Marine Pollution Bulletin 71 (2013) 168–178

Contents lists available at SciVerse ScienceDirect

Marine Pollution Bulletin

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

Testing different ecological scenarios in a temperate estuary: A contribution towards the implementation of the Ecological Potential assessment

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ARTICLE INFO

Keywords:
Water Framework Directive (WFD)
Heavily Modified Water Body (HMWB)
Ecological Potential
Macroinvertebrates
Estuaries
Management

ABSTRACT

The concept of Ecological Potential was explored using the macrobenthic communities of the Mondego estuary (Portugal). Different scenarios (loss of a primary producer and intertidal habitat, and habitat modification due to hydromorphological changes and continued press perturbation) were tested to predict changes in the biology if hydromorphological pressures could be reversed, assuming that differences with and without the pressure could indicate the potential.

Results showed noticeable changes in the system biology in each scenario. The approach followed, indicates that when data sets exist, differences in the measurement of ecological status with and without the hydromorphological change could be a way forward to determine the potential. In the particular case of the Mondego estuary, the South arm (physically unaltered water body) proved to be richer than the North (HMWB). For the Ecological Potential determination, the South arm could thus be used to derive and adjust future reference conditions for the North.

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1. Introduction

Estuaries, as transition areas between the riverine and marine environments, are naturally highly dynamic and productive systems, supporting many important ecosystem functions (e.g. biogeochemical cycling and movement of nutrients, purification of water, mitigation of floods and the maintenance of biodiversity) (Kennish, 2002; Meire et al., 2005). Amongst the most valuable ecosystems in the world (Costanza et al., 1997), with high resources and economic importance, estuaries have often been a target of considerable human exploitation. The increasing development and rapid population growth in coastal zones are closely coupled to the numerous anthropogenic perturbations affecting estuaries which compromise their ecological integrity (Halpern et al., 2008a; Borja et al., 2010). Human threats to these ecosystems include nutrient enrichment, chemical contaminants, hydrological modifications, habitat loss and alteration, introduced species, and harbor and dredging activities (Kennish, 2002).

Apart from the adverse effects of human activities, estuaries show wide variations in physical and chemical conditions, making difficult to discern natural from human-induced changes (Paerl, 2006; Dauvin, 2007; Elliott and Quintino, 2007). In addition, the interplay of multiple stressors which impact biodiversity and ecosystem functioning through single, cumulative or synergistic processes, adds further difficulty to managing these systems (Adams, 2005; Halpern et al., 2008b).

To manage pressures and impacts, several legislative instruments have been recently developed worldwide in order to protect and restore ecological quality or integrity within these systems, ensuring that human activities are carried out in a sustainable manner (Borja et al., 2008). In Europe, the Water Framework Directive (WFD; 2000/60/EC) establishes a framework for the protection and improvement of all waters (including inland surface waters, transitional waters, coastal waters, and groundwater), aiming to achieve a 'Good Ecological Status' (GES) by 2015 (Borja, 2005). An exception to GES achievement is considered for water bodies which were deeply changed in their hydromorphological character as a result from physical changes by human activity ('Heavily Modified Water Bodies', HMWBs). The latter are accepted as having a lower ecological status as a result of the anthropogenic hydromorphological modification, which cannot be reversed even in the long-term, because it would compromise the continuation of the uses for which the water body was altered, with high social and economic costs and adversely affecting the wider environment (CIS, 2003a,b). In the case of HMWBs, the directive allows thus less stringent quality targets, and the GES objective is replaced by the 'Good Ecological Potential' (GEP) as primary environmental goal.

The Ecological Potential concept has revealed challenging in terms of interpretation and practical application (Borja and Elliott, 2007; Hering et al., 2010). Currently, it has been pragmatically defined as the ecological quality expected in the absence of hydromorphological pressures, i.e., the state of the biology if these stressors were removed (Borja and Elliott, 2007; Hering et al.,

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0025-326X/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.marpolbul.2013.03.019

2010; Mazik et al., 2012). In agreement with the previous authors, some of the recognized concerns and difficulties regarding the meaning and definition of the Ecological Potential, include: (i) lack of knowledge on what can be measured in an cost-effective way, without measuring the whole ecosystem in order to create a single measure of ecological status; (ii) the assumption that, the pristine or at least the non-anthropogenically altered condition of the water body is known; (iii) a deeper knowledge on the ecological processes and functioning than that required for GES assessment, since it is necessary not only to compare monitoring data against the reference condition but also, to imagine how system can have appropriate structure and be functional if the pressure is removed, considering the interconnectedness and complicated interactions these can present; (iv) few data were collected along specific hydromorphological pressure gradients and data on the pre-modification condition is usually inexistent; (v) since there are almost no areas without human influence worldwide, some of the HMWBs itself are being used to derive reference conditions and this overlapping makes the distinction between reference conditions and Ecological Potential unclear; and (vi), ecological status assessment has been mostly based on small areas rather than at the water body level as required by the WFD, and the need to account for spatial heterogeneity in the assessment.

Accounting for these concerns, an approach to establish the Ecological Potential has been proposed through determining what would be the changes in the water body biology if the hydromorphological pressures were removed, suggesting that, differences in the measurement of the ecological status with and without the modifications could indicate the potential (Borja and Elliott, 2007; Mazik et al., 2012).

In the present study, three different ecological scenarios were tested using the Mondego estuary (Portugal) as a case study, in an attempt to understand what could be some of the ecological expectations under the Ecological Potential assessment. A preliminary exercise was undertaken in the estuary in order to predict potential changes in the system biology if some hydromorphological pressures could be reversed, assuming that differences in the biology with and without the hydromorphological modification, could indicate the potential. The macrobenthic communities were the WFD biological quality element chosen for illustrating what would the biology be like if the system was placed in its pre-amendment condition, this is, before physical modifications have been carried out. In particular, we addressed the effects on macrobenthic communities' structure and composition of: (A) a primary producer (*Zostera noltei*) loss; (B) intertidal habitat loss; (C) habitat modification due to hydromorphological changes and continued press perturbation. Insights on the HMWB concept and Ecological Potential assessment are discussed.

2. Materials and methods

2.1. Study site

The Mondego estuary is located on the South-Western Atlantic European coast (Portugal; 40°08′N, 8°50′W) (Fig. 1). It is a small mesotidal transitional system (860 ha surface area), separated by an alluvium-formed island into two arms with dissimilar hydrological features, North and South. The North arm is deeper (5–10 m during high tide), has about 21 km long and hosts the Figueira da Foz harbor constituting the main navigation channel. It is highly dynamic, receiving most of the freshwater input from the Mondego River and is thus, strong influenced by seasonal fluctuations in the river water flow. Dredging activities are frequent causing physical disturbance of the bottom and sediment suspension in the water column. Coarse to sandy sediments predominate along the North arm. The South arm is 7 km long and shallower (2–4 m during high tide) with about 75% of its total area covered by intertidal mudflats that are exposed during low tide. Fine sediments and higher sediment organic matter content are preponderant in the inner areas of the South arm (Marques et al., 1993; Teixeira et al., 2008).

The estuary supports several industries, salt-works, agricultural areas, mercantile and fishing harbors that impose a strong anthropogenic pressure on the system. Nutrients constitute one of the main pressures in the estuary. Together with the numerous hydromorphological modifications (in the riverbed topography and hydrodynamics) carried out in the system over the last decades, and that led to the interruption of the upstream communication between the two arms in 1994, it stimulated the eutrophication symptoms observed in the past for the South arm (Martins et al., 2001; Marques et al., 2003, 2007). To reverse the eutrophication effects and to improve the system's overall ecological condition, a management plan was initiated in the late 1990s. A detailed description of the mitigation measures implemented in the estuary can be found in Veríssimo et al. (2012, 2013).

2.2. Ecological scenarios

For testing the different scenarios, data from long-term studies on the Mondego estuary were considered. Scenarios tested were chosen since they represent situations that often occur when a water body is physically altered and becomes a Heavily Modified Water Body.

Changes in macrobenthic communities' structure were evaluated with regard to: (i) the presence versus absence of a primary producer (*Z. noltei*) (Scenario A); (ii) the loss of intertidal habitat (Scenario B); and (iii) habitat modification due to several

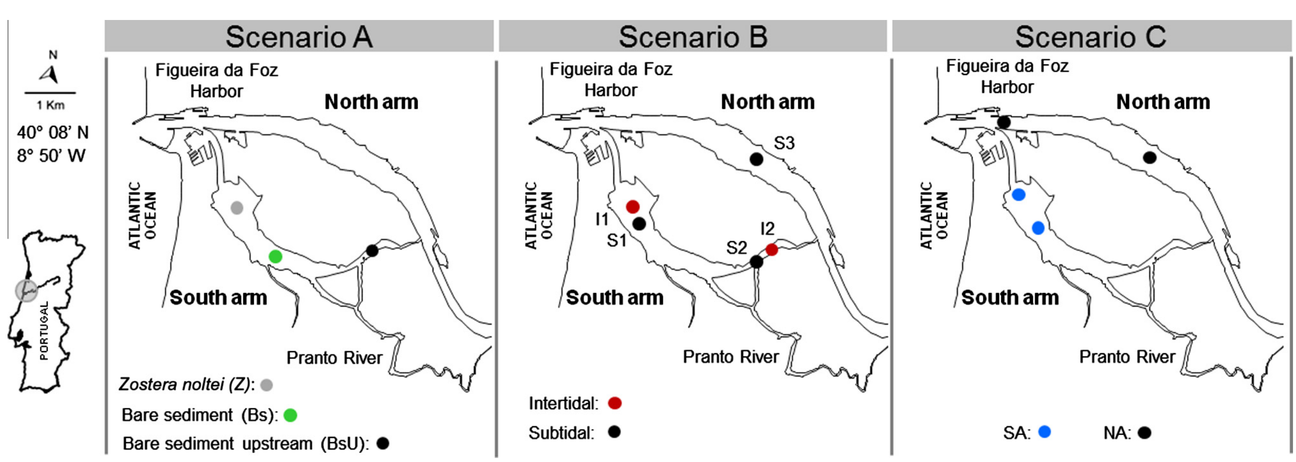

Fig. 1. Mondego estuary. Location of the sampling stations considered in scenarios A, B and C.

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