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Phytoplankton Dynamics of Tidal Influenced Stretch of River Nethravati, Dakshina Kannada, Karnataka

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Knowledge on the phytoplankton dynamics is vital for the ecological management of rivers. River ecosystems are widespread across the landscape through series of channels ultimately draining into the sea. The present exploration embarks on comprehending the temporal variations in the salinity, *chlorophyll a* and phytoplankton dynamics of water from tidal influenced stretch of Nethravati River at Farangipet. Surface water samples and plankton (Meso/Net plankton) were collected at monthly intervals for a period of 16 months covering post-monsoon, pre-monsoon, monsoon and post-monsoon of subsequent year. Plankton community composition revealed the

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order of diversity as Chlorophyta (28 genera) > Chrysophyta (16 genera), Cyanophyta (16 genera) > Rhodophyta (1 genera) and the order of abundance as Cyanophyta (20.25% to 91.39%) > Chlorophyta (5.25% to 74.58%) > Chrysophyta (1.48% to 30.75%) > Rhodophyta (0% to 0.22%). Alpha diversity indices of plankton were estimated and are as follows: Maegalef's Richness Index (1.15 to 2.29); Pielou's Evenness Index (0.36 to 0.71); Shannon's Diversity Index (1.17 to 2.52). Salinity varied from 0.03 ppt (monsoon) to 19.85 ppt (pre-monsoon). Based on salinity distribution river seemed to be mostly limnetic (<0.5 ppt) during post-monsoon and monsoon seasons as does with all other rivers, but unusually mesohaline (5.0 – 18 ppt) during the pre-monsoon time. Chlorophyll-*a* content fluctuated between 2.45 µg/L and 4.85 µg/L, thereby indicated the oligotrophic nature.

Keywords: Chlorophyll; nethravati river; phytoplankton; plankton indices; salinity.

1. INTRODUCTION

Rivers play a crucial role by providing essential ecosystem services to humans and serving as unique habitats for a diverse range of plankton. Phytoplankton are foundational to the health of aquatic ecosystems and have wide-ranging effects on global environmental processes. Their role as primary producers, oxygen generators, carbon sequesters, and nutrient cyclers makes them essential to life on Earth. Phytoplankton communities respond quickly to changes in environmental conditions, such as nutrient levels, water temperature, and pollution. As a result, they are often used as bioindicators to assess the health of aquatic ecosystems. Changes in phytoplankton diversity, abundance, or community composition can signal shifts in water quality or the onset of environmental issues, such as eutrophication or pollution. Healthy river systems contribute to the overall resilience of ecosystems, making them better able to withstand environmental changes.

River Nethravati originates in the Western Ghats near "Kudremukh" and flows through thick wooded forest over a rocky bed after forming rapids in Bengadi valley up to Belthangadi, which is further flowing through Uppinangadi, where it is joined by a stream-Kumardhara and finally reaches the Arabian Sea near Mangalore. It has an intrusion length of 19 Km, catchment area of 1232 sq.miles with an average depth of 3m and maximum depth of 8m. and it will be in flooding state during monsoon season, while in summer its discharge decreases. It is an important lifeline for the city of Mangalore and the surrounding regions, providing water for drinking, irrigation, and other essential activities.

2. MATERIALS AND METHODS

Composite samples were collected from surface waters at monthly intervals for a period of 16 months from tidal influenced stretch of Nethravati River at Farangipet, covering pre-monsoon, monsoon and post-monsoon seasons for analysing salinity and chlorophyll-*a* content of water. Salinity of water was determined in the laboratory by following Mohr's method [1] and the results are expressed in ppt.

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 [2] 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, again the plankton samples were 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 and quantitatively using Sedgwick Rafter cell and plankton abundance was expressed in number/m3. OLYMPUS - CKX41 (Inverted microscope) OLYMPUS - CX 21, and microscopes were used in the qualitative and quantitative analysis of phytoplankton and abundance was expressed in number/m^3.

3. RESULTS AND DISCUSSION

3.1 Salinity

The fresh water from rivers has salinity levels of 0.5 ppt or less. A unique feature of the rivers along the west coast of India is the phenomenal tides that they are subjected to. As a consequence, these rivers experience large influxes of sea water which have a significant impact on circulation, salinity [3] as well as water column turbidity caused by the disturbance of bottom sediments [4]. Based on salinity levels waters are referred to as limnetic (<0.5 ppt) oligohaline (0.5-5.0 ppt), mesohaline (5.0-18.0 ppt), or polyhaline (18.0 to 30.0 ppt) [5].

In the present study salinity of water ranged from 0.03 ppt (monsoon) to 19.85 ppt (pre-monsoon) and the temporal variations in the salinity of water are presented in Fig. 1.

The unusual higher values of salinity observed during pre-monsoon might be due to neritic water dominance, as the selected area for study is a tidal influenced river stretch. Hence, the influx of sea water had the overall control on higher salinity in the pre-monsoon months.

3.2 Chlorophyll-*a*

Planktonic algae serve as indicator organisms of the ecological state in water bodies. In this aspect, chlorophyll-*a* plays not only a functional, but also an indicator role in aquatic ecosystems. The content of chlorophyll-*a* is the basis for the scales developed to assess the trophic status [6] as oligotrophic, mesotrophic, moderately eutrophic, eutrophic, hypertrophic, and polytrophic waters, when chlorophyll-*a* concentrations are <1–3, 3–10, 10–15, 15–30, 30–60, and > 60 µg/L, respectively [7]. The trophic status of the river basing on the chlorophyll-*a* levels seemed to be oligotrophic in nature.

Chlorophyll-*a*, the main pigment of the green plants, serves as a universal ecological and physiological marker of biomass, photosynthetic activity, and production capabilities of algae. It is the most reliable and important index of phytoplankton biomass. Temporal variations in the Chlorophyll-*a* content were presented in Fig. 2.

In the present study it fluctuated between 2.45 µg/L and 4.85 µg/L, there by indicated oligotrophic nature. Chlorophyll content of water was reported to be in the range of 2.9 µg/L to 4.68 µg/L in case Yellow River, China [8], which is in line with present findings.

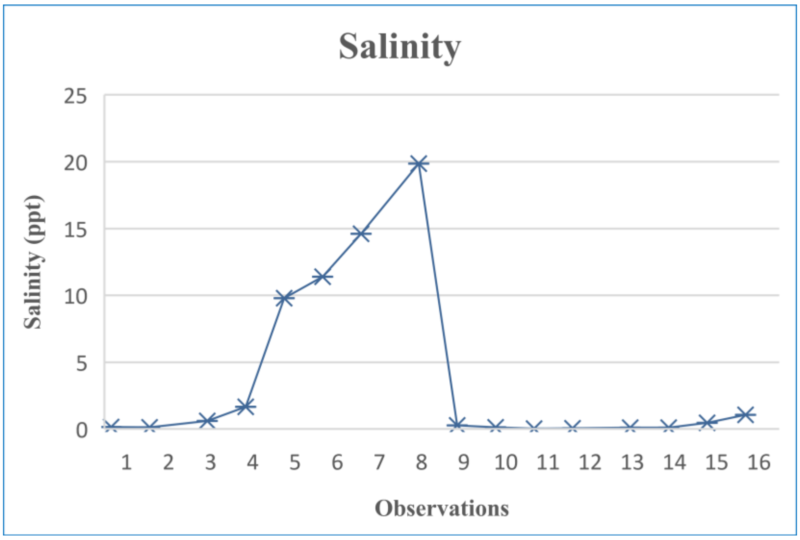

Fig. 1. Temporal variations in the salinity of water

Observations 1 to 4 represents post-monsoon, 5 to 8 represents pre-monsoon, 9 to 12 represents monsoon and 13 to 16 represents post-monsoon seasons, respectively.

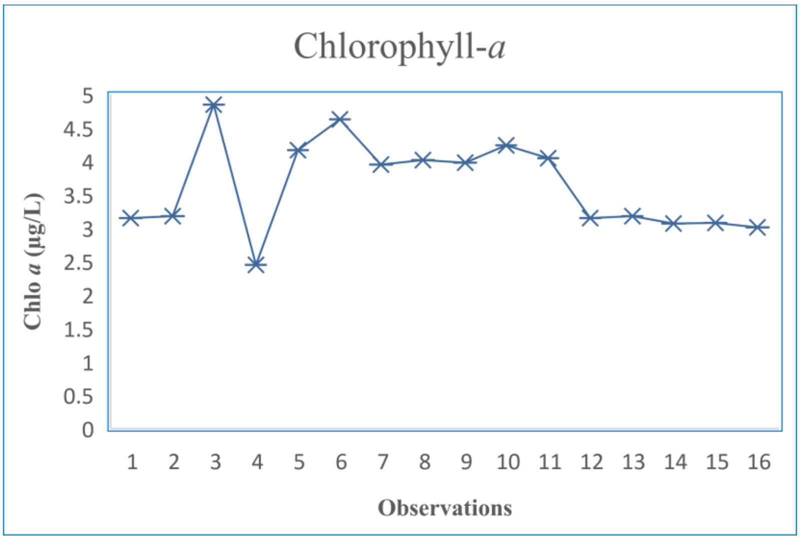

Fig. 2. Temporal variations in chlorophyll content of water

Observations 1 to 4 represents post-monsoon, 5 to 8 represents pre-monsoon, 9 to 12 represents monsoon and 13 to 16 represents post-monsoon seasons respectively

3.3 Phytoplankton Dynamics (Abundance & Diversity)

Phytoplankton ecology is the study of processes influencing the abundance and distribution of phytoplankton, their interactions with the environment, and their role in the flow and transformation of energy in an ecosystem. Qualitative determination of phytoplankton species was performed based on morphology following standard keys [9,10, 17]. Top ten 'net phytoplankton' genera (based on regularity & dominance) found at this station are *Merismopedia, Aphanizomenon, Hydrodictyon, Desmidium, Spirogyra, Pediastrum, Tabellaria, Coscinodiscus, Gomphosphaeria* and *Mougoetia spp*. Among the Chrysophytes, centrales were represented by regular/dominant forms like *Campylodiscus* (0 to 28000 cells/m^3), *Coscinodiscus* (4000 to 162000 cells/m^3), *Melosira* (0 to 398000 cells/m^3), and by a rare form, *Planktoniella spp*. Whereas, pennales were represented by the regular /dominant aforms like *Fragilaria* (0 to 170000 cells/m^3), *Gyrosigma* (0-20000 cells/m^3), *Pleurosigma* (0 to 44000 cells/ m^3), *Nitzschia* (0 to 20000 cells/m^3), *Tabellaria* (6000 to 616000 cells/m^3), and rare forms like *Cymbella, Diploneis, Gomphonema, Pinnularia, Navicula, Surirella and Thalassiothrix spp*. Cyanophyta was represented by the regular/dominant forms like *Aphanizomenon* (0 to 3200000 cells/m^3), *Gomphosphaeria* (0 to 512000 cells/m^3), *Lyngbya* (0 to 24000 cells/m^3), *Merismopedia* (0 to 4608000 cells/m^3), *Oscillatoria* (0 to 28000 cells/m^3), *Phormidium* (0 to 16000 cells/ m^3), *Spirulina* (0 to 16000 cells/ m^3) and rare forms like *Anabaena, Aphanocapsa, Aphanotheca, Coelosphaerium, Marssoniella, Microcystis, Nostoc, Raphidiopsis, Stigonema spp.* Chlorophyta is sensitive to environmental factors, such as water temperature, light intensity, nutrients, and organic pollutants. In the present study Chlorophyta was represented by the regular/dominant forms like *Basicladia* (0 to 56000 cells/m^3), *Closterium* (0 to 64000 cells/m^3), *Desmidium* (0 to 880000 cells/m^3), *Dichotomosiphon* (0 to 20000 cells/m^3), *Hydrodictyon* (0 to 1500000 cells/m^3), *Mougoetia* (0 to 54000 cells/m^3), *Pediastrum* (0 to 432000 cells/m^3), *Spirogyra* (0 to 542000 cells/m^3), *Ulothrix* (0 to 108000 cells/m^3) and rare forms like *Actinastrum, Bulbochaete, Chlorella, Cladophora, Cosmarium, Gonatozygon, Micrasterias, Microthamnion, Pithophora, Pleurotaenium, Prasinocladus, Radiofilum, Scenedesmus, Sphaerocystis, Spitotaenia, Staurastrum, Stigeoclonium, Triploceros and Zygnema spp*. Rhodophyta was represented by single genera *Lemanea spp*. (0 to 12000 cells/m^3).

Seasonal variations in the plankton community structure based on abundance was shown in Fig. 3. and temporal variations in abundance were represented through Table 1, while, Indices worked out on the basis of plankton dynamics were presented in Table 2.

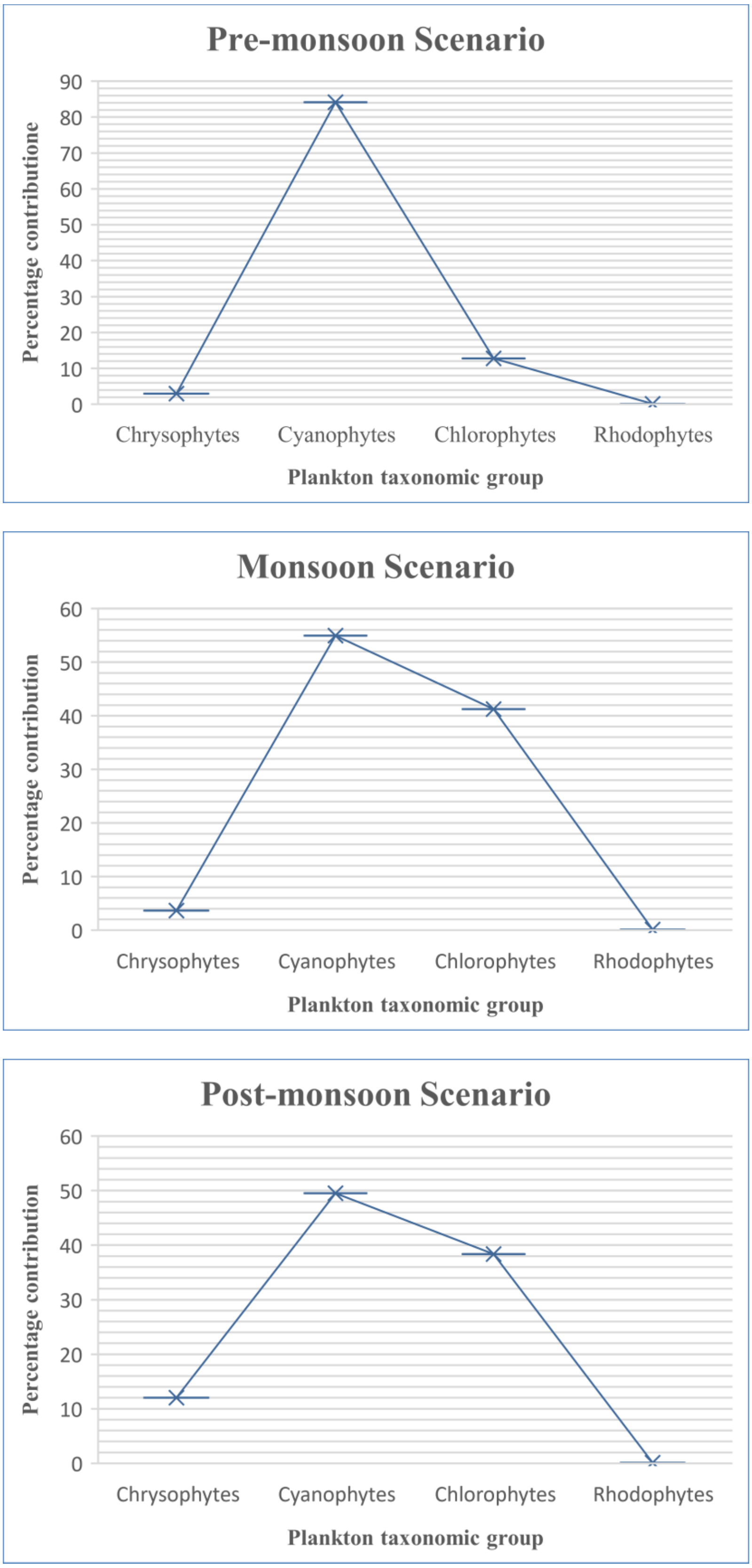

Fig. 3. Box-Whisker lines showing Seasonal variations in the plankton community structure

Table 1. Temporal variations in phytoplankton dynamics (Cells/m^3) of water (tidal influenced stretch of Nethravati River)

Plankton Taxonomic group / Observation	Centrales	Pennales	Total chrysophytes	Cyanophytes	Chlorophytes	Rhodophytes	Total phytoplankton
1	10000	36000	46000	1666000	899000	2000	2613000
2	18000	118000	136000	548000	2018000	4000	2706000
3	444000	692000	1176000	4674000	2130000	--	7980000
4	206000	92000	298000	896000	120000	--	1314000
5	144000	24000	216000	5924000	340000	2000	6482000
6	52000	42000	138000	6508000	768000	6000	7420000
7	86000	30000	136000	3498000	736000	4000	4374000
8	118000	38000	232000	4430000	1238000	12000	5912000
9	86000	118000	284000	2078000	2270000	10000	4642000
10	66000	68000	254000	3534000	2932000	10000	6730000
11	46000	64000	150000	4344000	1562000	4000	6060000
12	20000	18000	58000	1274000	1668000	4000	3004000
13	8000	100000	108000	1640000	1410000	4000	3162000
14	4000	32000	36000	1130000	1258000	4000	2428000
15	6000	478000	484000	458000	1224000	4000	2170000
16	400000	258000	658000	1128000	350000	4000	2140000

- *Observations 1 to 4 represents post-monsoon, 5 to 8 represents pre-monsoon, 9 to 12 represents monsoon and 13 to 16 represents post-monsoon seasons respectively*

Table 2. Temporal variations observed in the plankton indices of water (tidal influenced stretch of Nethravati River)

Observations / Plankton indices	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Margalef's Richness Index	1.56	1.15	2.08	1.28	1.53	1.77	2.29	1.54	2.21	2.23	2.05	1.54	1.47	1.16	1.30	1.58
Pielou's Evenness Index	0.62	0.54	0.59	0.66	0.36	0.40	0.58	0.37	0.71	0.54	0.52	0.61	0.59	0.57	0.62	0.70
Shannon's Diversity Index	1.96	1.57	2.07	1.93	1.17	1.35	2.00	1.19	2.52	1.95	1.83	1.94	1.84	1.64	1.86	2.21

- *Observations 1 to 4 represents post-monsoon, 5 to 8 represents pre-monsoon, 9 to 12 represents monsoon and 13 to 16 represents post-monsoon seasons respectively*

In the present investigation the order of abundance of phytoplankton was found to be Cyanophyta (20.25% to 91.39%) > Chlorophyta (5.25% to 74.58%) > Chrysophyta (1.48% to 30.75%) > Rhodophyta (0% to 0.22%). The community structure of river Ganges revealed dominance of Chrysophytes with respect to cell density followed cyanophytes and then by chlorophytes [11], which is in contrast to the present study. But, the dominance of Cyanophyta (55%), over that of Bacillariophyta (28%), and Chlorophyta (16%) was documented in case of Yangtze River, China [12], which is in accordance with the present study.

In the present investigation the order of generic diversity of phytoplankton was found to be Chlorophyta (28 genera) > Chrysophyta (16 genera), Cyanophyta (16 genera) > Rhodophyta (1 genera). But, higher generic diversity from Bacilariophyceae among others (Chlorophyceae, Cyanophyceae and Euglenophyceae) in case of Narmada River, Gujarat [13].

The dominance of blue-green algae and green algae over diatoms was reported from Cauvery River waters [14]. It was reported that, with respect to plankton community structure River Cauvery was dominated by Chlorophytes, while River Arasalar was dominated by Cyanophytes [15]. In the river waters of Mahanadi, the dominance of Chlorophyceae (53.45%) over that of Bacillariophyceae (25.77%) and Cyanophyceae (20.78%) was reported [16], and all these findings are in conformity with the present study.

3.4 Influence of Salinity on Chlorophyll-*a* and Plankton Dynamics

From the data obtained on salinity and chlorophyll -*a,* linear regression plot was constructed to estimate any trend in the variability among these parameters and represented in Fig. 4. No strictly specific trend was observed between salinity and chlorophyll a level in the study. Meagre temporal variability was observed in chlorophyll levels across the seasons, this might be due to: 1) During monsoon & post-monsoon seasons allochthonous nutrient input might have facilitated plankton growth, thereby chlorophyll 2) During pre-monsoon warmer surface temperature might have increased Chl-*a* concentrations by promoting the growth, photosynthesis rate and reproduction of phytoplankton.

Among the multitude of parameters affecting chlorophyll-*a* level, like light, temperature, nutrient availability etc. salinity has no strongly established such specific role in increasing or decreasing chlorophyll levels, rather it also might have affected along with other mentioned co-variables above. So only no specific increasing or decreasing trend was observed in chlorophyll content with respective changes in salinity [17].

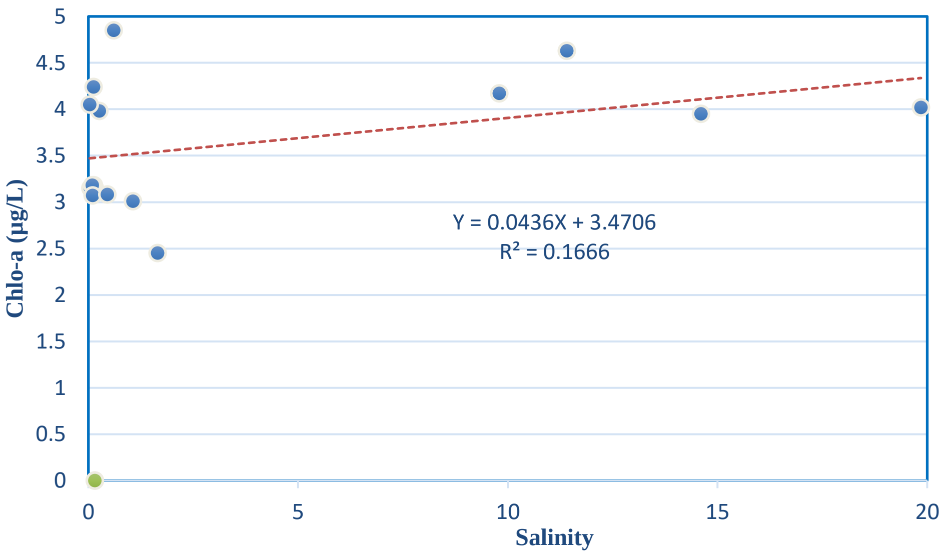

Fig. 4. Relationship between salinity and Chlorophyll-*a*

But a visible difference with respect to percentage contribution of different plankton taxonomic groups to the total cell density was observed, like predominance of centrale over pennate diatoms and cyanophytes over that of chlorophytes, with increasing salinity during pre-monsoon due to tidal influx.

4. CONCLUSION

The present study comprehended the study area with mesohaline nature during pre-monsoon with respect to salinity, oligotrophic nature with respect to observed chlorophyll *a* content. With respect to plankton cell density, chlorophytes showed increasing contribution to community structure as season changes from pre-monsoon (the period of significant tidal impact) towards monsoon and post-monsoon. Thereby, it can be understood that water salinity had a major impact on the plankton community structure. Rhodophytes were found to be rare in this study, with little effect on cell density and taxa composition of the phytoplankton community.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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