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Efficacy of single and multi-metric fish-based indices in tracking anthropogenic pressures in estuaries: An 8-year case study

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ABSTRACT

Facing a generalized increase in water degradation, several programmes have been implemented for protecting and enhancing the water quality and associated wildlife, which rely on ecological indicators to assess the degree of deviation from a pristine state. Here, single (species number, Shannon–Wiener H', Pielou J') and multi-metric (Estuarine Fish Assessment Index, EFAI) community-based ecological quality measures were evaluated in a temperate estuary over an 8-year period (2005–2012), and established their relationships with an anthropogenic pressure index (API). Single metric indices were highly variable and neither concordant amongst themselves nor with the EFAI. The EFAI was the only index significantly correlated with the API, indicating that higher ecological quality was associated with lower anthropogenic pressure. Pressure scenarios were related with specific fish community composition, as a result of distinct food web complexity and nursery functioning of the estuary. Results were discussed in the scope of the implementation of water protection programmes.

1. Introduction

Historical and persistent human disturbance have altered the stability, diversity and ecological integrity of the Earth's ecosystems (Kennish, 2002; MacDougall et al., 2013), inducing the loss of several attributes such as taxonomic, phylogenetic, genetic and functional diversity (Solan et al., 2004; Ives and Carpenter, 2007; Cardinale et al., 2012; Naeem et al., 2012; Dolbeth et al., 2013). In particular, marine and estuarine areas have been affected by man's activities worldwide (Borja and Dauer, 2008), resulting in generalized signs of habitat degradation, reduced water quality and loss of aquatic biota (Pérez-Domínguez et al., 2012), threatening the long-term health and sustainability of these important ecosystems (Goldberg, 1995; Costa et al., 2002; Kennish, 2002; Vasconcelos et al., 2007).

Considering that transitional ecosystems provide a wide range of goods and services that benefit human populations (Costanza et al., 2007), the equilibrium between socio-economic growth and environmental protection has become a central topic in marine environmental management (Borja and Dauer, 2008; Elliott and Whitfield, 2011). Over the last decades, a worldwide effort has been dedicated to developing and implementing policy and tools for the protection and/or restoration of aquatic systems, ensuring a sustainable use of water resources, such as the USA and Canada Clean Water Act, Australia's Oceans Policy, the National Water Act in South Africa and the EU Water Framework and Marine Strategy Framework Directives (see details in Cabral et al., 2012). For European countries, the Water Framework Directive (EU WFD, 2000/60/EC) has set the main agenda for community action in the domain of water policy, whose main objective is the protection and enhancement of groundwater, inland surface waters, estuarine and coastal waters.

In estuaries, assessment of ecological quality faces one important challenge, given the need to disentangle between changes due to natural variability and to man's activities, a concept usually termed as the "Estuarine Quality Paradox" (Dauvin, 2007; Elliott and Quintino, 2007). Hence, an index used to measure ecological integrity should be sensitive to anthropogenic stressors, but sufficiently robust against natural variability at different spatial and temporal scales (Rice and Cooper, 2003; Dauvin, 2007; Elliott and Quintino, 2007; Nõges et al., 2009). Consequently, the inclusion of measures of community structure, such as species diversity and composition, and function, such as nursery function and trophic integrity, is determinant for a proper ecological assessment in these areas (Elliott and Hemingway, 2002; Harrison and Whitfield, 2004; Elliott and Quintino, 2007; Fonseca et al., 2013). This approach has been followed for the development of several multimetric indices worldwide. Specifically in Europe, several multimetric indices have been developed by member states, combining data on community composition and functioning, and adapted to local specificities and data availability (see comparisons of several indices in Martinho et al., 2008; Cabral et al., 2012; Pérez-Domínguez et al., 2012).

Estuarine fish assemblages have been used as indicators of change over the last several years, in the scope of several programmes implemented for the protection of water resources worldwide (see Borja and Dauer, 2008; Cabral et al., 2012; Pérez-Domínguez et al., 2012 for

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a review). The use of fish as indicators relies mainly on their ubiquitous presence in aquatic ecosystems, easy collection, handling and identification, presence in several trophic and ecological levels, sensitivity to habitat loss, and on their wide range of likely responses to stress (Elliott and Hemingway, 2002; Harrison and Whitfield, 2004; Pérez-Domínguez et al., 2012).

Apart from multi-metric tools, traditional diversity measures can also be used to infer changes in the health status of an ecosystem, mainly due to their ease of estimation. For instance, a fish community facing significant environmental disturbances, such as habitat loss, will be characterized by a more simplified structure, with lower diversity and complexity (Kennish, 2002; Fonseca et al., 2013). Although several studies delved into relating ecological quality based on estuarine fish assemblages with anthropogenic pressures (e.g. Delpech et al., 2010; Cabral et al., 2012; Drouineau et al., 2012; Fonseca et al., 2013; Pasquaud et al., 2013), one aspect that is clearly lacking is the inclusion of a large and continuous timeframe.

In this context, the main objective of this work was to evaluate the changes in community-based measures of ecological quality in the Mondego estuary (Portugal) over an eight-year period, and to infer the interrelationship between them and the trends in anthropogenic pressures in the same time frame. This objective was achieved by evaluating a) changes in anthropogenic pressure over time; b) changes in several fish-based diversity measures; and by c) establishing relationships between diversity measures and anthropogenic pressures over time, based on the hypothesis that higher stressed environments will result in lower diversity and ecological quality status.

2. Materials and methods

2.1. Fish sampling surveys and laboratory procedures

Fish were collected in the Mondego estuary, located on the Atlantic coast of Portugal (40°08'N, 8°50'W) (see detailed description of the estuary in Martinho et al., 2007). Sampling was performed between 2005 and 2012 at five stations (Fig. 1) during the night, starting at high water of spring tides, using a 2 m beam trawl with one tickler chain and a stretched mesh size of 5 mm in the cod end. The selected sampling sites covered the majority of the estuarine area, representing several habitats and salinity ranges, providing a good overview of the whole ecosystem. At each sampling station, 3 hauls were towed at an average speed of two knots, covering at least an area of 500 m^2. Samples were transported in iceboxes to the laboratory, where fish were sorted, identified, measured (total length — TL, to the nearest 1 mm) and weighted (wet weight — WW, with 0.01 g precision).

Considering the recommendations for evaluating the ecological quality of Portuguese estuaries in the scope of the EU WFD, that fish sampling should be performed in the spring due to higher species richness and abundance (Cabral et al., 2012), sampling was performed in two months in each year during spring, and data from all five stations

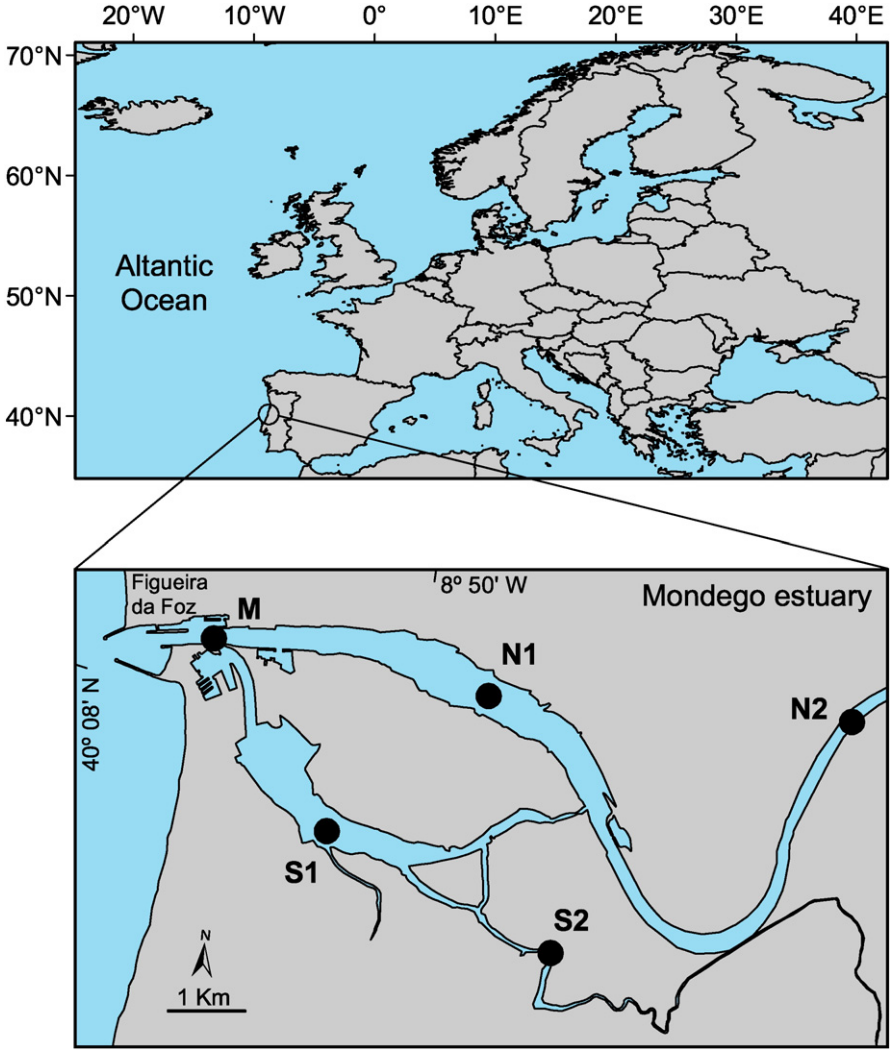

Fig. 1. Location of the Mondego estuary in the Portuguese Atlantic coast, highlighting the sampling stations (black circles).