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Organic matter composition and macrofaunal diversity in sediments of the Condor Seamount (Azores, NE Atlantic)

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ABSTRACT

In recent years increasing knowledge has been accumulated on seamounts ecology; however their sedimentary environments and associated biological communities remain largely understudied. In this study we investigated quantity and biochemical composition of organic matter and macrofaunal diversity in sediments of the Condor Seamount (NE Atlantic, Azores). In order to test the effect of the seamount on organic matter distribution, sediment samples were collected in 6 areas: the summit, the northern and southern flanks and bases, and in an external far field site. Macrofauna abundance and diversity were investigated on the summit, the southern flank and in the far field site. The organic matter distribution reflected the complex hydrodynamic conditions occurring on the Condor. Concentrations of organic matter compounds were generally lower on the whole seamount than in the far field site and on the seamount summit compared to flanks and bases. A clear difference was also evident between the northern and southern slopes of the Condor, suggesting a role of the seamount in conditioning sedimentation processes and distribution of food resources for benthic consumers. Macrofauna assemblages changed significantly among the three sampling sites. High abundance and dominance, accompanied by low biodiversity, characterized the macrofauna community on the Condor summit, while low dominance and high biodiversity were observed at the flank. Our results, although limited to five samples on the seamount and two off the seamount, do not necessarily support the paradigm that seamounts are more biodiverse than the surrounding seafloor. However, the abundance (and biomass), functional diversity and taxonomical distinctiveness of the macrofaunal assemblages from the Condor Seamount suggest that seamounts habitats may play a relevant role in adding to the regional biodiversity.

1. Introduction

Seamounts are elevations of the deep-sea characterized by high spatial heterogeneity and topographic complexity (Rogers, 2004). They have been described as unique ecosystems in terms of marine biodiversity and biomass, and hotspots of biodiversity and endemicity (Dower and Mackas, 1996; Genin, 2004; Richer de Forges et al., 2000; Rowden et al., 2010a; Stocks and Hart, 2007; Worm et al., 2003). Only recently the validity of these paradigms in seamount ecology has been questioned in function of the lack or scarce weight of existing scientific evidences (McClain, 2007; Rowden et al., 2010a). For example the idea of seamounts as isolated habitats (submerged island) and areas of elevated endemism has not been sufficiently supported by available literature (Cho and Shank, 2010; Hall-Spencer et al., 2007; Samadi et al., 2006). Theories of seamounts as areas of high productivity, higher biota abundance and biomass compared to adjacent open slopes and hotspots of species richness, although considered plausible, have been only partially supported due to the limited number of studies (Rowden et al., 2010a, and literature therein, 2010b; Samadi et al., 2006, 2007).

The establishment of lush pelagic and benthic communities on seamounts has been partially explained to reflect high trophic inputs driven by hydrographical processes such as eddies and circular currents (Taylor column), turbulent mixing of the benthic

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boundary layer, and regional up-wellings (Genin, 2004; Samadi et al., 2006). All these physical processes must exert their influence on nutrient dynamics, primary and secondary production, organic matter fluxes down to the seafloor and deposition of sediment and organic matter, thus affecting the biogeochemistry and resources availability over and around seamounts (Beckmann and Mohn, 2002; Dower et al., 1992; Genin, 2004; Mohn and Beckmann, 2002a, 2002b; Mullineaux and Mills, 1997; Roden, 1987).

Published results on patterns of organic matter distribution around seamounts are scarce and contradictory, showing a high degree of spatial and temporal variability. While some studies have suggested that large-scale entrapment of water by topographically rectified currents can increase the downward flow of particulate organic matter over the top of seamounts (Brink, 1995; Mullineaux and Mills, 1997), others have reported lower levels of sedimentary organic carbon at the seamounts summit than on their base, adjacent slopes and abyssal plain highlighting the relevance of lateral mechanism controlling particulate organic carbon distribution around these topographic features (Heinz et al., 2004; Smith et al., 1989).

Type and availability of food resources are generally thought to strongly influence benthic faunal assemblages and standing stock thus controlling patterns of distribution (Clark et al., 2010; Gooday, 2002; Piepenburg and Müller, 2004). High benthic biomasses were measured above the Cobb Seamount (NE Pacific) in correspondence with high chlorophyll concentrations (Dower et al., 1992). On the contrary an observed mismatch between organic carbon content and foraminiferal abundances in the sediments of the Great Meteor Seamount (NE Atlantic) led Heinz et al. (2004) to speculate on the importance of organic matter quality rather than quantity, although no further investigations were carried out to clarify this.

Despite the last decade have seen rapid advancements in the field of seamounts ecology, their sedimentary environments are still poorly known. In particular the distribution of sediment organic matter, its biochemical composition and diversity of infaunal organisms are almost unexplored.

The Condor Seamount located in the Archipelago of the Azores (North-East Atlantic Ocean) has been the focus of recent intensive studies (this issue) as it is a representative of Azorean seamount ecosystems and easily accessible for sampling.

In order to elucidate the potential effect of seamount on the distribution of sediment organic matter, sediment samples were collected in different areas (summit, northern and southern flanks and bases) of the Condor Seamount and in an external area (far field site). Moreover, abundance, community structure and biodiversity of soft-bottom macrofauna and its relationship with potential food source and other environmental constraints were investigated in the Condor summit, southern flank and in the far field site.

2. Material and methods

2.1. Study area and sampling strategy

The Condor, located at ca. 10 nautical miles southwest of the island of Faial in the Archipelago of the Azores (Portugal, NE Atlantic) is an elongated V-shaped ridge seamount having a WNW-ESE orientation. This elevation rises from a maximum of 2000 m depth at the seafloor (outer edge farthest from Faial Island) to 185 m depth beneath the sea surface (Tempera et al., 2013). It presents a flat summit area characterized by the presence of large rocky seafloor outcrops, boulders and gravels alternating with unconsolidated patches of bioclastic deposits (mostly shells and coral debris) and less than 1% of fine particles ($< 63\ \mu m$). Condor steep flanks (10–20° slope) are generally smooth and characterized by unconsolidated and cemented sandy-mud sediments, composed of 51–73% of fine particles (Caetano et al., 2013; Tempera et al., 2012). Deep–sea sediments far away from the Condor (far field site, SW of the seamount) are composed of 60–92% of fine sediment particles (Caetano et al., 2013).

Previous studies have shown that the Condor Seamount is most of the time under the influence of a background flow coming from N or NW that turns cyclonically around the SW slope of the seamount and then goes E. This tendency for cyclonic semi-rotation attenuates around 500 m depth. In the proximity of the upper flanks of the Condor a tendency for anticyclonic rotation is observed (anticyclonic cap). Mixing, local upwelling–downwelling patterns and the pronounced closed anticyclonic cap around the Condor, suggests that the average oceanographic conditions over the seamount are clearly distinct from those of the surrounding ocean (Bashmachnikov et al., 2013; Tempera et al., 2012).

Sediment samples were collected between July and August 2010 onboard the R/V Noruega. Sampling for organic matter analyses was undertaken in seven sites located between 206 and 1900 m depth: the Condor summit (site 9), the northern flank and base along the upstream slope (sites 1, 2, and 3), the southern flank and base along the downstream slope (sites 4 and 6) and in an external area (far field, site 8) located at ca. 10 nautical miles south-western to the seamount (Fig. 1, Table 1). This latter area was used as an example of external reference (presumably out of seamount influence) although the denomination "external reference" should be taken with caution due to the complex hydrodynamic conditions in the area and the lack of replications outside the seamount. At all sampling sites, sediments were collected by two independent deployments of a multiple corer (Midicorer Mark II 400) equipped with four core tubes having an inner diameter of 100 mm. Once on board, three cores were subsampled from each deployment. Sediment cores were sliced into 5 layers (0–1, 1–3, 3–5, 5–10 cm and when available 10–15 cm) and immediately stored at $-20\ ^{\circ}C$ until analyses. Only the upper 0–1 cm samples were further processed for organic matter analysis.

Macrofauna samples were collected from three sites: seamount summit, southern flank and far field (site 9, 4 and 8, respectively), and in each site by two independent deployments of a spade box corer (area$=0.2025\ m^2$). An additional third deployment was obtained for the summit site.

2.2. Analyses of sediment organic matter and water content

Chlorophyll-a and phaeopigment analyses were carried out according to Lorenzen and Jeffrey (1980). For all of the stations, pigments were extracted from about 1 g-triplicate superficial (0–1 cm) sediment samples using 5 ml of 90% acetone (incubated 12 h at 4 °C in the dark). Extracts were analyzed fluorometrically to estimate chlorophyll-a, and, after acidification with 200 μl 0.1 N HCl, to estimate phaeopigments. In deep-sea sediments chlorophyll degradation products are typically dominants due to the degraded algal material settled from the upper water column layers. Thus chlorophyll-a concentrations might not be indicative of organic carbon associated with algal material and the sum of chlorophyll-a and phaeopigment concentrations (i.e. total phytopigments) might represents a better estimate (Pusceddu et al., 2010).

The protein, carbohydrate and lipid contents of sediments were determined spectrophotometrically and their concentrations were calculated from calibration curves of bovine serum albumin, glucose and tripalmitine, respectively, and normalized to sediment dry weights (Pusceddu et al., 2004). For each biochemical assay, blanks were obtained using pre-combusted sediments (450 °C for 4 h). For all of the stations, analyses were performed on about 0.2–1 g-triplicate superficial (0–1 cm) sediment samples. Carbohydrate,