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Seasonal variations and trophic ecology of microzooplankton in the southeastern Arabian Sea

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ABSTRACT

The seasonal ecological response of microzooplankton in the southeastern Arabian Sea is presented. During the spring intermonsoon period, stratification and depletion of nitrate in the surface waters (nitracline was at 60 m depth) cause low integrated chlorophyll *a* (av. $19 \pm 11.3\,\mathrm{mg\,m^{-2}}$) and primary production (av. $164 \pm 91\,\mathrm{mgC\,m^{-2}\,d^{-1}}$). On the other hand, nutrient enrichment associated with coastal upwelling and river influx during the onset and peak summer monsoon resulted in high integrated chlorophyll *a* (av. $21 \pm 6\,\mathrm{mg\,m^{-2}}$ and av. $29 \pm 21\,\mathrm{mg\,m^{-2}}$, respectively) and primary production (av. $255 \pm 94\,\mathrm{mgC\,m^{-2}\,d^{-1}}$ and av. $335 \pm 278\,\mathrm{mgC\,m^{-2}\,d^{-1}}$, respectively). During all three periods, diazotropic cyanobacterium *Trichodesmium erythraeum* dominated in the nutrient depleted surface waters. A general increase in abundance of larger diatoms was evident in the surface waters of the inshore region during monsoon periods. The microzooplankton abundance was found to be significantly higher during the spring intermonsoon (av.$241 \pm 113 \times 10^3\,\mathrm{ind\,m^{-2}}$) as compared to onset of summer monsoon (av. $105 \pm 89 \times 10^3\,\mathrm{ind\,m^{-2}}$) and peak summer monsoon (av.$185 \pm 175 \times 10^3\,\mathrm{ind\,m^{-2}}$). Microzooplankton community during the spring intermonsoon was numerically dominated by ciliates while heterotrophic dinoflagellate was the dominant ones during the monsoon periods. The high abundance of ciliates during the spring intermonsoon could be attributed to the stratified environmental condition prevailed in the study area which favors high abundance of smaller phytoplankton and cyanobacteria, the most preferred food of ciliates. On the other hand, the dominance of heterotrophic dinoflagellates during the monsoon periods could be linked to their ability to graze larger diatoms which were abundant during the monsoon periods. The overall results show low abundance of microzooplankton in the eastern Arabian Sea during the monsoon periods mainly due to a decline in ciliates abundance. This decline during the monsoon periods could be the result of (a) low abundance of smaller phytoplankton and (b) high stock of mesozooplankton predators (av. $245\,\mathrm{ml}\ 100\,\mathrm{m^{-3}}$).

1. Introduction

The microzooplankton (MZP), heterotrophic plankton with body size 20–200 μm, plays an important role in marine pelagic ecosystems in transferring primary organic carbon to higher trophic levels (Dussart, 1963; Godhantaraman and Uye, 2004). They are mostly comprised of ciliates, heterotrophic dinoflagellates and crustacean nauplii, capable of exploiting pico and nanoplankton that are inefficiently utilized by other larger zooplankton (Marshall, 1973; Nival and Nival, 1976). MZP also acts as a significant food source for a variety of zooplankton and vertebrate predators (Robertson, 1983; Stoecker and Capuzzo, 1990; Fukami et al., 1999), thereby acting as a trophic intermediate between pico/nano plankton and mesozooplankton.

Studies have also shown that MZP dominates among grazers of tropical oceanic phytoplankton in the Pacific Ocean (Miller, 1993), Atlantic Ocean (Burkill et al., 1993a; Verity et al., 1993) and Indian Ocean (Burkill et al., 1993b). The high growth rates of MZP enable them to respond rapidly to changes in phytoplankton communities, resulting in a close coupling between primary producers and grazers within the food web (Verity et al., 1993; Landry et al., 1995). MZP are also known to be a critical link that transfers organic carbon from heterotrophic bacteria to higher trophic levels through the microbial loop (Azam et al., 1983). In the Arabian Sea, the microbial loop seems to play a significant role in maintaining high mesozooplankton biomass throughout the year (Madhupratap et al., 1996).

In spite of the crucial ecological importance of MZP in marine pelagic food webs, information on their diversity, abundance and

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biomass from the eastern Arabian Sea are lacking. The limited information available highlights their important functional role in the eastern Arabian Sea in mediating transfer of phytoplankton and bacterial carbon to higher trophic level (Gauns et al., 1996). On this backdrop, we studied the MZP community of the eastern Arabian Sea with respect to the environmental changes during the spring intermonsoon (SIM), onset of the summer monsoon (OSM) and peak summer monsoon (PSM) with the following objectives (a) to generate baseline information on their composition, abundance, diversity and ecology; (b) to characterize them with respect to the environmental changes from SIM to PSM periods and (c) to understand their relationship with the mesozooplankton community.

2. Materials and methods

2.1. Study area

The area of investigation was the southeastern Arabian Sea (8–15°N and 69–77°E), bordered by the Indian subcontinent on the eastern side (Fig. 1). This region has unique oceanographic features mainly with respect to the monsoonal winds, which drive near-surface currents and affect mixed layer development, hence nutrient availability in the upper euphotic zone. Based on the diverse oceanographic features of the study area, seasons are mainly classified into spring intermonsoon (March–May), summer monsoon (June–September) and winter monsoon (November–February).

The SIM is a transition period from winter to summer monsoons. During this period, the eastern Arabian Sea is exposed to intense solar heating (summer) and characterized by weak winds, making the surface layer of the ocean stratified (Muraleedharan and Prasanna Kumar, 1996). In addition, the low saline oligotrophic Bay of Bengal water that occupies the surface layers of the southeastern Arabian Sea (Fig. 2) intensifies the stratification during SIM period (Sanilkumar et al., 2003). Besides, the small amount of rainfall on the Indian subcontinent during the period causes a reduction in the volume of nutrient-rich river influx closer to the coast (Qasim, 2003). The combined effect of these processes cause depletion of nutrients in the upper euphotic zone (upper 60 m of the water column has near-zero concentrations of nitrate). This eventually leads to low primary production and phytoplankton abundance in the southeastern Arabian Sea during the SIM (Bhattathiri et al., 1996).

With the OSM, nutrient concentrations in the inshore surface waters increase due to coastal upwelling resulting in enhanced biological production (Madhupratap et al., 1990; Nair et al., 1992). The onset of upwelling occurs at the southern part of the west coast of India by the end of May–early June, propagating northwards with time (Madhupratap et al., 2001). Apart from upwelling, nutrient-rich river runoff also stimulates biological production along the southwest coast of India (Madhupratap et al., 2001; Nair et al., 1992). The resulting high nutrient content in the surface waters induces proliferation of diatoms (Madhupratap et al., 1990; Nair et al., 1992; Sawant and Madhupratap, 1996).

During the PSM, wind along the southwest coast of India attains its peak velocity intensifying the coastal upwelling (Shankar et al., 2002a). As a result, the vertical advection of nutrient-rich subsurface waters also increases resulting in high availability of macronutrients in the surface. In addition to this, increased nutrient-rich freshwater influx from the westward flowing Indian rivers maintains high level of macronutrient availability in the waters closer to the coast. The combined effect of both processes creates a nutrient-rich environment along the southwest coast of India during the PSM which supports the highest annual phytoplankton stock and production (Madhupratap, 1990; Banse et al., 1996).

2.2. Methods

Seasonal samplings were carried out onboard *FORV Sagar Sampada* during the SIM (19 March–7 April, 2004), OSM (27 May–13 June, 2005) and PSM (25 August–11 September, 2005).

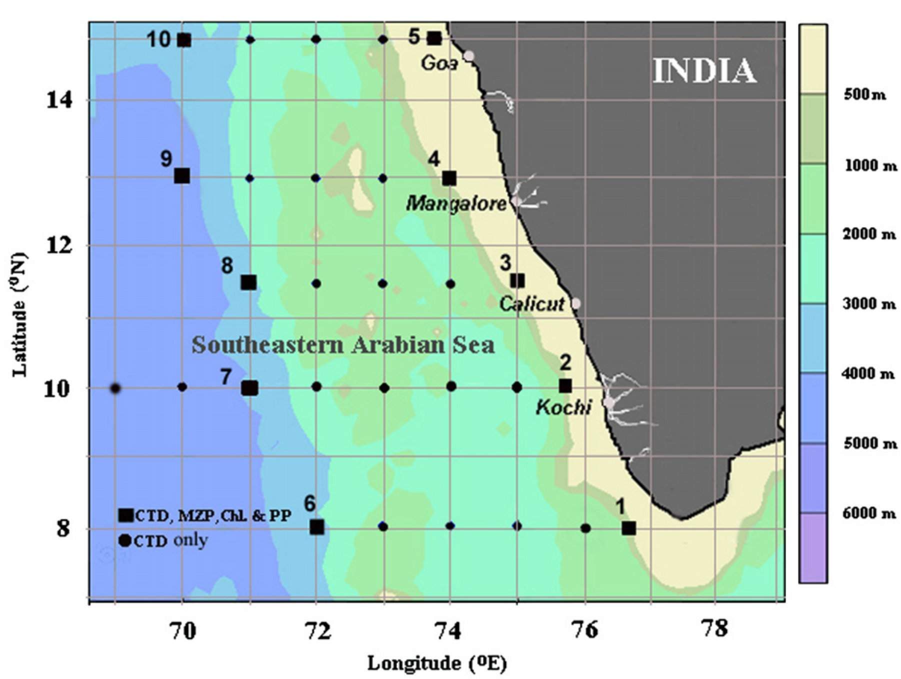

Fig. 1. Station locations.