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Research Article

Distribution and Species Composition of Phytoplankton Community in the Coastal Water Off Porbandar - North-Eastern Arabian Sea During Winter Season

Anima Tirkey* and Histesh Solanki

Department of Botany, Bioinformatics and Climate Change Impacts Management, University School of Sciences, Gujarat University, Ahmedabad, Gujarat, India

***Corresponding Author:** Anima Tirkey, Department of Botany, Bioinformatics and Climate Change Impacts Management, University School of Sciences, Gujarat University, Ahmedabad, Gujarat, India.

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Abstract

Phytoplankton are free floating, unicellular, photosynthetic micro-organism, which form the base of the marine food web, providing a vital biological function for all marine life. They live in well illuminated water column (euphotic zone) as they require light for performing photosynthesis. Phytoplankton in the marine ecosystem are composed of several taxonomic groups which together determine total production and their interaction at different trophic levels and also the flux of particulate carbon from the euphotic zone. Composition and distribution of phytoplankton vary from coast to coast according to their respective hydro-biological environmental. Present study aims to understand the composition and distribution of phytoplankton communities during onset of winter in coast of India. Total 144 species of phytoplankton were identified using microscope technique during study period. Diatoms presented the greatest diversity with 105 species, followed by Dinoflagellates with 25 species and other algae with 13 species. Diatoms were observed to be dominant phytoplankton group in term of percent contribution throughout the study period, contributing 60-86% of the total phytoplankton population followed by other algae (11-32%) except at station 6 and dinoflagellate (3-16%). Near shore station showed the high cell density compared to the off shore station (Figure 3) value ranging from 9.54 x 10^4 to 46.90 x 10^4 cell/l and 76. 60 x 10^3 to 95.10 x 10^3 cells/l respectively, which could be probably because of fact that the coastal areas are usually high productive.

Keywords: Phytoplankton Composition; Coastal Waters; Winter Monsoon; North-eastern Arabian Sea

Introduction

Phytoplankton are free floating, unicellular, photosynthetic micro-organism, which form the base of the marine food web, providing a vital biological function for all marine life. It's a key constituent of the marine environment as they are accountable for almost half of the global net primary production [1]. Approximately 25,000 species of phytoplankton have been described and classified among eight major phylogenetic groups [2]. They have the potential to serve as indicators of hydro-climatic change resulting from global warming as well as other environmental impacts, such as ocean acidification due to combustion of fossil fuels and eutrophication. The diversity of phytoplankton outbreak and elimination of some species can be considered as the indication in fluctuations in water quality. Phytoplankton distribution is dynamic and greatly influenced by various physical, chemical and biological processes like Sun-light, temperature, nutrients, grazing and water-column stability. Spatio-temporal variation in phytoplankton composition in response to changes in environmental conditions or the phytoplankton dynamics is thus applicable in illustrating the changing nature of aquatic ecosystems. Composition and distribution of phytoplankton vary from coast to coast according to their respective hydro-biological environmental. Phytoplankton in the marine ecosystem are composed of several taxonomic groups which together determine total production and their interaction at different trophic levels and also the flux of particulate carbon from the euphotic zone [3,4].

The phytoplankton community structure in coastal upwelling zone gets influenced by the temporal changes in physico-chemical parameters with the development of upwelling process. Coastal ecosystems face anthropogenic disturbances such as pollution which add excessive nutrients and subsequently to eutrophication

[5] that can drive marked changes in the phytoplankton community dynamics and hence in its structural characteristics, such as diversity, dominance. Phytoplankton express quick responses to altered nutrient levels by changing their biomass and composition [6]. Phytoplankton communities are made up of a variety of species, each with the unique physiological and morphological feature. The distribution and abundance of these diverse phytoplankton play a crucial role in the development and maintenance of marine ecosystems.

Coastal ecosystem is the most productive ecosystem in the world [7] making a considerable contribution to the coastal economy. Studies of phytoplankton composition, diversity and taxonomy can be useful to determine the marine ecosystem productivity.

Therefore, in pursuance to better understand the dynamics of marine ecosystem it is essential to accurately enumerate phytoplankton biomass and to determine community composition at the species level. The present study is an attempt to understand the phytoplankton community composition in north-west coast of Gujarat, India using microscopic technique.

Materials and Methods

Study area

Gujarat has the longest coastline in India. The total length of coastline of Gujarat is 1600 km. The continental self of Gujarat coast is very wide and having an area of 1,64,183 km^2. Of this 64,810 km^2 is within the depth ranges of 50m and 99373 km^2 within the depth range of 50-200m. The location of Porbandar makes it a significant port in the western coast of India. The global location of Porbandar city is 21.63° north latitude and 69.6° east longitude. For centuries, it has been the only link between the country and the western world. Even today, Porbandar serves as an important port connecting India to many other countries. As Porbandar is located beside the Arabian Sea, fishing and exporting fish naturally form a major part of the city business. Coastal cruise was conducted during the month of December 2014 in the off waters of Porbandar from December 15th 2014 to December 18th 2014 to study the phytoplankton community structure. The sampling transect were decided in three directions as north-west, south-west, and south-east. From each transect 2-3 sampling points were covered. Total 10 station (S1-S10) were covered during study period (Figure 1).

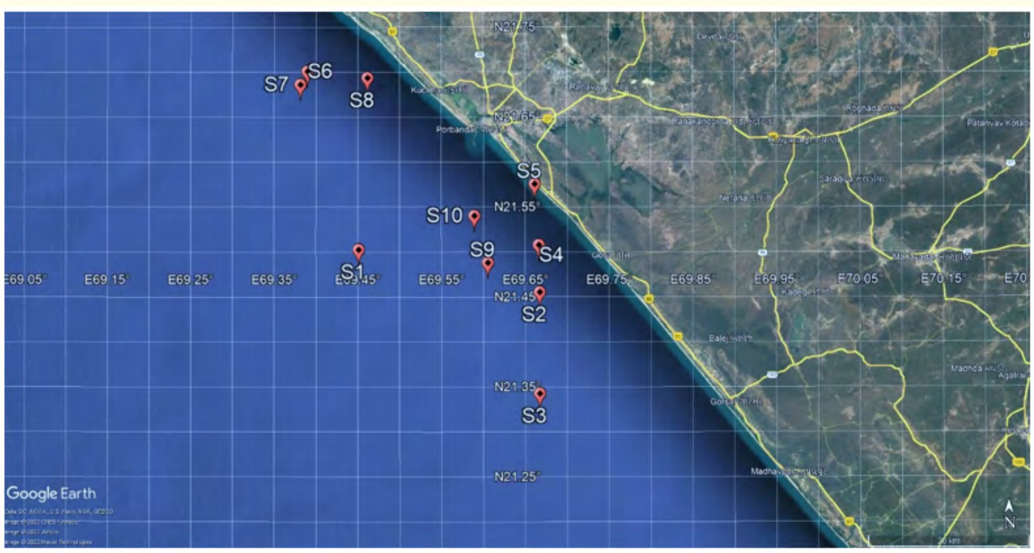

Figure 1: Study area showing the sampling station during study period (S1-S10). S1-S2 covered on 15th Dec, S3-S5 covered 16th Dec, S6-S8 covered on 17th and S9-S10 covered on 18th Dec.

Phytoplankton identification and enumeration

For phytoplankton identification and enumeration, 250 millilitre of water were fixed with 1% of Lugol's Iodine and preserved with 4% formaldehyde solution and further stored under dark and cool (4°C) conditions until microscopic analysis. Samples were concentrated approximately up to 10-15ml by siphoning the top layer of the sample carefully with a tube. 1ml of concentrated sample was transferred to the Sedgwick- Rafter slide and identified and counted using Zeiss® Observer A1 AX10 inverted microscope. Phytoplankton samples were enumerated and identified to the lowest possible taxonomic level using standard taxonomic key [8].

Results

Hydrographical study

During study period the *in-situ* measured sea surface temperature was observed high ranging from 27° C to 28.27 ° C

(Table 1). The pH value of surface water ranged from 8.42-8.91, remained alkaline and did not show much variation during study period. Salinity is one of the essential features which influence the chemical and physical characteristics of coastal waters. The surface salinity value ranged from 35.53 to 36.66 ppt, observed comparatively higher at the off shore stations.

Stations	Temperature	Salinity	pH
S1	27.8°C	36.66 ppt	8.91
S2	28.27°C	36.53 ppt	8.78
S3	27.9°C	36.56 ppt	8.73
S4	28.07°C	36.54 ppt	8.75
S5	27.8°C	35.78 ppt	8.42
S6	27.5°C	36.36 ppt	8.58
S7	27.8°C	36.06 ppt	8.53
S8	28.27°C	35.65 ppt	8.5
S9	27.77°C	36.05 ppt	8.7
S10	27 ˚68C	35.76 ppt	8.72

Table 1: Hydrographical parameter of various station during study period.

Phytoplankton community structure

Total 144 species of phytoplankton were identified using microscope technique during study period. In terms of species richness, Diatoms presented the greatest diversity with 105 species, followed by Dinoflagellates with 26 species and other algae with 13 species. Diatoms were observed to be dominant phytoplankton group in term of percent contribution throughout the study period contributing 60-86% (Figure 2) of the total phytoplankton population followed by other algae (11-32%) except at station 6 and dinoflagellate (3-16%). Among diatoms *Pseudo-nitzschia delicatissima, Pseudo-nitzschia pungens, Thalasisionema frauenfeldii, Thalssionema nitzschiodes, Navicula distans, Navicula directa, Odontella mobiliansis, Odontella aurita, Ditylum brightwellii, Coscinodiscus radiatus, Chaetoceros affinis,* and *Lauderia annulata* were found to be major contributors (Table 2 and 3). Among Dinoflagellate *Podolampas bipes, Prorcentrum micans, Dinophysis caudate, Dinophysis acuminata, Ceratium furca, Gonyaulax spinifera, Ceratium fusus, Scrippsiella trochoidea, Prorcentrum belezianum, Protoperidinium oblongam, Alexandrium tamarens* were main contributors*. Trichodesmium erythraeum, Dictyocha octanaria, Dictyocha fibula and Chrysochromulina sp., Coelosphaerium minutissima, Chlymidomonas sp.* were the common species identified among other algae (Table 2 and 3). Among other algae cyanobacteria, *Trichodesmium erythraeum* was observed to be most dominant species contributing 50-93% throughout the study period. List of all phytoplankton species identified during study period have been listed in table 3 and photo plate 1 shows the micrographic image of different phytoplankton species.

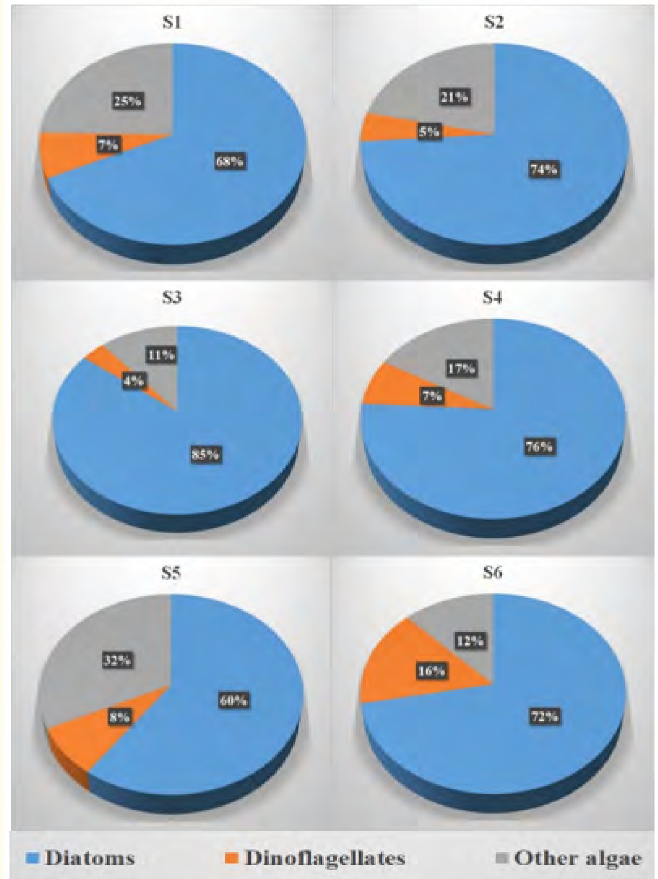

Figure 2: Percent contribution of different phytoplankton groups.

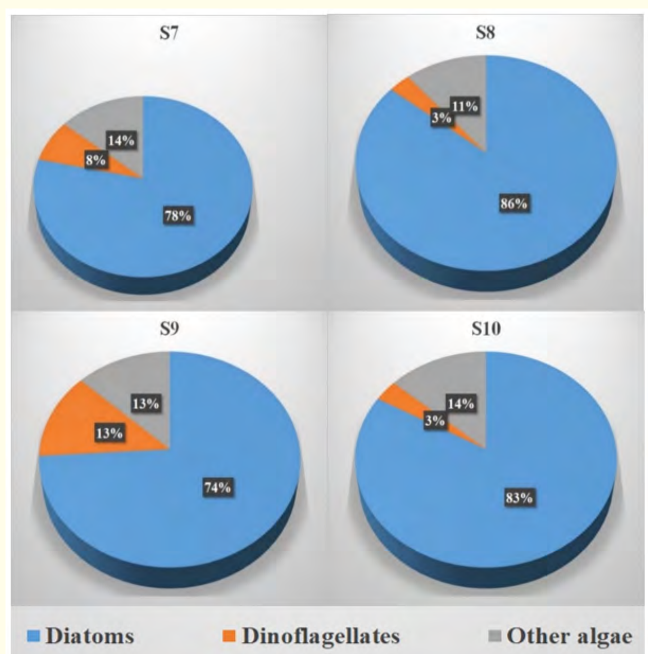

Figure 3: Percent contribution of different phytoplankton groups.

Species	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Diatoms										
Pseudo-nitzschia delicatissima	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Pseudo-nitzschia pungens	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Navicula directa	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Navicula distans	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Guinardia striata	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Proboscia alata	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Eucampia zodiacus	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Cerataulina bicornis	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Nitzschia longissima	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Thalassionema nitzschiodes	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Thalasisionema frauenfeldii	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Odontella mobiliansis	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Skeletonema costatum	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Ditylum brightwellii	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Coscinodiscus marginatus	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Chaetoceros curvisetus	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Chaetoceros affinis	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Coscinosiscus radiatus	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Pleurosigma normanii	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Bacteriastrum delicatulum	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Bacteriastrum elongatum	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Lauderia annulata	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Ditylum brightwellii	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Dactyliosolen phuketensis	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Dinoflagellate										

Podolampas bipes	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Prorocentrum micans	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Gonyaulax spinifera	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Prorocentrum belizeanum	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Scrippsiella trochoidea	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Alexandrium tamarinds	✓	✓	✓	X	✓	✓	✓	✓	✓	✓
Dinophysis caudata	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Dinophysis acuminata	✓	✓	✓	✓	X	✓	✓	✓	✓	✓
Ceratium furca	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Protoperidinium oblongam	✓	✓	X	✓	✓	✓	X	✓	✓	✓
Oxytoxum scolopax	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Amphisolenia bidenta	✓	✓	X	✓	✓	✓	X	✓	✓	✓
Ceratium longipes	✓	✓	✓	✓	X	✓	✓	✓	X	✓
Ceratium fusus	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Other algae										
Trichodesmium erythraeum	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Dictyocha octanaria	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Dictyocha fibula	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Pterospema sp.	✓	X	✓	✓	X	✓	✓	X	✓	✓
Chlamydomanas sp.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Chrysochromulina strobilus	✓	X	✓	✓	X	✓	✓	✓	✓	✓
Coelosphaerium minutissima	✓	✓	X	✓	✓	✓	X	X	✓	X

Table 2: Distribution of most abundant phytoplankton group during study period (tick sign indicate the presence and cross indicate the absence of the phytoplankton species).

	Diatoms	
Actinoptychus sp.	*Coscinodiscus granii*	*Nitzschia braarudii*
Asterionellopsis glacialis	*Coscinodiscus marginatus*	*Nitzschia longissima*
Asterionellopsis sp.	*Coscinodiscus radiatus*	*Nitzschia sicula*
Asteromphalus hookeri	*Cylindrotheca closterium*	*Odontella aurita*
Asteromphalus hyalinus	*Dactyliosolen fragilissimus*	*Odontella mobiliensis*
Asteromphalus sarcophagus	*Dactyliosolen phuketensis*	*Odontella sinensis*
Bacteriastrum comosum	*Detonula confervacea*	*Planktoniella sol*
Bacteriastrum elongatum	*Detonula pumula*	*Pleurosigma normanii*

Bellerochea horologicalis	*Ditylum brightwellii*	*Proboscia alata*
Cerataulina bicornis	*Eucampia cornuta*	*Proboscia alata*
Cerataulina pelagica	*Eucampia zodiacus*	*Pseudo-nitzschia delicatis-sima*
Chaetoceros aequatorialis	*Fragilariopsis doliolus*	*Pseudo-nitzschia granii*
Chaetoceros affinis	*Fragilariopsis oceanica*	*Pseudo-nitzschia heimii*
Chaetoceros compressus	*Guinardia cylindrus*	*Pseudo-nitzschia lineola*
Chaetoceros curvisetus	*Guinardia delicatula*	*Pseudo-nitzschia pungens*
Chaetoceros dadayi	*Guinardia flaccida*	*Pseudo-solenia calcar avis*
Chaetoceros danicus	*Guinardia striata*	*Rhizosolenia embricata*
Chaetoceros dicheta	*Haslea wawrikae*	*Rhizosolenia hebetata*
Chaetoceros dicheta	*Helicotheca tameisis*	*Rhizosolenia setigera*
Chaetoceros lorenzianus	*Lauderia annulata*	*Rhizosolenia styliformia*
Chaetoceros lorenzianus	*Leptocylendrus danicus*	*Skeletonema costatum*
Chaetoceros messanensis	*Leptocylindrus mediterraneus*	*Skeletonema costatum*
Chaetoceros peruvianus	*Lioloma logissima*	*Stephanopyxis turris*
Chaetoceros simplex	*Muneira membrancea*	*Thalasisionema frauenfeldii*
Chaetoceros socialis	*Navicula (vanhoeffeni?)*	*Thalassionema bacillare*
Chaetoceros sp.	*Navicula delicatula*	*Thalassionema nitzschoides*
Chaetoceros sp.	*Navicula directa*	*Thalassiosira delicatula*
Chaetoceros tetrastichon	*Navicula distans*	*Thalassiosira eccentrica*
Chaetoceros wighamii	*Navicula sp.*	*Thalassiosira grasilis*
Climacodium frauenfeldianum	*Navicula sp.*	*Thalassiosira sp.*
Corethron criophillum	*Navicula sp.*	*Thalassiothrix gibberula*
Corethron criophilum	*Navicula vanhoeffenii*	*Thalassiothrix longissima*
Coscinodiscus jonesianus	*Nitzschia bicapiata*	*Thalsssionema nitzschiodes*
Coscinodiscus argus	*Nitzschia bicapita cleve*	*Thalsssiosira glacialis*
Coscinodiscus centralis	*Nitzschia bifurcata*	*Toxarium undulatum*
	Dinoflagellates	
Alexandrium tamarense		*Podolampus sp.*
Amphisolenia bidenta	*Gonyaulax polygrama*	*Prorocentrum balticum*
Ceratium furca	*Gonyaulax spinifera*	*Prorocentrum belezianum*
Ceratium fusus	*Gynodinium sanguianum*	*Prorocentrum micans*
Ceratium longipes	*Noctiluca scintillans*	*Protoperidinium brivipes*
Ceratium trichoceros	*Ornithoceros magiphicus*	*Protoperidinium depressum*
Ceratiun tripos	*Oxytoxum scolopax*	*Protoperidinium oblongam*
Dinophysis acuminata	*Oxytoxum sp.*	*Protoperidinium oceanicum*
Dinophysis caudata	*Podolampas bipes*	*Scrippsiella trochoidea*

	Othe algae	
Bicosta spinifera	*Chrysochromulina strobilus*	*Pterospema sp.*
Cealospherum minutissum	*Diaphaoeca sphaerica*	*Tetraselmis*
Chlamydomanas sp	*Dictyocha fibula*	*Trichodesmium erythraeum*
Chrysochromulina hirta	*Dictyocha octanaria*	*Trichodesmium sp.*
		Umbilicosphaera sibogae

Table 3: List of Phytoplankton species identified during study period.

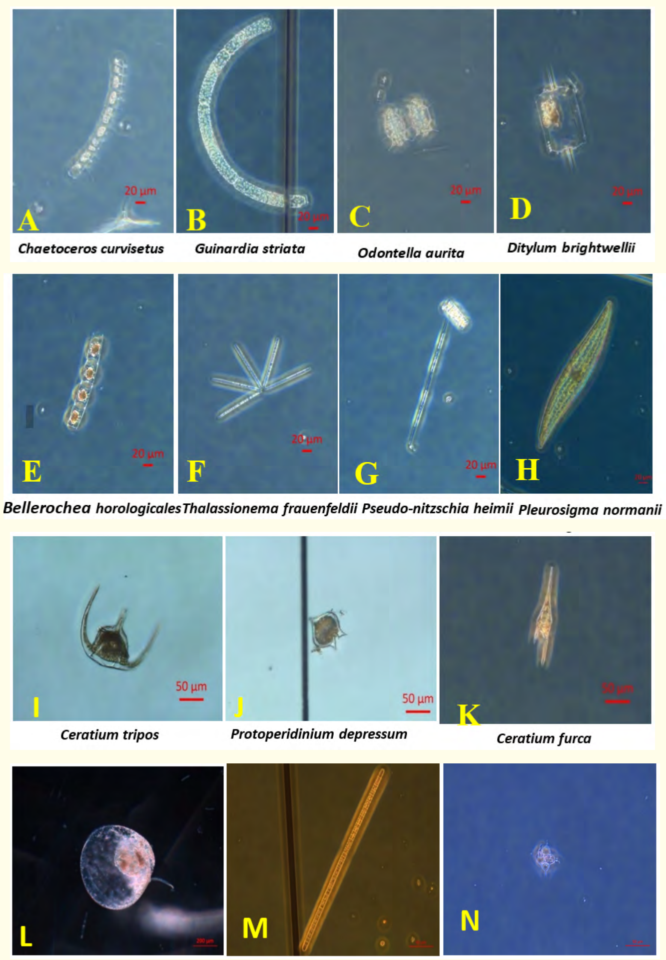

Photo Plate 1: Shows photographic image of some phytoplankton species identified during study period. A-H: Diatoms (A-E are centric diatoms, F-H pennate diatoms), H-L dinoflagellates and M-N other algae.

Phytoplankton abundance

In terms of cell density diatoms exhibited the highest cell count ranging from 4.52 x 10^4 - 40.03 x 10^4 cells/l followed by other algae cell count ranged from 72.73 x 10^3- 7.71 x 10^3 cells/l and dinoflagellates ranged from 3.05 x 10^3- 22.69 X 10^3 cells/l. Near shore station showed the high cell density compared to the off shore station (Figure 3) value ranging from 9.54 x 10^4 to 46.90 x 10^4 cells/l and 76. 60 x 10^3 to 95.10 x 10^3 cells/l respectively, which could be probably because of fact that the coastal areas are usually high productive.

Over all the in terms of cell density centric diatoms were found to be dominating contributing 70. 18 x10^4 cells/l while pennate diatoms contributed 60. 74 x10^4 cells/l. Centric diatoms were found to be dominating at S1, S3, S7 and S9 while pennate diatoms were observed to be dominating at S2, S4, S6, S8 and S10 (figure 4).

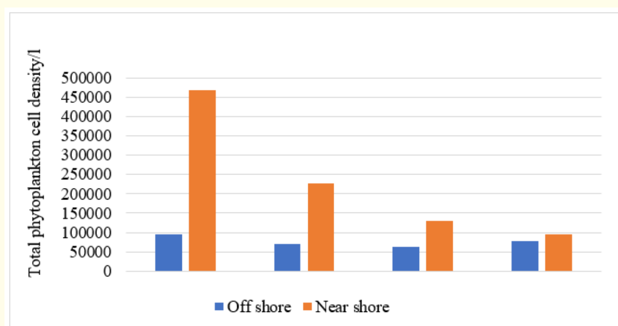

Figure 4: Comparison of total cell density between off shore and near shore station.

Among centric diatoms *Chaetoceros curvisetus, Chaetoceros affinis, Skeletonema costatum, Bacteriastrum delicatulum, Bacteriastrum elongatum, Lauderia annulata, Proboscia alata,* *Guinardia striata, Odontella aurita, Odontella mobiliansis, Ditylum brightwellii,* and *Coscinosiscus radiatus* were the dominating diatoms. *Pseudo-nitzschia delicatissima, Pseudo-nitzschia pungens, Thalassionema nitzschiodes, Thalasisionema frauenfeldii, Navicula directa, Nitzschia longissimi,* and *Navicula distans* were the major contributors among pennate diatoms.

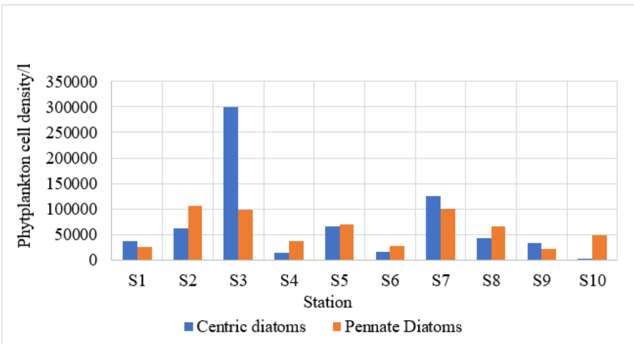

Figure 5: Contribution of centric and pennate diatoms at various stations.

Discussion

The distribution and composition of phytoplanktons are affected by physical parameters, seasonal differences in rainfall and its consequent impact on the spatial distribution of salinity [9]. The surface salinity value ranged from 35.53 to 36.66 ppt, observed comparatively higher at the off shore stations. The pH value of surface water ranged from 8.42-8.91, remained alkaline and did not show much variation during study period. Temperature is one of the significant factors in the coastal environment, which impacts the other physical and chemical environment of coastal ecosystems [10]. *In-situ* measured sea surface temperature was observed high ranging from 27˚C to 28.27˚C**.** Phytoplankton community composition of studied area was found to be very diverse with 144 species of phytoplankton. In terms of species richness, diatoms presented the greatest diversity with 105 species, followed by Dinoflagellates with 26 species and other algae with 13 species. While in terms of cell density diatoms exhibited the highest cell count followed by other algae and dinoflagellates. Usually, diatoms are known for well thriving phytoplankton group in upwelling coastal zone or tide-affected nutrient rich water [11,12], While dinoflagellates have different environmental alternatives, they can proliferate and form mono-specific blooms through onshore-offshore in decreased nutrients, reduced mixing zone and deepened euphotic zone [13]. Dominance of diatoms were also observed by the several authors in coastal waters of west coast of India [14-18]. Diazotrophic cyanobacteria *Trichodesmium erythraeum* was found to be dominating species among other algae, these diazotrophs can flourish in hot weather and high temperature in nitrogen depleted water [19]. Generally, the tropical marine ecosystem are likely to be extremely productive in terms of phytoplankton growth, irrespective of seasons, because of the significant nutrient inputs from a different source [20]. Diatoms are classified into two groups according to their symmetry. The centric diatoms are radially symmetrical, with parts radiating out from the central point. The pennate exhibit bilateral symmetry. Centric diatoms were found to be dominating at S1, S3, S7 and S9 while pennate diatoms were observed to be dominating at S2, S4, S6, S8 and S10 (Figure 4). But overall, in terms of cell count centric diatoms were found to be dominated contributing 70. 18 x10^4 cells/l during study period. Near shore stations were observed with the high cell density compared to the off shore station (Figure 3) which could be probably because of fact that the coastal areas are usually high productive, similar observation has also observed by Jiyalal., *et al.* [21] from Porbandar coast.

Conclusion

Present study identified 144 species of phytoplankton using microscope technique. In terms of species richness, diatoms presented the greatest diversity with 105 species, followed by Dinoflagellates with 26 species and other algae with 13 species. While in terms of cell density diatoms exhibited the highest cell count followed by other algae and dinoflagellates. Centric diatoms were found to be dominating phytoplankton among diatom. Near shore stations were observed with the high cell density compared to the off shore station.

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Bibliography

1. Field CB., *et al*. "Primary production of the biosphere: Integrating terrestrial and oceanic components". *Science* 281 (1998): 237-240.
2. Katz ME., *et al*. "Evolutionary Trajectories and Biogeochemical Impacts of Marine Eukaryotic Phytoplankton". *Annual Review of Ecology, Evolution, and Systematics* 35 (2004): 523-556.
3. Michaels AF and Silver MW. "Primary production, sinking fluxes and the microbial food web". *Deep-Sea Research* 3 (1988): 473-490.
4. Buesseler KO. "The decoupling of production and particulate export in the surface ocean". *Global Biogeochemical Cycles* 12 (1998): 297-310.
5. Paerl HW., *et al*. "Microbial indicators of aquatic ecosystem change: current applications to eutrophication studies". *FEMS Microbiology Ecology* 46 (2003): 233-246.
6. Reynolds C. In: The ecology of phytoplankton. Cambridge University Press, UK (2006): 535.
7. Panda SS., *et al*. "Phytoplankton diversity in response to abiotic factors along Orissa coast, Bay of Bengal". *International Journal of Environmental Science and Technology* 2.3 (2012): 1818-1832.
8. Tomas CR. "Identifying Marine Phytoplankton". Academic press, New York, NY, USA, (1997).
9. Twomey L and John J. "Effects of rainfall and salt-edge movement on phytoplankton sucession in the Swan-Canning Estuary, Western Australia". *Hydrological Processes* 15 (2001): 2655-2669.
10. Sundaramanickam A., *et al*. "A comparative study of physico-chemical investigation along Parangipettai and Cuddalore coast". *Journal of Environmental Science and Technology* 1.1 (2008): 1-10.
11. Margalef R. "Life-forms of phytoplankton as survival alternatives in an unstable environment". *Oceanologica Acta* 1 (1978): 493-509.
12. Odebrecht C., *et al*. "Surf zone diatoms: a review of the drivers, patterns and role in sandy beaches food chains". *Estuarine, Coastal and Shelf Science* 150 (2014): 24-35.
13. Smayda TJ., *et al*. "Strategies of marine dinoflagellate survival and some rules of assembly". *Journal of Sea Research* 49 (2003): 95-106.
14. George B., *et al*. "Study on the influence of hydro-chemical parameters on phytoplankton distribution along Tapi estuarine area of Gulf of Khambhat, India". *Egyptian Journal of Aquatic Research* 38 (2012): 157-170.
15. Temkar GS., *et al*. "Correlation of phytoplankton density with certain hydrological parameters along the coastal waters of Veraval, Gujarat". *Journal of the Marine Biological Association of India* 57.2 (2015).
16. Senthilkumar S., *et al*. "Diversity of phytoplankton in Vellar estuary, southeast coast of India". In: The 5th Indian fisheries forum Proceedings, Mangalore (2002): 245-248.
17. Thakur B., *et al*. "Phytoplankton diversity at some selected sites of the Gulf of Kachchh, Gujarat, India". *Bulletin of Environmental and Scientific Research* 4.4 (2015): 7-12.
18. Tiwari LR and Nair VR. "Ecology of phytoplankton from Dharamtar creek, west coast of India". I*ndian Journal of Geo-Marine Sciences* 27 (1998): 302-309.
19. Sellner KG. "Physiology, ecology, and toxic properties of marine cyanobacteria blooms". *Limnology and Oceanography* 42 (1997): 1089-1104.
20. Estrada M., *et al*. "Phytoplankton across tropical and subtropical regions of the Atlantic, Indian and Pacific oceans". *PLoS One* 11.3 (2016).
21. Jiyalal MR., *et al*. "Phytoplankton Distribution in the coastal waters off Porbandar (Saurashtra)". *Journal of the Indian Fisheries Association* 18 (1988): 357-367.