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Performance comparison of two biotic indices measuring the ecological status of water bodies in the Southern Baltic and Gulf of Lions

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Abstract

Two biotic indices, ATZI Marine Biotic Index (AMBI) and Benthic Quality Index (BQI) have been recently introduced within the EC Water Framework Directive to assess the quality of marine habitats: both are based on sensitivity/tolerance classification and quantitative information on the composition of soft-bottom macrofauna. Their performance, especially with regard to sampling effort was assessed based on two data sets collected in Southern Baltic and one from the Gulf of Lions Mediterranean. AMBI was not affected by sampling effort but BQI was. Two modifications were proposed for BQI (i.e., BQI) (1) the removal of the scaling term (i.e., BQI_W), and (2) the replacement of the scaling term by different scaling term (i.e., BQI_{ES}). Both modified BQIs were largely independent of sampling effort. Variability was slightly lower for BQI_W than for BQI_{ES}. BQI was highly correlated with BQI_W and with BQI_{ES} both in the Southern Baltic and in the Gulf of Lions. However, the proportions of stations, which were not attributed the same ecological quality status (EcoQ) when using BQI and its two modified forms were always high. Differences in ecological classification were mostly due to the scales used to infer EcoQ. Based on this study we recommend to use BQI_{ES} in future studies because it apparently constitutes the best compromise in (1) being independent of sampling effort, (2) limiting the variability in computation in relation with sampling effort, (3) being correlated with BQI and corresponding EcoQ.

Keywords: Biotic indices; AMBI; BQI; Sampling effort; Benthic macrofauna; Water Framework Directive; Southern Baltic; Gulf of Lions; Mediterranean

1. Introduction

The European Water Framework Directive (WFD; 2000/60/EC) establishes a basis for the protection of ground, continental, transitional and coastal waters. Its overall goal is to achieve an at least 'Good Ecological Status' for all water bodies defined within the WFD by 2015. The assessment of the status of each water will be based on a large variety of parameters including hydromorphological, physico-chemical and biological ones. Together with phytoplankton, macroalgae and fishes, benthic macrofauna is one of the biological compartments considered by the WFD. The WFD will first include the assessment of the currents EcoQ of each water body and then in the monitoring of these 'Ecological Quality status' (EcoQ). In order to unravel possible artefacts due to natural changes, the WFD recommends the definition of a reference per water

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body. This reference may either correspond to expert judgement, modeling, historical data or data collected at a reference site, which is known to be undisturbed. The term 'Ecological Quality Ratio' (EQR) defines the ratio of the values of the biological parameters at the monitored site by the values of the biological parameters at the reference site. EQR is supposed to vary between 0 and 1. It can be transformed in EcoQ using an appropriate scale (Borja et al., 2007). Temporal changes in EQR are supposed to reflect anthropogenic impacts on EcoQ of the water body irrespective of possible natural changes.

Benthic macrofauna has long been used as an index of habitat quality due to its rapid responses to natural and/or anthropogenic disturbances (Grall and Glemarec, 1997; Borja et al., 2000; Gesteira and Dauvin, 2000; Simboura and Zenetos, 2002; Rosenberg et al., 2004). The theoretical basis for this is the secondary succession theory, which describes spatio-temporal changes in the macrofauna composition related to a disturbance (Pearson and Rosenberg, 1978). The quantitative analysis of benthic macrofauna typically results in species/abundance tables, which can be analysed using a large variety of mathematical procedures including multivariate analyses (Field et al., 1982), ABC curves (Warwick and Clarke, 1994), and biotic indices (Borja et al., 2000; Rosenberg et al., 2004). Biotic indices clearly correspond to an extreme in term of data reduction since their computations involve the transformation of the whole data set in a single number. The use of biotic indices is however clearly favoured for the interpretation of benthic macrofauna data within the WFD (Borja et al., 2000; Rosenberg et al., 2004) because these indices are easier to translate in terms of EcoQ and EQR than the results of multivariate analyses. Biotic indices can be used on their own (Borja et al., 2003; Muxika et al., 2005) but also in conjunction with several other elements to assess the quality of marine habitats (Prior et al., 2004; Muxika et al., 2007).

Two biotic indices have been recently developed in view of the implementation of the WFD: (1) the AZTI Marine Biotic Index (AMBI) (Borja et al., 2000), and (2) the BQI (Rosenberg et al., 2004) (Eq. (1)). Both are largely based on the same paradigm: sensitive species tend to become dominant relative to tolerant species during the secondary succession process. Sensitive species are thus dominant in undisturbed environments, whereas tolerant species dominate in disturbed areas. The basis of calculation for these two indices however is completely different. In AMBI, the level of sensitivity/tolerance of a given species is based on the compilation of existing knowledge and its translation in a discrete value (i.e., Ecological group) between 1 and 5. Sensitive species are attributed a low value conversely to tolerant ones. This results in a single species list, which is available on the web (www.azti.es) and can thus be used for all data sets irrespective of their size.

Conversely the BQI uses a variable concept to integrate the sensitivity/tolerance of a given species in a certain region together with the species richness. The species richness is incorporated directly (Eq. (1)). The estimated species number (ES_n) calculation is the expected number of species within an hypothetical sample of n individuals (e.g., 50 individuals is ES_{50}) based on the composition and the abundance distribution within the original sample (Sanders, 1968; Hurlbert, 1971). The ES_n concept allows to compare the species richness between samples of different sample size. BQI incorporates the sensitivity/tolerance of a species based on the analysis of the studied data set itself. The in BQI used $ES50_{0.05}$ value derives from the function of ES_{50} and the abundance of a single species. The lower 5% of the abundance distribution is defined by Rosenberg et al. (2004) as the sensitivity/tolerance measure and determines a specific ES_{50} value. This ES_{50} value is defined as the species specific sensitivity/tolerance measure $ES50_{0.05}$. Disturbed stations tend to show low ES_{50} values because only few species dominate the species composition with high abundances. $ES50_{0.05}$ indeed constitutes an index of species sensitivity/tolerance levels, with low values associated with tolerant species and high values with sensitive ones (Rosenberg et al., 2004).

$$\mathrm{BQI} = \left(\sum_{i=1}^{n}\left(\frac{A_i}{A_{\mathrm{tot}}} \times \mathrm{ES50}_{0.05i}\right)\right) \times \log(S+1) \quad (1)$$

A_i Abundance of individuals of species i at the considered station;
A_{tot} Sum (at the considered station) of the abundances of individuals of all species for which it is possible to compute an $ES50_{0.05}$;
$ES50_{0.05i}$ $ES50_{0.05}$ of species i;
S Species richness at the considered station.

The computation of $ES50_{0.05}$ causes a severe limitation to the spread of the use of BQI, which is in practice restricted to large and often heterogeneous data sets characterized by a non uniform sampling effort (Rosenberg et al., 2004; Labrune et al., 2006). Heterogeneity in sampling effort may also be associated with the use of historical data as reference within the WFD. Another important difference between AMBI and BQI is that the later is taking into account species richness through a $\log(S+1)$ term, which is known to increase with sampling effort (Rumohr et al., 2001).

No specific study has been devoted to the effect of sampling effort on either AMBI or BQI. The aims of the present study were (1) to test the sensitivity of AMBI and BQI to sampling effort based on the very large number of replicated macrofaunal samples collected at the same station in the Kiel Bay by Rumohr et al. (2001), (2) hence to aim 1, to propose changes in the computation of these indices to make them independent of sampling effort, (3) to assess the relationships between original and modified indices based on two data sets collected in the Southern Baltic Sea (Zettler et al., 2007) and in the Gulf of Lions (Labrune