

Journal of The Marine Biological Association of India

ABBREVIATION : *J. mar. biol. Ass. India*

Vol. 39

June and December 1997

No. 1 & 2

CHLOROPHYLL 'a' AND PARTICULATE ORGANIC CARBON IN RELATION TO SOME PHYSICO-CHEMICAL PARAMETERS ALONG SOUTHWEST COAST OF INDIA

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ABSTRACT

Chlorophyll 'a', Particulate Organic Carbon and other environmental parameters were studied along Kerala coast during October 1987 and 1988. High chlorophyll 'a' content at surface water and decreasing trend towards offshore was observed. Spatial gradient in the Chl 'a' and POC distribution exhibited appreciable difference in the nearshore and offshore region. Gaylor and Hopper conditions tested to apply Satterthwaites approximation for unequal sets of sample observations showed that chlorophyll 'a' and environmental parameters except NO₂-N varied spatially, while POC and NO₂-N diurnally. For total and 60 µm size fractioned chlorophyll 'a' a negative relation of high gradient with salinity while, for 20 µm size fraction a positive relation of low gradient was observed. Inverse relation was observed between size fractioned chlorophyll 'a' and other parameters.

INTRODUCTION

BIOMASS of phytoplankton in the seas in terms of chlorophyll 'a' concentration is one of the most widely accepted methods in the study of primary production. Chlorophyll 'a' indicates total plant material available in the water at primary stages of food chain. An assessment of particulate organic carbon provides a more meaningful estimation of the available energy to the next trophic level where herbivore grazing is proposed to control phytoplankton within the limits set by nutrient concentration. The control of phytoplankton production by nutrient availability in the euphotic zone is the basis of any geochemical model calculation of

bioreactive element cycling, particularly in the coastal and estuarine systems dominated by detrital material. Further, it is increasingly recognised that the physico-chemical characteristics prevailing in the water column play an important role in selecting the size structure of the phytoplankton community (Malone, 1980; Platt, *et. al.*, 1983; Charez, 1989; Legendre and Le-Ferre, 1989). The spatial and temporal gradients in environmental parameters offered by the inshore/offshore waters make this ecosystem suitable for examining the relationship between physico-chemical parameters and phytoplankton pigment (size fraction) which forms the main objective of the present study.

Lot of information is available regarding the productivity and related parameters from the southwest coast of India. But all these are confined to a particular region or season, but the present work concentrates on the entire southwest coast of India.

Authors wish to thank the Director, National Institute of Oceanography, Dona Paula, Goa for the encouragement and help.

MATERIAL AND METHODS

This study is based on the samples collected along the southwest coast of India extending from Kasargod to Cape Comorin during the 187th and 204th cruises of RV *Gaveshani* during October, 1987 and 1988 respectively. The stations along the continental shelf (< 200 m depth) were taken as near shore and those on the continental slope (> 200 m depth) were classified as offshore stations. During October 1987, 12 nearshore stations, including 6 anchor stations were occupied covering 43 day and 26 night observations and also 6 offshore stations covering 3 day and 3 night observations. Collection during October 1988 included 18 nearshore stations, with 6 anchor stations covering 44 day and 21 night collections and 9 offshore stations covering 4 day and 5 night observations. Each anchor station was sampled 3 hourly intervals. Surface water was analysed for hydrographic parameters like temperature, salinity, DO and nutrients such as phosphate, nitrite, nitrate and silicate. Chlorophyll 'a' and Particulate Organic Carbon were determined by standard methods (Strickland and Parsons, 1968). For numerical interpretations the data of the two cruises were pooled and 7 anchor stations viz; Kasaragod, Cannanore, Calicut, Cochin, Quilon, Vizhinjam and Cape Comorin, 6 nearshore non-anchor stations and 6 offshore stations were considered. The numerical analysis include intraparameter association, box model for Chlorophyll 'a' distribution over the parameters POC, temperature, salinity, DO, PO₄-P, NO₂-N, NO₃-N and SiO₄-Si (Snedecor and Cochran 1967, Fisher and Yates 1963), critical ratio test and

student's *t* test for single sample and student's two sample test for comparison of independent samples (Federer, 1967), two way nested analysis for testing significance of difference between offshore, nearshore and anchor stations and difference between day and night with respect to the concentration of parameters stated earlier using Gaylor and Hopper conditions for Satterthwaites approximation, Kruskal-wallis non parametric test for comparing day and night collections of offshore, nearshore and anchor stations (Sokal and Rohlf, 1981). Based on these results day and night collections were combined together or not according as the difference was not significant or otherwise, for further analysis. Duncan's multiple range test was applied to determine the highly different shore types and significant differences are presented in the form of a Trellis diagram for each parameter (Sanders, 1973). For size fractionated chl 'a' studies, total water sample, 60 µm, and 20 µm size filters were used (Arantza Iriarte, 1993).

RESULTS AND DISCUSSIONS

Environmental features: A slight increase in temperature was observed towards offshore during both years showing an upward gradient from nearshore to offshore. Salinity and dissolved oxygen did not show much variations. Well oxygenated conditions prevailed throughout the study period. Of the four micronutrients only phosphate showed a wide range (0-2 µg atom/l) in the near shore regions during October 1987 and most of the values were less than 1 µg at/l. Nitrate was found in trace level in most of the collections. Nitrate showed considerable increase during October 1987 compared to 1988. Moderate values for silicate content was noticed during both cruises. The values ranged between 1.01 and 26.21 µg at/l and mostly the values were between 5 to 10 µg at/l irrespective of space and time.

Distribution of chlorophyll 'a' and Particulate Organic Carbon: In October 1987, Chl 'a' during day ranged between 0.007 to 3.32 mg/m³, lowest being near Cochin and

TABLE 1. Mean, Standard Deviation (SD) & Coefficient of variation (C. V. %) of the parameters

	Chl 'a'	POC	T°C	S%	D.O.	PO ₄ -P	NO ₂ -N	NO ₃ -N	SiO ₂ -Si
OFFSHORE :									
a) DAY									
X	1.311	0.564	29.410	35.070	4.440	0.199	0.091	0.934	2.130
SD	1.113	0.531	0.290	0.391	0.760	0.173	0.224	1.302	1.831
CV	84.89	94.15	0.98	1.11	17.12	86.93	246.15	139.40	85.96
b) NIGHT									
X	1.561	3.144	29.110	34.880	4.549	0.248	0.144	0.726	2.685
SD	1.989	4.892	0.383	0.370	0.303	0.137	0.264	0.322	2.457
CV	127.42	155.60	1.32	1.06	6.66	55.24	183.33	44.35	91.51
NEARSHORE :									
a) DAY									
X	1.625	16.386	29.409	34.030	4.757	0.413	0.068	0.619	3.550
SD	2.076	14.496	0.685	1.741	0.447	0.560	0.136	0.574	5.265
CV	127.75	88.47	2.33	5.12	9.40	135.58	199.85	92.77	148.31
b) NIGHT									
X	1.134	0.980	28.700	34.870	4.518	0.300	0.032	0.584	3.068
SD	0.518	0.371	0.405	0.277	0.226	0.188	0.064	0.809	2.759
CV	45.68	37.86	1.41	0.79	5.00	62.67	200.00	138.53	89.93
ANCHOR STATIONS									
1. KASARAGOD : a) DAY									
X	4.291	0.615	28.730	34.260	5.125	0.464	0.052	0.651	3.305
SD	4.593	0.419	0.989	0.811	0.553	0.335	0.149	1.211	0.360
CV	107.38	68.13	3.44	2.37	10.79	72.20	286.54	186.03	10.89
b) NIGHT									
X	2.996	0.762	29.350	33.450	4.824	0.214	0.304	0.200	0.196
SD	4.426	0.280	0.608	0.762	0.218	0.307	0.279	0.213	0.104
CV	147.73	36.75	2.07	2.28	4.52	143.46	91.78	106.50	53.06
2. CANNANORE : a) DAY									
X	22.490	0.818	29.40	33.18	5.177	0.351	0.016	0.464	6.957
SD	22.01	0.412	0.745	1.574	0.455	0.214	0.048	0.269	5.730
CV	97.86	50.37	2.53	4.75	8.79	60.97	300.00	57.97	82.36

Table 1. Contd.

b) NIGHT										
\bar{X}	10.300	0.773	29.720	33.710	5.107	23.860	0.271	0.416	6.047	
SD	48.86	0.585	0.732	1.260	0.257	0.127	0.044	0.243	8.186	
CV	144.27	75.68	2.46	3.74	5.03	0.53	16.23	58.41	135.37	
3. CALICUT : a) DAY										
\bar{X}	4.118	1.169	29.69	32.570	4.447	0.271	0.032	0.779	4.959	
SD	2.527	1.668	0.507	1.891	0.381	0.303	0.064	0.999	4.623	
CV	60.20	143.169	1.71	5.81	8.57	111.81	200.00	128.20	93.22	
b) NIGHT										
\bar{X}	2.815	1.765	29.22	32.34	4.441	34.25	0.00	1.013	2.420	
SD	2.005	1.808	0.472	2.626	0.337	0.335	0.00	1.340	3.617	
CV	71.23	102.44	1.63	8.12	7.59	0.98		132.28	149.46	
4. COCHIN : a) DAY										
\bar{X}	1.561	1.788	29.16	33.74	5.614	0.185	0.156	0.457	3.691	
SD	0.696	2.253	0.465	1.604	0.515	0.082	0.238	0.517	4.168	
CV	44.59	126.01	1.59	4.75	9.17	44.32	152.56	113.13	112.92	
b) NIGHT										
\bar{X}	1.174	0.986	28.96	34.58	5.543	0.213	0.00	0.534	4.149	
SD	0.383	1.231	0.333	0.529	0.283	0.071	0.00	0.612	3.682	
CV	32.62	124.85	1.15	1.53	5.11	33.33	—	114.65	88.74	
5. QUILON : a) DAY										
\bar{X}	1.954	1.103	28.66	34.63	5.596	0.187	0.063	0.387	6.187	
SD	1.275	1.055	0.526	0.573	0.316	0.131	0.164	0.382	6.842	
CV	65.25	95.65	1.84	1.65	5.65	70.05	260.32	98.71	110.59	
b) NIGHT										
\bar{X}	1.727	0.600	28.40	34.80	5.339	0.219	0.00	0.713	4.046	
SD	1.086	0.492	0.340	0.282	0.284	0.149	0.00	0.454	4.434	
CV	62.88	82.00	1.20	0.81	5.32	68.04	—	63.67	109.59	
6. VIZHINJAM : a) DAY										
\bar{X}	0.288	1.167	29.250	35.450	4.512	0.397	0.195	1.040	0.162	
SD	0.149	1.018	0.126	0.063	0.244	0.121	0.209	0.531	0.030	
CV	51.33	87.23	0.43	0.17	5.41	30.48	107.18	51.06	88.52	

b) NIGHT										
X	0.227	1.403	29.22	35.28	4.247	0.330	0.490	2.060	0.227	
SD	0.005	1.180	0.023	0.133	0.103	0.053	0.078	0.071	0.040	
CV	20.70	84.11	0.08	0.38	2.43	16.06	15.92	3.44	17.62	
7. CAPE COMORIN : a) DAY										
X	1.407	0.357	29.10	34.70	4.392	0.512	0.00	0.497	5.478	
SD	0.126	0.211	0.100	0.251	0.206	0.149	0.00	0.215	3.679	
CV	8.95	59.11	0.34	0.72	4.69	29.10	—	45.26	67.16	
b) NIGHT										
X	1.550	0.423	28.53	34.76	4.557	0.387	0.00	0.16	6.123	
SD	0.120	0.239	0.206	0.035	0.098	0.180	0.00	0.057	2.760	
CV	7.74	55.16	0.72	0.10	2.15	46.51	—	35.63	45.19	

highest near Quilon. The values during night were low ranging between 0.02 and 1.99 mg/m³, minimum being near Cape Comorin and maximum near Quilon. The day and night Chl 'a' concentration of the offshore region varied from 0.27 to 2.01 mg/m³ and 0.05 to 6.5 mg/m³ respectively. The particulate organic carbon of the nearshore region ranged between 0 and 6.60 mg/m³ and 0.22 and 4.14 mg/m³ during day and night respectively. High POC values were recorded near Cochin, Quilon and Vizhinjam and low values at Kasaragod and Calicut. In the offshore region, the values ranged from 0.11 to 6.6 mg/l during day and 0.22 to 4.15 mg/l during night. The mean Chl 'a' values for the 9 observations of the anchor stations ranged between 0.3 and 1.76 mg/m³ during day and 0.21 to 1.48 mg/m³ during night. From Kasaragod to Quilon Chl 'a' content was almost the same except a high value at Quilon (3.32 mg/m³) and from Vizhinjam to Cape Comorin low chl 'a' <1 mg/m³ was noticed. POC was low at Kasaragod and Calicut and high at Cochin.

During October 1988, chl 'a' of the nearshore region ranged between 0.17 and 66.65 mg/m³ during day and 0.88 to 10.99 mg/m³ during night, both at Calicut. In the offshore region the values ranged between 0.21 and 3.51 mg/m³ during day and between 0.32 and 2.18 mg/m³ during night. POC in the nearshore ranged between 0.12 and 1.81 mg/l during day and between 0.24 and 1.89 mg/l during night and in the offshore it ranged between 0.22 and 1.64 mg/l during day and 0.28 to 3.84 mg/l during night. The average chl 'a' value for the anchor stations ranged between 1.33 and 36.44 mg/m³ during day and 0.95 and 22.26 mg/m³ during night. The peak value of both were observed at Calicut and lowest value at Quilon. Comparatively high values were noticed at Kasaragod, Cochin and Vizhinjam irrespective of time. Cannanore and Quilon showed low levels of pigment concentration. Mean POC values were almost low at all anchor stations, the peak value 2.77 mg/l being at Vizhinjam (Table 1). Based upon the combined data, it was observed that mean chl 'a' ranged between

TABLE 2. Relative importance of parameters in the box model

Parameters	Offshore		Nearshore		Kasaragod		Cannanore		Calicut		Cochin		Quilon		Vizhinjam		Cape Comorin	
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
Temperature	1.37	1.15	2.40	0.03	0.61	0.29	1.11	1.61	2.19	166.88	0.55	0.01	0.68	0.44	0.05	0.01	0.17	0.31
Salinity	0.47	0.18	0.10	0.06	0.36	0.04	4.35	0.17	0.26	798.99	0.17	0.24	0.23	0.38	0.03	0.18	0.32	0.11
D.O.	0.15	0.77	0.04	0.32	0.67	0.02	3.92	2.22	2.29	65.52	1.33	0.64	0.90	0.25	0.53	1.27	1.68	2.52
PO ₄ -P	1.07	3.08	0.25	0.30	0.36	0.58	0.89	3.89	43.83	11.12	0.08	1.06	1.86	0.91	4.61	1.62	1.68	29.37
NO ₂ -N	2.80	0.22	0.35	4.31	0.13	0.10	8.26	1.34	1.00	0.00	0.56	0.00	2.22	0.00	2.70	8.89	0.00	0.00
NO ₃ -N	3.15	1.80	2.17	1.65	0.08	0.36	9.51	2.64	1.03	415.64	0.63	0.95	0.90	0.50	4.61	5.42	0.63	26.39
SiO ₄ -Si	0.80	0.76	0.06	2.90	0.38	0.35	17.16	4.93	0.10	61.92	1.50	1.33	0.35	0.01	3.64	39.55	0.07	16.82
POC	0.63	0.36	0.15	0.14	0.18	0.28	4.11	11.98	0.47	198.70	0.88	1.78	0.94	0.55	10.02	28.40	1.91	17.78

0.23 (Vizhinjam, day) to 22.490 (Cannanore, day) with c.v.(%) ranging between 7.74 (Cape Comorin, night) to 147.73 (Kasaragod, night). Higher variations for all parameters were observed for night collections taken from offshore and nearshore stations whereas for the day collections taken from anchor stations. NO₂-N is the parameter with the maximum variations (Table 1). Also in the offshore region, the set of parameters, (temperature, silicate, (.763)), (NO₂-N, NO₃-N, (.999)) were highly associated during day and (salinity, silicate, (-.803)) and (chl 'a', POC, (.904)) were significantly correlated during night. In the nearshore region, during day, (POC, Chl 'a', (-.528)), (salinity, POC, (-.594)), (POC, PO₄, (.580)) and (POC, Temp, (-.596)) which are highly correlated while *r* of (Chl 'a', temp., (-.967)), (DO, NO₂-N, -.926)), (DO, salinity, (-.893)) and (NO₂-N, NO₃-N, (.974)) during night were also high. In the nearshore anchor stations, intraparameter relationships were all highly significant except at Calicut and Vizhinjam during day and at Cape Comorin during night (Table 5).

The box model fitted to the normalised data of chl 'a' and other parameters showed that silicate was the relatively most important factor (being the factor with the highest value or the next highest value for partial regression coefficient), in controlling the total chl 'a' concentration, the primary production at anchor stations Quilon, Calicut and Cape Comorin and at other non anchor nearshore stations during night.

Nutrients were also found to be contributing substantially in controlling the distribution of chl 'a' in the offshore, nearshore and at the anchor stations viz. Calicut, Cape Comorin and Cannanore during day. Similarly nutrients play a prominent role in limiting chl 'a' distribution in the nearshore stations and anchor stations, namely Kasaragod, Calicut, Cape Comorin and Cannanore during night. This implies that availability of several elements particularly nutrients, control phytoplankton production at different oceanic locations whereas nonavailability generally limited primary

TABLE 3. Difference between day and night by Kruskal-wallis test H' corrected for ties

Parameters	Offshore	Nearshore	Kasaragod	Cannanore	Calicut	Cochin	Quilon	Vizhinjam	Cape Comorin
Chlorophyll	0.0134	0.0981	0.6746	1.6095	0.7103	1.7245	0.2400	2.4202	2.0336
POC	0.6598	1.2666	0.9747	0.2384	0.0494	0.1668	1.3039	0.1513	0.0678
Temperature	0.2158	2.8716	1.4021	0.7753	1.5022	0.6665	1.0453	0.0678	0.8235
Salinity	0.2756	-7.7590	3.0067	0.0858	-0.5716	0.5255	0.3760	2.8403	0.0000
D.O.	0.6831	0.5614	0.4771	0.1172	0.0178	2.9075	3.2267	2.4000	2.0167
PO ₄ -P	0.4281	0.2439	2.6536	1.0552	-0.5994	0.4040	0.3760	0.4274	1.0756
NO ₂ -N	0.7941	0.1329	2.9026	-4.8020	1.7000	4.0300	1.9000	3.3793	0.0000
NO ₃ -N	2.2364	2.5350	1.5261	10.4500	0.3342	-8.6073	1.8182	5.4454	3.2667
SiO-Si	0.2736	0.8769	2.6508	0.7724	2.0211	0.2053	0.1068	3.8136	0.0000

production in coastal environments. The prominence of NO₃-N in Chl 'a' distribution implies that it is used in the formation of phytoplankton biomass on a global ocean basis. It has been observed that the physical process that control NO₃-N supply to the euphotic zone also controls the magnitude of primary production. The functional relation between phytoplankton and NO₃-N is however the result of the processes that occur to the food chain after NO₃-N has been introduced into the euphotic zone and it is evident at all trophic levels of the marine ecosystems. The high negative correlation between chl 'a' and DO during day at Cochin indicates high respiratory demands for oxygen by the biota (Yakobi, *et al.*, 1993) (Table 2).

Gaylor and Hopper conditions were tested to apply Satterthwaites approximation when the sample sizes are unequal. It showed that chl 'a' distribution is significantly different between offshore, nearshore and anchor stations with more or less same form of distribution during day and night. But in the case of POC, day and night difference was high irrespective of the region. Temperature, salinity, DO PO₄-P, NO₃-N and silicate distribution varied between regions irrespective of the time of collection whereas NO₂-N concentration was almost same at all regions, being more during day than night (Table 6).

The non-parametric Kruskal-wallis test showed that chl 'a', salinity, POC, temperature, DO and silicate distribution are more or less in the same pattern throughout the investigation whereas the nutrients differed between day and night, irrespective of the shore type (Table 3.)

The disparity in the distribution pattern obtained by parametric and non-parametric analysis reveals that the assumption of normal distribution and additivity property for treatment effect is satisfied only for the parameters temperature, chl 'a', salinity (except nearshore), DO and silicate while for nutrients such as PO₄-P and NO₃-N and for POC, the observed data is to be subjected to Tukeys test of additivity to satisfy the additivity property by suitable transformations for treatment effects in nested two way ANOVA.

Based on the informations gathered from (Table 4). The result based on non-parametric Kruskal-wallis test, day and night data were combined for temperature, chl 'a', salinity, DO and silicate to test the difference between the transformation is required.

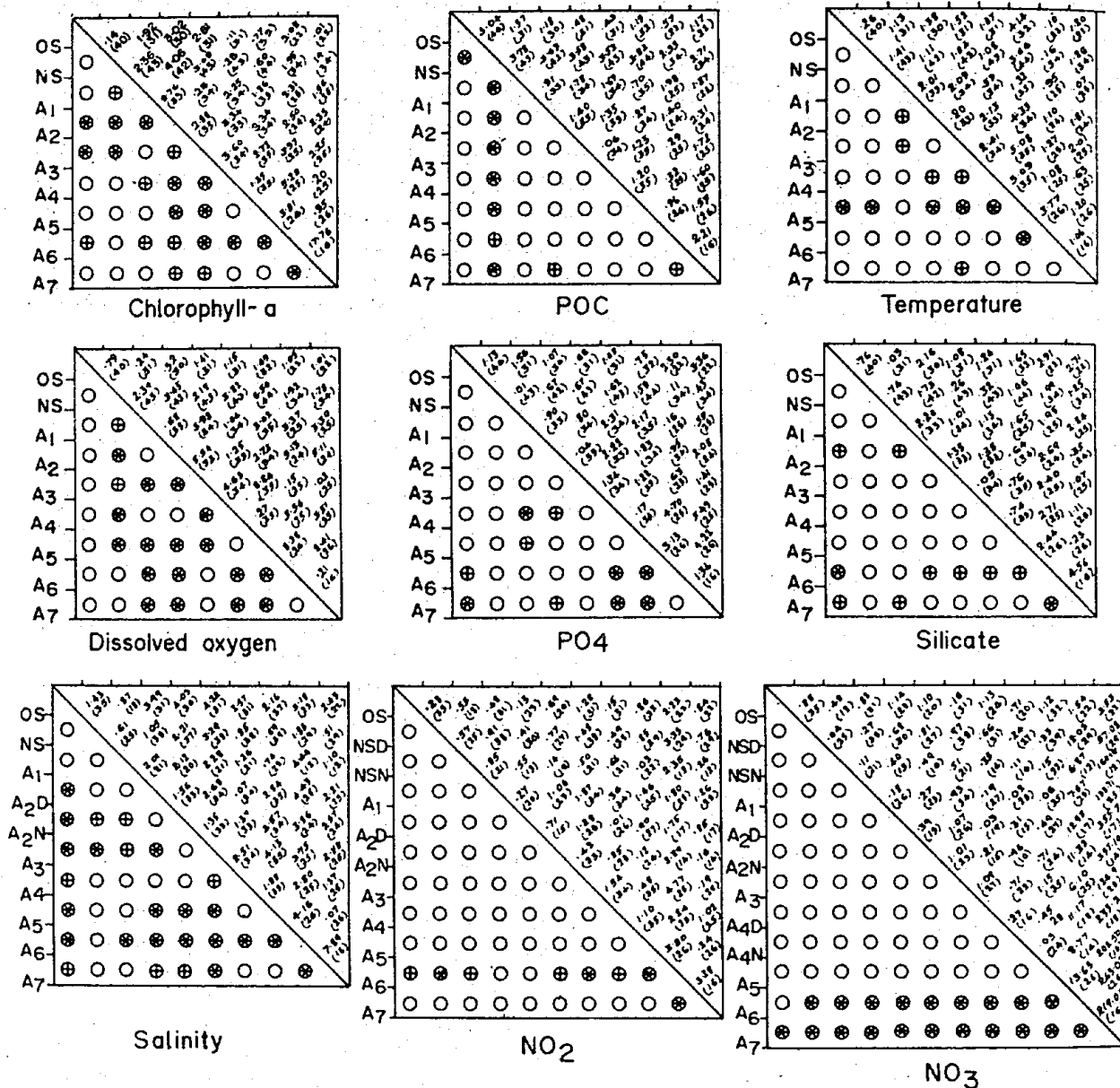


FIG. 1. Trellis diagram showing the similarity between offshore, nearshore and anchor stations with respect to (a) chl 'a' (b) POC, (c) temperature, (d) salinity, (e) dissolved oxygen, (f) PO₄-P (g) NO₂-N, (h) NO₃-N and (i) SiO₄-Si, O-' Not significant, ⊕ 't' significant at 5% level, ⊗ 't' significant at 1% level.

regions using the same test and for the rest of the parameters day and night data were treated separately. The test showed that in the case of POC and silicate, difference between the regions was within the significance limit

Multiple range test was applied based on the results of the nested two way ANOVA and similarity index in terms of student's range statistic, 't' is presented in the form of a Trellis diagram. High similarity was observed at all

regions except Trivandrum for $\text{NO}_2\text{-N}$, Cape Comorin and Cannanore for $\text{NO}_3\text{-N}$ and Calicut for POC with respect to their concentrations (Fig. 1).

TABLE 4. Kruskal-wallis test statistic (H^*) for significance of the difference between the shore types

Parameters	H^*	N	Remarks
Chlorophyll 'a'	44.914	9	*
POC	13.422	9	—
Temperature	28.569	9	*
Salinity	61.078	10	*
D.O.	80.917	9	*
$\text{PO}_4\text{-P}$	17.904	9	*
$\text{NO}_2\text{-N}$	19.106	11	*
$\text{NO}_3\text{-N}$	22.776	12	*
$\text{SiO}_4\text{-Si}$	14.937	9	—

* — Calculated H^* is significant at 5% level, $P < 0.05$

From the relation between chl 'a' and salinity at different size fractions and total, it was observed that total chl 'a' ranged between 0 and 10 mg/m^3 , lowest values were recorded at salinities ranging between 34 and 35 ppt, nearly 18.54% of the samples, mostly that collected from Cannanore and Calicut fall in the lowest range of chl 'a' ($< 1 \text{ mg/m}^3$) and salinity the range 29 to 33.9 ppt. In the $60 \mu\text{m}$ size fraction, chl 'a' ranged between 0 and 3.5 mg/m^3 and salinity ranged from 31.6 to 35.5 ppt. Most of the values were between 34 and 35.6 ppt of salinity. In the size fraction $20 \mu\text{m}$, chl 'a' ranged between 0 to 3 mg/m^3 and salinity between 34.4 to 35.6 ppt. For total and $60 \mu\text{m}$, a negative relationship of high gradient with salinity while for the $20 \mu\text{m}$ size fraction, a positive relation of low gradient with salinity was observed.

The size fraction of chl 'a' when plotted with respect to DO, observed ranges for chl 'a' were 0-5, 0-2.5, 0-3 mg/m^3 which vary with DO in the ranges 3.75 to 6, 4.1 to 6 and 4.1 to 5 ml/l with inverse relation but prominent only in the lowest size fraction. Silicate-chl 'a'

relation showed 3 narrowing ranges viz; 0 to 5, 0 to 2 and 0 to 1 mg/m^3 for chl 'a' and 0 to 15, 0 to 6 and 0 to 8 for silicate concentration for total, $60 \mu\text{m}$ and $20 \mu\text{m}$ size fractions respectively. However the relationship between the two, in the lowest range of silicate (0 to 1), was not significant and it constituted about 22% of the samples. Only in the range of 1 to $10 \mu\text{g at/l}$ for silicate, inverse relation was observed. Inverse relation was also observed between chl 'a' and nitrite + nitrate, and chl 'a' and phosphate with high values of chl 'a' falling in the lower range 0-2 of $\text{NO}_2 + \text{NO}_3$ and in 0 to 0.5 of phosphate. The ranges for chl 'a' were 0 to 5, 0 to 3.5 and 0 to 3 in the case in $\text{NO}_2 + \text{NO}_3$ relation and 0 to 8, 0 to 3.3 and 0 to 3 in the case of phosphate for total, $60 \mu\text{m}$ and $20 \mu\text{m}$ size fractions respectively.

The positive relationship of chl 'a' with salinity observed in $20 \mu\text{m}$ size fraction is likely to reflect the obligate regress for high amounts of ions (Waturburry *et. al.* 1986). Phyco erythrin containing *Synechococcus* spp. in agreement with this observation. But the negative relationship of chl 'a' with salinity observed for total water sample and $60 \mu\text{m}$ size fraction as against the positive relation in $20 \mu\text{m}$ size fraction suggests that these discrepancies could be a reflection of strain specific variation in salinity tolerance. It was also observed that small size phytoplankton rarely attain concentration of bloom level ($> 10 \text{ mg chl 'a' /m}^3$); ie; concentration is more tightly controlled and less frequently subjected to larger variations and it can be suggested that it is mainly the variations in the abundance of the larger phytoplankton that determine the size structure of phytoplankton communities.

The major changes in chl 'a' content are associated with varying nutrient levels in the euphotic zone and appears to be necessary adaptation to provide these slowly growing population at low nutrient concentration. High chlorophyll 'a' content at surface water and a

TABLE 5. Significant correlation between parameters

DAY	NIGHT
<p><i>Anchor Station 1 (Kasaragod)</i> (C, DO) = .616 (T,Si) = .724 (S, P) = .651 (S,Si) = .559 (T,P) = -.639 (S,DO) = .580 (S,NO₂) = -.617 (P,Si) = .693</p>	<p>(C,T) = -.943 (C,P) = .980 (C,Si) = -.947 (P,NO₃) = .967 (S,Si) = -.976 (P,Si) = -.909</p>
<p><i>Anchor Station 2 (Cannanore)</i> (C,Si) = .743 (S,Si) = .930</p>	<p>(C,Si) = .929 (P,Si) = .863</p>
<p><i>Anchor Station 3 (Calicut)</i> (C,Si) = -.707 (T,DO) = .701 (S,NO₃) = -.684 (P,NO₃) = .905 (C,DO) = -.700 (S,P) = -.735 (Si,DO) = -.651</p>	<p>(C,S) = .717 (C,NO₂) = -.770 (P,NO₂) = .737 (S,NO₂) = -.953 (P,NO₃) = .750 (C,P) = -.771 (P,POC) = .738 (S,P) = -.954 (S,NO₃) = -.874 (POC,S) = -.773</p>
<p><i>Anchor Station 4 (Cochin)</i> (S,DO) = .620 (S,NO₃) = -.819 (Si,DO) = .707 (P,NO₂) = .620 (DO,NO₃) = -.632 (NO₃ Si) = -.617</p>	<p>(C,POC) = .868 (POC,DO) = -.866 (T,P) = -.755 (T,Si) = -.821 (P,NO₂) = .894 (NO₂ NO₃) = .876 (POC,S) = -.772 (T,DO) = .841 (T,NO₂) = -.755 (Si,DO) = .894 (Si,P²) = .876 (Si,NO₂) = .876</p>
<p><i>Anchor Station 5 (Quilon)</i> (Si,DO) = .632 (NO₂, NO₃) = .727</p>	<p>(T,NO₃) = -.766 (S,DO) = .680 (DO,NO₂) = -.946 (T,Si) = -.749 (DO,P) = -.946 (Si, NO₃) = .876</p>
<p><i>Anchor station 6 (Vizhinjam)</i> (POC,Si) = .842 (DO,S) = .940 (S,Si) = -.838 (T,NO₂) = -.879 (S,NO₂) = -.862 (DO,NO₂) = -.914</p>	<p>(POC,Si) = -.998 (P,NO₂) = .999</p>
<p><i>Anchor station 7 (Cape Comorin)</i> (S,DO) = -.842 (S,NO₂) = -.935 (P,Si) = .951 (Si,NO₂) = .951 (S,PO₄) = -.935 (S,Si) = -.925 (NO₂,NO₃) = .951</p>	<p>(C,T) .998 (Si,DO) : -.998 (P,NO₂) = -.998</p>

decreasing tendency towards offshore as noticed in the present study was also reported by Radhakrishna *et. al.* (1977). They also could not observe any relation between POC and chl 'a'. The coastal and nearshore waters of westcoast of India are enriched by heavy rainfall and land runoff from June to September every year (Bhargava *et. al.* 1978). Devassy (1983) noticed high concentration of chl 'a' (10.2 mg/m³) at the surface during October and

November in the southwest coast of India. Bhargava *et. al.* (1978) reported an average chl 'a' value of 6.44 mg/m³ and 10.6 mg/m³ during October and December respectively, when the concentration of nutrients were also high along this coast. Balachandran *et. al.* (1989) reported high values (8 mg/m³) during October 1987 and 1988 in the inshore waters of Cochin. They stated that the variation in the observed values during 1987 and 1988 can be attributed

to the intensity of freshwater discharge. The spatial gradients in the chl 'a' and POC exhibited such as convergence and divergence as stated by earlier workers (Bhattathiri and Devassy

TABLE 6. Showing the significance of the difference between shore type and between day and night using 2 way ANOVA for unequal number of samples.

Parameters		Shore type		Day and night	
		F.value	d.f.	F. value	d.f.
Chlorophyll 'a'	(a)	8.0388*	(8,132)	1.1326	(9,132)
	(b)	7.8068*	(14,6)		
POC	(a)	3.8746*	(8,132)	3.0756*	(9,132)
	(b)	3.3056	(14,7)		
Temperature	(a)	2.3893*	(8,132)	1.7589	(9,132)
	(b)	2.1533	(14,7)		
Salinity	(a)	10.1250*	(8,132)	0.6424	(9,132)
	(b)	11.7908*	(8,4)		
D.O.	(a)	23.4512*	(8,132)	0.7771	(9,132)
	(b)	25.2920*	(8,5)		
PO ₄ -P	(a)	3.0731*	(8,132)	0.4968	(9,132)
	(b)	4.1368	(8,3)		
NO ₂ -N	(a)	1.4395	(8,132)	2.5176	(9,132)
	(b)	1.2485	(8,7)		
NO ₃ -N	(a)	2.4246*	(8,132)	0.7416	(9,132)
	(b)	2.6591	(8,5)		
SiO ₄ -Si	(a)	4.5855*	(8,132)		
	(b)	6.5916	(8,3)		

(a) — Actual F ratio for groups considered under shore type.

(b) — F ratio on applying Satterthwaites approximation.

appreciable difference in the nearshore and offshore region. This difference in the distribution can be taken as due to the variations in depth, currents prevailing in the area, sinking of water masses and other oceanic phenomena

1977). Krey (1976) opined that variability in temporal distribution and heterogeneity in spatial distribution which are naturally inherent in oceanic biological parameters make comparison of data rather troublesome.

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