ARTICLE IN PRESS

Marine Pollution Bulletin xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Marine Pollution Bulletin

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

Long-term functional changes in an estuarine fish assemblage

J. Baptista [a,*], F. Martinho [a], D. Nyitrai [a], M.A. Pardal [a], M. Dolbeth [a,b,*]

[a] CFE – Centre for Functional Ecology, Department of Life Sciences, University of Coimbra, Calçada Martim de Freitas, 3000-456 Coimbra, Portugal
[b] Biology Department & CESAM, University of Aveiro, Campus de Santiago, 3810-193 Aveiro, Portugal

ARTICLE INFO

Article history:
Received 27 December 2014
Revised 9 June 2015
Accepted 11 June 2015
Available online xxxx

Keywords:
Fish assemblages
Estuaries
Traits
Hydrology
Climate change

ABSTRACT

The functional diversity of the fish assemblages of the Mondego estuary was studied for a discontinuous 30-year period (1988–2012). During this time, hydrological changes occurred due to man-induced alterations and weather extremes. These changes led to alterations in the structure and function of the fish community. Species richness and functional richness decreased over time and the fish community started to explore new micro-habitats and food resources. Before severe hydrological changes, the community was dominated by pelagic, detritivorous and species with wider salinity ranges. After, the community became dominated by demersal, benthic, piscivorous and marine species. During a drought, omnivorous became increasingly important, reflecting greater possibilities of using available feeding resources. We have also found an increase in sub-tropical species throughout the years, which might be related to gradual temperature increases at a global scale. This study also confirmed estuaries as extremely important for restocking several commercial species.

1. Introduction

A major breakthrough in community ecology studies has been the incorporation of functional approaches and functional diversity measures, as an elucidating tool to explore species coexistence and impacts on ecosystem functioning (Mouillot et al., 2007, 2013; Boucek and Rehage, 2014). Functional diversity refers to the functional component of biodiversity and is usually measured by species traits (Violle et al., 2007). A trait is a biological attribute, measurable at the individual level that influences the organism performance, determining the species effect on the ecosystem (i.e. effect trait) or influencing the species fitness in the environment (i.e. response trait) (Violle et al., 2007). The theory behind functional diversity may be applied to several trophic groups, and has the advantage to enable comparisons between systems that do not share similar taxonomical composition, and in an ecosystem functioning approach.

For fish assemblages, functional approaches have been used for some decades in several studies identifying species' functional guilds (e.g. species ecological, feeding guilds, Elliott and Dewailly, 1995; Elliott et al., 2007) and more recently, as part of multi-metric indices to evaluate the ecological condition of an water body, within the application of EU directives (e.g. Martinho et al., 2008; Cabral et al., 2012), and international policies, such has the Oceans policy (Australia), the Oceans Act and the Clean Water Act (Canada and USA) or the National Water Act (South Africa) (see Borja et al., 2010). However, a functional characterization of the community based on fish traits, such as the ones related to fish morphology as great potential to explore impacts of environmental disturbance in the ecosystem is high, and should be encouraged (Dumay et al., 2004; Goldstein and Meador, 2014; Mouillot et al., 2007; Villéger et al., 2010, 2012).

In the present study, we explore the functional diversity of fish assemblages from an estuary that has been subjected to several disturbances related to human interference and climate change. Estuarine systems are important habitats for several fish, including several commercial marine and freshwater species that use them as a part of their lifecycle, by providing sheltered areas, plenty food availability, migratory routes and nursery grounds (Elliott and Hemingway, 2002; Elliott et al., 2007). The high productivity associated to these systems has attracted an important share of human population, which lives close to these coastal areas, benefiting from their ecosystem services, including fish production (Dolbeth et al., 2010). The major downside is that estuarine systems are particularly vulnerable to anthropogenic disturbance, which might be accentuated by the occurrence of weather extremes (Elsdon et al., 2009; Dolbeth et al., 2011; Vivier et al., 2010).

Among major sources of anthropogenic disturbance with impact on the hydro-morphology of estuaries is river

* Corresponding authors at: CFE – Centre for Functional Ecology, Department of Life Sciences, University of Coimbra, Calçada Martim de Freitas, 3000-456 Coimbra, Portugal.
E-mail addresses: jbaptista@uc.pt (J. Baptista), mdolbeth@ci.uc.pt (M. Dolbeth).

http://dx.doi.org/10.1016/j.marpolbul.2015.06.025
0025-326X/© 2015 Elsevier Ltd. All rights reserved.

regularization, margins embankment and dams (Vasconcelos et al., 2007; Neto et al., 2010; Nicolas et al., 2007), which might cause several changes in the fish communities (Costa et al., 2007). Climate change and the occurrence of extreme weather events, which are expected to increase in a nearby future (IPPC report, 2013), may accentuate these changes in the hydrology. As a consequence, estuarine fish assemblages composition and functioning are expected to change (Baptista et al., 2010; Dolbeth et al., 2010; Vivier et al., 2010), as a result of habitat degradation, loss of niches or by facilitated establishment of alien species, which compete for resources (Chessman, 2013).

In this study, we use traits to understand the processes structuring estuarine fish assemblages, taking into account three critical periods over a 30-year study, when several hydrological changes occurred, due to hydromorphological reconfiguration of the riverbanks and occurrence of weather extremes. We were interested in understanding how the functional organization of the fish assemblage was affected by these hydrological changes, which are representative of changes occurring in most estuarine systems worldwide. For this task, we evaluate variations in the fish assemblage functional composition over a discontinuous 30-year period. Our hypothesis is that the observed hydrological changes affected fish community structure, composition and overall functioning, including its commercial importance.

2. Materials and methods

2.1. Study site

The Mondego estuary (Fig. 1) is a small estuary (8.6 km^2) located in the western coast of Portugal (40°08′N, 8°50′W), with an average freshwater flow rate of 79 $m^3\,s^{-1}$ (Dolbeth et al., 2010). The estuary comprises two arms, the north and the south, separated at 7 km from the shore that join again near the mouth. The two arms have distinct hydrological characteristics: the north arm is deeper with 5–10 m at high tide and 2–3 m tidal range. The north arm is dredged frequently to maintain its depth, since it is the main navigation channel, leading to physical disturbances of the bottom. The south arm is shallower with 2–4 m depth at high tide and 1–3 m tidal range. The south arm has nearly 75% of intertidal mudflats, and the downstream areas contain several seagrass meadows. The mouth of the estuary depth ranges from 8 to 13 m, and this area is influenced by both river flow and neritic waters.

The Mondego estuary has undergone several anthropogenic pressures and hydromorphological transformations over the last decades (Neto et al., 2010; Veríssimo et al., 2013). From 1993 to 1997, the connection between the two arms was silted up, and the water circulating in the south arm was mainly dependent on tides and freshwater inputs from a small river, the Pranto River. The occlusion between the two arms resulted in an increase in water residence time and nutrients concentration, promoting macroalgae blooms and decrease of the seagrass coverage. During this time, the estuary showed symptoms of eutrophication, leading to a progressive decline in its environmental quality (Cardoso et al., 2010; Dolbeth et al., 2011). In 1998, a restoration plan was initiated to improve the ecological condition of the system, which consisted on the implementation of mitigation measures to decrease eutrophication and improve water circulation in the estuary (for more details see Lillebø et al., 2005; Neto et al., 2010; Dolbeth et al., 2011). In 2006, a second large-scale intervention was performed, consisting on the re-opening of the separation between the two arms, increasing the flow and reducing water residence time in the south arm (Veríssimo et al., 2013). In addition, extreme climatic events have also been observed, including floods in 2000–2001 and droughts in 2004–2005 (e.g. Baptista et al., 2010; Martinho et al., 2007; Primo et al., 2011).

2.2. Fish sampling and laboratory work

The fish assemblage of the Mondego estuary has been the subject of a long-term monitoring programme, from 1988 to 1992 and then from 2003 until the present (e.g. Jorge et al., 2002; Leitão et al., 2007; Nyitrai et al., 2012). For this study, we considered three critical periods with distinct hydro-climatic features: the first period, including 1988, 1991 and 1992; the second period, from 2004 to 2006; and the third one from 2010 to 2012.

In 1988/1992 fishing was performed using a beach seine net (7 m sac and 8 mm stretched mesh size in the cod end). Fishing occurred monthly, during the day at low water of spring tides, in

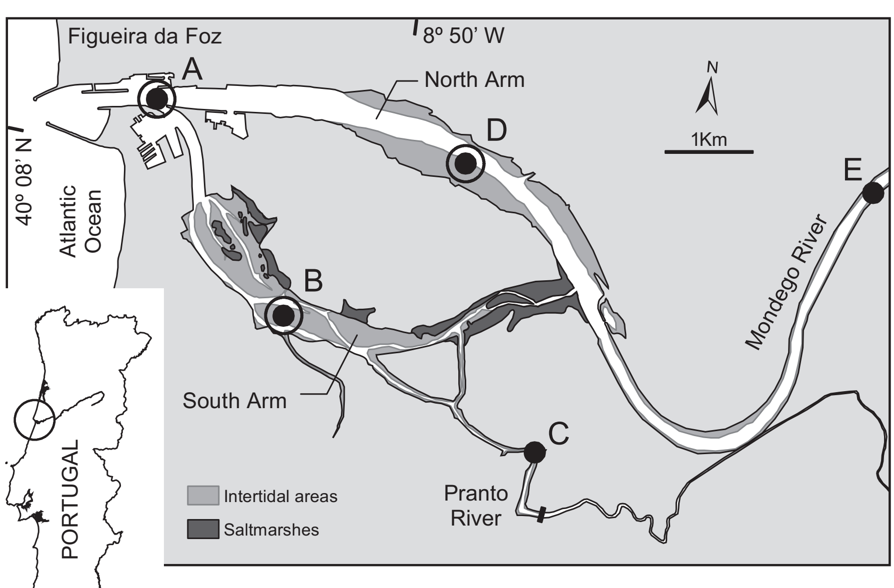

Fig. 1. The Mondego estuary, with the location of the sampling stations.