Journal of Aquaculture Research & Development

ISSN: 2155-9546

Thirunavukkarasu et al., J Aquac Res Development 2013, 5:2
DOI: 10.4172/2155-9546.1000211

Research Article Open Access

Phytoplankton Composition and Community Structure of Kottakudi and Nari Backwaters, South East of Tamil Nadu

K. Thirunavukkarasu[1], P. Soundarapandian[2], D. Varadharajan[2] and B. Gunalan[2]

[1]*Department of Advanced Zoology and Animal Biotechnology, Sree Sevugan Annamalai College, Devakottai, Tamail Nadu, India*
[2]*Faculty of Marine Sciences, Centre of Advanced Study in Marine Biology, Annamalai University, Parangipettai-608 502, Tamil Nadu, India*

Abstract

Phytoplankton is one of the important reserves and plays a vital role in aquaculture as food for the larval stages of crustaceans, fish and all stages of bivalves and zooplankton. In the present study, the gross primary production was ranged from 0.08 to 0.35 mg Cm^3/hr in station I and 0.07 to 0.34 mg Cm^3/hr in station II. Net primary production was ranged from 0.23 to 1.89 mg Cm^3/hr in station I and 0.32 to 1.73 mg Cm^3/hr in station II. Chlorophyll 'a' was ranged from 1.897 to 6.821 mg/m^3 in station I and 1.745 to 6.723 mg/m^3 in station II. Phaeo-pigments were ranged from 1.721 to 6.861 mg/m^3 in station I and 1.321 to 6.425 mg/m^3 in station II. During the study period, in station I; about 108 species of phytoplankton were recorded and station II; about 114 species of phytoplankton were recorded. Population density was ranged from 14,408 to 81,930cells/l in station I and 14,306 to 81,630cells/l in station II. Shannon - Wiener's diversity index (H') values were ranged from 5,110 to 6,612 (bits/ind) in station I and 5,112 to 6,710 (bits/ind) in station II. Simpson richness was ranged from 0.912 to 0.987 in station I and 0.913 to 0.989 in station II. Pielou's Evenness index (J') was ranged from 0.841 to 0.959 in station I and 0.846 to 0.959 in station II respectively.

Keywords: Phytoplankton; Composition; Community; Chlorophyll; Population density

Introduction

Aquatic ecosystems are rich with their biotic resources and they hold the key for the protein food security in India, where, phytoplankton is one of such important reserves. They play a vital role in aquaculture as food for the larval stages of crustaceans, fish and all stages of bivalves, in addition to serving as food for various zooplankton organisms [1]. Marine phytoplankton comprises a complex community of several thousand floating micro-algae, ranging in size from about 1 μm up to a few millimeters. Based on the size, phytoplankton can be classified as macro-plankton (more than 1 mm), micro-plankton (between 5 and 60 micrometers) and ultra-plankton (less than 5 micrometers) [2-4]. Phytoplankton being the autotrophs (primary producers), initiate the aquatic food-chain. Secondary producers (zooplankton) and tertiary producers (shell fish, finfish and others) depend on them directly or indirectly for food. Phytoplankton also serves as indicators of water quality and 'natural regions' which are characterized by typical species or species groups [4]. In addition, phytoplankton clearly plays a significant role in the global biogeochemical cycling of carbon, nitrogen, phosphorus, silicon and many other elements. Blooms including red-tides caused by phytoplankton are of significant value in the aquatic environment as they affect aquatic economy. Hence, analysis of phytoplankton becomes essential in any study concerning with hydro-biological investigations. A precise knowledge of phytoplankton pigments in water is necessary in several aspects of plankton research. Hence in recent years, there has been a marked increase in the use of photosynthetic pigments as markers in identifying different algal groups in the waters and to identify changes in the distribution of algae in vertical profiles. This approach is particularly valuable in oceanographic research because different algal group's reflect quite sensitively the physical changes in water [5]. In addition, pigment analysis is the useful tracer of food-chain relationship, zooplankton grazing and detritus formation [6]. Chlorophyll levels are also used in conjugation with other measurements to generate indices such as carbon; chlorophyll ratios which are used to indicate the general 'well being' of algal proportions [3,7]. Analysis of chlorophyll 'a' and carotenoid pigments helps to determine the phytoplankton community structure [5] and the analysis of phaeophytin will give an idea of the amount of pigment which is not photo synthetically active [8,9]. Phytoplankton as primary producers, form an important source of energy and basis for life in the aquatic environment. Hence, production at the higher tropic levels depends ultimately on photosynthetic primary production. Such an important process is always under the influence of a variety of physico-chemical and biological parameters. Measurement of primary production becomes essential for assessing the level of fish production and potential exploitable fisheries. It has also helped a great deal to classify the prawn/shrimp field as highly productive (1500 mgC m^{2}day^{-1}), moderately productive (500-1500 mgC m^{2}day^{-1}) and lowly productive (less than 500 mgC m^2 day^{-1}) area [10]. The present investigation was focused on the phytoplankton with reference to primary production, chlorophyll content, pigmentation, species composition, population density and community structure.

Materials and Methods

Phytoplankton samples were collected in monthly interval from the stations I (Kottakudi) and station II (Nari backwaters) for a period of two years from January 2010 to December 2011. The samples were collected by towing a plankton net (mouth diameter 0.35 m) made of bolting silk (No.30, mesh size 48 μm) for half an hour at one nautical

***Corresponding author:** P. Soundarapandian, Faculty of Marine Sciences, Centre of Advanced Study in Marine Biology, Annamalai University, Parangipettai-608 502, Tamil Nadu, India, Tel: 04144-243223; Fax: 04144-243553; E-mail: soundsuma@gmail.com

Received November 25, 2013; **Accepted** December 16, 2013; **Published** December 19, 2013

Citation: Thirunavukkarasu K, Soundarapandian P, Varadharajan D, Gunalan B (2013) Phytoplankton Composition and Community Structure of Kottakudi and Nari Backwaters, South East of Tamil Nadu. J Aquac Res Development 5: 211 doi:10.4172/2155-9546.1000211

mile speed. After the net operation was over, some plankton that remains on the gauze was washed into the bucket using water. Then the concentrated plankton samples were transferred in to a clean polythene container with 5% neutralized formalin as preservatives and used for qualitative analysis. For the quantitative analysis of phytoplankton, the settling method described by [11-14] was adopted. Numerical plankton analysis was carried out using Utermohl's inverted plankton microscope.

For the identification of phytoplankton, a standard research microscope magnification X 1000, with phase-contrast illumination can be used. Phytoplankton was identified using the standard works of [15-19]. For the sake of convenience, the phytoplankton collected were assigned to five major groups viz, Diatoms, Dinoflagellates, Blue-green algae and 'others'.

Light Extintion Co.efficient (LEC)

Light Extintion Co.efficient was analysed using Sechii disc.

Primary production

Primary production was estimated by adopting the light and dark bottle technique. The samples were incubated *in situ* in places from where they were collected for period of 3 hours. The Winkler's method of determining dissolved oxygen as described by Strickland and Parsons [20] was used for the estimation of production rate. Oxygen values observed were converted to the organic carbon per unit volume of water 'm^{3}' in time t' and the productivity has been expressed as mghr^{-1}. Both Gross Primary Productivity and Net Primary Productivity were calculated.

Seasons	Months	2010		2011	
		Station I	Station II	Station I	Station II
Post monsoon	January	2.23	2.18	2.13	2.14
	February	2.24	2.32	2.23	2.13
	March	2.43	2.52	2.44	2.32
Summer	April	2.32	2.25	2.12	2.21
	May	2.81	2.91	3.02	2.56
	June	2.10	2.12	2.10	2.11
Pre monsoon	July	2.75	2.78	2.63	2.72
	August	3.23	3.42	3.23	2.71
	September	2.42	2.37	2.44	2.53
Monsoon	October	2.32	2.48	2.52	2.62
	November	2.48	2.52	2.63	2.75
	December	2.90	2.82	2.72	2.81

Table 1: Monthly variations of Light Extinction Co-efficient (m) from January 2010 to December 2011.

Seasons	Months	2010		2011	
		Station I	Station II	Station I	Station II
Post monsoon	January	0.30	0.30	0.21	0.20
	February	0.15	0.14	0.16	0.16
	March	0.30	0.31	0.24	0.21
Summer	April	0.35	0.34	0.35	0.32
	May	0.23	0.21	0.13	0.12
	June	0.15	0.14	0.16	0.15
Pre monsoon	July	0.13	0.12	0.12	0.11
	August	0.27	0.28	0.26	0.22
	September	0.15	0.14	0.15	0.14
Monsoon	October	0.32	0.33	0.31	0.32
	November	0.27	0.26	0.08	0.07
	December	0.23	0.22	0.12	0.13

Table 2: Monthly variations of gross primary production (Cm^{3}/hr) from January 2010 to December 2011.

Chlorophyll 'a'

For the determination of phytoplankton pigment (chlorophyll 'a'), surface water samples were collected in clean 250 ml polyethylene bottles. These water samples were filtered through 4.7 cm Whatman GF/C glass fiber filter papers coated with Magnesium carbonate solution. The filtrate in the filter paper was allowed to dissolve in 5 ml of 90% acetone by soaking the filter paper in acetone and crushed well. After that it was kept in a refrigerator in complete darkness for 24 hours. Subsequently the filter paper was re-crushed using a homogenizer. The grounded mixture was centrifuged (3000-4000 rpm) for about 10 minutes and the supernatant was make up to 10ml with 90% acetone and was measured for chlorophyll at 665nm in a UV double beam (Systronics, Visiscan-167) spectrophotometer. Concentration of the functional pigments was worked out as outlined by Strickland and Parsons [20].

Phaeo-pigmentation

For the estimation of chlorophyll degradation products (phaeo-pigments), extinction of the acetone extract of chlorophyll was measured before and after treatment with diluted hydrochloric acid (6 Normality). The change following acidification was used as a measure of the quantity of phaeo-pigments in the original sample. Extinction was measured at 665nm and 750 nm and the concentration was worked out as described by Parsons et al. [21]. The biodiversity indices were calculated following the standard formula of [22] for diversity index (H'), [23] for richness (D'), [24] for evenness (J').

Statistical analysis

Two way ANOVA test was employed to find out the variations in population density, species diversity, species richness and species evenness in relation to stations and months. Pearson - correlation coefficient analysis was performed between physico-chemical parameters and biological parameters of both the stations.

Results

Light Extinction Co-efficient (LEC)

Light Extinction Co-efficient was ranged from 2.10 to 3.23 m in station I and 2.11 to 3.42m in station II. Minimum Light Extinction Co-efficient was recorded in the month of June (2010 and 2011) and maximum in the month of August (2010 and 2011) in station I. In station II, Light Extinction Co-efficient was recorded minimum in the month of June (2011) and maximum in the month of August (2010) (Table 1).

Gross primary production

Gross primary production was ranged from 0.08 to 0.35 mg Cm^{3}/hr in station I and 0.07 to 0.34 mg Cm^{3}/hr in station II. Minimum gross primary production was recorded in the month of November (2011) and maximum in the month of April (2010 & 2011) in station I. In station II, gross primary production was recorded minimum in the month of November (2011) and maximum in the month of April (2010) (Table 2). The gross primary production is positively correlated with rainfall, nitrite, nitrate, ammonia, inorganic phosphate and reactive silicate and negatively correlated with dissolved oxygen in station I (Tables 3 and 4).

Net primary production

Net primary production was ranged from 0.23 to 1.89 mg Cm^{3}/hr

Parameters	Ra.fa.	T	Salin.	pH	DO	NO_2	NO_3	NH_4	IP	SiO_3	GPP	NPP	Phaeo-Pig.	Chl.	Pop. Den.
Ra.fa.	1														
T	-0.226	1													
Salin.	-0.879**	0.493	1												
pH	-0.715*	0.611	0.838*												
DO	-0.372	0.693*	0.476	0.603	1										
NO_2	0.561*	-0.725**	-0.625*	-0.739**	-0.950	1									
NO_3	0.427*	-0.727**	-0.492*	-0.674**	-0.934	0.973	1								
NH_4	0.616**	-0.622**	-0.622**	-0.755**	-0.79	0.965	0.948	1							
IP	0.525*	-0.812	-0.610*	-0.799	-0.891	0.957	0.947	0.910	1						
SiO_3	0.663**	-0.619**	-0.693	-0.711**	-0.921	0.953	0.908	0.922	0.899	1					
GPP	0.352*	-0.282	-0.110	-0.247	-0.322*	0.448*	0.491*	0.481*	0.493*	0.432*	1				
NPP	-0.021	-0.290	-0.040	-0.273	-0.033	0.121	0.198	0.075	0.319*	0.033	0.408*	1			
Phaeo-Pig.	-0.027	-0.083	-0.104	0.217	0.375*	-0.283	-0.299	-0.321*	-0.241	-0.263	0.052	0.355*	1		
Chl.	-0.272	0.114	0.319*	0.382*	0.581**	-0.554**	-0.531**	-0.530**	-0.429*	-0.598**	0.011	0.318*	0.554**	1	
Pop. Den.	-0.389*	0.654	0.515**	0.561**	0.860	-0.818	-0.771	-0.767	-0.744	-0.843	-0.324	0.217	0.300	0.638**	1

* Correlation is significant at 5% level (P<0.05).
** Correlation is significant at 1% level (P<0.01).

Table 3: Correlation (r) values between physico-chemical parameters, biological parameters and phytoplankton for station-I.

Parameters	Ra.fa.	T	Salin.	pH	DO	NO_2	NO_3	NH_4	IP	SiO_3	GPP	NPP	Phaeo-Pig.	Chl.	Pop. Den.
Ra.fa.	1														
T	-0.274	1													
Salin.	-0.766*	0.694	1												
pH	-0.808*	0.593	0.970**	1											
DO	-0.350	0.543*	0.639*	0.541*	1										
NO_2	0.582*	-0.858	-0.542*	-0.724**	-0.930	1									
NO_3	0.428*	-0.872	-0.605**	-0.638**	-0.925	-0.962	1								
NH_4	0.6161. **	-0.529*	-0.729**	-0.701**	0.802	0.968	0.949	1							
IP	0.525*	-0.715**	-0.706**	-0.642**	0.849	0.930	0.945	0.910	1						
SiO_3	0.679	-0.564**	-0.804	-0.738	-0.906	0.959	0.908	0.924	0.908	1					
GPP	-0.054	-0.200	0.087	0.157	0.193	-0.241	0.097	0.156	0.056	0123	1				
NPP	0.602**	0.135	-0.291	-0.401*	-0.028	0.218	0.230	0.322	0.126	0.122	0.959	1			
Phaeo-Pig.	0.380*	-0.307	-0.442*	-0.428*	0.034	-0.011	-0.021	-0.036	-0.011	0.069	-0.003	0.193	1		
Chl.	-0.124	-0.333*	0.093	0.182	0.271*	-0.276	-0.132	-0.187	0.036	-0.251	0.707	-0.097	0.345*	1	
Pop. Den.	-0.391**	0.614	0.702	0.615	0.874	0.0778	-0..770	-0127	0.746	-0.818	0.096	-0.253	0.075	0.272*	1

* Correlation is significant at 5% level (P<0.05).
** Correlation is significant at 1% level (P<0.01).

Table 4: Correlation(r) values between physico-chemical parameters, biological parameters and phytoplankton for station-II.

in station I and 0.32 to 1.73 mg Cm^3/hr in station II. Minimum net primary production was recorded in the month of July (2011) and maximum in the month of November (2011) in station I. In station II, net primary production was recorded minimum in the month of July (2010 & 2011) and maximum in the month of November (2011) (Table 5). The net primary production is positively correlated with inorganic phosphate and gross primary production in station I. The net primary production is positively correlated with rainfall and negatively correlated with pH in station II (Table 3).

Chlorophyll 'a'

Chlorophyll 'a' was ranged from 1.897 to 6.821 mg/m^3 in station I and 1.745 to 6.723 mg/m^3 in station II. Minimum chlorophyll 'a' was recorded in the month of December (2010) and maximum in the month of May (2011) in station I. In station II, chlorophyll 'a' was recorded minimum in the month of December (2010) and maximum in the month of May (2011) (Table 6). Chlorophyll 'a' is positively correlated with salinity, pH, dissolved oxygen, net primary production and phaeo-pigments and negatively correlated with nitrate, nitrite, ammonia, inorganic phosphate and reactive slilicate in station I. Chlorophyll 'a' is positively correlated with dissolved oxygen and phaeo-pigments and negatively correlated with temperature in station II (Tables 3 and 4).

Phaeo-pigments

Phaeo-pigments were ranged from 1.721 to 6.861 mg/m^3 in station I and 1.321 to 6.425 mg/m^3 in station II. Minimum was recorded in the month of December (2010) and maximum in the month of October (2011) in station I. In station II, phaeo-pigments were recorded minimum in the month of December (2010) and maximum in the month of October (2011) (Table 7). Phaeo-pigments are positively correlated with dissolved oxygen and net primary production and negatively correlated with ammonia in station I. Phaeo-pigments are

Seasons	Months	2010		2011	
		Station I	Station II	Station I	Station II
Post monsoon	January	1.32	1.21	1.28	1.17
	February	1.13	1.12	1.12	1.15
	March	1.52	1.43	1.32	1.23
Summer	April	1.65	1.54	1.56	1.43
	May	1.12	1.10	1.23	1.18
	June	1.13	1.25	1.28	1.13
Pre monsoon	July	0.31	0.32	0.23	0.32
	August	1.23	1.08	1.42	1.38
	September	1.38	1.25	1.25	1.21
Monsoon	October	1.42	1.33	1.62	1.53
	November	1.31	1.28	1.89	1.73
	December	1.21	1.32	1.28	1.23

Table 5: Monthly variations of net primary production (Cm3/hr) from January 2010 to December 2011.

Seasons	Months	2010		2011	
		Station I	Station II	Station I	Station II
Post monsoon	January	5.101	5.283	5.214	5.382
	February	4.213	4.321	4.563	4.684
	March	4.521	4.635	6.124	6.213
Summer	April	4.635	4.231	6.213	6.381
	May	6.284	6.314	6.821	6.723
	June	3.841	3.942	4.231	4.112
Pre monsoon	July	3.234	3.673	3.432	3.892
	August	4.534	4.678	6.523	6.429
	September	3.189	3.289	4.12	4.001
Monsoon	October	3.824	3.789	5.624	5.871
	November	3.002	2.546	3.826	3.734
	December	1.897	1.745	2.901	3.002

Table 6: Monthly variations of chlorophyll ‘a’ (mg/m^3) from January 2010 to December 2011.

Seasons	Months	2010		2011	
		Station I	Station II	Station I	Station II
Post monsoon	January	5.210	5.113	5.222	5.282
	February	4.153	4.345	4.500	4.645
	March	4.610	4.618	6.125	6.214
Summer	April	4.645	4.234	6.118	6.212
	May	3.524	3.689	5.724	5.971
	June	3.741	3.542	4.331	4.212
Pre monsoon	July	3.214	3.683	3.422	3.872
	August	4.532	4.673	6.525	6.423
	September	3.689	3.789	4.129	4.101
Monsoon	October	6.312	6.315	6.861	6.425
	November	3.102	2.346	3.326	3.434
	December	1.721	1.321	2.215	3.162

Table 7: Monthly variations of phaeo-pigments (mg/m^3) from January 2010 to December 2011.

positively correlated with rainfall and negatively correlated with salinity and pH in station II (Tables 3 and 4).

Species composition

In station I, about 108 species of phytoplankton were recorded (2010 and 2011) which includes 15 species of Coscinodiscea, 6 species of Tricertiinae, 13 species of Chaetocercea, 5 species of Odontella, 4 species of Eucampiinea, 12 species of Solenoidea, 3 species of Euodiceae, 16 species of Naviculacea, 9 species of Fragilariaceae, 4 species of Dinophysialeas, 15 species of Peridiniales, 1 species of silicoflagellates and 5 species of Blue green algae. In station II, about 114 species of phytoplankton were recorded (2010&2011) which includes 14 species of Coscinodiscea, 6 species of Tricertiinae, 13 species of Chaetocercea, 6 species of Odontella, 4 species of Eucampiinea, 12 species of Solenoidea, 3 species of Euodiceae, 18 species of Naviculacea, 11 species of Fragilariaceae, 4 species of Dinophysialeas, 17 species of Peridiniales, 1 species of Silicoflagellates and 5 species of Blue green algae (Table 8).

Population density

Population density was ranged from 14,408 to 81,930 cells/l in station I and 14,306 to 81,630 cells/l in station II. Minimum population density was recorded in the month of December (2010) and maximum in the month of May (2011) in station I. In station II, the phytoplankton population densities were recorded minimum in the month of December (2010) and maximum in the month of May (2011) (Table 9). Population density showed significant variation between two stations (Table 10). Population density showed positive correlation with salinity, pH and chlorophyll ‘a’ and negative correlation with rainfall in station I. Population density showed positive correlation with chlorophyll ‘a’ and negative correlation with rainfall in station II (Tables 3 and 4).

Shannon- Wiener's diversity

Shannon - Wiener's diversity index (H') values were ranged from 5,110 to 6,612 (bits/ind) in station I and 5,112 to 6,710 (bits/ind) in station II. Minimum Shannon - Wiener's diversity index (H') values were recorded in the month of November (2010) and maximum in the month of June (2011) in station I. In station II, the Shannon - Wiener's diversity index (H') values were recorded minimum in the month of November (2011) and maximum in the month of June (2011) (Table 10). The species diversity showed significant variation between two stations (Table 11).

Simpson richness

Simpson richness was ranged from 0.912 to 0.987 in station I and 0.913 to 0.989 in station II. Minimum Simpson richness was recorded in the month of November (2010) and maximum in the month of August (2011) in station I. In station II, the Simpson richness was recorded minimum in the month of November (2010) and maximum in the month of August (2011) (Table 12). The species richness showed significant variation between two stations (Table 11).

Pielou’s Evenness (J')

Pielou’s Evenness index (J') was ranged from 0.841 to 0.959 in station I and 0.846 to 0.959 in station II. Pielou’s Evenness index (J') was recorded minimum in the month of November (2010) and maximum in the month of August (2010) in station I. In station II, the Pielou’s Evenness index (J') was recorded minimum in the month of November (2010) and maximum in the month of August (2010) (Table 13). The species evenness showed significant variation between two stations (Table 11).

Discussion

Phytoplanktons are limited in the uppermost layers of the water where light intensity is sufficient for photosynthesis to occur. The light incidence at different depths of water depends on a number of factors, like absorption of light by the water, the wave length of light, transparency of the water, reflection from the surface of the water, reflection from suspended particles, latitude and seasons of the year. When light strikes the surface of the water, certain amount of light is reflected the amount depends on the angle at which the light strikes

S.No.	Name of the species	Station-I		Station-II	
		2010	2011	2010	2011
	Coscinodiscea				
1.	*Coscinodiscus granii*	+	+	+	+
2.	*C. radiatus*	+	+	+	+
3.	*C. gigas*	+	+	+	+
4.	*C. lineatus*	+	+	+	+
5.	*C. subtilis*	+	+	+	+
6.	*C. ecentricus*	+	+	-	-
7.	*C. thori*	+	+	+	+
8.	*C. centralis*	+	+	+	+
9.	*Planktoniella sol*	+	+	+	+
10.	*Skeletonema costatum*	+	+	+	+
11.	*Thalassiosira sp.*	+	+	+	+
12.	*T subtilis*	+	+	+	+
13.	*T. ecentrica*	+	+	+	+
14.	*Lauderia sp.*	+	+	+	+
15.	*Cyclotella striata*	+	+	+	+
	Tricertiinae				
16.	*Lithodesmium undulatum*	+	+	+	+
17.	*Ditylum brightwelli*	+	+	+	+
18.	*D. sol*	+	+	+	+
19.	*Triceratium favus*	+	+	+	+
20.	*T. reticulatum*	+	+	+	+
21.	*T. robertsianum*	+	+	+	+
	Chaetocercea				
22.	*Chaetoceros affinis*	+	+	+	+
23.	*C. currivisetes*	+	+	+	+
24.	*C.compressum*	+	+	+	+
25.	*C. diversus*	+	+	+	+
26.	*C. debilis*	-	-	+	+
27.	*C. decipiens*	+	+	+	+
28.	*C. coarctatus*	+	+	+	+
29.	*C. lorenzianum*	+	+	-	-
30.	*C. messanensis*	+	+	+	+
31.	*C. peruvian*	+	+	+	+
32.	*C. indicus*	+	+	+	+
33.	*Bacteriastrum comosum*	+	+	+	+
34.	*B. hyalinium*	+	+	+	+
35.	*B. delicatilum*	+	+	+	+
	Odontella				
36.	*Odontella heteroceros*	+	+	+	+
37.	*O. biddulphia*	-	-	+	+
38.	*O. obtuse*	+	+	+	+
39.	*O. malleus*	+	+	+	+
40.	*O. sinensis*	+	+	+	+
41.	*O. mobiliensis*	+	+	+	+
	Eucampiinea				
42.	*Climocopium fraunfeldium*	+	+	+	+
43.	*Eucampia zoodiaus*	+	+	+	+
44.	*E. carnuta*	+	+	+	+
45.	*Streptothaeca indicus*	+	+	+	+
	Solenoidea				
46.	*Rhizosolenia alata*	+	+	+	+
47.	*R. cylindrica*	+	+	+	+
48.	*R. imbricata*	+	+	+	+
49.	*R. styliformis*	+	+	+	+
50.	*R. setigera*	+	+	+	+
51.	*R. hebetata*	+	+	-	
52.	*R. delicatula*	-	-	+	+
53.	*R. robusta*	+	+	+	+
54.	*Bacillaria paradoxa*	+	+	+	+
55.	*Leptocylindrus danicus*	+	+	+	+
56.	*L. minimus*	+	+	+	+
57.	*Guinordia sp.*	+	+	+	+
58.	*G. striata*	+	+	+	+
	Euodiceae				
59.	*Hemidiscus hardmannianus*	+	+	+	+
60.	*Hemiaulus sinensis*	+	+	+	+
61.	*H. membranaeceus*	+	+	+	+
	Order: Pennales Naviculacea				
62.	*Pleurosigma sp.*	+	+	+	+
63.	*Pleurosigma angulatum*	+	+	+	+
64.	*P. depressum*	+	+	+	+
65.	*P. normanii*	+	+	+	+
66.	*P. elongatum*	-	-	+	+
67.	*P. directum*	+	+	+	+
68.	*Gyrosigma sp.*	+	+	+	+
69.	*G. balticum*	+	+	+	+
70.	*Nitzschia sp.*	+	+	+	+
71.	*Nitzschia longissima*	+	+	+	+
72.	*N. seriata*	+	+	+	+
73.	*N. closterium*	+	+	+	+
74.	*N. granulata*	+	+	+	+
75.	*Navicula sp.*	+	+	+	+
76.	*N. henneydii*	+	+	+	+
77.	*N. granulate*	-	-	+	+
78.	*Diploneis sp.*	+	+	+	+
79.	*Stephanophysis palmariana*	+	+	+	+
	Fragilariaceae				
80.	*Thalassionema nitzschioides*	+	+	+	+
81.	*Thalassiothrix fraunfeldii*	+	+	+	+
82.	*T. longissima*	-	-	+	+
83.	*Fragillaria sp.*	+	+	+	+
84.	*F. intermedia*	-	-	+	+
85.	*F. oceanica*	+	+	+	+
86.	*Asterionella glacialis*	+	+	+	+
87.	*Dichtyocha sp.*	+	+	+	+
88.	*Pediastrum simplex*	+	+	+	+
89.	*Rhabdonema arcuatum*	+	+	+	+
90.	*Diatoma anceps*	+	+	+	+
	DINOFLAGELLATES				
	Dinophysialeas				
91.	Dinophysis caudata	+	+	+	+
92.	D. punctata	+	+	+	+
93.	D. hastata	+	+	+	+
94.	Ornithocercus steinii	+	+	+	+
	Peridiniales				
95.	*Ceratium macroceros*	+	+	+	+
96.	*C. extensum*	+	+	+	+
97.	*C .breve*	+	+	+	+
98.	*C. furca*	+	+	+	+
99.	*C. trichoceros*	+	+	+	+
100.	*C. inflatum*	+	+	+	+
101.	*C.lineatum*	+	+	+	+
102.	*C. fusus*	+	+	+	+
103.	*C. tripos*	-	-	+	+
104.	*Protoperidinium sp.*	+	+	+	+
105.	*Protoperidinium oceanicum*	+	+	+	+

106.	*P. depressum*	+	+	+	+
107.	*P. venustrum*	+	+	+	+
108.	*P. obtusum*	+	+	+	+
109.	*Pyrophacus steinii*	+	+	+	+
110.	*P. striata*	-	-	+	+
111.	*Noctiluca sp.*	+	+	+	+
	Silicoflagellates				
112.	*Prorocentrum micans*	+	+	+	+
	Blue green algae				
113.	*Trichodesmium erythraea*	+	+	+	+
114.	*Oscillatoria limosa*	+	+	+	+
115.	*Spirulina sp.*	+	+	+	+
116.	*Lyngbya sp.*	+	+	+	+
117.	*Anabena sp.*	+	+	+	+
	Total	108	108	114	114

+ Present - Absent

Table 8: Check list of phytoplankton species recorded from January 2010 to December 2011.

Seasons	Months	2010		2011	
		Station I	Station II	Station I	Station II
Post monsoon	January	30,638	30,612	30,128	30,169
	February	31,730	31,925	31,250	31,610
	March	40,315	40,515	40,180	40,121
Summer	April	60,318	60,618	60.794	62,390
	May	81,454	81,610	81,930	81,630
	June	70,635	70,638	70,916	70,618
Pre monsoon	July	32,633	32,938	32,610	32,910
	August	33,135	33,610	33,718	33,815
	September	22,338	21,334	23,038	20,339
Monsoon	October	21,373	21,156	20,181	20,193
	November	15,635	15,439	15,388	15,385
	December	14,408	14,306	14,610	14,615

Table 9: Monthly variations of the phytoplankton population densities (cells/l) from January 2010 to December 2011.

Seasons	Months	2010		2011	
		Station I	Station II	Station I	Station II
Post monsoon	January	6,128	6,210	6,119	6,129
	February	6,218	6,222	6,225	6,132
	March	6,318	6,418	6,425	6,428
Summer	April	6,415	6,420	6,510	6,328
	May	6,400	6,415	6,411	6,412
	June	6,512	6,500	6,612	6,710
Pre monsoon	July	6,415	6,490	6,418	6,415
	August	6,425	6,500	6,425	6,310
	September	5,638	5,916	6,119	6,210
Monsoon	October	5,715	5,818	6,221	6,332
	November	5,110	5,181	5,113	5,112
	December	5,929	5,815	5,991	5,891

Table 10: Monthly variations of Shannon - Wiener's diversity index (H') values (bits/ind) from January 2010 to December 2011.

the surface of the water. Most of the phytoplankton, the photosynthetic rate varies with light intensity. Different species have different curves of photosynthetic rate when plotted against light intensity, giving different optimal light intensified for maximum photosynthesis.

The Light Extinction Co-efficient (LEC) was maximum in the month of August and minimum in the month of June for both the stations. Maximum Light Extinction Co-efficient in August is due to high light intensity, transparency of water, less turbidity and absorption of light by water. The minimum Light Extinction Co-efficient value is recorded in the month of the June due to high turbidity of water and heated water in summer season, which reflect the light waves [25].

In the present study the seasonal cycles of temperature was high

Source of Variation	*SS*	*df*	*MS*	*F*	*F crit*	*P*
Population density						
Stations	35474606	1	35474606	33.47799	4.854336	<0.05
Months	9.39E+09	11	8.54E+08	783.6169	2.82793	<0.05
Error	11981032	11	1089186			
Total	9.44E+09	23				
Species diversity						
Stations	0.104413	1	0.104413	114.1064	4.844335	<0.05
Months	4.695614	11	0.426875	466.5075	2.81794	<0.05
Error	0.010066	11	0.000916			
Total	4.810092	23				
Species richness						
Stations	4.83E-05	1	4.83E-05	19.03594	4.844337	<0.05
Months	0.008263	11	0.000752	296.8324	2.81794	<0.05
Error	2.78E-05	11	2.53E-06			
Total	0.008338	23				
Species evenness						
Stations	0.000156	1	0.000156	5.355359	4.844337	<0.05
Months	0.038655	11	0.003515	121.39	2.81794	<0.05
Error	0.000319	11	2.9E-05			
Total	0.039129	23				

Table 11: Results of Two-way ANOVA for the phytoplankton composition.

Seasons	Months	2010		2011	
		Station I	Station II	Station I	Station II
Post monsoon	January	0.952	0.953	0.956	0.957
	February	0.941	0.948	0.942	0.945
	March	0.954	0.959	0.953	0,954
Summer	April	0.943	0.948	0.949	0.947
	May	0.952	0.953	0.954	0.956
	June	0.948	0.946	0.947	0.949
Pre monsoon	July	0.953	0.954	0.956	0.957
	August	0.959	0.959	0.958	0.956
	September	0.948	0.949	0.949	0.947
Monsoon	October	0.921	0.923	0.924	0.926
	November	0.841	0.846	0.847	0.849
	December	0.952	0.953	0.954	0.955

Table 12: Monthly variations of Pielou's Evenness index (J') from January 2010 to December 2011.

Seasons	Months	2010		2011	
		Station I	Station II	Station I	Station II
Post monsoon	January	0.971	0.972	0.978	0.979
	February	0.983	0.985	0.986	0.987
	March	0.978	0.975	0.976	0.973
Summer	April	0.981	0.982	0.982	0.980
	May	0.972	0.973	0.976	0.575
	June	0.975	0.976	0.975	0.974
Pre monsoon	July	0.968	0.963	0.962	0.963
	August	0.985	0.987	0.987	0.989
	September	0.976	0.975	0.973	0.963
Monsoon	October	0.958	0.959	0.959	0.954
	November	0.912	0.913	0.913	0.914
	December	0.968	0.963	0.963	0.968

Table 13: Monthly variations of Simpson richness from January 2010 to December 2011.

in summer (33°C) and low rates during monsoon (24°C). This was supported by [2] and [26]. Temperature acted along with other factors to influence the variations of photosynthetic production. Generally, the rate of photosynthesis increases with an increase in temperature, but diminishes sharply after a point is reached. Each species of phytoplankton is adapted to particular temperature. Temperature, together with illumination, influences the monthly variation of phytoplankton production in the temperate latitudes. Among different environmental parameters, salinity seems to play a key role for the phytoplankton species composition and density. In the present study, the number of species was high during moderate salinities [27]. Besides light and temperature, salinity is also known to influence primary production. Many species of Dinoflagellates such as *Ceratium*, *Peridiniales* and *Prorocentrum* reproduce actively at lower salinities. The present study was supported by [28], who found that the temperature, salinity and dissolved oxygen of Cochin water were influencing the phytoplankton distribution.

The major inorganic nutrients required by phytoplankton for growth and reproduction are nitrogen (as nitrate, nitrite, or ammonia) and phosphorus (as phosphate).These nutrients are entered into the aquatic system mainly from freshwater flow, sewage discharge and mixing between salt and freshwaters. Other inorganic and organic nutrients may be required in small quantities [29]. They are the limiting factors for phytoplankton productivity under most of the conditions. The upper layers of water usually have a reduced nutrients compared to lower waters. As the phytoplankton population grows in the upper 100m of water, the plants absorb more and more of the light. Less light means that the compensation depth begins to move upward and become shallower. It was interesting to note that when the concentration of nutrients increased, the phytoplankton population density decreased and vice versa. Decrease in nutrient concentrations corresponded well with an increase in phytoplankton population due to utilization of nutrients by phytoplankton especially during summer. The decline in reactive silicate, nitrate and inorganic phosphate concentrations during summer was a result of uptake by phytoplankton population. Further, [30] also noticed a marked seasonal pattern of phytoplankton and large depletion of nutrient concentrations in surface waters during summer. In the Plymouth area, where phytoplankton distribution is very much influenced by local climatic conditions, their growth was in conjunction with the nutrient depletion [31,32]. Among the different nutrients studied, reactive silicate showed marked seasonal variations. During maximum density of diatom population, the silicate concentration reached the minima.

Apart from the influence of physico-chemical factor on phytoplankton population, the grazing rate of zooplankton is one of the major factors that influencing the size of the standing crops of phytoplankton, and thereby the rate of production. This is correlated with the increase in quantity of zooplankton and so grazing by the zooplankton can be suggested as one of the causes for the decline in the standing crop of phytoplankton was also noticed in the present study which coincided with zooplankton dominance. An inverse relationship in the distribution of phytoplankton and zooplankton is usually discernible. Thus an explosion in the phytoplankton production is also due to the comparative scarcity of zooplankton. A phytoplankton bloom naturally results in the sudden depletion of available nutrients in the euophotic zone and such a bloom is usually followed by a lower rate of production. Production rate of phytoplankton will vary from place to place depending on geographical location and enrichment of water bodies. Chang [33] registered production ranging from 2.50 to 89.10 mg Cm^3/hr off the Westland of New Zealand coastal waters. In the present study, the gross primary production values were ranged from 0.07 to 0.35 mg Cm^3/hr and these values are comparatively low when compared to Point Calimere environment [34]. The seasonal cycle of photosynthesis characteristically follows the cycle of temperature with high rates during summer and low rates during winter [35]. In the present study also maximum primary production values were observed during summer for both stations which coincided well with high water temperature and salinity, while low values were noticed during monsoon when water temperature and salinity values were low. From the results of the present study, it was inferred that no single factor could be found to influence the production in Kottakudi and Nari backwaters but it was due to the collective responsibility of various parameters.

In the present survey, the chlorophyll 'a' and phaeo-pigment concentration fluctuated widely and the variation between the months was similar. Chang [33] noticed a maximum concentration of 32.00 mg/m^3 in the Westland off New Zealand coastal waters. Bhattathiri et al. [26] found that the organic carbon and nitrogen were influence the phytoplankton production and chlorophyll'a' distribution in the eastern and central Arabian Sea. Minimum concentration of chlorophyll was noticed during monsoon in parallel with decreasing densities of phytoplankton population during this season [7,36]. Species composition of phytoplankton observed in the present study was more or less similar for both the stations. In the present study, almost all the species observed were higher numbers in November. The dominant forms include diatoms (*T. fraunfeldii* and *T. nitzschioides*) and dinoflagellates (*C. trichoceros* and *P. depressium*) were predominant during November because nutrients (No_2, No_3, TN, IP, TP and Sio_3) showed higher values in this month and enhance the growth of phytoplankton. This was coincide with earlier reports that they are dominant forms of phytoplankton population in tidal area near Seronicos Bay [37], in Dutch Wadden Sea [33] and in Greater Cook Strait [38]. In India similar observations of diatoms domination amidst various groups of phytoplankton were made by [39] and [40] from Portonovo waters, [41] from Cuddalore Uppanar backwaters, [42] from Parangipettai and Cuddalore marine environs, [43] from Kollidam eastuary, [44] and [45] from Pichavaram mangroves, [46] from Coromandel coast, [47] from Tranquebar-Nagapattinam and [48] from Ayyampattinam.

In the present study, maximum population density was registered during summer when temperature and salinity values were high. This substantiates the findings of [31]. They have recorded maximum phytoplankton density in summer season near the base of the stratified region in the Southern Bight of North Sea. Selvaraj et al. [49] recorded 12,000 to 322,000 cells/l in the Cochin waters and 3.92×10^4 to 7.23×10^4 cells/l were recorded by Panigrahy et al. [50] in Gopalpur, east coast of India. Among different environmental variables, highly turbid nature of the water column might have contributed much to the drastic reduction of phytoplankton density during monsoon [40,51-55]. In the present study, diversity index values were ranged from 5.110 bits/ind. to 6.710 bits/ind. These index values were comparable to those reported earlier by Ignatiades et al. [37] in the Saronicos Bay. In general, an increase in population density will increase the diversity index. In the present study, high index values were observed during summer season in the month of June, due to high population density, along with a fairly good richness of species [43]. As like the diversity index, the species were rich in the month of August of pre-monsoon season due to the upwelling of the nutrients in the coastal waters [56]. But during monsoon season particularly in the month of December, low population counts were encountered with paucity of species when the index values were low. This could be attributed to adverse conditions like high turbidity, low salinity and greater freshwater flow. The results of the present study showed that a different environmental factors influence the phytoplankton production, chlorophyll and species composition and population density in estuary.

References

1. Volkman JK, Jeffrey SW, Nichols PD, Rogers GI, Garland CD(1989) Fatty Acid and Lipid Composition of 10 Species of Microalgae Used in Mariculture. J Exp Mar Biol Ecol 128:219-240.
2. Boynton WR, Kemp WM, Keefe CW (1982) A Comparative Analysis of Nutrients and Others Factors Influencing Estuarine Phytoplankton Production. In Estuarine Comparisons (Ed. V.S. Keennedy.). Academic Press, New York. 69-90.
3. Bo Riemann, Peter Simonsen, Lars Stensgaard (1989) The Carbon and Chlorophyll Content of Phytoplankton From Various Nutrient Reimes. J Plankton Res 11: 1037-1045.
4. Sampathkumar P, Ananthan G (2007) Phytoplankton. In: Coastal Biodiversity in Mangrove Ecosystems, UNU-INWEH-UNESCO- International Training Course Manual. 205-212.
5. Everitt DA, Wright SV, Volkman JK, Thomas DP, Lindstom EJ (1990) Phytoplankton Community Compositions in The Western Equatorial Pacific Determined From Chlorophyll and Carotenoid Pigment Distributions. Deep Sea Res 37: 975-997.
6. Vernet M, Lorenzen CJ (1987) The Presence of The Chlorophyll-B and The Estimations of Phaeopigments in Marine Phytoplanton. J Plankton Res 9: 255-265.
7. Dalal SG, Bhargava RMS (1986) Relationship Between Chlorophyll-A and Column Primary Productions. Mahasagar Bull Natl Inst Oceanogr 19: 61-63.
8. Carpenter SR, Elser MM, Elser JJ (1986) Chlorophyll Producuon Degradation and Sedimentauon: Nnphcations For Paleolimnology. Limnol Ocennogr 31. 112-124.
9. Welschmeyer NA, Lorenzen CJ (1985) Chlorophyll Budgets, Zooplankton Grazing and Phytoplanktons Growth in the Temperature Fjord and the Central Pacific Gyres. Limnol Oceanog 30: 1-21.
10. Gopinathan CP, Nair PVR, Pillai VK, Pillai PP, Vijayakumar M, Balachandran VK (1982) Environmental Characteristics of The Seasonal and Perennial Prawn Culture Fields in The Estuarine System of Cochin. Proc Symp Coast Aquacult 1: 368-382.
11. Davis CC (1957) The Marine and Freshwater Plankton. Michigan State University Press. 562.
12. Newell GE, Newell RC (1963) Marine Plankton-A Practical Guide. 5th Edition. Hutchinson and Company (Publishers) Ltd, London. 244.
13. Sukhanova ZNI (1978) Settling without the Inverted Microscope. In: Phytoplankton Manual, UNESCO, (Ed.A. Sournia), Page Brothers (Nourich) Ltd. 97.
14. Mitra A, Banerjee K, Gangopadhyay A (2004) Marine Plankton New Well (G.E) Sivewnt (R.C) Book.
15. Venkataraman G (1939) A Systematic Account of Some South Indian Diatoms. Proc Indian Acad Sci 10: 293-368.
16. Cupp EE (1943) Marine Plankton Diatoms of The West Coast of North America. Bull. Scripps Inst Oceanogr 5: 1-237.
17. Prescott GW (1954) How To Know The Freshwater Algae. (Ed. H. E. Jaques) WMC Brown Company Publishers. IOWA. 272.
18. Taylor FJR (1976) Dinoflagellates from the International Indian Ocean Expedition. A Report on Material Collated By the R.V. Anton Bruun. 1963-1964. Bibil Botan Left 132: 1-226.
19. Anand N, Mohan E, Hopper RSS, Subramanian TD (1986) Taxonomic Studies on Blue Green Algae from Certain Marine Environments. Seaweed Res Utiln 9: 49-56.
20. Strickland JDH, Parsons TR (1972) A Practical Hand Book of Seawater Analysis. Bull Fish Res Bed Canada 167: 310.
21. Parsons TR, Maita Y, Lalli CM (1984) A Manual of Chemical and Biological Method For Sea Water Analysis. Pergamon Press, Oxford. 173.
22. Shannon CE, Wiene W (1949) The Mathematical Theory of Communication. University of Illionis Press, Urbana. 1-117.
23. Gleason HA (1922) On the Relation Between Species and Area. Ecol 3: 156-162.
24. Pielou EC (1966) The Measurement of Diversity in Different Types of Biological Collections. J Theoret Biol 13: 144.
25. Sampathkumar P, Kannan L (1998) Seasonal Variations in Physico-Chemical Characteristics In The Tranquebar-Nagapattinam Region, Southeast Coast of India. Poll Res 17: 397-402.
26. Bhattathiri PM, Aditi Pant A, Surekkha Sawant, Gunus M, Matondkar SGP, Mohanrajum R (1995) Phytoplankton Production and Chlorophyll Distribution in The Eastern and Central Arabian Sea in 1994-1995. Special Section: JGOFS (INDIA).
27. Marshall HG, Alden RW (1990) A Comparison of Phytoplankton Assemblages and Environmental Relationship in Three Estuarine Rivers of The Lower Chesapeake Bay. Estuar 13: 287-300.
28. Jayalakshmi KV, Kumaran S, Vijayan M (1986) Phyotoplankton Distribution in Cochin Backwaters. A Seasonal Study. Mahasagar-Bull Natl Inst Oceanogr 19: 29-37.
29. Verlenkar XN (1984) Dissolved Organic Nutrients and Phytoplanktons Productions in The Mandovi Estuary and Coastal Waters of Goa. Mahasagar–Bull Natl Inst Oceanogr 17: 141-149.
30. Maddock L, Boalch GT, Harbour DS (1981) Population of Phytoplankton in the Western English Channel Between 1964 and 1974. J Mar Biol Ass UK 61: 565-583.
31. Gieskes WWC, Kraay GW (1984) Phytoplankton, Its Pigments and Primary Production At a Central North Sea Station In May, July And September 1981. Netherland J Sea Res 18: 51-70.
32. Rennella AM, Quiros R (2006) The Effects of Hydrology on Plankton Biomass in Shallow Lakes of The Pampa Plain. Hydrobiol 556: 181-191.
33. Chang FH (1983) Winter Phytoplankton and Micro-Zooplankton Population of the Coast Off Westland, New Zealand In 1979. New Zealand J Mar Fresh Wat Res 17: 165-168.
34. Sundharesan T (2008) Diversity of Marine Plankton in Point Calimere Coastal Water (South East Coast of India) M.Phil, Thesis, Annamalai University, India1-92.
35. Das J, Das SN, Sahoo RK (1997) Semidiurnal Variation of Some Physico-Chemical Parameters in the Mahanadi Estuary, East Coast of India. Indian J Mar Sci 26: 323-326.
36. Sasamal SK, Panigraghy RC, Sahu BK (1985) Distribution of Photosynthetic Pigments and Particulate Organic Carbon in Coastal Waters of North Western Bay of Bengal. Indian J Mar Sci 14 : 167-168
37. Ignatiades L, Vassilion A, Karydis M (1985) A Comparison of Phytoplankton Biomass Parameter and Their Inter-Relation with Nutrients in Saronicos Gulf (Greece). Hydrobiol 128: 201.
38. Bradford JM, Lapennas PP, Murtag RA, Chang FH, Wilkinsons V (1986) Factors Influencing Estuarine Phytoplankton Production In Greater Cook Strait, New Zealand. J Mar Fresh Wat Res 20: 253-275.
39. Thangaraj GS (1984) Ecology of the Marine Zone of the Vellar Estuary, Ph.D. Thesis, Annamalai University, India. 1- 192.
40. Vasantha K (1989) Studies on Hydrobiology and Decomposition of Macrophtes in Portonovo Marine Environment (South East Coast of India). Ph.D. Thesis, Annamalai University, India. 1- 252.
41. Murugan A, Ayyakkannu K (1991) Ecology of Uppanar Backwaters. Cuddalore, I. Physico-Chemical Parameters. Mahasagar-Bull Natl Inst Oceanogr 24: 31-38.
42. Ananthan G (1991) Hydrobiology of Parangipettai and Cuddalore Marine Environs with Special Reference To Heavy Metal Pollution. M.Phil Thesis, Annamalai University, India. 1-57.
43. Patterson Edward JK, Ayyakkannu K (1991) Studies on the Ecology of Plankton Community of Kollidam Estuary, Southeast Coast of India. I. Phytoplankton. Magasagar-Bull Natl Inst Oceanogr 24 : 89-97.
44. Kannan L, Vasantha K (1992) Microphytoplankton of The Pitchavaram Mangals, Southeast Coast of India. Species Composition and Population Density. Hydrobiol 247: 77-86.

45. Mani P (1994) Phytoplankton in Pichavaram Mangroves, East Coast of India. Indian J Mar Sci 23: 22-26.

46. Govindasamy C (1992) Coromental Coast of India-A Study on Hydrobiology and Heavy Metals, Ph.D., Thesis, Annamalai University, India, 1-119.

47. Sampathkumar P (1992) Investigations on Plankton In Relation To the Hydrobiology and Heavy Metals in the Tranquebar-Nagapattinam Coast India. Ph.D., Thesis, Annamalai University, India.1- 267.

48. Santhosh Kumar C, Perumal P (2012) Studies on Plankton Characteristics in Ayyampattinam Coast, India. J Environ Biol 33: 585-589.

49. Selvaraj GSD, Thomas VJ, Khambadkar LR (2003) Seasonal Variation of Phytoplankton and Productivity in the Surf Zone and Backwater at Cochin. J Mar Biol Ass India 45: 9-19.

50. Panigrahy RC, Sangeeta Mishra, Gouri Sahu, Mohanty AK (2006) Seasonal Distribution of Phytoplankton in the Surf Waters Off Gopalpur, East Coast of India. J Mar Biol Ass India 48: 156-160.

51. Anbazhagan P (1988) Hydrobiology and Benthic Ecology of Kodiakkarai Coastal Sanctuary (Southeast Coast of India). Ph.D Thesis, Annamalai University, India. 1-208.

52. Ananthan G (1995) Plankton Ecology and Heavy Metal Studies in the Marine Environs of Pondicherry, India. Ph.D Thesis, Annamalai University, India. 1-125.

53. Geetha Madhav V, Kondalaro B (2004) Distribution of Phytoplankton in the Coastal Waters of East Coast of India. Indian J Mar Sci 33 :262-268.

54. Ananthan G, Sampathkumar P, Soundarapandian P, Kannan L (2008) Phytoplankton Composition and Community Structure of Ariyankuppam Estuary and Veerampattinam Coast of Pondicherry. J Fish Aqu Sci 3: 12-21.

55. Ananthan G, Soundarapandian P, Sankar S (2012) Hydrological and Diversity of Phytoplankton Composition and Community Structure in Chennai Coastal Water. Recent Advan Biodiver India. Zool Sur India, Mumbai.169-183.

56. Saraswathi R (1993) Hydrobiology of Two Estuarine Systems (Arasalar and Kaveri) in The Southeast Coast of India With Special Reference To Plankton. Ph.D Thesis, Annamalai University, India 1- 267.