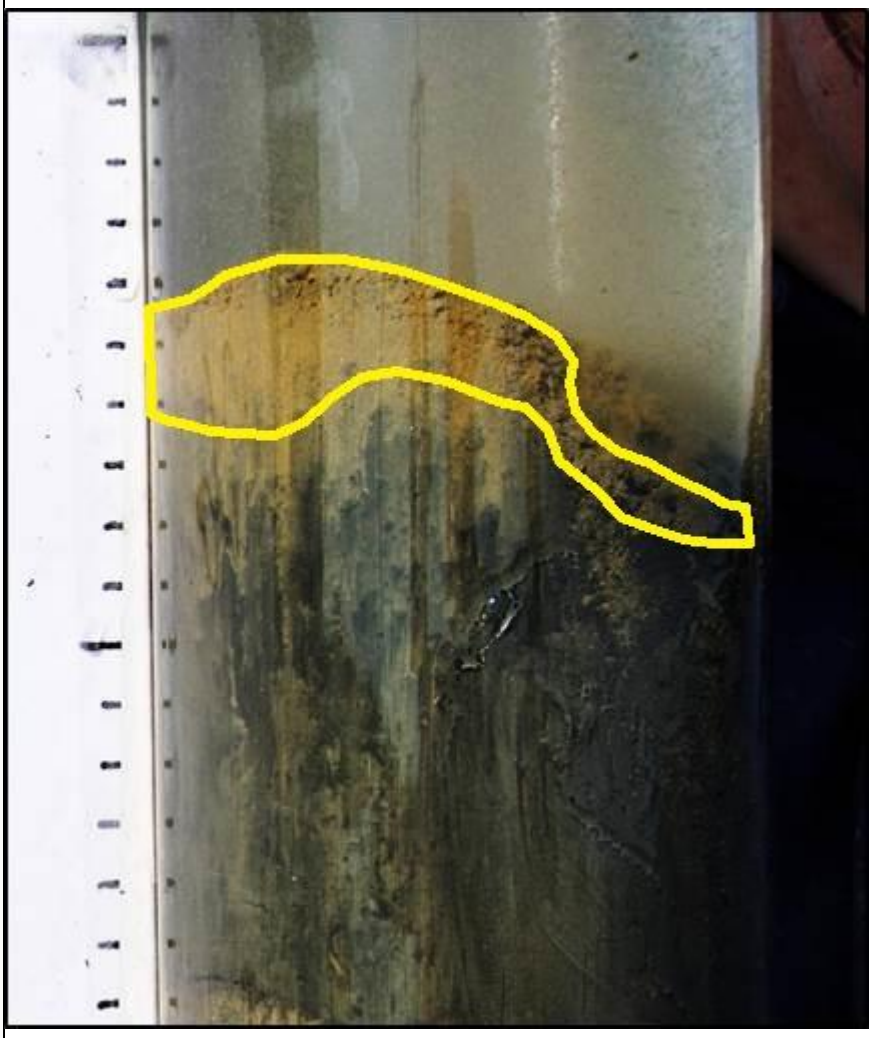
Name of indicator	2.8 Condition of soft sediment habitats – the aRPD approach
Type of Indicator	State indicator
Author(s)	Henrik Nygård
Description of the indicator	A soft bottom habitat in good condition can support a zoobenthic community able to sustain a favourable living environment e.g. through 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	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

and pressure	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 assessing 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.