Indian Journal of Marine Sciences
Vol. 18, March 1989, pp. 33-36

Phytoplankton in relation to pollution in Visakhapatnam harbour, east coast of India

A V Raman & K Phani Prakash
Department of Zoology, Andhra University, Waltair 530 003, India
Received 17 May 1988; revised 28 November 1988

Sporadic outbursts of phytoplankton, notably diatoms and phytoflagellates, are observed from Visakhapatnam harbour waters subjected to pollution. The harbour waters are characterised by high proportions of inorganic nutrients attributable to sewage and industrial waste discharges. High phytoplankton standing crop and chlorophyll concentrations accompanied by low species diversity at the harbour locations indicate severe eutrophication of waters in this area as against near normal conditions in the open sea.

Ganapati and Raman[1] have reported periodic outbursts of *Skeletonema* as a result of pollution in Visakhapatnam harbour. Since then, this harbour has gone through massive changes in its physiography following several expansion programmes[2]. Over the years, the barbour has become highly eutrophic with no means of adequate flushing of industrial and domestic wastes discharged by the neighbouring establishments. With a view to assessing the impact of the overall changes in relation to pollution on the water quality and phytoplankton in the harbour, the present study has been undertaken at 4 selected stations in the harbour.

Materials and Methods

Four stations (Vc, IIa, IIb and Ia), located along an area of decreasing pollution intensity were chosen for the study (Fig. 1). Surface water samples were collected during low tide at fortnightly intervals for 1 y (August 1985 to July 1986). At st Ia, the observations could be made only from November 1985 to July 1986. The parameters investigated were temperature, transparency, turbidity, salinity, *p*H, dissolved oxygen and inorganic nutrients. In addition, phytoplankton pigments (chlorophyll *a*, *b* and *c*) were also estimated. All analytical estimations were carried out following standard methods[3,4]. Qualitative and quantitative enumerations of phytoplankton at the selected stations were also done. Seawater (1 l) was fixed with Lugol's iodine[5], and the phytoplankton allowed to settle in a measuring jar before further analysis. After 48 h the supernatant was carefully siphoned out and the residual material made up to 100 or 250 ml depending on phytoplankton concentration. From this, 1 ml aliquots were taken into a Sedgwick-Rafter counting chamber and the cell counts made with the help of a microscope. Chain forming species (*Skeletonema costatum*, *Chaetoceros* spp and *Thalassiosira decipiens*) were counted 10 cells as one unit. Phytoplankton diversity was calculated following the formula suggested by Margalef[6].

Results and Discussion

During the study, marked differences in the water quality and phytoplankton composition existed (Table 1) between the harbour locations (sts Vc,

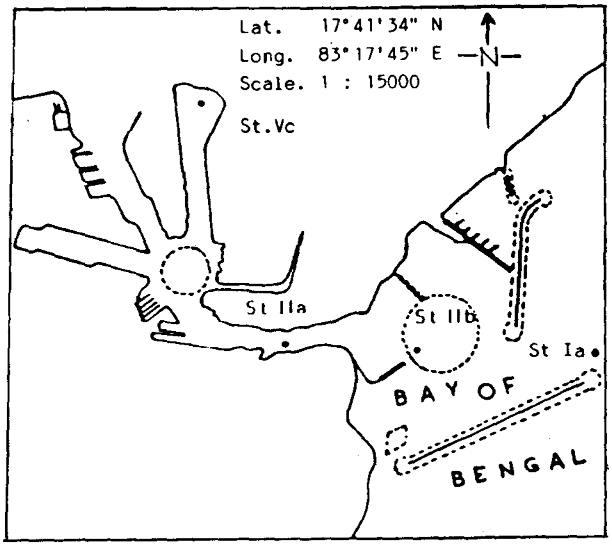

Fig. 1—Station locations

IIa and IIb), subjected to high pollution, and the open sea environment (st Ia), which was comparatively free from pollution.

In the harbour, where the waters were practically stagnant the effect of pollution was high. Here, the waters were characterised by an overall range of high temperature (25°-35.5°C), turbidity (1-100 ppm), low transparency (median 0.6-1.4 m), fluctuating salinity ($4.5\text{-}34.56 \times 10^{-3}$), *p*H (5.8-8.8), dissolved oxygen (1.4-18.8 mg. l^{-1}) and abnormally high proportions of inorganic nitrogen (NO_2 0-0.91; NO_3 0-0.1 mg.l^{-1}), phosphate (0.02-3.63 mg.l^{-1}) and silicate (0.16-7.83 mg.l^{-1}) indicating severe eutrophication in this area. The concentration of phytoplankton pigments, (chl *a* range 0.6-1517.8; chl *b* 0.42-1096.5 and chl *c* 0-1571.2 mg.m^{-3}) was very high indicating high phytoplankton density. At st Ia, located in the

Table 1—Physico-chemical and biological characteristics of surface waters
[Values are pooled ranges for period August 1985-July 1986, values in parentheses are median values)

	Stations (no. of samples)			
	Vc (23)	IIa (23)	IIb (22)	Ia (10)
Temp. (°C)	26.4-35.5 (30.0)	25.5-31.5 (28.5)	25.0-31.0 (27.5)	24.0-27.0 (26.0)
Transparency (m)	ND-2.40 (0.60)	0.30-3.90 (1.25)	0.65-9.4 (1.40)	2.0-5.8 (2.30)
Turbidity (ppm)	1.0-100 (20.0)	4.0-20.0 (10.0)	1.0-20.0 (6.0)	ND-9.0 (1.0)
Salinity ($\times 10^{-3}$)	4.5-31.8 (27.3)	12.97-34.14 (32.0)	14.04-34.56 (33.15)	33.33-34.56 (33.56)
*p*H	6.8-8.3 (7.7)	5.8-8.8 (7.4)	7.0-8.4 (7.4)	7.7-7.9 (7.8)
Dissolved O_2 (mg.l^{-1})	1.4-18.8 (8.6)	4.4-12.8 (8.8)	5.0-10.4 (7.4)	4.8-7.0 (5.9)
NO_2-N (mg.l^{-1})	0.01-0.91 (0.09)	ND-0.60 (0.05)	ND-0.42 (0.05)	0.004-0.21 (0.01)
NO_3-N (mg.l^{-1})	ND-0.10 (0.01)	ND-0.09 (0.02)	ND-0.05 (0.01)	ND-0.01 (0.005)
PO_4-P (mg.l^{-1})	0.49-2.80 (1.62)	0.06-3.63 (2.13)	0.02-2.80 (1.44)	0.06-0.59 (0.39)
SiO_4-Si (mg.l^{-1})	0.43-7.83 (2.80)	0.16-3.24 (0.81)	0.26-3.20 (0.67)	0.33-0.87 (0.49)
Chlorophyll (mg.m^{-3})				
Chl *a*	8.0-1517.80 (40.40)	0.61-51.18 (28.61)	0.60-43.68 (16.46)	ND-6.55 (2.23)
Chl *b*	1.10-1096.50 (18.50)	0.98-38.31 (12.55)	0.42-27.18 (7.82)	ND-2.23 (0.89)
Chl *c*	1.89-1571.20 (55.60)	0.69-106.86 (18.66)	ND-66.85 (17.11)	ND-5.72 (1.25)
Phytoplankton				
No. of species	31	42	42	50
Abundance (no. ml^{-1})	540-6258000 (292225)	120-191405 (16196)	70-123000 (8954)	40-3235 (916)
Dominant species	*Tetraselmis sp.*	*Chaetoceros diversus* *Skeletonema costatum*	*Thalassiosira pseudonana*	*Thalassiosira subtilis* *Chaetoceros socialis*
Margalef index (*d*)	1.9	3.19	3.36	3.5

ND = not detectable

open sea, where near normal conditions prevailed water transparency was more (median 2.3 m), turbidity negligible (median 1 ppm), salinity (33.33-34.56 $\times 10^{-3}$), *p*H (7.7-7.9) and dissolved oxygen (4.8-7 mg.l^{-1}) fairly stable and the concentration of nutrients was very low (median NO_2 0.01; NO_3 0.005; PO_4 0.39 and SiO_4 0.49 mg.l^{-1}) as also the chlorophyll content (median chl *a* 2.23; *b* 0.89 and *c* 1.25 mg.m^{-3}).

A total of 61 species of phytoplankton belonging to 20 genera and 15 families, notably Bacillariophyceae, Dinophyceae, Prasinophyceae, Cryptophyceae and Euglenophyceae, was observed. Inside the harbour (sts Vc, IIa and IIb), sporadic outbursts of phytoplankton chiefly *Skeletonema costatum, Thalassiosira pseudonana, Chaetoceros diversus, Tetraselmis* sp. and *Cryptomonas* sp. occurred.

At st Vc, located in the immediate vicinity of sewage outfall, there were 31 species of phytoplankton. Numerically, the average abundance of phytoplankton in this area was 292225 no. ml^{-1}. Out of this, the phytoflagellate, *Tetraselmis* sp. alone contributed >78% of the total population. *Tetraselmis* sp. occurred here in bloom proportions on 4 occasions and once (8 March 1986) exclusively (5257000 no. ml^{-1}) when the salinity decreased (19.4 $\times 10^{-3}$) due to dilution by sewage water. In a lagoon in the North Adriatic Sea, Fanuko[7] observed unusual blooms of flagellates due to discharge of sewage water. Mahoney and McLaughlin[8] showed that the sewage water mixed with seawater, under warm conditions, produced intense flagellate blooms in New York harbour. Studies showed[9-11] that flagellates were the characteristic species of organisms near the sewage outfalls in areas which had restricted circulation. Caljon[12] classified the flagellate, *Tetraselmis*, as an indicator of eutrophic waters. Locally, at st Vc, in the harbour *Tetraselmis* outnumbered other species and its presence therefore can be considered as an indicator of sewage pollution in this area. Other important bloom forming species encountered (average no. ml^{-1}) at this station included, *Thalassiosira pseudonana* (8306), *Skeletonema costatum* (2941), *Nitzschia longissima* (821), *Cryptomonas* sp. (520) and *Chaetoceros diversus* (341). This area also supported a rich population of ciliates notably *Tetrahymena, Stylonychia* and *Euplotes* known for their preference to organically rich areas.

At st IIa (entrance channel), a total of 42 species of phytoplankton were encountered. Here, the phytoplankton was chiefly represented by (average no. ml^{-1}) *Thalassiosira pseudonana* (9000), *Chaetoceros diversus* (680), *Skeletonema costatum* (350), *Thalassiosira decipiens* (328) and *Cryptomonas* sp. (308). Out of these, *S. costatum* and *C. diversus* can be considered as the 2 most important species in this area on account of their high frequency of occurrence and total abundance. Earlier investigations in the harbour[1] showed that *Skeletonema* was an important component of phytoplankton in this area. This species is known to possess a wide adaptability to changes in salinity and would proliferate rapidly under conditions of decreasing salinity[13,14]. Abundance of *Skeletonema* along with *Chaetoceros* sp. was reported from several other polluted marine areas[9,15-20].

During the present study, *S. costatum* was found at st IIa on 14 out of 23 occasions. On all these occasions this species occurred in bloom proportions (7 no. ml^{-1}) and once (11 December 1985) exclusively (2120 no. ml^{-1}). Similarly, *C. diversus* occurred at this station on 10 occasions and thrice with overwhelming dominance (6400, 5100 and 10040 no. ml^{-1} respectively on 8, 12 and 26 March 1986).

At st. IIb (outer harbour), the total number of species encountered was 42. Of this, the diatom, *Thalassiosira pseudonana* (average no. 6590 ml^{-1}) contributed >73% of the total population found at this station. Here, *T. pseudonana* occurred with overwhelming dominance on 2 occasions (27 November 1985, 21400 and 24 February 1986, 120000 no. ml^{-1}) when there were no other organisms in the plankton. *Thalassiosira* is known to occur in bloom proportions in Duwamish estuary[22] and Howe Sound, British Columbia[15] where the waters are affected by sewage pollution. Parslow *et al.*[23] showed that *T. pseudonana* proliferated in quick succession under conditions of moderate pollution when there was a rich supply of ammonia-nitrogen in water. Visakhapatnam harbour waters were characterised by high concentration of ammonia nitrogen (0.35-0.48 mg.l^{-1}) which on occasions assumed high (0.8 mg.l^{-1}) proportions (unpublished data). In the harbour, *T. pseudonana* occurred immediately following such conditions. The other important species found at this station were, *Skeletonema costatum* (average no. 450 ml^{-1}) and *Chaetoceros diversus* (351 no. ml^{-1}).

St Ia supported a different nature of phytoplankton community. There were 50 species of phytoplankton mostly represented by diatoms and dinoflagellates. Of these, the diatoms, *Thalassiosira subtilis* (537 no. ml^{-1}), *Chaetoceros socialis* (90 no. ml^{-1}) and *S. costatum* (31 no. ml^{-1}) were considered as the most important species since they contributed >75% of the total population found.

Inside the harbour, while the numerical abundance of phytoplankton was high, the species diversity was low. For instance, at st Vc, on account of its proximity to the sewage outfall, Margalef diversity (*d*) was only 1.9. Diversity increased in the direction of open sea as water quality improved and was maximum (3.5) at st Ia (Table 1).

Eppley and Weiler[24] while describing nanoplankton dominance as an indicator of pollution in the sea, suggested three ways pollution may alter phytoplankton composition and abundance. They are exclusion through competition for resources, selective killing of sensitive species and outright stimulation of certain others. Local harbour findings revealed a preponderance of nanoplankton at stations inside the harbour where the waters are characterised by high concentrations of nutrients attributable to sewage and industrial waste discharges. For example, at the sewage outfall area (st Vc), the flagellate, *Tetraselmis* sp., was the characteristic organism. At the downstream location (st IIa), the population was dominated chiefly by the diatoms, *S. costatum* and *Chaetoceros* sp. At the seaward location (st IIb), *T. pseudonana*, was the characteristic organism. In the unaffected open sea environment (st. Ia), the principal inhabitants were typically the marine forms notably *T. subtilis* and *C. socialis.*

Acknowledgement

Grateful thanks are due to the authorities of Visakhapatnam Port Trust, Visakhapatnam for providing boat facilities and to the Department of Environment and CSIR, New Delhi for grant-in-aid.

References

1 Ganapati P N & Raman A V, *Indian J Mar Sci*, 3 (1979) 184.
2 Raman A V & Ganapati P N, in *Indian Ocean-Biology of benthic marine organisms*, edited by M F Thomson, R Sarojini & R Nagabhushanam (Oxford & IBH Publishing Co. New Delhi) 1986, 608.
3 Strickland J D H & Parsons T R, *A practical hand book of sea water analysis* (Fisheries Research Board of Canada, Bull No 167) 1968, pp 311.
4 APHA, *Standard methods for the examination of water and waste water*, (APHA, Washington) 1971, pp 874.
5 UNESCO, *Monographs on oceanographic methodology-phytoplankton manual* (UNESCO, Paris) 1978, pp 337.
6 Margalef R, in *Perspectives in marine biology*, edited by A A Buzzati-Traverso (University California Press, Los Angeles) 1958, 323.
7 Fanuko N, *Mar Poll Bull*, 5 (1984) 195.
8 Mahoney J B & McLaughlin J J A, *J Exp Mar Biol Ecol*, 37 (1979) 213.
9 Sanders G J & Kuenzler J E, *Estuaries*, 2 (1979) 87.
10 Arfi R, Dufour P & Maurer D, *Oceanol Acta*, 3 (1981) 319.
11 Mihnea P E & Cuingioglu E, *Cercetari Marine*, 16 (1983) 271.
12 Caljon A, *Brackish-water phytoplankton of Flemish low land*, (Dr W Junk Publishers, Hague) 1983, pp 272.
13 Qasim S Z, Bhattathiri P M A & Devassy V P, *Mar Biol*, 12 (1972) 200.
14 Smayda T J, *Norwegian J Bot*, 20 (1973) 219.
15 Stockner J G, Cliff D D & Shortreed K R S, *J Fish Res Board Canada*, 36 (1979) 657.
16 Thomson G B & Ho J, *Mar Poll Bull*, 5 (1981) 168.
17 Wear R G, Thomson G B & Sterling H P, *Asian Mar Biol*, 1 (1984) 59.
18 Mihnea P E, *Comm Int Mer Medit*, 9 (1985) 85.
19 Roden C M, Rodhouse P G, Hensey M P, McMahon T, Ryan T H & Mercer J P, *J Mar Biol Assoc U K*, 67 (1987) 359.
20 Tsuruta A, Ohgai M, Ueno S & Yamada M, *Bull Jap Soc Sci Fish*, 1 (1987) 141.
21 Yamada M, Tsuruta A & Yoshida Y, *Bull Jap Soc Sci Fish*, 12 (1980) 1439.
22 Welch B E, *J Wat Poll Control Fed*, 10 (1968) 1711.
23 Parslow J S, Harrison P J & Thomson P A, *Mar Biol*, 83 (1984) 51.
24 Eppley R W & Weiler C S, *Oceanol Acta*, 2 (1979) 241.