nordström, M., Högmander, J., Laine, J., Nummelin, J., Laanetu, N., Korpimäki, E. 2003. Effects of feral mink removal on seabirds, waders and passerines on small islands in the Baltic Sea. Biological Conservation, 109: 359–368. Ottvall R, Edenius L, Elmberg J, Engström H, Green M, Holmqvist N, Lindström Å, Tjernberg M & Pärt T (2008) Populationstrender för fågelarter som häckar i Sverige. Naturvårdsverket

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Österblom H, Bignert A, Fransson T & Olsson O (2001) A decrease in fledging body mass in common guillemot *Uria aalge* chicks in the Baltic Sea. Marine Ecology Progress Series 224: 305-309.

Österblom H, Olsson O, Blenckner T & Furness RW (2008) Junk-food in marine ecosystems. Oikos 117: 967-977

Illustrative material for indicator documentation

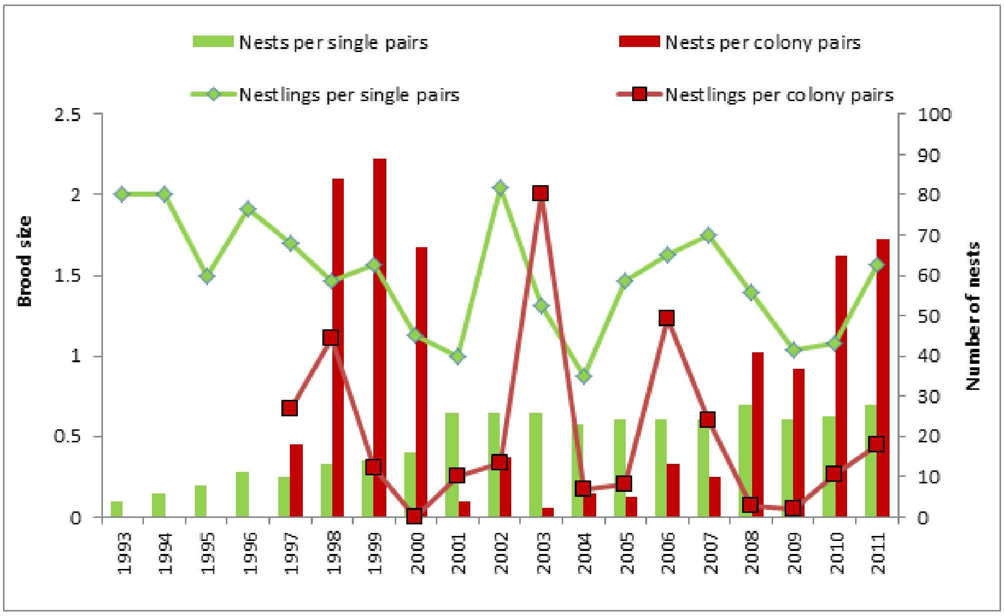


Figure 1. Brood size and the number of nests of Caspian Tern of single pairs and colony breeders in the eastern Gulf of Finland. Modified from Hokkanen (2012).

The brood size of Caspian Tern in the Eastern Gulf of Finland has fluctuated during the time series and the poor nestling production of the colony-breeders is especially noteworthy. The greatest threats to the breeding success are bad weather conditions and predation by Herring Gull, American mink and White-tailed Eagle and to a smaller extent disturbance by boating and landing on breeding sites.

Name of indicator	**4.11 Age/sex ratio of waterbird species (ARI/SRI)**
Type of Indicator	State indicator
Author(s)	Ainars Auniņš, Leif Nilsson, Andres Kuresoo, Leho Luigujõe, Antra Stīpniece
Description of the indicator	This indicator consists of two single species indicators reflecting population condition of particular species. Separate indices are calculated for age ratios and sex ratios. Indices are calculated for all species holding considerable populations in the Baltic Sea in any of the seasons where they have sex and/or age specific differences in plumage that are distinguishable using the selected data collection method. The aim of these indicators is to give early warning on negative demographic processes going on in the population of the particular species. The age ratio indicator serves as a proxy to information on productivity and age specific survival of the species. These indices are known to be more sensitive and able give earlier warning than changes in the species abundance. Age ratio indicator is calculated separately for each of the following species: *Cygnus olor, Melanitta fusca, Melanitta nigra, Clangula hyemalis, Bucephala clangula, Somateria mollissima, Polysticta stelleri, Aythya marila, Phalacrocorax carbo*. National indicators may have a subset of the species listed above. Sex ratio indicator is calculated separately for each of the following species: *Melanitta fusca, Melanitta nigra, Clangula hyemalis, Bucephala clangula, Somateria mollissima, Polysticta stelleri, Aythya marila*. National indicators may have a subset of the species listed above.
Relationship of the indicator to marine biodiversity	The indicator reflects status (population condition) of important components of the marine biodiversity. The indicator gives an early warning on negative demographic processes going on in the population.
Relevance of the indicator to different policy instruments	MSFD descriptor 1 (species level – population condition, demographic characteristics, habitat level - condition of typical species and communities). HELCOM CORESET (general agreement for the need of this indicator at least for Long-tailed Duck *Clangula hyemalis*).
Relevance to commission decision criteria and indicator	1.3. Population condition 1.3.1. Population demographic characteristics (e .g. body size or age class structure, sex ratio, fecundity rates, survival/mortality rates) 1.6.1. Condition of the typical species and communities
Method(s) for obtaining indicator values	Field data collection**:** There are several options for data collection depending on target species. For *game species*, data can be collected from game bags by identifying sex and age of the birds shot. For *non-game species* or *game species that are rarely shot* or to *collect data outside the hunting season*, photographs from random flocks of birds (or random single birds) can be taken using high resolution DSLRs with long lens (focal length 300mm and more). Data can be collected during other data collection events carried out for collection of abundance data. Boat or ground counts are most suitable for collection of data for sex and age ratio, however it needs additional person for collection of images. Organising separate ground surveys is feasible while separate boat surveys for sex/age data collection might be cost ineffective. The obtained images are processed providing figures for flock size, number of adult birds, number of juvenile/immature birds and their sexes where appropriate (K. Larsson pers.comm.). Indicator calculation**:** The *age ratio* is calculated as proportion of juveniles in the postbreeding population. If young females are inseparable from adult females in images, the age ratio is calculated dividing juvenile males with number of adult males. The *sex ratio* is calculated dividing number of females with number of males.
Documentation of relationship between indicator and pressure	This indicator is more sensitive to short term changes such as problems with productivity or survival of young during the breeding season than abundance indicators (either in breeding or nonbreeding seasons). Biased sex proportions in the population suggest either different mortality of sexes or that

	sex ratio of hatched chicks is biased. Decreasing female proportion in a population suggests higher mortality of females, usually due to increased predation during breeding season. Lehikoinen *et al.* (2008) has shown that population decline of Eider has been accompanied by increasing male bias in the population that can be explained by increased female mortality during breeding season as a result of increased predation by both native (White-tailed Eagle) and invasive alien species (American Mink). Biased sex ratios of declining waterbird populations have been reported also for Scaup (Afton, Anderson 2001) and Stellers Eider (Flint *et al.* 2000). Decreasing proportion of young (1st year) birds shows reduced breeding performance of the species. The pressures associated with this are predation, insufficient food stocks, contamination of food sources, habitat loss, coastal development.
Geographical relevance of indicator	3. National waters 4. Baltic Sea wide
How Reference Conditions (target values/thresholds) for the indicator were obtained?	Target sex ratio indicator value for monogamous species is 1 as the breeding potential of such species is maximal when the sex ratio is equal (Nunney 1999). GES thresholds should be put on both sides of the target value. The actual GES threshold for each species still needs to be defined. Meanwhile trend based GES reference conditions can be used - if there is a significant trend in sex ratio and the actual indicator values are driving away from the GES target value, the indicator cannot be at GES. Target age ratio indicator value is species specific. The actual GES targets and boundaries have not been set. Meanwhile trend based GES reference conditions can be used - if the trend in the proportion of young in the population is negative, the indicator cannot be at GES.
Method for determining GES	Currently species specific GES levels have not been set. The GES target for sex ratio has been set at value where a monogamous population theoretically has maximal breeding potential (Nunney 1999). However, more ecological studies are needed to set species specific GES boundary values on both sides of the target value. While precise GES levels cannot be set, an existence of a trend where indicator values are driving away from the target, suggests that the indicator can be considered as not being at GES. More ecological studies are needed to set species specific GES targets and boundary values for age ratio. While precise GES targets and levels cannot be set, a negative trend in juvenile proportion in the population suggest that the indicator can be considered as not being at GES.
References	Lehikoinen A., Christensen T. K., Öst M., Kilpi M., Saurola P., Vattulainen A. 2008. Large-scale change in the sex ratio of a declining eider *Somateria mollissima* population. Wildlife biology 14: 288-301. Flint P.L., Petersen M.R., Dau C.P., Hines J.E., Nichols J.D. 2000. Annual survival and site fidelity of Steller's Eiders molting along the Alaska Peninsula. Journal of Wildlife Management 64: 261 - 268. Nunney L. 1999. The effective size of a hierarchically structured population. Evolution 53: 1 - 10. Skov. H., Heinänen S., Žydelis R., Bellebaum J., Bzoma S., Dagys M., Durinck J., Garthe S., Grishanov G., Hario M., Kieckbusch J.J., Kube J., Kuresoo A., Larsson K., Luigujõe L., Meissner W., Nehls H.W., Nilsson L., Petersen I.K., Roos M.M., Pihl S., Sonntag N., Stock A., Stipniece A., Wahl J. 2011. Waterbird Populations and Pressures in the Baltic Sea. Nordic Council of Ministers, Copenhagen, 201 pp.

Illustrative material for indicator documentation

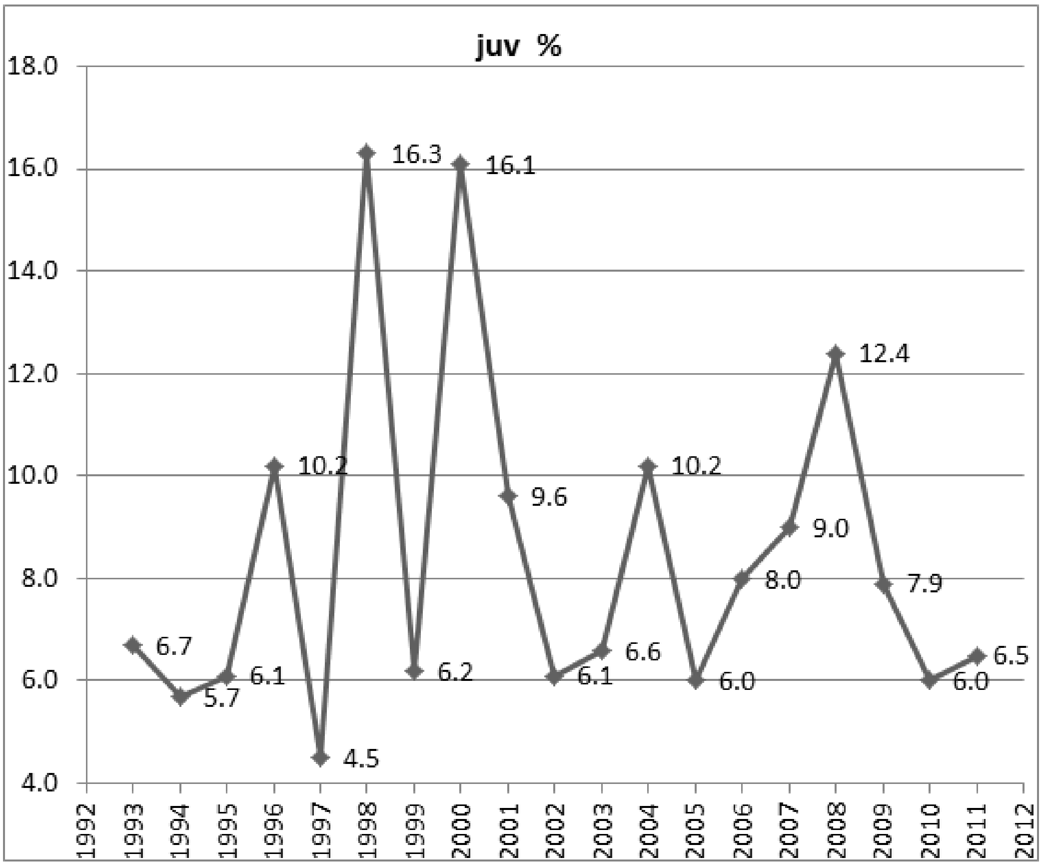
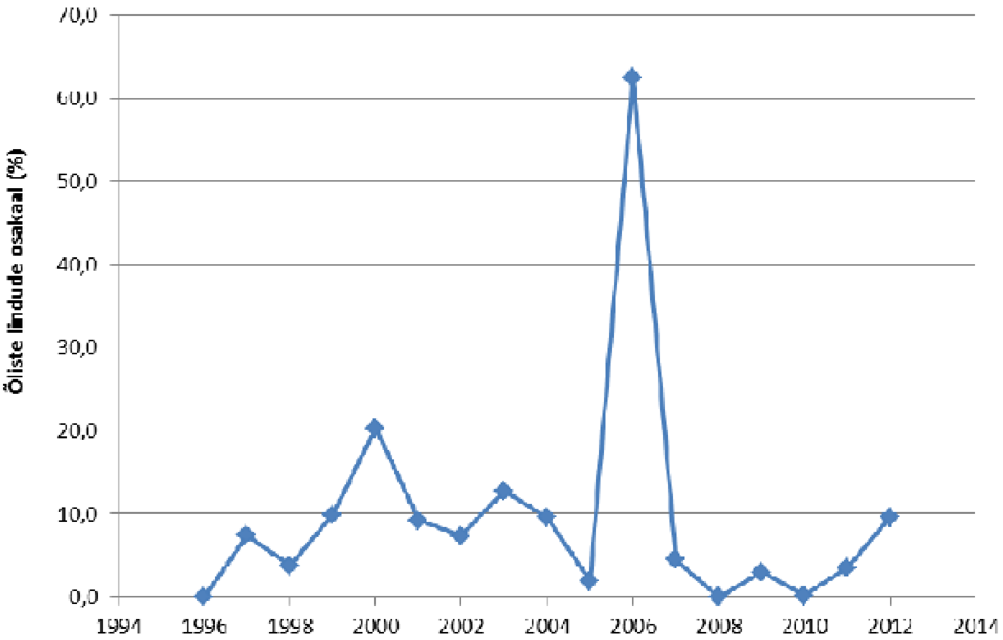
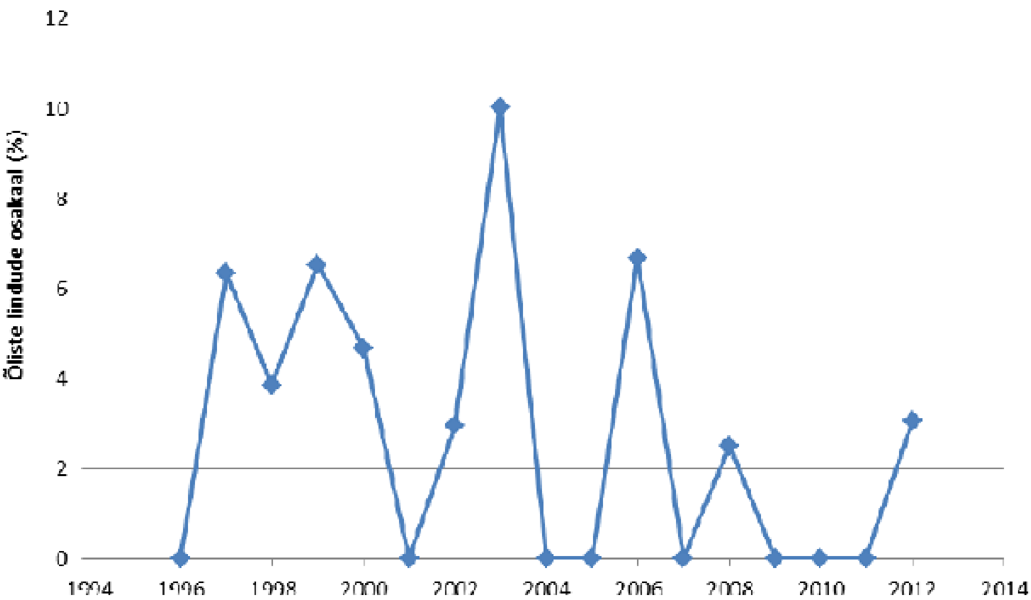


Figure 1. Example draft ARI indicator. Age ratio indicator (% juv birds) calculated for the wintering population of the Mute Swan *Cygnus olor* in Estonia 1992-2012

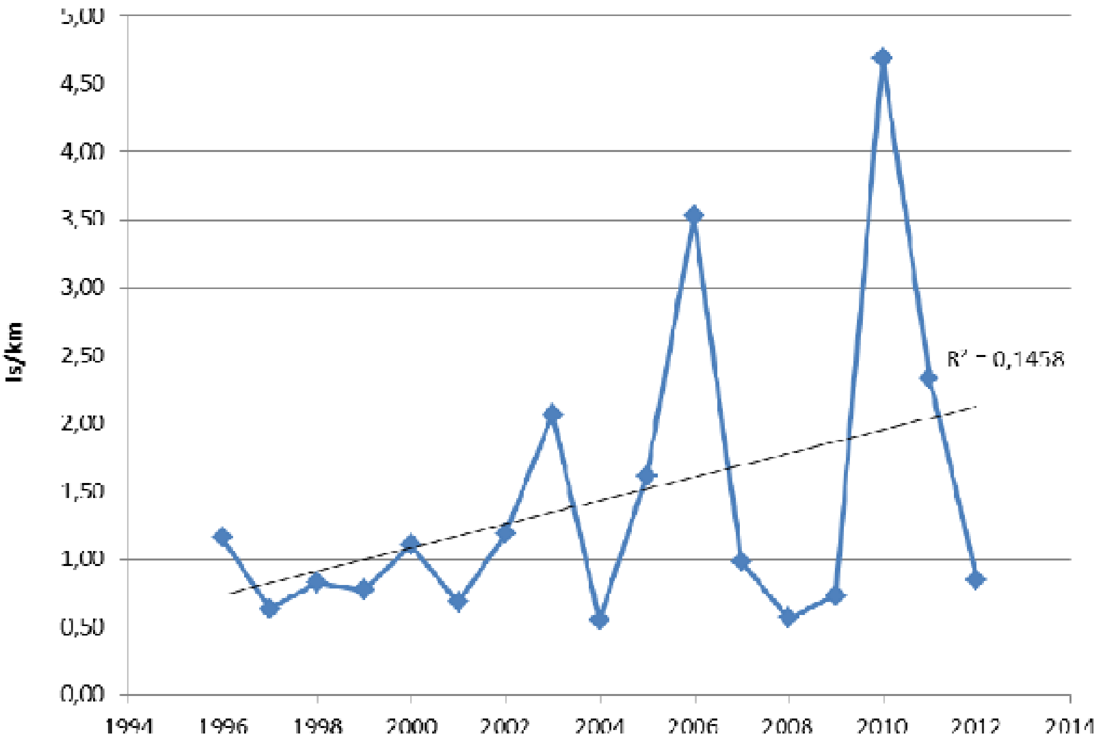
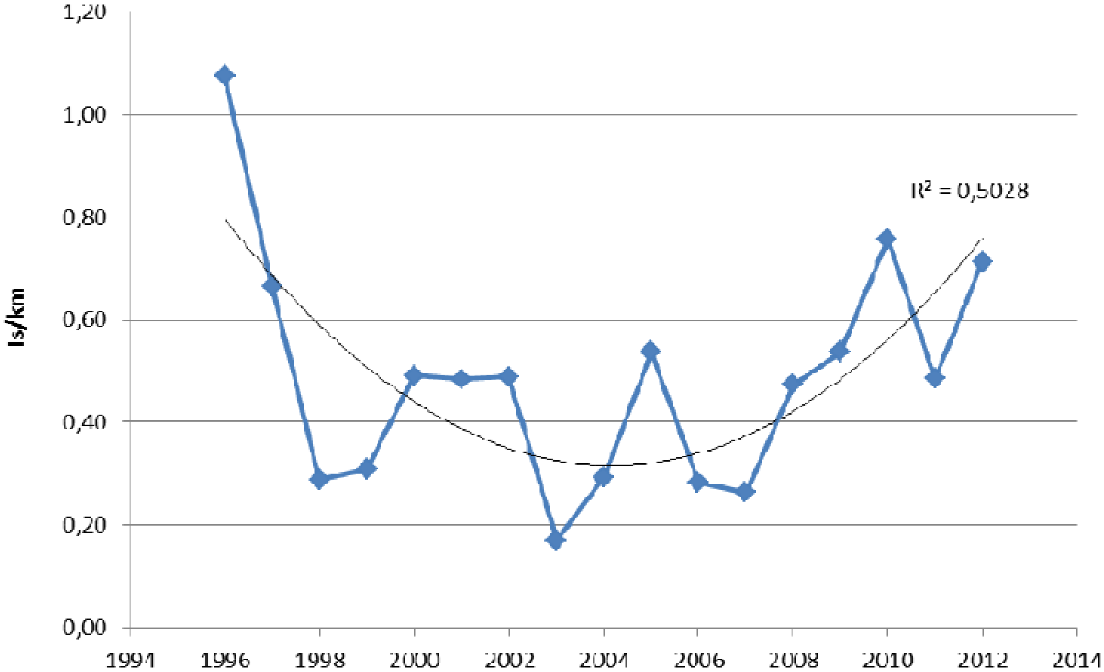
Name of indicator	**4.12 Proportion of oiled waterbirds**
Type of Indicator	Pressure indicator
Author(s)	Ainars Auniņš, Leif Nilsson, Andres Kuresoo, Leho Luigujõe, Antra Stīpniece
Description of the indicator	This indicator reflects impact and specific pressure of oil pollution to waterbirds in marine environment. The indicator shows the proportion of birds in the collected population sample (or alternatively an index reflecting relative abundance of oiled birds) having been affected by oiling. The indicator can have single species and multi-species versions. Single-species version of the indicator is calculated separately for each species. This allows identifying species being more affected by oiling as the impact can vary among the species. The following species need to be considered: *Gavia arctica, Gavia stellata, Somateria mollissima, Polysticta stelleri, Clangula hyemalis, Melanitta nigra, Melanitta fusca, Alca torda.* Multi-species version of the indicator is calculated as a single measure for all waterbirds (i.e. all species pooled). This allows assessing total impact on waterbird community.
Relationship of the indicator to marine biodiversity	The indicator reflects impact and pressure of oil pollution to birds in marine environment. Thus it shows condition of particular species at species level (single-species version) as well as condition of habitat typical species at habitat level (multi-species version).
Relevance of the indicator to different policy instruments	MSFD descriptor 1 (habitat level/condition of typical species). Birds Directive (Article 12 requires reporting on existing impacts and threats to all regularly occurring wintering marine waterbird species).
Relevance to commission decision criteria and indicator	1.3. Population condition 1.3.1. Population demographic characteristics (e.g. body size or age class structure, sex ratio, fecundity rates, survival/mortality rates) 1.6.1. Condition of the typical species and communities
Method(s) for obtaining indicator values	Field data collection: Two data collection methods have been suggested: Using beached bird survey approach (Camphuysen 1989) where rate of oiled birds among dead birds is assessed. The following information is recorded in each patrol: date, site, observer, length of the patrolled segment, length of segment with visible oil contamination and for each bird found on the beach also species, presence of oil in feathers, type of body found. It has been argued that counts of oiled carcasses result in underestimate of the indicator as large part of birds affected by oil pollution are killed and removed by various predators instead of being stranded (Larsson, Tyden 2005), however, as predation equally affects also birds that have been affected by other impacts such as diseases, starvation etc., the recorded proportion of oiled birds among all stranded birds is still a valid measure. Using proportion of oiled birds that drowned in the fishing nets (i.e. proportion of oiled birds in by-catch) Using visual observations as suggested by Larsson, Tyden (2005). In this case absolute numbers of birds affected by oiling are used instead of the proportion as the number of birds that can be treated as absolute number of birds present (needed for calculation of the proportion) is unknown. Oiled birds more likely move closer to the coast than unaffected individuals thus oiled birds are more likely to be observed during coastal surveys than individuals not affected by oiling. Thus in these conditions the proportion of oiled birds will give overestimate of the impact. To obtain field data for the indicator, constant routes with constant observation spots are needed where all birds that can be defined as being oiled are counted. Birds are considered as being oiled if oil spots can be observed in their plumage or bird behaviour suggests it (bird is continuously preening specific part of its body) Indicator calculation**:** the proportion based indicator is expressed as proportion (%) of oiled birds from all birds collected in the specific survey. If visual observations are used, the indicator value is expressed as an abundance index, i.e. abundance of oiled birds in a particular year relative to abundance of oiled birds at base year (time period) or it is standardised as a density - number of observed oiled individuals per route unit. Freeware program TRIM is available to produce annual indices based on loglinear models (Pannekoek & van Strien 1998). In addition to annual indices, TRIM allows the estimation of trends over the whole period.

Documentation of relationship between indicator and pressure	This indicator has a direct relationship to oil pollution as a pressure. Impact of oil pollution on marine birds (and thus also relationship of this indicator to the oiling pressure) has been described in a number of articles (Camphuysen 1989, 1998, Camphuysen, van Franeker 1992, Camphuysen, Heubeck 2001, Fleet, Reineking 2001, Wiese, Ryan 2003, Larsson, Tyden 2005, Žydelis *et al.* 2006, Skov *et al*. 2011)
Geographical relevance of indicator	1. Local 2. Regional 3. National waters 4. Baltic Sea wide
How Reference Conditions (target values/thresholds) for the indicator were obtained?	GES target value for this indicator is 0. GES threshold should be put slightly above 0, however precise value need to be defined yet. Threshold values will be different depending on field method used for data collection due to different measurement scale. Meanwhile trend based GES reference conditions can be used - if there is a significant increasing trend in the value of this indicator, the indicator cannot be at GES. A negative trend of this indicator suggests improvement in ecological status and thus the indicator might be considered as being in GES.
Method for determining GES	The GES target value has been set at value which indicates that marine bird populations are not being affected by the particular pressure (oiling). GES threshold level has not been set and approach will differ depending on the field method used for data collection. If indicator is expressed as a proportion - a constant GES level set at value at which the population can still be regarded as sustainable can be used. If indicator is expressed as an abundance index of oiled birds, the GES thresholds might be site specific due to different levels of oiling pressure in the particular site at base time. While precise GES threshold level cannot be set, a positive trend in this indicator suggest that the indicator can be considered as not being at GES, while negative trend suggests the opposite.
References	Camphuysen, C.J. 1989. Beached bird surveys in the Netherlands 1915–1988: seabird mortality in the southern North Sea since the early days of oil pollution. Technisch Rapport Vogelbescherming 1. Amsterdam: Werkgroep Noordzee. 308 pp. Camphuysen, C.J. & van Franeker, J.A. 1992. The value of beached bird surveys in monitoring marine oil pollution. Technisch Rapport Vogelbescherming 10. Zeist, Netherlands: Vogelbescherming, Netherlands. 191 pp. Camphuysen, C.J. 1998. Beached bird surveys indicate decline in chronic oil pollution in the North Sea. Marine Pollution Bulletin 36: 519–526. Camphuysen, C.J. & Heubeck, M. 2001. Marine oil pollution and beached bird surveys: the development of a sensitive monitoring instrument. Environmental Pollution 112: 443–461. Fleet, D.M. & Reinrking, B. 2001. What do systematic beached bird surveys tell us about oil pollution in the southern North Sea? Wadden Sea Newsletter 3: 21–23. Larsson K., Tyden L. 2005. Effects of oil spills on wintering Long-tailed Ducks *Clangula hyemalis* at Hoburgs bank in central Baltic Sea between 1996/97 and 2003/04. Ornis Svecica 15: 161 - 171. Skov. H., Heinänen S., Žydelis R., Bellebaum J., Bzoma S., Dagys M., Durinck J., Garthe S., Grishanov G., Hario M., Kieckbusch J.J., Kube J., Kuresoo A., Larsson K., Luigujõe L., Meissner W., Nehls H.W., Nilsson L., Petersen I.K., Roos M.M., Pihl S., Sonntag N., Stock A., Stipniece A., Wahl J. 2011. Waterbird Populations and Pressures in the Baltic Sea. Nordic Council of Ministers, Copenhagen, 201 pp. Wiese, F.K. & Ryan, P.C. 2003. The extent of chronic marine oil pollution in southeastern Newfoundland waters assess Williams, J.M., Tasker, M.L., Carter, I.C. & Webb, A. 1995. A method of assessing seabird vulnerability to surface pollutants. Ibis 137: 47–152.ed through beached bird surveys 1984–1999. Marine Pollution Bulletin 46: 1090–1101. Žydelis R., Dagys M., Vaitkus G. 2006. Beached Bird Surveys in Lithuania Reflect Marine Oil Pollution and Bird Mortality in Fishing Nets. Marine Ornithology 34: 161 – 166.

Illustrative material for indicator documentation	 Figure 1. Proportion of oiled waterbirds in north-western Estonia in the spring surveys of beached birds (1996 - 2012) (Nellis 2013).  Figure 2. Proportion of oiled waterbirds in north-western Estonia in the autumn surveys of beached birds (1996 - 2012) (Nellis 2013).

Name of indicator	**4.13 Abundance index of beached birds**
Type of Indicator	Pressure indicator
Author(s)	Ainars Auniņš, Leif Nilsson, Andres Kuresoo, Leho Luigujõe, Antra Stīpniece
Description of the indicator	This indicator reflects mortality of birds due to different reasons (mainly pollution and by-catch; Camphuysen 1989, Camphuysen, Heubeck 2001, Žydelis *et al.* 2006). It is expressed as relative abundance of stranded birds. The indicator can have single species and multi-species versions. Single-species version of the indicator is calculated separately for each species identified. This allows identifying changes in species-specific mortality as this parameter can vary among the species. The following species need to be considered: *Gavia arctica, Gavia stellata, Podiceps cristatus, Somateria mollissima, Polysticta stelleri, Clangula hyemalis, Melanitta nigra, Melanitta fusca, Alca torda.* Multi-species version of the indicator is calculated as a single measure for all waterbirds (i.e. all species pooled). This allows assessing changes in mortality in the whole waterbird community.
Relationship of the indicator to marine biodiversity	The indicator reflects impacts and pressures to birds in marine environment that cause their mortality. Pollution (including oiling) and bycatch have been described as main impacts that can be assessed by this kind of indicator (Camphuysen 1989, Camphuysen, Heubeck 2001, Žydelis *et al.* 2006
Relevance of the indicator to different policy instruments	MSFD descriptor 1 (habitat level/condition of typical species). Birds Directive (Article 12 requires reporting on existing impacts and threats to all regularly occurring wintering marine waterbird species).
Relevance to commission decision criteria and indicator	1.3. Population condition 1.3.1. Population demographic characteristics (e .g. body size or age class structure, sex ratio, fecundity rates, survival/ mortality rates) 1.6.1. Condition of the typical species and communities
Method(s) for obtaining indicator values	Field data collection**:** Data for this indicator should be collected using coastal surveys and recording all beached birds as well as possible cause of their death. Standard methodology has been suggested by Camphuysen (1989) and has successfully been adopted on the Baltic coast (Vaitkus *et al.* 1993, 1994, Kurochkin 1993, Žydelis *et al.* 2006 and others). The following information is recorded for each segment in each patrol: date, site, observer, length of the patrolled segment, length of segment with visible oil contamination. For each bird found stranded on the beach species, cause of death, type of body found are recorded. Indicator calculation**:** the indicator value is expressed as an abundance index, i.e. abundance of beached birds in a particular year relative to abundance of beached birds at base year (time period) or it is standardised as a density - number of counted beached birds (individuals) per route unit. Freeware program TRIM is available to produce annual indices based on loglinear models (Pannekoek & van Strien 1998). In addition to annual indices, TRIM allows the estimation of trends over the whole period.
Documentation of relationship between indicator and pressure	Relationship between number of stranded birds and pressures, especially pollution (including oiling) and bycatch have been described in a number of articles (Camphuysen 1989, 1998, Camphuysen, van Franeker 1992, Camphuysen, Heubeck 2001, Fleet, Reineking 2001, Vaitkus 1994, Wiese, Ryan 2003, Žydelis *et al.* 2006, Skov *et al*. 2011).
Geographical relevance of indicator	1. Local 2. Regional 3. National waters 4. Baltic Sea wide
How Reference Conditions (target values/thresholds) for the indicator were obtained?	GES target value and GES threshold for this indicator need to be defined yet. Meanwhile a trend based GES reference conditions can be used - if there is a significant increasing trend in the value of this indicator, the indicator cannot be at GES.
Method for determining GES	The GES target need to be set at value equal to value that could be obtained in beached bird surveys id only mortality caused by natural factors was playing a role. GES threshold values need to be set at values at which mortality is low enough for the population to be considered as sustainable (safe). To set ecologically justified targets for this indicator, more species and site-specific ecological studies are needed. The GES targets and thresholds might

	be site specific due to different levels of mortality among sites and varying base time of the indicator. While precise GES threshold level cannot be set, a positive trend in this indicator suggest that the indicator can be considered as not being at GES, while negative trend suggests the opposite.
References	Camphuysen, C.J. 1989. Beached bird surveys in the Netherlands 1915–1988: seabird mortality in the southern North Sea since the early days of oil pollution. Technisch Rapport Vogelbescherming 1. Amsterdam: Werkgroep Noordzee. 308 pp. Camphuysen, C.J. & van Franeker, J.A. 1992. The value of beached bird surveys in monitoring marine oil pollution. Technisch Rapport Vogelbescherming 10. Zeist, Netherlands: Vogelbescherming, Netherlands. 191 pp. Camphuysen, C.J. 1998. Beached bird surveys indicate decline in chronic oil pollution in the North Sea. Marine Pollution Bulletin 36: 519–526. Camphuysen, C.J. & Heubeck, M. 2001. Marine oil pollution and beached bird surveys: the development of a sensitive monitoring instrument. Environmental Pollution 112: 443–461. Fleet, D.M. & Reinrking, B. 2001. What do systematic beached bird surveys tell us about oil pollution in the southern North Sea? Wadden Sea Newsletter 3: 21–23. Kurochkin, A. 1993. Late winter beached bird survey in Latvia. Acta Ornithologica Lituanica 7–8: 74–77. Skov. H., Heinänen S., Žydelis R., Bellebaum J., Bzoma S., Dagys M., Durinck J., Garthe S., Grishanov G., Hario M., Kieckbusch J.J., Kube J., Kuresoo A., Larsson K., Luigujõe L., Meissner W., Nehls H.W., Nilsson L., Petersen I.K., Roos M.M., Pihl S., Sonntag N., Stock A., Stipniece A., Wahl J. 2011. Waterbird Populations and Pressures in the Baltic Sea. Nordic Council of Ministers, Copenhagen, 201 pp. Van Strien, A.J., Pannekoek, J. et Gibbons, D.W. (2001): Indexing European bird population trends using results of national monitoring schemes: a trial of a new method. Bird Study 48: 200-213. Vaitkus, G., Petraitis, A. & Žydelis, R. 1994. Beached bird density trends in Lithuania during 1991–1994. Acta Ornithologica Lituanica 9–10: 73–77. Vaitkus, G., Dagys, M., Žydelis, R. & Kilesinskas, T. 1993. Preliminary report on winter-period beached bird densities in Lithuanian coastal waters. Acta Ornithologica Lituanica 7–8: 68–73. Wiese, F.K. & Ryan, P.C. 2003. The extent of chronic marine oil pollution in southeastern Newfoundland waters assessed through beached bird surveys 1984–1999. Marine Pollution Bulletin 46: 1090–1101. Žydelis R., Dagys M., Vaitkus G. 2006. Beached Bird Surveys in Lithuania Reflect Marine Oil Pollution and Bird Mortality in Fishing Nets. Marine Ornithology 34: 161 – 166.

Illustrative material for indicator documentation	 Figure 1. Density of beached waterbirds in north-western Estonia in the spring surveys (1996 - 2012) (Nellis 2013).  Figure 2. Density of beached waterbirds in north-western Estonia in the autumn surveys (1996 - 2012) (Nellis 2013).

Name of indicator	**4.14 Abundance index of by-caught birds**
Type of Indicator	Pressure indicator
Author(s)	Ainars Auniņš, Leif Nilsson, Andres Kuresoo, Leho Luigujõe, Antra Stīpniece
Description of the indicator	This single-species indicator reflects mortality of birds due to drowning in fish nets (gillnets and driftnets) and thus specifically shows impact/pressure of gillnet fishery to marine birds. Single-species version of the indicator is calculated separately for each species. Some species are more affected by bycatch and the impact varies among the species (Žydelis *et al*. 2009). The following species need to be considered: *Gavia arctica, Gavia stellata, Podiceps cristatus, Podiceps grisegena, Phalacrocorax carbo, Aythya fuligula, Aythya marila, Somateria mollissima, Polysticta stelleri, Clangula hyemalis, Melanitta nigra, Melanitta fusca, Bucephala clangula, Mergus albellus, Mergus merganser, Mergus serrator, Alca torda, Uria aalge, Cepphus grylle.*
Relationship of the indicator to marine biodiversity	The indicator reflects impacts and specific pressure of gillnet and driftnet fishery on birds in marine environment that cause their mortality. Thus it shows condition of particular species at species level as mortality rate due to fishing activities.
Relevance of the indicator to different policy instruments	MSFD descriptor 1 (species level/population condition). Birds Directive (Article 12 requires reporting on existing impacts and threats to all regularly occurring wintering marine waterbird species).
Relevance to commission decision criteria and indicator	1.3. Population condition 1.3.1. Population demographic characteristics (e .g. body size or age class structure, sex ratio, fecundity rates, survival/ mortality rates)
Method(s) for obtaining indicator values	Field data collection**:** using a voluntary logbook in cooperation with fishermen. For this scheme of data collection position of vessel, catching effort (net length per time unit), number of birds drowned by species. Using of electronic monitoring or CCTV systems has been suggested recently (Dalskov, Kindt-Larsen 2009, Tilander, Lunneryd 2010). This includes taking high quality images of the catch and recording data on vessel position, hydraulic pressure and winch/drum rotations. The total catch record is audited by use of 4 video cameras, each filming different angles of catch handling. Additionally a methodology for data collection using coastal surveys and recording all beached birds as well as possible cause of their death exists. Standard methodology has been suggested by Camphuysen (1989) and has successfully been adopted on the Baltic coast (Vaitkus *et al*. 1993, 1994, Kurochkin 1993, Žydelis *et a.l* 2006 and others). However, data collected this way does not show the true picture of mortality as not all drowned birds are beached later. Thus the first two data collection methods above are preferred. To achieve usable results and to allow assessment of by-catch impact on waterbird populations, monitoring the number of birds drowned (by species) needs to be accompanied with regular monitoring of the population size of waterbird population (Bellebaum *et al*. 2012, Degel *et al.* 2010). The latter can be achieved by collecting data for indicators 4.1 to 4.3 and 4.6 to 4.8., however, for other seasons additional fieldwork is needed. Indicator calculation: Indicator is expressed as number of birds drowned per 1000 m of net length per day (birds/NMD)
Documentation of relationship between indicator and pressure	This indicator has a direct relationship to gill-net fisheries as a pressure. Relationship has been described in a number of articles (Qartyukhin, Burkanov 2000, Dagys, Židelis 2002, Kies, Tomek 1990, Miller, Skalski 2006, Žydelis *et al*. 2006, 2009, Skov *et al*. 2011)
Geographical relevance of indicator	1. Local 2. Regional 3. National waters 4. Baltic Sea wide

How Reference Conditions (target values/thresholds) for the indicator were obtained?	GES target value for this indicator is 0. GES threshold should be put slightly above 0, however precise value needs to be defined yet. Meanwhile trend based GES reference conditions can be used - if there is a significant increasing trend in the value of this indicator, the indicator cannot be at GES. A negative trend of this indicator suggests improvement in ecological status and thus the indicator might be considered as being in GES.
Method for determining GES	The GES target value has been set at value which indicates that marine bird populations are not being affected by the particular pressure (drowning in fishnets). GES threshold level has not been set. GES thresholds might be site specific due to different levels of oiling pressure in the particular site at base time. While precise GES threshold level cannot be set, a positive trend in this indicator suggests that the indicator can be considered as not being at GES, while negative trend suggests the opposite.
References	Artyukhin, Y.B., Burkanov, V.N., 2000. Incidental mortality of seabirds in the drift net salmon fishery by Japanese vessels in the Russian Exclusive Economic Zone, 1993–1997. In: Kondratyev, A.K., Litvinenko, N.M., Kaiser, G.W. (Eds.), Seabirds of the Russian Far East. Canadian Wildlife Service, Ottawa, pp. 105–116. Bellebaum J, Schirmeister B, Sonntag N & Garthe S (2012) Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast. Aquatic Conservation: Marine and Freshwater Ecosystems. DOI: 10.1002/aqc.2285. Dagys, M., Žydelis, R., 2002. Bird bycatch in fishing nets in Lithuanian coastal waters in wintering season 2001–2002. Acta Zoologica Lituanica 12 (3), 276–282. Dalskov J., Kindt-Larsen L. 2009. Final Report on Fully Documented Fishery. DTU Aquarapport, National Institute of Aquatic Resources, Technical University of Denmark, 49 pp. Degel, H., Petersen, I.K., Holm, T.E., Kahlert, J. (2010). Fugle som bifangst i garnfiskeriet. Estimat af utilsigtet bifangst af havfugle i garnfiskeriet i området omkring Ærø DTU Aqua-rapport nr. 227-2010. Charlottenlund. Institut for Akvatiske Ressourcer, Danmarks Tekniske Universitet, 56 p. Kies, B., Tomek, T., 1990. Bird mortality in fishing nets in the Gulf of Gdansk, Polish Baltic coast. Pelagicus 5, 23–27. Miller, T.J., Skalski, J.R., 2006. Estimation of seabird bycatch for North Pacific longline vessels using design- and model-based methods. Canadian Journal of Fisheries and Aquatic Sciences 63, 1878–1889. Skov. H., Heinänen S., Žydelis R., Bellebaum J., Bzoma S., Dagys M., Durinck J., Garthe S., Grishanov G., Hario M., Kieckbusch J.J., Kube J., Kuresoo A., Larsson K., Luigujõe L., Meissner W., Nehls H.W., Nilsson L., Petersen I.K., Roos M.M., Pihl S., Sonntag N., Stock A., Stipniece A., Wahl J. 2011. Waterbird Populations and Pressures in the Baltic Sea. Nordic Council of Ministers, Copenhagen, 201 pp. Tylander D., Lunneryd S.G. 2010. Pilot Studies of Electronic Monitoring (EM) system for fisheries control of small vessels. Paper presented at the 3rd meeting of ICES Study Group for Bycatch of Protected Species, Copenhagen, February 1-4, 2010. Žydelis R., Dagys M., Vaitkus G. 2006. Beached Bird Surveys in Lithuania Reflect Marine Oil Pollution and Bird Mortality in Fishing Nets. Marine Ornithology 34: 161 – 166. Žydelis R., Bellebaum J., Österblom H., Vetemaa M., Schirmeister B., Stīpniece A., Dagys M., van Eerden M, Garthe S. 2009. Bycatch in gillnet fisheries – an overlooked threat to waterbird populations. Biological Conservation 142: 1269 – 1281.

Name of indicator	**4.15 Indicator on condition of waterbirds**
Type of Indicator	Pressure indicator
Author(s)	Ainars Auniņš, Leif Nilsson, Andres Kuresoo, Leho Luigujõe, Antra Stīpniece
Description of the indicator	A body condition index based on condition of the pectoral flight muscles and the presence and quantity of subcutaneous and intestinal fat depots. Body condition of seabirds is measured by sampling by-caught seabirds as these probably represent a good subset of the whole population in the respective area (unlike beached birds that might rather represent diseased individuals). Due to high water content in the feathers of the drowned birds, the body mass (which represents a good indicator of body condition in other circumstances) cannot be measured with sufficient accuracy. The index supplies general information on overall physical condition or the likely cause of death, e.g. starvation. Possible supplemental data to be collected (Leopold *et al*. 2000, van Franeker 2004): - information on injuries, oiling and entanglement - condition of organs (score system) See van Franeken 2004, van Franeken, Camphuysen 2007, and Laboch, Hayes 2012.
Relationship of the indicator to marine biodiversity	The indicator reflects condition of typical species populations. It primary responds to the following pressures and drivers: removal of prey, disturbance, disease, hazardous sub-stances.
Relevance of the indicator to differ-ent policy instru-ments	MSFD descriptor 1 (species level/population condition and habitat level/condition of typical species). Birds Directive (Article 12 requires reporting on existing impacts and threats to all regularly occurring wintering marine waterbird species).
Relevance to commission deci-sion criteria and indicator	1.3. Population condition 1.3.1. Population demographic characteristics (e .g. body size or age class structure, sex ratio, fecundity rates, survival/ mortality rates) 1.6.1. Condition of the typical species and communities
Method(s) for ob-taining indicator values	Field data collection**:** Three components are evaluated for every collected specimen: 1. condition of the pectoral flight muscles 2. presence and quantity of subcutaneous fat depots 3. presence and quantity of intestinal fat depots These are scored on a scale ranging from 0 to 3. Subsequently, these scores are summed up to a condition index. Thus total score for each bird can be in range 0 to 9. In order to describe the overall condition of birds the following system for interpreting the scores has been suggested (Van Franeker 2004): 0-1 as mortally emaciated, 2-3 as critically emaciated, 4-6 as moderate body condition and 7-9 as good body condition.
Documentation of relationship be-tween indicator and pressure	The indicator primary responds to the following pressures and drivers: removal of prey, disturbance, disease, hazardous substances
Geographical rele-vance of indicator	2. Regional 3. National waters

How Reference Conditions (target values/thresholds) for the indicator were obtained?	The target condition score is in range from 7 to 9, meaning that all birds are in good physical condition. The actual GES threshold still needs to be defined. Meanwhile trend based GES reference conditions can be used - if there is a significant negative trend in body condition index and the actual indicator values are driving away from the GES target range (7 - 9), the indicator cannot be at GES.
Method for determining GES	Currently GES levels have not been set. More ecological studies are needed to set GES boundary value of the target. While precise GES levels cannot be set, an existence of negative trend in this indicator and values outside the target range (7 - 9) suggest that the indicator can be considered as not being at GES.
References	Labocha M.K., Hayes J.P. 2012. Morphometric indices of body condition in birds: a review. J Ornithol 153: 1-22. van Franeker J.A. & C.J. Camphuysen2 2007. Condition manual: the physical condition of stranded seabirds. Technical documents 4.1, Handbook on Oil Impact Assessment, version 1.0. Online edition, www.oiledwildlife.eu van Franeker J.A. 2004. Save the North Sea Fulmar-Litter-EcoQO manual part 1: collection and dissection procedures. Wageningen.

Name of indicator	**4.16 Feeding pressure on waterbird food sources**
Type of Indicator	Pressure indicator
Author(s)	Ainars Auniņš, Leif Nilsson, Andres Kuresoo, Leho Luigujõe, Antra Stīpniece
Description of the indicator	This indicator reflects impact and specific pressure of feeding marine birds on their food resources/other organisms in their food-chain/structure and conditions of their habitat and its forming species.
Relationship of the indicator to marine biodiversity	The indicator reflects impact and pressure of marine waterbirds on their food sources.
Relevance of the indicator to different policy instruments	MSFD descriptor 1 (habitat level/condition of typical species). Habitats Directive (Article 17 requires reporting on existing impacts and threats to all occurring habitat types and their typical species. Marine waterbird species are known to have impact on their food sources/typical species of Annex I habitat type 1170).
Relevance to commission decision criteria and indicator	1.6. Habitat condition 1.6.1. Condition of the typical species and communities 1.6.2. Relative abundance and/or biomass, as appropriate
Method(s) for obtaining indicator values	Field data collection**:** using any of the standard methods. For inshore part of the indicator coastal ground counts (such as International Waterbird Census; methods described in Wetlands International 2010) are used. This type of data has been collected in all Baltic Sea countries for decades. Data for offshore part of the indicator need to be collected using ships or planes (Komdeur *et al*. 1992, Petersen *et al.* 2005, Camphuisen *et al*. 2006, Nilsson 2012). The difference from wintering waterbird censuses is that these counts are carried out on daily (weekly) basis to assess presence and abundance of birds for certain time periods.
Documentation of relationship between indicator and pressure	The indicator itself characterizes a pressure - pressure of waterbirds to their food sources. If pressure exceeds the carrying capacity of the site, the affected benthic or pelagic communities become unsustainable.
Geographical relevance of indicator	1. Local 2. Regional 3. National waters 4. Baltic Sea wide
How Reference Conditions (target values/thresholds) for the indicator were obtained?	Reference conditions are site specific depending on bottom substrate and communities. The target should be set at safe level where number of bird days does not pose a risk exceeding the carrying capacity of the site. The site specific target levels still need to be set. GES boundary should be put on the upper side of the target level at the assumed carrying capacity of the site.
Method for determining GES	Currently neither target levels nor GES boundaries have been set. More ecological studies are needed to set site specific target levels. These should be set at levels where number of bird days does not pose a risk exceeding the carrying capacity of the site. GES boundary should be put on the upper side of the target level at the assumed carrying capacity of the site.
References	Camphuysen C.J., Fox A.D., Leopold M.F. & Petersen I.K. 2004. Towards standardised seabirds at sea census techniques in connection with environmental impact assessments for offshore wind farms in the U.K. Report commissioned by COWRIE for the Crown Estate, London. Royal Netherlands Institute for Sea Research, Texel, 38 pp. Komdeur, J., Bertelsen, J. & Cracknell, G. (Eds.). 1992. Manual for Aeroplane and Ship Surveys of Waterfowl and Seabirds. IWRB Special Publication No. 1, Slimbridge, UK, 37 p. Nilsson, L. 2012. Distribution and numbers of wintering sea ducks in Swedish offshore waters. Ornis Svecica 22: 39-60. Petersen, I.K, Fox, A.D. 2005. An aerial survey technique for sampling and mapping distributions of waterbirds at sea. Department of Wildlife Ecology and Biodiversity, National Envi-

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ANNEX I

Table 1. Analysis of selected existing indicators against different criteria (Rees et al. Criteria 1-4) prformed in the first phase of the project before actual indicator development.

Rees et al. criterion number:	1			2		3		4
Merged criterion (Rees et al 2008 and NordBio2010):	Capable of conveying information that is responsive and meaningful to decision-making (directly tied to management questions and linked to thresholds for appropriate action relative to designated ecosystem goals)			Linked to a conceptual stressor–response framework (with the ability to communicate potential cause–effect relationships)		Capable of measuring change or its absence with confidence (robust to influences of confounding environmental factors)		Highly sensitive and anticipatory (Measured qualities more sensitive to change than their environment, early warning of potential problems)
Indicator	Relevant to directives and policies	Indicates what it is supposed to indicate	Precise	Possible to link to conceptual framework such as DPSIR	Impacts and causes of change measured by the indicator are known	Robust to env. influences	Can be updated routinely (i.e. annually)	
Depth distribution of *Fucus vesiculosus*	1	1	0.5		1		1	0
Depth distribution of vegetation	1	1	0.5		1		1	0
Share of annual and perennial species	1	0.5	0.5		1		1	0
Number of species	1	1	1		0.5		1	1
ZKI macrozoobenthos community index	1	0	0.5		1		1	0
Species accumulation or rarefaction curves	0	0.5	0.5		0		0.5	0
Relative abundance (or biomass) and species-rank curves	0	0.5	0.5		0		0.5	0
Number (diversity) of functional traits	1	0.5	0.5		0		0.5	0
Community wide synchronicity	0	0.5	0.5		0		0.5	0
Community stability (the ratio be-	0	0.5	0.5		0		0.5	0

tween the mean and the standard deviation)								
Number of perennial algal species	1	1	1	1	0.5	0.5	1	0
Total algal cover	1	1	1	1	0.5	0.5	1	0
Cumulative algal cover	1	1	1	1	0.5	0.5	1	0
Depth distribution of macroalgal species	1	1	1	1	0.5	1	1	0
Lower growth limit of perennials: *Fucus vesiculosus*	1	1	1	1	1	1	1	0
Multimetrics index (BQI)	1	1	0.5	1	0.5	0	1	0
Catch per unit effort (CPUE)	1	0.5	0.5	1	0.5	1	1	0
CPUE of large fish individuals	1	0.5	0.5	1	0.5	1	1	0
Catch per unit effort (CPUE) perch 25	1	1	0.5	1	0.5	1	1	0
Catch per unit effort (CPUE) cyprinid fish	1	0.5	0.5	1	0.5	1	1	0
Catch per unit effort (CPUE) piscivorous fish	1	1	0.5	1	0.5	1	1	0
Catch per unit effort (CPUE) of non-piscivorous fish	1	0.5	0.5	1	0.5	1	1	0
Catch per unit effort (CPUE) of marine fish species	1	1	0.5	1	0.5	1	1	0
Mean trophic level	1	1	0.5	1	0.5	0.5	1	0
Mean maximum length	1	1	0.5	1	0.5	0.5	1	0
Species diversity	1	1	0.5	1	0.5	0.5	1	0
Chl a measurement (HELCOM IFS part 1)	1	1	1	1	1	0.5	1	1
Phytoplankton species succession (HELCOM IFS part 2)	1	0.5	0.5	1	0.5	1	1	1

Table 1. continued (Rees et al. Criteria 5-7).

Rees et al. criterion number:	**5**			**6**			**7**	
Merged criterion (Rees et al 2008 and NordBio2010):	Applicable over a variety of spatial scales and conditions (to support global as well as local comparisons)			Desirable operationally (easy to measure, reproducible with minimum measurement error, cost-effective)			Integrative (serves multiple indicator purposes)	
Indicator	Applicable at both local and Baltic Sea scale	Indicates changes in a bigger scale	Aggregatable and disaggregatable	Reproducible (with low mesurement error)	Cost effective	Based on existing monitoring programmes	Serves mult. purposes	Simplifying information
Depth distribution of *Fucus vesiculosus*	0	0.5	1	1	0.5	1	1	1
Depth distribution of vegetation	1	1	1	1	0.5	1	1	1
Share of annual and perennial species	0.5	1	1	1	1	1	1	1
Number of species	1	1	1	0.5	0.5	1	1	1
ZKI macrozoobenthos community index	1	0.5	0.5	0.5	0.5	1	0	1
Species accumulation or rarefaction curves	1	0		0.5	0.5	0	0.5	1
Relative abundance (or biomass) and species-rank curves	1	0		0.5	0.5	0	0.5	1
Number (diversity) of functional traits	1	0.5		0.5	0.5	0	1	1
Community wide synchronicity	1	0.5		0.5	0.5	0	0.5	1
Community stability (the ratio between the mean and the standard deviation)	1	0.5		0.5	0.5	0	0.5	1
Number of perennial algal species	0.5	0.5	1	0.5	0	1	0.5	0.5
Total algal cover	1	0.5	1	0.5	0	1	0.5	0.5
Cumulative algal cover	1	0.5	1	0.5	0	1	0.5	0.5
Depth distribution of macroalgal species	1	0.5	1	0.5	0	1	1	0.5
Lower growth limit of perennials: *Fucus vesiculosus*	0.5	0.5		0.5	0.5	1	0	1
Multimetrics index (BQI)	1	0	1	0.5	0.5	1		1
Catch per unit effort (CPUE)	1	0.5	1	1	0	1	0	1
CPUE of large fish individuals	1	0.5	1	1	0	1	0	1

Catch per unit effort (CPUE) perch 25	1	0.5	1	1	0	1	0	1
Catch per unit effort (CPUE) cyprinid fish	1	0.5	1	1	0	1	0	1
Catch per unit effort (CPUE) piscivorous fish	1	0.5	1	1	0	1	0	1
Catch per unit effort (CPUE) of non-piscivorous fish	1	0.5	1	1	0	1	0	1
Catch per unit effort (CPUE) of marine fish species	1	0.5	1	1	0	1	0	1
Mean trophic level	1	0.5	1	1	0	1	0	1
Mean maximum length	1	0.5	1	1	0	1	0	0.5
Species diversity	1	0.5	1	1	0	1	0	1
Chl a measurement (HELCOM IFS part 1)	1			1	1	1	0	1
Phytoplankton species succession (HELCOM IFS part 2)	1			0.5	0.5	1	0	0.5

Table 1 continued (Rees et al. Criteria 8-10).

Rees et al. criterion number:	8	9			10			NB
Merged criterion (Rees et al 2008 and NordBio2010):	Non-destructive (measurement does not cause ecosystem damage)	Easy to understand and communicate (non-specialists need to act on findings)			Scientifically and legally defensible (robust to peer review and wider challenge)			Representative and good coverage (Includes a large enough or representative group of species and has a good spatial coverage)
Indicator		Easy to understand	Clear presentation (possible to display eye-catching graphics)	Responds to stakeholder needs and is broadly accepted amongst them	Based on real observations	Statistically sound data collection methods	May be used in legal processes (environmental impact assessments etc.)	
Depth distribution of *Fucus vesiculosus*	1	1	1	1	1	1	1	0.5
Depth distribution of vegetation	1	1	1	1	1	1	1	0.5
Share of annual and perennial species	1	1	1	1	1	1	1	0.5
Number of species	1	1	1	1	1	1	1	1
ZKI macrozoobenthos community index	1	0.5	1	1	1	1	1	1
Species accumulation or rarefaction curves	1	0.5	1	0.5	1	1	1	1
Relative abundance (or biomass) and species-rank curves	1	0.5	1	0.5	1	1	1	1
Number (diversity) of functional traits	1	0.5	1	0.5	1	1	1	1
Community wide synchronicity	1	0.5	1	0.5	1	1	1	1
Community stability (the ratio between the mean and the standard deviation)	1	0.5	1	0.5	1	1	1	1
Number of perennial algal species	1	1	0.5	0.5	1	0.5	1	0.5
Total algal cover	1	1	0.5	0.5	1	0.5	1	0.5

Cumulative algal cover	1	0.5	0.5	0.5	1	0.5	1	0.5
Depth distribution of macroalgal species	1	1	0.5	1	1	0.5	1	0.5
Lower growth limit of perennials: *Fucus vesiculosus*	1	1	1	1	1	1	1	1
Multimetrics index (BQI)	1	1	1	1	1	1	1	1
Catch per unit effort (CPUE)	1	1	1	1	1	1	0.5	1
CPUE of large fish individuals	1	1	1	1	1	1	0.5	0.5
Catch per unit effort (CPUE) perch 25	1	1	1	1	1	1	0.5	1
Catch per unit effort (CPUE) cyprinid fish	1	1	1	1	1	1	0.5	0.5
Catch per unit effort (CPUE) piscivorous fish	1	1	1	1	1	1	0.5	0.5
Catch per unit effort (CPUE) of non-piscivorous fish	1	1	1	1	1	1	0.5	0.5
Catch per unit effort (CPUE) of marine fish species	1	1	1	1	1	1	0.5	0.5
Mean trophic level	1	0.5	1	1	1	1	0.5	1
Mean maximum length	1	1	1	1	1	1	0.5	1
Species diversity	1	1	1	1	1	1	0.5	1
Chl a measurement (HELCOM IFS part 1)	1	1	1	1	1	1	1	1
Phytoplankton species succession (HELCOM IFS part 2)	1	1	1		1	0.5		1

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