

## Distribution of phytoplankton in the coastal waters of east coast of India

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Received 13 May 2003, revised 12 May 2004

In the present study qualitative and quantitative distribution of phytoplankton with regional and seasonal variations in the coastal waters of east coast of India are presented out of the pooled data of 292 stations sampled during 12 cruises of FORV *Sagar Sampada* from 1999 to 2002. The study recorded 131 species of dinoflagellates, 111 species of diatoms and 7 species of Cyanophyta. Southeast coastal region has more endemic forms (34 species) than the northeast region (29 species). Quantitatively very low mean densities (1 to 367 nos l<sup>-1</sup>) are observed. Regionally, 143 species are present at all the latitudes between 11°N and 20°N. Seasonally, monsoon season recorded more number of phytoplankton (193) species. The study indicates the high diversity and low production of phytoplankton in the coastal waters of east coast of India.

[**Keywords:** Phytoplankton, coastal waters, east coast of India]

[**IPC Code :** Int. Cl.<sup>7</sup> AO1]

### Introduction

Under favourable conditions, marine phytoplankton occur in large numbers and form blooms. Besides the normal and periodical blooms of phytoplankton, exceptional/harmful algal blooms also occur<sup>1</sup>. Earlier works<sup>2-11</sup> on phytoplankton distribution were confined to specific regions in Indian waters and data on regional and seasonal distribution of phytoplankton were meagre. The present paper gives the qualitative and quantitative distribution of phytoplankton in a comprehensive way with regional and seasonal variations in the coastal waters of east coast of India as this information forms the database on biodiversity and production of phytoplankton species of coastal water bodies besides their significance in trophic dynamics and in identifying water masses.

### Materials and Methods

The phytoplankton samples were collected during the cruises of FORV *Sagar Sampada* from January 1999 to August 2002 in the coastal waters, along east coast of India (Fig. 1). The present study includes the data collected from 292 stations spread over 12 cruises conducted between 1999 and 2002 (Table 1). At each station, phytoplankton samples were collected by filtering 50 litres of surface seawater samples through a plankton net cloth (pore size: 20 µm) and preserved in 2% formaldehyde. Data on physico-chemical parameters i.e. temperature, salinity (CTD recorder, SB Electronics, USA) and dissolved oxygen (Winkler's Method) were collected on board. The phytoplankton samples were analyzed for their

species composition and density using bright field microscope. Density counts were made using Sedjwick-Rafter counting cell and are expressed as no/l. Taxonomic identifications of microalgae were based on the standard publications.

The samples of all 292 stations were pooled for seasonal distribution analyses into samples of three seasons: summer (Feb-Jun) (Cruise Nos: 185, 193,

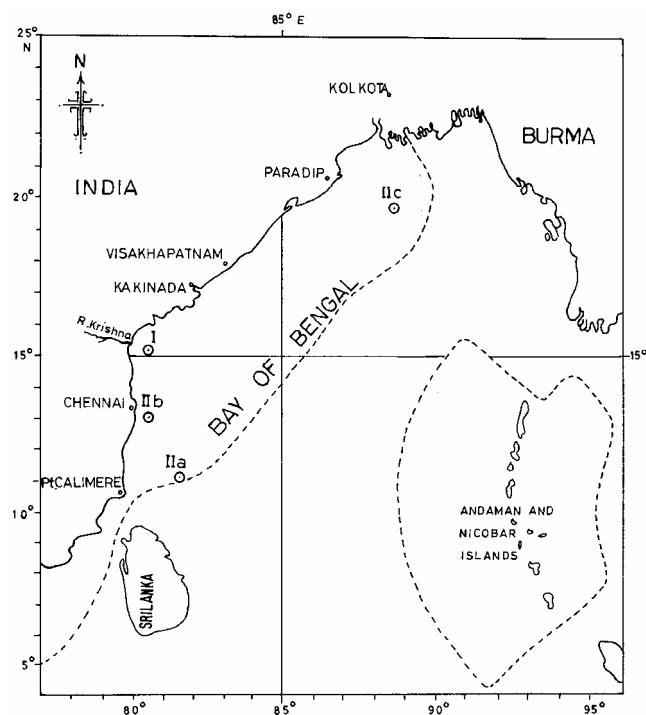


Fig. 1—Map showing the coastal waters east coast of India. (I & II are *Trichodesmium* bloom areas)

Table 1 – Sampling data and mean distribution of temperature, salinity and dissolved oxygen of surface water during 12 cruises of FORV *Sagar Sampada* in the coastal waters, east coast of India. (EC : East coast, SEC: Southeast coast, NEC : Northeast coast, A&N: Andaman & Nicobar Islands)

Cruise No.	171	175	176	179	185	186	187	193	194	198	202	205
Sampling area	EC	SEC	SEC	EC	EC	EC	A&N	EC	EC	NEC	SE+A&N	EC
Lat °N	11-20	11-15	11-15	12-20	11-20	11-20	10-14	10-21	11-20	19-20	11-17	11-20
Long °E	80-87	80-85	80-81	80-88	80-89	80-87	91-95	80-89	80-89	86-89	80-84	80-89
Dates	06.01.99	25.07.99	20.08.99	02.12.99	06.06.2K	04.07.2K	28.07.2K	03.04.01	03.05.01	29.11.01	09.04.02	17.07.02
from – to	24.01.99	10.08.99	07.09.99	21.12.99	01.07.2K	22.07.2K	22.08.2K	29.04.01	26.05.01	12.12.01	05.05.02	05.08.02
Number of Samples	42	15	27	29	31	18	14	34	25	08	24	25
Temp (°C)	25.8	27.8	27.8	25.9	28.2	27.9	27.6	29.1	29.6	26.3	29.9	29.3
Sal (‰)	30.8	32.2	30.3	29.2	32.0	32.8	32.1	33.8	33.9	28.9	32.8	31.7
Diss O <sub>2</sub> (ml/l)	3.6	4.5	4.5	3.4	4.1	4.4	4.3	3.8	3.0	4.6	3.3	2.5

194, 202; total 114 samples), monsoon (Jul-Sep) (Cruise Nos: 175, 176, 186, 187, 205; total 99 samples) and postmonsoon (Oct-Jan) (Cruise Nos: 171, 179, 198; total 79 samples) seasons. Hence the observed seasonal variations in species distribution have limitations in respect of sample number. The analyses of samples, for spatial distribution, were done by pooling the samples on latitude and longitude basis i.e. lats 11°N, 12°N ... etc. The samples, collected between latitudes and longitudes, were allocated to the nearest lat./long. (e.g. lat 11°N includes all samples collected between lat 10°31'N and lat 11°30'N). The distribution of samples (samples number in brackets) at different longitudes on each latitude is as follows:

10°N : E 91°(1), 92°(1), 93°(1), 94°(1), 95°(1)  
 11°N : E 79°(1), 80°(21), 81°(2), 82°(4), 83°(3), 84°(3), 95°(1)  
 12°N : E 80°(17), 81°(3), 94°(1), 95°(2)  
 13°N : E 80°(5), 81°(32), 82°(3), 83°(3), 84°(3), 85°(1), 93°(4), 94°(1)  
 14°N : E 80°(11), 81°(6), 91°(1), 92°(2), 93°(1) 94°(1)  
 15°N : E 80°(25), 81°(7), 82°(3), 83°(2), 84°(3), 85°(2)  
 16°N : E 81°(7), 82°(3)  
 17°N : E 82°(1), 83°(21), 84°(2), 85°(2), 86°(2), 87°(2),  
 18°N : E 84°(6), 85°(2)  
 19°N : E 85°(15), 86°(8), 87°(3), 88°(3), 89°(3)  
 20°N : E 85°(1), 87°(14), 88°(3), 89°(14)  
 21°N : E 86°(1)

Hence it is more appropriate to say that the present study reveals the distribution of phytoplankton at 11°N 80°E, 12°N 80°E, 13°N 81°E, 14°N 80°E, 15°N 80°E, 16°N 81°E, 17°N 83°E, 18°N 84°E, 19°N 85°E and 20°N 87° and 89° E as they represent more samples. Species diversity in phytoplankton species

was measured, using Margalef<sup>12</sup> species diversity index. Degree of uniformity or homogeneity of the phytoplankton species was established by matrix method<sup>13</sup>.

## Results and Discussion

### Physico-chemical parameters

In the present study, the mean surface water temperature (°C) values ranged from 25.8° to 29.9° (av. 27.9°C). The mean temperature values for the summer (Feb., Mar., Apr., May, Jun.), monsoon (Jul., Aug., Sep.) and postmonsoon seasons (Oct., Nov., Dec., Jan.) are 29.2°, 28.1° and 26.0° respectively. In general temperature variations, either regionally or seasonally, are low. The surface water mean salinity (‰) values varied between 28.9 and 33.9‰ (av. to 31.7‰). The mean salinity values for the summer, monsoon and postmonsoon seasons are 33.1, 31.8 and 29.6‰ respectively. Eventhough salinity of the surface water decreased from summer to monsoon season, low salinity values are recorded during postmonsoon period. The surface water dissolved oxygen (ml/l) values fluctuated from 3.4 to 4.5 (av. 3.6 ml/l). The mean DO values for summer, monsoon and postmonsoon seasons are 3.5, 4.4 and 3.8 ml/l respectively. Relatively low DO values were recorded during the present study. The high DO values observed in the monsoon season reflect the dilution effect of the monsoon and consequent increase in dissolved oxygen concentration in the water.

### Qualitative distribution

The present investigation recorded 249 species of phytoplankton (10 orders, 37 families and 77 genera). Of these, 131 species (52.6%) are dinoflagellates (7 orders, 19 families and 30 genera), 111 species

(44.5%) are diatoms (2 orders, 17 families and 43 genera) and 7 species (2.8%) are cyanophytes (one order, 2 families and 4 genera). They are:

**Dinoflagellates:**

*Actiniscus pentasterias*, *A. carteri*, *A. curcubita*, *A. klebsei*, *Amphisolenia bidentata*, *A. rectangulata*, *Amphisolenia* sp., *Blepharocysta compressa*, *B. splendor-maris*, *Ceratium belone*, *C. bergonii*, *C. bigelowii*, *C. buceros*, *C. candilabrum*, *C. carriense*, *C. concilians*, *C. contortum*, *C. declinatum*, *C. extensum*, *C. furca*, *C. fusus*, *C. gibberum*, *C. hexacanthum*, *C. hircus*, *C. inflatum*, *C. kofoidinum*, *C. limulus*, *C. longirostrum*, *C. lunula*, *C. macroceros*, *C. massiliense*, *C. pentagonum*, *C. pulchellum*, *C. ranipes*, *C. schroteri*, *C. symmetricum*, *C. teres*, *C. trichoceros*, *C. tripos*, *C. vultur*, *Ceratocorys horrida*, *Cochlodinium* sp., *Dinophysis caudata*, *D. hastata*, *D. miles*, *D. ovum*, *Dinophysis* sp., *Diplopsalis lenticula*, *Diplopsalis* sp., *Dissodinium lunula*, *Fragilidium* sp., *Glenodinium* sp., *Gonyaulax diacantha*, *G. diegensis*, *G. digitalis*, *G. fragilis*, *G. monilata*, *G. polyedra*, *G. polygramma*, *G.*, *Gymnodinium coeruleum*, *G. falcatum*, *G. splendens*, *Gymnodinium* sp., *Gyrodinium falcatum*, *G. fissum*, *Histioneis depressa*, *Histioneis* sp., *Kofoidinium pavillardii*, *Noctiluca scintillans*, *Ornithocercus heteroporus*, *O. magnificus*, *O. quadratus*, *O. splendidus*, *O. stenii*, *O. thumii*, *Ostreopsis monotis*, *Oxytoxum elegans*, *O. gigas*, *O. milneri*, *O. periclaudicans*, *O. scolopax*, *O. tessellatum*, *Oxytoxum* sp., *Peridinium abei*, *P. biconicum*, *P. brochii*, *P. claudicans*, *P. conicum*, *P. crassipes*, *P. depressum*, *P. divergens*, *P. elegans*, *P. excentricum*, *P. fatulipes*, *P. globulus*, *P. grande*, *P. leonis*, *P. longipes*, *P. nipponicum*, *P. oblongum*, *P. oceanicum*, *P. ovatum*, *P. pallidum*, *P. pedunculatum*, *P. pellucidum*, *P. pentagonum*, *P. polonicum*, *P. spiniferum*, *P. subinermis*, *P. trochoideum*, *P. tuba*, *P. venustum*, *Podolampis bipes*, *P. reticulata*, *P. spinifer*, *Pronoctiluca acuta*, *Prorocentrum compressum*, *P. gracile*, *P. maximus*, *P. micans*, *P. pyriforme*, *P. reticulatum*, *Prorocentrum* sp., *Protoceratium reticulatum*, *Protoceratium* sp., *Ptychodiscus noctiluca*, *Pyrocystis pseudonociluca*, *Pyrophacus horologium*, *Triadanium acuminatus*, and *T. sphericus*.

**Diatoms:**

*Achnanthes stromii*, *Amphipleura gigantia*, *Amphora decussata*, *A. lineolata*, *Asteromphalus whyvelli*, *Aulacodiscus orbiculatus*, *Bacillaria*

*paradoxa*, *Bacteriastrum cosmosum*, *B. declinatum*, *B. delicatulum*, *B. elegans*, *B. hyalinum*, *B. pavillardii*, *B. varians*, *Biddulphia heteroceros*, *B. mobiliensis*, *B. rhombus*, *B. sinensis*, *Cerataulina bergonii*, *Chaetoceros affinis*, *C. coarctatus*, *C. compressus*, *C. denticulatum*, *C. didymus*, *C. diversus*, *C. extensum*, *C. indicus*, *C. lascinosus*, *C. lauderi*, *C. lorenzianus*, *C. messanensis*, *C. paradoxum*, *C. pelagicus*, *C. socialis*, *C. wighami*, *Climacodium frauenfeldianum*, *Climacosphenia elongata*, *C. moniligera*, *Cocconeis littoralis*, *C. sigmoides*, *Corethron hystrix*, *C. inermis*, *Coscinodiscus apiculatus*, *C. asteromphalus*, *C. concentricus*, *C. excentricus*, *C. gigas*, *C. granii*, *C. jonesia*, *C. lineatus*, *C. marginatus*, *C. rothii*, *C. sublineatus*, *Cyclotella striata*, *Diploneis* sp., *Ditylum brightwellii*, *D. sol*, *Eucampia cornuta*, *E. zodiacus*, *Fragilaria oceanica*, *Grammatophora undulata*, *Guinardia flaccida*, *Hemiaulus sinensis*, *Lauderia annulata*, *Leptocylindrus danicus*, *L. minimus*, *Mastogloia exilis*, *Melosira sulcata*, *Navicula clavata*, *N. forcipata*, *N. hennadyie*, *N. longa*, *Nitzschia closterium*, *N. forcipata*, *N. longissima*, *N. panduriformis*, *N. sigma*, *N. vitrea*, *Planktoniella sol*, *Planktoniella* sp., *Pleurosigma aestuarie*, *P. angulatum*, *P. carinatum*, *P. directum*, *P. elongatum*, *P. normanii*, *Pseudonitzschia seriata*, *Pyxidicula minuta*, *Rhabdonema magnificum*, *R. mirificum*, *Rhaphoneis discoides*, *Rhizosolenia alata*, *R. castracanei*, *R. crassispira*, *R. cylindrus*, *R. hebetata*, *R. robusta*, *R. setigera*, *R. styliformis*, *Stephanopyxis palmeriana*, *Surirella fluminensis*, *Thalassionema nitzschioides*, *Thalassiosira decipiens*, *T. subtilis*, *Thalassiothrix frauenfeldii*, *T. longissima*, *Trachyneis antellarium*, *T. aspera*, *Triceratium dublum*, *T. favus* and *T. reticulatum*.

**Cyanophyta:**

*Lyngbya majuscula*, *Oscillatoria acutissima*, *O. agardhii*, *O. nigroviridis*, *Schizothrix calcicola*, *S. delicatula* and *Trichodesmium erythraeum*.

At genus-level, diatoms are dominant (43 genera, 56%), than dinoflagellates (30 genera, 39%) and cyanophytes (4 genera, 5%). Among dinoflagellates, Order Peridiniales contributed significantly to the composition (10 families, 14 genera and 91 species). Order Actinisciales is represented by one family, one genus and one species only. In Order Peridiniales, the two families, Ceratiaceae and Peridiniaceae are together represented by 60 species. Further analysis indicates that the two genera *Ceratium* and

*Peridinium* governed the qualitative distribution of dinoflagellates with 31 and 29 species respectively. Thirteen genera of dinoflagellates are represented by single species only. Taylor recorded 40 genera and 300 species of dinoflagellates during International Indian Ocean Expedition. He also recorded the dominance of the two genera viz. *Ceratium* (72 species) and *Peridinium* in the dinoflagellates composition.

In Bacillariophyceae, Centrales (11 families, 23 genera and 72 species) contributed significantly to the diatom composition than Pennales (6 families, 20 genera and 39 species). Chaetoceraceae (2 genera and 23 species) in centric diatoms and Naviculaceae (6 genera and 16 species) in pennate diatoms contributed more towards the diatoms species composition. Twenty two genera of diatoms are represented by single species only, which are responsible for high generic diversity of diatoms than of dinoflagellates during the present study.

Regionally, number of phytoplankton species ranged from 1 (10°N; 5 samples) to 164 (15°N; 42 samples) (Table 2). Species number of dinoflagellates fluctuated between 2 (21°N; 1 sample) and 95 species (15°N; 42 samples). Diatom species number ranged between 1 (10°N; 5 samples) and 65 (11°N; 35 samples). Cyanophyte species number varied from 1

(21°N; 1 sample) to 5 (17°N; 30 samples). In general, the lats. 11°N, 12°N, 13°N, 14°N, 15°N and 16°N recorded more than 100 species of phytoplankton. The lat. 18°N registered a very low number of species (40 species, 8 samples) which may be due to the less number of samples collected. The latitudes between 11°N and 20°N (except lat. 18°N), recorded more number of dinoflagellate species than diatom species.

Table 3 presents the Margalef's species diversity index (d) values for dinoflagellates, diatoms and cyanophytes, both spatially and seasonally. In dinoflagellates, the species diversity is more at 13°N and 15°N (each 26.4) and low at 18°N (5.5). In diatoms, the the index value is high at 15°N (19.8) and low at 18°N (8.2). In cyanophytes, species diversity is relatively more at 17°N (1.7) and less at 16°N and 18°N (0.5 each). Higher species diversity has been observed both for dinoflagellates and diatoms regionally at all latitudes (except 16°N and 18°N). Very low diversity was observed for Cyanophyta at all the latitudes.

Of the 249 species recorded, 143 species were recorded from all latitudes between 11°N and 20°N. They include 84 species (26 genera) of dinoflagellates, 56 species (27 genera) of diatoms and 3 species (2 genera) of cyanophytes. The 77 species, recorded exclusively between lat. 11°N and 15°N i.e.

Table 2—Density distribution of phytoplankton species between latitudes 10° & 21° N and between summer (S), monsoon (M), postmonsoon (P) seasons in the coastal waters, east coast of India during the study period (- = NIL)

GROUP	LATITUDE (N)												SEASON		
	10°	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°	21°	S	M	P
Dinoflagellates Spp. No.	-	84	80	95	73	95	20	61	15	52	55	2	104	104	82
Diatoms sp. No.	1	65	50	62	52	65	15	39	23	36	40	5	73	83	55
Cyanophytes sp. No.	-	5	4	3	3	4	2	5	2	4	3	1	6	5	3
Total Species No.	1	154	134	160	128	164	39	105	40	92	98	8	183	192	140
Mean density No/l															
Dinoflagellates	-	87	87	71	73	86	53	77	44	56	56	3	114	53	30
Diatoms	1	54	42	31	39	41	29	43	60	305	51	12	46	119	45
Cyanophyta	-	10	14	7	3	7	8	7	9	6	24	10	16	4	7
Total	1	151	143	109	115	134	90	127	113	367	131	25	176	176	82
Total density															
Dinoflagellates No.	-	3036	2007	3654	1597	3605	529	2316	353	1789	1772	3	13008	5268	2385
Diatoms No.	5	1900	953	1621	857	1718	291	1289	479	9753	1634	12	5260	11732	3520
Cyanophytes No.	-	345	327	380	72	310	80	199	70	204	770	10	1824	403	540
Total No.	5	5281	3287	5655	2526	5633	900	3804	902	11746	4176	25	20092	17403	6445
Number of Samples															
	5	35	23	52	22	42	10	30	8	32	32	1	114	99	79

Table 3—Margalef's species diversity index (d) values for dinoflagellates, diatoms and cyanophytes at different latitudes (11°N - 20°N) and in different seasons during the study period

Lat(N)/Season	Dinoflagellates	Diatoms	Cyanophyta
11°	23.6	19.5	1.6
12°	23.9	16.5	1.2
13°	26.4	17.5	0.8
14°	22.2	17.4	1.1
15°	26.4	19.8	1.2
16°	6.6	5.7	0.5
17°	17.5	12.2	1.7
18°	5.5	8.2	0.5
19°	15.7	8.8	1.3
20°	15.7	12.1	0.7
Summer	25.0	19.4	1.5
Monsoon	28.0	20.1	1.5
Postmonsoon	24.6	15.5	0.7

in the southeast region, include 34 species (16 genera) of dinoflagellates, 40 species (23 genera) of diatoms and 3 species (3 genera) of cyanophytes. The 29 species, recorded exclusively between 16°N and 20°N i.e. northeast region contain 13 species (6 genera) of dinoflagellates, 15 species (11 genera) of diatoms and one species of Cyanophyta. Further regional analyses indicate that 56 species (21 species of dinoflagellates, 33 species of diatoms and 2 species of Cyanophyta) are registered exclusively on certain latitudes and longitudes:

Lat. (N) Long. (E)	Species
11°N80°E	: <i>Dinophysis hastata</i> , <i>Oxytoxum</i> sp., <i>Bacteriastrum pavillardii</i> , <i>Coscinodiscus lineatus</i> , <i>Nitzschia forcipata</i> , & <i>Triceratium favus</i>
11°N81°E	: <i>Rhaphoneis discoides</i>
11°N84°E	: <i>Diploneis</i> sp.
13°N80°E	: <i>Amphidinium curcubita</i> , <i>Gymnodinium falcatum</i> , <i>Ornithocercus heteropus</i> , <i>Peridinium biconicum</i> , <i>P.pellucidum</i> , <i>Nitzschia vitrea</i> , <i>Chaetoceros extensum</i> and <i>Coscinodiscus excentricum</i> .
14°N80°E	: <i>Nitzschia closterium</i> , <i>Cyclotella striata</i>
15°N80°E	: <i>Amphidium klabsie</i> , <i>Hestioneis</i> , sp., <i>Oxitoxum elegans</i> , <i>Amphora decussata</i> , <i>A.lineolata</i> , <i>Chaetoceros wighami</i> , <i>Eucampia cornuta</i> , <i>Pleurosigma carinatum</i> , <i>Rhizosolenia setigera</i> , <i>Trachyneis aspera</i>
15°N81°E	: <i>Ceratium longirostrum</i> , <i>Peridinium fatulipes</i> , <i>Ptychodiscus noctiluca</i> , <i>Coscinodiscus concentricus</i>
16°N81°E	: <i>Trachyneis antellarum</i>
17°N83°E	: <i>Gonyaulax polyedra</i> , <i>Ceratium bigelowii</i> , <i>Peridinium ovatum</i> , <i>Cerataulina bergonii</i> , <i>Chaetoceros diversus</i> , <i>Schizothrix calcicola</i>
17°N84°E	: <i>Dinophysis ovum</i>

17°N85°E	: <i>Gonyalax monilata</i>
18°N84°E	: <i>Ditylum sol</i> , <i>Hemiaulus sinensis</i>
19°N85°E	: <i>Gonyaulax digitalis</i> , <i>Peridinium oceanicum</i> , <i>Bacteriastrum elegans</i> , <i>Cocconeis sigmoides</i> , <i>Planktoniella</i> sp.
19°N88°E	: <i>Ceratium schroteri</i>
20°N87°E	: <i>Climacosphenia elongata</i> , <i>Coscinodiscus apiculata</i>
20°N88°E	: <i>Chaetoceros pelagicus</i> , <i>Coscinodiscus asteromphalus</i>
20°N89°E	: <i>Cocconies littoralis</i> , <i>Corethron inerme</i>

Besides, 5 phytoplankton species (3 dinoflagellates and 2 diatoms) are recorded exclusively from waters of Andaman & Nicobar Islands.

10°N 95°E	: <i>Navicula hennadyi</i>
12°N 95°E	: <i>Glenodinium</i> sp., <i>Navicula forcipata</i>
13°N 94°E	: <i>Prorocentrum maximus</i>
14°N 92°E	: <i>Ceratium kofoidinium</i>

Subrahmanyam & Sarma<sup>2</sup>, prepared a list of 37 phytoplankton species as “mass forms”, which include 29 species of diatoms, 7 species of dinoflagellates and one species of blue-green. Except 3 diatoms (*Asterionella japonica*, *Coscinodiscus oculus-viridis* and *Schroederella delicatula*) and one dinoflagellate (*Glenodinium lenticulata*), the remaining 33 “mass forms” are recorded in the present study. In the present study dinoflagellate species contributed significantly to phytoplankton than diatom species. Krey<sup>14</sup>, also reported the dominance of dinoflagellates and cyanophytes in the “Central Arabian Sea and Bay of Bengal” which formed the second plankton-geographical regions in the International Indian Ocean Expedition. Raymont<sup>15</sup> opined that many diatom species are cosmopolitan and form blooms locally when conditions are favourable. Smayda<sup>16</sup> suggested that although there are relatively few tropical diatoms, a surprisingly large number of temperate diatom species can thrive in tropical waters. Earlier investigations<sup>2,3,6-11</sup> indicated the dominance of diatom species in coastal waters of India. *Nitzschia*<sup>5</sup>, *Chaetoceros*<sup>6</sup> and *Coscinodiscus*<sup>6,8,9</sup> were identified as dominant diatom genera. Raymont<sup>15</sup> recognised the diatom species *Planktoniella sol*, *Thalassionema nitzchioides*, *Chaetoceros compressus*, *Leptocylindrus-danicus*, *Skeletonema costatum* and the dinoflagellate species *Prorocentrum micans* and *Ceratium furca* as typical members as warmwater phytoplankton. Only *Skeletonema costatum* was not recorded in the present

Table 4—Distribution of phytoplankton species number in different seasons during the study period

Seasons	Dinoflagellates		Diatoms		Cyanophyta		Total	
	Species No.	%	Species No.	%	Species No.	%	Species No.	%
'Summer' only	12	9.2	17	15.3	2	28.6	31	12.5
'Monsoon' only	15	11.5	23	20.7	1	14.2	39	15.6
'Postmonsoon' only	7	5.3	7	6.3	--	--	14	5.6
'Summer and Monsoon' only	21	16.0	16	14.4	1	14.2	38	15.2
'Monsoon and Postmonsoon' only	5	3.8	8	7.2	--	--	13	5.2
'Postmonsoon and Summer' only	7	5.3	4	3.6	--	--	11	4.4
All seasons	64	48.9	36	32.4	3	42.9	103	41.4
Total species	131		111		7		249	

study. The present study also recorded the typical oceanic diatom *Planktoniella sol*, and typical neritic diatom *Thalassionema nitzchioides*. Prakash & Raman<sup>5</sup> reported the dominance of the cyanophyte *Trichodesmium* (57.2%) in the northwest Bay of Bengal. A characteristic feature of Indian Ocean phytoplankton<sup>14</sup> is the abundance of cyanophytes with massive blooms of *Trichodesmium*. The present study recorded the regular occurrence and the periodic blooming (Fig. 1) of *Trichodesmium* in the coastal waters along east coast.

Seasonally, the phytoplankton species number fluctuated from 140 (postmonsoon; 79 samples) to 192 (monsoon; 99 samples). Dinoflagellate species number varied from 82 (postmonsoon) to 104 (monsoon) species. Diatom species number ranged from 55 (postmonsoon) to 83 (monsoon) species. Cyanophyta species number varied from 3 (postmonsoon; 79 samples) to 6 (summer; 114 samples) species. Margalef's species diversity index (d) values indicate that in all seasons dinoflagellates, diatoms and cyanophytes exhibited high (d= 24 to 28), moderate (d=15 to 20) and low (d=0.7 to 1.5) diversity respectively (Table 3). Table 4 presents the species number distribution in different seasons during the present study period. About 103 (41.4%) phytoplankton species were recorded in all the seasons. Thirty nine (15.6%) species were recorded in monsoon (Jul – Sep) season only. Thirty eight species (15.2%) were observed during summer and monsoon (Feb – Sep) seasons only. Eleven species (4.4%) were recorded during postmonsoon and summer (Oct – Jun) seasons and fourteen (5.6%) species were present during postmonsoon (Oct – Jan) season only.

#### Quantitative distribution

In general the densities of phytoplankton species were very low (Table 2). This observation further substantiates the concept that in open tropical marine

waters, the biomass of phytoplankton will be low and exhibit very little seasonal fluctuations<sup>17</sup>. The diatom *Thalassiothrix frauenfeldii* is only recorded in high density (8500 nos l<sup>-1</sup>) at lat.19°N and long 89°E during monsoon season, which is characterized by a decrease in temperature (28.1°C) and salinity (31.7‰) and an increase in dissolved oxygen concentration (4.4 ml/l) from the preceding summer season.

The phytoplankton species uniformity or homogeneity analyses indicated maximum (76.2%) similarity in dinoflagellate species between 12°N and 14°N regions; while it (75.6%) is between 13°N and 14°N regions for diatoms; and it (97.1%) is between 14°N and 18°N regions for cyanophytes (Fig. 2). Minimal similarity was observed for dinoflagellates (12.4%) between 15°N and 18°N and for diatoms (8.1%) between 12°N and 19°N regions. In general, the species homogeneity in the present study, either for dinoflagellates (mean value 47.0%) or for diatoms (mean value 47.5%) is low between 11°N and 20°N latitudes.

#### *Trichodesmium* bloom

The present study recorded the bloom of *Trichodesmium erythraeum* on two occasions. The first bloom was recorded in Cruise No: 185, (lat. 15°02'65"N, long. 80°23'74"E) on 19<sup>th</sup> and 20<sup>th</sup> June 2000, with a mean density of 6.5×10<sup>6</sup> nos.l<sup>-1</sup> (Fig. 2:I). The calanoid copepod *Temora turbinata* co-existed in abundance. The second bloom was observed in cruise No: 193 at three localities: at 11°N; 81°50'E on 6 April 2001, at 13°N; 80°42'E on 11 April 2001 and at 19°44'N; 89°04'E on 25 April 2001 with a mean density of 6.1×10<sup>7</sup> nos.l<sup>-1</sup> (Fig 2:II a,b,c) No mass mortality of organisms was observed during the bloom periods. The occurrence of these blooms

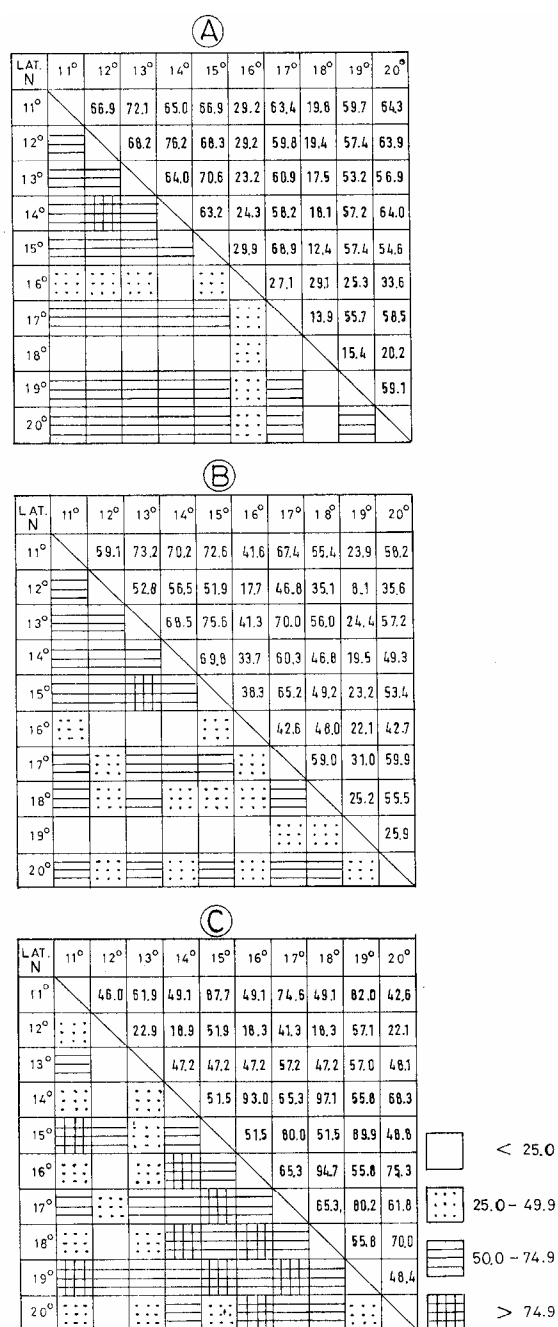


Fig. 2—Trellis diagram illustrating degree of homogeneity (%) of species between latitudes during study period— A) Dinoflagellates, B) Diatoms, C) Cyanophyta

substantiate the observation of Krey<sup>14</sup> i.e. *Trichodesmium* blooms are characteristic feature of Indian Ocean.

#### Acknowledgement

Authors are thankful to the Department of Ocean Development, Government of India, New Delhi for financial assistance through the research grant

DOD/10-MLR/13/97-OD-II. Our thanks are due to Prof. K.V. Ramana Murty, Marine Living Resources Department, Andhra University and Prof. K.J. Joseph, School of Marine Sciences, Cochin University for their cooperation and interest in the programme. We thank the masters and the crew of the FORV *Sagar Sampada* for their help and assistance.

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