A first look into the Holocene calcareous dinoflagellate cyst record of the eastern Arabian Sea

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ABSTRACT: Marine microfossil records from the Arabian Sea (AS) are mainly limited to foraminifera, with scanty information on other phyto- and zoo-plankton remains. Calcareous dinoflagellate cysts are one of the rarely studied microfossil groups across the world. In the present study, a calcareous dinoflagellate cyst (dinocyst) record from the eastern Arabian Sea (Off-Goa (SC-26)) during the Holocene is presented. Coccoides (vegetative stage of calcareous dinoflagellates) of *Thoracosphaera heimii*, *Leonella granifera* shows a dominance of 82–92% of the total assemblage suggesting a eutrophic environment throughout the studied period. The relative percentage of the dominant species *T. heimii* and *L. granifera* shows an opposite trend. The high relative abundance of *Calciodinellum* species during the early Holocene (prior to 10 ka BP) indicates a comparatively warm and low productivity environment compared with the late Holocene. A strengthening trend in the monsoon during the Holocene since 10 ka BP is reflected by the gradual increase in *L. granifera*, which is a runoff/terrestrial nutrient indicator. The high relative abundance of *L. granifera*, eutrophic taxa, and TOC since 6 ka BP reveals high primary productivity during middle to late Holocene compared with the early Holocene in the eastern Arabian Sea. Sand % which reflects runoff and *L. granifera* records show high similarity revealing that *L. granifera* % can be used as a terrestrial nutrient indicator, which has been suggested previously in studies from the Mediterranean Sea and South Atlantic. This record reveals the potential of calcareous dinoflagellate cysts to reconstruct monsoon variation, particularly runoff changes, in the Arabian Sea.

Keywords: Indian Ocean, Monsoon; Primary productivity, Runoff, Calcareous dinoflagellate cysts.

INTRODUCTION

The Arabian Sea is one of the most productive regions in the world, lying in the low latitudes (Bauer et al. 1991). The biological productivity in the Arabian Sea is profoundly influenced by seasonally reversing monsoon winds and associated processes, i.e., upwelling and winter mixing (Brink 1998; Kumar et al. 2001). These processes show spatial and temporal heterogeneity in the Arabian Sea (Gupta et al. 2003; Reichert et al. 2004; Singh et al. 2006; 2011). The summer monsoon induces intense upwelling in the western part and it is comparatively less intensified in the eastern part. The winter monsoon induces convective mixing which is prominent in the northern Arabian Sea (north of 10°N) and weaker in the remaining basin (Prasanna Kumar 1996). The southeastern Arabian Sea receives high runoff discharge from the Western Ghats during the summer monsoon which enhances productivity locally (Sarkar et al. 2000). Several studies have reported the variation in the strength of summer and winter monsoon during glacial and interglacial time scales based on the biotic and geochemical proxies (Sarkar et al. 2000; Thamban et al. 2001; Pattan et al. 2003; Singh et al. 2006; 2011; Pattan and Pearson 2009; Carbarcos et al., 2014; Naik et al. 2016). Monsoon records utilizing biotic proxies are mainly limited to foraminiferal and temporally contrasting productivity variation in the different proxies within the last glacial cycle is recorded from the eastern Arabian Sea (Singh et al. 2011; Cabarcos et al. 2014).

Dinoflagellates represent one of the major phytoplanktons with a benthic resting stage. They produce species-specific cysts that can fossilize in ocean sediments (Head 1996). The cyst wall may be organic or calcareous walled. Calcareous dinoflagellates are primary producers and live in the photic zone in the oceans. Their distribution is highly influenced by the environmental parameters including nutrients, light availability, temperature, and salinity (Esper et al. 2000; 2004; Zonneveld et al. 2000; 2005; Meier and Willems 2003; Vink 2004; Richter et al. 2007; Bison et al. 2009). In the last two decades, several studies have demonstrated their utility in palaeoclimate and paleoceanographic studies (Esper et al. 2000; 2004; Zonneveld et al. 2000; 2005; Meier and Willems 2003; Meir et al. 2004; Vink 2004; Richter et al. 2007; Bison et al. 2009; Heinrich and Zonneveld 2013).

While numerous studies are present on the organic walled dinoflagellate cysts (Narale et al. 2015; Uddandam et al. 2018), calcareous dinoflagellate cysts proxy is relatively a recent development. Calcareous dinoflagellate studies are also sparse from the eastern Arabian Sea. Previous calcareous dinoflagellate cysts studies from the southwestern and northeastern Arabian Sea oxygen minima zone (OMZ) surficial sediments emphasize their potentiality to reflect unaltered primary productivity signals (Wendler et al. 2002). Dinoflagellate cysts species are also found to sensitive to the terrestrial nutrient input (Wendler 2002). In the northern Indian monsoon summer monsoon runoff