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Population dynamics of the phytoplankton assemblage of Ashtamudi Wetland, India

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ABSTRACT

Thekkumbhagam creek, the part of the Ashtamudi estuary, a tropical estuarine system that is located in the southwest coast of India that needs a restoration for its deterioration due to anthropogenic activities. As phytoplankton is a bioindicator of the natural environmental quality, a purposeful study was therefore undertaken to track the seasonal variations of phytoplankton assemblages encompassing a period of two years. Among the four selected stations, station1 showed the dominance of Bacillariophyceae. Station 4 expressed the highest mean value of Cyanophyceae during the pre-monsoon period. Station 3 recorded the highest mean value of Bacillariophyceae in the pre-monsoon period during 2008-2009. From the study it was noted that the Chlorophyceae, Cyanophyceae, Dinoflagellates and diatoms dominance were registered in the summer season with a comparatively high temperature. This paper reviews the issue concerned with anthropogenic impact and the anticipatory effects, especially on the biological diversity of the wetland "Ashtamudi", a wetland of International importance that is having one of the vibrant fishing industries of Kerala, Neendakara. So, any study concerning with its conservation strategy should be taken into consideration. Besides that, one of the vibrant fishing industries of Kerala, Neendakara is a part of it. Further these studies will go long way in helping the authorities concerned as well as the local people to take suitable measures for restoring and to preserve the pristine nature of this creek besides sustainable utilization of its resources

KEYWORDS

Phytoplankton | Chlorophyceae | Cyanophyceae | Dinoflagellates | Bacillariophyceae

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Introduction

The health status and biological diversity of the Indian wetland ecosystem are deteriorating day-by-day by dumping of enormous quantities of sewage in to the estuary that has drastically reduced the population of fishes. It has also caused considerable ecological imbalance and resulted in large scale disappearance of their flora and fauna. Having recognized the importance of the Ashtamudi wetland a comprehensive monitoring and an evaluation of the pollution status of the wetland is inevitable. A perusal of literature shows that no sufficient study was carried out on the phytoplankton dynamics of the Thekkumbhagam Creek of Ashtamudi wetland. Planktons are very sensitive to the environment they live in and any alteration in the environment leads to the changes in the plankton communities in terms of tolerance, abundance, diversity and dominance in the habitat (Mathivanan *et al.,* 2007). Therefore, plankton population observation may be used as a reliable tool for biomonitoring studies to assess the pollution status of aquatic bodies.

Phytoplankton forms the foundation stone of world fishery due to its role as food for fishes. Species composition of the phytoplankton community is an efficient indicator of water quality (Peerapornpisal et *al.,* 2004). Phytoplankton production contributes about 95 % of total production in the marine environment (Karlson *et al.,* 2010). Many biotic and abiotic processes contribute to variability in phytoplankton diversity in aquatic ecosystems. Seasonal replacement of phytoplankton assemblages are closely linked to seasonal changes in temperature, external hydraulic, nutrient loads and light availability (Malten *et al.,*1991) Other processes acting on as time periods on days to week, like meteorological (wind, rain and cloudiness) and hydrological events(water and inputs, hydrological withdrawal and water level fluctuations) (Guillermo,2009). As the most sensitive organisms they serve as indicators of water quality with their ability to detect even the subtle changes taking place in their ambient environment (Mohamed *et al*., 2009). Due to the ever-increasing quest of man to conquer nature has led to degradation causing the plankton population to be affected leading to drastic changes in the food chain of the marine environment. Hence the abundance of phytoplankton can be taken as the best means for quantitative assessment of potential fisheries of an area. In the present study, seasonal variations of phytoplankton community of four selected stations of the Thekkumbhagam creek of Ashtamudi wetland had been documented. During the study of the present work, it was found that there were various sources of pollution responsible for the deterioration of the water quality of the Thekkumbhagam creek. Moreover, this creek as per the study conducted seems to be one with great economic, cultural, aesthetic values among the eight creeks of the Ashtamudi wetland. Considering the obtained results, phytoplankton assemblages can cause harmful algal blooms that may effect on future needs of this wetland ecosystem and appropriate decisions can be taken to satisfy its conservation strategy.

Materials and Methods

Ashtamudi estuary is the second largest estuary in Kerala. Monthly collections of plankton samples were made from four selected stations for a period of two years from June 2008 to May 2010 (Fig.1).

Water was collected from the surface early morning with minimal disturbances with a plankton net of mesh size of 55µ m (bolting silk no 25) and the planktons were then transferred to a storage bottle using 100 ml distilled water. The samples were immediately preserved in 5% formalin. Drop count method was adopted for plankton's enumeration (Adoni, 1985). Identification and enumeration were done with a compound microscope. Identification of planktons was done following Adoni (1985), APHA (1985), Battish (1992). The data collected at monthly intervals from all the stations were statistically analysed, with a view to understand the nature of variations in the physico-chemical parameters between stations and seasons. Analysis includes Mean, Standard Deviation, ANOVA.

Fig. 1: Map showing the selected stations

Result

In station 1, phytoplankton ranged from 4 units /l to 1000 units/l in 2008-2009 and 14units/l to 11000units/l in 2009-2010.About 36genera of phytoplankton were recorded, 12 genera of Cyanophyceae, 16 genera of Chlorophyceae, 5 genera of Bacillariophyceae and 3 genera of Dinoflagellates. Bacillariophyceae was the dominant group (64.7%) followed by Cyanophyceae (23%), Dinoflagellates (11%) and Chlorophyceae (1.05%) in the first year. In the second year Bacillariophyceae was dominant (45.2%) followed by Dinoflagellates (38.13%), Cyanophyceae (13.09%), Chlorophyceae (3.57%). The annual mean ± SE of Chlorophyceae, Cyanophyceae, Dinoflagellates and Bacillariophyceae were 46.42 ±16.86, 1022.92 ± 532.68, 481.58 ± 241.22 and 3009.08 ± 1197.68 in the first year and237.83 ± 161.83, 871.92 ± 570.23, 2538.42 ± 1203.14 and 3309.08 ± 1197.68 in the second year respectively. (Table 1, 5, 9, 10 and fig 2, 3, 4,5, 6, 7, 8,9,10,11)

Phytoplankton in station 2, ranged from 5 units /l to 20000 units/l in 2008-2009 and 11units/l to 12500 units/l in 2009-2010. About 39 genera of phytoplankton were recorded 7 genera of Cyanophyceae, 14 genera of Chlorophyceae,14 genera of Bacillariophyceae and 4 genera of Dinoflagellates. Bacillariophyceae was the dominant group (50.23%) followed by Dinoflagellates (28.54%) and Chlorophyceae (12.27%), Cyanophyceae (8.55%) in the first year. In the second year Bacillariophyceae was dominant (66.13%) followed by Dinoflagellates (22.55%), Chlorophyceae (8.82%) and Cyanophyceae (2.48%), The annual mean ± SE of Chlorophyceae, Cyanophyceae, Dinoflagellates and Bacillariophyceae were 829.92 ±499.19, 577.92 ± 493.3, 1956.17 ± 1658.58 and 3395.25 ± 1277.59 respectively in the first year and 547.83 ± 353.15, 154.08 ± 79.5, 1399.67 ± 898.68 and 4103.5 ± 1428.78 in the second year respectively. (Table 2, 6, 9, 10and fig 2, 3, 4,5, 6, 7, 8,9,10,11).

In station 3, phytoplankton ranged from 9 units /l to 15000 units/l in 2008-2009 and 9 units/l to 6000 units/l in 2009-2010. About 47 genera of phytoplankton were recorded 10 genera of Cyanophyceae, 20 genera of Chlorophyceae, 15 genera of Bacillariophyceae and 2 genera of Dinoflagellates. Bacillariophyceae was the dominant group (61.04%) followed by Cyanophyceae (29.23%), Chlorophyceae (8.75%), Dinoflagellates (1.01%) and in the first year. In the second year Cyanophyceae (55.41%) was dominant followed by Chlorophyceae (21.42%), Dinoflagellates (15.52%), and Bacillariophyceae (7.63%). The annual mean ± SE of Chlorophyceae, Cyanophyceae, Dinoflagellates and Bacillariophyceae were 629.75 ± 392.17, 2031.33 ± 855.05, 73.58 ± 20.73 and 4415.5 ± 1603.41 in the first year and 729.67 ± 405.79, 1887.08 ± 673.4, 528.5 ± 355.42 and 259.83 ± 133.19 in the second year respectively.(Table 3,7,9,10 and fig 2, 3, 4,5, 6, 7, 8,9,10,11).).

In station 4, phytoplankton ranged from 6units /l to 15000 units/l in2008-2009 and 9 units/l to 13000 units/l in 2009-2010. About 56 genera of phytoplankton were recorded 10 genera of

Cyanophyceae, 15 genera of Chlorophyceae, 29 genera of Bacillariophyceae and 2 genera of Dinoflagellates. Bacillariophyceae was the dominant group (75.82%) followed by Cyanophyceae (13.02%), Chlorophyceae (10.73%), Dinoflagellates (0.41%) and in the first year. In the second year Bacillariophyceae was the dominant group (46.69%) followed by Cyanophyceae (45.51%), Chlorophyceae (4.407%), Dinoflagellates (3.37%). The annual mean ± SE of Chlorophyceae, Cyanophyceae, Dinoflagellates and Bacillariophyceae were 523.25 ± 337.93, 634.92 ± 308.74, 421.73 ± 3.78 and 3696.42± 1407 in the first year and 226.5 ± 162.55, 2339.17 ± 840.94, 173.58 ± 101.79 and 299.83 ± 1315.96 in the second year respectively. (Table 4, 8, 9, 10 and fig 2, 3, 4,5, 6, 7, 8,9,10,11).).

Parameters	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**
Chlorophyta	4	150	180	25	55	19	60	15	12	8	17	12
Cyanophyta	58	4000	5000	3000	45	43	30	32	25	16	9	17
Dinoflagellates	45	27	12	176	2000	199	2500	187	165	100	178	190
Diatoms	18	15	23	8	16	17	19	5000	10000	9000	4000	6000

Table:1 Distribution of phytoplankton(units/l) in station 1 (2008-2009)

Parameters	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**Ma**
Chlorophyt	4	1500	165	400	3	1	195	4	2	3	3	190
Cyanophyt	154	175	1	3	143	180	200	9	143	176	3500	100
Dinoflagell	1	9	3	1	1	3	4	1	3	1	6	1
Diatoms	250	3	3000	165	4500	1000	1	8000	1500	1000	9	4

Table: 2 Distribution of phytoplankton (units/l) in station 2 (2008-2009)

Parameters	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**
Chlorophyta	164	189	176	190	167	5000	4000	12	5	8	25	23
Cyanophyta	19	31	17	36	40	145	190	143	27	90	197	6000
Dinoflagellateees	46	29	37	3000	20000	34	40	41	163	45	19	20
Diatoms	2000	1500	2500	16	9	13	16	3500	11000	12000	8000	189

Table :3 Distribution of phytoplankton(units/l) in station 3 (2008-2009)

Parameters	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**
Chlorophyta	150	25	100	3000	4000	14	156	24	21	30	28	9
Cyanophyta	34	15	5000	23	65	6000	32	8000	75	87	6000	45
Dinoflagellates	23	60	25	190	38	195	17	43	50	39	16	187
Diatoms	3000	4000	45	32	23	23	9500	165	8000	13000	198	15000

Table :4 Distribution of phytoplankton(units/l) in station 4 (2008-2009)

Parameters	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**
Chlorophyta	100	2000	85	146	187	30	179	16	34	21	15	41

Cyanophyta	27	186	4000	29	47	6000	38	40	17	25	39	15
Dinoflagellates	1500	39	16	8000	11000	179	9000	120	195	178	150	84
Diatoms	23	12	13	14	16	17	14	10000	11000	4000	5000	6000

Table :5 Distribution of phytoplankton(units/l) in station 1 (2009-2010)

Parameters	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**
Chlorophyta	25	2000	145	102	168	31	4000	18	15	33	20	17
Cyanophyta	12	195	14	30	19	1000	125	158	28	38	43	187
Dinoflagellates	189	45	32	9000	7000	14	36	37	185	16	194	48
Diatoms	3000	11	3500	13	32	169	17	12000	12500	11000	5000	2000

Table :6 Distribution of phytoplankton(units/l) in station 2 (2009-2010)

Parameters	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**
Chlorophyta	55	12	115	900	125	4200	3100	18	180	9	26	16
Cyanophyta	5000	34	6000	165	19	154	41	4500	3500	3000	187	45
Dinoflagellates	29	2000	27	14	4000	16	16	46	17	18	14	145
Diatoms	16	187	18	28	34	47	35	152	38	163	1500	900

Table :7 Distribution of phytoplankton(units/l) in station 3 (2009-2010)

Parameters	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**Ma**
Chlorophyt	1	200	175	3	1	1	4	3	9	1	169	198
Cyanophyt	174	152	1	300	3	4	500	165	5800	185	650	700
Dinoflagell	1	1	4	1	100	850	1	1	3	3	1	1
Diatoms	150	4	230	187	168	145	177	1100	198	1300	4	3

Table :8 Distribution of phytoplankton (units/l) in station 4 (2009-2010)

Stations	**Year 2008-09**	**Season**	**Chlorophyta Mean and SE Values a**	**Cyanophyta Mean and SE Values b**	**Dino flagellatus Mean and SE Values c**
1	a) 46.42 **16.86** b) 1022.92 **532.68** c) 481.58	1 2 3	89.75 a **44.08** 37.25 b **11.76** 12.25 c	3014 a **1066.71** 37.5 b **3.8** 16.75 c	65 a **37.61** 1221.5 b **602.52** 158.25 c
2	a) 829.92 **499.19** b) 577.92 **493.3** c) 1956.17	1 2 3	179.75 a **6.14** 2294.75 b **1289.85** 15.25 c	25.75 a **4.61** 129.05 b **31.75** 1578.5 c	778 a **740.67** 5028.75 b **4990.42** 61.75 c

3	a) 629.75 **392.17** b) 2031.33 **855.05** c) 73.58	1 2 3	818.75 a **727.54** 1048.5 b **984.37** 22 c	1268 a **1244.01** 3274.25 b **1873.55** 1551.75 c	74.5 a **39.43** 73.25 a **40.97** 73 a
4	a) 523.25 **337.93** b) 634.92 **308.74** c)421.73 **3.78**	1 2 3	1427.5 a **918.7** 72.25 b **41.17** 70 b **40.17**	94.75 a **40.84** 605.25 b **465.22** 1204.75 c **790.34**	16.75 a **4.87** 26.75 b **7.74** 17.75 a **7.32**
Stations	**2009-2010**	**Season**			
1	a) 237.83 **161.23** b) 871.92 **570.23** c) 2538.42	1 2 3	582.75 a **472.58** 103 b **46.31** 27.75 c	1060.5 a **980.54** 1531.25 b **1489.58** 24 c	2388.75 a **1902.35** 5074.75 b **2872.78** 151.75 a
2	a) 547.83 **353.15** b) 154.08 **79.5** c) 1399.67	1 2 3	568 a **477.98** 1054.25 b **982.5** 21.25 c	62.75 a **44.27** 325.5 b **226.78** 74 c	2316.5 a **2228.12** 1771.75 b **1742.76** 110.75 c
3	a) 729.67 **405.79** b) 1887.08 **673.4** c) 528.5	1 2 3	270.5 a **210.89** 1860.75 b **1057.37** 57.75 c	2799.75 a **1572.52** 1178.5 b **1107.56** 1683 c	517.5 a **494.18** 1019.5 b **993.53** 48.5 c
4	a) 226.5 **162.55** b) 2339.17 **840.94** c) 173.58	1 2 3	554 a **483.39** 26.75 b **7.39** 98.75 c	835.25 a **722.44** 1311 b **1230.02** 4871.25 c	23.25 a **7.3** 471 b **263.9** 26.5 a

Table 9: Mean and SE values of Chlorophyta, Cyanophyta, Dinoflagellates at Stations, 1 - 4 (2008-2010)

Stations	**Year 2008-09**	**Season**	**Diatoms Mean and SE Values d**	**Total Plankton Mean and SE Values e**
1	d) 3009.08d1 **1197.68** e) 4393.92e1 **895.44**	1 2 3	16a **3.14** 1263b **1245.67** 7250c	3185.25a **1099.21** 2559.25b **1022.96** 7437.25c
2	d) 3395.25d1 **1277.59** e) 6759.25e2 **1568.16**	1 2 3	1504a **536.36** 884.5b **871.83** 7797.25c	2487.5a **321.49** 8337.5b **3971.53** 9452.75c

3	d) 4415.5d2 **1603.41** e) 7150.17e3 **1114.28**	1 2 3	1769.25a **1019.89** 2427.75b **2357.65** 9049.5c	3930.5a **461.74** 6823.75b **1158.17** 10696.25c
4	d) 3696.42d1 **1407.71** e) 4875e4 **1226.89**	1 2 3	1424.25a **772.67** 3379.25b **1815.97** 6285.75c	2963.25a **520.22** 4083.5b **1537.79** 7578.25c

Stations	2009-2010	Season		
1	d) 3009.08d1 **1197.68**	1	15.5 a **2.53**	4047.5 **1477.11**
		2	2511.75 b **2496.08**	9220.75 **1080.08**
	e) 6657.25e1 **965.57**	3	6500 c	6703.5
2	d) 4103.5d2 **1428.78**	1	1631 a **940.29**	4578.25 **1551.53**
		2	3054.5 b **2982.03**	6206 **2347.75**
	e) 5205.08e2 **1195.08**	3	7625 c	7831
3	d) 259.83d3 **133.19**	1	62.25 a **41.67**	3650 **1185.94**
		2	67 a **28.49**	4125.75 **330.13**
	e)3405.08e3 **466.77**	3	650.25 b	2439.5
4	d) 2399.83d4 **1315.96**	1	1007.25 a **541.49**	2419.75 **320.97**
		2	2872.5 b **2709.18**	4682.25 **2383.34**
	e) 5139.08e2 **1145.8**	3	3319.75 c **3226.96**	8316.25 **1660.88**

Table:10 Mean and SE values of Diatoms and Total phytoplanktons at Stations 1 - 4 (2008-2010)

Fig. 2 Monthly variations of Chlorophyta at the stations(2008-2009)

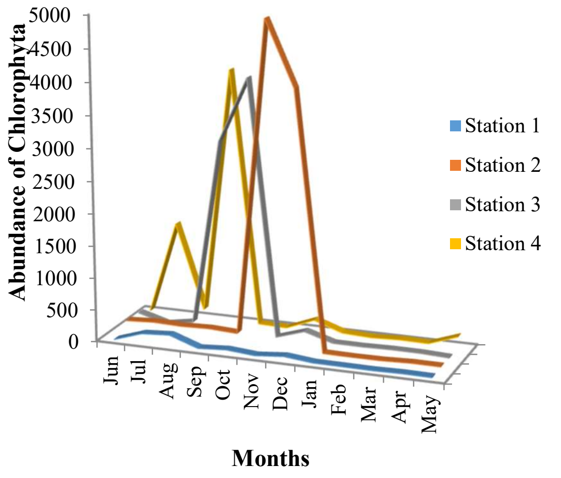


Fig 3 Monthly variations of Chlorophyta at the stations (2009-2010)

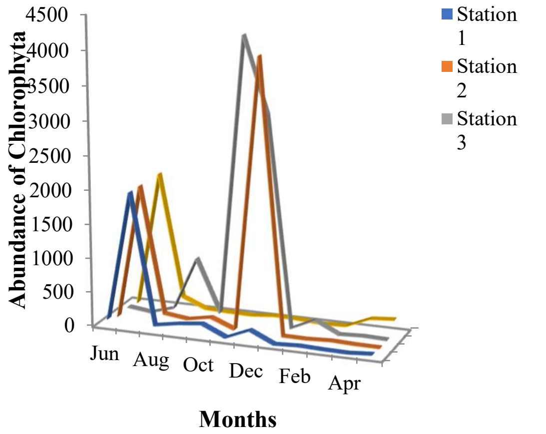


Fig 4 Monthly variations of Cyanophyta at the stations(2008-2009)

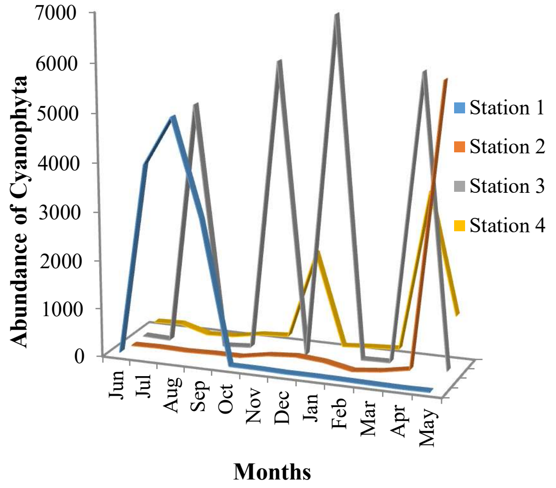


Fig.5 Monthly variations of Cyanophyta at the stations (2009-2010)

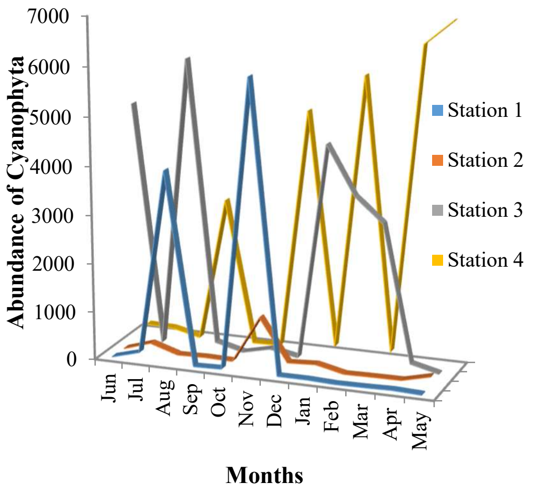


Fig.6 Monthly variations of Dinoflagellates at the stations (2008-2009)

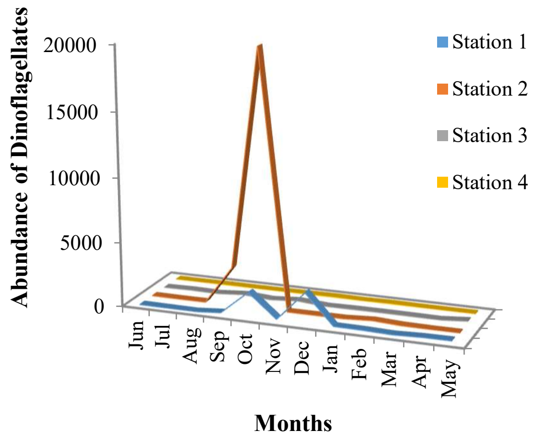


Fig.7 Monthly variations of Dinoflagellates at the stations (2009-2010)

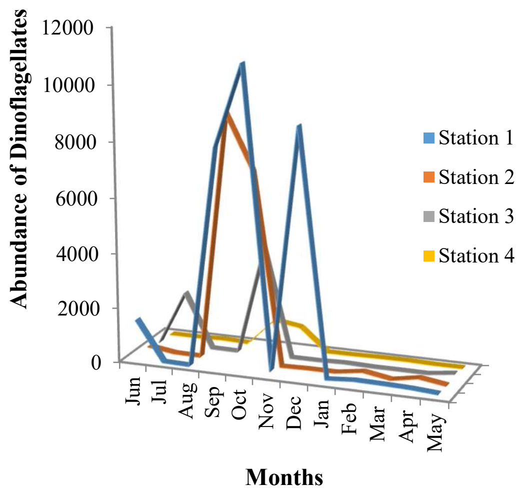


Fig.8 Monthly variations of Diatoms at the stations (2008-2009)

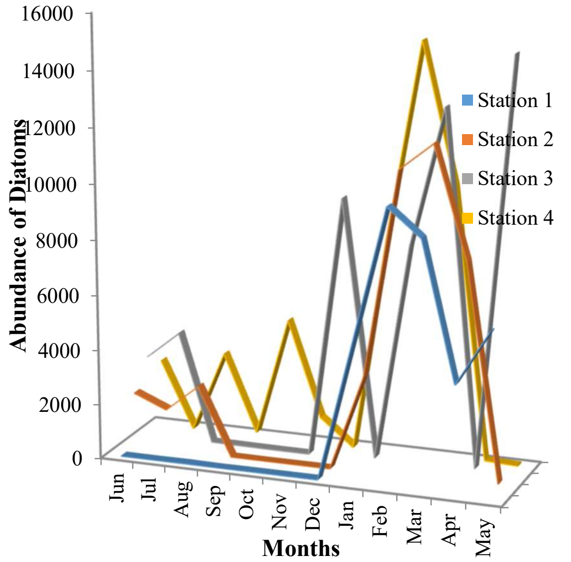


Fig.9 Monthly variations of Diatoms at the stations (2009-2010)

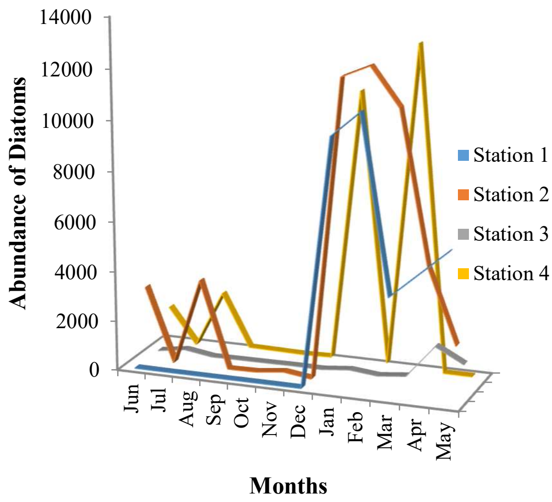


Fig 10 Monthly variations of Total phytoplanktons at the stations (2008-2009)

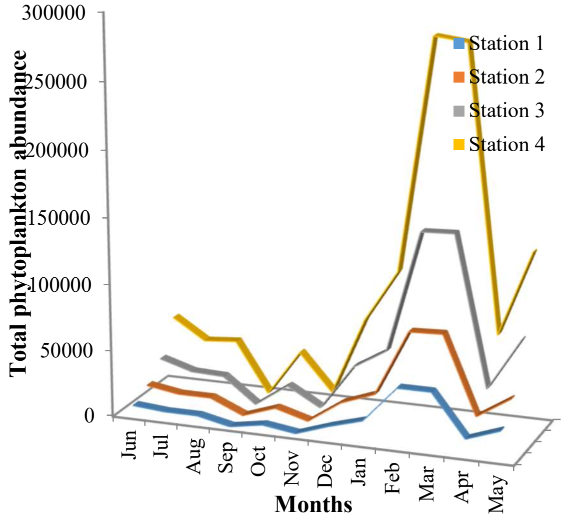
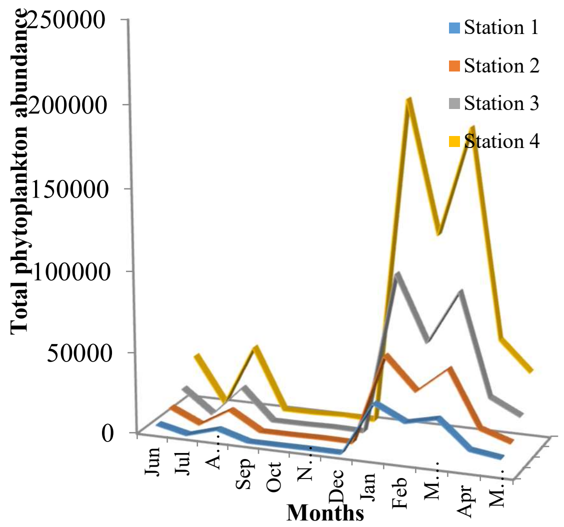


Fig.11 Monthly variations of total phytoplanktons at the stations (2009-2010)



Phytoplankton belonging to Chlorophyceae, Cyanophyceae, Dinoflagellates and Bacillariophyceae was found in all 4 stations. In station 1, station2, station 4 Bacillariophyceae was the dominant group for the entire period of study. But in station3 Bacillariophyceae dominated during the first year while Cyanophyceae dominated in the second year. Chlorophyceae showed highest mean seasonal values for station 1 and station 4 during monsoon and for station 2 and station 3 during the post-monsoon period. Bacillariophyceae indicated highest mean seasonal values during the pre-monsoon season. Dinoflagellates exhibited highest mean seasonal values during post monsoon except station 3 of the first year and station 2 of the second year. Cyanophyceae reached its peak in post monsoon for station 1, station 2 (2009-2010) and station 3 of first year. It exhibited highest seasonal mean value in the case of station1 for the first year and station 3 for the second year. (Table 9,10).

ANOVA comparing phytoplankton between stations revealed that Bacillariophyceae showed variations significant between stations at 1% level for 2008-2009 and between seasons and also for periods within seasons at 1% level and at 5% level. Dinoflagellates showed significant variations for periods within seasons and between seasons at 5% level in the second year (Table 11,12,13,14).

		Chlorophyta			Cyanophyta			Dinoflagellates		
Source	**DF**	**Sum of squares**	**Mean Sum of squares**	**F**	**Sum of squares**	**Mean Sum of squares**	**F**	**Sum of squares**	**Mean Sum of squares**	**F**
Total	47	72287640.00			194958300.00			400400900.00		
Between stations	3	3980920.00	1326973.00	0.90	16293370.00	5431123.00	1.30	29542830.00	9847611.00	1.20
Between seasons	2	5910179.00	2955090.00	1.92	74300.00	37150.00	0.01	22065790.00	11032900.00	1.38
Periods	9	11541573.00	1282397.00	0.83	38039688.00	4226632.00	0.99	85038219.00	9448691.00	1.18
Error	33	50854970.00	1541059.69		140550900.00	4259118.18		263754100.00	7992548.49	

		Chlorophyta			Cyanophyta			Dinoflagellates		
Source	**DF**	**Sum of squares**	**Mean Sum of squares**	**F**	**Sum of squares**	**Mean Sum of squares**	**F**	**Sum of squares**	**Mean Sum of squares**	**F**
Total	47	72287640.00			194958300.00			400400900.00		
Between stations	3	3980920.00	1326973.00	0.90	16293370.00	5431123.00	1.30	29542830.00	9847611.00	1.20
Between seasons	2	5910179.00	2955090.00	1.92	74300.00	37150.00	0.01	22065790.00	11032900.00	1.38
Periods within	9	11541573.00	1282397.00	0.83	38039688.00	4226632.00	0.99	85038219.00	9448691.00	1.18
Error	33	50854970.00	1541059.69		140550900.00	4259118.18		263754100.00	7992548.49	

Table 11: ANOVA comparing Chlorophyta, Cyanophyta, Dinoflagellates between the stations (2008-09)

		Chlorophyta			Cyanophyta			Dinoflagellates		
Source	DF	Sum of squares	Mean Sum of squares	F	Sum of squares	Mean Sum of squares	F	Sum of squares	Mean Sum of squares	F
Total	47	47300980.0			232004300.0			355675500.0		
Between stations	3	2182871.00	727623.70	0.90	35042780.00	11680930.0 0	2.30	39951390.00	13317130.0 0	2.90
Between seasons	2	4112395.00	2056198.00	2.54	3024872.00	1512436.00	0.29	32546550.00	16273280.0 0	3.52*
Periods within seasons	9	14332032.0 0	1592448.00	1.97	23531463.00	2614607.00	0.51	2339646.66	259960.74	3.13*
Error	33	26673680.00	808293.33		170405200.00	5163793.94		152740800.00	83054.55	

Table 12: ANOVA comparing Chlorophyta, Cyanophyta, Dinoflagellates between the stations(2009-2010**)**

* denote significance (p < .05) ** denote significance (p < .01)

		Diatom			Total Plankton		
Source	DF	Sum of squares	Mean Sum of squares	F	Sum of squares	Mean Sum of squares	F
Total	47	992867100.00			179395600000.00		
Between stations	3	15464260.00	5154750.00	5**	42561310000.00	14187100000.00	11.3**
Between seasons	2	390805600.00	195402800.00	18.46**	56022600000.00	28011300000.00	22.33**
Periods within seasons	9	237268862.90	26363206.99	2.49	39397769802.00	4377529978.00	3.49*
Error	33	349391900.00	10587633.33		41392117272.00	1254306584.00	

Table 13: ANOVA comparing Diatoms and Total phytoplanktons between the stations (2008-09)

		Diatom			Total Plankton		
Source	DF	Sum of squares	Mean Sum of squares	F	Sum of squares	Mean Sum of squares	F
Total	47	783893200.00			95061620000.00		
Between stations	3	94149470.00	31383160.00	3.5*	16139920000.00	5379973000.00	7.4**
Between seasons	2	120662800.00	60331420.00	6.74**	14120760000.00	7060378000.00	9.76**
Periods within seasons	9	273826778.00	30425197.60	3.4**	40934024136.00	4548224904.00	6.29**
Error	33	295303000.00	8948575.76		23861911260.00	723088220.00	

Table 14: ANOVA comparing Diatoms and Total phytoplanktons between the stations (2009-2010)
* denote significance (p < .05),** denote significance (p < .01)

		Chlorophyta			Cyanophyta			Dinoflagellates		
Source	DF	**Sum of squares**	**Mean Sum of squares**	**F**	**Sum of squares**	**Mean Sum of squares**	**F**	**Sum of squares**	**Mean Sum of squares**	**F**
Total	23	3701103.00			80558970.00			224886800.00		
Between stations	1	214515.00	214515.00	1.50	136354.00	136354.00	0.10	25603940.00	25603940.00	4.20
Between seasons	2	388186.10	194093.00	1.40	11202020.00	5601012.00	2.07	83182720.00	41591360.00	6.76*
Periods within seasons	9	1569043.00	174338.20	1.25	39426246.00	4380694.00	1.62	48406671.00	5378519.00	0.87
Error	11	1529359.00	139032.64		2979434.00	2708576.36		67693470.00	6153951.82	

Table 15: ANOVA comparing Chlorophyta,Cyanophyta,Dinoflagellates between the years of study at station 1

		Diatom			Total Plankton		
Source	**DF**	**Sum of squares**	**Mean Sum of squares**	**F**	**Sum of squares**	**Mean Sum of squares**	**F**
Total	23	342674900.00			3182927000.00		
Between stations	1	165664.00	165664.00	0.10	327103700.00	327103700.00	13.1**
Between seasons	2	279174500.00	139587300.00	59.43**	1850543000.00	925271400.00	36.94**
Periods within seasons	9	37500228.00	4166692.00	1.77	730453757.00	81161528.60	3.24*
Error	11	25834460.00	2348587.27		275548400.00	25049854.50	

Table 16: Anova Comparing Diatoms, Total Phytoplankton between the years of study at station

		Chlorophyta			Cyanophyta			Dinoflagellates		
Source	**DF**	**Sum of squares**	**Mean Sum of squares**	**F**	**Sum of squares**	**Mean Sum of squares**	**F**	**Sum of squares**	**Mean Sum of squares**	**F**
Total	23	49833360.00			34034030.00			471584400.00		

Between stations	1	477426.00	477426.00	0.40	1077808.00	1077808.00	0.70	1858152.00	1858152.00	0.20
Between seasons	2	12163360.00	6081678.00	4.95*	2676283.00	1338142.00	0.91	44135270.00	22067540.00	2.41
Periods within seasons	9	23670234.00	2630026.00	2.14	14067603.00	1563067.00	1.06	324519606.00	36057734.00	3.94*
Error	11	13522340.00	409767.88		16212340.00	1473849.10		100668800.00	9151709.10	

Table 17: ANOVA comparing Chlorophyta, Cyanophyta, Dinoflagellates between the years of study at station 2

		Diatom			**Total**		
Source	**DF**	**Sum of squares**	**Mean Sum of squares**	**F**	**Sum of squares**	**Mean Sum of**	**F**
Total	23	487929200.00			4783012000.00		
Between stations	1	3009696.00	3009696.00	0.80	475090900.00	475090900.00	13.8**
Between seasons	2	188992000.00	94495980.00	24.17**	86576100.00	432588000.00	12.56**
Periods within seasons	9	252964215.00	28107135.00	7.19**	3063257631.00	340361959.00	9.88**
Error	11	43001180.00	3909198.20		378945500.00	34449591.00	

Table 18: ANOVA comparing Diatoms, Total phytoplankton between the years of study at station 2

		Chlorophyta			**Cyanophyta**			**Dinoflagellates**		
Source	**DF**	**Sum of squares**	**Mean Sum of squares**	**F**	**Sum of squares**	**Mean Sum of squares**	**F**	**Sum of squares**	**Mean Sum of squares**	**F**
Total	23	42127660.00			156810500.00			18105950.00		
Between stations	1	59302.00	59302.00	0.00	124712.00	124712.00	0.00	1261333.00	1261333.00	1.60
Between seasons	2	18994240.00	9497122.00	4.59*	19950870.00	9975436.00	1.83	1128183.00	564091.40	0.73
Periods within seasons	9	308152.00	34239.11	0.02	76801239.00	8533471.00	1.57	7214943.00	801660.00	1.04
Error	11	22765970.00	2069633.64		59933670.00	5448515.45		8501491.00	772862.82	

Table 19: ANOVA comparing Chlorophyta, Cyanophyta, Dinoflagellates between the years of study at station 3

		Diatom			**Total Plankton**		
Source	**DF**	**Sum of squares**	**Mean Sum of squares**	**F**	**Sum of squares**	**Mean Sum of squares**	**F**
Total	23	283264000.00			1171519000.00		

Between stations	1	53303260.00	53303260.00	5*	89714430.00	89714430.00	9.1*
Between seasons	2	18415450.00	9207724.00	0.86	114516700.00	57258340.00	5.79*
Periods within seasons	9	93768850.80	10418761.20	0.97	858665422.00	95407269.10	9.65**
Error	11	118150900.00	10740990.90		108754400.00	9886763.64	

Table 20: ANOVA comparing Diatoms,Total phytoplankton between the years of study at station 3

		Chlorophyta			**Cyanophyta**			**Dinoflagellates**		
Source	**DF**	**Sum of squares**	**Mean Sum of squares**	**F**	**Sum of squares**	**Mean Sum of squares**	**F**	**Sum of squares**	**Mean Sum of squares**	**F**
Total	23	19297270.00			94466880.00			1513988.00		
Between stations	1	530442.50	530442.50	0.80	8702512.00	8702512.00	4.60	140454.00	140454.00	2.30
Between seasons	2	1194892.00	597446.10	0.88	16030540.00	8015272.00	4.26*	279295.00	139647.80	2.27
Periods within seasons	9	10079172.00	1119908.00	1.64	49030983.00	5447887.00	2.89	416606.30	46289.58	0.75
Error	11	7492764.00	681160.36		20702840.00	1882076.36		677632.10	61602.91	

Table 21: ANOVA comparing Chlorophyta, Cyanophyta, Dinoflagellates between the years of study at station 4

		Diatom			**Total Plankton**		
Source	**DF**	**Sum of squares**	**Mean Sum of squares**	**F**	**Sum of squares**	**Mean Sum of squares**	**F**
Total	23	5006654700.00			3910714000.00		
Between stations	1	10076400.00	10076400.00	0.90	235238300.00	235238300.00	7*
Between seasons	2	204472700.00	102236300.00	9.45*	1771429000.00	885714500.00	26.51**
Periods within seasons	9	167439420.00	18604380.00	1.72	1536727833.00	170747537.00	5.11**
Error	11	118981500.00	10816500.00		367558300.00	33414390.90	

Table : 22 ANOVA comparing Diatoms,Total phytoplankton between the years of study at station 4
*** denote significance (p < .05),** denote significance (p < .01)**

As per the ANOVA comparing phytoplankton between the years of study revealed that Dinoflagellates exhibited significant variations between seasons and for periods within seasons at 5% level for station 1 and station 2. Bacillariophyceae showed significant variations between seasons in station 1 and station 2 at 1% level and station 4 at 5% level, between years at 5% level for station 3. Chlorophyceae showed significant variations between seasons at 5% level for station 2 and station3. Cyanophyceae exhibited significant variations only between seasons at 5% level for station 4. Tukey test revealed that Bacillariophyceae showed significant variations between seasons in all stations except station 3 of the second year showing no significant variations between monsoon and post-monsoon. Dinoflagellates exhibited significant variations in the case of station1 and station2 only for the entire period of study. (Table 9,10,13,14,15,16,17,18,19,20,21, 22).

Discussion

Phytoplankton is an important primary producer. As it forms the basis of whole food chain in open waters, species composition of the phytoplankton community is an efficient bioindicator for water quality (Peerapornpisal *et al*., 2004). Phytoplankton can thus be used as bioindicators since it can reflect even the slight changes taking place in their immediate environment by changing their species composition, biomass, community structure, chlorophyll pigment content and productivity (Mohamed *et al*., 2009). Phytoplankton studies and monitoring are useful for the control of the physico-chemical and biological conditions of the water body. Therefore, proliferation of harmful organisms such as blue green algae can degrade the recreational values of surface waters, particularly thick surface scum, which reduces the use of amenities for contact sports, or large concentrations that can result deoxygenation of the water leading to fish death.

In the present study, the collected phytoplanktons were grouped under Chlorophyceae, Cyanophyceae, Dinoflagellates, Bacillariophyceae *etc*. Among the four studied stations Bacillariophyceae ranked the highest in abundance for the two years except the station 3 during the period 2009-2010. Station 1 showed the dominance of Bacillariophyceae. Among the stations, highest mean value of Chlorophyceae was shown by station 2, in the post-monsoon season during 2008-2009. Station 4 expressed the highest mean value of Cyanophyceae during the pre-monsoon period in the year 2009-2010. Station 1 recorded the highest mean value of Dinoflagellates during the post-monsoon period during the second year. Station 3 showed the highest mean value of Bacillariophyceae in the pre-monsoon period during the first year. Station 1 showed the minimum mean value of Chlorophyta and Cyanophyta during the pre-monsoon period during the first year. Station 4 recorded the minimum mean value of Dinoflagellates and Bacillariophyceae during the monsoon season in the first year. Total phytoplankton mean maximum was found in station 3 during pre-monsoon period.

From the study it was noted that the Chlorophyceae, Cyanophyceae, Dinoflagellates and diatoms dominance were registered in the summer season with a comparatively high temperature. From this it is evident, that temperature is one of the crucial factors determining the abundance of planktons. This agrees with the reports of Mehra (1986). Golterman (1975) reported that an increase in water temperature affected the growth of phyto plankton positively or negatively depending upon the type of plankton. The role of temperature in determining the abundance of Cyanophyceae was demonstrated earlier by Hutchinson (1967);

Forsberg (1972). These reports agree with the present study.

The phytoplankton abundance during the summer seasons could be attributed to the increased salinity, pH, higher temperature and high intensity of light penetration during this season (Mani and Krishnamurthy, 1989). The lowest abundance of certain phytoplankton groups during the monsoon months, when the water column was remarkably stratified to a large extent because of heavy rain fall, reduced salinity, decreased temperature and pH. The observed high density of phytoplankton during the summer could be attributed to more stable hydrographic conditions prevailed in the stations that showed comparatively high population density due to high nutrient concentrations and opportunal salinity (Gouda *et al.,* 1996). This is in conformation with the present study.

Maximum abundance and diversity of Cyanophyceae were recorded in the pre-monsoon when phosphate and biological oxygen demand values were high indicating at that time it was rich in nutrients. Bacillariophyceae showed its dominance during the pre-monsoon period when the silicate value was the highest. This agrees with the reports of (Abdulla and Abdulla, 2006). Prasad *et al.,* (1992) have opined that Secchi disc transparency can be used meaningfully to interpret long term changes in phytoplankton distribution was due to high light intensity and availability of nutrients such as silicate, nitrite, nitrate, phosphate, sulphate. During monsoon, the diatoms number was seen in a maximum range due to the higher concentration of silica observed. The monsoonal peak in dissolved oxygen showed a direct effect on the qualitative distribution of phytoplankton. Highest phytoplankton observed in stations, which means that this system can be considered to be environments characterized by intrinsic eutrophication.

Over the last few decades, there has been much interest in the processes influencing the development of phytoplankton communities, primarily in relation to physico-chemical factors (Peerapornsial *et al.,*1999). The algae co-occur even though each species has a specific niche based on its physiological requirements and the constraints of the environment. Diatoms are good indicators of the water quality (Odum, 1971). *Cyclotella* and *Melosira* might be used as bioindicators of the oligomesotrophic status. Algae are the important group of organisms which affects the quality of water considerably (Palmer, 1980). When the concentration of naturally occurring, substances is increased or when unnatural synthetic compounds are released into the environment, pollution is caused. With the origin of pollution, the algal growth may be inhibited or stimulated and finally may either be inhibited or stimulated and finally algae themselves become the cause of concern. As a result of domestic, agricultural and industrial activities, hospital wastes, poultry waste, slaughter wastes, organic wastes are released into the environment leading to organic pollution. Most of the information available on algae in relation to polluted waters is confined to water containing treated or untreated domestic sewage and organic wastes. Household sewage contains various kinds of organic materials besides phosphates from detergents and other wastes. The growth of *Chlorella* has been found to be enhanced with the addition of sodium triphosphate, an ingredient of a synthetic detergent. The algae commonly found in organic wastes are *Oscillatoria, Anaebena, Phormidium, Ankistrodesmus, Chlorella, Melosira, Scenedesmus, Navicula*. The most striking effects of cultural eutrophication are seen in the increased growth of filamentous algae like *Spirogyra, Enteromorpha* etc. Blue green algae like *Microcystis, Anaebena* etc forms blooms when gross eutrophication is reached. Besides these, many other algae viz *Oscillatoria*, *Spirullina, Cladophora, Oedogonium*, *Spirogyra etc*., start growing luxuriantly in eutrophic waters.

ANOVA comparing phytoplankton between stations revealed that Bacillariophyceae showed variations significant between stations at 1% level for 2008-2009 and between seasons and also for periods within seasons at 1% level and at5% level. Dinoflagellates showed significant variations for periods within seasons and between seasons at 5% level in the second year. As per the ANOVA comparing phytoplankton between the years of study revealed that Dinoflagellates exhibited significant variations between seasons and for periods within seasons at 5% level for station 1 and station 2. Bacillariophyceae showed significant variations between seasons in station 1 and station 2 at 1% level and station 4 at 5% level, between years at 5% level for station 3. Chlorophyceae showed significant variations between seasons at 5% level for station 2 and station3. Cyanophyceae exhibited significant variations only between seasons at 5% level for station 4. Tukey test revealed that Bacillariophyceae showed significant variations between seasons in all stations except station 3 of the second year showing no significant variations between monsoon and post-monsoon. Dinoflagellates exhibited significant variations in the case of station1 and station2 only for the entire period of study.

Conclusion

When the concentration of naturally occurring, substances is increased or when unnatural synthetic compounds are released into the environment, pollution is caused. With the origin of pollution, the algal growth may be inhibited or stimulated and finally may either be inhibited or stimulated and finally algae themselves become the cause of concern. As a result of domestic, agricultural and industrial activities, hospital wastes, poultry waste, slaughter wastes, organic wastes are released into the environment leading to organic pollution. Most of the information available on algae in relation to polluted waters is confined to water containing treated or untreated domestic sewage and organic wastes. Household sewage contains various kinds of organic materials besides phosphates from detergents and other wastes. Under nutrient enriched conditions this alga often formed large "nuisance" blooms that decrease the habitat quality of estuary. In addition to aesthetic concerns related to nuisance blooms, the enhanced production of algal biomass can have severe ecosystem impacts, including the promotion of hypoxia and the suppression of submerged aquatic plants. Reduced oxygen levels can result in fish and invertebrate mortality. Algal blooms can also affect recreational enjoyment of the aquatic ecosystems by impeding boat progress or by producing toxins of noxious odours that keeps visitors away. Anthropogenic pollution and global climate change warning influence on the marine ecosystems has resulted in an increase of harmful algal blooms. Hence phytoplanktons acts as bioindicators of the natural environmental quality. Thus, the basic information of the fluctuations in the phytoplankton abundance and distribution of the Thekkumbhagam creek due to anthropogenic activities would form a useful tool for further ecological assessment, monitoring of coastal systems, and the role of plankton as biomarkers.

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