Available online at www.sciencedirect.com
ScienceDirect
Estuarine, Coastal and Shelf Science 75 (2007) 468–480
ESTUARINE COASTAL AND SHELF SCIENCE
www.elsevier.com/locate/ecss

Demersal fishes in a tropical bay in southeastern Brazil: Partitioning the spatial, temporal and environmental components of ecological variation

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Received 25 September 2006; accepted 10 May 2007
Available online 20 July 2007

Abstract

This study analyzed the factors structuring demersal fish community in a tropical bay in southeastern Brazil. The results were used to quantify the partitioning of ecological variation among the environmental, spatial and temporal components molding the fish community. Three bay zones (inner, middle and outer) were defined according to depth and salinity gradient. Monthly samplings were conducted by bottom trawl tows during daylight hours, between October 1998 and September 1999. In each zone, three replicate samples were taken. Ninety-three fish species from 73 genera and 37 families were recorded in the 108 samples. Two demersal fish assemblages were evidenced, one in the inner and the other in the outer zone. These assemblages were characterized by changes in species composition and relative abundance. Depth, followed by transparency and salinity, influenced spatial pattern of fish assemblages. The largest part of the explained variation occurred as a result of the spatial structure of environmental variables, which means that both species and environmental variables presented similar spatial structure. The spatial effect, not the seasonal, explained the highest part of species variations. The amount of unexplained variation was relatively high (76%), even assuming that part of it is due to nondeterministic fluctuation, which could be due to local effects of unmeasured (biotic and abiotic) controlling variables. Knowing the relative importance of these factors can be of decisive importance when applying casual hypotheses in the framework of some precise ecological theory and should facilitate management, planning, and usage of bay resources.

Keywords: fishes assemblages; bay; Brazil; variation partitioning; environmental gradient

1. Introduction

Many mechanisms may influence the distribution of fish within coastal marine systems. Several investigators have suggested that biotic processes may be influential in driving the spatial and temporal patterns of occurrence in fish (Ogburn-Matthews and Allen, 1993; Rueda, 2001; Rueda and Defeo, 2001). In addition, a myriad of abiotic factors have been associated with the structure of these assemblage communities, with well-defined boundaries corresponding to discontinuity in the environment, while the opposite situation corresponds to a continuum along the environmental gradient (Akin et al., 2003; Martino and Able, 2003). In many surveys, it is often not clear what environmental factors and

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doi:10.1016/j.ecss.2007.05.027

interactions were most important in determining patterns of fish distribution and community structure because controlling factors are usually complex, obscuring patterns, scales of variability, and the interpretation of causal effects (Jung and Houde, 2003).

Two classic models explaining the observed patterns in biological communities are found in the literature. In the environmental control model, environmental variables are deemed responsible for the observed variations in the presence or abundance of the species; whereas in the biotic control model, the links among organisms, horizontal (competition) or vertical (predation), are considered to be the primary factors structuring communities (May, 1984). Some authors believe that fish communities seem to be dominated by species that respond primarily to a given mechanism (Grossman et al., 1982; Rahel et al., 1984), although they recognize that it would be simplistic to suggest that assemblages are regulated by a process type only. Others consider it a mistake to model the observed variations in patterns and processes of the communities in terms of one cause only (Jackson et al., 2001). Although these two models of community structure can represent fundamental philosophical differences regarding the nature of their organization, the crucial empiric problem is to relate identifiable causal factors to the number of species or relative abundances in fish assemblage (Wootton, 1991). Recently, it has been recognized that the observed patterns in species occurrence or abundance can be caused by a variety of ecological processes as well as evolutionary and geographical circumstances; this means recognizing connections between local habitat and historical events, and between the present moment and the long history of life on earth (Schluter and Ricklefs, 1993). Multivariate statistical methods used to quantify the spatial structure of abiotic and biotic variables can show patterns only, which can be evidence of those several processes that are being generated, or represent a synthesis of the indirect descriptors that are acting on fish assemblages.

There are several different approaches in the description of fish assemblages and their explanatory factors. Some studies focus on environmental influences on the assemblage structure (Thiel et al., 1995; Lara and González, 1998; Marshall and Elliott, 1998; Araújo et al., 2002); others describe seasonal (Maes et al., 1998) and spatial patterns only (Araújo et al., 1997, 1998) without determining an effective cause. In a more detailed view, some other studies tested the hypotheses of the importance of biotic, abiotic and spatial factors (Jackson et al., 2001; Laegdsgaard and Johnson, 2001), and local, regional and historical influences (Jackson and Harvey, 1989; Oberdorff et al., 1997) structuring fish community. While it is possible to obtain measures of some abiotic descriptors of the sites, biotic interactions such as predation and competition, or historical events such as natural catastrophes or human alterations cannot be directly measured. However, due to the diversity and frequently unknown nature of the causes, it is very difficult to evaluate their relative contributions (Borcard and Legendre, 1994; Méot et al., 1998). Anderson and Gribble (1998) studied the temporally structured variation and its overlap with the environmental and spatial components. Borcard et al. (1992) proposed a method to partition the variation of species abundance data into independent components: pure spatial, pure environmental, spatial component of environmental influence and undetermined. Some assumed relationships between species occurrence and environmental variables can be spurious, implying a common spatial gradient, while others are real. Identifying explanatory variables that are independent can be very useful for a detailed understanding of more local ecological structures. In this scope, the availability of a set of standardized data on fish collections in Sepetiba Bay is a good opportunity to test such models in a tropical area.

Sepetiba Bay is located in the state of Rio de Janeiro in southeastern Brazil. It is connected to the sea through a wide mouth at its west end and a narrow channel at the east, with a sandbank forming the southern limit and the continental margin at the north. Because most human activities in the drainage basin of the Sepetiba Bay are concentrated in the innermost region, we hypothesized that there would be inner, middle and outer zones that differ in fish abundance and assemblages; that these differences would be related to environmental variables and anthropogenic influences; and that biotic interactions could play a role on fish assemblage structure. Several marine fishes enter and leave the bay for nursery, reproductive, and feeding purposes (Araújo et al., 2002). Azevedo et al. (2006) reported that habitat segregation in the Sepetiba Bay during most seasons (except summer) explains the pattern of reduced co-occurrence, indicating the presence of two fish assemblages associated with different environmental characteristics. The objective of this work is to explain further these patterns and to try to separate the effects of the several factors and their different forces, thus allowing us to partition the relative importance of the environmental, spatial and temporal components that shape the demersal fish community in Sepetiba Bay.

We partition the total variance of species data in terms of: (1) nonspatial environmental/temporal variation; (2) spatially structured environmental/temporal data; and (3) spatial species variation that is not shared by the environmental/temporal variables. This would be an alternative concept for understanding ecological patterns in terms of the relative contribution of each factor, because it quantifies more precisely the partitioning of the variation among its spatial, temporal and environmental components.

2. Methods

2.1. Study area and survey program

Sepetiba Bay (Fig. 1) is a sedimentary embayment on the coast of Rio de Janeiro State (22°54′–23°04′S; 43°34′–44°10′W) in southeastern Brazil. It was shaped by an extensive process of sand deposition, which formed a barrier beach at its southern end. It ends in a wide confluence with the Atlantic Ocean at its western boundary. 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 has a continental drainage area of 2700 km^2 (Fonseca, 1978). The annual rainfall ranges from