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Application of biotic indices and relationship with structural and functional features of macrobenthic community in the lagoon of Venice: an example over a long time series of data

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Abstract

In the context of the application of WFD, a scientific debate is growing about the applicability of biotic indices in coastal and transitional waters. In the present work, the question about the discriminating power of different biotic indices and the relationships with the structure and functioning of the macrobenthic community in a transitional environment is discussed. A time series of samples collected during the last 70 years in the lagoon of Venice, reflecting different environmental conditions (a sort of 'pristine state' in 1935, the distrophic crisis in 1988 and subsequent modifications in 1990, the invasion by an alien species and the developing of high impacting fishery in 1999) has been used. The comparison of results obtained by applying different biotic indices, such as AMBI, Bentix and BOPA, shows differences in the discriminating power of indices and a general overestimation of environmental conditions. Discrepancies between environmental status as indicated by biotic indices and the structure and functioning of the benthic community have been highlighted.

Keywords: Biotic indices; Diversity; Exergy; Ecosystem functioning; Lagoon of Venice

1. Introduction

The implementation of the European Water Framework Directive (WFD, 2000/06/EC; EC, 2000) has produced, on one side the developing of a series of common concepts, terminologies and tools, and on the other a sort of race to the development of 'new indices' (Dauvin, 2007).

In this context there is a scientific debate about the applicability of biotic indices, both 'old' and 'new', to determine the quality of European coastal and transitional waters, according to Ecological Quality Status (EcoQ) (Borja et al., 2000, 2003, 2004a,b; Borja and Heinrich, 2005; Simboura and Zenetos, 2002; Simboura, 2004; Simboura et al., 2005; Dauvin et al., 2007). Indeed, a biotic index is unlikely to be universally applicable, because all organisms are not equally sensitive to all types of anthropogenic disturbances and thus are likely to respond differently to different types of perturbations. Moreover, many of these indices are still dependent on the Pearson–Rosenberg model for organic enrichment; hence they must be validated for other stressors, such as physical disturbance and chemical pollution (Quintino et al., 2006). All this generates the so-called 'paradox of estuarine quality' (in Dauvin, 2007). Transitional estuarine waters are naturally organic rich environments where stress-tolerant species are typical, so transitional environments would therefore likely be, by definition, characterised by low scores and so low EcoQ values.

At present, in the context of environmental management/policy, there is an increase in the need for a more services-oriented scientific work, to assess effects of community structure changes (such as biodiversity loss) on services, but this implies the improving of the knowledge in the process-oriented ecology, bridging the gap between community ecology and ecosystem ecology, as suggested by Raffaelli (2006). It is necessary to improve the knowledge about the cause–effect relationships between changes in the structure of biological communities and ecological

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processes, taking into account that all this operates at large spatial scales and generally involves many different trophic levels simultaneously. To face what is essentially an ecosystem-level question, an ecosystem-level approach is required (Raffaelli, 2006).

In this context, it is interesting to assess the applicability, in terms of discriminating capacity, of different biotic indices in particular for environments such as the lagoons, comparing obtained results with independent indications about the structure and functioning of the benthic compartment (see also JRC-EEWAI, 2007).

The aim of this paper is to compare the results of different indices, recently proposed for evaluation of the state of marine coastal environments, by using a time-series of macrobenthos samples collected in the Venice lagoon during the last 70 years. Results will be discussed in the light of the temporal pattern of main ecological driving forces and in the comparison between structure and functioning of the soft-bottom macrobenthic community of the lagoon.

2. Materials and methods

During the last century, the lagoon of Venice, one of the widest Mediterranean lagoon environments, has been subjected to intense anthropogenic pressures which have deeply modified it.

Three main events can be recognized:

- the modification of hydrodynamic conditions, with profound effects on habitat morphology in the 1960s (Ravera, 2000);
- the increase of nutrient load in the 1960s and 1970s (Cossu and De Fraja Frangipane, 1985), with eutrophication and subsequent macroalgae blooms and anoxia events recorded in the 1980s (Sfriso et al., 2003);
- the invasion by an alien species, Manila clam, at the end of the 1980s and the subsequent development of the mechanical clam harvesting in the 1990s (Cesari and Pellizzato, 1985; Provincia di Venezia, 2000; Pranovi et al., 2004).

2.1. Macrobenthic community data

The dataset (303 taxa, belonging to 8 different Phyla, and more than 450 samples) is composed from data collected by different surveys carried out in the lagoon during the last 70 years (Table 1) (for details about the database please refer to Pranovi et al., submitted for publication).

The time series is characterized by a heterogeneous distribution of samples through the time, with an important gap from 1935 to 1988, and by different survey's extension. Three surveys (1935, 1990 and 1999) covered the entire lagoon, whereas the other ones included one or two basins (Table 1, for the location of the basins see Fig. 1).

All collected species were checked for nomenclature, and data were standardized to m^2.

Table 1
Time series available for each basin of the lagoon

	1935	1988	1990	1995	1997	1999	2001	2004
Northern	x	x	x			x		x
Central	x	x	x	x		x	x	
Southern	x		x	x	x	x		

2.2. Marine biotic indices

In general terms, the theoretical basis of marine biotic indices is the community succession in a gradient of organic enrichment as proposed by Pearson and Rosenberg (1978), based on the concept that biological communities respond to environmental stress by means of different adaptive strategies. In the present study three different indices (AMBI, Bentix and BOPA) were tested.

AMBI (AZTI's Marine Biotic Index), as defined by Borja et al. (2000, 2003), is a biotic index which provides a classification of a site, representing benthic community health (sensu Grall and Glémarec, 1997). It is based on the distribution of the abundance of each species, into one of five ecological groups (EG), according to their sensitivity to environmental stress (mainly organic pollution). The index ranges between 0 (the best condition) and 7 (the worst one). Since, as reported also by Magni et al. (2005), better results in the assessment of EcoQ is achieved by applying a combination of different indices, the AMBI index was recently developed in a new version, called m-AMBI, to include in the assessment the number of species and the Shannon index (Muxika et al., 2007). For the index calculation the software available on http://www.azti.es was used.

Bentix is a biotic index proposed by Simboura and Zenetos (2002), based on the same idea as AMBI, but benthic species are grouped into two wider EG (the sensitive and the tolerant) (Simboura et al., 2005). The index can produce a series of continuous values from 2 to 6, being 0 when the sediment is azoic (all groups zero). The Bentix methodology and an extended list of species scores can be found on http://www.hcmr.gr/english_site/services/env_aspects/bentix.html.

BOPA (benthic opportunistic polychaetes amphipods) is an index, substantially based on the same ecological bases of previous ones, which uses the ratio between the frequency of opportunistic (tolerant) polychaetes and the frequency of amphipods to classify the state of a community (Gomez Gesteira and Dauvin, 2000; Dauvin and Ruellet, 2007). This index ranges between 0 (best condition, in the case of absence of opportunist polychaetes) and log2 (in the case of absence of amphipods).

In the context of the implementation of the European Water Framework Directive (WFD, 2000/06/EC), a growing scientific effort has been dedicated to the definition of the Ecological Quality Status (EcoQ) and its categorization (Borja et al., 2000, 2003, 2004a,b; Borja and Heinrich, 2005; Simboura and Zenetos, 2002; Simboura, 2004; Simboura et al., 2005; Dauvin et al., 2007). In Table 2, the