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## Macrobenthic community structure in the deep waters of the Red Sea

Thadickal V. Joydas<sup>a,\*</sup>, Mohammad A. Qurban<sup>a,b</sup>, Said M. Ali<sup>a</sup>, Joselito F. Albarau<sup>a</sup>, Lotfi Rabaoui<sup>a</sup>, Karuppasamy P. Manikandan<sup>a</sup>, Mohamed Ashraf<sup>a</sup>, Vassilis P. Papadopoulos<sup>c</sup>, Salvatore Giacobbe<sup>d</sup>, Periyadan K. Krishnakumar<sup>a</sup>

<sup>a</sup> Center for Environment & Water, Research Institute, King Fahd University of Petroleum & Minerals, Dhahran 31261, Saudi Arabia

<sup>b</sup> Geosciences Department, King Fahd University of Petroleum & Minerals, Dhahran 31261, Saudi Arabia

<sup>c</sup> Hellenic Centre for Marine Research, Anavissos, Greece

<sup>d</sup> Department of Chemical, Biological, Pharmaceutical and Environmental Sciences, University of Messina, Messina, Italy

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## ABSTRACT

Even though the Red Sea is characterized by unique oceanographic conditions, only few studies have addressed the ecology of its deep-sea benthos. This work discusses some traits of the Saudi deep waters of the Red Sea between 23°N and 28°N. Macrobenthic samples were collected using a box corer (0.1 m<sup>2</sup> surface area) from 59 stations at depths ranging between 220 m and 1678 m. The stations were categorized into four depth zones ( $\leq 500$  m, 501–750 m, 751–1000 m and  $> 1000$  m) and two latitudinal areas (northern and central) for data analysis. A total of 186 species have been identified including polychaetes (135), crustaceans (27), molluscs (18), echinoderms (3), echiuroid (1), sipunculoid (1), and oligochaete (1). While 114 species were present in only 1–3 stations, only 30 species were found to be widely distributed, being recorded in all depth zones from northern and central areas. The trophic structure analysis indicated high functional diversity with the presence of seven feeding levels represented mainly by surface deposit feeders, facultative detritivores, and benthic carnivores. In general, the density and biomass of the deep sea macrobenthic community studied herein are lower than those reported in other seas with similar depth zones. This is most likely due to the particular environmental factors of the Red Sea, represented mainly by its oligotrophic nature, high temperature, high salinity, and low food availability in the form of organic matter. It is worth noting that some ecological parameters considered showed a general decreasing pattern (density: 10–1666 ind. m<sup>-2</sup>; biomass: 0.02 – 10.98 g m<sup>-2</sup>; species richness S: 1–59; Shannon-Wiener diversity index  $H'$ : 0 – 5.1) in relation with the increasing depth in northern and central areas. The bathymetric trends of the macrobenthic communities were also demonstrated with findings of multivariate analyses. The distribution of benthic communities at all depth zones appeared to be controlled by the availability of organic matter and abiotic factors such as temperature and salinity. Pronounced latitudinal and longitudinal trends in the macrobenthic communities are not evident, most likely due to the limited latitudinal and longitudinal variation of the sampling stations of this study. No spatial variations were found with the feeding types, species evenness index, and species dominance index. Considering the scarcity of published data on the deep benthic community from the Red Sea, this study provides some useful baseline information on this topic and contributes to decrease the knowledge gap on the diversity of macrobenthic communities in this region.

### 1. Introduction

The advances in deep-sea exploration achieved in the recent past have expanded the available knowledge on the ecology, diversity, and evolution of deep-sea benthos (Rowe, 1983; Wilson and Hessler, 1987; Gage and Tyler, 1991; Tunnicliffe, 1991; Young and Eckelbarger, 1994; Snelgrove, 1999; Van Dover, 2000; Rex et al., 2005; Judd and Hovland, 2007; Koslow, 2007; Foucher et al., 2009; McClain et al., 2009; Glover

et al., 2010; Taviani, 2011; German et al., 2011; Chown, 2012; Marsh et al., 2012). The standing stock (density and biomass) and the diversity of the benthic communities in deep-sea ecosystems are generally low as they depend on the flux of organic matter produced in the upper water column (e.g. Sibuet et al., 1989; Levin et al., 2001; Lamshead et al., 2002; Smith et al., 2008). The decrease of the benthic standing stock and diversity with increasing depth is one of the most well-established patterns in marine ecology (Danovaro et al., 2010; Coll et al., 2010). A

\* Corresponding author.

E-mail address: [tvjoydas@kfupm.edu.sa](mailto:tvjoydas@kfupm.edu.sa) (T.V. Joydas).

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similar decreasing trend of these faunal parameters with increasing latitude has also been established (Rex et al., 1993; Rex and Etter, 2010). Different feeding structures have been described among deep-sea benthos showing the prevalence of sub-surface deposit feeders in organic rich sediments contrasting with predominance of surface deposit feeders as well as the presence of a large number of carnivores and scavengers on the oligotrophic abyssal floor (Kroncke et al., 2000; Tselepidis et al., 2000). Where currents are stronger, filter feeders or suspension feeders may become prevalent (Kroncke et al., 2003; Baldrighi et al., 2014). It was also reported that many benthic organisms change their feeding modes depending on the food source (Jumars and Gallagher, 1982; Gage and Tyler, 1991). A vast majority of deep-sea benthic data reported to date are from the Atlantic Ocean (Grassle and Maciolek, 1992; Etter and Grassle, 1992), Mediterranean Sea (Fredj and Laubier, 1985; Cartes et al., 2004; Danovaro et al., 2010), Pacific Ocean (Lambshhead et al., 2002; Gambi et al., 2003), and the Arabian Sea (Gooday et al., 1998; Levin et al., 2000). Despite its unique oceanographic conditions, deep-sea benthic studies reported from the Red Sea are so far scarce (Thiel, 1979, 1980; Thiel et al., 1987; Pfannkuche, 1993; Taviani, 1994, 1998a, 1998b; Janssen and Taviani, 2015).

The semi-enclosed Red Sea basin has depths that exceed 2500 m along its axial trough. Due to the very narrow continental shelf, most of the basin exhibits depths below 200 m making it suitable for the settlement of deep-water benthic life (Taviani et al., 2007). The most important hydrographical feature of the Red Sea is the homogeneously high temperature (about 21.5 °C) below the thermocline until a depth of about 2000 m. This feature results from the separation of the Red Sea by a narrow and shallow sill (about 137 m) from the deep areas of the Indian Ocean characterized by low temperatures (Morcos, 1970; Sofianos et al., 2002). The other important feature of the Red Sea is its high salinity. The very high evaporation rates (over 2 m yr<sup>-1</sup>) make the Red Sea one of the most saline seas in the world (Sofianos et al., 2002). The low rate of primary production and the low concentration of nutrients (particularly nitrate) are evidence of the oligotrophic nature of the northern Red Sea (Qurban et al., 2014a; Wafar et al., 2016a, 2016b). These unique hydrographic conditions suggest that this ecosystem functions differently from those of other deep-sea areas which mostly have temperatures of < 10 °C at corresponding depths (Thiel, 1987). Even the very neighboring Eastern Mediterranean is characterized by less saline and significantly colder deep waters with temperatures around 14 °C all the way down to over 5000 m together with an oligotrophic environment (Baldrighi et al., 2014; Techtmann et al., 2015).

As described in the reviews of Thiel (1980) and Türkay (1996), the first sampling surveys of the deep-sea benthos in the Red Sea were made during the two expeditions on the Austrian/Hungarian Vessel *S.M.S. Pola* during 1895–1896 and 1897–1898 in the northern and southern areas of the Red Sea, respectively (Pott, 1898, 1899; Balss, 1915). During the cruises of Atlantis II Deep (MESEDA) program through *R.V. Sonne* in 1977 (as part of MESEDA-I) and *R.V. Valdivia* in 1979 (as part of MESEDA-II), deep-sea benthos samples from several locations of the Red Sea were collected and studied (Thiel, 1979, 1980). Thiel (1979) published the first quantitative data on benthic meiofauna from five deep-sea locations (below 500 m) at a latitude of ~21°. He reported low faunal densities attributed to the low productivity, distinctive temperature regime with a temperature of 21.5 °C down to a depth of more than 2000 m, and the likely high degradation rates of organic matter. Further studies have also reported a lower density and a biomass than in other subtropical regions with comparable primary production and an enhanced benthic standing stock and metabolic activity south of 18°N (Thiel et al., 1987; Pfannkuche, 1993). The early efforts to compile the taxonomic details of benthic invertebrates of the deep Red Sea reported only 96 taxa (Türkay, 1996), reflecting the scarcity of information available on deep-sea benthos at the time. Janssen and Taviani (2015) improved the knowledge base on deep-sea benthic taxa, reporting 262 molluscan species, based on the samples collected during

the expeditions undertaken between 1977 and 1995. Deep water corals (Marenzeller, 1907; Fricke and Hottinger, 1983; Fricke and Schuhmacher, 1983; Fricke and Knauer, 1986; Taviani et al., 2007; Roder et al., 2013; Qurban et al., 2014b) and molluscs (Sturany, 1900a, 1990b, 1901, 1904; Janssen, 1989; Rützen-Kositzkau, 1999; Janssen and Taviani, 2015) have attracted more research interest than the other taxa such as ostracods (Bonaduce et al., 1983), foraminifera (Edelman-Furstenberg et al., 2001), and cumaceans (Mühlenhardt-Siegel, 2008). Recent studies have described the deep-sea communities (molluscs, polychaetes and sponges) in some of the brine pools of the Red Sea (Batang et al., 2012; Vestheim and Kaartvedt, 2016).

A hypothesis of the annihilation of stenoeious fauna and flora of the Red Sea during the last glacial period due to the high salinity at times of low sea levels has been proposed (Taviani, 1994, 1998a, 1998b). The present-day benthic fauna of the Red Sea is assumed to be due to recolonization during the post-glacial period (Gvirtzman et al., 1977; Taviani, 1998a, 1998c; Taviani et al., 2007). The deep-sea benthos of the Red Sea is facing challenges in surviving in this highly atypical environment (Janssen and Taviani, 2015). Firstly, the fauna has to depend on special reproductive and dispersal mechanisms to cross the shallow sill separating the Red Sea and the Indian Ocean (Janssen and Taviani, 1985). Secondly, the abnormally high salinity and temperature of the deep water are not very conducive for the survival of the larvae (Janssen and Taviani, 2015).

Within the context of the unique oceanographic conditions and the current understanding of the deep-sea macrobenthic communities of the Red Sea, it is conjectured that the structure and composition of the microbenthic communities depend on (i) a low standing stock and diversity compared to other seas with similar depth zones, (ii) the effect of spatial (bathymetric and latitudinal) variations, and (iii) the influence of both hydrographic and sediment structure gradients. During the cruise conducted in November 2012 (on board of *R.V. Aegaeo*) along the northern and central deep Saudi areas (> 200 m depth) of the Red Sea, this hypothesis was tested through (i) the description of the spatial (bathymetric and latitudinal) trends of the abundance, biomass, structural diversity (i.e., alpha diversity) and functional diversity (i.e., feeding guilds) of the macrobenthos, and (ii) testing the effects of environmental factors. Previous studies involving quantitative measurements of deep sea macroinvertebrate communities (including the density and biomass) are very limited spatially (Thiel et al., 1987; Pfannkuche, 1993). Thus, there still is a knowledge gap on the diversity of the deep macrobenthic assemblages of the Red Sea. The present work was conducted to redress this shortcoming and it represents the first complete study on the structure and composition of the deep macrobenthic community of the Red Sea.

## 2. Materials and methods

### 2.1. Sampling strategy

Sediment samples were collected from 59 stations on 16 transects located between 22° 59' 57.84" N to 27° 44' 52.065" N latitude and 35° 2' 9.229" E to 38° 39' 7.559" E longitude along the Saudi Arabian coast of the Red Sea (Fig. 1, Appendix A). Four stations with a depth in the range of 220–1678 m were located on each transect. Twelve transects (Stations 1–48) were spaced at 28 km intervals and the remaining four (Stations 49 – 64) at 56 km intervals. 15% of the stations had a depth of ≤ 500 m and 85% > 500 m.

The Red Sea basin is generally divided into southern (15–20°N), central (20–24°N), and northern (above 24°N) sections (Batang et al., 2012). This classification was adopted in this study. Sampling was restricted to areas north of 23°N and samples were not collected from the southern part of the Red Sea.

Two benthos samples per station were collected using a 0.1 m<sup>2</sup> box corer. Only the undisturbed samples with an adequate sample volume (sample height ≥ 15 cm) were used in this study. After determining that

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