Marine Pollution Bulletin 61 (2010) 234–239

Contents lists available at ScienceDirect

Marine Pollution Bulletin

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

Ecological quality assessment of the lower Lima Estuary

Sérgia Costa-Dias [a,b,*], Ronaldo Sousa [a,c], Carlos Antunes [a]

[a] *CIMAR/CIIMAR – Centro Interdisciplinar de Investigação Marinha e Ambiental, Universidade do Porto, Rua dos Bragas 289, 4050-123 Porto, Portugal*
[b] *ICBAS – Instituto de Ciências Biomédicas de Abel Salazar, Universidade do Porto, Lg. Prof. Abel Salazar, 2, 4099-003 Porto, Portugal*
[c] *Departamento de Biologia, Universidade do Minho, Campus de Gualtar, 4710-057 Braga, Portugal*

ARTICLE INFO

Keywords:
Lima Estuary
Macrozoobenthos
Anthropogenic impacts
AMBI
M-AMBI
Ecological status

ABSTRACT

Monitoring biotic factors is gaining in importance within Europe, due in large extent to the ecological approach of the European Water Framework Directive (WFD) and the importance attributed to biological elements in the assessment of quality status. Despite its ecological importance, the Lima Estuary is subjected to a range of perturbations, including urban, agricultural and industrial waste discharge, dredging activities, and introduction of non-indigenous invasive species. This work uses macrozoobenthic data to study the ecological status of the lower Lima Estuary where most disturbance factors are concentrated. We were able to verify consistent differences along space, and to identify different degrees of disturbance in the estuarine area. These results allow us to suggest cost-effective approaches to monitor this estuarine area, aiming on contributing to effective management actions.

1. Introduction

Human populations have a long history of exploiting the coastal and estuarine areas for food, transport, commerce and for settlement. At the same time these coastal areas possess very high ecological importance for numerous species. Nevertheless, such ecosystems are subjected to a wide range of anthropogenic pressures which are responsible for considerable environmental impacts (Duffy et al., 2007). Along coastal and estuarine areas, anthropogenic pressures succeed one another and the lack of adequate management actions may be determinant to the loss of ecological richness. The implementation of sensitive tools aiming on providing managers an easy to interpret methodology with a rapid time response to impacts on a system can reveal itself decisive.

Over the past decades water quality has been defined primarily in chemical terms. However, water management agencies and scientific community have been increasingly aware of the need to bring biology back into the water quality equation (Minshall, 1996; Salas et al., 2006). Nowadays, a variety of biological assessment tools is available (Salas et al., 2006), which facilitates possible interpretations and improved our understanding of ecosystem functioning. In this line of thought, the European Union Directive 2000/60/EC (Water Framework Directive – WFD) came into force to prevent the deterioration of the Communities water and to achieve a good ecological status by 2015. Additionally and as a complement to abiotic factors, this new directive emphasizes biotic criteria as monitoring tools, enabling a better assessment of the effects of environmental stressors on biological systems (Adams, 2002; Borja, 2005; Borja et al., 2004). Biotic indices summarize in a single value the complexity of biological communities and their environment, and can be related statistically to a wide range of physical, chemical and biological measures (Pinto et al., 2009).

The lack of research within coastal and transitional waters in relation to the WFD (Borja, 2005), lead to an urgent need to develop and improve adequate methodologies to evaluate environmental and ecological conditions. Biotic indices applicability and usefulness come from the fact that biological communities are the product of their environment and that they include organisms with different habitat preferences and pollution tolerance (Pinto et al., 2009). Macrobenthic invertebrates are considered sensitive indicators of change, integrating water and sediment quality conditions over time (Reiss and Kröncke, 2005). Consequently, many indices and software were developed for those taxa in the last years (e.g. Diaz et al., 2004, and references therein), optimized for usage in different environments. The assessment of several types of estuarine and coastal ecosystems gained with the accessibility to the software AMBI, based on the analysis of the macrozoobenthic assemblages. This index, developed by Borja et al. (2000), was used in order to assess environmental impacts such as harbour and dyke constructions, heavy metals inputs, drill cutting discharges, submarine outfalls, eutrophication processes, diffuse pollution inputs, dredging activities, mud disposal, sand extraction and oil spills (Borja et al., 2000, 2003; Muxika et al., 2005; Salas et al., 2006).

Although questioned by some authors concerning the species classification (Labrune et al., 2006; Salas et al., 2004), the ability

* Corresponding author. Address: CIMAR/CIIMAR – Centro Interdisciplinar de Investigação Marinha e Ambiental, Universidade do Porto, Rua dos Bragas 289, 4050-123 Porto, Portugal. Fax: +351 223 390 608.
E-mail address: sergiacd@ciimar.up.pt (S. Costa-Dias).

0025-326X/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.marpolbul.2010.02.019

of AMBI to efficiently detect physical disturbances (Muxika et al., 2005; Labrune et al., 2006), and its sensitivity to an increase in the organic matter content in the sediment (Pranovi et al., 2007), this index has proven its applicability to estuarine areas in several case studies (Muxika et al., 2005, and references therein; Salas et al., 2006, and references therein). That was also the case of some Portuguese coastal areas (Quintino et al, 2006), estuaries (Chainho et al., 2006; Quintino et al, 2006; Salas et al., 2004, 2006) and a coastal lagoon (Carvalho et al., 2006). Most recently, a new tool became available: a factor analysis multivariate approach, incorporating Shannon-Wiener diversity, richness and AMBI – M-AMBI (Borja et al., 2004; Muxika et al., 2007), enabling the assessment of ecological status. The M-AMBI overcomes many of the critics on the limitations of AMBI, and allows a more direct ecological assessment regarding the WFD.

In the Lima Estuary, a protected and sensitive area subjected to several anthropogenic stressors, studies have been carried out in an attempt to raise our knowledge of the system functioning and condition (Antunes and Dias, 2005; Sousa, 2003; Sousa et al., 2006a,b, 2007). Nevertheless, the next step – management, is generally undertaken by persons less familiarized with the hard scientific language and its means of dissemination. The same may be assumed for the local populations, an important partner in any management action. Therefore, one should look for a single tool able to integrate different types of information, evaluate the impact of physical, chemical and biological stressors, both spatially and temporally (Adams, 2002), and merge the ecological information in such a way that the output would be easily interpreted.

The purpose of this study was not to simply classify Lima Estuary according to the WFD, but to test if an index such as AMBI would detect the variation in the benthic community described in some recent works. Furthermore, authors wanted to compare if differences in classification (and ranking) attributed by the index would be in agreement with their previous evaluation of the sites. If so, that index would be responding to changes in a sensitive way since sources of impact vary within the studied area and all sites are within the estuary downstream 6 km.

2. Study area

2.1. Lima Estuary characterization

The river Lima basin, located between 41° 35′ N and 41° 15′ N of latitude, and 07° 35′ W and 08° 55′ W of longitude, comprises a total area of 2480 km^2, with 1303 km^2 in Spain (53 %) and 1,177 km^2 in Portugal (47 %). This river has an extent of 108 km (67 km in Portuguese territory) draining into the Atlantic Ocean, and has an annual freshwater discharge of 54 m^3 s^{-1} (Alves, 1996).

The Lima Estuary, located in the NW of Portugal (Fig. 1), extends approximately for 20 km and comprises a total estuarine area of

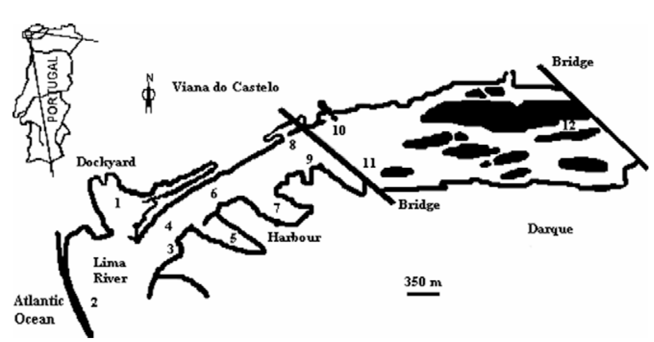

Fig. 1. Map of the Lima Estuary showing the 12 sampling sites. Black areas represent salt marsh islands.

approximately 6 km^2. It is a mesotidal estuary, with a mean tidal range of 2 m, and partially mixed, evolving towards a salt wedge estuary during flood events (Sousa et al., 2006b). The mean residence time in the estuarine area is of 1 day, which is in part responsible for a high capacity to dilute and flush nutrients.

Besides protected areas along Lima basin, the estuarine ecosystem comprises important and sensitive areas (e.g. salt marsh, sand flats and mud flats), valuable for species and habitats conservation. The Lima mouth is a CORINE biotope, mainly due to peat-bog coverage, and the coastal area integrates another CORINE biotope (IA, 2002). It is important to note the occurrence of economically and/or conservational valuable fish species such as flounder (*Platichthys flesus*), sole (*Solea solea*), brill (*Scophthalmus rhombus*), sea bass (*Dicentrarchus labrax*), sea lamprey (*Petromyzon marinus*), European eel (*Anguilla anguilla*), allis shad (*Alosa alosa*), twaite shad (*Alosa fallax*) and Atlantic salmon (*Salmo salar*) (Antunes and Dias, 2005; Sousa, 2003). Several important conservational species of birds such as *Platea leucorodia*, and mammals such as *Lutra lutra* also inhabit this estuary (Sousa, 2003).

2.2. Anthropogenic pressures

Despite its ecological relevance, the lower estuarine area has been subjected to several anthropogenic impacts in the last years. The Lima mouth has its right margin modified by a city, Viana do Castelo (Fig. 1), with 46,000 inhabitants and the predictable existence of domestic waste discharges. Additionally, the Lima Estuary is the recipient for diffuse pollution originated from agriculture, adding persistent organic pollutants to the estuarine water, and for industrial waste discharge. Input of nutrients into the system may increase the eutrophication processes in the lower part of the estuary (Sousa, 2003).

Also at the mouth of the river, there is an important harbour, leading to continuous petrochemical contamination through the activity of commercial and fishing vessels (Lima et al., 2007). In 2000 the *Coral Bulker* oil spill severely affected that area (Moreira et al., 2004), and in 2001 a chemical enrichment was verified in the harbour and adjacent areas (Santos and Gonçalves, unpublished data). Additionally, the existence of a marina within the estuary implies the hypothetical disturbance by boat navigation and the introduction of fuel and paint residuals into the estuarine system.

In the most downstream part of the Lima Estuary, a 3 km navigational channel is maintained by regular dredging activities. These dredging activities are responsible for the continuous disruption of the biological communities that otherwise would evolve in the navigation channel and in the sand washing areas (Sousa et al., 2007). Such interventions might also be responsible for changes in the sediments composition (enrichment of fine sediments with high organic matter content) and presumably for hydrological changes.

In the last years that area was also subjected to the introduction of non-indigenous invasive species (NIS) which are responsible for ecological and economic impacts (details in Sousa et al. (2006a,b)).

3. Material and methods

3.1. Data set

Data from Sousa et al. (2007) were considered suitable for the purpose of the present analysis. In that study samples were collected seasonally between autumn 2001 and summer of 2002 at high tide, as part of a sampling program in order to characterize the macrozoobenthic biological structure and its relation with abiotic factors. Twelve subtidal sites representing different abiotic