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Assessing proposed modifications to the AZTI marine biotic index (AMBI), using biomass and production

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ABSTRACT

Initially described in 2000, AZTI's Marine Biotic Index (AMBI) aims to assess alterations in communities of soft-bottom marine benthic macroinvertebrates caused by anthropogenic impacts. Although it was designed to be used in European estuaries and coasts this index, based on Pearson and Rosenberg's model of responses to organic enrichment, is being used successfully worldwide. Taking into account statistical difficulties associated with the use of raw abundance data, modifications to the index were recently proposed. These included transforming abundances prior to its calculation, or to use data other than abundances which might be more functionally relevant (such as biomass or production data). Using data from the Basque coast and estuaries (northern Spain), collected between 1995 and 2009, where the evolution of human pressures and restoration actions in the area may be taken into account, the performance of AMBI is compared to that of the proposed modifications in order to assess their usefulness. Despite large variations in the form and nature of the input data, all variations of AMBI index are shown to be highly correlated, even when presence/absence data are used. New boundaries between disturbance categories were calculated, reflecting inter-relationships between different forms of the index. The disturbance classification obtained from all variations using the recalculated boundaries agreed closely with that derived from AMBI. The finding that AMBI values calculated with presence/absence data are potentially useful opens up many possibilities, such as determining the status of assemblages retrospectively using historical data.

1. Introduction

AMBI (AZTI's Marine Biotic Index: Borja et al., 2000) is a univariate measure of community structure that uses information about proportional abundances of benthic macroinfaunal species in samples for its calculation. It is the average (within samples) of species scores, where each species has been assigned a score according to its sensitivity to anthropogenic stress (from I, sensitive, to V, first-order opportunistic), weighted by the abundances of the species and scaled to give continuous values between 0 (all species in ecological group I) to 6 (all species in ecological group V). This response is based upon the Pearson and Rosenberg's paradigm (Pearson and Rosenberg, 1978), which predicts an increase in the abundance of opportunistic species and a decrease of sensitive species, following an organic enrichment of the sediment.

Numerical abundances generally vary widely, even between replicate counts of the same species. This is, in part, a motivation for the routine pre-treatment of abundance data using some sort of transformation prior to conducting multivariate analyses (Clarke et al., 2006). Changes in numbers within species may not be a good proxy for changes in ecosystem function. For example, a single individual of a small opportunistic species may not have the same functional importance as a single large bivalve or echinoderm. Motivated by such considerations, Warwick et al. (2010) proposed calculating AMBI using different types of input data, specifically numerical abundances (NAMBI), biomass (BAMBI) and production (PAMBI). They also suggested that pre-treating data prior to calculating the indices, using a spectrum of power transformations (square root, fourth root, logarithm, presence/absence) such as are routinely used in nonparametric multivariate analyses (Clarke, 1993), might usefully down-weight the influence of dominant species and give a better overview of the status of assemblages. To avoid confusion and facilitate comparisons with previous work, in what follows we will retain AMBI to refer to the index calculated using untransformed abundances.

Warwick et al. (2010) went on to demonstrate that, in a series of samples reflecting a strong organic enrichment gradient (Warwick and Clarke, 1993), a mild transformation (square root) improved the ability of AMBI-derived measures to discriminate samples along the gradient. They also showed that the measures calculated using

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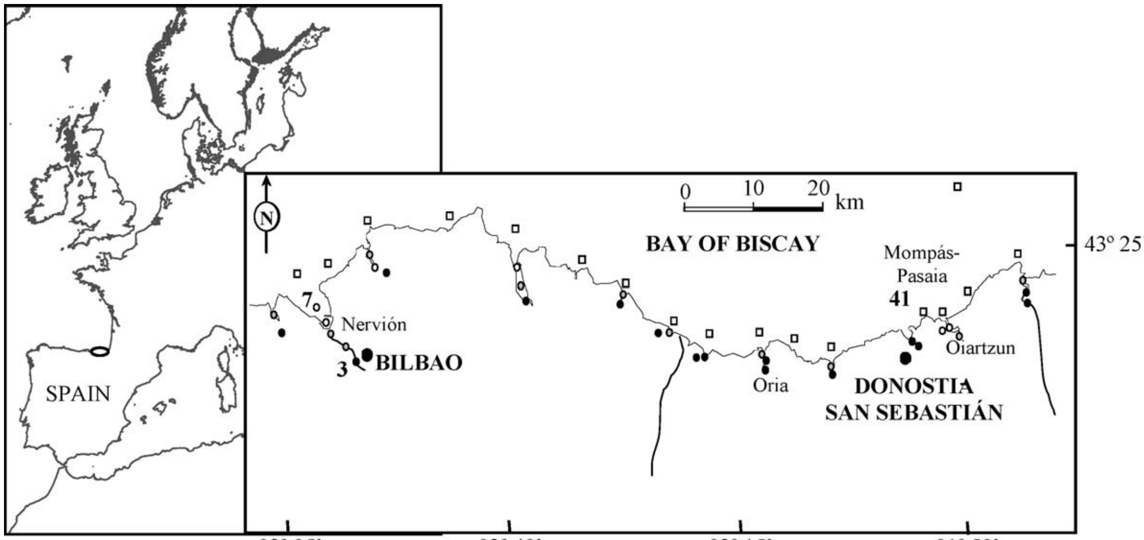

Fig. 1. Sampling stations within the Littoral Water Quality Monitoring and Control Network of the Basque Country. Those that have been used for the analysis of temporal trends are numbered (3 = inner Nervión; 7 = outer Nervión; 41 = Mompás-Pasaia). Key: squares = coastal stations; white circles = euhaline estuarine stations; grey circles = polyhaline estuarine stations; black circles = meso- and oligohaline estuarine stations.

different input data (raw and pre-treated abundance, biomass and production) were surprisingly strongly related to each other, although the relationships were non-linear.

Here, a large dataset of samples collected from the Basque coast of northern Spain, previously used in many studies describing and using AMBI (Borja et al., 2000, 2003a; Muxika et al., 2005, etc.), was used to assess the reproducibility of findings by Warwick et al. (2010) and to take forward some suggestions made in that work. Specifically: (1) the relationships between measures calculated using different input data (AMBI, NAMBI, BAMBI, PAMBI) were determined, together with the underlying patterns that underpin their calculation; (2) the effects of applying pre-treatments to the input data prior to calculating the indices on overall patterns in values of the indices were examined; (3) the relationships between different measures calculated following various pre-treatments and measured environmental variables were determined, and; (4) the variation in the differently derived measures along selected temporal patterns was illustrated.

2. Materials and methods

2.1. Data description

The Basque Water Agency, by means of the Littoral Water Quality Monitoring and Control Network, has monitored Basque coastal and estuarine water quality since 1994 (Fig. 1) (Borja et al., 2009, 2010a). This network comprises the analyses of both physico-chemical (in water, sediment and biota) and biological elements (phytoplankton, macroalgae, benthos and fishes). The data series includes 32 coastal and estuarine stations sampled from 1995 to 2009, together with 19 additional locations sampled since 2002.

Soft-bottom macrobenthic communities are sampled annually in winter, using a van Veen grab in sublittoral locations (0.07–0.1 m^2), combined with quadrats (0.5 m × 0.5 m) sampled directly at intertidal locations (see Sampling Methods, in Borja et al., 2003b, 2010a). Three replicates are collected at each sampling station.

To explore the responses of benthic communities to abiotic factors and human pressures, data from the same sampling locations were used. These included: sediment characteristics (grain-size, organic matter content, redox potential, etc.), and concentrations of metals and organic compounds. For methods used in sampling and analyses, Rodríguez et al. (2006) and Tueros et al. (2008, 2009) can be consulted.

2.2. Data treatment

Production of each species within communities was approximated using values of abundance (A) and biomass (B) by the allometric equation:

$$P = \left(\frac{B}{A}\right)^{0.73} \times A$$

where B/A is the mean body size and 0.73 is the average exponent of a regression of annual production on body size for macrobenthic invertebrates (Brey, 1990). Abundance, biomass (dry biomass) and production data were transformed using a set of transformations of increasing severity: square root, fourth root and $\log(1+x)$ and presence/absence, and through the use of dispersion weighting (Clarke and Gorley, 2006), which down-weights clustered species.

Biotic indices were calculated using raw (AMBI) and transformed abundance (NAMBI), biomass (BAMBI) and production (PAMBI) values (Warwick et al., 2010) using AMBI 4.1 software (freely available at http://ambi.azti.es) and the February 2010 species list. This software provides values calculated for replicate samples, and also average and standard deviations within samples. Guidelines derived from Borja and Muxika (2005) were used in the calculation of the measures.

As noted by Warwick et al. (2010), the mean AMBI score is often reduced to a simple integer scale or discretised into an even smaller number of status categories, e.g. AMBI ≤ 1.2, unpolluted; 1.2 < AMBI ≤ 3.3, slightly polluted; 3.3 < AMBI ≤ 5, moderately polluted; 5.0 < AMBI ≤ 6.0, heavily polluted; AMBI > 6.0, extremely polluted (Borja et al., 2000) but the cut-off points and boundaries for such classifications need to be set at appropriate points on the scale, dependent on which combination of input data (abundance, biomass, production) and transformation is being used. The relationships between AMBI (calculated using raw abundance data) and indices calculated using different input data (biomass or production) and transformations across all samples (replicates) were fitted using quadratic trend lines. The formulae for the trend lines were then used to calculate values of the various indices