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Inter-decadal changes in fish communities of a tropical bay in southeastern Brazil

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HIGHLIGHTS

- We compared fish community structure in a tropical bay over three decades.
- The fish assemblage structure differed significantly between the two bay zones.
- Decreases in the fish richness, abundance and biomass were detected over time.
- The highest decreases in the richness was recorded for the marine migrants species.
- This is the first study to examine long-term changes in the fish community in Brazil.

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ABSTRACT

Long-term evaluations of coastal fish communities worldwide have in many cases showed a decrease in the species richness and abundance as a result of anthropogenic impacts. Fish communities in two zones (inner and outer) of a tropical bay in southeastern Brazil were sampled monthly during six years over two decades (1983–1985, 1993–1995, 1999–2001) using identical sampling methods. Over time, an increase in temperature and a decrease in water transparency were detected, while salinity remained stable. Fish assemblage was dominated by benthivorous species both migrant and resident species. The fish assemblage structure differed significantly between the two bay zones. Significant decreases in the fish richness, abundance and biomass were detected over time. The highest decreases in the species richness was recorded between 1983–1985 and 1993–1995 for the marine migrants in both bay zones and for the resident and marine straggler species in the outer zone. Dominant species such as the clupeoids *Anchoa januaria, Anchoa tricolor, Harengula clupeola*, the gerreid *Eucinostomos argenteus*,the sciaenid *Micropogonias furnieri,* the atherinopsid *Atherinella brasiliensis* and the ariid *Genidens barbus* decreased over time, whereas the mugilid *Mugil liza* increased. Persistent differences in the fish assemblage structure between the two bay zones over the three periods can be attributed at least in part to differences in environmental variables between the zones and seem to be a key ecological element to maintenance of biodiversity. This is the first study to examine long-term changes in the fish community of a tropical bay in Brazil.

1. Introduction

Changes in fish communities over time have been recorded in many coastal habitats and are often linked to abiotic variables (e.g. temperature, salinity) or anthropogenic impacts such as fishing (Jackson et al., 2001; Last et al., 2011), pollution and habitat degradation (Hewitt et al., 2008; Defeo et al., 2009; Ecoutin et al., 2010). Consequently, dramatic long-lasting changes in the relative abundance of species occur, enhancing a decline in fish species richness and potential local extinctions. The intensification of anthropogenic activities have significantly changed community/species distribution patterns, leading to changes in the richness and composition of assemblages across various spatial scales (Vitousek et al., 1997; Sax and Gaines, 2003; Johnston and Roberts, 2009; Azevedo et al., 2013). Therefore, long-term studies on fish distribution and community structure are fundamental for detecting changes in the ichthyofauna and crucial for understanding the dynamics of coastal ecosystem functioning to help managers in natural resource conservation. Studies on long-term (inter-decadal) changes in fish populations have mainly been done for commercially valuable and exploited species, but such studies on fish communities are rare in tropical bays.

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Sepetiba Bay is a sedimentary embayment in the southeastern Brazilian coast that plays an important role in the ecology of nearby coastal fish populations (Araújo et al., 2002). This bay harbors mangroves, mud/sand flats and rocky shore habitats. In the last decades, increased anthropogenic activities have brought a great load of organic and industrial effluents into the bay through rivers and drainage channels in the outskirts of Rio de Janeiro City (Copeland et al., 2003), enhancing eutrophication and pollution problems (Molisani et al., 2006; Cunha et al., 2009). In addition, the bay has been subjected to overfishing, building construction and habitat degradation (Lacerda et al., 1987; Barcellos et al., 1991; Barcellos and Lacerda, 1994; Molisani et al., 2004; Cunha et al., 2006; Molisani et al., 2006). Recent enhancement of the Itaguaí Port included dredging of the access channel to 20 m depth, which enables it to receive ships up to 150 000 t (Azevedo et al., 2007), the construction of a major steel company and the construction of a terminal for building submarines. All these recent changes have contributed to massive coastal habitat destruction and introduction of greater pollutant loads. It is, therefore, reasonable to suppose that such alterations are reflected in the change in the fish community structure in the last decades, resulting in decreased species richness and abundance.

Various abiotic factors have been associated with the structure of fish assemblages such as salinity, temperature, transparency, among others (Martino and Able, 2003; Aguirre-León et al., 2014). These variables are important drivers of fish distribution in estuarine areas. Changes in fish community linked to the changes in temperature and salinity have been reported for several estuarine systems (Martino and Able, 2003; Harrison and Whitfield, 2006; Last et al., 2011). In temperate estuaries, salinity has been reported as a major factor associated with fish richness because of physiological tolerance limits, whereas temperature affects fish densities associated with seasonal use of estuaries by abundant marine migrant species (Thiel et al., 1995; Whitfield and Elliott, 2002). Furthermore, there are complex suites of direct and indirect responses to coastal impacts including changes in water transparency, community composition, and changes in ecosystem functions (Cloern, 2001). For example, the level of suspended solids increases with the intensity of coastal development and the level of nutrient enrichment (Barcellos et al., 1997; Cunha et al., 2006). Increases in nutrients alter the ecosystems, reflected in high primary production capacity and reduced transparency (Costa et al., 2007; Defeo et al., 2009).

The aim of this study is to compare fish communities in two zones (inner and outer) of the Sepetiba Bay over two decades and to analyze the physico-chemical variables dynamics at spatial and temporal scales. We expect that (1) fish assemblage changes across the two decades (1983–1985, 1993–1995, 1999–2001) as consequence of increased pollution and habitat destruction, and that abiotic factors such as temperature, salinity, and transparency changes over the three-yearly period influenced fish communities; that (2) differences between the inner and the outer zone have decreased because of habitat homogenization; and that (3) in overall the fish richness, abundance and biomass decreased. The hypotheses are tested using a unique multi-annual dataset and a focus is made on ecological groups of fish and selected abundant species.

2. 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 formed by extensive sand deposition, which built a barrier beach as its southern boundary (Fig. 1) and 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. The bottom is predominantly muddy. Its shoreline is characterized by several small beaches and a few estuarine zones. This microtidal system has a tidal range of approximately 1 m. Predominant northeasterly and southwesterly winds activate thermal currents between the bay and the ocean. The annual rainfall varies between 1000 mm and 2100 mm (Barbiere and Kronemberger, 1994).

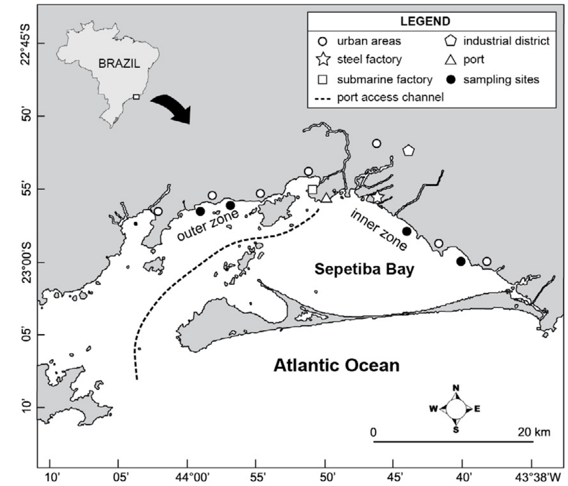

Fig. 1. Map of the study area, Sepetiba Bay, with indications of the sampling sites and the main human activities along the two bay zones (inner and outer).

The bay has two different zones (Fig. 1) according to depth, salinity gradient and level of human influences (Azevedo et al., 2007). The inner zone is influenced by discharges from perennial small rivers characterized by a downstream–upstream gradient of increased turbidity and temperature and decreased salinity. In the inner zone, the salinity is on average 28 psu, the depth is mostly <5 m and the substratum is dominated by mud (Araújo et al., 2002; Leal Neto et al., 2006). The outer zone near the sea connection has contrasting environmental conditions with substratum mainly sandy, comparatively lower temperature and higher salinity and transparency, maximum depth is ca. 28 m, and salinity averages 33 psu (Pessanha and Araújo, 2003). Furthermore, the outer zone is bounded by several islands in the west part of the bay.

Urbanization and industrialization are recent trends in the region. Agriculture has been replaced by industrial development since the 1960s and expanding during the 1970s mainly chemical and metallurgical factories (Barcellos and Lacerda, 1994). The inner zone sediment has indications of more concentrations of heavy metal compared with the outer zone (Molisani et al., 2006). Sediment deposition rates varied from 5 (in the outer) to 50 mg cm^{-2} day^{-1} (inner zone) (Barcellos et al., 1997). On the other hand, the outer zone has undergone a higher increase in the population and expansion of the urban area compared with the inner zone (Molisani et al., 2004).

2.2. Survey design

Monthly samplings were performed between July and June in two sites of the two different bay zones (inner and outer) during three periods (1983–1985, 1993–1995 and 1999–2001) over two decades, with exception of July 1994 to June 1995 when samples were bimestrial. A total of 83 samples in 1983–1985, 59 samples in 1993–1995 and 105 samples in 1999–2001 were analyzed (Table 1).

Fish were collected by a beach seine net (12 m long × 2.5 m height; 13 mm mesh), with a pocket of 5 mm mesh size in its rear portion. Hauls were 30 m long, parallel to and closing to shore, and were taken out to approximately 1.5 m depth. The total sampled