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Summer micro- and mesozooplankton from the largest reef system of the South Atlantic Ocean (Abrolhos, Brazil): Responses to coast proximity

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ABSTRACT

Zooplankton samples were collected in summer and in three distinct Neotropical areas (the coastal reef arc, the outer reef arc and the Abrolhos Archipelago). Two stations in each sampling area were established (a reef station and an outer station) to sampling zooplanktonic assemblage with two different mesh sizes (64- and 200-μm plankton nets). Approximately 110 taxa were identified, and the assemblages from the two nets were significantly different. Zooplankton abundances were three orders of magnitude higher in the 64-μm net samples with an average abundance of 217,000 ± 93,418 ind m^{-3} (64-μm net) and 189 ± 122 ind m^{-3} (200-μm net). A permutational multivariate analysis of variance (PERMANOVA) of the zooplankton community structure revealed significant differences between all three regions and showed a heterogeneous distribution of these animals, even though no significant differences were observed in terms of abundance for both net catches (*two-way* ANOVA, $P > 0{,}05$). SIMPER analyses showed that most highly abundant taxa occurred in all sampling areas. Though, some other taxa were clearly identified as characteristic of a particular area by their relative frequency, rather than relative abundance. It is hypothesized that variations in suspended particle concentration play an important role in the observed differences in community composition. Our results suggest that the pelagic components of these reef zooplankton assemblages may be as important as demersal zooplankters to benthic-pelagic coupling. Because the much higher abundance of the microzooplankton assemblages compared to the mesozooplankton is a common feature of reef communities, the studies that use only coarse nets miss assessing the contribution of a large and important portion of the reef zooplankton assemblage and therefore misinterpret the community as a whole.

1. Introduction

Coral reefs are limited to tropical oceans and cover only 0.1% of the surface of the earth, yet they have major consequences for global marine biodiversity. Reefs provides habitat for remarkably diverse animal phyla with characteristic distribution patterns and composition (Kohn, 1997). These patterns reflect the effect of several processes, which are largely characterized as niche-based (Armstrong and McGehee, 1980; Leibold, 1995) or determined by dispersal limitation (Hubbell, 2001). It is importance to strive in the study of groups that are important to maintaining environmental resilience (Walker, 1992). Among these, zooplankton play major roles in most ecosystem processes and are essential links in food webs. In addition, they also exhibit a tremendous diversity of traits, ecological strategies and consequently impact other trophic levels in the cycling of materials and energy (Litchman et al., 2013).

Zooplankton are probably the best studied component of planktonic communities of reef ecosystems because they have been studied since the 1930s (Sorokin, 1990a). In most of these pioneer studies (Edmondson, 1937; Farran, 1949; Russel, 1934), zooplankton were collected only during the daytime and the migratory behavior of this community was unknown, which led to a misunderstanding that reef zooplankton consist mostly of planktonic organisms of adjacent waters passing over the reef (Emery, 1968; Johannes et al., 1970). However,

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according to Sorokin (1990a), a feature of reef zooplankton is the domination of the population by species connected to the benthos to which they migrate during the daytime. At night some species go up into the water column causing reef zooplankton to differ from that of the surrounding pelagic areas in its species composition, behavior, and abundance. Among these species are holoplanktonic forms (copepods, mysids and amphipods) as well as demersal species and meroplanktonic larvae (Alldredge and King, 1980; Emery, 1968; Melo et al., 2010). Therefore, studies in reef areas should recognize the importance of this variability in order to assess all of the biodiversity in these systems.

Recent studies have created a better understanding of the dynamics of reef zooplankton based on their diversity, vertical distribution, biomass and production. Many studies have used finer mesh (i.e. 64 μm) aiming to collect the smaller zooplankton fractions missed when passing through coarser meshes (i.e. 200–300 μm) (Hopcroft et al., 1998). Small-size classes play an essential role in marine food webs by feeding on autotrophic and heterotrophic protists, marine snow and bacteria (Green and Dagg, 1997; Roff et al., 1995; Turner, 2004) and may represent the greater portion of local zooplankton production (Hopcroft et al., 1998). Therefore, Hopcroft et al. (1998) stressed the importance of using two standard nets in field work (64 and 200 μm) to better assess the community and reduce possible biases due to the selectivity of the nets. Nevertheless, reef zooplankton studies simultaneously using two different mesh nets are rare around the world (Chisholm and Roff, 1990a, 1990b; Hopcroft et al., 1998; Webber and Roff, 1995a; Webber and Roff, 1995b) and absent in South Atlantic reef systems.

A great deal is known about reef zooplankton communities from the Pacific Ocean (the Great Barrier Reef in Australia) (Alldredge and King, 1977; Hamner et al., 1988; McKinnon et al., 2005; McKinnon and Thorrold, 1993; Roman et al., 1990) and the North Atlantic Ocean (Caribbean Sea reefs) (Álvarez-Cadena et al., 2009; Heidelberg et al., 2010; Heidelberg et al., 2004; Moore and Sander, 1976; Yoshioka et al., 1985). However, even though the Abrolhos Bank in the South Atlantic is comparable in size to the Caribbean Sea in the North Atlantic Ocean (Amado-Filho et al., 2012; Moura et al., 2013), fewer studies have been conducted in this area.

The Abrolhos Bank comprises the most important coralline reefs in the South Atlantic with high levels of endemism and unique mushroom-shaped coralline pinnacles (Leão and Kikuchi, 2005). The continental shelf in the Abrolhos Region encompasses a complex benthic habitat mosaic in which the world's largest rhodolith bed covers ≈20,900 km^2, whereas coralline reefs cover ≈8800 km^2 (Moura et al., 2013). However, despite the ecological importance of the Abrolhos Bank, other smaller reef sites of Brazil have been better studied. In the Abrolhos, plankton studies have detailed the tintinnids community (Costa et al., 2015), phytoplankton biomass and production (Gaeta et al., 1999), meroplankton spatial structure (Koettker and Lopes, 2013), zooplankton communities size spectra (Marcolin et al., 2015; Marcolin et al., 2013; Schultes and Lopes, 2009), pico-, nano-, and microplankton (Ribeiro, 1999), and microphytoplankton structure (Susini-Ribeiro et al., 2013).

The present study was conducted to evaluate the reef zooplankton biodiversity and abundance in the Abrolhos Region using two different mesh nets. Our goal was to assess the community in terms of species composition, the community changes related to the coast proximity, and the influence of the reefs over the pelagic zooplankton community. Additionally, the biases in communities abundances estimated by the different plankton nets were explored.

2. Material and methods

2.1. Study area

The Abrolhos Bank is located between 17°S and 20°S on the Eastern Brazilian Continental Shelf (EBCS) (Fig. 1). The EBCS is generally narrow from 5°S up to 15°S and at some point reaches < 10 km offshore, which results in a strong influence by oceanic oligotrophic waters of the South Equatorial Current (Lopes and Castro, 2013). The Abrolhos Bank represents an enlargement of the EBCS, reaches 245 km offshore (Knoppers et al., 1999), and covers an amazing set of mega-habitats hosting rhodolith beds (Amado-Filho et al., 2012) and unique coralline reef cover (Leão and Kikuchi, 2001; Moura et al., 2013), seagrass, and algae bottoms (Creed and Amado-Filho, 1999) with a great extent of soft bottom (Marchioro et al., 2005). Despite this enlargement, the topographic gradient of the continental shelf of the Abrolhos Bank facilitates a high shoreward intrusion of Tropical Water coming from the Brazil Current, which is warm, saline and nutrient-poor (Castro and Miranda, 1998; Koettker and Lopes, 2013). This feature makes the waters homogenous throughout the Abrolhos Bank area (Lessa and Cirano, 2006; Susini-Ribeiro et al., 2013), where no vertical or horizontal variations have been observed neither during winter periods (24.48 ± 0.61 °C and 37.62 ± 0.22 salinity; Marcolin et al., 2013) nor during the summer (27.42 ± 0.40 °C and 36.81 ± 0.17 salinity; unpublished results, 2016). Wind stress is the primary agent forcing water motion southward on the inner and middle shelf, whereas the Brazil current is a major influence on the outer shelf.

The Abrolhos Bank's coralline reefs are unique in terms of structure. Coralline mushroom-shaped pinnacles, known locally as “Chapeirões”, grows toward the surface (Leão, 1999). The combined influences of oligotrophic oceanic waters and muddy sediment deposition on the Abrolhos coastal reefs originating from river discharge (Doce River) also contribute to the unique features of this reef ecosystem, since carbonate sedimentation predominates in other tropical reefs (Lopes and Castro, 2013). The major coralline formations include an inner arc and an outer arc in relation to the proximity of the coast.

The coastal arc is located at 5–30 km from the coastline in which “Parcel das Paredes” (PP) is the main coralline formation. Here, the reef developed to form coalesced reef tops reaching up to 17 km wide at “Pedra Grande” (Leão, 1999). Depths from the unconsolidated bottom to the surface are typically 15 m, though the reef top can emerge in places during low tide periods. The outer arc is located at 60–65 km offshore and borders the east side of the Abrolhos Archipelago at depths of up to 25 m (Moura et al., 2013). Extending for 15 km in the north-south direction, the outer arc consists of multiple and sparse pinnacles that sometimes reach the surface. This arc is known as “Parcel dos Abrolhos” (PAB) (Leão, 1999). The Abrolhos Archipelago (AA) presents fringing reefs extending up to 50–60 m from the coast. These reef formations developed over volcanic or sedimentary hard substrates with little growth upward at depths up to 5 m (Leão, 1999).

2.1.1. Field collection

Intensive samplings were conducted during the summer (February) of 2012. Three areas were sampled: Parcel das Paredes (PP) located ≈30 km from the coastline (17°52′48.1″S, 38°56′19.2″W); Abrolhos Archipelago (AA) located ≈52 km from the coastline (17°57′57.4″S, 38°42′09.2″W); and Parcel dos Abrolhos (PAB) located ≈62 km from the coastline (17°59′55.2″S, 38°40′15.9″W). In each area, one station was established directly over the reef top (reef station; RS) and another was located nearly 1 km away from the reef (outer station; OS). Sub-surface plankton tows were conducted simultaneously with two cylindrical-conical nets (mesh sizes: 64 and 200 μm) equipped with a flowmeter for 5 min. The hauls were conducted every 6 h over a 24-h period (0 h, 6 h, 12 h, 18 h) in subsequent days for each station to be used as a measure of the variability in communities' abundance. The samples were fixed with 4% formaldehyde and buffered with 4 g L^{-1} sodium tetraborate for laboratory analyses.

2.1.2. Sample analyses

The 64-μm samples were subsampled (1 mL) and examined using Sedgewick-Rafter chambers and an optical microscope. For each sample, three subsamples with at least 300 individuals were analyzed, and their mean was calculated for later estimation of abundance. For