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Influence of sampling effort on metrics of fish-based indices for the assessment of estuarine ecological quality

Rita Gamito[a,*], Stéphanie Pasquaud[a], Anne Courrat[b], Hilaire Drouineau[b], Vanessa F. Fonseca[a], Catarina I. Gonçalves[a], Noémie Wouters[a], José L. Costa[a], Mario Lepage[b], Maria J. Costa[a], Henrique N. Cabral[a]

[a] Universidade de Lisboa, Faculdade de Ciências, Centro de Oceanografia, 1749-016 Lisboa, Portugal
[b] Unité Ecosystèmes Estuariens et Poissons Migrateurs Amphihalins, IRSTEA Groupement de Bordeaux, 50 avenue de Verdun, 33 612 Cestas, France

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ABSTRACT

Multimetric fish-based indices have been increasingly gaining importance in Europe, as the Water Framework Directive (WFD) requires fish fauna, and particularly its composition and abundance, to be taken into account in the assessment of the ecological quality of continental surface waters, including transitional waters. These indices are composed of several metrics, mostly related with structural and functional characteristics of fish communities, such as species richness, the role of nursery areas, or trophic web structure. Therefore, ecological quality assessments should ensure that these structural and functional characteristics of fish communities were covered by the sampling methods used. In the present work, the influence of sampling effort on several metrics of the Estuarine Fish Assessment Index (EFAI) was studied. Pseudo-random samples were generated from data of four Portuguese estuaries and bootstrap cycles were performed, in order to obtain metrics' means and standard deviations per number of hauls analysed. The number of hauls necessary for the means to level off differed with the metrics considered. Generally, for metrics on percentages (percentage of marine migrants, percentage of estuarine residents and percentage of piscivores) the curve levelled off with less than 20 hauls, both for the estuary as a whole and for different estuarine salinity zones. On the other hand, metrics on species richness required much larger samples. In order to decrease to −5% the current estimated bias of metrics, the WFD sampling costs would have to be more than 3 times higher than they currently are. The findings in the present study are of great importance for an effective assessment of estuarine ecological quality and particularly in the context of the WFD, as the metrics studied are common to other Member State indices.

1. Introduction

Estuarine ecosystems support a wide array of fauna, from resident to freshwater and marine species, and are particularly important for fish fauna by providing permanent habitats, habitats for reproduction, nursery grounds, refuge from predators and migration routes (Cabral et al., 2007; Elliott et al., 2007). Estuaries are highly variable ecosystems, influenced by fluctuating marine and freshwater flows, and at the same time they are exposed to high anthropogenic pressures (Elliott and Quintino, 2007).

The European Water Framework Directive (WFD), established for the protection of inland surface waters, transitional waters, coastal waters and groundwater (WFD, 2000/60/EC), demands that Member States: (a) protect, enhance and restore all bodies of surface water in order to achieve good ecological status by 2015 and (b) ensure the establishment of programmes for the monitoring of water status. Therefore, Member States must assess the ecological quality status of water bodies, taking into account biological, hydro-morphological, chemical and physico-chemical elements and specific pollutants. In the case of estuaries, five biological quality elements are considered for this assessment: phytoplankton, macroalgae, angiosperms, benthic invertebrate fauna and fish fauna.

Environmental indicators are measures which allow for changes in an ecosystem to be monitored and for complex information about the environment to be summarized without having to capture the full complexity of the ecosystem (Whitfield and Elliott, 2002). Fish fauna has been used as an indicator of water ecological quality, namely through the development of fish-based multimetric indices over the past few decades (Karr, 1981; Deegan et al., 1997; Harrison and Whitfield, 2004). The advantages of fish as environmental indicators, outlined by several authors, rely on key aspects of their biology and ecology, namely their wide dispersion in aquatic environments, diversity of functional guilds, major

* Corresponding author. Tel.: +351 217 500 826; fax: +351 217 500 207.
E-mail address: rgamito@fc.ul.pt (R. Gamito).

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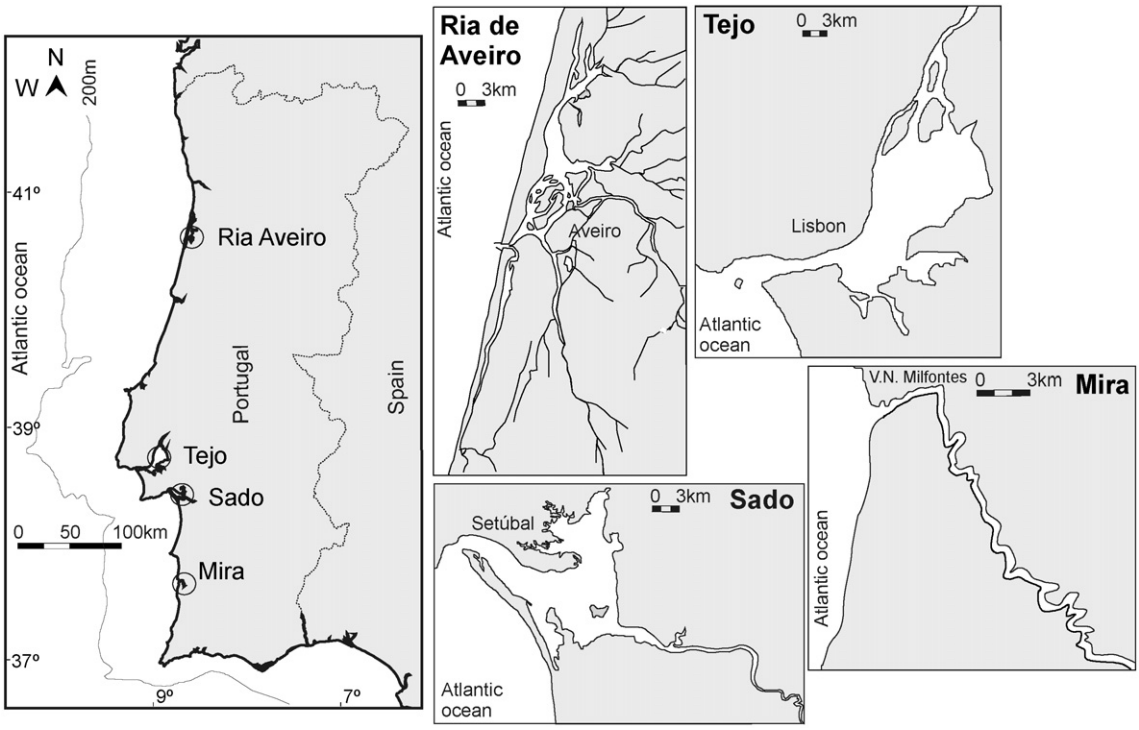

Fig. 1. Location of the Ria de Aveiro, Tejo, Sado and Mira estuaries, along the Portuguese coast.

ecological role in food webs, relatively long life-span accounting for long-term effects, and their value for mankind, particularly as a food resource (e.g. Karr, 1981; Whitfield and Elliott, 2002; Harrison and Whitfield, 2004). However, some disadvantages of this biological quality element should also be considered, such as their high mobility, their high tolerance to contaminants and physical degradation of habitats, the selective nature of the sampling gears and the large sampling effort often required to adequately characterise fish assemblages (Karr, 1981; Whitfield and Elliott, 2002; Harrison and Whitfield, 2004). Nevertheless, many of these disadvantages, which also apply to other taxonomic groups, namely benthic invertebrates (Karr et al., 1986; Whitfield and Elliott, 2002), are out-weighed by the advantages (Harrison and Whitfield, 2004).

As the WFD requires fish fauna, particularly its composition and abundance, to be considered in the assessment of the ecological quality of transitional waters, the use of fish-based indices has recently been increasing in importance in Europe (e.g. Borja et al., 2004; Coates et al., 2007; Breine et al., 2010; Brind'Amour and Lobry, 2010; Delpech et al., 2010; Cabral et al., 2012). Most of these indices included metrics on different aspects of the structure and functioning of fish assemblages, namely species richness and functional guilds. The efficiency of the assessment tools relies on the sampling techniques and effort used in monitoring plans, which differ among Member States. Birk et al. (2012) advocated a better reflection on the necessary sampling effort and precision of the ecological quality assessment of European waters. In fact, the structure and composition of fish samples can be affected by the sampling gear (Gray et al., 2005; Johnson et al., 2008; Pasquaud et al., 2012) and by the sampling effort (Blocksom et al., 2009), having effects on the functional characterization of the fish community and, subsequently, on the fish-based assessment of the ecological quality of the ecosystem.

Given the importance of understanding the impacts of the sampling protocol in the assessment of an ecosystem's ecological quality and the particular lack of studies on the effect of the sampling effort, the objective of the present work was to study the influence of sampling effort on the metrics of the Estuarine Fish Assessment Index (EFAI) (Cabral et al., 2012).

2. Materials and methods

2.1. Study area

Four estuaries from the Atlantic Portuguese coast were considered in the present study: Ria de Aveiro, Tejo, Sado and Mira (Fig. 1). Concerning geomorphology and hydrology, these estuarine systems are considerably different (Table 1). The Tejo and the Sado are the largest and widest estuaries studied, whereas the channel-like Mira is the smallest. Ria de Aveiro is a shallow coastal lagoon system with large intertidal areas. River flow is highest in the Tejo, presenting a mean value of 300 $m^3 s^{-1}$, and lowest in the Mira estuary, with a mean value of 3 $m^3 s^{-1}$. Mean river flow for both Ria de Aveiro and the Sado estuary is 40 $m^3 s^{-1}$.

2.2. Sampling procedures

Fish densities used in the present work were obtained in the months of May and July of 2005 and 2006. Sampling took place during the night, at ebb-tide, using a 2 m wide beam-trawl, with one tickler chain and a stretched mesh size of 5 mm at the cod end. Hauls were performed at a constant speed, for 10 min, sweeping an average area of 862 m^2. All fish caught were identified and counted and fish density was expressed as number of individuals per 1000 m^2. Data were available for the oligohaline (salinity lower than 5), mesohaline (salinity values between 5 and 18) and polyhaline (salinity higher than 18) zones of the Tejo and Mira estuaries and for the mesohaline and polyhaline areas of Ria de Aveiro and Sado estuaries.