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An adjustment of benthic ecological quality assessment to effects of salinity

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ABSTRACT

In the last decade a politically inspired marine protection movement arose in the European Union. This movement leads to an holistic strategy. Merging the Water Framework Directive (WFD) and the Marine Strategy Directive (MSD) along the European coastline demands sophisticated ecological classification procedures. The 'Benthic Quality Index' (BQI) is one of several indices created in view of the WFD. We used the dynamic species reference system $ES_{50_{0.05}}$ to test the capability of BQI to exclude primary environmental factors including the salinity gradient and depth (a proxy for the oxygen regime) from the ecological quality (EcoQ) assessment.

A macrozoobenthos dataset of the southern Baltic Sea spreading over more than 20 years and over 100,000 km^2 was used for the EcoQ assessment. Quality assurance rules were applied to the record set and an analytical dataset of 936 sampling events with 20,451 abundance records was used in the analysis. We show that the natural salinity gradient has a severe impact on the BQI based EcoQ. We adapted the calculation procedure to reduce the salinity effects to a minimum.

According to the adaptation 503 sensitivity/tolerance values for 87 species were computed. These values were calculated within seven salinity ranges from 0 to >30 PSU and two depth zones. These values can be used as a reference for further investigation in the Baltic and other areas with similar environmental conditions.

1. Introduction

Recent realisation of the extent of ecosystem service provision by marine systems has motivated a politically inspired protection movement over the last decade. The European 'Maritime Policy' and 'Marine Strategy Directive' (MSD) are the most recent attempt to create optimal conditions for sustainable use of the European oceans and seas. The European Commission has already initiated the MSD together with the recommendation of a framework for sustainable development towards a 'Good' marine environmental condition (EC, 2005a,b). Experience with the Water Framework Directive (WFD; 2000/60/EC) has shown that the definition of 'Good' ecological status is not trivial. Natural reference conditions are hard to find in coastal waters and this is also true for off-shore areas as well (Dauvin et al., 2007; Muxika et al., 2007; Borja, 2006). As a consequence of these circumstances there have been several attempts to create references either by modeling or paleoecology (Muxika et al., 2007; Bald et al., 2005; Andersen et al., 2004).

In recent years, a variety of benthic indices has been developed (Grall and Glémarec, 1997; Weisberg et al., 1997; Borja et al., 2000; Simboura and Zenetos, 2002; Rosenberg et al., 2004) most of which are based on the succession model published by Pearson and Rosenberg (1978).

However, the applicability of all these measures to several scenarios needs further investigation. Their aim is to identify anthropogenic impacted sites from reference conditions, but all indices are sensitive to any causal factor either natural or manmade (Borja et al., 2003; Muxika et al., 2005; Reiss and Kröncke, 2005; Labrune et al., 2006; Zettler et al., 2007). Since all these indices will be used to confirm political actions according to the WFD it is crucial to know the influence of natural factors on results of ecological quality indices. Therefore it is necessary to determine the index sensitivity at least on all natural environmental factors (Vincent et al., 2002) occurring within the area of the WFD or MSD. This study was an attempt to ascertain wether it is possible to minimize the influence of salinity (one of the main forces in the Baltic) and depth on the results of Benthic Quality Index (BQI).

The specifications of the WFD share common problems: (1) the reference conditions for the calculation of the ecological quality ratio (EQR); (2) the animal sensitivity references. The use of static reference locations, either from expert judgement or from direct knowledge of pristine conditions, is problematic (Nielsen et al., 2003). A static reference in an evolving and changing environment can cause political decisions not based on any anthropogenic influence (Bonsdorff, 2006; Gröger and Rumohr, 2006). In an environment like the Baltic Sea, still recovering from the last glacial

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period (Bonsdorff, 2006), this shifting baseline (Pauly, 1995) might be more obvious (Rumohr et al., 1996; Jansson and Jansson, 2002) than in other regions. Therefore, even if historic data are available, the selection of a reference site presumed to be representative for pristine conditions is always a judgement call.

In this study, we focused on the problem of defining species references. Static reference lists have more often been used (Borja et al., 2000) than other methods. Even though these lists have been enlarged in recent years, each species is always categorised only once in a distinct ecological group. In areas with strong environmental gradients, like the brackish southern Baltic, it is well known that species can adapt and change their live history (Remane, 1958). The salinity gradient is so strong in the southern Baltic that in the same geographical area a large range of salinity can be measured. As Zettler et al. (2007) found, the fixed ecological species reference list needs reconsideration in the Baltic. This and the adaptive behaviour of species has to be considered in a species sensitivity/tolerance reference list. Therefore, we investigated the impact of salinity on ecological status classification in this study.

The BQI uses a variable concept to integrate both the sensitivity/tolerance of a given species and the species richness. This index works best with large datasets that allows values to be calculated from the dataset itself instead of using values from other areas or times. This assumes that large datasets cover either a long period of time and/or of a large area containing all conditions from ‘High’ to ‘Bad’.

We tested the performance of the ‘Benthic Quality Index’ (BQI) and adapted the calculation procedure along the strong natural salinity gradient in the southern Baltic Sea. This study was based on a very large dataset sampled during the HELCOM monitoring program and further investigations, allowing us to evaluate the influence of salinity on the classification of ecological quality and species sensitivity. In this study we calculated species reference lists for seven salinity ranges and two depth horizons. This constitutes a significant advance on the system of static species reference lists.

2. Material and methods

We have analysed a dataset of 2156 sampling events with 47404 records located in the Baltic Sea for this study. The individual records were selected from the archived data of in-house projects either the Leibniz-Institute for Baltic Research or the Leibniz-Institute for Marine Research IFM-GEOMAR. For quality assurance, we applied the following selection criteria: (1) data recorded during the years 1980–2007, (2) Van Veen grab with 0.1 m^2 sampling area with at least 2 replicates, (3) salinity measured at the sampling event. Using these criteria, we have reduced the dataset to a final set of 936 sampling events from 683 locations and a total of 20,451 records (Fig. 1).

To investigate the influence of salinity and depth (used as a proxy for oxygen supply) on the Benthic Quality Index (BQI), we used the same dataset for Approach I and Approach II. As a common first processing step, we separated the dataset into two depth zones (Fig. 2), with the separation at 20 m depth horizon. By doing so we applied the same depth for separating as used by Rosenberg et al. (2004); it represents the natural thermo-haline stratification of the southern Baltic sea. This first step created two subset with 11579 ($\leqslant$20 m) and 8872 (>20 m) records (Fig. 2). The applied salinity ranges for Approach II were ‘0–4.$\bar{9}$’, ‘5–9.$\bar{9}$’, ‘10–14.$\bar{9}$’, ‘15–19.$\bar{9}$’, ‘20–24.$\bar{9}$’, ‘25–29.$\bar{9}$’ and ‘$\geqslant$30’ PSU.

The depth based datasets (Approach I) and the salinity range based datasets (Approach II) were equally used in the following as source for the calculation of BQI. Beginning with the $ES50_{0.05}$ calculations for each species adapted to specific depth horizons and salinity ranges (according to the applied dataset). The $ES50_{0.05}$ value is the sensitivity/tolerance measure included in BQI and published by Rosenberg et al. (2004). The second step comprised the BQI calculation for each dataset. Following Approach II the five EcoQ classes were evenly distributed in the range of BQI values of each salinity dataset (Rosenberg et al., 2004).

The analytical dataset contained averaged 1 m^2 values from replicated samplings. The sampling effort of the combined data

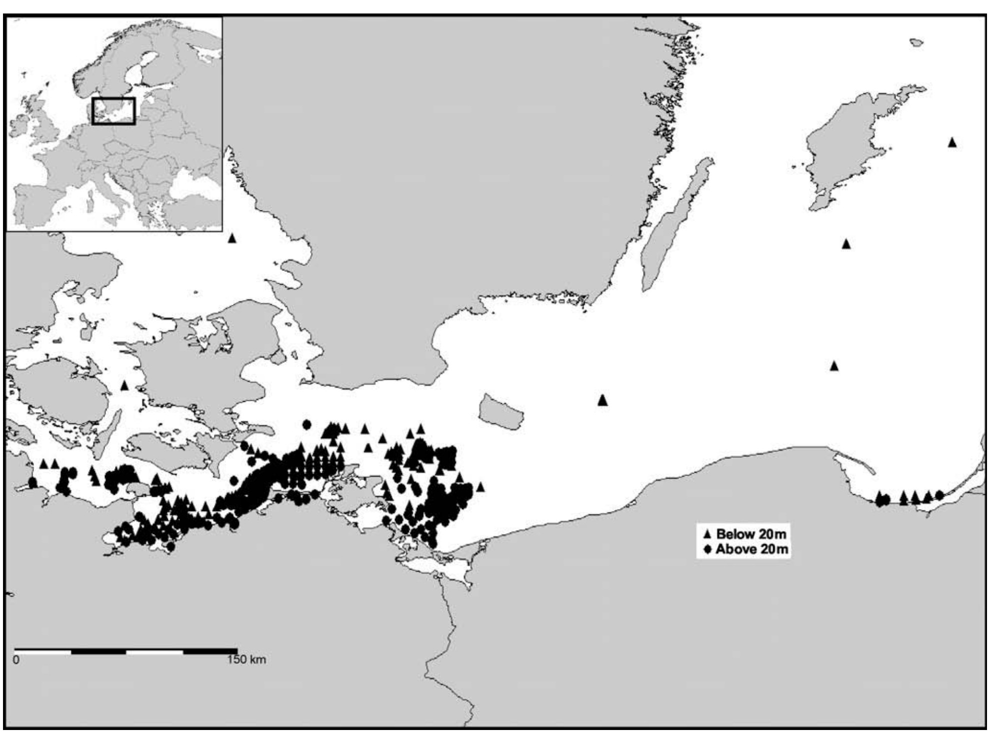

Fig. 1. Distribution map with all sampling event locations included in this study, separated by the 20 m depth horizon.