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Productivity parameters in relation to hydrography of the inshore surface waters off Visakhapatnam

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Abstract

Time-scale study on physico-chemical and productivity parameters of inshore surface waters was carried out from two fixed stations at the outer harbour off Visakhapatnam during 1986-90. The inter-relations between various parameters were studied and discussed in the background of upwelling and sinking processes along this coast. High values of chlorophyll-*a* (14.1 mg m^{-3}), phaeopigments (28.8 mg m^{-3}) and primary production (1552.7 mg C m^{-3} d^{-1}) were recorded in the study. SST and dissolved oxygen showed negative relation with productivity and pigments while phosphate, silicate and nitrate showed positive relations with productivity parameters. The anomaly in the trend of SST and salinity during 1987-88 is attributed to the influence of changes in major ocean-atmospheric processes. Based on the results, the need for continuous monitoring of hydrographic parameters from fixed stations is suggested.

Keywords: Productivity, inshore waters, Visakhapatnam

Introduction

Several workers have investigated different aspects of hydrography off Visakhapatnam harbour waters (Ganapati and Raman, 1979; Raman and Ganapati, 1986; Sarma *et al.*, 1982; Vijayakumar and Sarma, 1988; Phani Prakash, 1989; Nanda, 1991). The use of ^{14}C technique for measurement of primary production, initiated in Bay of Bengal during *Galathea* Expedition (Steeman-Neilsen and Jensen, 1957) was employed in the present study. Long-term studies on the productivity and hydrography of inshore waters off Visakhapatnam are very rare. This paper presents the results of the investigation on primary production, plant pigments and physico-chemical parameters from fixed stations at the Visakhapatnam outer harbour, conducted during a four-year period from April 1986 to March 1990.

Materials and methods

Weekly surface samples were collected during April 1986 to March 1990 (188 observations) from two fixed stations at Visakhapatnam outer harbour. The first station (17° 41.60' N, 83° 18.38' E) is located on the outside of the breakwaters where water depth is about 7 m and the second one (17° 41.84' N, 83° 18.34' E) inside the Fisheries Harbour nearer to the entrance where water depth is about 4m. The second station, which is about 500 m north of the first and within the breakwaters, was selected to study the influence of fishing harbour and absence of surf action on various parameters. The surface temperature was measured using a bucket thermometer. Standard procedures were adopted for estimating dissolved oxygen, salinity, and inorganic nutrients (Strickland and Parsons, 1968; Parsons *et al.*, 1984). Primary production was estimated by simulated *in situ* incubation of samples for six hours after addition of (5μci) ^{14}C. Incubated samples were filtered through *Sartorius* membrane filters (pore size 0.45 μm) and photosynthetic uptake of radiocarbon was estimated by counting the filters on a G-M Counter (Strickland and Parsons, 1968; Dyson *et al.*, 1965). Samples for plant pigments were filtered using *Whatman* GF/D glass fibre filters and pigments extracted in 90% acetone were estimated using spectrophotometer (ECIL GS 866 C) (Strickland and Parsons, 1968). Standard statistical methods (Snedecor and Cochran, 1967) and software packages were used for analyzing the data.

Results and discussion

Surface temperature

The surface temperature (SST) varied from 21.8 °C to 31.1 °C (av. 27.6 °C) and 22.7 °C to 32.2°C (av. 27.7 °C) at st.1 and st.2 respectively (Fig.1-a). Except in 1988, the lowest value was in April, indicating the upwelling of cooler water to the near shore surface (La Fond, 1954). A change in the usual pattern observed in 1988, which also recorded the highest mean, is indicative of a probable change in the oceanic circulation. Though ANOVA indicated no significant difference between the SST at the two stations, the slightly higher range and average at st.2

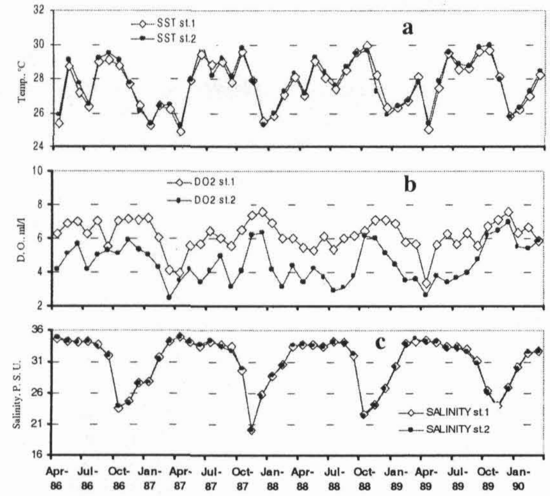

Fig.1. The monthly mean of a) SST (°C), b) dissolved oxygen (ml l^{-1}) and c) salinity (psu) in the surface waters at the two stations.

could be attributed to the terrestrial influence and relative lack of mixing.

Dissolved oxygen

The dissolved oxygen (DO) varied between 2.7 and 7.8 ml l^{-1} (av. 6.23 ml l^{-1}) and 1.7 and 7.8 ml l^{-1} (av. 4.58 ml l^{-1}) at st. 1 and st. 2 respectively. The monthly means at st.1 were higher throughout the period (except in March 1990), though the general trend was more or less similar at the two stations (Fig.1-b). Generally, the values were higher during October-January and lower during February-May, the latter being the period of upwelling (Narasinga Rao *et al.*, 1986; Vijayakumaran, 1996; Vijayakumaran, 2004). The higher values were recorded when temperature and salinity were relatively low, showing the normal relationships among these parameters (Fig.1-b). ANOVA indicated highly significant ($F_{1, 373}$ = 157.5; p=3.183x 10^{-21}) difference between the DO values at both the stations. The surface mixing and wave action have caused higher mean values at st.1 whereas the relatively stagnant conditions and the biochemical demand due to organic load (Nanda, 1991) might have contributed to the reduced values at st.2.

Salinity

The salinity ranged between 17.3 to 35.1 (av.30.8) practical salinity units (psu) and 17.7 to 35.8 (av. 30.7) psu at st.1 and st.2 respectively. The monthly mean at both the stations followed nearly the same trend, remaining above 30 psu during February-September and below 30 psu during October-January. A general drop in salinity observed during October-November was more severe (reaching 20 psu) during November 1987 (Fig. 1-c). ANOVA showed no significant difference between the salinity values at the two stations. The drop in monthly mean during October-November coincided with the intensification of anticlockwise circulation along the upper Bay (La Fond, 1958) and enhanced transport of river discharge from the north (La Fond, 1957; Ganapati and Rama Sarma, 1958; Varkey *et al.*, 1996). The trend of mean SST and salinity during winter-pre-monsoon period of 1987-88 was markedly different from other years. The fact that 1987 and 1988 were identified respectively as *El Nino* and *La Nina* years (Sadhuram *et al.*, 1998) is indicative of the probable influence of these phenomena on the circulation in the Bay and consequently on the local physico-chemical features.

Nutrients

ANOVA indicated no significant difference between the values at the two stations with respect to phosphates, Chlorophyll-*b* and *c*, carotinoids and phaeopigments. But the values of silicates ($F_{1, 364}$ = 6.6; p = 0.01) indicated significant difference.

The phosphates (PO_4) varied between 0 and 0.33 *mg* l^{-1} (av. 0.09 *mg* l^{-1}) and 0.01 and 0.43 *mg* l^{-1} (av. 0.09 *mg* l^{-1}) (Fig. 2-a). Silicates were more abundant during April-

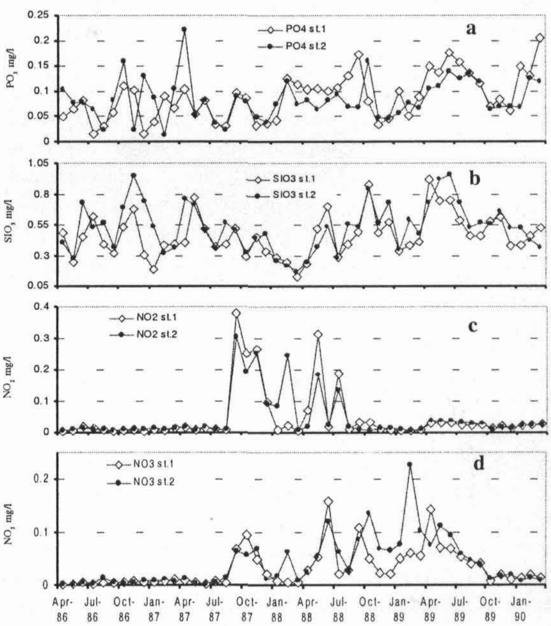

Fig.2. The monthly mean values (mg l^{-1}) a) phosphates, b) silicates, c) nitrites and d) nitrates at the two stations.

July and October-January. Low mean values were observed at both the stations during January-May 1998 (Fig. 2-b). Nitrites (NO_2), the average value was 0.04 *mg* l^{-1} at both stations (Fig. 2-c). ANOVA indicated no significant difference between the stations. The higher monthly mean values more or less coincided with the period of anomaly in the temperature and salinity. Nitrates (NO_3), the average was 0.03 *mg* l^{-1} and 0.04 *mg* l^{-1} at these stations (Fig. 2-d). ANOVA indicated no significant difference between the values at the two stations. Vijayakumaran *et al.* (1996) reported lower nitrite and nitrate values compared to silicates and phosphates in adjacent waters. The low nitrate values were ascribed to denitrifying bacteria by some earlier workers (Ganapati and Rama Sarma, 1958; Jayaraman, 1954). Citing the low N/P ration in the adjacent locations, Sarma *et al.* (1988) mentioned that nitrogen could be a limiting nutrient in these waters.

Plant pigments

The Chlorophyll-*a* ranged between 0 and 14.12 mg m^{-3} and 0 and 13.3 mg m^{-3} at st.1 and st.2 (Fig. 3-a). ANOVA indicated significant ($F_{1,\,342} = 4.5$; $p = 0.03$) difference between the values at the two stations, st.2 recording higher values. Chlorophyll-*b*, the average values were 0.95 mg m^{-3} and1.11 mg m^{-3} at these stations (Fig. 3-b). Chlorophyll-*c*, the average values were 1.03 mg m^{-3} and 1.17 mg m^{-3} (Fig. 3-c). The total chlorophyll ($a + b + c$) varied from 0 to 31.36 mg m^{-3} and 0 and 28.51 mg m^{-3} (Fig. 3-d). Generally the fluctuations in the monthly mean values of chlorophylls were minimal during September 1987 to March 1989 at both the stations. Carotenoids, the averages were 0.47 m-SPU m^{-3} and 0.66 m-SPU m^{-3} (Fig. 4-a). The phaeopigments ranged from 0 to 28.84 mg m^{-3} and 0 and 27.34 mg m^{-3} (Fig. 4-b).

Total pigments (chlorophylls + carotenoids + phaeopigments), the monthly mean remained below 6 mg m^{-3} during most of the period but recorded values higher than 10 mg m^{-3} during July 1986 and April and July of 1987 and 1989 (Fig. 4-c). The range and average values of chlorophyll *a* and *b* were much higher in the present study compared to the previous studies from same area (Nanda, 1991) and adjacent waters (Vijayakumaran, 1996). So also the maximum of chlorophyll-*c* observed in this study was much less than that reported earlier (13.21 mg m^{-3}) by Nanda (1991). Similarly, the range and average of total pigments were also higher in the present study.

Primary production

The primary production varied from 3.1 to 991.2 mg-C m^{-3} d^{-1} and 3.5 to 1552.7 mg-C m^{-3} d^{-1} (Fig. 4-d). ANOVA indicated significant ($F_{1,\,365} = 9.5$; $p = 0.002$) difference between the values at the two stations (st.2

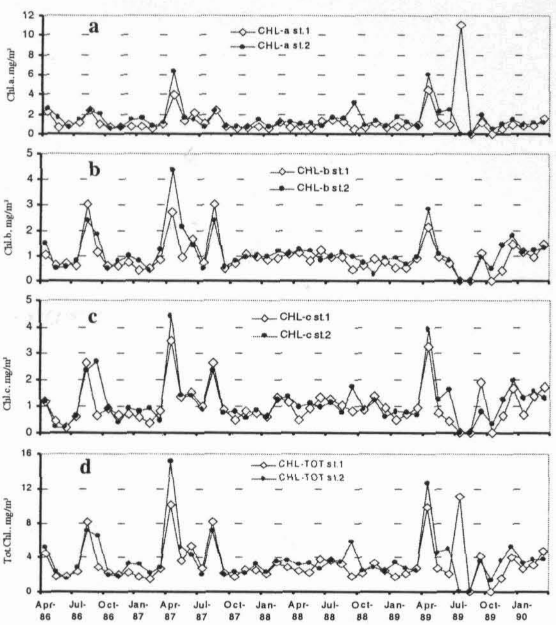

Fig.3. The monthly mean (mg m^{-3}). a) chlorophyll-*a*, b) chlorophyll-*b&c*). chlorophyll-*c*, and d) total chlorophylls in the surface waters at the two stations.

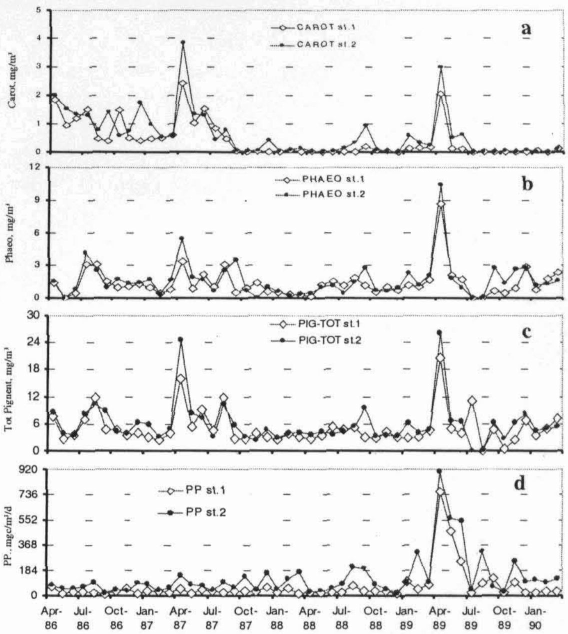

Fig.4. The monthly mean. a) carotenoids (m-SPU m^{-3}), b) phaeopigments (mg m^{-3}), c) total pigments (mg m^{-3}) and d) primary production (mg-C m^{-3} d^{-1}) in the surface waters at the two stations.

recording higher values). It showed a higher value, range and average compared to earlier report by Nanda (1991) and Vijayakumaran (1996). However, seasonal peaks reported earlier were different obviously due to viewing data trends in relatively shorter periods.

Interrelations

In order to understand the relationships among different parameters, coefficients of correlation (*r*) were worked out (Table 1). The *r*-values were tested at two levels denoted as highly significant (α=0.01) and significant

Table1. *The matrix of coefficient of correlation (r) among different parameters at st.1 & 2*

Parameter	*st.#*	Atm-T	SST	Sal	DO_2	PO_4	SiO_3	NO_2	NO_3	PP	Chl-*a*	Chl-*b*	Chl-*c*	Carot	Phaeo
Atm-T	*# 1*	1	0.66**	0.32**	-0.26**	0.18*	0.24**	0.07	0.21**	0.16*	0.17*	0.12	0.15	0.13	0.11
	# 2	1	0.73**	0.31**	-0.13	0.14	0.08	0.03	0.09	0.11	0.13	0.09	0.18**	0.08	0.07
SST	*# 1*		1	-0.06	0.16*	0.11	0.05	0.11	0.11	-0.07	-0.25**	-0.20**	-0.22**	-0.26**	-0.23**
	# 2		1	0.03	0.06	0.09	0.03	-0.02	0.09	0.09	-0.16*	-0.18*	-0.12	-0.19*	-0.17*
Sal	*# 1*			1	-0.55**	0.20**	-0.08	-0.02	0.08	0.15*	0.22**	0.16*	0.13	0.17*	0.13
	# 2			1	-0.57**	0.08	-0.17*	0.0	0.01	0.14	0.27**	0.21**	0.20**	0.25**	0.15
DO_2	*# 1*				1	-0.27**	-0.23**	-0.10	-0.26**	-0.24**	-0.34**	-0.29**	-0.38**	-0.26**	-0.28**
	# 2				1	-0.14	-0.01	-0.14	-0.19**	-0.06	-0.13	-0.04	-0.07	-0.09	-0.13
PO_4	*# 1*					1	0.30**	0.05	0.24**	0.18*	0.08	0.03	0.05	0.03	0.06
	# 2					1	0.15*	0.06	0.13	0.15*	0.27**	0.25**	0.26**	0.23**	0.18*
SiO_3	*# 1*						1	-0.08	0.32**	0.28**	0.18*	0.09	0.15	0.12	0.22**
	# 2						1	-0.16*	0.15*	0.12	0.07	0.02	0.01	0.09	0.11
NO_2	*# 1*							1	0.27**	-0.02	-0.05	-0.05	0.00	-0.13	-0.06
	# 2							1	0.20**	-0.01	-0.07	-0.05	-0.04	-0.15	-0.06
NO_3	*# 1*								1	0.33**	0.13	0.07	0.11	-0.04	0.21**
	# 2								1	0.36**	0.06	-0.09	0.03	-0.13	0.04
PP	*# 1*									1	0.41**	0.26**	0.26**	0.27**	0.50**
	# 2									1	0.39**	0.12	0.22**	0.13	0.12
Chl-*a*	*# 1*										1	0.84**	0.85**	0.77**	0.83**
	# 2										1	0.75**	0.82**	0.80**	0.68**
Chl-*b*	*# 1*											1	0.84**	0.60**	0.70**
	# 2											1	0.81**	0.63**	0.58**
Chl-*c*	*# 1*												1	0.59**	0.71**
	# 2												1	0.64**	0.65**
Carot	*# 1*													1	0.72**
	# 2													1	0.61**
Phaeo	*# 1*														1
	# 2														1

** Highly significant (α = 0.01), * Significant (α = 0.05)
Atm-T: Atmospheric temperature, SST: Sea surface temperature, Sal: Salinity, PP: Primary production, Chl: Chlorophyll, Carot: Carotenoids, Phaeo: Phaeopigments

(α=0.05). At st.1, the atmospheric temperature showed highly significant positive correlations with SST, salinity, silicates and nitrates. As expected, the atmospheric temperature showed negative correlation with dissolved oxygen at st.1. Atmospheric temperature also showed significant positive correlations with phosphates, primary production and chlorophyll-*a*. At st.2, atmospheric temperature showed highly significant positive correlations with SST, salinity and chlorophyll-*c*. The SST at st.1 showed significant positive correlation with dissolved oxygen and highly significant negative correlations with all the plant pigments. At st.2, SST showed significant negative correlation with all pigments except chlorophyll-*c*.

Salinity at st.1 showed highly significant positive correlations with phosphates and chlorophyll-*a*, primary production, chlorophyll-*b* and carotenoids, and negative correlation with dissolved oxygen. At st.2, it showed highly significant negative correlation with dissolved oxygen, and with silicates compared to highly significant positive correlation with all chlorophylls and carotenoids. At st.1, dissolved oxygen showed highly significant negative correlation with all parameters except SST and nitrites whereas at st.2 it showed significant negative correlation with salinity and nitrates.

At st.1 phosphates, silicates and nitrates showed highly significant correlation among each other. However, nitrites showed significant positive correlation only with nitrates. Silicates and nitrates showed highly significant positive relations with primary production and phaeopigments whereas phosphates showed significant positive relation only with primary production. At st.2, phosphates showed significant positive relation with primary production and highly significant relation with all pigments. Nitrates showed highly significant positive correlation with nitrites and primary production. At st.1, pigments and primary productivity showed highly significant correlation among each other. At st.2, primary productivity showed significant correlation with chlorophyll *a* and *c* whereas pigments showed highly significant correlation among each other.

While the influence of atmospheric temperature on SST is direct, that on salinity could be incidental. The upwelling brings high saline water to near-shore surface during summer and the sinking process in winter leads to the appearance of low saline water (La Fond, 1954). Dissolved oxygen having a negative correlation with several nutrients and productivity parameters could be the influence of upwelling, which enhance these parameters and diminish dissolved oxygen simultaneously. The notable absence of a negative relation between dissolved oxygen and SST could also be easily attributed to upwelling, which brings low temperature-low oxygen water to the surface. The reduced SST and enhanced plankton production during upwelling could be the reason for a negative relation existing between SST and plant pigments.

There were instances of primary productivity being negatively correlated with phosphates (Radhakrishna, 1978), positively correlated with chlorophyll-*a* (Bhattathiri *et al.*, 1980) and temperature and salinity (Purushothaman and Bhatnagar, 1976). Compared to the earlier works, the interrelations among physicochemical parameters, pigments and productivity were much significant as would be expected in a natural system. It could be presumed that the different interrelations among parameters, which are not evident in short-term studies, emerge significantly when the data for longer period are considered for analysis.

Conclusions

The influence of surf action was observed at st.1, while that of the fishing harbour was indicated in certain parameters at st.2. Compared to previous short-term studies the interrelations between various parameters were quite normal and explainable (especially at st.1). The data on surface temperature and salinity at the study stations clearly reflect the changes in coastal waters due to upwelling and sinking processes and even indicate probable signals of the anomalies due to global ocean-atmospheric features such as *El-Nino* and *La-Nina*. Since interannual variations in coastal oceanic features are a reality, the patterns, trends, interrelations and anomalies could be clearly understood by carrying out time-scale studies from fixed stations for fairly longer periods. Vijayakumaran (2004) has suggested installation of a moored buoy for this purpose in the nearshore waters off Visakhapatnam.

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