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Feeding diversity index as complementary information in the assessment of ecological quality status

Sofia Gamito[a,*], Joana Patrício[b], João M. Neto[b], Heliana Teixeira[b], João Carlos Marques[b]

[a] IMAR-CMA, CTA – Department of Biology and Biotechnology, Faculty of Sciences and Technology, University of the Algarve, Campus de Gambelas, 8005-139 Faro, Portugal
[b] IMAR-CMA, Department of Life Sciences, Faculty of Sciences and Technology, University of Coimbra, Largo Marquês de Pombal, 3004-517 Coimbra, Portugal

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ABSTRACT

The feeding diversity of macroinvertebrates from the estuary of Mondego was estimated with Shannon–Wiener complementary evenness following the methodology presented in Gamito and Furtado (2009. Ecological Indicators. 9, 1009–1019). Results were compared with those from BAT (Benthic Assessment Tool; Teixeira et al., 2009. Marine Pollution Bulletin. 58, 1477–1786) applied to the same data set, obtained from sampling carried out in 14 estuarine subtidal stations in Spring of 1990, 1992, 1998, 2000 and 2002. The BAT is a multimetric methodology based on three indices, the Shannon–Wiener and Margalef diversity indices, applied in conjunction with AMBI (AZTI Marine Biotic Index). To determinate the feeding diversity, each invertebrate was assigned to a feeding group. Six trophic groups were considered: surface deposit feeders, subsurface deposit feeders, herbivores or grazers, suspension feeders and suspension/deposit feeders. The carnivorous, omnivorous and scavengers were all grouped together, forming the sixth group.

The results obtained with both tools pointed out, in general, to the same tendencies. However, in few occasions the feeding diversity pointed out to a high or a bad ecological quality condition whereas the BAT indicated a moderate condition. Occasionally, in stations with average species richness, all individuals were assigned to only one to three feeding groups, and the feeding diversity was low. Even if these taxa were included in the first two or three AMBI sensitive groups, with their presence indicating a possible good ecological condition, they all perform the same ecological function, for example, they are all omnivorous. In these cases the trophic functioning of the system is reduced and the lower trophic levels are missing, such as the suspension-feeders and the decomposers or deposit-feeders. On the contrary, a highly diverse trophic assemblage might be found, but composed of taxa assigned to AMBI ecological groups of species indifferent or tolerant to organic enrichment, and of second-order opportunistic species, indicating a moderate ecological condition, while the feeding diversity will be high. The feeding diversity is, therefore, useful as a complementary information index, measuring other aspects of the community organization, which are not required for ecological quality assessment by the WFD, and so not included in metrics such as BAT.

1. Introduction and aims

Under the scope of the Water Framework Directive (WFD), several biotic indices have been proposed for the ecological status classification of transitional waters. Specifically for macroinvertebrates, different European countries are adopting multimetric approaches, which try to include different aspects of macroinvertebrate community structure, compliant with the WFD, such as species richness, diversity and taxa composition (see Pinto et al., 2009, for a revision). Recently, however, the scientific community is becoming increasingly aware that for benthic quality assessment in transitional waters, it would be necessary to assess not only the structural attributes of the community, but also its functional attributes (Bremner et al., 2006; Elliott and Quintino, 2007; Mouillot et al., 2006). Functional features refer to the overall performance of ecosystems and are directly related with ecosystem processes (properties, goods and services) and to the individual components involved (Bremner et al., 2006).

Functioning of benthic communities has been assessed by different approaches including trophic group analysis (e.g. Bremner et al., 2006; Lavesque et al., 2009; Nickell et al., 2003; Roth and Wilson, 1998). Invertebrate trophic groups have been included in multimetric indexes (e.g. Fano et al., 2003; Lavesque et al., 2009) or multivariate analysis (e.g. Bremner et al., 2003) and ecological

* Corresponding author. Tel.: +351 289 800976; fax: +351 289 800069.
E-mail address: sgamito@ualg.pt (S. Gamito).

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modelling (e.g. Rybarczyk and Elkaim, 2003). Word (1978) developed the Infaunal Trophic Index (ITI) to assess the trophic condition of benthic communities based in the relative proportions of four trophic groups: suspension feeders, carrion feeders, surface deposit feeders and subsurface deposit feeders. The ITI was developed for ecologists surveying the benthos on large areas of the continental shelves (Word, 1978). ITI has also been used in aquaculture environmental impact modelling (Aguado-Giménez et al., 2007), by way of the modelling tool DEPOMOD (Cromey et al., 2002). Some attempts have been made to adapt ITI to ecological quality assessment of transitional waters (Dauvin et al., 2007; Gamito and Furtado, 2009; Patrício et al., 2009). However, ITI appears not to be an appropriate index to infer the ecological quality of transitional waters, since it attains its maximal value (100%) when the entire community is composed by suspension feeders (Gamito and Furtado, 2009), a situation seldom observed in transitional waters. When the benthic trophic diversity is maximal, the ITI is equal to 50%, indicating a changed environment, although this may be considered a healthy community for those systems (Gamito and Furtado, 2009).

In fact, Pearson and Rosenberg (1978) pointed out that the relative proportions of five broad trophic groups in marine environments (deposit feeders, suspension feeders, carnivores, scavengers and herbivores) change according to several environmental factors such as sediment type, depth, salinity and organic load. In a comprehensive sampling program carried out in all estuaries of the northern Gulf of Mexico, Gaston et al. (1998) concluded that trophic diversity (determined with the Shannon–Wiener diversity index) increased in areas free of contaminants, and also in areas with higher salinity and higher dissolved oxygen levels. The surface deposit-feeders, together with the subsurface deposit-feeders and the suspension-feeders, dominated numerically by nearly equal proportions the trophic groups of these American estuaries. However, if biomass was considered, the suspension-feeders was the dominant group. In the Tagus estuary, the dominant group in abundance was the surface deposit feeders; when biomass was considered, the dominant groups were the suspension-feeders and the suspension-feeders/detritivores (Gaudêncio and Cabral, 2007). According to the authors, a more even distribution of the trophic groups was found in the higher salinity areas, the upper estuary being dominated by surface deposit feeders, and the lower estuary by suspension feeders and other trophic groups.

In organically impacted areas, a decrease in almost all trophic groups and dominance by subsurface deposit feeders has been observed (e.g. Pearson and Rosenberg, 1978; Weston, 1990). In sediments contaminated by metals, by polynuclear aromatic hydrocarbons and/or pesticides, the invertebrates were also dominated by subsurface deposit-feeders (Gaston et al., 1998).

Assuming the presence of five or six trophic groups in healthy sediments with no clear dominance of a single group, Gamito and Furtado (2009) proposed the use of the Shannon–Wiener complementary evenness as an approach to estimate the feeding diversity of benthic invertebrates, and tested the index with historical data from subtidal samples of Ria Formosa coastal lagoon.

Although any index developed for evaluating the trophic organization of macroinvertebrate fauna is not compliant with the WFD, the feeding diversity is a useful and simple index to evaluate a functional aspect of the community, which could be used as a complement (even if not WFD compliant) to a multimetric index such as BAT (Benthic Assessment Tool; Teixeira et al., 2009). BAT was adopted by Portugal to assess the ecological quality of coastal waters using macroinvertebrate communities (Carletti and Heiskanen, 2009). In this work, we evaluate the applicability and complementarity of this feeding diversity index by comparing the results it yields with those derived from BAT when applied to the same data set. The variations of each of the three indices that compose BAT were also compared with the feeding diversity, together with species richness.

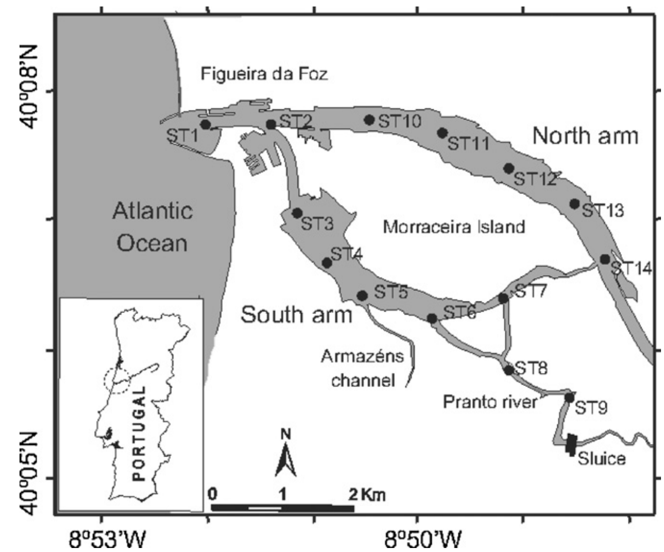

Fig. 1. Location of sampling stations in the Mondego estuary, Portugal.

2. Methods

The data set was gathered from an extensive monitoring programme carried out in the Mondego estuary. Fourteen estuarine subtidal stations were sampled for macroinvertebrates in the Spring of 1990, 1992, 1998, 2000 and 2002, in the Mondego estuary (Fig. 1). At each station, three to five sediment replicates were randomly collected using a van Veen grab model LMG of 0.05–0.08 m^2 sampling surface; the 1 mm fraction was analysed and benthic invertebrates identified and quantified (for sampling and laboratory procedures, see Teixeira et al., 2009). Following the Venice Classification System for salinity, sampling stations can be classified as euhaline estuarine and polyhaline (Teixeira et al., 2008). Almost all stations showed sandy sediments with very low organic content (0.5–2%) except the inner stations of the south arm (stations 6–9) composed of muddy sands with higher organic matter content, varying between 3 and 8%.

To determine feeding diversity, each invertebrate species was assigned to a feeding group (Annex). Feeding information was based on Gamito (2008) compilation, and on MARBEF available information (http://www.marbef.org/data/erms.php). Six trophic groups were considered: surface deposit feeders, subsurface deposit feeders, herbivores or grazers, suspension feeders and suspension/deposit feeders. The carnivorous, omnivorous and scavengers were all grouped together, forming the sixth group. The Shannon–Wiener complementary evenness index (j_{FD}) was then applied, following the methodology presented in Gamito and Furtado (2009):

$$j_{FD} = \frac{H'_{FD}}{\log_2 n}$$

where n is equal to the number of trophic groups considered, in this case, 6 trophic groups. This number will be always 6, independently of the number of trophic groups found in each station. It is assumed that in a healthy environment almost all trophic groups will be present, by opposition to a degraded environment dominated by few trophic groups (Gamito and Furtado, 2009). Identical ecological quality ratio intervals and correspondent ecological quality status (EQS) were adopted, namely: evenness values above 0.8 correspond to a High EQS; values between 0.8 and 0.6 indicate Good