State of the soft-bottom macrofauna communities

Authors

HELCOM Secretariat

Developed based on HELCOM reports and the reports of the Baltic GIG group for the intercalibration of the benthos indicators under the EU Water Framework Directive.

Reference to this core indicator report: [Author's name(s)], [Year]. [Title]. HELCOM Core Indicator Report. Online. [Date Viewed], [Web link].

Contents

Key message

The states of the coastal soft-bottom macrozoobenthic communities differ greatly within and across sub-basins. No geographical spatial trend can be seen from Figure 1.

Offshore soft-bottom macrozoobenthic communities show a clear response to the physicochemical state of the offshore areas, particularly oxygen deficiency. The communities are in good environmental status is the Gulf of Bothnia and Arkona Basin. The worst statuses are found from Gulf of Finland, Baltic Proper and Bornholm Basin.
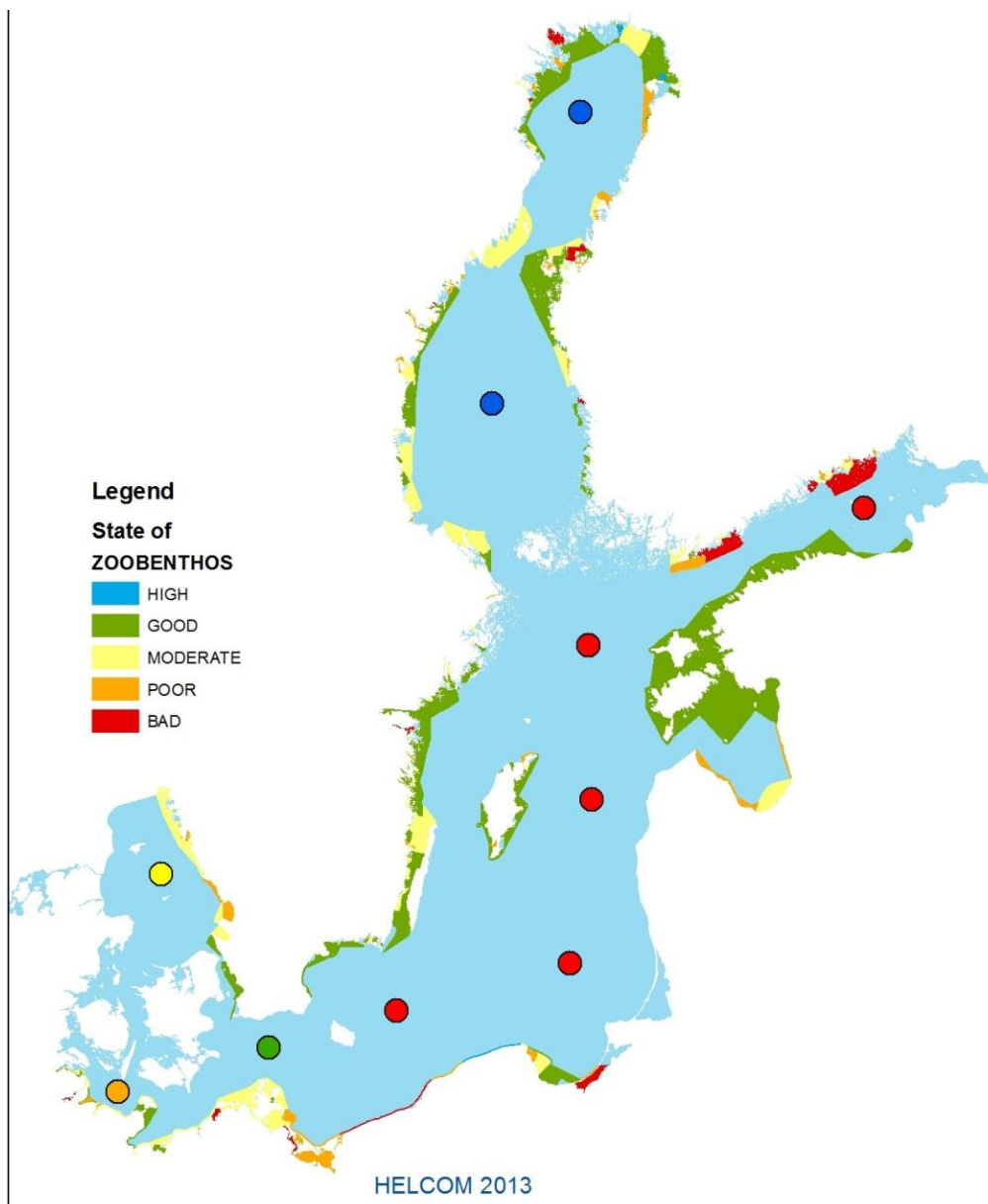

Figure 1. *Status of soft-bottom macrozoobenthic communities. The coastal status originates from the coastal multimetric indices of the national reporting under the EU Water Framework Directive and the statuses of offshore index are taken from the HELCOM Thematic Assessment on Eutrophication. See Metadata for assessment years of the coastal indices.*

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Description of the indicator

The benthic invertebrate communities are an essential part of any environmental assessment. They are sensitive indicators of contamination, eutrophication and physical disturbances.

This indicator assesses the state of the soft-bottom macroinvertebrate communities by using indices developed to notice changes in abundance of sensitive species. The indices have been validated against various pressure gradients. The validations show that at least nutrient inputs, hypoxia and contamination affect the communities, but the effects of physical disturbances have not been tested thoroughly.

The results of the core indicator can be supported by sediment profile imagery, showing the condition of the sediment habitat (Annex 1).

Policy relevance

The indicator can be used to address two HELCOM ecological objectives: "Natural distribution and occurrence of plants and animals" (Eutrophication) and "Thriving communities of plants and animals" (Nature conservation).

Under the EU Marine Strategy Framework Directive, the indicator describes the state of benthic habitats (Descriptor 1, criterion 1.6 Habitat condition and Descriptor 6, criterion 6.2 Condition of the benthic communities).

The coastal multimetric indices were developed for the EU Water Framework Directive under which they estimate the ecological status of the coastal and transitional waters.

What is the status of benthic invertebrates?

Current status in the Baltic Sea

The status of benthic invertebrates in the Baltic Sea depends greatly on the amount of anthropogenic pressures. Figure 1 shows that the coastal invertebrate communities vary even across three or four status classes between neighboring assessment units. The greatest difference is often found along the gradient from contaminated or eutrophied coastal water bodies to offshore waters. For example, in the Quarck area, a coastal water body having a 'bad status' is gradually changing to 'high status' when reaching the offshore. Good environmental status has been reported from the entire Estonian coast, many parts of the Swedish outer coast and many waterbodies in the Finnish Gulf of Bothnia.

Also the offshore benthic invertebrate diversity and, therefore, reference conditions differ markedly between sub-basins owing to the gradient in salinity, which constrains species distributions (Figure 2). A total of eight basins were evaluated and the reference conditions, measured as the average number of species, varied between 18.3 in the Arkona Basin and 2.0 in the Bothnian Bay. For the years 2003–2007, benthic invertebrate status varied considerably between sub-basins and was related to the widespread occurrence of hypoxia and anoxia in the Baltic Proper and the Gulf of Finland (see figure below). None of the sub-basins can be regarded as pristine and even the Gulf of Bothnia, where EQR values were the highest at 0.83, showed a 17 % reduction from defined reference conditions. The entire Baltic Proper, from the Bornholm Basin to the northern Baltic Proper and the Gulf of Finland, was in a severely disturbed state.

The Arkona Basin is regularly flushed by saltwater inflows; the average EQR value for the assessment period was 0.71, which is above the good/moderate border. However, this value is based on limited data, and larger deviations from reference conditions probably occurs. In the Bornholm Basin conditions were severely disturbed, with an average EQR value of 0.44 (range: 0.25–0.81), representing a 56 % reduction from defined reference conditions. Also in the southeastern Gotland basin and the northern and central Eastern Gotland Basin, conditions were severe, with EQR values of 0.33 and 0.12 (range: 0.06–0.19), respectively.

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In the northern Baltic Proper, no fauna whatsoever was recorded for the assessment period, resulting in an EQR value of 0. This reflects the consistently bad oxygen conditions in this open sea area. Conditions in the Gulf of Finland were more variable, but also there benthic invertebrate status was bad, with an EQR of 0.24 (range: 0.13–0.34).

In the Gulf of Bothnia, where water column stratification is weak and oxygen conditions are generally good, EQR values were above the good/moderate border, i.e. an average of 0.91 in the Bothnian Sea (range: 0.69–1.0) and 0.83 in the Bothnian Bay (range: 0.71–0.94).
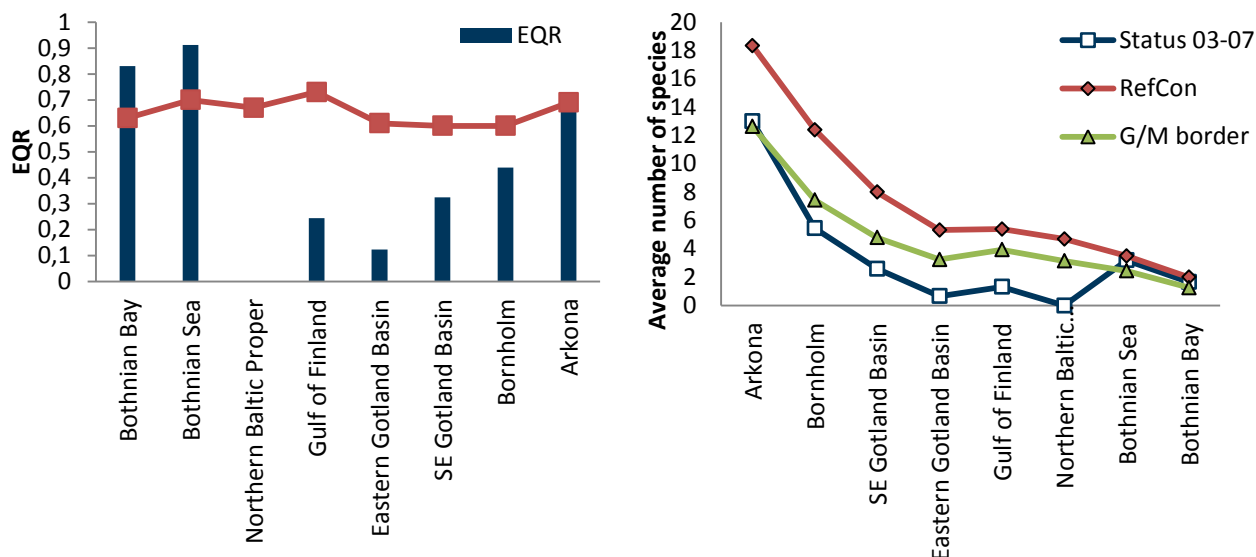

Figure 2. *Offshore species richness. Reference values and the border between good and moderate (G/M) ecological status in the different sub-basins in open sea areas of the Baltic Sea depicted as EQR (A) and the average number of species (B). Benthic invertebrate status is described as an average for the assessment period 2003–2007.*

Temporal development of benthic invertebrate communities in the Baltic Sea from the 1960s to 2007

When examining long-term trends in data collected between 1965 and 2007, it becomes immediately obvious that conditions were already disturbed in the mid-1960s. Benthic invertebrate status in the central parts of the Baltic Sea, in particular, is more or less entirely controlled by the presence or absence of hypoxia/anoxia. Current evidence suggests that the spatial and temporal extent of oxygen deficiency has increased over the past decades. In the light of historical work, it is also likely that reference conditions defined for open sea areas in this assessment are underestimates.

Generally, Baltic benthic macrofauna are characterized by small shallow-dwelling species owing to low salinity and transient hypoxia; historically it was only in the southern Baltic where more mature communities composed of deeper-dwelling, larger species, e.g. some long-lived bivalves and large polychaetes, could have developed. However, currently macrobenthic communities are severely degraded and below a 40-year average in the entire Baltic Sea.

Seasonal hypoxia, owing to increased nutrient inputs, has caused mortalities in the benthic communities in the Kattegat since the 1980s. The effects of hypoxia have been very patchy in both space and time, however, and cannot fully explain the general abundance pattern with high densities in the mid-1990s and relatively low values in the assessment period. Nor can hypoxia fully explain the long-term decrease in alpha species richness which occurred

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from the mid-1990s until 2006 (Figure 3 A). The more wide-ranging implications of reduced benthic communities, hypoxia-induced or not, has been observed for demersal fisheries in this sea area.

In comparison with the Kattegat, benthic diversity is much reduced in the deep waters of the Arkona Basin, the Bornholm Basin and the southern Gotland Basin, owing to the lower salinity regime. Benthic community composition in this area co-varies strongly with oxygen-rich saltwater inflows from the Danish Straits. A shift towards more polychaete-dominated communities, which are more tolerant to eutrophication, has been observed in the Bornholm and Arkona Basins (Figures 3 B–C). It is often the polychaete Bylgides (Harmothoe) sarsi together with Scoloplos armiger that dominate the community at deep-water stations, while the bivalve Macoma balthica and the amphipod Pontoporeia femorata occur only when oxygen conditions improve. Anoxic conditions occur repeatedly below the halocline. The southern Baltic has experienced an overall reduction in salinity during the 20th century, which has resulted in a replacement of marine species with brackish-water species (BCSIII-10 in the Figure above). This also highlights the problem of setting reference conditions as baselines shift.

The benthic communities in the northern Baltic Proper and the northern and central parts of the Eastern Gotland Basin are seriously reduced (Figures 3 D–E). Owing to a permanent halocline and reduced oxygen conditions, this area had impoverished macrozoobenthic communities or anoxic sediment conditions during the 1970s and 1980s. Intermittently recovering communities were recorded in the 1990s. The saltwater inflow in 1993 strengthened the halocline, resulting in a lack of zoobenthic communities on approximately one third of this sea area. Bylgides sarsi is the most frequently occurring species at these deep stations (80–170 m), occasionally together with the bivalve Macoma balthica, the amphipods Pontoporeia femorata and the priapulid Halicryptus spinulosus. The response of opportunistic benthic species to improved oxygen conditions can be rapid, but with a delay in the recovery of total community abundance and biomass.

In the Gulf of Finland, generally low benthic community abundance, biomass and diversity were recorded below the halocline during the 1960s and 1970s. When the halocline weakened and disappeared because of the prolonged stagnation period from 1977–1993, this resulted in an increased oxygen content of the bottom waters and recovery of the macrozoobenthic communities. The halocline was re-established in 1993–1994 and the abundant macrobenthic communities recorded in the early 1990s in the deep central parts of the Gulf crashed almost completely in 1996–1997, and have not recovered to any larger extent owing to continued poor oxygen conditions (Figure 3 F). As the oxygen content of bottom waters is reduced, key species in the Gulf of Finland such as Monoporeia affinis and Pontoporeia femorata disappear, along with more resistant species such as Macoma balthica and Saduria entomon. The polychaete Bylgides sarsi is a fast colonizer in intermittently recovering areas.

In the Gulf of Bothnia, low salinity strongly reduces faunal diversity, but also prevents the formation of water column stratification and hence makes conditions less susceptible to oxygen deficiency. However, in recent years some low oxygen levels (<40 % saturation) have been recorded, possibly due to early-stage eutrophication. Historically, macrobenthic communities have been entirely dominated by the amphipod Monoporeia affinis, which exhibits strong natural fluctuations in population abundance and usually comprises 70–100 % of total community abundance. Abundances have been severely reduced since the peaks in abundance and biomass in the early to mid-1990s and are generally below the longterm average (Figures 3 G–H). The reasons for this decline are unknown. However, some recovery has been observed in certain areas of the Bothnian Sea during the past years. The invasive polychaete Marenzelleria spp. has spread rapidly throughout most of the Gulf of Bothnia. In the southern Bothnian Sea (station SR5), its abundances increased noticeably between 2004 and 2006 (when it comprised about 80 % of total community abundance), but now polychaete numbers appear to be declining and the amphipods Monoporeia affinis and Pontoporeia femorata are recovering, at least in some areas of the Gulf.

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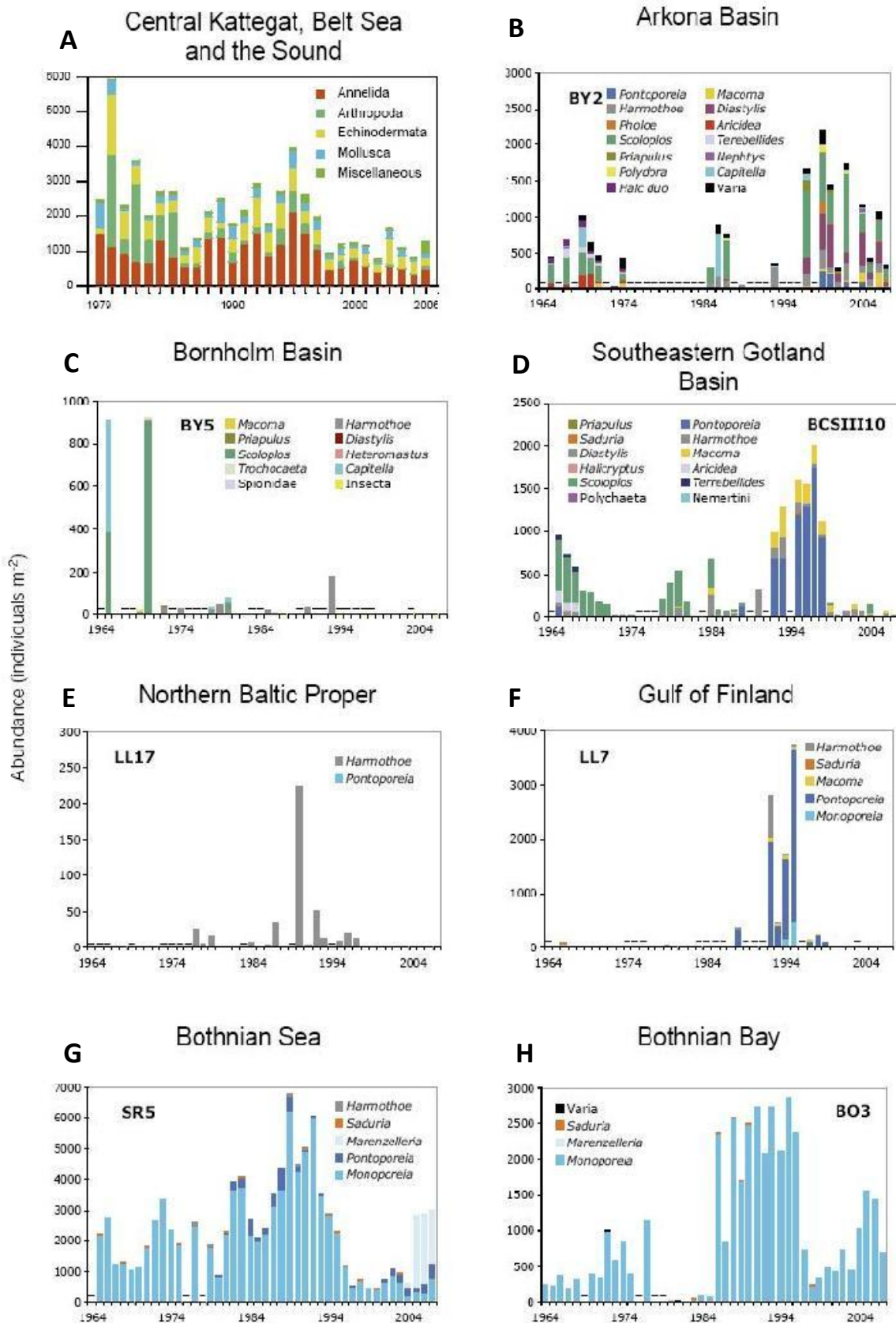
Figure 3. *Examples of long-term changes in macrobenthic communities in the open-sea areas of the Baltic Sea, with inclusion of data from the Kattegat. Note differences in x-axes and groupings of taxa between the Kattegat and the other sea areas.*

How the indicator describes the Baltic environment

Anthropogenic pressures on benthic communities

Faunal communities are adversely affected by the eutrophication, changes in water and sediment quality and hydrographic conditions such as salinity or temperature.

Table 1. Impacts of anthropogenic pressures on soft-bottom invertebrate diversity.

Slight eutrophication improves diversity, but severe eutrophication reduces diversity.
Physical disturbance (due to abrasion, smothering, changes in siltation) reduces diversity.
Physical loss (due to sealing or selective extraction) reduces diversity.
Introduction of synthetic compounds (due to ship accidents or harbours) reduces diversity.
Changes in the hydrological conditions (due to changes in salinity and/or temperature) alter diversity.

A conceptual model of the relation between benthic invertebrate communities and eutrophication

Initial positive effects of eutrophication and organic matter enrichment on food-limited benthic communities are reflected as increasing abundances and biomasses of benthic invertebrate fauna. For example, in the Bothnian Bay, where the background concentrations of nutrients are relatively low, positive correlations between increased nutrients in the water column and benthic communities can be observed.

Increasing amounts of nutrients result in a surplus of organic material reaching benthic habitats. This is not tolerated by sensitive species, and the increase in organic material input and subsequent disturbance will initially be seen as large fluctuations in benthic diversity, abundance and biomass. Species composition will change as conditions deteriorate, and the advantage gained by smaller-sized, tolerant species will result in decreasing total biomass and diversity of the benthic community. At advanced stages of organic enrichment, most bottom-water oxygen is consumed by the aerobic microbial decomposition of organic material, resulting in hypoxia and anoxia and initiating the release of toxic hydrogen sulphide from the sediments. At these advanced stages of hypoxia and anoxia, macrozoobenthos is eliminated and important ecosystem services are lost.

Perhaps the single strongest factor negatively influencing the biodiversity of benthic communities in the Baltic Sea is the increased prevalence of oxygen-depleted deep water. Hypoxia has resulted in habitat destruction and the elimination of benthic macrofauna over vast areas and has severely disrupted benthic food webs.
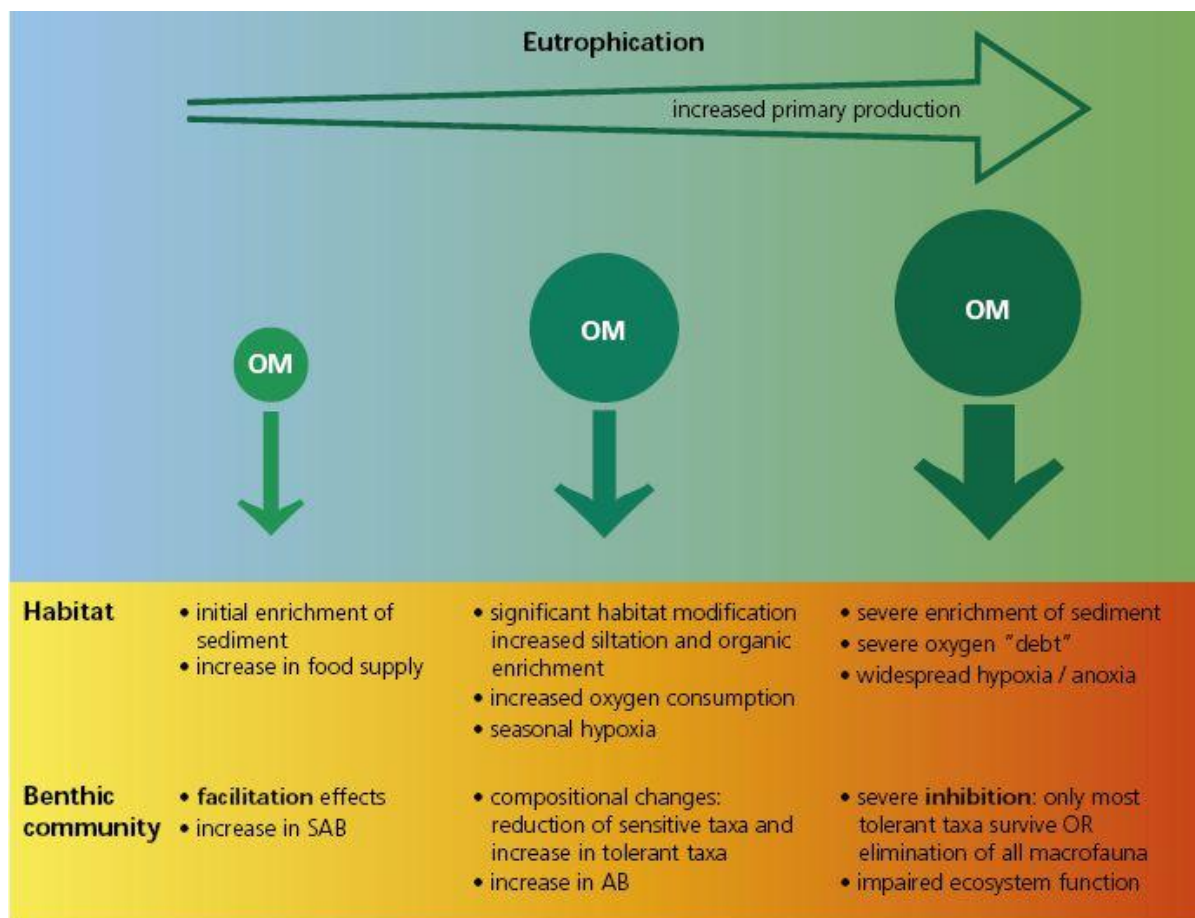
Figure 4. *A conceptual model describing the relationship between increasing deposition of organic matter (OM) and changes in soft-sediment habitats and macrobenthic communities. S = species, A = abundance, B = biomass.*

The off-shore index for the macrozoobenthic communities

Pressures affecting the off-shore imdex

The indicator responds mainly to the anthropogenic eutrophication, which causes hypoxia and anoxia in bottom waters (Pearson and Rosenberg 1978, Hyland et al. 2005, Norkko et al. 2006). The indicator reflects the increase in nutrient levels only indirectly and therefore the quantitative relationship to nutrient levels is difficult to ascertain. The relationship has however been found in the Bothnian Bay, where the background concentrations of nutrients are relatively low (HELCOM 2009). Increasing amounts of nutrients were seen to result in a surplus of organic material, leading to large fluctuations in benthic diversity as sensitive, large-sized and long-lived species did not tolerate the altered consitions. At more advanced stages of organic enrichment, the diversity starts to decline. The single strongest factor influencing the benthic diversity is, however, hypoxia.

Determination of the boundary for Good Environmental Status

The GES boundaries for the indicator in the sub-basins were set on the basis of historical data and standard deviations from those (Villnäs & Norkko, 2011). Reference values and acceptable deviations for the indicator were based on long-term monitoring data at >200 monitoring stations during 1964. Data from ~1800 sampling occasions was used. Generally only stations with a depth >40 m were included and anoxic and/or hypoxic periods (<2 mL O2/L) were

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excluded from the data. The reference value for each sub-area was identified as the average of the 10 % highest annual average regional diversity values during the monitoring period.

Acceptable deviation from reference conditions determines the Good-Moderate border. i.e the critical border between an acceptable and non-acceptable condition of benthic diversity (cf. the EU Water Framework Directive) and it represents natural fluctuations of species numbers in an area. Based on the long-term data used for identifying reference conditions, the acceptable deviation was defined as the relative standard deviation of average regional diversity in a sub-area per year. An average acceptable deviation for each sub-area was based on data from several years. The highest acceptable deviation allowed was set to 40 %.
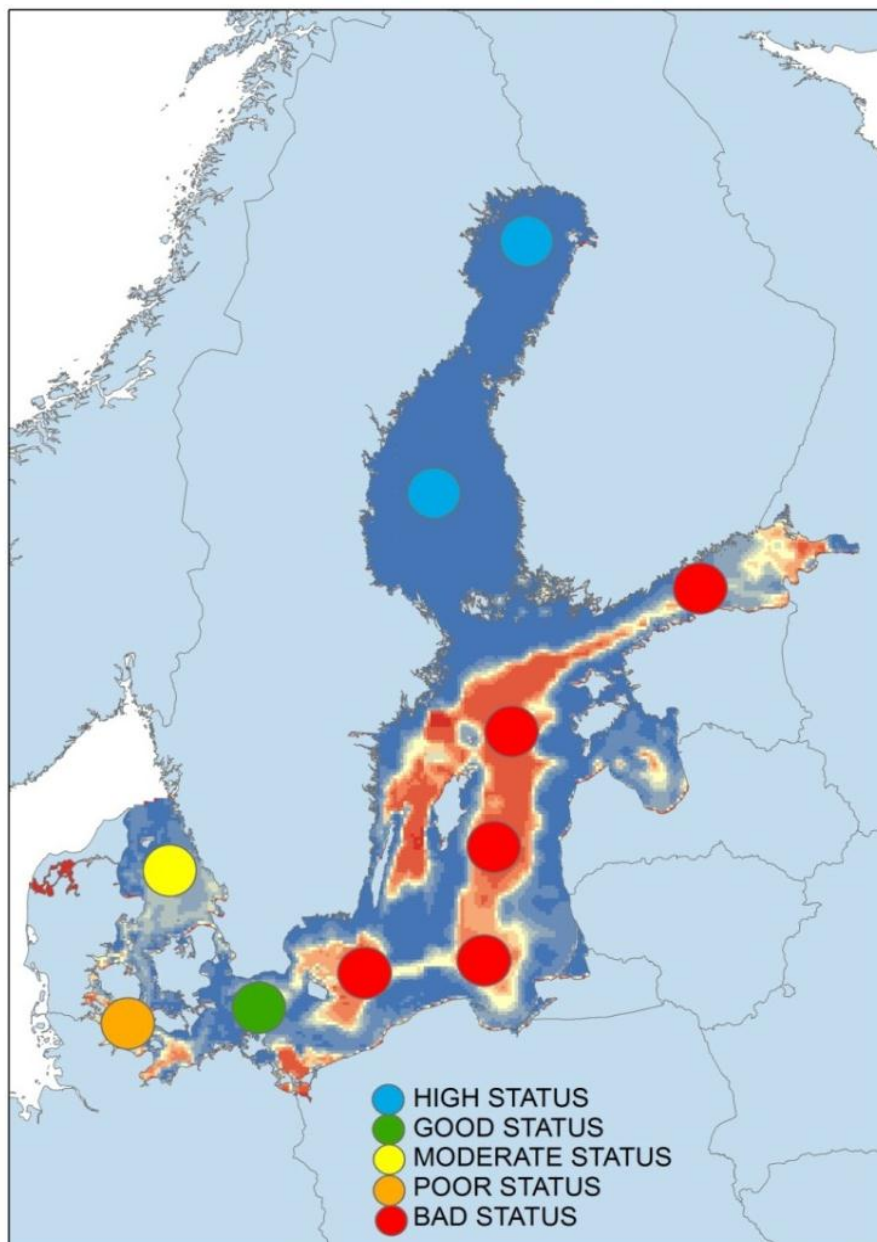
Figure 5. *The state of the offshore macrozoobenthic communities and oxygen concentrations. The key to the classification of communities is given in the figure. In the oxygen concentrations, red colour means low concentration and blue colour high concentration. The oxygen concentrations are modified from Hansen et al. (2007) and consist of an average concentration during 2003–2006.*

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The national multimetric indices for coastal water

An overview of the national indices

The indices for the assessment of the state of the benthic macroinvertebrates were developed as a response to the requirements arising from the EU Water Framework Directive which stated that benthic invertebrates are part of the biological quality element. As a result of no regional coordination, all EU Member States developed own indices (Table 2) and reference criteria and their compatibility was checked only later. The intercalibration exercises that aimed to bridge the national indices were finalized in 2011 and for the benthic invertebrates some countries in the Baltic Sea were able to intercalibrate their classification systems

Table 2. *National indices developed for assessment of WFD relevant water bodies using benthic macroinvertebrates in the Baltic Sea.*

Country	Method
Denmark (DK)	DKI, version 2
Finland (FI)	BBI
Estonia (EE)	ZKI
Germany (DE)	MarBIT
Latvia (LV)	BQI
Lithuania (LT)	BQI
Poland (PL)	B
Russia	
Sweden (SE)	BQI

Denmark. The Danish DKI index assesses soft bottoms by measuring abundance of all invertebrates in the van Veen 0.1m2 grab (sieve mesh size: 1mm). The boundary between the good and moderate status classes is based on discontinuities of the index to anthropogenic pressures (Josefson et al. 2009). In the DKI version 2, the species richness component was dropped.

Estonia. The Estonian ZKI index is based on relative biomasses (proportions of sensitive taxa) and species richness of benthic species on soft bottoms (Lauringson et al. 2012). The sieve mesh size is 0.25 mm. The good-moderate boundary is based on data from 1960s in non-polluted areas. The index was tested against the HELCOM Baltic Sea Pressure Index and inputs of nitrogen and phosphorus and statistically significant correlations were found.

Finland. The Finnish BBI index is a combination of BQI and Shannon diversity (Perus et al. 2007). The five samples are taken by Ekman grab and pooled. The sieve mesh size is 0.5 mm. The reference conditions are mostly based on current least disturbed areas (1990–2000) and in some cases to historical data. The status classes are set by statistics.

Germany. The German MarBIT index aggregates four separate metrics including indices on sensitive and tolerant species, species richness and abundance. The index is calculated from 10–20 pooled samples taken from each of up to three different substrates (soft bottom, phytal and hard bottoms) which are initially assessed separately (Meyer et al. 2009). Abundance of invertebrates is by default sampled by Kautsky frame (0.1m2) or alternatively by van Veen grab (0.1m2) on soft-bottoms in deeper water. The reference conditions are defined by autoecological information and expert judgment and verified by historical data and the good-moderate boundary was set on the basis of a significant change from the reference condition. It was tested against the Baltic Sea Pressure Index and inputs of nutrients with significant correlations.

Latvia, **Lithuania** and **Sweden** use the Benthic Quality Index (BQI, Rosenberg et al. 2004), which uses species abundance (weighted by species-specific sensitivity values) and the species richness. The index calculates the proportion of each species' abundance of the total abundance, weighs that by the sensitivity score, sums the weighted proportions, and finally the sum is multiplied by log-transformed species richness.

In Sweden, the index is sampled by van Veen grab (0.1 m2) from soft bottoms by a 1 mm sieve. The reference conditions are found from the least disturbed areas in 1981–2006; the highest BQI values per water type is the reference. The good-moderate boundary was set by a statistically significant change from the reference condition (Leonardsson et al. 2009). The index is calculated per sample.

In Lithuania, the index is sampled from soft bottoms by a 0.5 mm sieve. The reference conditions are based on historical data from 1980–2009 and expert judgment. The good-moderate boundary is set on the basis of proportions of sensitive species. The method has been tested against winter nutrient concentrations.

In Latvia, the index is sampled from soft bottoms by a 0.5 mm sieve. The reference conditions are based on historical data. The method has been tested against anthropogenic pressures and the good-moderate boundary is based on a discontinuity in the relationship of the index and the pressures.

Poland uses a B index which is basically the species richness of benthic macroinvertebrates. The sampling is done on soft bottoms by the van Veen grab (0.1 m2, 1 mm sieve). The reference conditions are based on data from 1999 to 2009 and expert judgment. The highest index value per water type is used as the reference. All the class boundaries were found by the natural jenks method (Blenska et al. 2010). The method has been tested against nutrient concentrations.

Table 3. *A summary table of the national macrozoobenthic multimetric indices. Source: The final report of the Baltic intercalibration group.*

Country	Parameters in the index						Combination rule of metrics
	Composition[#]	Abundance	Disturbance sensitive taxa	Diversity	Bio-mass	Taxa indicative of pollution	
Germany MarBIT CW	Taxonomic spread index TSI based on reference taxa list for each area (also see section 3.2. below)	Correlation with reference log-normal abundance distribution	Fraction of taxa sensitive to disturbance in relation to reference taxa list for each area	Taxonomic spread index based on reference taxa list for each area	No	Fraction of taxa tolerant to disturbance in relation to reference taxa list for each area	Median value of 4 indices
Sweden BQI CW-TW	composition of taxa with preclassified sensitivity values	Species abundance weighted with sensitivity value + adjustment factor abundance	4 sensitivity classes for the East- and South coast, continuous sensitivity value on the West-coast	Species richness (logarithmic)	No	Oligochaeta, Chironomidae etc.	1 formula of multiplications of metrics (20th percentile is compared to the reference values within each waterbody)
Finland BBI	composition of	Species abundance	4 sensitivity classes	Species richness	No	Oligochaeta, Chironomidae	1 formula including

CW	preclassified sensitivity classes	weighted with sensitivity value + adjustment factor abundance		(logarithmic), Shannon - Wiener's index		etc.	averaging and multiplications
Denmark DKI ver2 CW	composition of preclassified sensitivity classes	Species abundance weighted with sensitivity value (from AMBI component)*	As in AMBI method (5 sensitivity classes)	Shannon – Wiener's entropy index H	No	Specific opportunistic species	1 formula including averaging and multiplications
Lithuania BQI CW-TW	composition of preclassified sensitivity classes	Species abundance weighted with sensitivity value + adjustment factor abundance	4 sensitivity classes	Species richness (logarithmic)	No	Oligochaeta, Chironomidae etc.	1 formula including multiplications
Latvia BQI CW-TW	composition of preclassified sensitivity classes	Species abundance weighted with sensitivity value + adjustment factor abundance	4 sensitivity classes	Species richness (logarithmic)	No	Oligochaeta, Chironomidae etc.	1 formula including multiplications
Estonia ZKI CW	composition of preclassified sensitivity classes	No (see below)	3 sensitivity classes, no very sensitive taxa	Species richness adjusted to salinity at waterbody level (number of taxa divided by the maximum number of taxa per sample in the respective waterbody	Relative dry shell-free biomass of 3 sensitivity classes	Oligochaeta, Chironomidae	1 formula including multiplications
Poland B CW-TW	composition of taxa grouped into pre-classified sensitivity classes	species abundance weighted with sensitivity value + adjustment factor abundance	3 sensitivity classes	species richness (logarithmic)	No	Oligochaeta, Chironomidae, etc.	Average EQR for each water body, with more than one monitoring station

Metadata

Data source

Offshore data: Data on macrobenthic community composition was obtained during monitoring cruises of the Finnish Institute of Marine Research since 1964–65. The data is stored in the database of the Finnish Environment Institute (SYKE).

Coastal data: Sweden: www.viss.lst.se; Finland: www.ymparisto.fi/oiva; Estonia: ; Latvia: ; Denmark: ; Russia: ; Poland: Chief Inspectorate for Environmental Protection http://www.gios.gov.pl/artykuly/1046/Contact-us; Lithuania: ; Germany:

Description of data

Offshore data: Data from multiple monitoring stations per open sea area over the period 1964–2007 is used. Values are presented as mean of 3-5 parallel samples (sampler area 0.1 m^2, sieved on 1 mm mesh size), and are multiplied to values per square meter. The data are collected within the framework of the HELCOM COMBINE programme.

Geographic coverage

The indicator covers almost the entire Baltic Sea, but in offshore waters and coastal waters of Estonia, Latvia, Lithuania and Sweden it covers only soft bottoms. In waters outside the 1-nm limit, the offshore index misses some smaller sub-basins.

Offshore data: All regions of the Baltic Sea except for the Gulf of Riga, the western Gotland Basin, the Danish Straits and Kattegat.

Recommendations for monitoring

The benthic macrofauna should be monitored from all coastal assessment units and from the offshore sub-basins. The monitoring stations should cover also mixed-sediment bottoms.

Temporal coverage

Offshore waters: From 1964–65 to 2007. Current status is the average of 2003-2007.

Coastal waters: the assessment reports under the EU Water Framework Directive in 2009.

Methodology and frequency of data collection

Offshore waters: Vilnäs & Norkko 2011. Sampling and analyses are made according to the guidelines for the HELCOM COMBINE programme. Sampling is performed once a year in May-June.

Coastal waters:

Denmark: Josefson et al. 2009

Estonia: Lauringson et al. 2012

Finland: Perus et al. 2007

Germany: Meyer et al. 2009

Latvia:

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Lithuania:

Poland: Blenska et al. 2010

Russia:

Sweden: Leonardsson et al. 2009

Methodology and data analyses

Offshore index

The offshore index is considered preliminary because of its low geographical accuracy and lack of information on abundance or species composition.

The status of the Baltic Sea according to the described indicator has been classified using the multi-metric indicator-based HELCOM Eutrophication Assessment Tool (HEAT). Each area was assessed using information on reference conditions (RefCon) and acceptable deviation from reference condition (AcDev) combined with national monitoring data from the period 2003–2007. The basic assessment principle is RefCon ± AcDev = EutroQO, where the latter is a "eutrophication quality objective" (or target) corresponding to the boundary between good and moderate ecological status. When the actual status data (average for 2003–2007) exceeds the EutroQO or target, the areas in question is regarded as affected by eutrophication.

The Ecological Quality Ratio (EQR) is a dimensionless measure of the observed value (AcStat) of an indicator compared with the reference value (RefCon). The ratio is equal to 1.00 if actual status is better than or equal to reference conditions and approaches 0.00 as deviation from reference conditions becomes large. The value of EQR is used to assign a quality class to the observed status. The classes in descending order of quality are RefCon, High, Good, Moderate, Poor, Bad. The central definition of the quality classes is given by the value of acceptable deviation (AcDev).

The RefCons and AcDev values for the benthic invertebrate assessment were first defined by a group of national experts from the HELCOM Contracting Parties for the HELCOM thematic assessment on eutrophication (HELCOM 2009a). The first assessment was based on identifying the status for the period 2001-2006, including data from coastal areas. This assessment covers the period 2003–2007 and includes data from only open sea areas.

For a complete explanation of the methodology used, please see Andersen et al (2010) and thematic integrated assessment on eutrophication of the Baltic Sea (HELCOM 2009a).

Determination of GES boundaries
See above.

Strengths and weaknesses of data

Strengths

Benthic invertebrate communities are good indicators of environmental status. Owing to their relative longevity (years to decades), the composition of benthic communities integrates environmental conditions over longer periods of time. Hence, variations in environmental characteristics, such as salinity, oxygen, food supply, biotic interactions, and different types of disturbances (both natural and anthropogenic), are reflected in the composition of communities in time and space.

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The coastal indicator has gone through an international intercalibration which is a strengthness, although the intercalibration was not successful for all cases (see JRC Technical Report). The obvious weakness is that the indicator is based on several metrics.

Weaknesses

- Offshore species richness reflects mainly the oxygen deficiency, does not consider species proportions or densities and its geographical accuracy is rather low.
- Several national indices are adapted only to soft bottoms.

Further work required

The coastal indices should be made applicable to all seabed types.

The offshore seabed should be assessed by a compatible index

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References

Andersen, J.H., P. Axe, H. Backer, J. Carstensen, U. Claussen, V. Fleming-Lehtinen, M. Järvinen, H. Kaartokallio, S. Knuuttila, S. Korpinen, M. Laamanen, E. Lysiak-Pastuszak, G. Martin, F. Møhlenberg, C. Murray, G. Nausch, A. Norkko, & A. Villnäs. 2010. Getting the measure of eutrophication in the Baltic Sea: towards improved assessment principles and methods. Biogeochemistry. DOI: 10.1007/s10533-010-9508-4.

Andersin, A.-B., J. Lassig, L. Parkkonen & H. Sandler (1978): The decline of macrofauna in the deeper parts of Baltic Proper and Gulf of Finland. Kieler Meeresforschungen 4:23–52.

Blomqvist, M., Cederwall, H., Leonardsson, K. & Rosenberg, R. 2007. Bedömningsgrunder för kust och hav. Bentiska evertebrater 2006. Rapport till Naturvårdsverket 2007-04-11. 70 pp. (in Swedish with English summary)

Błeńska M, Osowiecki A, Kraśniewski W, Piątkowska Z, Łysiak-Pastuszak E (2010): Macrozoobenthos quality assessment in the Polish part of the southern Baltic Sea using a biotic index "B". ICES Annual Science Conference 2010, 20–24 September 2010, Nantes, France, Abstracts – Theme Session H, ICES CM 2010/H:34, http://www.ices.dk/iceswork/asc/2010/ThemeSessions (poster).

Fleischer, D. & Zettler, M. (2009): An adjustment of benthic ecological quality assessment to effects of salinity. Marine Pollution Bulletin 351-357.

Hansen IS, Keul N, Sørensen JT, Erichsen A & Andersen JH (2007) Oxygen Maps for the Baltic Sea. BALANCE Interim Report No. 17. Available at: http://balance-eu.org/xpdf/balance-interim-report-no-17.pdf

HELCOM. 2009. Thematic Assessment of eutrophication. Balt. Sea Envin. Proc. No. 115 B. Available at: www.helcom.fi/publications.

HELCOM 2009b. Biodiversity in the Baltic Sea. An integrated thematic assessment on biodiversity and nature conservation in the Baltic Sea. Baltic Sea Environment Proceedings No. 116B.

Hessle, C. (1924): Bottenboniteringar i inre Östersjön. Meddelanden från Kungliga Lantbruksstyrelsen, No. 250:12–29.

Hyland, J., L. Balthis, I. Karakassis, P. Magni, A. Petrov, J. Shine, O. Vestergaard, and R. Warwick. 2005. Organic carbon content of sediments as an indicator of stress in the marine benthos. Marine Ecology Progress Series 295:91–103.

Josefson AB, Blomqvist M, Hansen JLS, Rosenberg R, Rygg B (2009): Assessment of marine benthic quality change in gradients of disturbance: Comparison of different Scandinavian multi-metric indices. Marine Pollution Bulletin 58, 1263-1277.

Karlson, K., R. Rosenberg & E. Bonsdorff (2002). Temporal and spatial large-scale effects of eutrophication and oxygen deficiency on benthic fauna in Scandinavian and Baltic waters - a review. Oceanography and Marine Biology: an Annual Review 40:427-289.

Laine, A.O., A.-B. Andersin, S. Leiniö & A.F. Zuur (2007): Stratifi cation-induced hypoxia as a structuring factor of macro zoobenthos in the open Gulf of Finland (Baltic Sea). Journal of Sea Research 57:65–77.

Laine, A.O., H. Sandler & J. Stigzelius (1997): Longterm changes of macrozoobenthos in the Eastern Gotland Basin and the Gulf of Finland (Baltic Sea) in relation to the hydrographical regime. Journal of Sea Research 38:135–159.

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. http://www.sciencedirect.com/science/article/pii/S1470160X11000902.

Leonardsson K, Blomqvist M, Rosenberg R (2009): Theoretical and practical aspects on benthic quality assessment according to the EU-Water Framework Directive - examples from Swedish waters. Marine Pollution Bulletin 58, 1286–1296.

Meyer Th, Berg T, Fürhaupter K (2009): Ostsee-Makrozoobenthos-Klassifizierungssystem für die Wasserrahmenrichtlinie - Referenz-Artenlisten, Bewertungsmodell und Monitoring. (in German, with English summary), 131pp, http://www.marilim.de/marbit/download/files/MarBIT.pdf

Norkko, A. & M. Jaale (2008): Trends in soft sediment macrozoobenthic communities in the open sea areas of the Baltic Sea. In: Olsonen, R. (ed.). MERI 62:73–80.

Norkko, A., R. Rosenberg, S. F. Thrush, and R. B. Whitlatch. 2006. Scale- and intensity-dependent disturbance determines the magnitude of opportunistic response. Journal of Experimental Marine Biology and Ecology 330:195–207.

Norkko, A., T. Laakkonen & A. Laine (2007): Trends in soft-sediment macrozoobenthic communities in the open sea areas of the Baltic Sea. In: Olsonen, R. (ed.). MERI 59: 59–65.

- -

- -

Pearson, T. H., and R. Rosenberg. 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanography and Marine Biology: an Annual Review 16:229–311.

Perus J, Bonsdorff E, Bäck S, Lax HG, 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., Blomqvist, M., Nilsson, H.C., Cederwall, H., Dimming, A., 2004. Marine quality assessment by use of benthic species-abundance distributions: a proposed new protocol within the European Union Water Framework Directive. Marine Pollution Bulletin 49, 728–739.

Villnäs, A. & Norkko, A. (2011): Benthic diversity gradients and shifting baselines: implications for assessing environmental status. Ecological Applications 21: 2172–2186

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Annex 1

Proposed indicator for soft benthic habitats:

Distribution and extent of the oxygenated soft sediment habitat for macrozoobenthos

1. Introduction

The CORESET interim report of the development of a set of core indicators (HELCOM 2012) pinpointed that a severe gap in the progress of CORESET work was the lack of indicators for benthic habitats and associated communities. In order to bridge the gap, the first team meeting of the CORESET benthos experts convened on 15 March 2012 in Helsinki, Finland, to discuss possible indicators and plan the next steps in the development work. The meeting considered a method to photograph sediment profiles and examine the oxygenated sediment layer as a potentially cost-efficient way to make spatial overviews of the extent and volume of the oxygenated sediment habitat for macrozoobenthos, which could be used as a first-step proxy for the condition of benthic communities.

This document is a first draft of the indicator description and it should be seen as a living document which will be updated with fresh information, best practices and lessons-learnt and the method will be sharpened during the process.

2. Description of the indicator

Oxygen conditions are important in structuring the benthic communities. On soft bottoms the oxygen conditions reflect the condition of the sediment and status of the macrobenthic community (Cicchetti et al. 2006). On the other hand, burrowing organisms keep the sediment oxygenated, thus providing conditions suitable also for more sensitive species, which result in higher diversity.

The oxygen conditions in the sediment can be demonstrated by the redox potential discontinuity (RPD), which is the depth where oxidizing processes are displaced by reducing processes. In a picture of the sediment profile, the shift from brownish sediment where particles are covered with ferric hydroxide, to grayish-black sulphidic sediment can be used to identify the RPD depth and is referred to as the apparent redox potential discontinuity (aRPD) (Nilsson & Rosenberg 1997; Fig. 1). The depth of the aRPD can be used to characterize the benthic habitat and to identify successional stages of the benthic community (Bonsdorff et al. 1996, Nilsson & Rosenberg 1997, 2000; Fig. 1). Thus, the depth of the aRPD can be used as a proxy for the function and condition of the soft bottom communities, as well as for habitat quality (Birchenough et al. 2012).

Temporal variations in oxygen concentration are reflected in the depth of the oxygenated sediment layer and measurements of aRPD thus integrate changes in oxygen conditions over ecologically relevant time scales (Cicchetti et al. 2006). Potentially, the measures of aRPD could be combined with scores for infaunal and epifaunal activity from sediment profile images to calculate the Benthic Habitat Quality index (Nilsson & Rosenberg 1997; see '4. Methods')

The indicator would reflect the distribution and extent of soft sediments where the oxygenated layer exceeds a certain depth, thus indicating the extent of soft bottom habitat suitable for a diverse community of macrofauna. Although this method cannot replace traditional benthos monitoring, it will allow a higher spatial resolution in the estimates of soft sediment habitat quality.
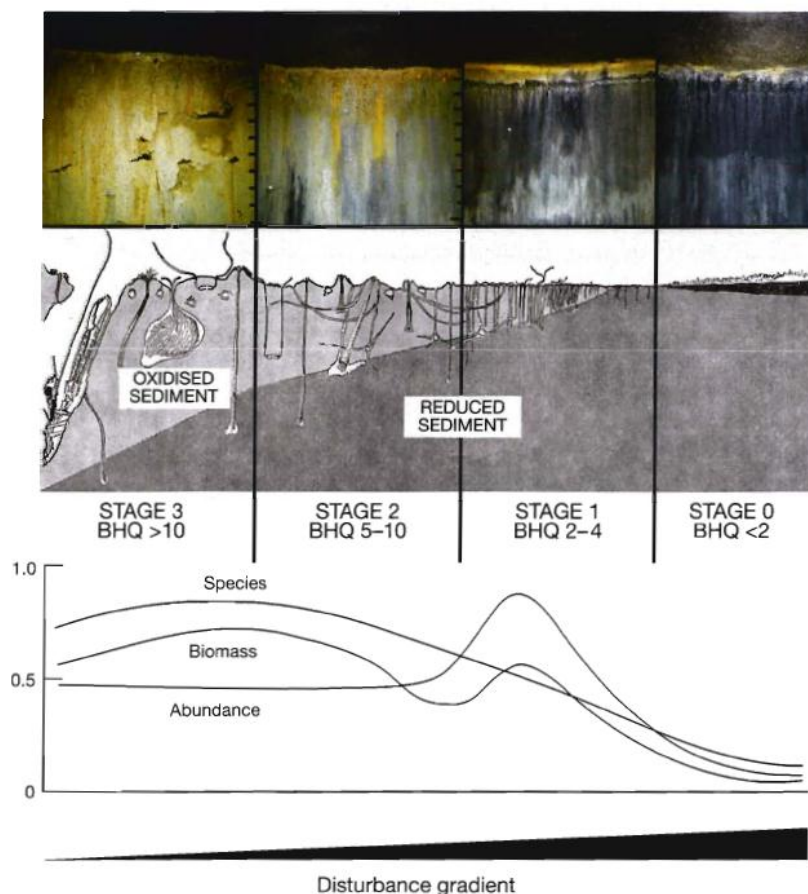
Figure 1. *Successional stages of the infaunal benthic community and corresponding sediment profile images. Species, abundance and biomass changes along the disturbance gradient are based on Pearson & Rosenberg (1978). Figure from Nilsson & Rosenberg (2000).*

3. Policy relevance

The indicator for the distribution and extent of oxygenated soft benthic habitats responds to several environmental policies. Benthic habitats are an essential part of the Baltic Sea ecosystem, supporting a wide range of associated species and being sometimes also structured by plants or mussels. For highly mobile species like fish, waterbirds and mammals the benthic habitats provide feeding grounds, spawning grounds or nursery areas of young.

The Baltic Sea Action Plan sets a biodiversity goal 'Favorable Conservation Status of Baltic Biodiversity' and ecological objectives for 'Thriving communities of plants and animals' and 'Natural marine landscapes', which include the benthic (abiotic) habitats and associated communities.

The EU Marine Strategy Framework Directive (MSFD) requires an assessment of the distribution and extent of benthic habitats as part of the qualitative descriptor 1 ('biodiversity is maintained'). Also the descriptor 6 ('sea-floor integrity') addresses benthic habitats and particularly the condition of benthic communities. The EC Decision Document (477/2010/EU) suggests an indicator under the criterion 5.3 (descriptor 5, eutrophication) for dissolved oxygen, representing indirect effects of nutrient enrichment. The parameter proposed in this document can be used to support also this criterion.

4. Methods

Sediment profile imagery (SPI) can offer *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 the sediment and like an up-side-down periscope takes a vertical picture of the sediment profile (Fig. 2). The pictures are

analyzed for surface structures, epifauna, infauna, burrows, voids and the aRDP depth is measured. Based on these parameters an index describing the habitat quality can be calculated (Benthic Habitat Quality, BHQ; Nilsson & Rosenberg 1997). SPI has been used to study the effects on the benthic habitat by for example hypoxia (Nilsson & Rosenberg 1997, 2000, Cicchetti et al. 2006) and trawling (Rosenberg et al. 2003, Nilsson & Rosenberg 2003).

Using the SPI-system is probably the most efficient method to picture the sediment profile. An alternative, which will be used during the testing, is to take sediment cores which are photographed to measure the aRPD using image analysis.
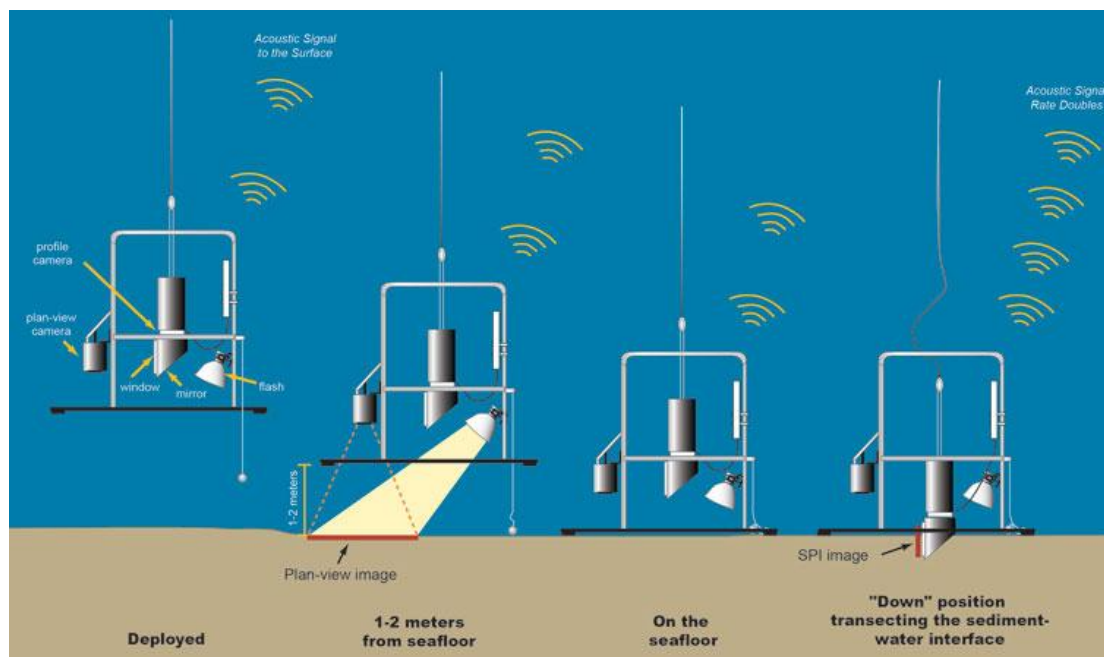

Figure 2. Overview of the sediment profile imagery (SPI) method. Source: www.remots.com

5. Approach for defining GES boundaries

To be developed.

6. Gaps and weaknesses

To be filled at a later stage

7. 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

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.

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

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

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

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