Published by: National Cave Research and Protection Organization, India

RESEARCH ARTICLE

Seasonal Variation of Phytoplankton Cherthala-Aroor-Edakochi Coastal Belt of Kerala, India

Vidya Vijayakumari, Gopal Prasad

Department of Zoology, University of Kerala, Kariavattom,
Thiruvananthapuram Kerala, India, 695581,

Study Area: Vembanad wetland, Kerala

Coordinates: 9°35'N; 76°25'E

Key words: Physico-chemical Parameters, Vembanad,
Seafood industry, Sea Pollution

Abstract

A seasonal variation of plankton and its relation to the physico-chemical parameters in Cherthala-Aroor-Edakochi coastal belt of Kerala, where maximum numbers of seafood processing industries are located is studied. The phytoplankton samples were collected from ten pre-selected sites. Nine of the selected sites were closely associated with the discharge mouth of seafood processing plants and one kept as the reference site which is free from the seafood plant discharge. From all the study sites, a total of 38,472 phytoplankton individuals belonging to 11 classes were identified on the basis of standard keys. The major classes obtained were Bacillariophyceae (21,812 individuals), Chlorophyceae (7111 individuals), Cyanophyceae (6118). The correlation analysis showed that physico-chemical parameters like DO, BOD, COD, transparency and pH significantly influenced the distribution of phytoplankton.

Introduction:

Phytoplanktons are plants (microscopic), drifting at the mercy of water current. They do not have control over their movements thus they cannot escape pollution in the environment Abowei *et al.* (2012). The distributions, abundance, species diversity and species composition of the phytoplankton are used to assess the biological integrity of the water body Begon *et al.* (2014). Planktons are very sensitive to the environment they live in and any alteration in the environment leads to change in plankton communities in terms of tolerance, abundance, diversity and dominance in the habitat. They react fast to the pollution in the aquatic environment. Therefore, plankton population observation may be used as a reliable tool for biomonitoring studies to assess the pollution status of aquatic bodies Davies *et al.* (2009). Phytoplanktons are also the diagnostic tools in assessing water quality and hydrological status Nwankwo, (2004). Its distribution, abundance and diversity reflect the physico-chemical conditions of aquatic ecosystem in general and its nutrient status, in particular, Anene, (2003). There has been much interest in the processes influencing the development of phytoplankton communities, primarily in relation to physico-chemical factors Akbay *et al.* (1999); Peerapornpisal *et al.* (1999). There are many detailed descriptions of phytoplankton succession being correlated with changes in environmental parameters particularly

temperature, light, nutrients availability and mortality factors such as grazing and parasitism (Roelke & Buyukates, 2002). Phytoplankton satisfies conditions to qualify as suitable indicators in that they are simple, capable of quantifying changes in water quality, applicable over large geographic areas and can also furnish data on background conditions and natural variability (Lee, 1999). Vembanad and Kol wetland are the third largest wetland system in India and are designated Ramsar sites. Vembanad wetlands, apart from their ecological, regional and economic importance serve as a sink for the disposal of waste from different sources. Several studies explained the pollution status of Vembanad lake from various sources including domestic and municipal sewage, fertilizer and pesticide residues, heavy metals, coconut retting, industrial effluents from oil refineries, fertilizer plants, and chemical industries (Rai *et al.* 1976; Remani *et al.*, 1980; Saraladevi *et al.*, 1979). There are about 287 seafood exporters in Kerala with 124 processing plants and 169 cold storages. Kerala accounted for 10,8616 ton valued at Rs.1524.12 crores sharing 17.7% in quantity and 18.2% in value of marine export from India (www.ksidc.org). The Kochi region has a vast majority of export processing plants within the state. 81 out of the 91 registered exporters in Kerala are situated within the Kochi and Cherthala taluks (SIFFS, 2002). Effluents from fish and crustacean processing plants are generally characterized by high concentrations of

*Corresponding Author: vidyaveee@gmail.com

nutrients, high levels of nitrogen content found as ammonia ($\text{NH}_3\text{-N}$; 29 to 35 $\text{mg}\cdot\text{L}^{-1}$), high total suspended solids (0.26 to 125,000 $\text{mg}\cdot\text{L}^{-1}$), increased biological oxygen demand (10 to 110,000 $\text{mg}\cdot\text{L}^{-1}$) and chemical oxygen demand (496 to 140,000 $\text{mg}\cdot\text{L}^{-1}$), and by the presence of sanitizers (AMEC Earth and Environmental Limited 2003). The direct discharge of waste from the seafood processing industries into the adjacent wetlands affects the aquatic life and thus may affect the whole food chain. Uncontrolled discharge of waste disturbs the natural self-purification capacity of the river. The fish processing effluents detrimentally affect the quality of water bodies (Hamid *et al.*, 2010). Considering the aforementioned reasons, the present study has been formulated to understand the seasonal variation of phytoplankton in relation to the physico-chemical parameters in selected sites of Vembanad wetland.

Materials and methods:

The surface water samples were collected on a monthly basis from the ten pre-selected sites of Vembanad wetlands where the maximum numbers of processing plants have been started since a period of last two years (October 2010-September 2012). Nine of the selected sites (S1-S9) were closely associated with the discharge mouth of the seafood processing plants wetlands and one kept as the reference site (S10) which was free from the seafood plant discharge. Phytoplankton samples were collected from the surface water using a conical net of mesh size 50 μm , for a period of two year on a monthly basis. A known volume (25 liters) of water is passed through the net and was collected in a 50 ml plastic container. The labeled samples were preserved in 4% formalin solution at the site itself, labeled and brought to the laboratory. Taxonomic identification of plankton up to genus level was done using standard keys (Adoni, 1985; Newell & Newell, 1986; Palmer, 1980; Santhanam *et al.*, 1987). Quantitative analysis of plankton was done by employing Sedgewick-rafter cell counting chamber. One ml of filtered plankton sample was transferred to the counting chamber and counted using a binocular microscope and reported as units or organisms per milliliter (mL) APHA *et al.* (2005).

Season-wise correlation analysis was employed to determine the relationship between physico-chemical parameters and phytoplankton.

Results and Discussions:

During the study period, a total of 38,472 phytoplankton individuals belonging to 11 classes were reported from all the study sites. The taxonomic classes reported were Bacillariophyceae (21,812 individuals), Chlorophyceae (7111 individuals), Cyanophyceae (6118), Dinophyceae (2445 individuals), Euglenophyceae (511 individuals), Eustigmatophyceae (181 individuals), Rhodophyceae (92 individuals), Haptophyceae (79 individuals), Chrysophyceae (71 individuals), Cryptophyceae (30

individuals) and Dictyophyceae. The study reported dominance of Bacillariophyceae in all the nine sites (S1-S9) compared to the reference site. This may be due to its tolerance to a wide range of physico-chemical parameters as reported by Ajuonu *et al.* (2011). Bellinger & Siegee (2010) also reported that the abundance of Bacillariophyceae was a characteristic feature of a eutrophic environment. The class Chlorophyceae followed by Cyanophyceae were the next dominant groups. These classes showed the highest individuals in the polluted sites compared to the reference site (Table-1). According to Rawson (1956), oligotrophic lakes are typically rich in the Chlorophyceae. Cyanophyceae dominance and its blooms are the most visible symptom of accelerated eutrophication of lakes and reservoirs (Moss, 1995). The fourth dominant class reported during the study period was Dinophyceae and its dominance is a characteristic of polluted water (Palmer, 1980).

The Mean $\pm$ SE of the different phytoplankton classes were tabulated and given as Tables-2 to 4. To determine the extent of influence of the environmental factors on certain dominant classes of phytoplankton, season-wise correlation coefficients were calculated (Tables- 5 to 7). Various correlations between different phytoplankton classes were also done (Tables-8 to 10). In the current study, the phytoplankton group showed a few significant correlations with the physico-chemical parameters.

During post-monsoon season, Bacillariophyceae was highest in S3 (154.50 $\pm$ 24.25) and lowest in S10 (44.38 $\pm$ 12.38). The Dinophyceae was highest in S9 (23.75 $\pm$ 4.75) and lowest in S10 (0.25 $\pm$ 0.25). The Chlorophyceae was highest in S2 (94.38 $\pm$ 28.38) and lowest in S10 (18.00 $\pm$ 8.00). The Cyanophyceae was reported maximum at S5 (48.88 $\pm$ 17.63) and minimum at S7 (11.63 $\pm$ 4.13). During the post-monsoon season, the Bacillariophyceae showed a significant negative correlation with air temperature ($p=-0.655$), nitrate ($p=-0.252$), silica ($p=-0.202$) and with DO ($p=-0.390$). The Dinophyceae showed positive correlation with alkalinity ($p=0.617$), hardness ($p=0.470$), BOD ($p=0.805$), COD ($p=0.725$), phosphate ($p=0.720$), ammonia ($p=0.570$) and silica ($p=0.518$) while it showed a weak negative correlation with pH ($p=-0.049$) and transparency $p=-0.789$) and with DO ($p=-0.728$).

Chlorophyceae showed a positive correlation with light intensity ($p=0.650$) and negative correlation with air temperature ($p=-0.733$) while Cyanophyceae showed a significant positive correlation with pH ($p=0.659$). During pre-monsoon season, Bacillariophyceae was highest in S1 (113.88 $\pm$ 41.38) and lowest at S9 (53.63 $\pm$ 19.88). The Dinophyceae was highest in S2 (12.00 $\pm$ 3.25) and lowest in S10 (0.75 $\pm$ 0.50). The Chlorophyceae was maximum in S2 (46.50 $\pm$ 9.25) and minimum in S10 (17.88 $\pm$ 3.13). The Cyanophyceae was highest in S2 (82.88 $\pm$ 42.63) and lowest in S8 (15.13 $\pm$ 7.88). In the pre-monsoon season, the phytoplankton group showed a few significant correlations

Table 1: Family-wise Distribution of phytoplankton class in ten sites (S₁ to S₁₀)

Name of the Families	S ₁	S ₂	S ₃	S ₄	S ₅	S ₆	S ₇	S ₈	S ₉	S ₁₀	Total
Bacillariophyceae	2415	2255	3094	2770	2119	2265	1883	1922	1893	1196	21812
Dinophyceae	219	241	401	199	316	247	274	159	370	19	2445
Chlorophyceae	703	1271	863	833	696	620	632	499	566	428	7111
Cyanophyceae	715	977	897	715	753	524	484	335	438	280	6118
Chrysophyceae	0	4	15	10	8	6	14	9	2	3	71
Dictyochophyceae	1	2	6	2	2	4	1	3	1	0	22
Rhodophyceae	10	8	4	3	8	13	15	10	7	14	92
Haptophyceae	6	7	11	15	5	10	7	8	8	2	79
Eustigmatophyceae	8	57	25	27	32	8	3	16	4	1	181
Cryptophyceae	6	0	0	7	3	2	7	4	1	0	30
Euglenophyceae	37	25	61	72	54	43	36	76	106	1	511
Total	4120	4847	5377	4653	3996	3742	3356	3041	3396	1944	38472

Table 2: Distribution of different phytoplankton class (Mean± SE) during the post monsoon season

Site	Bacillarioph.	Dinoph.	Chloroph.	Cyanoph.
S ₁	97.50±22.25	8.88±2.38	28.88±13.88	17.38±6.63
S ₂	144.63±38.38	11.88±3.88	94.38±28.38	24.25±3.50
S ₃	154.50±24.25	13.50±3.50	42.75±2.50	24.13±2.63
S ₄	142.00±28.75	12.50±2.25	41.38±6.13	30.25±11.50
S ₅	132.38±32.13	22.75±5.25	41.63±6.38	48.88±17.63
S ₆	116.88±5.38	14.25±3.25	36.50±2.50	13.50±1.50
S ₇	86.00±15.25	16.38±5.13	28.88±4.63	11.63±4.13
S ₈	78.63±16.63	10.13±1.13	24.75±13.25	13.38±2.38
S ₉	113.13±17.63	23.75±4.75	30.88±16.13	18.25±3.00
S ₁₀	44.38±12.38	0.25±0.25	18.00±8.00	12.13±10.88

Table 3: Distribution of different phytoplankton class (Mean± SE) during the pre monsoon season

Site	Bacillarioph.	Dinoph.	Chloroph.	Cyanoph.
S ₁	113.88±41.38	10.38±4.88	40.38±9.13	28.38±13.62
S ₂	93.25±18.75	12.00±3.25	46.50±9.25	82.88±42.63
S ₃	84.38±21.38	11.00±3.00	25.50±7.25	42.75±18.75
S ₄	93.75±15.25	7.25±1.50	33.25±8.50	23.88±4.63
S ₅	73.88±23.88	9.63±5.88	25.75±10.50	17.50±6.25
S ₆	72.00±19.50	9.75±5.50	19.13±7.38	31.25±15.50
S ₇	76.63±27.13	8.63±4.38	23.00±5.75	28.13±18.13
S ₈	60.50±14.75	3.25±2.00	19.63±6.13	15.13±7.88
S ₉	53.63±19.88	11.13±5.88	21.13±4.88	17.63±10.38
S ₁₀	63.50±23.25	0.75±0.50	17.88±3.13	11.38±4.88

Table 4 : Distribution of different phytoplankton class (Mean± SE) during the monsoon season

Site	Bacillarioph.	Dinoph.	Chloroph.	Cyanoph.
S ₁	90.50±25.50	8.13±3.63	18.63±5.63	43.63±18.13
S ₂	44.00±8.25	6.25±4.25	18.00±8.50	15.00±8.00
S ₃	147.88±46.88	25.63±16.63	39.63±25.88	45.25±4.25
S ₄	110.50±59.75	5.13±2.38	29.50±18.00	35.25±15.75
S ₅	58.63±15.63	7.13±3.13	19.63±7.88	27.75±8.50
S ₆	94.25±19.50	6.88±3.13	21.88±13.38	20.75±12.75
S ₇	72.75±38.50	9.25±6.75	27.13±17.63	20.75±16.25
S ₈	101.13±67.13	6.50±4.25	18.00±10.50	13.38±6.63
S ₉	69.88±20.13	11.38±3.38	18.75±6.50	18.88±6.63
S ₁₀	41.63±16.63	1.38±0.63	17.63±7.13	11.50±6.00

Table 5: Correlation matrix relating Phytoplankton class with physico chemical parameters during the post monsoon season

Parameters	Bacillarioph.	Dinoph.	Chloroph.	Cyanoph.
Airtemp	-.655*	-.152	-.733*	-.272
Watertemp	-.258	.177	.098	.294
pH	.093	-.049	.184	.659*
TDS	-.067	.277	.100	.312
EC	-.174	.362	.001	.232
Salinity	-.210	.290	-.090	.254
Transparency	-.144	-.789**	-.177	-.126
Lightintensity	.621	.600	.650*	.397
FreeCO ₂	.026	.452	.033	-.028
Alkalinity	.012	.617	.052	.119
Hardness	-.096	.470	.077	.188
DO	-.390	-.728*	-.450	-.226
BOD	-.017	.805**	.097	.281
COD	.107	.725*	.029	.166
Phosphate	-.160	.720*	.013	.003
Nitrate	-.252	.537	-.116	-.144
Ammonia	-.124	.570	-.120	.075
Silica	-.202	.518	.003	-.026

Table 6: Correlation matrix relating Phytoplankton class with physico chemical parameters during the premonsoon season

Parameters	Bacillarioph.	Dinoph.	Chloroph.	Cyanoph.
Airtemp	-.410	-.169	-.447	-.303
Watertemp	-.642*	.128	-.295	-.356
pH	-.216	-.735*	-.033	-.359
TDS	-.212	.375	-.296	-.269
EC	-.168	.332	-.317	-.301
Salinity	-.008	.434	-.215	-.154
Transparency	-.638*	-.815**	-.259	-.407
Lightintensity	.329	.474	.076	-.050
FreeCO ₂	.590	.623	.459	.254
Alkalinity	.667*	.859**	.215	.627
Hardness	.824**	.708*	.375	.454
DO	-.644*	-.431	-.139	-.437
BOD	.671*	.849**	.439	.374
COD	.474	.686*	.354	.126
Phosphate	.724*	.740*	.323	.378
Nitrate	.655*	.551	.238	.270
Ammonia	.658*	.689*	.099	.454
Silica	.728*	.766**	.140	.562

Table-7: Correlation matrix relating Phytoplankton class with physico chemical parameters during the monsoon season

Parameters	Bacillarioph.	Dinoph.	Chloroph.	Cyanoph.
Airtemp	.201	.103	.215	-.447
Watertemp	.180	.240	.296	-.361
pH	-.050	.051	-.022	.448
TDS	.198	.227	.185	-.273
EC	.324	.357	.289	-.184
Salinity	.288	.208	.072	-.301
Transparency	-.307	-.611	-.350	-.318
Lightintensity	.291	.464	.388	.206
FreeCO ₂	.108	.236	.059	.435
Alkalinity	.179	.281	.305	.422
Hardness	.493	.436	.266	.059
DO	-.405	-.334	-.316	-.573
BOD	.184	.499	.244	.395
COD	.107	.344	.253	.369
Phosphate	-.056	.138	.027	.208
Nitrate	.384	.587	.376	.404
Ammonia	.141	.175	.214	.380
Silica	.090	.226	-.042	.477

Table8 : Correlation matrix relating Phytoplankton class with other during pre-monsoon

Families	Bacillarioph.	Dinoph.	Chloroph.	Cyanoph.
Bacillariophyceae	1	.432	.665*	.616
Dinophyceae		1	.132	.403
Chlorophyceae			1	.347
Cyanophyceae				1

Table-9: Correlation matrix relating Phytoplankton class with other during monsoon

Families	Bacillarioph.	Dinoph.	Chloroph.	Cyanoph.
Bacillariophyceae	1	.432	.665*	.616
Dinophyceae		1	.132	.403
Chlorophyceae			1	.347
Cyanophyceae				1

Table 10 :Correlation matrix relating Phytoplankton class with other during post monsoon

Families	Bacillarioph.	Dinoph.	Chloroph.	Cyanoph.
Bacillariophyceae	1	.432	.665*	.616
Dinophyceae		1	.132	.403
Chlorophyceae			1	.347
Cyanophyceae				1

* 5 % level significant (p<0.05); ** 1% level significant (p<0.01).

with the physico-chemical parameters. The Bacillariophyceae showed a negative correlation with air temperature (p=-0.655) and DO (p=-0.390). The Dinophyceae showed a significant positive correlation with BOD (p=0.805), COD (p=0.725) and with phosphate (p=0.720) while it showed a significant negative correlation with transparency (p=-0.789) and with DO (p=-0.728). The Chlorophyceae showed significant correlation with light intensity (p=0.650) whereas it showed a significant negative correlation with air temperature (p=-0.733). The

Cyanophyceae showed a significant positive correlation with pH (p=0.659).

During monsoon season, Bacillariophyceae was highest reported in S₃ (147.88±46.88) and lowest in S₁₀ (41.63±16.63). The Dinophyceae was highest recorded in S₃ and lowest in S₁₀ (1.38±0.63). The Chlorophyceae and Cyanophyceae were recorded maximum in S₃ (39.63±25.88) (45.25±4.25) and minimum in S₁₀ (17.63±7.13) (11.50±6.00) respectively. Statistically, significant correlation was not shown by the physico-chemical parameters and phytoplankton groups during the monsoon season.

The season wise correlation analysis between phytoplankton groups also showed some statistically significant results. In the post-monsoon season, the Chlorophyceae showed a significant positive correlation with Bacillariophyceae (p=0.665). In the pre-monsoon season, the Chlorophyceae showed a significant positive correlation with Bacillariophyceae (p=0.834) and also with Cyanophyceae (p=0.725). In the monsoon season, the Chlorophyceae showed a significant positive correlation with Bacillariophyceae (p=0.782) and with Dinophyceae (p=0.640) while Cyanophyceae showed a significant positive correlation with Bacillariophyceae (p=0.688) and also with Chlorophyceae (p=0.644). In all the seasons, the phytoplankton population (Mean±SE) was less in the reference site when compared to the other sites (S₁-S₉).

The study showed that the physico- chemical parameters like DO, BOD, COD, transparency, and pH significantly influenced the distribution of phytoplankton classes. The pH, DO, alkalinity and the dissolved nutrient are important for the phytoplankton production (Sivakumar & Kareppasmy, 2008). Plankton abundance and taxonomic diversity depend upon the supply of nutrients in natural waters (Chowdhury *et al.*, 2007). The accumulation of organic matter from seafood waste will lead to the depletion of dissolved oxygen in the water column and reduces transparency (Mazik *et al.*, 2005) which in turn showed a significant negative correlation with phytoplankton during the pre-monsoon and post-monsoon periods. A decrease in transparency was associated with elevated phytoplankton biomass (Cloern, 2001). In the present study, the highest plankton density was recorded during pre-monsoon season when N-NO₃ concentrations were found to be highest. A similar positive relationship was also reported by Shukla *et al.* (2013). In this study, phytoplankton responded positively to the higher phosphate concentration. These findings contradicted with Patra & Azadi (1987) who found a negative relationship between P-PO₄ and plankton population. The physico-chemical parameters significantly influenced the phytoplankton population, especially in the pre-monsoon season. During the summer season, the river water turns to more lacustrine and the additions of nutrients favoured the growth of plankton (Sileika *et al.*, 2006). The season wise

correlation of the physico-chemical parameters and the phytoplankton could be used as a baseline and reference point when assessing further changes in the wetland due to the discharge of seafood waste associated pollution.

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