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Benthic community structure and organic matter variation in response to oceanographic events on the Brazilian SE inner shelf

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ABSTRACT

For 13 months, this study monitored the sedimentary organic matter composition, benthic bacteria and macrofauna at a permanent sampling station on the inner shelf (~ 40 m depth) near Ubatuba in SE Brazil. The sedimentary organic matter compounds were evaluated for total organic matter content, lipid biomarkers and phytopigments. The organic matter content varied significantly over time but no clear seasonal trend was evident. Lipid biomarker composition revealed that particulate organic matter was primarily derived from autochthonous sources, such as diatoms, other microalgae, zooplankton, sediment bacteria and benthic metazoan fauna. Phytopigment results revealed that the majority of the organic matter in the sediments was refractory as opposed to labile, suggesting that the labile portion is rapidly consumed. The benthic dynamics off the coast of Ubatuba is highly influenced by the intrusion of the South Atlantic Central Water (SACW) onto the shelf, which brings nutrients up to the euphotic zone and stimulates new phytoplanktonic production. This enhances the flux of organic matter to the bottom and increases benthic biota density, mainly bacteria. These results suggest a strong and complex benthic–pelagic coupling that is influenced by both mesoscale oceanographic events (i.e., intrusion of SACW) and local events (cold fronts) through remobilization of the sediments.

Contents

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1. Introduction

Coastal marine sediments have great importance in carbon cycling, with organic carbon fluxes to the seabed representing approximately 0.1% of the total reserve of marine organic carbon (Harvey, 2006). These fluxes are directly related to local planktonic primary production, sedimentation rates, water column depth, sources of organic matter and oxygen exposure time (Hedges and Keil, 1995). Almost one quarter of the organic matter produced in the water column reaches the seabed in continental shelf areas, with faster accumulation rates than on the deep ocean floor (Hedges and Keil, 1995).

A fraction of this autochthonous organic matter is composed of smaller molecules such as carbohydrates, proteins, nucleic acids and lipids and is rapidly degraded on the benthos (Danovaro et al., 1999). Macromolecules, such as humic and fulvic acids and long-chain alcohols, represent the refractory fraction of the organic matter; they undergo slow degradation and are often preserved in sediments (Fabiano and Danovaro, 1994; Bouillon and Boschker, 2006). The quality of organic matter is often estimated using the phytopigment ratio (chlorophyll-a/phaeopigments) and lipid biomarkers (Dell'Ano et al., 2002). Chlorophyll-a is a proxy for the amount of labile organic matter (Wieking and Kröncke, 2005); lipid biomarkers, on the other hand, trace the origins, pathways and transformation processes of organic matter due to their stability in aquatic environments, structure diversity and relative source specificity (Wakeham et al., 1997; Volkman, 2006).

The amount of labile organic matter is directly influenced by the presence of bacteria in the sediment (Sun et al., 1994; Fabiano et al., 1995). The role of this bacteria in degrading organic material makes them key players in the benthic food web (Boschker et al., 2001), both from remineralization and from enhancing the quality of organic matter through protein enrichment (Fabiano et al., 2004). Environmental factors (e.g., organic enrichment, oxygen deficiency, hydrodynamics) have been shown to play an important role in these processes (Zajac et al., 1998). For instance, benthic microbiota respond positively to increases in the supply of planktonic detritus due to upwelling enrichment (Sumida et al., 2005).

The relationship between detrital supply and the fate of organic matter in sediments, influenced by physical factors and benthic community structure, has been extensively described in inner shelf areas in high latitudes (e.g. Albertelli et al., 1999; Stoeck and Kröncke, 2001; Hernández-Arana et al., 2003; Wieking and Kröncke, 2005; Chapman and Tolhurst, 2007; Montserrat et al., 2008). However, little is known about the temporal variation of organic matter composition and its influence on the structure and function of benthic communities in tropical and subtropical areas, with a few notable exceptions (Quijón et al., 2008; Quintana et al., 2010, Venturini et al., 2011, 2012).

Along the southeastern coast of Brazil, the intrusion of nutrient-rich South Atlantic Central Water (SACW) from the slope onto the inner shelf during the summer causes strong stratification of the water column (Castro and Miranda, 1998). SACW advection introduces nutrients into the mixing layer which increases phytoplankton biomass (Valentin et al., 1987; Rocha et al., 1998; Saldanha-Corrêa, 1999, 2004; Villac et al., 2008). This is the primary influence on the productivity of the coastal ecosystem in the SE Brazil, influencing the growth both of fish stocks (Pires-Vanin, 1993; Rocha et al., 2003) and of mega- and macrobenthic communities (Pires-Vanin, 1992; Sumida and Pires-Vanin, 1997; Muniz et al., 1998; De Léo and Pires-Vanin, 2006). During autumn and winter, the SACW retreats and the region is subjected to strong southwesterly winds due to the intensification of cold fronts passages. These winds increase water column mixing and sediment resuspension (Mahiques et al., 2004). The latter influences sediment biogeochemistry (Wainright and Hopkinson Jr., 1997) and thus infaunal communities; for the SE Brazilian coast, these effects are not yet fully understood (Quintana et al., 2010).

A relationship has been defined between water column parameters and the quality of sedimentary organic matter (Sumida et al., 2005; Quintana et al., 2010, Venturini et al., 2012), but not for the influence of these parameters on sediment characteristics over time. This study monitored the sedimentary organic matter composition, benthic bacteria and macrofauna on a monthly basis at a permanent station in the inner shelf off Ubatuba, SE Brazil, and related them to the main physical and biological forcing mechanisms in the area. This paper aims to explain the influence of temporal changes and seasonal factors, such as cold fronts, to the organic matter load and quality of the sediment. Also, it seeks to establish the relationship between the organic fraction of the sediment and the bacterial and community structure. This work was a component of a long-term monitoring network (ANTARES) that records temporal changes on South American coastal waters.

2. Materials and methods

2.1. Study area

The sampling area (23°36.79S–44°53.46W) is located on the continental shelf near Ubatuba (SE Brazil) at a depth of 42 m (Fig. 1). This region is under the influence of three water masses: the warm (>25 °C) and low saline (32–33) Coastal Water (CW), the colder (16–18 °C) and higher salinity (35–36) South Atlantic Central Water (SACW) and the Tropical Water (TW) which has an intermediate temperature (20–23 °C) and high salinity ($\sim$36) (Silveira et al., 2000). During the summer, the nutrient-rich SACW shifts from the shelf slope and moves onshore to the central and outer portions of the continental shelf (20 –100 m), while the CW is constricted to a narrow band near shore. This results in stratification across the inner shelf, with a strong thermocline at intermediate depths. In winter, when SACW is farther offshore (on the outer shelf and slope), the horizontal and vertical thermal gradients are reduced and almost no stratification is rarely observed on the inner shelf. The intrusion of the SACW onto the continental shelf results from meanders and eddies formed by the Brazil Current, which in turn results from the interaction of the SACW with TW (Castro and Miranda, 1998). The sediment is poorly sorted with patches of mud deposits (Mahiques et al., 2004).

2.2. Sampling

Monthly cruises were conducted between October 2006 and October 2007. Water column temperature, salinity, dissolved oxygen and macrofauna density and biomass were sampled for 13 months.