Ecological Indicators 23 (2012) 232–241

Contents lists available at SciVerse ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

A methodology for applying Taxonomic Sufficiency and benthic biotic indices in two Mediterranean areas

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ARTICLE INFO

Article history:
Received 5 September 2011
Received in revised form 13 February 2012
Accepted 27 March 2012

Keywords:
Macroinvertebrates
Taxonomy Sufficiency
Biotic index
BENTIX
BOPA
Mediterranean

ABSTRACT

Biotic indices have been developed to summarise information provided by benthic macroinvertebrates, but their use can require specialized taxonomic expertise as well as a time-consuming operation. Using high taxonomic level in biotic indices reduces sampling processing time but should be considered with caution, since assigning tolerance level to high taxonomic levels may cause uncertainty. A methodology for family level tolerance categorization based on the affinity of each family with disturbed or undisturbed conditions was employed. This family tolerance classification approach was tested in two different areas from Mediterranean Sea affected by sewage discharges. Biotic indices employed at family level responded correctly to sewage presence. However, in areas with different communities among stations and high diversity of species within each family, assigning the same tolerance level to a whole family could imply mistakes. Thus, use of high taxonomic level in biotic indices should be only restricted to areas where homogeneous community is presented and families across sites have similar species composition.

1. Introduction

The high population density in coastal areas has led to many environmental problems and the need of developing effective strategies for their monitoring and evaluation of their ecological status. In order to attain this aim, several tools have been developed, using ecological indicators to supply synoptic information about this status (Salas et al., 2006). One of the components more widely used as indicator in marine environmental assessment is the macrobenthos. Benthic organisms are good ecological indicators because they are relatively sedentary, thus unable to avoid deteriorating water/sediment quality. They have relatively long life-spans, show marked responses to stress depending on their species-specific sensitivity/tolerance levels, and play a vital role in cycling nutrients and materials between the underlying sediment and the overlying water column (Borja et al., 2000; Dauer, 1993; Dauvin et al., 2007; Ferraro and Cole, 1995; Gray et al., 1988).

Several biotic indices have been developed to summarise information provided by the status of benthic communities. These indices are useful tools to communicate with managers because they reduce complex scientific data, integrate different types of information, and produce results that can be easily interpreted in the perspective of water quality management (Chainho et al., 2007; Wilson and Jeffrey, 1994). However, some of these indices require taxonomic classification to species level that can be a labour intensive and time-consuming operation (De Biasi et al., 2003), producing a reduction of the use of macroinvertebrates in monitoring studies due to requirement of specialized taxonomists, sampling and identification costs (Bilyard, 1987; Dauvin et al., 2003; Warwick, 1993).

According to several authors, analyses of higher than species taxonomic level may not produce a substantial loss of discriminatory power for studies of anthropogenic effects on benthic infauna (Ellis, 1985; Ferraro and Cole, 1990). These higher levels (e.g. family) give useful results in multivariate ordinations, since if the abundance and composition of taxa differ in polluted and unpolluted areas, little or no relevant information may be lost by identifying organisms to higher taxonomic level (Gray et al., 1990; Help et al., 1988; Herman and Heip, 1988; Olsgard et al., 1997; Somerfield and Clarke, 1995; Warwick, 1993). However, the taxonomic level of identification may have a great influence on biotic indices, since sensitivity to pollution for the same taxonomic group may differ from one species to another. In this way, biotic indices as BENTIX (Simboura and Zenetos, 2002), AMBI (Borja et al., 2000) or BQI (Rosenberg et al., 2004) were created on the basis of taxonomic identification at the species level, attributing a sensitivity/tolerance level to each individual species. Some studies proposed to develop an adaptation of these indices for use at high taxonomic level

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http://dx.doi.org/10.1016/j.ecolind.2012.03.029

(Dimitriou et al., 2012) and two biotic indices have been developed in order to reduce this taxonomic effort solving problems registered from use of high taxonomic levels: BOPA (Dauvin and Ruellet, 2007) and BITS (Mistri and Munari, 2008). BOPA index is restricted to a part of the community, being based on the principle of antagonism between a sensitive group (order Amphipoda) and opportunistic polychaetes (Dauvin and Ruellet, 2007). Whereas BITS is based on the whole community working at family level identification, though it is specific for Italian non-tidal lagoons, where each family is composed by a few number of species (Mistri and Munari, 2008).

BENTIX (Simboura and Zenetos, 2002) has been tested successfully in a variety of Eastern Mediterranean benthic ecosystem subjected to organic pollution, oil spills accidents, mining-impacted ecosystems (Simboura et al., 2005, 2007; Zenetos et al., 2004) and aquaculture (Simboura and Argyrou, 2006). This index classifies benthic species in only two groups, with respect to other indices like AMBI that requires classifying taxa in 5 groups. Therefore, an approach for higher taxonomic levels could be affordable to BENTIX since certain families, for example Capitellidae, have a clear disturbance reaction pattern and this family could be assigned to the “tolerant” group, while on the other hand capitellid species are classified among three different groups by AMBI (GIII, GIV and GV). However, other families could contain species with different tolerance levels, such that they would present different disturbance reaction depending on their specific composition of the studied community or area. To cope with the main inconvenience of assigning ecological groups to these taxa, we used a methodology based on Smith et al. (2001) and Pelletier et al. (2010) which allow to determine the degree of affinity of each taxa with disturbed or undisturbed conditions in a specific area. The aim of this paper is to elucidate the advisability of using higher taxonomic level in biotic indices normally using species level information as BENTIX, and in biotic indices that are partly using species information (opportunistic polychaetes) as BOPA, testing their response to sewage pollution in two different areas of the Mediterranean Sea: Iberian Peninsula east coast (Spain, Western Mediterranean) and Saronikos Gulf (Greece, Eastern Mediterranean).

2. Materials and methods

2.1. Studied areas

The Western Mediterranean area (Fig. 1) is located off the Iberian Peninsula east coast (NE Spain) where five locations affected by sewage outfalls were analyzed. These outfalls correspond to the villages of Vinaroz (location I), Benicarló (location II), Peñíscola (location III), Alcossebre (location IV) and Torreblanca (location V) (Fig. 1a). Wastewater is discharged through submarine pipelines at a depth of approximately 15 m. The mean sewage flow reaches 222,597 m^3/month; the highest flow was registered in location II (502,612 m^3/month) whereas the lowest was registered in location V (43,256 m^3/month). Wastewater treatment plants from locations I, II, III and IV utilize only a pre-treatment process, which includes an automated mechanically raked screen, a sand catcher and grease trap. Whereas, secondary treatment, consisting of biological treatment of activated sludge, was implemented in location V. The study area has a constant water depth, homogeneous bottom sediment and is uniformly inhabited by the medium-to-fine sand community of *Spisula subtruncata* (da Costa, 1778). This homogeneous area with several well-established pollution spots represents an ideal site for investigating links between macrofaunal assemblages and the effect of contaminants (de-la-Ossa-Carretero et al., 2009, 2010; Del-Pilar-Ruso et al., 2010). At each location, two sites were sampled at three distances from the discharge (0, 200 and 1000 m), following the coastline in order to keep a constant depth. All samples were collected in July during five consecutive years (2004–2008). Three Van Veen grab samples (400 cm^2) were obtained at each station for the study of the benthic community; samples were sieved through a 0.5 mm screen and preserved in 10% formalin for further identification at family taxonomic level.

The Eastern Mediterranean area is located in Saronikos Gulf, surrounding the Athens metropolitan area (Fig. 1b). The gulf receives the effluents of the central sewage outfall of Athens through a deep underwater outlet situated on Psittalia Island, at the inner part of Saronikos Gulf, discharging through two 1870 m long submarine pipelines and at a depth of approximately 65 m the treated urban sewage effluents. The Psittalia Waste Water Treatment Plant – WWTP (http://www.eydap.gr/) is the main wastewater treatment plant in the greater Athens area, receiving an average wastewater flow of approximately 730,000 m^3/d. It has been in operation since 1994, through a stage-wise construction that involved three phases: Phase A (Primary treatment) completed in 1994, Phase B (advanced Secondary biological treatment), using activated sludge processes was completed in 2004 and Phase C (Tertiary treatment), comprising the Sludge Thermal Drying Unit completed in 2007. Nowadays wastewater treatment achieves suspended solids and organic load reduction by about 93% and total nitrogen reduction by about 80% in comparison with influent loads. At the time of the study period (2000–2004) only the primary treatment was functioning, while the secondary had been just implemented.

The effects of the Psittalia sea outfalls on the ecosystem of Saronikos Gulf have been monitored regularly by the Hellenic Centre for Marine Research (HCMR) from 1986 (Krassakopoulou et al., 2010 and Siokou-Fragou, 2004) and up to date.

Samples were collected from a network of 19 stations in the inner Saronikos Gulf, extending for the Psittalia outfall station (S7) and at an increasing distance for the point source of the effluents (Fig. 1B). Fifteen stations were visited in May, December 2000 and April 2002 and 19 stations in May 2003 and February 2004. At each station two replicate benthic samples were collected with a Box Corer benthic sampler of 1000 cm^2 sampling surface and sieved through a 1 mm sized mesh. Samples were preserved in a 4% buffered formalin solution and the fauna were sorted and identified to the species level, except from broken or unidentifiable specimens.

2.2. Family tolerance classification

The BENTIX index (Simboura and Zenetos, 2002) was designed to fit the Mediterranean benthic ecosystem. It is based on the concept of indicator groups and uses the relative contribution of tolerant (GT) and sensitive species (GS) in the fauna weighted analogously to derive a single formula

$$\text{BENTIX} = \frac{(6)(\%GS) + (2)(\%GT)}{100}$$

where the numerical factor ‘6’ is assigned to the sensitive species group GS and the factor ‘2’ to the tolerant species groups GT (http://bentix.ath.hcmr.gr/).

In order to cluster families in these groups, a method based on Pelletier et al. (2010) and Smith et al. (2001) was employed.

Firstly, stations from the two areas were selected based on previous studies (de-la-Ossa-Carretero et al., 2009; Simboura et al., 2005; Simboura and Reizopoulou, 2008) to clearly reflect a well defined bipolar situation with one end corresponding to disturbed ones and the other end to undisturbed conditions. In the Iberian Peninsula east coast (Fig. 1), stations closest to outfalls from locations where wastewater treatment plants utilise only a pre-treatment process (locations I, II, III and IV) were classified as disturbed, whereas stations at 1000 m to these outfalls were