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Inter-annual changes in fish communities of a tropical bay in southeastern Brazil: What can be inferred from anthropogenic activities?

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ABSTRACT

We assessed inter-annual changes in fish assemblages of a tropical bay which experienced a heavily industrialized process in the last decades. A highly significant difference in community structure among the bay zones, and a decrease in fish richness and abundance over time were found. Changes in fish richness and abundance between the two first (1987–1988 and 1993–1995) and the two latter time periods (1998–2001 and 2012–2013) were sharpest in the inner bay zone, the most impacted bay area, and in the middle zone, whereas the outer zone remained comparatively stable over time. These changes coincided with increased metal pollution (mainly, Zn and Cd) in the bay and with the enlargement of the Sepetiba Port. Spatial changes in the fish community structure among the bay zones were related to differences in salinity, transparency and depth with this latter variable acting as a buffer stabilizing temporal community changes.

1. Introduction

Shallow inshore areas such as bays and other semi-closed systems are highly productive and capable of sustaining great diversity and densities of organisms (Nagelkerken et al., 2001; Ray, 2005; Vasconcelos et al., 2011). A plentiful supply of food resources and high habitat availability turn these estuarine ecosystems into a focal point around which many coastal fish communities develop and grow (Martínez et al., 2007; Barbier et al., 2011). However, these aquatic ecosystems are also among the most extensively modified and threatened by human activities (Kennish, 2002; Ribeiro et al., 2008; Defeo et al., 2009; Van der Veer et al., 2015).

Anthropogenic activities in coastal areas have changed fish community distribution patterns, decreasing richness and abundance across various spatial and temporal scales (Sax and Gaines, 2003; Johnston and Roberts, 2009). Often, such changes are linked to overfishing (Ecoutin et al., 2010; Last et al., 2011; Staglicic et al., 2011), pollution (Hewitt et al., 2008; Johnston and Roberts, 2009) and habitat degradation (Kennish, 2002; Pihl et al., 2006; Hewitt et al., 2008; Defeo et al., 2009; Sobocinski et al., 2013). There is a need to understand long-term changes in fish communities, and what management measures should be implemented to protect fish biodiversity. In this sense, studies on fish distribution and community structure are fundamental for detecting changes in the ichthyofauna and crucial for understanding the dynamics and functioning of the system to help managers in policies of natural resource conservation.

Estuarine areas are naturally dynamic ecosystems exposed to numerous human pressures, making it difficult to distinguish between natural and anthropogenic-induced changes to the biological community (Macpherson, 2002; Elliott and Quintino, 2007; Basset et al., 2013). These areas have long been regarded as environmentally naturally stressed because of the high degree of variability in their physico-chemical characteristics. Accordingly, the biota is adapted to such changes, being naturally stress tolerant and hence resilient to change (Elliott and Quintino, 2007; McLusky and Elliott, 2007).

Sepetiba Bay is a sedimentary embayment in the southeastern Brazilian coast that supports a rich and diversified fish fauna, and is used as rearing grounds for several coastal fish species, harboring mangroves, mudflats, sandy beaches and rocky shore habitats (Araújo et al., 2002; Azevedo et al., 2007). The bay has been subjected to intense environmental pressure, because of overfishing (Freitas and Rodrigues, 2014), eutrophication (Amado-Filho et al., 1999; Magalhães et al., 2003), building construction (Molisani et al., 2004; Cunha et al., 2006) and pollution (Lacerda and Molisani, 2006; Fonseca et al., 2013), resulting in general environmental degradation (Lacerda et al., 1987; Molisani et al., 2006). The most recent human interferences in the bay were the enlargement of the Sepetiba Port, including dredging of the access channel to 20 m depth, and the construction of a large steel factory in 2010 and a terminal for building submarines in 2013 (Araújo et al., 2016). Such activities contribute to shoreline degradation, impoverishing of natural habitats, and increasing pollutants loads into the bay (Carneiro et al., 2013; Ribeiro et al., 2013; Pereira et al., 2015).

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Studies that evaluate long-term changes in fish communities associated with anthropogenic activities are uncommon in developing countries. The lack of robust and consistent environmental quality monitoring programs impairs direct association between fish and environmental data. Therefore, it is necessary to adjust and to relate the available information on fish occurrence with historical available data on environmental quality to uncover probable environmental-biotic relationships.

The aim of this study was to assess the fish community in three bay zones (inner, middle and outer) of the Sepetiba Bay over four time periods encompassing three decades, and to evaluate changes in community structure and in the abundance of selected species over time. This long-term series of fish data for the Sepetiba Bay used in the present study offers an unusual opportunity to study the effects of environmental changes and anthropogenic influences on a tropical fish community. It was our hypothesis that decreases in habitat quality and increases in anthropogenic stress would negatively impact the fish community composition, species richness and abundance of individual species. We expect that (1) the fish community structure changed over the three decades (1987–1988, 1993–1995, 1998–2001, and 2012–13); that (2) the fish richness and abundance decreased over time; and that (3) changes in the assemblage structure differed among the three bay zones associated to different environmental conditions.

2. Materials and methods

2.1. Study area

Sepetiba Bay (22°54′–23°04′ S; 43°34′–44°10′ W) has a wide opening to the sea and was originated by extensive sand deposition, which formed a barrier beach as its southern boundary (Fig. 1). The bay has a surface area of approximately 450 km^2, a mean depth of 8.6 m, a maximum depth of 30 m, and a drainage area of 2700 km^2. This microtidal system has a tidal range of approximately 1 m. Water circulation in the bay generally follows a clockwise direction (Cunha et al., 2006), with seawater going inside the bay through the west side, mixing with freshwater inputs of small rivers in the northern part of the bay, then moving across the southbound, and going outside the bay through the southwestern bound. Predominant northeasterly and southwesterly winds activate thermal currents between the bay and the ocean. The annual rainfall in the area varies between 1000 mm and 2100 mm (Clarke et al., 2004).

The bay can be divided into three zones (inner, middle and outer), according to environmental conditions and human influences (Araújo et al., 2002; Azevedo et al., 2006). These zones are geographically continuous and reflect hydrology and sedimentology. The inner zone is influenced by discharges of perennial small rivers, that contribute to increased turbidity and temperature and decreased salinity; the substratum is mainly muddy, with depths that are mostly <5 m, and an average salinity of 28. This zone is the most altered because of the industrial development nearby (Leal Neto et al., 2006). The outer zone, located near the sea, has comparatively lesser influence of anthropogenic activities and exhibits contrasting environmental conditions: the substratum is predominantly sandy, water temperature is comparatively lower and salinity and transparency are comparatively higher; the maximum depth is ca. 30 m, and the average salinity is 33. This zone did not cover shallow waters. Furthermore, several islands in the west part of the bay bound the outer zone. The middle zone displays intermediate environmental conditions between the inner and the outer zones, and is limited by the islands in the west, and by the lowest depth (<5 m) of the inner zone located on its northern part.

2.2. Fish sampling

Bi-monthly samplings in each bay zone (inner, middle and outer) were conducted from June 1987 to June 1988 and from July 1994 to

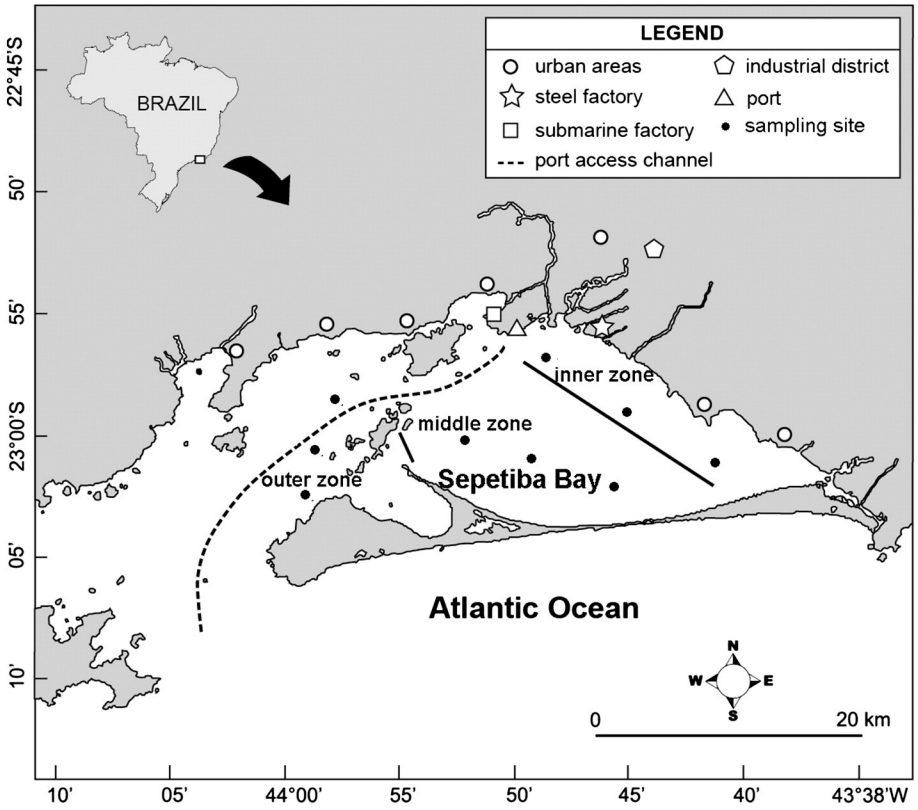

Fig. 1. Map of the study area, Sepetiba Bay in Southeastern Brazil, showing the sampling sites in the three bay zones (inner, middle and outer) and the main anthropogenic activities near the shoreline.

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