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Taxonomic and functional distinctness of the fish assemblages in three coastal environments (bays, coastal lagoons and oceanic beaches) in Southeastern Brazil

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A B S T R A C T

Several species of marine fish use different coastal systems especially during their early development. However, these habitats are jeopardized by anthropogenic influences threatening the success of fish populations, and urgent measures are needed to priorize areas to protect their sustainability. We applied taxonomic (Δ+) and functional (X+) distinctiveness indices that represent taxonomic composition and functional roles to assess biodiversity of three different costal systems: bays, coastal lagoons and oceanic beaches. We hypothesized that difference in habitat characteristics, especially in the more dynamism and habitat homogeneity of oceanic beaches compared with more habitat diversity and sheltered conditions of bays and coastal lagoons results in differences in fish richness and taxonomic and functional diversity. The main premise is that communities phylogenetically and functionally more distinct have more interest in conservation policies. Significant differences ($P < 0.004$) were found in the species richness, Δ+ and X+ among the three systems according to PERMANOVA. Fish richness was higher in bays compared with the coastal lagoons and oceanic beaches. Higher Δ+ was found for the coastal lagoons compared with the bays and oceanic beaches, with the bays having some values below the confidence limit. Similar patterns were found for X+, although all values were within the confidence limits for the bays, suggesting that the absence of some taxa does not interfere in functional diversity. The hypothesis that taxonomic and functional structure of fish assemblages differ among the three systems was accepted and we suggest that coastal lagoons should be priorized in conservation programs because they support more taxonomic and functional distinctiveness.

1. Introduction

Understanding the links between species distribution and habitat characteristics is often the first step in unraveling the mechanisms that control biodiversity distribution (Matthews and Whittaker, 2015; Vasconcelos et al., 2015; Whitfield and Pattrick, 2015; McLean et al., 2016). In this sense, the investigation of species composition and functional traits has been proposed as a means to assess the structure and dynamics of ecological communities. Species richness is practically always used as an explanatory variable for ecosystem function because it is easy to estimate and assumed to be a good estimator for functional diversity (Tilman, 1999). The introduction of functional groups was an important step in estimating functional diversity, with species being grouped by similar function, similar effects on ecosystem processes or similar responses to environmental pressures (Wilson, 1999; Walker and Langridge, 2002). Therefore, classifying species into groups based on taxonomic relationship and similar function is a useful approach to studying species environmental or perturbation influences on the coastal systems.

Several species of marine fish use sandy beaches in different coastal systems especially during their early development. However, this kind of habitat is at risk because of anthropogenic activities, which jeopardize the success of fish populations, and urgent measures are needed to priorize areas to protect the sustainability of such natural resources. The traditional diversity indices have been used in the last decades to quantify changes in communities, reducing complexity for ecological groups to numbers that are

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based on species composition and their relative abundances. Such indices are poor predictors of communities' structure and function. One of their inconsistence is the premise that all species are equivalent in composition and function, that is, all species have the same importance in respect to quantified information that they carry, irrespective of their degree of relatedness, and role in the community processes. The development of more efficient tools to assess diversity, both taxonomic and functional, and their relation with environmental constraints has been proposed. The main premise is that communities phylogenetically (average taxonomic distinctiveness) and functionally (average functional distinctiveness) more distinct have more interest in conservation policies.

Taxonomic distinctness does not measure the number of species per se but rather the taxonomic relatedness of species in a community (Clarke and Warwick, 1998, 1999; Leonard et al., 2006). This is done by defining the path length along the taxonomic hierarchy of each species pair in the community and then averaging across all species pairs. A major benefit of this index over species richness is its virtual independence of sampling effort. Rogers et al. (1999) applied to an extensive dataset of bottom-dwelling fish in the coastal waters of NW Europe, suggesting that the use of taxonomic distinctness measures provided additional insights of relevance to biodiversity assessment. O'Connell et al. (2009) calculated taxonomic distinctness of fish assemblages from multiple estuarine regions of Southeastern Louisiana, and concluded that this method is more useful for large scale than other diversity measures. Lefcheck et al. (2014) analyzing demersal fishes in Chesapeake Bay concluded that an index of diversity derived from taxonomic hierarchy served well as a practical surrogate for functional and phylogenetic diversity of the demersal fish community. Barjau-González et al. (2016) analyzed rocky reef fish in southwestern Gulf of California and found greater anthropogenic impact would cause differences in taxonomic distinctness. To date, such approaches have not being applied for the tropics.

Functional diversity is by sure an important component of biodiversity that quantifies the difference in functional traits between organisms and explains the roles that organisms play within ecosystems. A trait-based approach to diversity is attractive because functional traits can, in principle, be directly linked to ecosystem processes (Mouillot et al., 2005, 2007; Somerfield et al., 2008; Mouchet et al., 2010, 2013; Stuart-Smith et al., 2013; Laureto et al., 2015). Villéger et al. (2010) studied changes in taxonomic and functional diversity in the Términos Lagoon (Gulf of Mexico) of estuarine fish communities facing environmental and habitat alterations and found that three, among the four largest bay zones, did not show strong functional changes but in one of them there was an increase in fish richness but a significant decrease of functional diversity. They explained this result by a decline of specialized species, while newly occurring species are redundant with those already present. Wiedmann et al. (2014) found that trait-based methods detect substantial spatial variation in functional diversity of fish community in Barent Sea partly associated with hydrographic characteristics.

The 650 km extent of the coast of Rio de Janeiro State, Southeastern Brazil, encompasses different coastal systems, with oceanic coastal beaches predominating in the North, coastal lagoons in the Center, and large bays in the South (Fig. 1). In this study, we focused on comparing fish assemblages richness and taxonomic ($\Delta+$) and functional ($X+$) distinctiveness of fish community in these three different coastal systems that have different environmental conditions: (1) the oceanic beaches with more dynamisms and wave exposure; 2) the coastal lagoons with marked stable salinity gradient, low hydro dynamism and well protected habitats due to the narrow sea connection; and (3) the bays with a slight salinity gradient and more tidal influence. We hypothesized that these differences in the environmental conditions result in differences on richness, taxonomic and functional distinctiveness of the fish assemblages of these different systems. The following questions were postulated: 1) Do differences in environmental conditions among the three systems result in different fish assemblages? 2) Do taxonomic and functional distinctness changes among the systems? With the answers to these questions we will test our raised hypothesis and we hope to provide useful information for conservation managers.

2. Material and methods

2.1. Study area

The coast of Rio de Janeiro State, located near to the southern

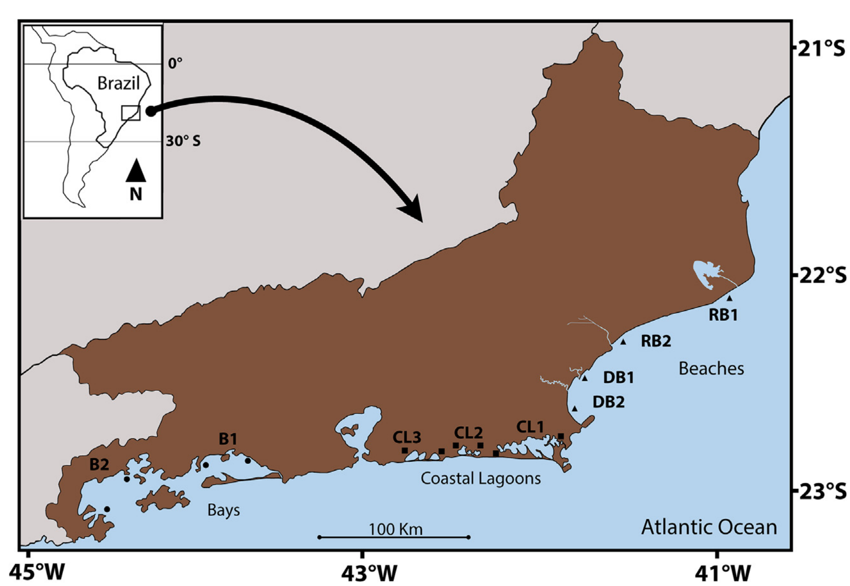

Fig. 1. Map of the study area with indication of the three coastal systems along the Rio de Janeiro State: 1) oceanic beaches, RB1 and RB2 (reflective beaches) and DB1 and DB2 (dissipative beaches); 2) coastal lagoons, Araruama (CL1) Saquarema (CL2) and Maricá (CL3); 3) bays, Sepetiba (B1) and Ilha Grande (B2).