Marine Pollution Bulletin xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Marine Pollution Bulletin

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

Can we assess the ecological status of estuaries based on larval fish assemblages?

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ARTICLE INFO

Keywords:
Fish larvae
Human pressures
Ecological quality assessment
Estuaries
Brazil

ABSTRACT

Fish larvae of four SE Brazilian estuaries were investigated to assess if the larval fish assemblages reflect the ecological status of estuaries. All samples were collected in the same water mass to guarantee similar natural water parameters, assuring that major differences among estuaries were related to anthropogenic pressures. Water temperature, oxygen, pH, chlorophyll *a*, faecal coliforms, nutrient load and total particulate matter were obtained at each sampling area. A pressure index was used to assess the overall anthropogenic pressures acting in each estuary. Results showed that fish larvae were sensitive to water contamination, reducing the diversity and especially exhibiting a high dominance of few species. Furthermore, this study reinforced the idea that the high sensitivity of fish larvae can increase the accuracy of the environmental assessments when tackling short-time events of hydrological controls (physical barriers and control of the freshwater input), representing an advance in the water ecological quality assessments.

1. Introduction

Estuaries are essential fish habitats, compiling several functions such as nursery grounds, migration routes and refuge areas for a variety of fish species (Cattrijsse and Hampel, 2006). Nevertheless, numerous anthropogenic perturbations affect estuarine environments (Elliott and Whitfield, 2011), contributing to habitat alteration and changes in the structure and dynamics of biotic communities (Kennish, 2002), compromising the long-term ecological function of these ecotones (e.g. Whitfield and Elliott, 2002; Gilliers et al., 2006; Coates et al., 2007; Le Pape et al., 2007). In response to the increasing degradation of marine ecosystems observed worldwide (Halpern et al., 2007, 2008), several studies have assessed the ecological status of aquatic ecosystems and the impacts of anthropogenic activities (e.g. Borja et al., 2013; Ruaro and Gubiani, 2013; Martinez-Haro et al., 2015), in order to trace effective management plans and mitigation actions in these ecosystems.

In estuarine environments, several groups of organisms have been used as quality indicators of ecosystem health, mainly macroinvertebrates and fishes (e.g. Harrison et al., 2000; USEPA, 2000; Alvarez et al., 2013; Nebra et al., 2014; Alves et al., 2015). Ecological indicators based on fish communities have been recognized as useful tools to assess anthropogenic impacts affecting estuarine fish communities (Whitfield and Elliott, 2002; Harrison and Whitfield, 2006; Borja and Dauer, 2008; Fonseca et al., 2013). Typically, a fish community facing increased anthropogenic induced stress tends to show a decreased of number and abundance of species with high habitat and environmental specificities, i.e. sensitive and low tolerance fish species, while generalist species tend to increased dominance, resulting in a simplified community structure (e.g. Odum, 1983; Karr and Chu, 1999; Fonseca et al., 2013). Nevertheless, the use of fishes as indicators of environmental quality can also have limitations because of their high mobility, temporal variability (seasonality) and specific sampling requirements (Whitfield and Elliott, 2002; Harrison and Whitfield, 2004).

Given these limitations, early larval stages of fishes can be considered good indicators of ecosystem integrity, since they have reduced sampling costs and sampling bias, low mobility (planktonic phase) and sensitivity to reflect anthropogenic pressures acting on a water body (Ramos et al., 2015). Indeed, fish larvae show a high vulnerability to environmental changes (Ramos et al., 2006a; Eick and Thiel, 2014; Strydom, 2015; Santos et al., 2017), highlighting their importance as pollution indicators (Longwell et al., 1992; Gordina et al., 2001; Westernhagen et al., 2001). Ramos et al. (2012) demonstrated that estuaries with different levels of anthropogenic pressures exhibit

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http://dx.doi.org/10.1016/j.marpolbul.2017.07.043
Received 1 February 2017; Received in revised form 3 July 2017; Accepted 17 July 2017

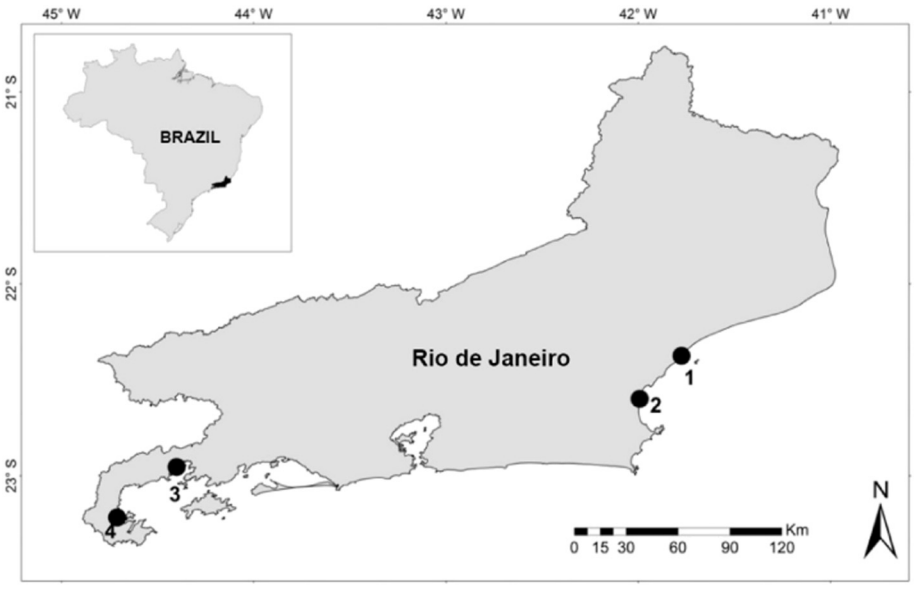

Fig. 1. Location of the four estuaries of the study. (1) Macaé, (2) São João, (3) Bracuí and (4) Perequê-Açu, in Rio de Janeiro State, SE Brazil.

distinct larval fish assemblages, and also emphasized the potential role of larval stages of fishes as indicators of hydrological pressures that are difficult to measure (Ramos et al., 2015). Moreover, the use of fish larvae to assess ecological conditions of estuaries integrates valuable information about spawning and nurseries areas, and about connectivity pathways between marine/riverine habitats.

Estuarine fish larvae assemblages continually vary in time and space, according to reproductive seasons of the species and due to environmental fluctuations (Barletta-Bergan et al., 2002; Ramos et al., 2006a; Montoya-Maya and Strydom, 2009; Strydom, 2015). Consequently, the environmental conditions may interfere with ecological quality assessment when fish larvae are used as quality indicators, as well as temporal variability patterns associated with natural fluctuations of species-specific reproductive seasons, considered as a major driver of the estuarine larval fish assemblages (Rakocinski et al., 1996). The Estuarine Quality Paradox (Elliott and Quintino, 2007), which suggests that anthropogenic stress is difficult to detect in estuaries because their existing communities also show the natural variability, has been reflected in many studies of ecological quality assessments (e.g. Courrat et al., 2009; Dauvin and Ruellet, 2009; Ramos et al., 2015; Tweedley et al., 2015). This is a particular problem in estuaries since their natural environmental conditions vary both spatially and temporally (Sheaves, 2016). Thus, the constancy of environmental characteristics is fundamental to the spatial comparisons of the category and level of anthropogenic pressures, by removing the potentially confounding effects of natural variability on fish assemblages (Elliott and Quintino, 2007). In this context, we tested the hypothesis that estuaries with similar environmental characteristics, but distinct anthropogenic pressures, carry distinctly different larval fish assemblages, by investigating the larval fish assemblages of four similar tropical estuaries with different types and levels of human pressures.

2. Material and methods

2.1. Methodological approach

To test the hypothesis that estuaries with similar environmental characteristics suffering from specific anthropogenic pressures comprise distinct larval fish assemblages, we selected four estuaries located in the same biogeographic area of SE Brazil, in order to remove assemblage differences due to geographic location of the estuaries. In addition, all samples were collected in the same water mass (salinity 15–25) to guarantee similar natural water parameters allowing inter-estuarine comparisons. Considering that estuarine larval fish assemblages are highly seasonal (Ramos et al., 2006b; Arévalo-Frías and Mendoza-Carranza, 2015; Strydom, 2015), we analyzed rainy/dry seasons separately, ensuring that possible assemblages differences were not related to seasonal influences. Hence, we restricted inter-estuarine variability in terms of natural environmental conditions, assuring that major differences among estuaries were related to type and level of anthropogenic pressures. The anthropogenic pressures acting in the estuaries were assessed based on contamination indicators, as nutrient load (nitrate, nitrite, ammonia and phosphate) and sewage contamination determined by microbial faecal coliforms contamination. Also, a pressure index was calculated for each estuary based on human activities and hydro-morphological pressures.

2.2. Estuarine models

Four estuaries of SE Brazil, Macaé, São João, Bracuí and Perequê-Açu were investigated (Fig. 1). Macaé (22° 22′ S and 41° 46′ W) and São João (22° 35′ S and 41° 59′ W) are larger systems directly connected to the ocean with 130 km and 120 km in length, respectively; and total area of 1765 km^2 and 2160 km^2, respectively. Bracuí (22° 57′ S and 44° 23′ W) and Perequê-Açu (23° 13′ S and 44° 42′ W) are smaller systems with 32 km in length and a total area of 190 km^2, and 22 km and area of 110 km^2, respectively; connected to a coastal bay (Ilha Grande Bay). The four estuaries are shallow (mean depth of 2–4 m), channel type, microtidal and partially mixed, with semidiurnal regime.

The levels of anthropogenic pressures vary among the estuaries. In Macaé and Perequê-Açu estuaries, the unplanned urbanization process promoted the removal of mangroves in the estuarine region and discharge large loads of organic matter and other compounds of human waste without treatment directly into the water (INEA, 2014, 2015). Both estuaries are used for navigation, mainly tour boats in Perequê-Açu Estuary, which relies on constant dredging to improve navigability. Macaé Estuary is used as navigation route for support vessels to oil and gas drilling platforms. The freshwater input of Macaé River is highly controlled by water abstraction for human consumption, industrial use and to cool the power-producing equipment in thermoelectric plants (INEA, 2014). Additionally, there are several dams, agricultural activities and commercial sand extraction along the Macaé River. São João Estuary still holds mangrove areas in the middle and lower sections, although there are agricultural and fishing activities that might represent a potential pressure. Also, the main river is obstructed by a dam, which controls the river flow reaching the São João Estuary.