



Coastal marine zoobenthos as an ecological quality element: a test of environmental typology and the European Water Framework Directive

Jens Perus¹, Saara Bäck², Hans-Göran Lax³, Vincent Westberg³, Pirkko Kauppila² & Erik Bonsdorff¹

¹Environmental and Marine Biology, Åbo Akademi University, Turku, Finland

²Finnish Environment Institute, Helsinki, Finland

³West Finland Regional Environment Centre, Vasa, Finland

Abstract

The European Water Framework Directive focuses on the importance of biological and ecological quality elements (phytoplankton, macroalgae, zoobenthos and fish) in classification of the ecological status (EcoQ) of surface waters within Europe. Most surface waters typologies are constructed based on hydro-morphological factors while the EcoQ is based on the status of the biological, hydro-morphological and physico-chemical quality elements, with the importance of biological elements emphasised.

A crucial question is whether a typology constructed on hydro-morphological factors reflects the characteristics of the quality elements to be used in the assessing the EcoQ, i.e. whether “ecology” follows “typology”.

This contribution presents a test on the possible coupling between a proposed typology based on hydro-morphological data and the community assemblages of an ecological quality element, namely macrozoobenthos, for the Finnish Baltic Sea coastal waters under the WFD.

1 Introduction

Nutrient enrichment has been the major threat to the environmental health of coastal marine waters on a global scale for the last 30 years (NIXON 1995; CLOERN 2001; ELMGREN 2001). National and international initiatives and treaties have been agreed upon to combat this threat locally and globally. Recently new legislation was brought forward within Europe, the European Union’s Water Framework Directive (2000/60/EC) (ANON 2000). The Water Framework Directive (WFD) establishes a framework for the protection of all waters (including inland surface waters, transitional waters, coastal waters and groundwater). Overall, the directive aims at achieving good ecological status for all waters by the year 2015 and all EU Member states are therefore required to protect and enhance the status of all types of water. Member states are to assess the ecological status (EcoQ) of these water bodies. The EcoQ is based on the status of the biological, hydro-morphological and physico-chemical quality elements, with the importance of biological elements emphasised. Biological elements to be used in coastal marine and transitional waters are phytoplankton, macroalgae, benthos and fish (the latter only in transitional waters).

The WFD requires surface waters to be split into water bodies, representing the classification and management unit of the Directive (BORJA et al. 2004). The Baltic Sea is defined as one Ecoregion under the WFD and its water bodies can belong to one of six surface water categories (e.g. rivers, lakes, transitional waters, coastal waters, artificial and heavily modified water bodies), which are subdivided into types into which the surface waters are later assigned. The water bodies of one type can be sub-divided into smaller units according to pressure and resulting impact (VINCENT et al. 2002). Water bodies within each surface water category are differentiated according to type using a system

of typology as defined in the WFD. The use of both obligatory factors (A-system: latitude, longitude, tidal range and salinity) and optional factors (B-system: depth, wave exposure and other factors) are recommended until an ecologically relevant type of water with unique characteristics is achieved (VINCENT et al. 2002). This typology process has been tested at a Baltic Sea level within the EU-project "CHARM" (Characterization of the Baltic Sea Ecosystem: Dynamics and Function of coastal types; <http://charm.dmu.dk>) as well as at national level in all countries affected by the EU WFD legislation. This work requires a close link to ecology: The crucial question is whether a typology constructed on hydro-morphological factors reflects the characteristics of the ecological quality elements to be used in the assessing the EcoQ, i.e. whether "ecology" follows "typology", and whether it should, in fact, be the other way around.

The aim of this study is to test the coupling between the proposed typology built on hydro-morphological data and the community assemblages of an ecological quality element, namely macrozoobenthos, for the Finnish coastal waters under the WFD.

1.1 Characterization of Finnish coastal waters

In the Finnish national characterization process, **System A** was found to be too simplistic, providing only a crude differentiation between potential types. The system produced only three different types based on salinity and depth (SCHERNEWSKI & WIELGAT 2004). The lack of differentiation is due to the fact that most of Finnish coastal waters belong to the depth class ≤ 30 m and that salinity is within one of two categories: oligohaline (salinity < 0.5 or $0.5-5$ PSU) or mesohaline (salinity $5-18$ PSU). System A also characterized two remote and separate areas, namely the Bothnian Bay/Quark and the eastern Gulf of Finland as one common type, whilst the Archipelago Sea, Bothnian Sea and western Gulf of Finland formed another. Based on expert judgment (Finnish National Committee for coastal waters; SYKE), this kind of environmental typology does not form a sensible basis for reliable ecological classification.

System B created a more sensible array of types and was found better suited for the characterisation of Finnish coastal areas. This proposal (KANGAS et al. 2003) suggested 16 coastal water types (Fig. 1). The coastal waters were first split into four types based on salinity and location (latitude and longitude). The resulting typology, where the Bothnian Bay and the eastern Gulf of Finland were assigned into the same type, was not considered adequate to represent the ecological communities along the coast. Therefore, each of the separate sections of the coast (Gulf of Finland, Archipelago Sea, Bothnian Sea, Quark and Bothnian Bay; Fig. 1) was divided into separate types using the duration of ice coverage and, to a lesser extent, mean substratum composition (i.e. rocky or sandy coasts, muddy or stony bottoms, etc.). Finally, each of the sections of the coast was split into an outer open zone and an inner coastal zone based on mixing conditions and wave exposure, which was derived from the density of islands, openness of water areas and mean water depth. The Archipelago Sea could be split further into inner, middle and outer zones due to its topographic complexity and zonation patterns described both for the biota (BONSDORFF et al. 1996; 2003; HÄNNINEN & VUORINEN 2001; O'BRIEN et al. 2003; PERUS & BONSDORFF 2004) and hydrography (JUMPPANEN & MATTILA 1994; BONSDORFF et al. 1997; HÄNNINEN et al. 2000).

For the entire Baltic Sea a separate **CHARM Typology** was also created as a basis for a common ecological environmental quality testing, and developing a joint monitoring strategy for all coastal waters of the Baltic Sea. This typology is intended to serve as an umbrella and be a basis for further more detailed splitting of water areas on national basis. In this classification salinity is the main factor along with depth/mixing and water residence time of enclosed areas (SCHERNEWSKI & WIELGAT 2004). This approach produced 4 water types for the Finnish coast.

In this analysis, the original national division (16 types; Fig. 1) is used and tested against soft-bottom macrozoobenthos (species composition, number of species and abundance patterns).

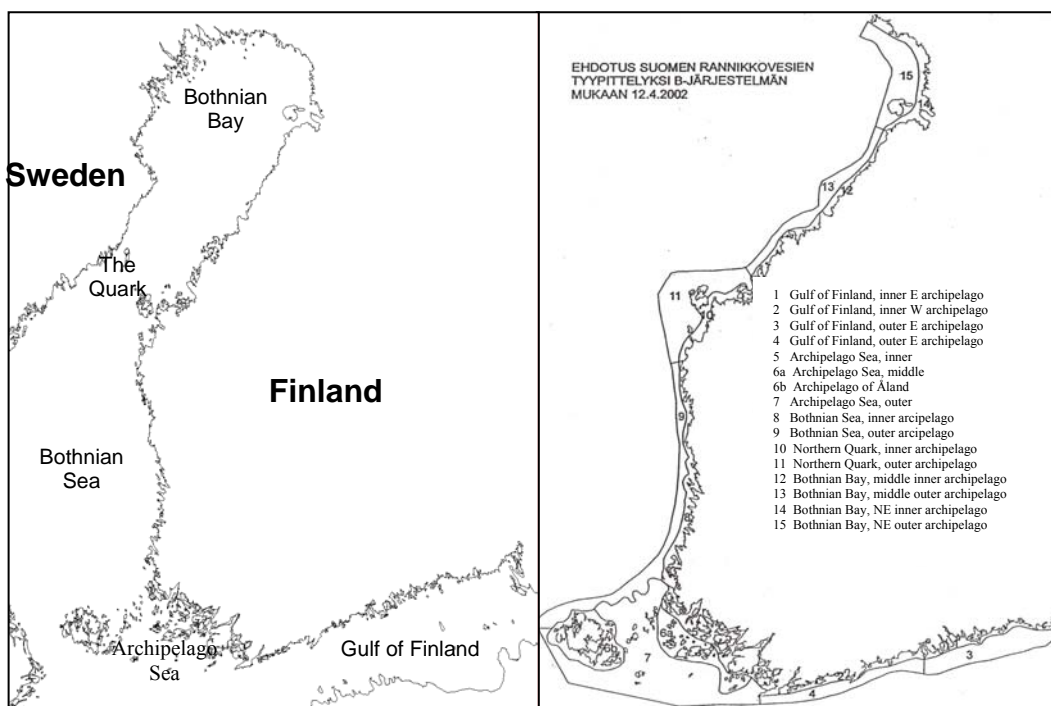


Figure 1: Finnish coastal regions and the proposed Finnish typology under the WFD (Maps from the Finnish Environment Institute, SYKE).

2 Methods

2.1 Monitoring data used

In order to be able to potentially confirm environmental typology with the use of biological data, in this case macrozoobenthos, there is a need for expert knowledge and large amounts of reliable data. Finnish coastal waters have been monitored for decades and the longest annually sampled stations were started already in 1964 for one pair of sampling-stations (KARJALA & LASSIG 1985). Monitoring can either be targeted on recipient studies of anthropogenic impact or on follow-up of the changes in relative health of coastal areas and ecosystems. Available databases of the ecological quality elements were analysed, and for macrozoobenthos data-gathering and subsequent quality-control had to be done from zero, and data requests were sent out to national, regional and local authorities, consulting firms and universities conducting monitoring- or research-studies. The database contains station-wise information about geographical position (coordinates, sea area and type), sampling date, station ID, monitoring programme, depth, number of replicates, sieve mesh-size, method of preserving samples, species, abundance, and biomass. ICES nomenclature has been applied for species, genera and higher taxa.

The benthic database today contains of some 8000 inputs from about 1000 individual stations data, spatially covering the entire Finnish coastline. The bulk of data covers the time period 1990-present.

2.2 Test of zoobenthos and typology

A test was carried out comparing the possible agreement between the proposed typology built on only hydro-morphological data and the community assemblage of the ecological quality element, macrozoobenthos.

Quality-assured abundance data was used from the database covering the time-period 1990-2000. The taxonomical resolution of some taxa was unevenly reported in the different studies and hence in the current analysis species within the family *Chironomidae* and the class *Oligochaeta* have been pooled as one each in order to standardise the data and thereby avoiding comparing the individual skills of

taxonomists between geographical areas or between taxa. Only data collected with a mesh-size < 0.6 mm was used.

Abundance data was grouped into $\leq 10\text{m}$ and $>10\text{m}$ depth-strata and divided into types assigned *a priori*. Depth plays an important role in structuring the coastal ecosystems. The choice of 10 meters as a separator was based on the knowledge that the average depth of the thermocline in the summertime in the northern Baltic Sea is at about 10m. The 10m depth threshold also reflects the euphotic zone in most coastal areas and sets the limit on the depth of the littoral zone. This depth limit, perhaps not as important for macrozoobenthos as for macroalgae and phytoplankton, will thus help compare results for similar future studies on the other two quality elements. This separation was also done in order to check for the possibility to identify type-specific community-assemblages both in the littoral zone as well as in deeper residing areas. Types were deemed significantly different if benthic community-assemblages from both depth classes showed similar interpretations, i.e. higher inter-type variation than intra-type. Types tested against each other were either neighbouring types, types within mosaic archipelago regions, types residing within common subbasin or distant types having similar hydromorphological characteristics such as salinity.

Abundance data was square root-transformed and analysed using non-parametric multidimensional scaling (MDS), analysis of similarity (ANOSIM) and similarity percentage (SIMPER) – analysis methods included in the PRIMER software (CLARK & WARWICK 1993; CLARKE & GORLEY 2001).

The ANOSIM-analysis used for testing for assemblage differences between groups of samples (types), specified *a priori*, puts no restrictions on a balanced number of replicates (CLARK & WARWICK 1994). Comparison of pairwise R values, measuring how separate groups are, on a scale of 0 (indistinguishable) to 1 (all similarities within groups are less than any similarity between groups) gives an interpretable number for the difference between groups. We interpreted R-values >0.75 as well separated; $R>0.5$ as overlapping, but clearly different and $R<0.25$ as barely separable at all, in accordance with the PRIMER-manual (CLARKE & GORLEY 2001). A SIMPER-analysis was used for identifying which species primarily account for observed differences in benthos assemblages between types. This routine also identifies species typical of a specific environmental type.

3 Results

The results showed that an environmental typology constructed solely by using factors in System B reflects the community assemblage of one of the quality elements, macrozoobenthos, reasonably well. However, there were some areas along the Finnish coastline where these two aspects did not match.

3.1 The Finnish coast

According to the definition of "coastal waters" in the WFD, Finland has a 1300 km long coastal zone (under the WFD), which comprises 34 000 km² of coastal waters. Below follows a brief description of the characteristics of the regions in which the different types have been defined, according to system B in the Finnish national coastal typology (KANGAS et al. 2003; Fig. 1).

3.1.1 The Gulf of Finland

The Gulf of Finland is defined as the area east of the uttermost tip of the Hanko peninsula. In the gulf salinity ranges from 3 to 6 PSU. For typology-purposes, the gulf is split at the 5 PSU border. Extent of ice cover 60-150 d a⁻¹ and level of exposure were used to divide the region into 4 categories of environmental classes (Types 1-4) within the Gulf of Finland. The eastern inshore type (Type 1) is shallow (average depth 15m) and consists of a variety of highly different environments. The shoreline is broken with many semi-enclosed bays and river mouths with large islands or groups of smaller islands outwards. The bottom-substrate is both soft and hard with deep trenches in between (30-40m).

The western inshore category (Type 2) is similar but even shallower (but more saline) than the eastern inshore type. The eastern outer category (Type 3) has an average depth of 15-30m with deeper

trenches (30-60m) from the open sea area cutting into the area. Land is scarce and the islands, when present, are small. The western outshore category (Type 4) is similar to the eastern type regarding depth, land/sea ratio and bottom characteristics. However, in the westernmost part where the type borders to the mosaic Archipelago Sea a mix of different environments is created, affecting the biota, and potentially demanding an environmental category of its own.

Testing benthos on environmental typology within the Gulf of Finland showed high intra- and inter-category variation for the types defined when analysing benthic infauna. Types 1 and 2 showed high levels of similarity between categories, but species composition differed considerably, and thus these type-areas may be considered “real” in the sense that biology confirms typology.

3.1.2 The Archipelago Sea and the Åland Island

The Archipelago Sea is characterized by numerous islands and skerries covering an area of 8300 km². This mosaic region is shallow (average depth 23m) and the proportion of the littoral zone is pronounced, emphasising the importance of near-shore shallow areas for the functioning of the ecosystem. The water residence time varies in the area covering both inner bays and open sea. Salinity ranges between 5,5 and 6,5 PSU and is the highest along the Finnish coast. Due to the high diversity of biotopes in this region, and the relatively high salinity, benthic biodiversity is the highest found in Finnish coastal waters.

The region is split into 4 environmental classes (Types 5, 6a, 6b & 7) describing the zonation going from the inner archipelago towards the open sea. The inner zone (Type 5) is characterized by proportionally more land than sea, large islands and narrow bays stretching far inland. Water depth is shallow (< 10m) and water exchange poor. The middle part (Types 6a & 6b) of the archipelago contains numerous smaller islands separated by more exposed waters. The outer zone (Type 7) is characterized by high exposure and only small barren islands and skerries positioned in the open sea with deep furrows in between.

Benthic community data from this region showed high intra- and inter-type variability, illustrating the high complexity and multiple biotopes in the area. Inner (Type 5) and middle (Type 6a) archipelago zones showed the highest similarities but the species composition of the two types differed, separating between species of marine (e.g. common blue mussel *Mytilus edulis*, Baltic clam *Macoma balthica*) and freshwater origin (e.g. oligochaetes and chironomids).

3.1.3 The Bothnian Sea

This open coast is a rather homogenous area with a long, shallow and exposed coastline with no major shift in salinity (about 5 to 5.5 PSU). This coastal area is located in between two shallow sill areas, namely in the south by the Archipelago Sea, and in the north by the Quark.

This area is divided into an inner (Type 8) and an outer (Type 9) environmental category. The narrow and shallow inner type is characterized by shallow bays and a few large islands. The outer type is an exposed open maritime environment with increasing depth.

No ecological test on typology could be carried out for this area due to a more or less complete lack of reliable data on macrozoobenthos from the outer coastal region.

3.1.4 The Quark

The shallow (average depth ca 10m) Quark region with its extensive archipelago functions as a sill in the Gulf of Bothnia separating the Bothnian Sea and the Bothnian Bay from each other (Fig. 1). Primary production in the Bothnian Sea is normally nitrogen limited in summertime while the Bothnian Bay is phosphorus limited. The basic ecology of the system thus changes dramatically passing north of the Quark as salinity decreases from 5,5 PSU to ≤ 4 PSU and many species of marine

origin meets their northern limit of distribution. The extent of ice cover ranges from 120-150 d a⁻¹ in the outer coastal parts of the Quark to > 150 d a⁻¹ in the inner nearshore regions.

The Quark is split into an inner (Type 10) and outer category (Type 11) in the Finnish typology proposal. This separation is also detectable for the benthic assemblages at depths >10m.

The environmental types in the Quark also differ from those in the Bothnian Bay (Fig. 2), reflected also in the disappearance of the benthic key-species such as *Macoma balthica* when salinity drops below 4 PSU.

3.1.5 The Bothnian Bay

The shallow Bothnian Bay is characterised by low salinities (1-4 PSU), great influence by river inflow and the long extent of ice cover (> 150 d a⁻¹). Biodiversity is low in the Bothnian Bay due to the low salinity, and the cold climate.

In the national Finnish proposal for typology under the WFD, the Bothnian Bay is split into 4 types (Types 12-15), namely inner and outer coast, and a north-south division of the Bothnian Bay, based on salinity (the 3 PSU limit).

Macrozoobenthic community data showed that the 4 types resembled each other to a high extent, and no ecological distinction could be made based on zoobenthos alone to verify or justify the division of typology.

ANOSIM-analysis showed that Types 12, 14 & 15 were barely separable at all at both depth intervals tested (Table 1). Data was too scarce from Type 13 to draw any conclusions. The typology of the Bothnian Bay can thus be pooled into 2 types separating landlocked inner bays with riverine influence from outer exposed coastal areas. SIMPER-results show low dissimilarity between community assemblages of zoobenthos in the Types 12-15 (Table 2), underlining the need to simplify or refine typology.

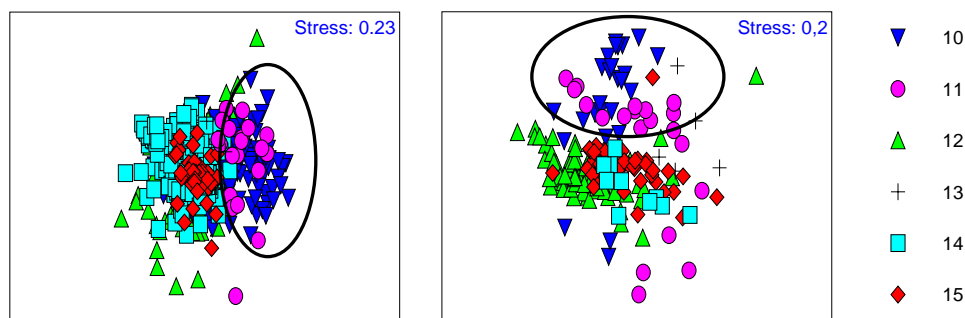


Figure 2: MDS-ordination showing a clear separation of the Quark-region (Types 10&11) from Bothnian Bay (Types 12-15). Left graph 0-10m; right graph >10m.

3.2 A uniform typology for the entire Baltic Sea coastal area?

The option of using the suggested common and general environmental typology developed within the EC-CHARM-project (SCHERNEWSKI & WIELGAT 2004) was considered, but abandoned of the following reasons. This typology divides the Finnish coastal waters into only a few types based on salinity, depth/mixing, and water residence time, but no consideration is given to the local climate, which along the Finnish coast involves ice every winter, but no tides, for example. Thus this approach only to some extent confirms the Finnish national typology proposal in using an inner and an outer basic category along the entire coastline, dividing it further along the coast bases primarily on salinity

and number of days with expected ice cover. The CHARM-approach also marks out the characteristics of the inner part of the Archipelago Sea with its prolonged water residence time. The need for further splitting of the umbrella typology is needed if it is to be useful for further implementation under the WFD. The typology fails in only producing one division line for salinity (oligohaline 0.5-6 PSU). A further splitting at 4 PSU is important due to the fact that this salinity-level sets a physiological limit for many species of marine origin, and hence the entire benthic community changes when reaching salinities of 3 PSU and below.

4 Discussion

Most modern scientific research-programmes investigating marine environmental quality monitor parameters in the water column, at and in the sediment and in sentinel organisms (BORJA et al. 2000) and are centred on physico-chemical and ecotoxicological variables and to a lesser extent biological parameters. Biological parameters are important components when determining water quality since a) they are direct measures of the condition of the biota b) they may uncover problems undetected or underestimated by other methods and c) provide measurement of the progress of restoration efforts (DAUER 1993). The shift in focus towards increased importance of biotic parameters in determining ecological status of water bodies stated in the WFD is a significant challenge for most monitoring programmes operating in Europe today. The coastal waters covered by the WFD with respect to biological features are limited to surface waters one nautical mile from the coastline, or – as in the case of Finland with its extensive archipelago regions – from the outermost islands. This concept violates the suggested ecosystem approach for the Baltic Sea as defined in the EC-marine strategy. By artificially truncating environmental categories, classes or types, a comprehensive Baltic system concerning reference conditions, water quality classification schemes and monitoring is hardly possible (SCHERNEWSKI & WIELGAT 2004).

Table 1: ANOSIM R-values for assemblage-differences between coastal categories (Types 1-15) and depth strata (0-10m; 10+m). (No data available in type 9)

	1	2	3	4	5	6a	6b	7	8	9	10	11	12	13	14	15
1		0,27	0,45	0,46												
2	0,24		0,66	0,45	0,17	0,34		0,36								
3	0,08	0,27		0,83												
4	0,51	0,24	0,62		0,20	0,28		0,42								
5		0,21		0,48		0,06	0,10	0,25	0,13		0,04	0,30				
6a		0,32		0,24	0,20		0,14	0,24	0,27		0,18	0,51				
6b								0,13	0,25		0,60	0,44				
7		0,30		0,36	0,31	0,31			0,46		0,54	0,50				
8					0,05	0,14		0,09			0,33	0,37	0,69	0,72		
9																
10					0,24	0,41		0,67	0,23			0,51	0,67	0,80	0,69	0,66
11					0,14	0,15		0,82	0,01		0,018		0,75	0,43	0,47	0,66
12									0,38		0,44	0,68		0,82	0,32	0,23
13		0-10m							0,38		0,03	0,53	0,38		0,65	0,57
14											0,61	0,77	0,22	0,44		0,13
15											0,34	0,79	0,09	0,65	0,09	
	<div style="background-color: #cccccc; width: 15px; height: 10px; display: inline-block;"></div> >0,75 WELL SEPARATED					<div style="background-color: #cccccc; width: 15px; height: 10px; display: inline-block;"></div> >0,50 OVERLAPPING, BUT CLEARLY DIFFERENT										
	<div style="background-color: #cccccc; width: 15px; height: 10px; display: inline-block;"></div> <0,25 BARELY SEPARABLE AT ALL															

Table 2: SIMPER average dissimilarity values between coastal categories (Types 1-15) and depth strata (0-10m; 10+m). Lower table shows similarity-percentage of within type comparison and depth strata. (No data available in type 9).

	1	2	3	4	5	6a	6b	7	8	9	10	11	12	13	14	15
1		75,7	84,7	78,8												
2	74,8		88,0	59,7	68,9	71,7		71,6					10+m			
3	66,3	77,3		85,8												
4	81,7	77	82,2		67,4	67,6		62,9								
5		74,7		78,7		64,9	67,5	70,9	67,4		65,5	73,2				
6a		79,6		75,7	70,5		65,2	67,7	68,7		66,6	76,2				
6b								54,6	66,0		65,9	64,4				
7		78,3		65,4	73,7	72,5			73,0		71,6	71,7				
8					69,5	73,1		71,6			69,2	70,6	82,5	83,7		
9																
10					70,7	74,8		80,4	74,7			70,7	69,9	79,9	74,2	67,6
11					67,5	71,2		72,5	68,4		61,7		72,4	72,7	71,5	68,9
12		0-10m							77,4		66,2	67,4		78,6	55,2	51,0
13									80,7		61,6	64,8	55,4		68,3	62,9
14											69,9	73,4	57,9	61,9		45,7
15											66,6	70,8	53,6	58	47,2	
	<60% dissimilarity				60-70% dissimilarity				>70% dissimilarity							

	1	2	3	4	5	6a	6b	7	8	9	10	11	12	13	14	15
0-10m	36,8	31,8	29,9	36,5	35,9	30,6	43,4	47	32,5	-	38,1	48,8	55,6	51,2	49,9	61,7
10+m	33,4	39,5	19,1	50,3	35,4	39,3	54,3	46,7	41,1	-	48,1	40,1	55,4	46,5	55,2	58,3

Macrozoobenthos is a standard element in monitoring programmes today due to its usefulness as bio-indicators sensitive to anthropogenic and natural stress (PEARSON & ROSENBERG 1978; DAUER 1993). Benthic softbottom invertebrate community structure is useful in environmental monitoring because they are relatively sedentary, long-lived and consist of different species exhibiting different tolerance to stress. They have an important role in cycling nutrients and materials between the underlying sediments and the overlying water column.

The benthic community assemblages may vary considerably between sites depending on the environmental conditions present. Factors structuring benthic communities are depth, salinity, sediment grain size, sediment organic matter content, near-bottom oxygen concentration, trophic status and water residence time of the water body.

An additional important feature in determining proper benthic communities is seafloor landscape, or benthoscape, structure. This factor is not included in the WFD. Habitat heterogeneity occurs at all scales and the relative mix of large-scale, mesoscale and small-scale heterogeneity can differ across a benthoscape depending on location in the benthoscape, the types and mixture of the elements, and prevailing hydrologic and geologic dynamics (ZAJAC et al. 2003). The existence of large-scale, as well as small-scale, patterns in infaunal community structure is well known (HALL et al. 1994). However, infaunal populations exhibit complex and spatially varying patterns of abundance in relation to benthoscape structure and suggest that mesoscale variation ($\text{km}^2\text{-m}^2$) may be particularly critical in this regard. Benthoscape elements add structure to the seafloor landscape, thereby increasing habitat diversity. In addition, transition zones among benthoscape features add considerably to this variation and may be ecologically important areas in seafloor environments (ZAJAC et al. 2003). This would then imply the urgent need for stronger focus on sediment characteristics and biological elements in the process of typology since mesoscale will be the size-level on which most

water bodies will be at. In addition to abundance, also habitat type (<http://eunis.eea.eu.int>) should be included when comparing calculated results of EcoQ regarding benthic quality element.

In this test no attempt of classification of the ecological status of types/water bodies within the coastal waters has been made. The classification will be based on the deviation from defined ecological reference conditions (phytoplankton, macro-vegetation and macrozoobenthos) within these water bodies. Reference conditions should have no or very minor deviations from undisturbed conditions, which in practice is defined as conditions prior to the intensification of agriculture 100-150 years ago. Post-war intensification of agriculture (nutrient enrichment in the sea) and urban pollution are believed to have had the largest impacts on coastal waters (ANON 2000). Reference conditions can be derived by a) measurements in existing undisturbed site or a site with only very minor disturbance b) using historical data and information c) models, and/or d) expert judgement (VINCENT et al. 2002). Reference conditions should be defined in a pragmatic and realistic way, taking into account existing data and expert judgement in order to avoid impossibility of accomplishing good status classification of the marine coastal environment (BORJA et al. 2004).

Paleoecological studies of sediment conditions have attracted interest in determining nutrient conditions of the recent past (CLARKE et al. 2003; ANDERSEN et al. 2004; WECKSTRÖM et al. 2004; KAUPPILA et al. in press). This is an interesting and promising approach for determining nutrient reference conditions, however the studies have only yet been made on a local scale and will probably not advance fast enough for use in the initial decision of reference conditions in the WFD.

The absence of unimpacted areas in the Baltic Sea of today means that values for the biological quality elements determining the EcoQ:s will have to be made up using either models or expert judgement since monitoring data regarding these is lacking for those time periods at question. Adding to this problem, JACKSON & SALA (2001) states that “our basic concept about the ecology of pristine marine ecosystems have hardly been questioned, even though most of our textbook wisdom was obtained long after intensive fishing began”. This also adds to the difficult task of building reliable models for reference conditions since this, to the extent it is possible, requires detailed paleoecological, archeological and historical analyses to determine what and how much was present, combined with observations and manipulations of succession due to the absolute cessation of human exploitation within very large marine areas (JACKSON 2001; JACKSON & SALA 2001). Are we then left with only expert judgement as the tool for determining ecological status within the coastal areas or are there methods that can still guide us? Various numerical indices have been available in benthic ecology already since the 1960s and are now coming into focus again. ROSENBERG et al. (2004) presents a good summary of usable indices, both subjective and objective, for detecting secondary effects of eutrophication and proposes a new benthic quality index (BQI) as well. However, most indices have been created for fully marine environments with high biodiversities and may therefore not entirely capture environmental changes in a low-diversity brackish environment such as the Baltic Sea represents. This becomes even more evident in the low-saline Bothnian Bay where only a handful of taxa are present and available for determining environmental changes and quality status. In our analyses we had pooled the records of species belonging to family *Chironomidae* and class *Oligochaeta* due to uneven taxonomic resolution in the studies, yet these are taxa where there are species indicative of specific environmental conditions. These are taxa requiring taxonomical expertise to identify and might result in comparisons of taxonomical skilfulness between areas instead of environmental status if indices involving species richness are used. The use of species richness as a parameter of environmental status should be avoided since it tells nothing about species turnover and community assemblage structure. Further, we need to consider the occurrence of non-native invasive (‘alien’) species in the coastal environment, as these undoubtedly affect the benthic assemblages (about 100 species are known invasive in the Baltic Sea; about 50% of them marine benthic), though not necessarily in a negative way. The best known example is the North American polychaete, bioturbator, *Marenzelleria viridis* (<http://www.ku.lt/nemo>).

Whatever methodology used in the assessment of reference conditions or ecological status they all need to be intercalibrated between ecoregions and national typologies.

Based on the results from this study together with experiences gained from co-operation with the international CIS-group, the pan-Baltic CHARM-project and comments received from the evaluation round of this proposal of the Finnish typology a new typology, containing fewer categories (11 types instead of 16), has been constructed. Borders between types have also been slightly moved in order to better reflect the ecological quality element communities. The new alternative typology proposal is currently under national scientific evaluation and, if accepted, will be presented at a later stage, and tested for suitability using not only zoobenthos, but also plankton and macroscopic vegetation.

Acknowledgements

This paper is part of and financially supported by the EU project CHARM (Characterization of the Baltic Sea Ecosystem: Dynamics and Function of coastal types; EVK3-CT-2001-00065), and Academy of Finland project IMAGINE within the Research Programme BIREME. The Finnish Ministry of the Environment has helped in financing the setup of the macrozoobenthic database. The authors thank the national expert group producing the typology proposals and West Finland Regional Environment Centre for providing work space and tools.

References

- Andersen, J. H., D. J. Conley & S. Hedal (2004): Palaeoecology, reference conditions and classification of ecological status: the EU water framework in practice. *Mar. Poll. Bull.* 49, 283-290.
- Anon. (2000): Directive 2000/60/EC of the European Parliament and the Council of 23 October 2000 establishing a framework for community action in the field of water policy. *Official Journal L327/1*.
- Bonsdorff, E., R. J. Diaz, R. Rosenberg, A. Norkko & G. R. Cutter Jr (1996): Characterization of soft-bottom benthic habitats of the Åland Islands, northern Baltic Sea. *Mar. Ecol. Prog. Ser.* 142, 235-245.
- Bonsdorff, E., E. M. Blomqvist, J. Mattila & A. Norkko (1997): Coastal eutrophication: causes, consequences and perspectives in the archipelago areas of the northern Baltic Sea. *Estuar. Coast. Shelf Sci.* 44, 63-72.
- Bonsdorff, E., A. O. Laine, J. Hänninen, I. Vuorinen & A. Norkko (2003): Zoobenthos of the outer archipelago waters (N. Baltic Sea) – the importance of local conditions for spatial distribution patterns. *Bor. Envir. Res.* 8, 135-145.
- Borja, A., J. Franco, V & V. Perez (2000): A marine biotic index to establish the ecological quality of soft-bottom benthos within European estuarine and coastal environments. *Mar. Poll. Bull.* 40, 1100-1114.
- Borja, A., J. Franco, V. Valencia, J. Bald, I. Muxica, M. J. Belzunce & O. Solaun (2004): Implementation of the European water framework directive from the Basque country (northern Spain): a methodological approach. *Mar. Poll. Bull.* 48, 209-218.
- CHARM: Characterization of the Baltic Sea Ecosystem: Dynamics and Function of coastal types; EVK3-CT-2001-00065. <http://charm.dmu.dk>
- Clark, K. R. & R. N. Gorley (2001): PRIMER v5: User manual/Tutorial. Primer-E. Plymouth, 91p.
- Clark, K. R. & R. M. Warwick (1993): A method linking multivariate community structure to environmental variables. *Mar. Ecol. Prog. Ser.* 92, 205-219.
- Clark, K. R. & R. M. Warwick (1994): Change in marine communities: an approach to statistical analysis and interpretation. Plymouth: Plymouth marine laboratory, 144p.
- Clarke, A., S. Juggins & D. J. Conley (2003): A 150-year reconstruction of the history of coastal eutrophication in Roskilde Fjord, Denmark. *Mar. Poll. Bull.* 46, 1615-1629.
- Cloern, J. E (2001): Our evolving conceptual model of the coastal eutrophication problem. *Mar. Ecol. Prog. Ser.* 210, 223-253.
- Dauer, D. M (1993): Biological criteria, environmental health and estuarine macrobenthic community structure. *Mar. Poll. Bull.* 26, 249-257.

- Elmgren, R (2001): Understanding human impact on the Baltic ecosystem: changing views in recent decades. *Ambio* 30, 222-231.
- EUNIS: European Nature Information System. <http://eunis.eea.eu.int>
- Hall, S. J., D. Raffaelli & S. F. Thrush (1994): Patchiness and disturbance in shallow water benthic assemblages. In: Giller, P. S., A. G. Hildrew & D. G. Raffaelli (eds.): *Aquatic ecology: Scale, pattern and process*. Blackwell Scientific, 333-375.
- Hänninen, J., I. Vuorinen, H. Helminen, T. Kirkkala & K. Lehtilä (2000): trends and gradients in nutrient concentrations and loadings in the Archipelagos Sea, northern Baltic, in 1970-1997. *Estuar. Coast. Shelf Sci.* 50, 153-171.
- Hänninen, J & I. Vuorinen (2001): Macrozoobenthos structure in relation to environmental changes in the Archipelago Sea, northern Baltic Sea. *Bor. Envir. Res.* 6, 93-105.
- Jackson, J. B. C. (2001): What was natural in the coastal oceans? *Proc. Natl. Acad. Sci. USA.* 98, 5411-5418.
- Jackson, J. B. C. & E. Sala (2001): Unnatural oceans. In: Gili, J. M., J. L. Pretus & T. T. Packard (eds.): *A marine science odyssey into the 21st century*. *Sci. Mar.* 65, 273-281.
- Jumppanen, K & J. Mattila (1994): Saaristomeren tilan kehitys ja siihen vaikuttavat tekijät. Lounais-Suomen vesiensuojeluyhdistyksen julkaisuja. 82, 206p (In Finnish with English summary).
- Kangas, P., S. Bäck & P. Kauppila (eds.): Suggestions for a typology of coastal waters for the Finnish coast according to the European union water framework directive (2000/60/EC). Mimeographs series of Finnish environment institute 284, Helsinki, 52p.
- Karjala, L & J. Lassig (1985): Studies on benthic macrofauna in the Tvärminne area, Gulf of Finland, 1964-1967 and 1973-1976. *Hydrobiological Researches.* XV, 169-181.
- Kauppila, P., K. Weckström, S. Vaalgamaa, A. Korhola, H. Pitkänen, N. Reuss & S. Drew (2004): Tracing pollution and recovery using sediments in an urban estuary, northern Baltic Sea: Are we far from ecological reference conditions? *Mar. Ecol. Prog. Ser.* (In press).
- NEMO: Baltic Sea Alien Species Database. <http://www.ku.lt/nemo>
- Nixon, S. W (1995): Coastal marine eutrophication: a definition, social causes and future concerns. *Ophelia* 41, 199-219.
- O'Brien, K., J. Hänninen, T. Kanerva, L. Metsärinne & I. Vuorinen (2003): Macrozoobenthic zonation in relation to major environmental factors across the Archipelago Sea, northern Baltic Sea. *Bor. Envir. Res.* 8, 159-170.
- Pearson, T. H & R. Rosenberg (1978): Macrobenthic succession in relation to organic enrichment and pollution of marine environment. *Oceanogr. Mar. Biol. Ann. Rev.* 16, 229-311.
- Perus, J. & E. Bonsdorff (2004): Long-term changes in macrozoobenthos in the Åland archipelago, northern Baltic Sea. *J. Sea. Res.* 52, 45-56.
- Rosenberg, R., M. Blomqvist, H.C. Nilsson, H. Cederwall & A. Dimming (2004): Marine quality assessment by use of benthic species-abundance distributions: a proposed new protocol within the European Union water framework directive. *Mar. Poll. Bull.* (In press)
- Schernewski, G. & M. Wielgat (2004): Towards a typology for the Baltic Sea. In: Schernewski, G. & N. Löser (eds.): *Managing the Baltic Sea. Coastline Reports* 2, 35-52.
- Vincent, C., H. Heinrich, A. Edwards, K. Nygaard & J. Haythornthwaite (2002): Guidance on typology, reference conditions and classification systems for transitional and coastal waters. Produced by: CIS Working Group 2.4 (Coast), Common implementation strategy of the water framework directive, European Commission, 119p.
- Weckström, K., S. Juggins & A. Korhola (2004). Quantifying background nutrient concentrations in coastal waters: A case study from an urban embayment of the Baltic Sea. *Ambio* 33(6), 324-327.
- Zajac, R. N., R. S. Lewis, L. J. Poppe, D. C. Twichell, J. Vozarik & M. L. DiGiacomo-Cohen (2003): Responses of infaunal populations to benthoscape structure and the potential importance of transitional zones. *Limnol. Oceanogr.* 48(2), 829-842.

Address

MSc. Jens Perus
Åbo Akademi University
Dept. Of Environmental and Marine Biology
Akademigatan 1
20500 Åbo
Finland

E-mail: jens.perus@abo.fi