Biological Forum – An International Journal 16(2): 166-170(2024)

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Temporal Variability in the Mesophytoplankton Dynamics at Confluence of River Nethravati with Arabian Sea, off Mangalore, Karnataka

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(Received: 16 December 2023; Revised: 05 January 2023; Accepted: 20 January 2024; Published: 15 February 2024)
(Published by Research Trend)

ABSTRACT: Studies on the phytoplankton dynamics gives information on the their qualitative and quantitative distribution in the water body concerned, thereby helps in understanding their community structure, food web dynamics, their potential in supporting fisheries and also gives a clue for developing strategies in view of maintaining biodiversity, improving water quality, and ensuring the sustainability of aquatic resources. A holistic understanding of the plankton community and its role in the aquatic ecosystem, is essential for monitoring, managing, and conserving water bodies, hence the present study. Surface water samples and plankton (meso/net plankton) were collected at monthly intervals from the confluence area of River Nethravati with Arabian Sea, off Mangalore, for a period of 12 months covering pre-monsoon and two consecutive post-monsoon seasons, sampling couldn't be done during monsoon period due to rough weather conditions. A total of 48 genera encountered in the study area, including 23 genera from centrales, 10 from pennales, 7 from pyrrophyta and 4 each from cyanophyta and chlorophyta. Of the total genera recorded, centrale diatoms contributed nearly to half of the diversity of total phytoplankton. The abundance (cells/m^3) of phytoplankton varied from 111220 cells/m^3 1768800 cells/m^3 and was in the order of Chrysophyta (15.83% to 98.81%) > Cyanophyta (0.21% to 82.72%) > Pyrophyta (0.68% to 9.79%) > Chlorophyta (0% to 4.17%). Alpha diversity indices of plankton were estimated using Primer software and are as follows: Maegalef's Richness Index (1.18 to 2.48); Pielou's Evenness Index (0.21 to 0.87); Shannon's Diversity Index (0.61 to 2.68). The study area exhibited mesohaline nature (with an average salinity of 16.23 ppt) during pre-monsoon, while euhaline (with an average salinity of 32.59 ppt) nature during pre-monsoon season.

Keywords: Phytoplankton, confluence point, salinity, chlorophyll.

INTRODUCTION

Estuaries are unique aquatic environments where strong interaction occurs between rivers and seawater (Dan *et al.,* 2020). The uniqueness of the transitional environment makes estuary a productive ecosystem and this distinctness is favourable for human occupation and thus estuarine regions all over the world are known for rapid economic growth with dense human populations. With rapid economic development, tropical estuaries are facing tremendous anthropogenic pressures like industry and agricultural activities, urban land expansion, and mining activities and thus exhibit clear evidence of nutrient pollution (N'Goran *et al.,* 2019).

The Netravathi estuary is a tropical, micro- to meso-tidal estuary situated at Mangalore, southwest coast of India. This estuary is formed by the confluence of Netravathi River. Because the estuary passes through the urbanized coastal city Mangalore, it is subjected to anthropogenic and industrial activities leading to continuous inflow of domestic and municipal sewage, and industrial effluents. Anthropogenic activities like dredging, discharge of waste from various industries like oil and petrochemical industry, leather and fertilizer industries, iron ore industry, soda factories, port activities, and also the runoff from sediment and agriculture influences the estuarine sediment quality. The biological communities inhabiting these systems are subject to high spatial and temporal contrasts: spatial variations depending on the tidal and river influence; and very high temporal variability at different scales, from daily (mainly due to tidal fluctuations) to seasonal (fluctuations in river discharge and meteorology) (McLusky and Elliott 2004).

The present work is that part of investigation on Nethravati estuary, where Nethravati river meets the Arabian Sea, off Mangalore.

MATERIALS AND METHODS

Surface water samples (composite samples) were collected from the confluence region of River Nethravati with Arabian Sea, at monthly intervals for a period of 12 months, covering pre-monsoon and two consequent post-monsoon seasons to analyze salinity and chlorophyll-*a* content of water.

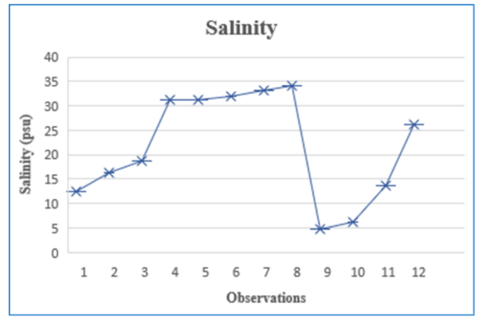
Salinity of water was estimated in the laboratory by following Mohr's method (Strickland and Parsons 1972) and the results are expressed in psu. Water samples collected for the estimation of chlorophyll-*a* were filtered through 198 µm nylon bolting silk net to remove the grazers. Then a known volume (1000 mL) was filtered immediately through a Millipore membrane filter of 47 mm diameter, having a pore size of 0.45µm by adding two drops of magnesium carbonate suspension during filtration. Particulate matter on the filter paper was extracted with 10 mL of 90% v/v acetone under dark, at low temperatures by keeping over night with periodic shaking. Then the extract was centrifuged for 20 minutes at 2000 rpm. The supernatant was decanted into 1cm path length cuvette, to measure the extinction at different wave lengths *i.e.,* 630, 647, 664 and 750 nm against an acetone blank. Chlorophyll-*a* concentration was then calculated by using the equation, recommended by Parsons *et al.* (1989) and the values are expressed in terms of µg/L. The absorbance was measured colorimetrically using Spectrophotometer (Systronics UV-VIS Spectrophotometer 119).

Standard Plankton net was used to collect plankton samples. In the laboratory, the plankton samples were again filtered through a 198 µm nylon bolting silk cloth to remove the zooplankton trapped, if any. The filtrate along with the phytoplankton was made up to a known volume (100 mL) and was preserved in Lugol's solution. The 'net phytoplankton' (includes phytoplankton retained after filtration *i.e*., in the size range of 60 µm - 198 µm) present in quadruple aliquots of 1mL from a subsample (25% of total sample) was analyzed both qualitatively, based on morphology following standard keys (Davis, 1955; Bellinger and Sigee 2010) and quantitatively using Sedgwick Rafter cell and plankton abundance was expressed in number/m3. OLYMPUS - CKX41 (Inverted microscope) and OLYMPUS - CX 21 microscopes were used in the qualitative and quantitative analysis of phytoplankton. Alpha diversity indices of plankton were estimated using Primer Software.

RESULTS AND DISCUSSION

Salinity: In the present study the salinity pattern (which can be considered a proxy for fresh and marine water influx) indicated 'oligohaline/mesohaline/polyhaline nature' and 'euhaline nature' of water during post-monsoon and pre-monsoon seasons, respectively. With in the estuary, salinity levels are referred to as oligohaline (0.5-5.0 ppt), mesohaline (5.0-18.0 ppt), or polyhaline (18.0 30.0 ppt). Near the connection with the open sea, estuarine waters may be euhaline, where salinity levels are the same as the ocean at more than 30.0 ppt (Mitsch and Gosselink 1986). Phytoplankton in terms of quantity, community structure and physiological status is closely related to the salinity gradients in the estuary (Ahel *et al.,* 1996). The study area exhibited mesohaline nature (with an average salinity of 16.23 ppt) during pre-monsoon, while euhaline (with an average salinity of 32.59 ppt) nature during pre-monsoon season.

Temporal variations in the salinity of water are presented in Fig. 1.

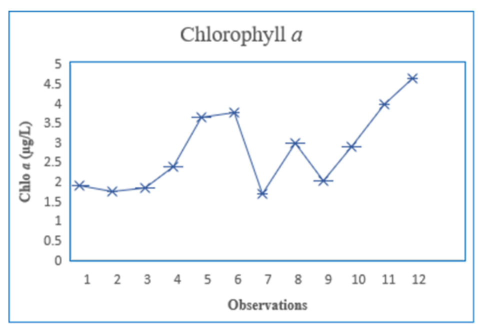


Observations **1 to 4** represents **post-monsoon**, **5 to 8** represents **pre-monsoon**, **9 to 12** represents ensuing **post-monsoon** seasons respectively.

Fig. 1. Temporal variations in the salinity of water.

Chlorophyll-*a*: Chlorophyll-*a*, the main pigment of the phytoplankton, serves as a universal ecological and physiological marker of biomass, photosynthetic activity, and production capabilities of phytoplankton, thereby it serves as a proxy for the estimation of phytoplankton biomass estimation.

Temporal variability in the Chlorophyll-*a* content were presented in Fig. 2. In the present study it fluctuated between 1.69µg/L and 4.62µg/L, with a mean of 2.78 ± 1.01 c, there by indicated mesotrophic nature, in accordance with Mineeva (2000). In the present study the mean chlorophyll a content during pre-monsoon and post-monsoon seasons were found to be 3.01 ± 0.95 µg/L and 2.67 ± 1.08 µg/L. Naik *et al*. (2009) in Mahanadi estuarine waters recorded chlorophyll-*a* concentrations in the range of 1.95 ± 0.59 to 4.09 ± 1.89 µg/L and 2.28 ± 1.22 to 6.07 ± 1.20 µg/L, during pre-monsoon and post-monsoon seasons, respectively.



Observations **1 to 4** represents **post-monsoon**, **5 to 8** represents **pre-monsoon**, **9 to 12** represents ensuing **post-monsoon** seasons respectively.

Fig. 2. Temporal variations in *chlo-a* content of water.

The relationship between chlorophyll-*a* and total plankton count is represented through (Linear regression) Fig. 3. The obtained R^2 value revealed that 85% of the variability in the total plankton count can be explained by the chlorophyll-*a* level, in the present study.

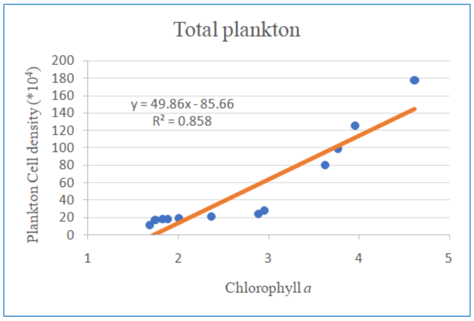


Fig. 3. Linear regression between chlorophyll *a* and total plankton count (as No.*10^4).

Phytoplankton dynamics : Their community structure can give more evidence concerning the water quality of the system (Yusuf, 2020) through alteration in their community composition, distribution and proportion of sensitive species (Gharib *et al.,* 2011). To attain a better perspective of the structure and dynamics of the aquatic environment, it is imperative to understand the quantification of phytoplankton biomass and their community composition (Roy *et al.,* 2006).

A total of 48 genera encountered in the study area, including 23 genera from centrales, 10 from pennales, 7 from pyrophyta and 4 each from cyanophyta and chlorophyta. The abundance (cells/m^3) of phytoplankton varied from 111220 cells/m^3 in pre-monsoon to 1768800 cells/m^3 in post-monsoon. The planktonic groups that stood out in the characterization of the mesophytoplankton assemblages at this confluence point includes Chrysophyta (15.83% to 98.81%), Cyanophyta (0.21% to 82.72%), Chlorophyta (0% to 4.17%) and Pyrophyta (0.68% to 9.79%). Abundance of the phytoplankton was in the order of Chrysophyta > Cyanophyta > Pyrophyta > Chlorophyta. Among the Chrysophytes, centrales were dominant, which contributed from 75.76% to 98.47%, when compared to pennales, which contributed from 1.53% to 20.29%. Top ten phytoplankton genera (based on regularity & dominance) found at this station are *Merismopedia*, *Chaetoceros, Biddulphia, Ditylum, Helicotheca, Coscinodiscus, Skeletonema, Melosira, Ceratium and Asterionella* spp.

Among **Chrysophytes**, Centrales were represented by the regular/ dominant forms like *Bacteriastrum* (0 to 32160 cells/m^3) *Biddulphia* (3685 to 79730 cells/m^3), *Chaetoceros* (6030 to 692780 cells/m^3), *Coscinodiscus* (3015 to 39865 cells/m^3), *Cyclotella* (0 to 6030 cells/m^3), *Ditylum* (0 to 271350 cells/m^3), *Helicotheca* (2010 to 140700 cells/m^3), *Leptocylindrus* (0 to 25460 cells/m^3), *Melosira* (0 to 75040 cells/m^3), *Planktoniella* (0 to 2010 cells/m^3), *Rhizosolenia* (1675 to 20770 cells/m^3), *Triceratium* (670 to 3350 cells/m^3) and rare forms like *Bellerochea, Campylodiscus, Ceratulina, Climacodium, Eucampia, Guinardia, Lampriscus, Lauderia, Lithodesmium, Proboscia* spp. Pennales were represented by the regular/dominant forms like *Asterionella* (0-36180 cells/m^3), *Fragilaria* (0 to 33500 cells/m^3), *Navicula* (0 to 1340 cells/m^3), *Nitzschia* (0 to 6030 cells/m^3), *Pleurosigma* (0 to 12730 cells/m^3) and rare forms like *Bacillaria, Gyrosigma, Pseudonitzschia, Thalassionema, Thalassiothrix* spp. Cyanophyta was represented by the regular/dominant forms like *Merismopedia* (0 to 1029120 cells/m^3), *Trichodesmium* (0 to 23450 cells/m^3) and rare forms like *Oscillatoria* (appeared in 6 out of 12 samplings*), Phormidium (*twice out of 12 samplings*), Spirulina* spp (once out of 12 samplings). Chlorophyta was represented by *Spirogyra, Mougeotia*, *Pediastrum, Stigeoclonium* spp. and their frequency of appearance was found to be four, three, two and one sampling respectively, out of 12 samplings during the study period. Pyrrophyta was represented by the regular/dominant forms like *Ceratium* (1340 to 20100 cells/m^3), *Noctiluca* (0-14070 cells/m^3), *Preperidinium* (0-1340 cells/m^3), *Protoperidinium* (335 to 18090 cells/m^3), with rare forms like *Akashiwo, Dinophysis* and *Lingulodinium* spp. Of the total genera observed, *Biddulphia, Chaetoceros, Coscinodiscus, Helicotheca, Rhizosolenia, Triceratium, Ceratium and protoperidinium* were present continuously throughout the study period in this station.

Seasonal variations in the plankton community structure based on abundance was shown in Fig. 4 as pre- monsoon and post-monsoon scenario. Temporal variations in abundance of plankton taxonomic groups were represented through Table 1, and in the percentage contribution of different planktonic groups with respect to salinity was represented through Table 2, while, Indices worked out on the basis of plankton dynamics were presented in table 3.

In the present study, during the pre-monsoon period (euhaline waters), chrysophytes overwhelmingly outcompeted their counterparts, thereby contributed to around 96% of total standing crop of plankton, but the cyanophytes could contribute only to 1.66%. But, during post-monsoon season (oligohaline/ mesohaline/ polyhaline), a drastic decline in the abundance of chrysophytes (to 50.73%) and a tremendous increase in the abundance of cyanophytes (to 45.33%) was noticed. The predominance of diatoms in an estuarine ecosystem is not only due to its high rate of division but also to its euryhaline ability (Ribeiro *et al.* 2003). Even though diatoms are euryhaline, the probable reason for this drastic decrease could be due to the allelopathic effect of cyanophytes. Allelopathy can influence the competition between different photoautotrophs for the same resource and can bring changes to the species succession in the phytoplankton community. Through the study of Gross (2003) it was revealed that, cyanophytes can produce effective allelochemicals interfering with the growth of competing algae. Therefore, the present study is also establishing the fact that cyanophytes can have an allelopathic effect on the diatom community. Our observations are in tune with Niveditha *et al*. (2022), who also have reported dominance of diatoms (by >70 % under euhaline and polyhaline conditions; and their drastic decrease to 37% under mesohaline and further down to 18% under oligohaline conditions), and their decreasing abundance (with decrease in salinity) due to the outnumbering of cyanophytes (by their affinity to low saline conditions) under oligohaline conditions.

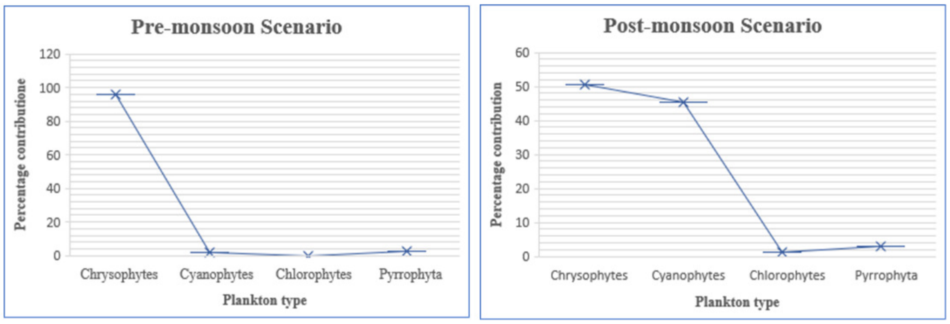


Fig. 4. Seasonal variations in the plankton community structure.

Table 1: Temporal variability in the mesophytoplankton dynamics (Cells/m^3) of water at confluence of river with sea.

Plankton Taxonomic group / Observation	Centrales	Pennales	Total chrysophytes	Cyanophytes	Chlorophytes	Pyrophytes	Total phytoplankton
1	61040	10050	71090	87435	5025	17755	181305
2	51325	13065	64390	86430	2010	14070	166900
3	58625	15410	77385	86765	5360	10050	179560
4	92125	15075	107200	86095	--	11725	205020
5	774520	12060	786580	1675	--	12395	800650
6	959440	16750	976190	5025	--	6700	987915
7	88105	9380	98825	5025	--	7370	111220
8	213730	16415	230145	24455	335	25125	280060
9	70685	16080	86765	85760	8040	12395	192960
10	111890	18760	130650	86095	6030	14405	237180
11	167165	27135	197650	1032470	10720	7370	1248210
12	1282380	101840	1384220	343710	--	40870	1768800

Observations 1 to 4 represents **post-monsoon**, 5 to 8 represents **pre-monsoon**, 9 to 12 represents ensuing **post-monsoon** seasons respectively.

Table 2: Temporal variability in the percentage contribution of different planktonic groups with respect to salinity (at confluence of River Nethravati with Arabian sea).

Observations / Parameters	1	2	3	4	5	6	7	8	9	10	11	12
Salinity	12.5	16.24	18.75	31.24	31.24	31.86	33.11	34.16	4.87	6.25	13.75	26.24
Chrysophytes	39.21	38.58	43.10	52.29	98.24	98.81	88.86	82.18	44.97	55.08	15.83	78.26
Cyanophytes	48.23	51.79	48.32	41.99	0.21	0.51	4.52	8.73	44.44	36.30	82.72	19.43
Chlorophytes	2.77	1.20	2.99	0	0	0	0	0.12	4.17	2.54	0.86	0
Pyrrophytes	9.79	8.43	5.60	5.72	1.55	0.68	6.63	8.97	6.42	6.07	0.59	2.31

Observations **1 to 4** represents **post-monsoon**, **5 to 8** represents **pre-monsoon**, **9 to 12** represents ensuing **post-monsoon** seasons respectively.

Table 3: Temporal variations observed in the plankton indices of water (at confluence of River Nethravati with Arabian sea)

Observations / Plankton Indices	1	2	3	4	5	6	7	8	9	10	11	12
Margalef's Richness Index	2.06	2.16	2.48	2.45	1.18	1.81	1.64	1.91	1.81	1.94	2.21	2.22
Pielou's Evenness Index	0.62	0.64	0.63	0.69	0.21	0.29	0.87	0.83	0.67	0.69	0.27	0.65
Shannon's Diversity Index	2.01	2.11	2.18	2.36	0.61	0.93	2.60	2.68	2.09	2.23	0.93	2.28

Observations **1 to 4** represents **post-monsoon**, **5 to 8** represents **pre-monsoon**, **9 to 12** represents ensuing **post-monsoon** seasons respectively.

CONCLUSIONS

The study highlights significant temporal variations in the mesophytoplankton community at the confluence of River Nethravati with Arabian Sea, influenced by associated shift in the dominance of river/tidal influx with seasons. During the pre-monsoon period, the dominance of Chrysophyta in euhaline waters was evident, while a substantial increase in Cyanophyta was observed during the post-monsoon period under mesohaline conditions. This shift underscores the impact of salinity gradients on phytoplankton distribution and abundance. The results suggest that the phytoplankton community structure serves as a reliable indicator of estuarine water quality, reflecting the estuary's response to freshwater influx and tidal dynamics. The allelopathic effects of Cyanophyta on diatoms further emphasize the competitive interactions within the phytoplankton community, which are crucial for understanding ecosystem health and resilience.

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How to cite this article: K. Madhavi, A. Padmanabha, N. Jesintha, N. Chetan and Adnan Amin (2024). Temporal Variability in the Mesophytoplankton Dynamics at Confluence of River Nethravati with Arabian Sea, off Mangalore, Karnataka. *Biological Forum – An International Journal, 16*(2): 166-170.