Marine Pollution Bulletin 56 (2008) 1834–1843

Contents lists available at ScienceDirect

Marine Pollution Bulletin

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

Assessing estuarine environmental quality using fish-based indices: Performance evaluation under climatic instability

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ARTICLE INFO

Keywords:
Water Framework Directive
Fish-based indices
Ecological Quality Status
Ecological indicators
Fish community
Mondego estuary

ABSTRACT

The seasonal variation of five selected multimetric indices for the determination of the Ecological Quality Status (EQS) of transitional waters was evaluated, as well as the indices' responses to an extreme drought event that occurred in 2005. The database used regards the Mondego River estuary, which was sampled from June 2003 to August 2006 on a monthly basis. Among the selected indices (EBI – Deegan et al. [Deegan, L., Finn, J.T., Ayvazlan, S.G., Ryder-Kieffer, C.A., Buonaccoesi, J., 1997. Development and validation of an Estuarine Biotic Integrity Index. Estuaries 30(3), 601–617], EDI – Borja et al. [Borja, A., Franco, J., Valencia, V., Bald, J., Muxika, I., Belzunce, M.J., Solaun, O., 2004. Implementation of the European Water Framework Directive from the Basque Country (northern Spain): a methodological approach. Marine Pollution Bulletin 48(3–4), 209–218], EFCI – Harrison and Whitfield [Harrison, T.D., Whitfield, A.K., 2004. A multi-metric fish index to assess the environmental condition of estuaries. Journal of Fish Biology 65, 683–710], EBI – Breine et al. [Breine, J.J., Maes, J., Quataert, P., Van den Bergh, E., Simoens, I., Van Thuyne, G., Belpaire, C., 2007. A fish-based assessment tool for the ecological quality of the brackish Scheldt estuary in Flanders (Belgium). Hydrobiologia 575, 141–159] and TFCI – Coates et al. [Coates, S., Waugh, A., Anwar, A., Robson, M., 2007. Efficacy of a multi-metric fish index as an analysis tool for the transitional fish component of the Water Framework Directive. Marine Pollution Bulletin 55, 225–240]), the EBI by Breine et al. (2007) was the only that evidenced clear interannual and seasonal variations. The EQS by the several indices ranged from "Low" to "High", depending on the index considered, evidencing the high level of mismatch between indices. The results are discussed in the scope of the EU Water Framework Directive, regarding monitoring strategies, application of indices and EQS assessment.

1. Introduction

The Water Framework Directive (WFD, 2000/60/EC) has set a new approach to the management and monitoring of water resources, aiming to achieve a "Good" ecological status by 2015 in all European water bodies (i.e., the values of the biological quality elements for the surface water body type should show low levels of distortion resulting from human activity, deviating only slightly from those normally associated with undisturbed conditions (Vincent et al., 2002). This directive establishes a framework for the protection of groundwater, inland surface waters, estuarine (=transitional) and coastal waters (Borja, 2005), whose main objectives are: (a) to prevent further deterioration, to protect and to enhance the status of water resources; (b) to promote sustainable water use; (c) to enhance protection and improvement of the aquatic environment, through specific measures for the progressive reduction of discharges; (d) to ensure the progressive reduction of pollution of groundwater and prevent its further pollution; and (e) to contribute to mitigating the effects of floods and droughts. Accordingly, all EU member states are required to assess the Ecological Quality Status (EQS) of water bodies, and in transitional waters (=estuaries) the measurement of biological integrity will be emphasized on phytoplankton, macroalgae, benthos and fishes.

Transitional waters are of great importance for the fish fauna, playing a vital role by providing nursery habitats, reproduction grounds, refuge from predators and migratory routes (Haedrich, 1983; Elliot and McLusky, 2002; Cabral et al., 2007; Martinho et al., 2007a,b). Nevertheless, these systems are being subjected to high environmental pressure due to anthropogenic forcing, such as eutrophication, overfishing, bank reclamation and general environmental degradation.

The use of fishes as indicators of environmental change has recently gained attention (Whitfield and Elliott, 2002), with several authors developing multimetric tools in order to assess the estuarine ecosystem status for the fish component at various latitudes

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0025-326X/$ - see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.marpolbul.2008.07.020

(e.g. Deegan et al., 1997; Borja et al., 2004; Harrison and Whitfield, 2004; Breine et al., 2007; Coates et al., 2007). In addition, studies of population dynamics, food-web organization and structure of communities have been more successful than single species bioassays at predicting the effects of multiple stresses on biological systems (Schindler, 1987; Plafkin, 1989; Dolbeth et al., 2007a). The use of indicators provides the possibility to evaluate the fundamental condition of the environment without having to capture the full complexity of the system (Whitfield and Elliott, 2002), and according to the WFD guidance, the evaluation methods for the fish component should take in account both aspects of composition and abundance of fish species.

Extreme climatic events, such as floods or droughts are increasing in frequency worldwide (Mirza, 2003), and as a consequence, river discharge into many estuaries may be affected (Gleick, 2003). In the Mondego River basin, a severe drought occurred in 2005, and was classified by the Portuguese Weather Institute (http://web.meteo.pt/clima/clima.jsp) as the worst drought of the past 60 years. As a result, the decreasing precipitation and runoff induced changes in the estuary's planktonic and fish communities, with an increase in typical marine species during the drought (Marques et al., 2007; Martinho et al., 2007b). Since the implementation of the WFD by EU member states will be a continued process in time, to cope the various methodologies with climate instability is a key issue for the success of such an ambitious and promising directive. Within this framework, the objectives of the present work were to compare the results obtained by the methodologies developed by Deegan et al. (1997), Borja et al. (2004), Harrison and Whitfield (2004), Breine et al. (2007) and Coates et al. (2007) for determining the Ecological Quality Status of transitional waters using fish data, and to evaluate their responses in different climatic scenarios, namely in the presence of an extreme event (severe drought).

2. Materials and methods

2.1. Study site

The Mondego estuary is a small intertidal system, located on the Atlantic coast of Portugal (40°08′N, 8°50′W) (Fig. 1), where approximately 1072 ha correspond to wetland habitats. In its terminal part, it comprises two arms that join near the mouth, separated by an alluvium-formed island (Murraceira Island). The northern arm is deeper (average 10 m during high tide) and is the main navigation channel and the location of the commercial harbour. The southern arm is shallower (2–4 m during high tide) and water circulation is mostly dependent on the tides and on the freshwater input from the Pranto River, a small tributary system. For further detailed information on the Mondego estuary's characteristics see Teixeira et al. (2008).

2.2. Sampling procedures and data acquisition

Fish sampling was performed monthly from June 2003 to August 2006 (except in July, September, October, December 2004 and July 2006, due to technical constraints or bad weather conditions), using a 2 · 0.5 m beam trawl with one tickler chain and 5 mm mesh size in the cod end. Samples were collected during the night, at high water of spring tides and in 5 stations throughout the estuary (Fig. 1). At each station, three tows were carried out, covering at least an area of 500 m^2 each. All fish caught were identified, counted, measured (total length) and weighted (wet weight). Bottom water salinity and temperature were measured after fishing took place.

Hydrological data was obtained from INAG, Portuguese Water Institute (http://snirh.inag.pt). Monthly precipitation (from

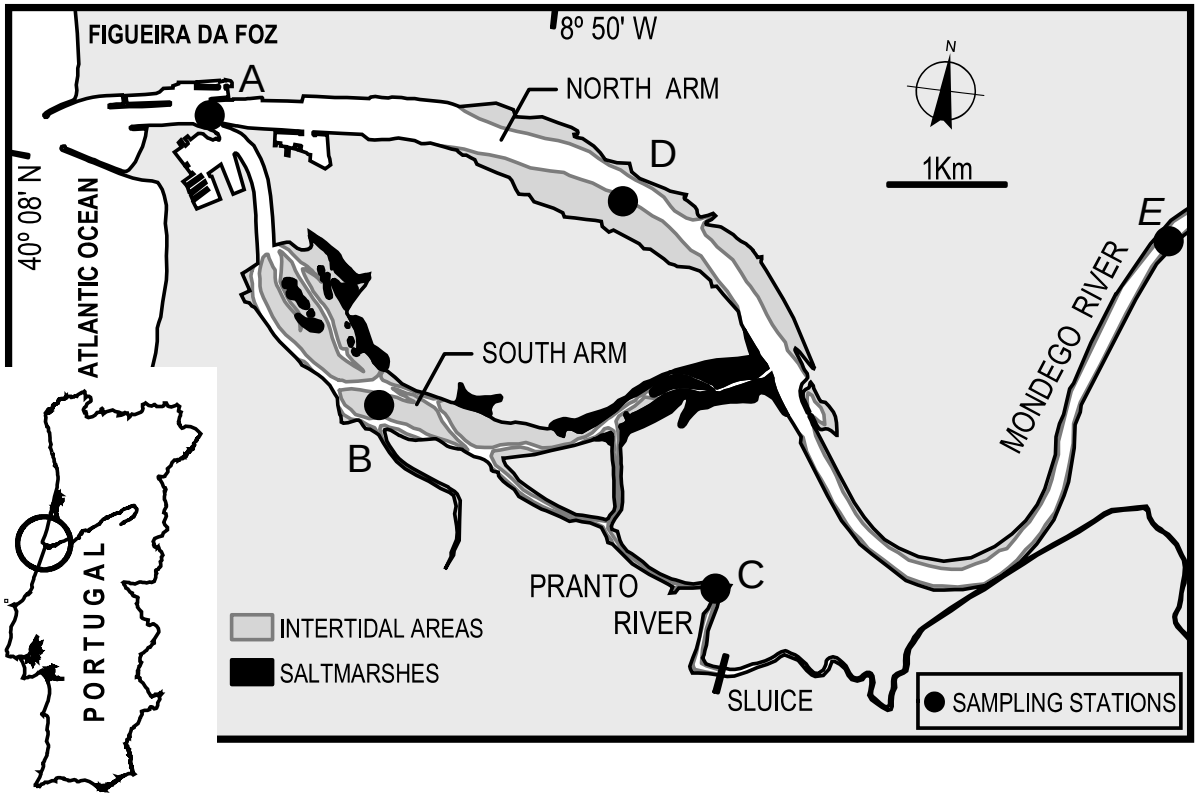

Fig. 1. Geographical location of the Mondego estuary and the five sampling stations (A–E).