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Monsoon driven changes in phytoplankton populations in the eastern Arabian Sea as revealed by microscopy and HPLC pigment analysis

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Abstract

Like the rest of the Arabian Sea, the west coast of India is subject to semi-annual wind reversals associated with the monsoon cycle that result in two periods of elevated phytoplankton productivity, one during the northeast (NE) monsoon (November–February) and the other during the southwest (SW) monsoon (June–September). Although the seasonality of phytoplankton biomass in these coastal waters is well known, the abundance and composition of phytoplankton populations associated with this distinct and predictable seasonal cycle is poorly known. Here we present for the first time, the results of a study on the community structure of phytoplankton for this region, derived from HPLC pigment analysis and microscopic cell counts. Our sampling strategy allowed for large spatial and temporal coverage over regions representative of the coastal and offshore waters, and over seasons that included the NE and the SW monsoon. Monthly observations at a fixed coastal station in particular, allowed us to follow changes in phytoplankton community structure associated with the development of anoxia. Together these measurements helped establish a pattern of seasonal change of three major groups of phytoplankton: diatoms, dinoflagellates and cyanobacteria that appeared to be tightly coupled with hydrographic and chemical changes associated with the monsoonal cycle. During the SW monsoon when nitrate concentrations were high, diatoms were dominant but prymnesiophytes were present as well. By October, as nitrate fell to below detection levels and anoxic conditions began to develop on the shelf below the shallow pycnocline, both diatom and prymensiophytes declined sharply giving way to dinoflagellates. In the well oxygenated surface waters, where both nitrate and ammonium were below detection limits, pico-cyanobacterial populations became dominant.

During the NE monsoon, a mixed diatom-dinoflagellate population was quickly replaced by blooms of *Trichodesmium erythraeum* and *Noctiluca miliaris* with higher amounts of zeaxanthin, β-carotene, Chl *b* and prasinoxanthin. *Trichodesmium* trichomes were noticed in the water column as early as December when nitrate concentrations became limiting. The low phytoplankton biomass and high ammonium concentrations argue that active grazing populations may be responsible for preventing diatom-dinoflagellate populations from establishing themselves to bloom proportions in the eastern Arabian Sea during the early NE monsoon. *Trichodesmium* continued its dominance well into May, when nutrient enrichment associated with its death and decay helped simulate the growth of both diatoms and dinoflagellates. Given that anoxic conditions are becoming more pervasive in the eastern Arabian Sea, our observations in

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particular, those of a shift towards dinoflagellate dominance during the development of anoxia assume particular importance.

Keywords: Phytoplankton; Pigments; HPLC; Chemotaxonomy; West coast of India

1. Introduction

Extensive measurements of Chl *a* in the eastern Arabian Sea prior to, and during the comprehensive, multinational Joint Global Ocean Flux Study (JGOFS) have helped establish the distinct and predictable oscillations in phytoplankton biomass that are strongly linked to monsoonal wind-driven forcing during the NE and SW monsoons (Goes et al., 1992; Banse and English, 1993, 2000; Madhupratap et al., 1996; Prasanna Kumar et al., 2001). The increase in phytoplankton biomass to bloom proportions during these two periods is responsible for high rates of primary production and carbon export measured using moored sediment trap arrays (Nair et al., 1989; Haake et al., 1993). Yet very little information is available on the composition of phytoplankton associated with these blooms, even though such information is vital for biogeochemical process and food web studies including fisheries (John and Menon, 1942).

Along the west coast of India, since the early 1940s the method of choice for studying phytoplankton diversity has been microscopy (Chacko, 1942; John and Menon, 1942; Subrahmanyan, 1959; Subrahmanyan and Sarma, 1961, 1967; Devassy et al., 1978, 1979; Devassy and Goes, 1988; Sawant and Madhupratap, 1996). Although the data sets obtained have provided valuable insights into the diversity of phytoplankton, such information has been limited to regions very close to the coast. In addition, even though microscopic identifications are highly specialized, very often the sample preservation for microscopy can result in significant losses of fragile forms of phytoplankton unable to retain their integrity (Throndsen, 1978).

As an alternative and complement to microscopic examination, photosynthetic and non-photosynthetic pigment distributions can be used to identify the presence of different algal groups (Wright et al., 1991; Jeffrey et al., 1997; Bidigare and Charles, 2002). Accessory pigments can provide class-specific differentiation, allowing for the recognition of major taxonomic groups of marine phytoplankton (Wright et al., 1991). Over the last 20 years, the development of high performance liquid chromatography (HPLC) has greatly advanced our understanding of phytoplankton pigment composition and functionality in response to ecosystem changes (Wright et al., 1991; Barlow et al., 1999). In the western and central Arabian Sea for example, HPLC-analyzed pigments helped provide new information as well as a better understanding of changes in phytoplankton populations associated with the seasonal cycle of the monsoons (Latasa and Bidigare, 1998; Barlow et al., 1999; Goericke, 2002; Brown et al., 2002).

In this study, we have examined the variability of HPLC-derived phytoplankton pigments in conjunction with microscopic analysis of preserved seawater samples to understand the distribution, abundance and composition of phytoplankton in the eastern Arabian Sea in response to monsoonal forcing. A wide and varied sampling strategy offshore as well as close to the coast ensured a comprehensive investigation on the seasonality of phytoplankton during the SW monsoon (June–August) when upwelling occurs along the west coast of India (Shetye et al., 1990), during the NE monsoon (November–February) when winter cooling takes place (Banse and English, 1993, 2000; Madhupratap et al., 1996; Prasanna Kumar et al., 2001) and during the inter-monsoon (March–May) when the water column becomes highly stratified and devoid of nutrients (DeSouza et al., 1996). More frequent sampling in the coastal regions in particular allowed us to investigate phytoplankton populations associated with the seasonal development of anoxia along the coast (Naqvi et al., 2000). This study constitutes the first report on HPLC-analyzed phytoplankton pigment distribution in the coastal and offshore regions along the west coast of India in the eastern Arabian Sea. By comparing pigment signatures with information on phytoplankton species composition derived from microscopy, we have also attempted to highlight some of the limitations of utilizing microscopic methods alone to study community changes.