Spatial and Temporal Variations in Phytoplankton Bio-Diversity of Arabian Sea

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ABSTRACT

Phytoplankton samples of North Eastern Arabian Sea were collected during remote sensing cruise from 2003-2009. Phytoplankton types were studied and its community organization and distribution was analyzed using Shannon's Diversity Index. The results showed that *Chaetoceros*, *Navicula* and *Rhizosolenia* were most abundant among the diatoms. *Ceratium* and *Protoperidinium* were the dominant dinoflgellates. *Noctiluca* (dinoflagellate) dominated the open ocean waters whereas *Trichodesmium* (cyanobacteria) dominated the shallow coastal waters.

Keywords: Phytoplankton, Shannon's Diversity Index, dinoflgellates, chlorophyll

INTRODUCTION

Phytoplankton are predominantly single celled and microscopic (0.5 to 250 μm). They are green plants with chlorophyll pigments for photosynthesis and are mostly confined to the surface illuminated layers of the ocean. They are ubiquitous and abundant upto 10^5 cells per ml. It controls the color of water and is detectable from space. It consumes CO_2 and controls the ocean carbon cycles and climate.

Phytoplankton plays two important ecological roles. Firstly, they fix inorganic carbon and convert solar (light) energy to chemical energy. In this process they convert CO_2 to organic carbon. Their rate of growth and carbon fixation is called primary production. As the phytoplankton die, they sink into the abyss and sequester carbon in the deep ocean, in a process called the biological pump. Secondly, they form the base of the marine food web. Small oceanic animals such as zooplankton derive their energy by grazing on phytoplankton. In turn larger species of fishes and

mammals consume these zooplanktons.

Although 70% of the Earth's surface is occupied by the oceans, our knowledge of biodiversity patterns in marine phytoplankton is very limited in comparison to that of the biodiversity of plants on the land (Irigoien *et al*., 2004). It is well established that diversity enhances productivity and stability in communities of higher organisms; however, knowledge of such relationships between unicellular organisms like phytoplankton, which contribute to about 50% to the global primary productivity, is still lacking (Ptacnik *et al.*, 2008).

In this study we have tried to analyze phytoplankton richness, its spatial and temporal variability for winter and inter monsoon seasons, along with its community structure using Shannon's Diversity Index. Chlorophyll-a concentration was studied as a function of phytoplankton diversity and correlated with phytoplankton cell counts at various light levels for both winter and inter monsoon season. Remote sensing was additionally used as a tool to support the *in-situ* data for phytoplankton distribution and chlorophyll concentration.

Study area

The Site selected for this study was Northern and Eastern section of Arabian Sea, which occupying an area 6.225 x 10^6 km Sq. and extends from 0º to 25ºN and 50º to 80ºE (Qasim 1977). It is bordered by Oman at the west, Iran at the North-West and the India at the east.

Periyar, Bharathapuzha and Pamba rivers from Kerala; Kali, Netravati and Sharavati rivers from Karnataka, Tiracol, Chapora, Baga, Mandovi and Zuari rivers from Goa; Shastri, Gad, Vashishti, Savitri, Patalganga, Ulhas and Vaitarna rivers from Maharashtra; Tapti, Narmada, Mahi and Sabarmati rivers from Gujarat and Indus from Pakistan bring fresh water into Arabian Sea (www.museumstuff.com). Phytoplankton samples of North Eastern Arabian Sea were collected during ship cruises organized for ocean colour satellite validation from 2003-2007 as shown in figure 1. The details of samples collected and analyzed for various cruises are summarized in table 1.

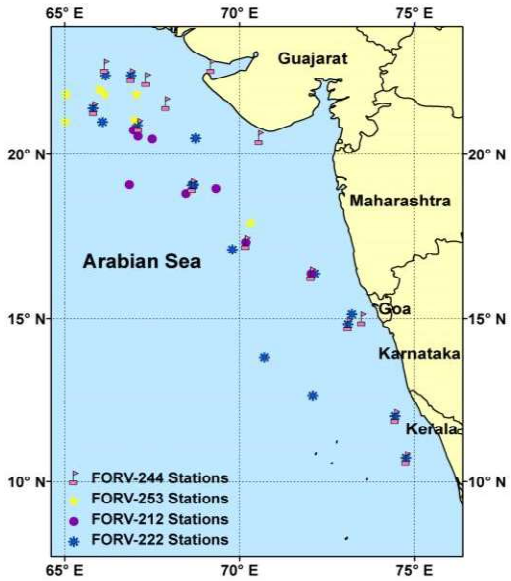


Fig-1 Map of stations at various cruises showing sites of sample

Table-1 Details of the cruise, season, sampling stations and depths

Cruise Id	Period of Study/season	No. of stations analysed	Sampling Depths
FORV-212	27th February to 5th March 2003, Winter-Monsoon	5	100% light level (Surface) only.
FORV-222	21th February to 11th March 2004, Winter-Monsoon	3	100% light level (Surface) only.
FORV-244	15th April to 28th April 2006, Inter-Monsoon	15	100% light level (Surface), to 1 % light level.
FORV-253	**28th February to 11th March 2007, Winter-Monsoon**	**8**	**100% light level (Surface), to 1 % light level.**

METHODOLOGY AND DATA ANALYSIS

The water samples were collected from various sampling stations, which were decided on the basis of percent light intensity/ penetration with reference to the surface irradiance in the water column. Satlantic under water Hyper-spectral radiometer was used to measure the light levels at the sampling sites.

For microscopic identification and cell counts 500 ml of sea water was fixed with 1% lugol's Iodine and preserved in 3 % buffered formaldehyde solution and stored under dark and cool conditions till analysis. Samples were concentrated approximately to 5-10 ml by siphoning the top layer of the sample carefully with a tube, 1ml of sample were transferred to a SedgwickRafter slide and identified and counted using an Olympus Inverted Microscope (Model IX 50) at 200 % magnification. Standard taxonomic keys (Tomas, 1997) were used for identification. The cruises were temporally categorized into winter-monsoon (Dec-March) and inter-monsoon (April-May) to better understand the seasonal variation in phytoplankton type and concentration. Surface diversity (at 0m depth) was evaluated for FORV-212 and FORV-22 whereas surface as well as depth wise (vertical profile) evaluation of diversity was carried out for FORV-244 and FORV-253. For analyzing the community structure of phytoplankton in the North-Eastern Arabian Sea the index was calculated as follows:

Shannon Diversity Index:

This index is applied to biological systems very commonly for calculating diversity. It was derived from a mathematical formula by Shannon in 1948 (Mandaville 2002).

$H' = -\Sigma [(ni / N) \times \ln (ni / N)]$

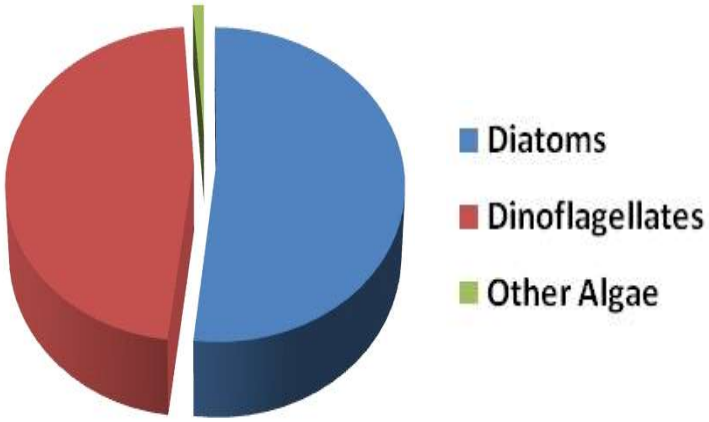
Where : H': Shannon Diversity Index ni: Number of individuals belonging to i species

N: Total number of individuals

RESULT AND DISCUSSION

Phytoplankton Richness

The phytoplankton community structure of the Arabian Sea was highly diverse with 274 species identified. Diatoms (Bacillariophyceae) exhibited the greatest diversity with 142 species followed by dinoflagellates (Dinophyceae) 129 species; other Algae (Cyanophyceae) with 3 species. Diatoms and dinoflagellates were the most diverse groups. Out of 142 species of diatoms 28% was contributed by three genera: *Chaetoceros* (18 species), *Navicula* (12 species), *Rhizosolenia* (11 species). Of the 129 species of dinoflagellates, 30% were represented by two genera: *Ceratium* (21 species) and *Protoperidinium* (17 species). As a whole, a pronounced prevalence of diatoms was typical for the phytoplankton community in the Arabian Sea during the period of analysis. On an average, diatoms contributed 52% to the total species diversity as shown in figure 2. Their prevalence was at a maximum (70.2%) during the winter-monsoon period, in February and March, and reduced to 65% during the Inter-monsoon period (April to May). Dinoflagellates contributed only 47% to the total species diversity, with 25.4% during the winter-monsoon period, and reduced to 19.24% during the Inter-monsoon period. The remaining 1% was contributed by other algae. 2 Species of *Trichodesmium* represented this category.



Temporal variation in phytoplankton concentration at surface

Total phytoplankton cells observed at the surface (0m depth) of the Arabian Sea ranged from (11 cells/lit to 10440 cells/lit) during 2003 to 2007. This shows that the waters of Arabian Sea are highly productive. Their concentrations in winter monsoon and inter monsoon periods is summarized in table 2 and figures 3 and 4 illustrate their group wise concentration in the two periods. More than half (60%) of the total diatoms was contributed by *Rhizosolenia alata* (10779 cells/lit), *Rhizosolenia shrubsolei* (6552 cells/lit), *Navicula* sp. (4500 cells/lit) and *Rhizosolenia hebatata* (3710 cells/lit). *Noctiluca scintillans* (10440 cells/lit) alone contributed to 68% of the total dinoflagellates in the winter monsoon period. *Trichodesmium erythraeum* (6316 cells/lit) was the greatest contributor (72%) among other algae (Cyanophyceae), in the inter monsoon period. Among dinoflagellates observed in the inter monsoon period, 21% was formed by *Scripsiella trachoidea* (2220 cells/lit) and 14% was formed by *Prorocentrum minimus* (1462 cells/lit).

Among diatoms that occurred in the inter monsoon period, *Navicula* sp. (5782 cells/lit); *Thalassiothrix frauenfeldii* (2504 cells/lit) and *Rhizosolenia fragilissima* (2220 cells/lit) were the major ones.

Table-2 Phytoplankton cell concentration and percent contribution, in winter monsoon and inter monsoon periods and their group wise concentration and percent contribution in the two periods

Total cell Concentration (116525 cells/lit)					
Winter monsoon period			**Inter monsoon period (60867 cells/lit) 52%** (55658 cells/lit) 48%		
Diatoms (42568cells/lit) 70%	**Dinoflagellates** (15407cells/lit) 25%	**Other Algae** (2892cells/lit) 5%	**Diatoms** (36170cells/lit) 65%	**Dinoflagellates** (10714cells/lit) 19%	**Other Algae** (8774cells/lit) 16%

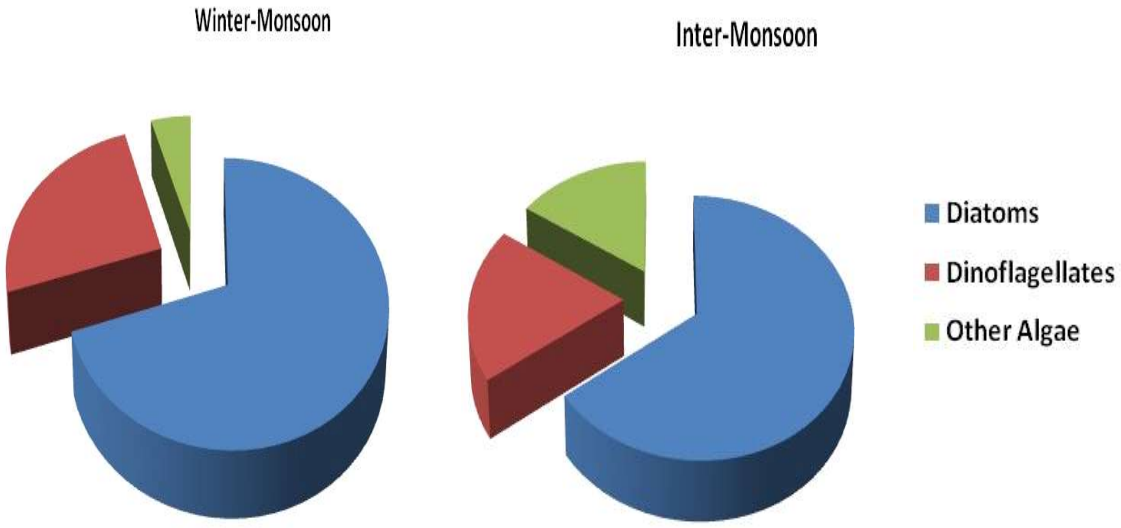


Fig-3 and 4 Percent contribution of diatoms, dinoflagellates and other algae in winter and inter monsoon periods

Spatial variation in phytoplankton concentration at surface

To study the spatial distribution of phytoplankton Arabian Sea was categorized as Coastal (< 50m depth), shelf (50-200m depth), slope (200-500m depth) and Open Ocean (>500m depth). *Noctiluca scintillans* formed massive blooms in the open ocean of northern Arabian Sea covering a large area from 17º19.40'N and 70º11.95'E to 20º28.72'N and 67º30.51'E during winter monsoon period as shown in figure 5. Whereas *Trichodesmium erythraeum* formed bloom in the coastal waters at 20º31.87'N and 70º34.77'E during inter monsoon period as shown in figure 6.

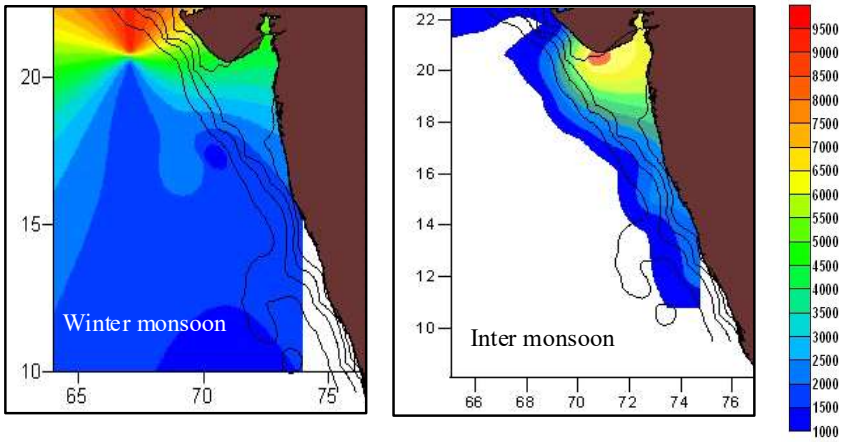


Fig-5 and 6 Spatial distribution of phytoplankton cells over the Arabian Sea during winter and inter monsoon periods. The colour bar shows cell concentration (cells/lit); green to red colour in the map shows the region covered by the bloom.

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