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Benthic biodiversity indices versus salinity gradient in the southern Baltic Sea

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Abstract

The need to assess the environmental status of marine and coastal waters according to the EU Water Framework Directive (WFD) encouraged the design of specific biotic indices to evaluate the response of benthic communities to human-induced changes in water quality. In the present study three of these indices, the traditional Shannon Wiener Index (H′) and the more recently published AMBI (AZTI′ Marine Biotic Index) and BQI (Benthic Quality Index), were tested along a salinity gradient in the southern Baltic Sea. The comparison of the three indices demonstrates that in the southern Baltic Sea the ecological quality (EcoQ) classification based on macrozoobenthic communities as indicator greatly depends on the biotic index chosen. We found a significant positive relation between species number, H′, BQI and salinity resulting in EcoQ status of ''Bad'', ''Poor'' or ''Moderate'' in areas with a salinity value below 10 psu. The AMBI was less dependent on salinity but appear to partly overestimate the EcoQ status. Presently none of these biotic indices appear to be adjusted for application in a gradient system as given in the southern Baltic Sea. A potential approach describing how to overcome this limitation is discussed.

Keywords: Southern Baltic Sea; Macrozoobenthos; Biotic indices; Ecological quality; Salinity gradient; Water Framework Directive; Oxygen depletion

1. Introduction

The development of biological indicators as a tool for the assessment and hence protection of biological diversity in European coastal and marine ecosystems has been advanced due to the implementation of the Habitats Directive and the Water Framework Directive (WFD). Benthic invertebrates are often used as bioindicators to detect and monitor environmental changes, because of their rapid responses to natural and/or anthropogenic caused stress (e.g., Pearson and Rosenberg, 1978; Grall and Glémarec, 1997; Simboura and Zenetos, 2002; Perus et al., 2004). Benthic species are relatively long-living sessile organisms unable to avoid unfavourable conditions. In this way, they integrate water and sediment quality conditions over time and their presence/absence indicates temporal as well as spatial disturbances (Reiss and Kröncke, 2005). In the past years different biotic indices have been designed to assess the ecological quality of European coasts. In this respect, the Shannon–Wiener index H′ (Pielou, 1975), the BQI (Benthic Quality Index, Rosenberg et al., 2004) and the AMBI (Azti Marine Biotic Index, Borja et al., 2000) are among those indices generally used. The AMBI has been proposed for the assessment of the ecological status of estuarine and coastal waters, whereas the BQI were mainly designed for application in marine areas. The main purpose of all of them is to separate impacted sites from undisturbed (reference) sites (e.g., Borja et al., 2003; Muxika et al., 2005; Labrune et al., 2006). Their application, however, does not necessarily allow distinguishing between natural or man-induced disturbances and their natural variability both on temporal and spatial scales has to be assessed (Vincent et al., 2002).

In brackish water system such as the Baltic Sea two main environmental variables (salinity and oxygen supply) affect the composition of the benthic community and

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species' abundance (e.g., Rönnberg and Bonsdorff, 2004). Benthic diversity differs from other coastal systems (e.g., North Sea) and the applicability of biodiversity indices has to be evaluated (Rosenberg et al., 2004).

The Baltic Sea, formed after the latest glaciation, is a young ecosystem continuously undergoing post-glacial successional changes (Jansson and Jansson, 2002). It is an enclosed, non-tidal ecosystem and has steep latitudal and vertical salinity gradients. The southern parts including the Belt Sea are closely connected to the Kattegat and Skagerak and show salinities between 25 and 30 psu. Within few 100 km east- or northwards the values drop down to 5 psu and, finally, in the northern part to more or less freshwater conditions. As a consequence, the number of marine species is significantly decreased or has been displaced by limnic species in the North and inner coastal waters (Bonsdorff, 2006). Even though the Baltic is a young ecosystem, species-poor and vulnerable to the threat of invasive marine and exotic species, both the strong gradient and the rapid change of salinity conditions especially in the southern Baltic inhibit an unhindered colonisation. As a result, the Baltic benthic fauna is still largely characterised by species with obviously opportunistic life history traits (Rumohr et al., 1996).

The salinity gradient is particularly pronounced in the transition zone ranging from the euhaline Skagerrak and Kattegat to the brackish Baltic Proper (down to 5 psu). Owing to the strong salinity reduction from West to East macrobenthic biodiversity decreases rapidly in the southern Baltic (Zettler and Röhner, 2004). Whereas in the Kiel Bight about 700 species occur, only ≈100 are present in the Pomeranian Bay. The rapid decline in the overall number of species along the Baltic Sea salinity gradient is illustrated by Bonsdorff (2006).

The objectives of the present study were to (i) use different biotic indices to assess macrozoobenthic diversity along a strong salinity gradient, (ii) compare different indices and their correlation to salinity and (iii) assess their sensitivity to severe impacts (e.g., temporal oxygen depletion). We compared the H′, BQI and AMBI at 625 stations located in the southern Baltic Sea, sampled during the last 10 years. The salinity range in the investigation area was 1.5–27.8 psu. Our work represents the first comparison of these biotic indices for the southern Baltic Sea and German coastal waters in particular and their applicability for the Water Framework Directive along this strong salinity gradient.

2. Material and methods

2.1. Study area

The investigation area has an expansion of 300 km in longitude and 150 km in latitude and is composed of different water bodies (Fig. 1). The Belt Sea extends from the Kiel Bight via Mecklenburg Bight to the Darss Sill and is regarded as a part of the transition zone between the Kattegat and the deep basins of the Baltic Proper. The first of these basins with water depths up to 50 m (Arkona Basin) borders to the Bornholm area in the East and to the

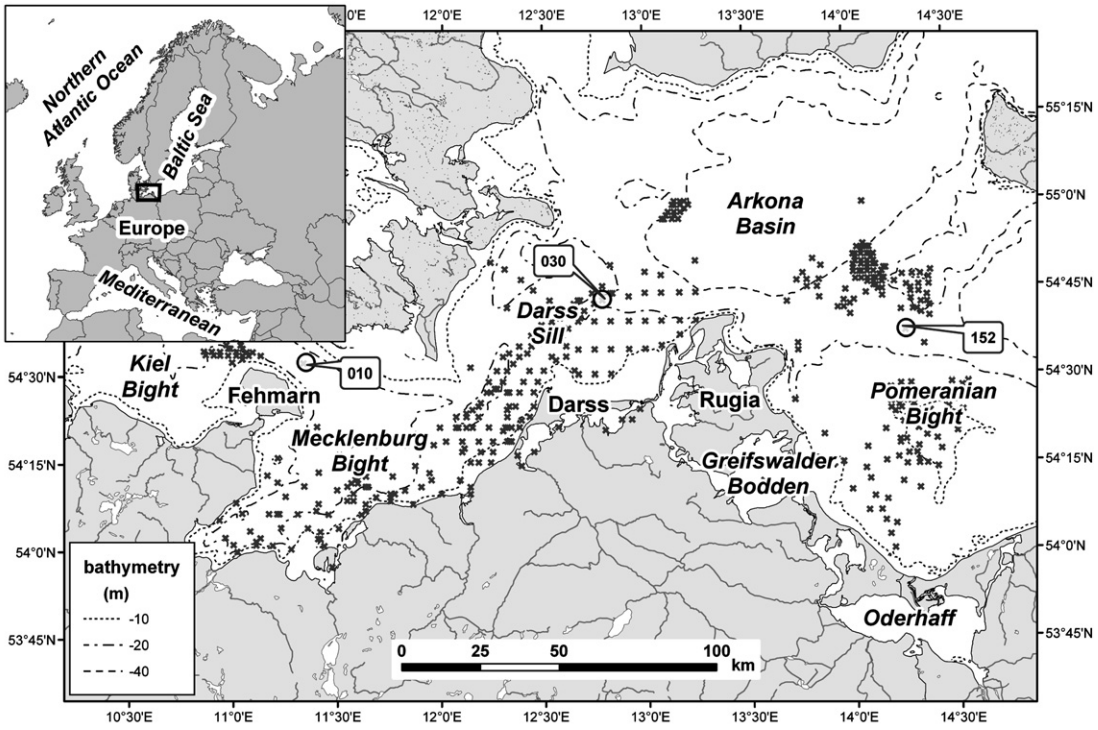

Fig. 1. Investigation area in the southern Baltic Sea. In total 625 stations (crosses) were sampled between 1995 and 2005, including three long term monitoring stations (010, 030, 152).