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Application of the Benthic Ecosystem Quality Index 2 to benthos in Dutch transitional and coastal waters

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ABSTRACT

The Benthic Ecosystem Quality Index 2 (BEQI2) is the Dutch multi-metric index (MMI) for assessing the status and trend of benthic invertebrates in transitional and coastal waters for the Water Framework Directive (WFD). It contains the same indicators, i.e. species richness, Shannon index and AMBI, as in the multivariate m-AMBI. The latter MMI has been adopted by several European countries in the context of WFD implementation. In contrast to m-AMBI, the BEQI2 calculation procedure has been strongly simplified and consists of two steps, i.e. the separate indicator values are normalized using their long-term reference values resulting in three Ecological Quality Ratios (EQRs), which are subsequently averaged to give one BEQI2 value. Using this method only small numbers of samples need to be analysed by Dutch benthos laboratories annually, without the necessity to co-analyse a larger historical dataset. BEQI2 EQR values appeared to correlate quantitatively very well with m-AMBI EQR values. In addition, a data pooling procedure has been added to the BEQI2 tool which enables the pooling of small core samples (0.01–0.025 m^2) into larger standardized data pools of 0.1 m^2 in order to meet the data requirements of the AMBI indicator and to obtain comparable reference values. Furthermore, the BEQI2 tool automatically and efficiently converts species synonym names into standardized species names. The BEQI2 tool has been applied to all Dutch benthos data monitored by Rijkswaterstaat in the period of 1991–2010 in the transitional and coastal waters and salt lakes and these results are reported here for the first time. Reference values for species richness and Shannon index (99 percentile values) and AMBI reference values (1 percentile values) were estimated for all water body–ecotopes and are discussed. BEQI2 results for all these water bodies are discussed in view of natural and human pressures. The pressure sensitivity of the BEQI2 for sewage and dredging/dumping, via the state variables oxygen and suspended matter respectively, was demonstrated.

1. Introduction

The Water Framework Directive (WFD) is the European legislation aimed to protect and improve the European aquatic habitats and ecosystems for fresh, brackish and coastal marine waters (EC 2000). The WFD constitutes a comprehensive framework for the monitoring, assessment and reporting of the status and trends of ecological, chemical and hydrological quality elements of all European water bodies with the exception of the marine waters outside the 1-mile coastal zone (Hering et al., 2010). The definition of ecological status takes into account specific aspects of the biological quality elements, one of them being the composition and abundance of benthic invertebrate fauna.

In the WFD good ecological status for benthos in transitional and coastal waters is defined by the following normative definition: "The level of diversity and abundance of invertebrate taxa is slightly outside the range associated with the type-specific conditions. Most of the sensitive taxa of the type-specific communities are present". Evaluation of the status of benthos is frequently achieved by applying a multimetric index (MMI) which combines several indicators each addressing different stressors or components of the biocoenosis (Hering et al., 2010). The MMIs for benthos which have been reviewed by Boon et al. (2011) typically contain three indicators: (a) diversity, (b) (relative) abundance and (c) a ratio of sensitive, tolerant and opportunistic

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species. An important advantage of the use of a multi-metric index is that it clearly reduces the sensitivity of the individual indicators for natural variations (Borja et al., 2011; Kröncke and Reiss, 2010) which enhances the possibility to detect changes of benthic communities as a result of changing human pressures.

Dutch transitional (Westerschelde, Ems–Dollard) and coastal (Wadden sea, Delta coast, Dutch coast and Wadden coast) water bodies (Fig. 1) are subject to a variety of natural and human pressures and resulting changes in physical and chemical state variables (De Jonge et al., 2014; Janssen and Mulder, 2005; Meire et al., 2005; Van Buuren et al., 2010). Typical natural pressures in tidal estuaries are relatively high maximum flow rates, salinity variations, and periodic exposure on intertidal flats (Bouma et al., 2005). Occasional heavy rainfall lead to large variations in salinity (Lacroix et al., 2004) while seasonal temperature variations and particularly extremely cold winters have an impact on benthos especially on intertidal flats (Beukema and Essink, 1986; Mees et al., 1993). Gradual climate warming appears to lead to density shifts of certain species (Beukema et al., 2009). Typical human pressures in the Dutch estuaries are discharges of organic material and nutrients from agriculture and sewage causing eutrophication and hypoxia (Essink and Beukema, 1986), toxic substances, dredging and dumping, bottom trawling, and introduction of non-native species by shipping. The dominant human pressure in the Dutch coastal zone is most likely beam trawling by small vessels (<200 hp). In addition, extraction of sand just outside the coastal zone and subsequent nourishment of the beach and shore-face impact benthos on many parts of the Dutch coast (Van Dalfsen and Essink, 2001). The complex mix of natural and human pressures especially in estuaries makes it difficult to discriminate the different components quantitatively (Schaffner et al., 2001; Hiscock et al., 2004 for a review).

In the North East Atlantic countries, a range of MMIs for benthos in transitional and coastal waters has been developed (Borja et al., 2007; Josefson et al., 2009; Muxika et al., 2007; Teixeira et al., 2009). In a review, Boon et al. (2011) suggested that the indicators which are used by the m-AMBI, viz. species richness, Shannon–Wiener index and AMBI, are probably also suited for the WFD assessment of benthos in Dutch waters. The sensitivity of the m-AMBI for human pressures has been demonstrated in a suite of circumstances, including impacts due to organic material and pollutants, dredging and dumping, oil platforms and aquaculture (Muxika et al., 2005, Borja et al., 2008; Borja et al., 2011). Furthermore, the m-AMBI and comparable Benthic Assessment Tool (BAT) are used by several countries in Europe (Spain, Portugal, Germany) which is favourable for intercalibration purposes.

Therefore, it was first attempted to adopt this commonly used Western European multi-metric tool for Dutch marine benthos. However, several methodological and practical drawbacks were encountered when testing the m-AMBI software (http://ambi.azti.es). First is the

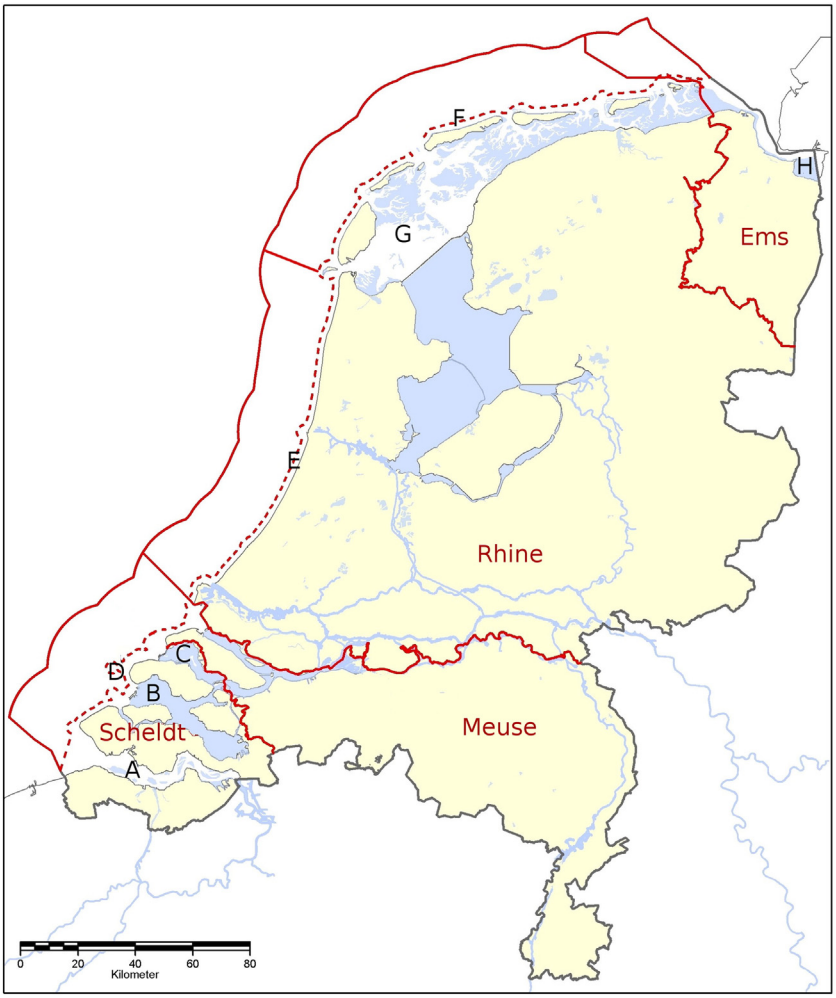

Fig. 1. Global locations of the investigated water bodies. A. Westerschelde, B. Oosterschelde, C. Lake Grevelingen, D. Delta coast, E. Dutch coast, F. Wadden coast, G. Wadden sea and H. Ems–Dollard. Red lines indicate the outer border of the 12-mile coastal zone, borders between regions mentioned above, or borders between water shed areas of the Scheldt, Meuse, Rhine and Ems. Stippled red line is the outer border of the 1-mile coastal zone. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)