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Seasonal variability of benthic indices: An approach to test the applicability of different indices for ecosystem quality assessment

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Abstract

In recent studies, several benthic biological indices were developed or used to assess the ecological quality status of marine environments. In the present study the seasonal variability of several univariate and multimetric indices was studied on a monthly scale (September 2000 until May 2002) in different areas of the North Sea such as the German Bight, the Oyster Ground and the Dogger Bank. The stations were chosen to reflect a gradient in the hydrographic regime, temperature and organic matter supply. The seasonal variability was highest for the univariate indices such as the Shannon–Wiener Index and the Hurlbert Index. Thus, due to sensitivity to recruitment the corresponding ecological status ranged from 'good' to 'poor' depending on the season. For the multimetric indices such as the AMBI or the BQI the seasonal variability and the corresponding ecological status were low. The results are discussed concerning possible consequences for ecological quality assessment especially related to the Water Framework Directive (WFD).

Keywords: Indicator species; AMBI; BQI; Diversity indices; Macrofauna; Water Framework Directive (WFD); North sea

1. Introduction

Due to the increasing impact of human activities on the marine ecosystem in the last decades the need for quality assessment and monitoring of marine systems has become increasingly important. The European Water Framework Directive (WFD), which came into force in December 2000, emphasises the assessment and achievement of the ecological quality status of coastal and estuarine waters. Also other international initiatives and agreements draw attention to the need for the assessment of the quality of marine environments, e.g., the Ecological Quality Objectives (EcoQO) concept developed by OSPAR (Frid and Hall, 2001; Painting et al., 2004; Rogers and Greenaway, 2005). The assessments of the ecological status will comprise physico-chemical and hydromorphological characteristics as well as different biological compartments of the ecosystem (e.g. plankton, benthos, fish).

The benthic fauna is an important component in marine ecosystems, playing a vital role in nutrient cycling, detrital decomposition and as a food source for higher trophic levels. Due to the relatively sessile habit and, thus, the incapability to avoid unfavourable conditions, macrobenthic species are sensitive indicators of changes in the marine environment caused by natural or anthropogenic disturbances. Since benthic species are relatively long-lived they integrate water and sediment quality conditions with time and, thus, indicate temporal as well as chronic disturbances.

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Effects of these disturbances include changes in diversity, biomass, abundance of stress tolerant or sensitive benthic species, and the trophic or functional structure of the benthic community (Pearson and Rosenberg, 1978; Warwick and Uncles, 1980; Warwick, 1986; Warwick and Clarke, 1994; Kaiser et al., 2000; Grall and Chauvaud, 2002). Thus, a variety of indices are available, which measure the status of ecological conditions and trends in succession of marine benthic systems. Univariate diversity indices such as the Shannon–Wiener index were the most commonly used indices in the past. In more recent studies multimetric indices were developed to get a more sensible tool for the assessment of ecological quality in a benthic ecosystem. Based on the model of Pearson and Rosenberg (1978), many of these indices used indicator species or ecological groups of species according to their sensitivity to stress, such as the Benthic Index (BI) Grall and Glémarec, 1997), the biotic index (BENTIX) (Simboura and Zenetos, 2002) and the Azti Marine Biotic Index (AMBI) (Borja et al., 2000) or used a combination of univariate and multimetric indices such as the benthic index of biotic integrity (B-IBI) (Weisberg et al., 1997) and the Ecological Quality Ratio (EQR) (Borja et al., 2003b). However, most of these indices have been designed to differentiate anthropogenic impacted sites from undisturbed reference sites (Van Dolah et al., 1999; Borja et al., 2003a; Muxika et al., 2005), but univariate as well as multimetric indices respond to any disturbance, be it natural or man-induced (Wilson and Jeffrey, 1994). For the assessment of a general ecological quality status of marine environments as well as for the indication of reference conditions, the 'natural' variability of the indices on different temporal and spatial scales has to be assessed and taken into account (Vincent et al., 2002).

In the present study macrofauna communities were sampled in three different areas of the southern North Sea on a monthly scale from September 2000 until May 2002 in order to assess the seasonal variability of the benthic fauna. Previous results showed that the seasonal fluctuations in a marine environment result in changes of abundance, diversity and community structure of benthic communities (Reiss and Kröncke, 2005).

The objectives of this study were to (i) compare different univariate and multimetric indices used for quality assessment purposes with regard to their variability on a seasonal scale and (ii) whether this seasonal variability differs under different environmental conditions.

2. Material and methods

A total of 16 monthly sampling cruises were carried out at three stations in the southern German Bight (station GB5), the Oyster Ground (station OG7) and at the north-eastern Dogger Bank (DG9) from September 2000 to May 2002 (North Sea, Germany; Fig. 1). The stations reflect a gradient in the hydrographic regime, temperature and organic matter supply. Details of the study sites and their macrofaunal communities are given in Kröncke and Rachor (1992), Kröncke et al. (2004),

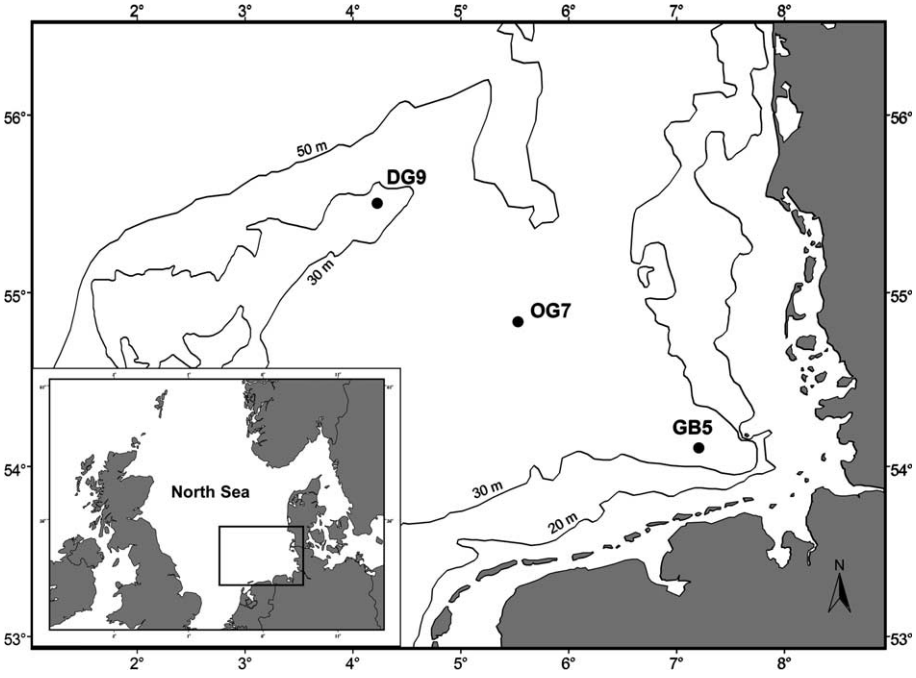

Fig. 1. Area of investigation in the North Sea with sampling sites.