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The seasonal oscillation of physico-chemical parameters and phytoplankton distribution from South West Coast of India (Bharathapuzha river basin)

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ABSTRACT

This work aimed to determine the limnological status of the Bharathapuzha river basin using the physico-chemical and biological parameters (phytoplankton) throughout the period from November 2018 to October 2019. A total of 168 species were identified, belonging to five different classes, Bacillariophyceae, Chlorophyceae, Euglenophyceae, Dinophyceae, and Cyanophyceae. The most dominant classes obtained from the study area are Bacillariophyceae, Chlorophyceae and Euglenophyceae. The present study revealed that species distribution depends upon the physico-chemical parameters and attained their maximum density during pre-monsoon, whereas minimum populations were observed during monsoon. The diversity profile was higher during pre-monsoon and lower in monsoon season. Canonical Correspondence Analysis revealed that temperature, nitrate, silicate, and DO have a more significant influence on phytoplankton abundance.

Key words : *Algae, Diversity, Environmental monitoring, Freshwater ecosystem, Physico-chemical parameters, Seasonal variation*

Introduction

Phytoplankton community structure, composition, and species diversity in the aquatic ecosystem are controlled by several physico-chemical parameters (Vajravelu *et al.*, 2017). Phytoplankton composition and density are susceptible to environmental changes, and their documentation will give valuable information about water quality (Baliarsingh *et al.*, 2012). These remarkable changes in physico-chemical parameters exhibit differential impact on phytoplankton distribution and abundance of many species, thus ultimately reflects the average ecological condition, and therefore, used as an indicator of water quality (Madhu *et al.*, 2007). Phytoplankton or microalgae are phototrophic microorganisms with simple nutritional requirements and can respond rapidly to environmental changes. So they are considered as good indicators of water quality because of their short generation time and fast population renewal. River bowls are generally areas with a high population density because of favourable living conditions such as proper irrigation and the fertility of lands. Biological monitoring is beneficial for assessing the ecological value of aquatic ecosystems that results from the integrative approach of both biological guild and physico-chemical attributes of water (Jindal *et al.*, 2011). The physico-chemical aspects of river water were reported by Santhosh, (2007). Alterations in phytoplankton distribution are widely affected by hydrophysical and chemical factors such as temperature, salinity, pH, nitrate, nitrite, ammo-

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nia, silicate, and inorganic phosphate. Environmental stress results from species diversity and abundance changes used to explore the changes in the environment (Sampoorani *et al.,* 2002). Scientific reports from the status of Indian rivers and their deterioration due to pollution are many (Menon *et al.,* 2000; Sridhar *et al.,* 2006; Sahu *et al.,* 2012; Varol *et al.,*2015). Kerala's riverine ecology status concerning seasonal variation by (Sankar *et al.,* 2002; Joseph and Tessy, 2010). The present study is aimed to determine the seasonal changes within the communities of phytoplankton and physico-chemical characteristics may provide the basis for deciding the trophic state of water bodies. The outcome of this study will undoubtedly be helpful for environmental monitoring and impact assessment work.

Materials and Methods

The present study was conducted on the Bharathapuzha river basin, South West Coast of India. The River Bharathapuzha is a significant west-flowing and the second-longest river in Kerala. It originates from Anamalai hills and lies approximately between 10°26' and 11°13' north latitudes and 75°53' and 77°13' east longitudes. It has a total area of 6186 Km^2, out of which 4400 Km^2 falls within Kerala (Fig. 1) and 1786 Km^2 in Tamil Nadu (CWC, 2012). The river Bharathapuzha links three districts in Kerala, namely Palakkad, Malappuram, and Thrissur. Study of the Bharathapuzha river's algal biodiversity, six sites selected for collecting algae with an approximately 13 to 20 km distance were selected.

Water samples were collected monthly from the Bharathapuzha river basin from November, 2018 to

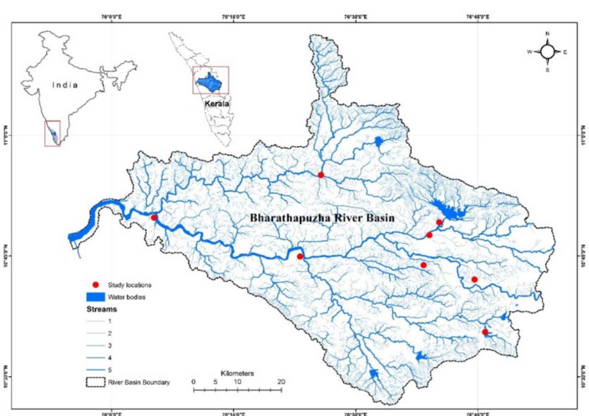

Fig. 1. Location map of sampling sites

October, 2019. The water samples were collected from 6 study sites between 8.30 and 11.00 am in 2-litre plastic containers and soon carried to the laboratory for analysis without delay. Measurements of physico-chemical and environmental factors measured simultaneously with sampling. Samples were collected as 2l to analyze each station's phytoplankton diversity and physico-chemical parameters. The samples were preserved, and the methodology followed to study the algae as per APHA (1998). Statistically, the data were analyzed using SPSS software, version 14. Biodiversity indices of algal community structure by Shannon index (H2) and Margalef richness index. Canonical Correspondence Analysis between ecological parameters and algal density was calculated with the help of statistical software PAST to analyze the environmental conditions on algal assemblages.

A total of 8 different characteristics of water were analyzed in triplicates every month from November 2018 to October 2019. The physico-chemical parameters analyzed were temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), and dissolved oxygen (DO) were noted on the spot at the time of collection using standard instruments (digital thermometer, pH pen, EC, and TDS, DO meter). Water samples were filtered and analyzed for nitrate, phosphate and silicate. Samples for biota analyses at different sampling points were collected with the help of using towing plankton net (mouth diameter-1.5 m) and stored in polythene bottles after preservation with 4% formalin and Lugol's iodine solution. After concentrating the sample by sedimentation method, 1 ml of sample was taken and examined with a Sedgwick rafter counting chamber under a compound light microscope with different magnifications. Quantification of phytoplankton using Sedgwick rafter counting chamber and phytoplankton species were identified by following standard manuals of (West and West, 1904; Desikachary, 1959; Scott and Prescott, 1961; Philippose, 1967; Iyengar and Desikachary, 1981; Sarod and Kamat (1984).

Results

Water quality assessment can be achieved by phytoplankton forms the freshwater ecosystem indicators and physico-chemical analysis. This will result in the current nature of the water body and its previous conditions. This study analyzed the first-time freshwater algal community and qualitative parameters during the study period.

Monitoring the physico-chemical parameters is crucial for studying the influence of the distribution of phytoplankton and the effect of water quality parameters in the aquatic stream (Sharma *et al.* 2016). Water temperature is one of the essential factors that control aquatic life. Temperature shows significant variation between the effects of month F = 37.920, P = 0.037 and varied from 28.19 ^{o}C (January 2019) to 33.59 ^{o}C (April, 2019) with the mean of 30.37 (±2.10). Fluctuations in temperature may be due to wind force, the influx of freshwater and atmospheric temperature, and heavy rainfall. Alkaline water promotes high primary productivity. Bharathapuzha river was alkaline throughout the study period. pH reached the maximum of 8.96 (June, 2019), and the minimum was recorded in 8.34 (November, 2018) with the mean value of 8.64 (±0.38). pH showed significant differences among months (F = 7.203, P = 0.001). Electrical conductivity varied from 384.4 (March 2019) to 744.17 (November 2018), with a mean of 504.54±175.45. Analysis of variance showed significant differences (F = 7.54, P = 0.001). Throughout the investigation period, a comparatively high value of TDS was recorded, which varied from 179.25 mgl^{-}1 (August 2019) to 364.22 mgl^{-}1 (November 2018), indicating maximum disturbance due to human activities (Sharma *et al.*, 2007). The observed TDS show statistically significant variance between months (F = 2.61, P = 0.004) with a mean of 252.29±130.61.

Nitrate, Phosphate, and Silicate ratio within phytoplankton fluctuate according to their physiological and biological state (Balzano *et al.*, 2015). Nitrogen and phosphorus are the most critical nutrient requirement needed by all taxa and silicate for the frustule development in Bacillariophyceae. Bacillariophyceae also require silicate for their frustules. Analysis of variance in Nitrate showed that significant differences observed (F = 10.89, P = 0.001) varied from 0.034 mgl^{-}1 (December 2018) to 0.512 mgl^{-}1 (May 2019) with the mean of 0.131±.01. High levels of nitrates in freshwater are mainly due to increased domestic sewage arising from anthropogenic activities and agricultural runoffs (Sylvester 1969). A lower Nitrate concentration might be due to the high consumption of Nitrate by photosynthetic organisms. Nitrate concentration along with temperature strongly affected riverine diversity.

Inorganic phosphorus at 0.03 mgl^{-}1 concentration is sufficient to cause algal blooms (Sheela *et al.* 2011). Phosphate varied from 0.043 mgl^{-}1 (January 2019) to 0.273 mgl^{-}1 (March 2019) with a mean of 0.114±.10. Phosphate showed significant differences between months (F = 6.089, P = 0.001). Silicate is a considerable component of the aquatic ecosystem, ranging from 0.424 mgl^{-}1 (October 2019) to 2.386 mgl^{-}1 (May 2019) with a mean of 1.307±0.852. Analysis of variance showed that significant variance between months (F = 11.54, P = 0.001). High consumption of silicate by diatoms results in a lower concentration during post-monsoon. Dissolved oxygen is one of the indicators of aquatic system well-being. The metabolism of aerobic organisms depends purely on the amount of oxygen dissolved in the water. The minimum value of DO was 6.4±0.46 (June, 2019) to 7.6±0.61 (November 2018), with a mean of 7.01±.0.70. Univariate analysis showed that (F = 7.1, P = 0.001).

A total of 58 genera and 168 species belong to Bacillariophyceae (22 genera, 72 species), Chlorophyceae (19 genera, 57 species), Cyanophyceae (5 genera, 9 species), Euglenophyceae (5 genera, 26 species), Xanthophyceae (1 genus, 1 species) and Dinophyceae (3 genera, 3 species) were obtained from 10 sample sites noted in Table 2. Maximum density (2421 individuals L^{-}1) of phytoplankton was observed at S2 and minimum (1359 individuals L^{-}1) at S4 shown in Fig. 2. During premonsoon (February- May), maximum density declined from June onwards due to monsoon rain and vital water flow in rivers. Again, attained high density during post-monsoon from October to December. The phytoplankton population density was recorded in the order of Pre-monsoon> Post-monsoon>Monsoon, ranged between 2610 individuals K^{-}1 (Monsoon) to 10639 individuals L^{-}1 (Pre-

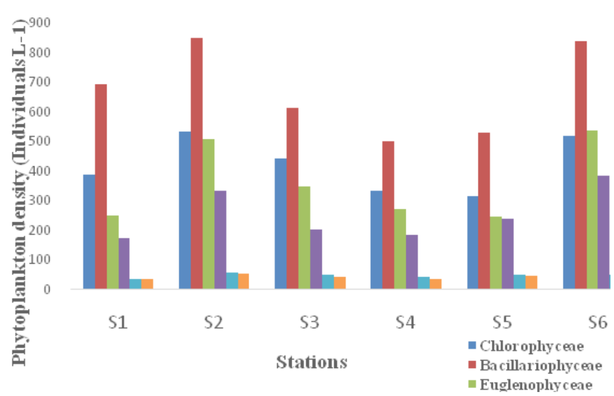

Fig. 2. Density of phytoplankton at different study sites

monsoon) shown in Fig.3. Seasonal variations in phytoplankton abundance reveal that Euglenophyceae follows maximum growth of Bacillariophyceae in all the seasons. Similar observations were noted by (Singh *et al.*, 2010). The dominance of Euglenophyceae results in the eutrophic nature of the study area. The distribution of phytoplankton in all stations and seasons varied considerably due to change in environmental variables, especially nutrients and temperature. The distribution of species varied between 256 individuals L^{-1} to Xanthophyceae and 4121 individuals L^{-1} to Bacillariophyceae.

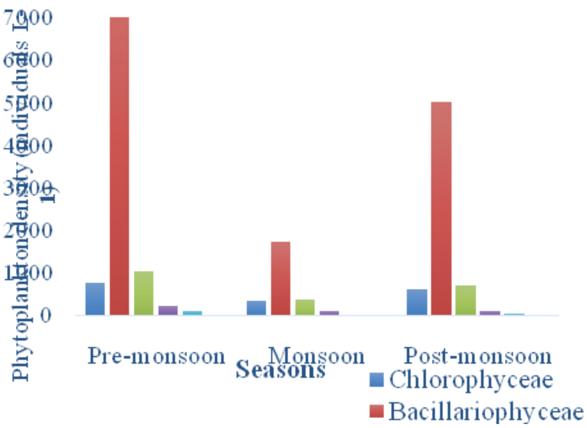

Fig. 3. Seasonal variations in phytoplankton population density

Bacillariophyceae has been recorded as the most dominant group, followed by Chlorophyceae and Euglenophyceae. It contributed 44% to the total phytoplankton, followed by 25% and 16% to Chlorophyceae and Euglenophyceae, respectively. Bacillariophyceae are the most diverse group of algae present in the study area. This is due to the highly concentrated form of silicate during pre-monsoon with low water runoff, which enhanced the species composition. The highly alkaline nature of the study area also results from rich diatom flora (Thakur *et al.*, 2013). A total of 72 species reported from the Bharathapuzha river. The density of Bacillariophyceae ranged between 501 (individuals L^{-1}) at S4 during Monsoon and 839 (individuals L^{-1}) at S6 during pre-monsoon.

Chlorophyceae were the second most abundant group of phytoplankton obtained from the study area. A total of 25% of phytoplankton contributed to this group. The density of the Chlorophyceae population ranged between 314 (individuals L^{-1}) at S5 during Monsoon and 532 (individuals L^{-1}) at S2 during pre-monsoon. A total of 57 species recorded with dominant species were *Cosmarium blyttii* and *Pediastrum tetras*. The next abundant group is Euglenophyceae, with 16% of the phytoplankton population ranged between 244 (individuals L^{-1}) at S5 to 534 (individuals L^{-1}) at S6. A total of 26 species with dominant were *Trachelomonas volovocina* and *Trachelomonas dubia*. A total of 9 species with 11% of phytoplankton population contributed to Cyanophyceae ranged between 172 (individuals L^{-1}) at S1 to 283 (individuals L^{-1}) at S6. Higher Temperature with nutrient concentration favors the growth of Cyanophyceae. The least abundant group belongs to Xanthophyceae and Dinophyceae, have 2% of phytoplankton population ranged between 31(individuals L^{-1}) to 54 (individuals L^{-1}) and 33 (individuals L^{-1}) to 58 (individuals L^{-1}). Occurrence of *Peridinium* species in all the seasons known as indicators of the meso-eutrophic nature of the study area.

Monthly variations in phytoplankton diversity and richness are illustrated in Fig. 4, 5. Diversity profile and richness in different seasons ranged from 1.45 to 1.61 and 0.68 to 0.79, respectively. The observed highest value was recorded during the pre-

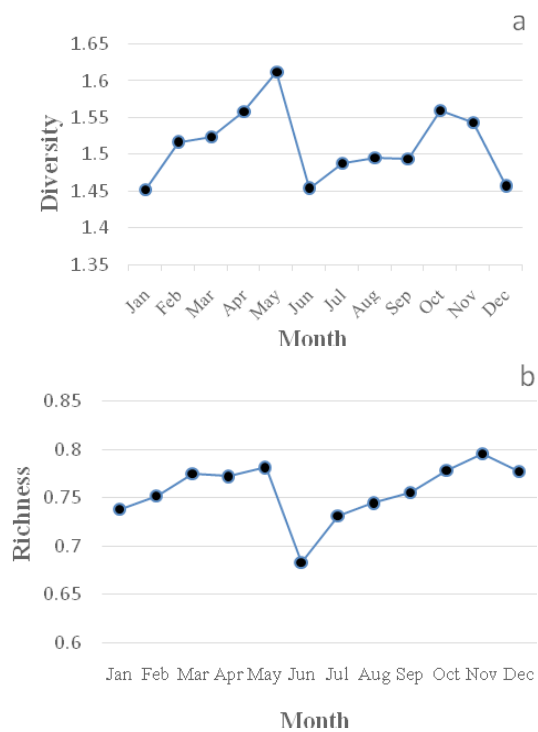

Fig. 4. Monthly variation of Phytoplankton species. a Diversity. b Richness.

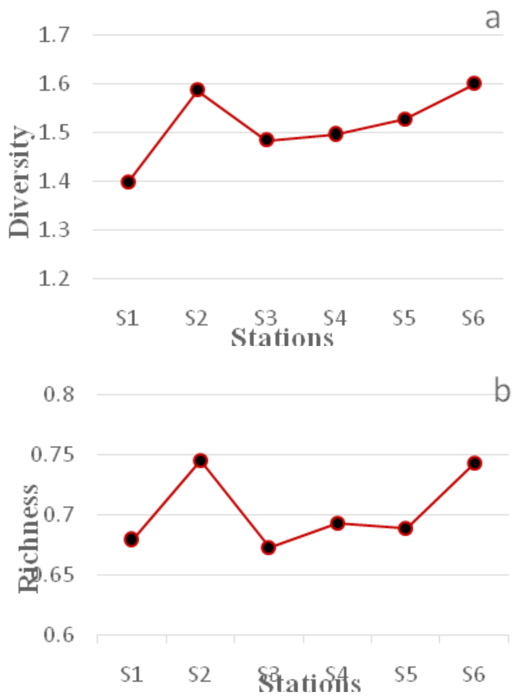

Fig. 5. Variationof Phytoplankton species in different stations. a Diversity. b Richness.

monsoon season, followed by post-monsoon in the present study. The lowest value was reported from the monsoon. Lowest abundance during monsoon due to the stratification of the water column because of heavy rainfall, high turbidity caused by river run-off, reduced salinity, decreased Temperature, and pH. Species diversity and richness in different stations ranged from 1.39 to 1.59 and 0.67 to 0.74. The highest value was recorded from S2 and S6, least from S3. The increase in phytoplankton density in pre-monsoon may be attributed to the rise in the temperature and concentration of available nutrients. Species richness and density correlated strongly with water temperature.

The canonical Correspondence Analysis (CCA) method was used to determine the relationship between environmental variables and phytoplankton distribution (Liu et al. 2010). The percentage of variance and Eigenvalues in all the seasons were higher on-axis 1 than axis 2.

During pre-monsoon, CCA had been drawn between 8 physicochemical parameters and 47 species (Fig. 6). The eigenvalue for axis 1 (0.021) explained a 40.8 % correlation, and axis 2 (0.014) demonstrated a 27.27% correlation between physicochemical parameters and dominant species of phytoplankton. Temperature, pH, EC, TDS, Nitrate and Silicate, and DO positively correlate on axis 1, exhibited maximum canonical values (1.93, 1.91, 1.85 1.63 and 1.87). Distribution of *Pinnularia* significantly least affected

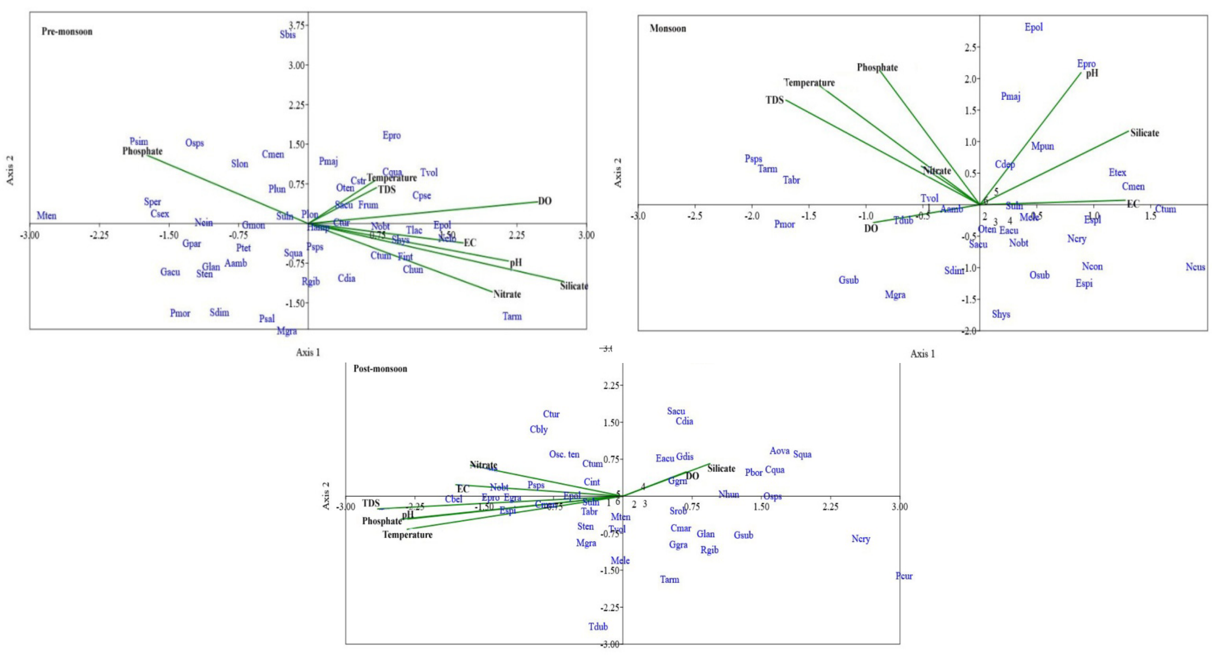

Fig. 6. CCA biplot showing the seasonal variation between phytoplankton species and environmental parameters. Environmental variables are depicted by long arrows and species are given in code words. The correlation between species and environmental variables are explained by the length of the arrows

by parameters. In axis 2, Temperature, TDS, Phosphate and DO have a close association phytoplankton distribution with maximum canonical values (1.75, 1.61, 1.63, 1.39, 1.25). CCA plot explained Temperature, TDS, and DO have strong relation with phytoplankton distribution in both axes than other variables indicated their presence responsible for algae growth.

During monsoon, the variation explained by CCA in the first two axes was 38.81% and 29.75%, with Eigenvalues 0.038 and 0.029, respectively. CCA biplot implies the influence of freshwater on contributing 8 hydrochemical parameters and 31 species. Species were positively correlated with pH, EC and Silicate in axis 1. Temperature, pH, EC, TDS, Nitrate, Phosphate, and Silicate show positively relation in axis 2. P-value significant in both axis (0.214 and 0.173). The revealed results agree with the earlier investigation as monsoon season causes dramatic changes in environmental parameters due to heavy freshwater discharges, reducing Phytoplankton diversity and abundance (Vengadesh *et al.* 2009). Similarly, low Temperature with nutrient concentration promotes the growth of Euglena as indicator species; it reveals that heavy discharge from agriculture and anthropogenic activities during monsoon activates the growth of Euglenophyceae. As in Post-monsoon, 8 physico-chemical parameters and 42 species were considered to draw a CCA plot. At axis 1, Eigenvalue (0.024) explained 36.72% correlation and Eigenvalue of axis 2 (0.016) explained 25.44% relationship. Silicate and DO showed positive correlation with axis1 and EC, Nitrate, Silicate, and DO showed a positive correlation with axis 2. High nutrient input after monsoon rainfall results in the phytoplankton abundance during post-monsoon.

Discussion

This paper summarizes the seasonal variations of physico-chemical parameters and the distribution of the phytoplankton community at the Bharathapuzha river basin. Variations in water's physico-chemical properties and temporal fluctuations can bring about changes in the composition and abundance of aquatic organisms. Introduction of the high organic content during pre-monsoon season containing silicate, and nitrate plays a significant role in phytoplankton growth which helps the phytoplankton to utilize the nutrients and increase under favorable condition. ANOVA revealed that the nutrients vary considerably between seasons and significantly influence the phytoplankton diversity and abundance. Depending on the nutrient availability, phytoplankton diversity is highly dynamic, clearly explained by Canonical Correspondence Analysis. This study clarifies that temperature, nitrate, silicate, and DO played a significant role in phytoplankton growth and abundance. The comprehensive research provides a good framework for the seasonal relationship between phytoplankton distribution and physico-chemical parameters.

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