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RESEARCH

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Temporal changes in plankton diversity in relation to hydrographical characteristics at Perumal Lake, Cuddalore District, Tamil Nadu, India

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Abstract

Background The fresh water environment supports the productivity of phyto- and zooplankters and fin and shell fishes. The rate of fish productivity of an aquatic ecosystem solely depends on the rate of plankton productivity, and which in turn critically depend on the concentration and variation of hydrographical features. The current investigation was focused on the distributional pattern of phyto- and zooplankton vis-à-vis physicochemical characteristics in Perumal Lake, Cuddalore District, Tamil Nadu State (India).

Results The hydrographical factors and phytoplankton as well as zooplankton diversity were studied at the monthly interval of 12 months by following the standard methods in freshwater of Perumal Lake from September 2018 to August 2019. Presently a total of 15 species of phytoplankton and 15 species of zooplankton were recorded in Perumal Lake. The present study reveals good variation in the hydrographical characteristics, such as temperature (24.2–30.1 °C), turbidity (10.4–43.2 NTU), total suspended solids (300.2–1800.8 mg/L), conductivity (3.25–10.54 mhos/cm), pH (6.92–8.2), total hardness (8.58–23.8 mg/L), dissolved oxygen (2.8–7.26 mg/L), dissolved carbon dioxide (0.96–13.2 mg/L), chloride (1.92–23.8 mg/L), nitrate (0.28–3.18 mg/L), sulphate (1.1–8.2 mg/L) and phosphate (0.19–3.34 mg/L).

Conclusions The findings of the present study indicate that the temperature has influence on phytoplankton as well as zooplankton diversity of species. Regular monitoring of hydro-biological parameters is necessary to assess the health of the lake ecosystem.

Keywords Perumal Lake, Biodiversity, Phytoplankton, Zooplankton, Physicochemical parameters

Background

The freshwater environment is represented by different ecosystems like lakes, rivers, ponds, streams, temporary puddles and thermal springs. Although freshwater environment accounts for a small portion of the world's total aquatic part, the inland aquatic habitats shows far more heterogeneity in their physicochemical characteristics that houses unusually large portion of the world's biodiversity. Lakes, both the natural and artificial, are the important freshwater ecosystem that have varied

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utilization. They support a variety of flora and fauna, viz. phytoplankton, macrophytes, zooplankton, benthos and nekton. The plankton are defined as the heterogeneous assemblage of organisms which float as well as passively drift along the course of water current of aquatic environments. The phytoplankton (plants) and zooplankton (animals) are the important components of aquatic environments. In view of their high sensitivity to the water quality changes, plankton are considered to be indicator species (Jena et al., 2017). The variation in the density and diversity of plankton is an important criterion to assess the health of aquatic ecosystems. Aquatic population is represented by many species (Manickam et al., 2020). The freshwater ecosystems are of great help for human welfare as they are the sole habitat for an extraordinarily rich endemic and sensitive biota (Jasmine et al., 2013).

The interactions between the physical and chemical properties of water play an important role in the abundance, distribution, diversity, growth, reproduction and the movements of aquatic organisms (Anne Rebecca, 2019; Deepak & Singh, 2014). Plankton are often used as indicator of environmental and aquatic health because of their high sensitivity to changes such as eutrophication and pollution. The plankton are divisible into two main groups, the phytoplankton and the zooplankton (Jena et al., 2017). Together with the various physicochemical characteristics of water and soil, such biotic communities form an interdependent and balanced ecological system. The hydrographical features of an aquatic environment have been found to be greatly influencing the biological productivity (Ahmed et al., 2013; Bais & Agarwal, 1990). The lakes are largely being used for the purposes of drinking, irrigation, fishing, eco-tourism, etc. (Bhatt et al., 2014). Generally, the lakes situated in urban areas are mainly used for recreational purposes like swimming, bathing and other water sports. Unfortunately, such aquatic ecosystems are also being used for the discharge of industrial and domestic wastes and thereby the degradation of the water quality considerably. The plankton productivity rate is determined by the physical and chemical parameters (e.g. temperature, light availability, micro- and macro-nutrients) of the water as well as the soil nature. Data on the abundance and diversity of plankton in relation to inorganic factors provide information of energy turnover of aquatic ecosystems (Forsberg, 1982). Damodharan et al. (2010) have stated the importance of zooplankton as live feed to fish larvae in wild. Hence, it is important to investigate the plankton resources of freshwater ecosystems (Kather Bee et al., 2015).

In view of the movement of nutrient from sediments to water column, bloom formation occurs (Ekholm and Mitikka, 2006). While the oligotrophic lakes are transparent and hypertrophic lakes are turbid, the shallow lakes (at intermediate nutrient concentrations) may exhibit either clear water or turbid state (Scheffer et al., 2001). Research studies on plankton were carried out in India since 1950 onwards (Rajashekhar et al., 2009). The present investigation pertains to the spatio-temporal variation of phyto- and zooplankton in relation to hydrography at Perumal Lake.

Methods

Study area

The study area, Perumal Lake, is situated in Cuddalore District, Tamil Nadu, with an area of 500 acres, and is 24 km east of Neyveli town and 16.7 km south of Cuddalore. The lake is also used for Agricultural and regular fishing by local fishermen. Totally, three sampling stations were covered, viz. ST-1 (11.5474° N; 79.6542° E), ST-2 (11.6143° N; 79.7017° E) and ST-3 (11.5806° N; 79.6754° E) (Fig. 1). Monthly samplings were carried out for 1 year from September 2018 to August 2019.

Hydro-biological samplings

Plankton and water samplings were made every month's 1st week (September 2018–August 2019). For zooplankton quantification, 100 L of water sample was filtered through conical-shaped plankton-net mesh size (150 µm). The samples were then taken to the laboratory and preserved with 5% formalin (Ajithamol et al., 2014).

Analyses of hydro-biological parameters

Various parameters like salinity, temperature, pH, electrical conductivity and total dissolved solids were analysed through a standard kit "µP based Water & Soil Analysis Kit Model 1160". Winkler's method was used to determine the primary production, and the light and dark bottle method was followed to estimate the dissolved oxygen and inorganic nitrate, phosphate, sulphate and chloride (Parsons et al., 1984; Strickland & Parsons, 1968). The plankton species were studied under the light microscope, and the identification was made by referring the standard works (Battish, 1992; Murugan et al., 1998; Altaff, 2004; Manickam et al., 2017). Phytoplankton counting was made by drop method and zooplankton quantification by employing Sedgwick Rafter's cell. And 1 mL of sample was taken with a wide mouthed pipette and poured into the counting cell of the Sedgwick Rafter. After allowing for settlement, they were counted. Each plankton was counted five times, and the average value was obtained. The total number of plankton present in 1 L of water sample was calculated (Santhanam et al., 2019) by using the following formula: $N = n \times v/V$; where N = total number of plankton per litre of water filtered;

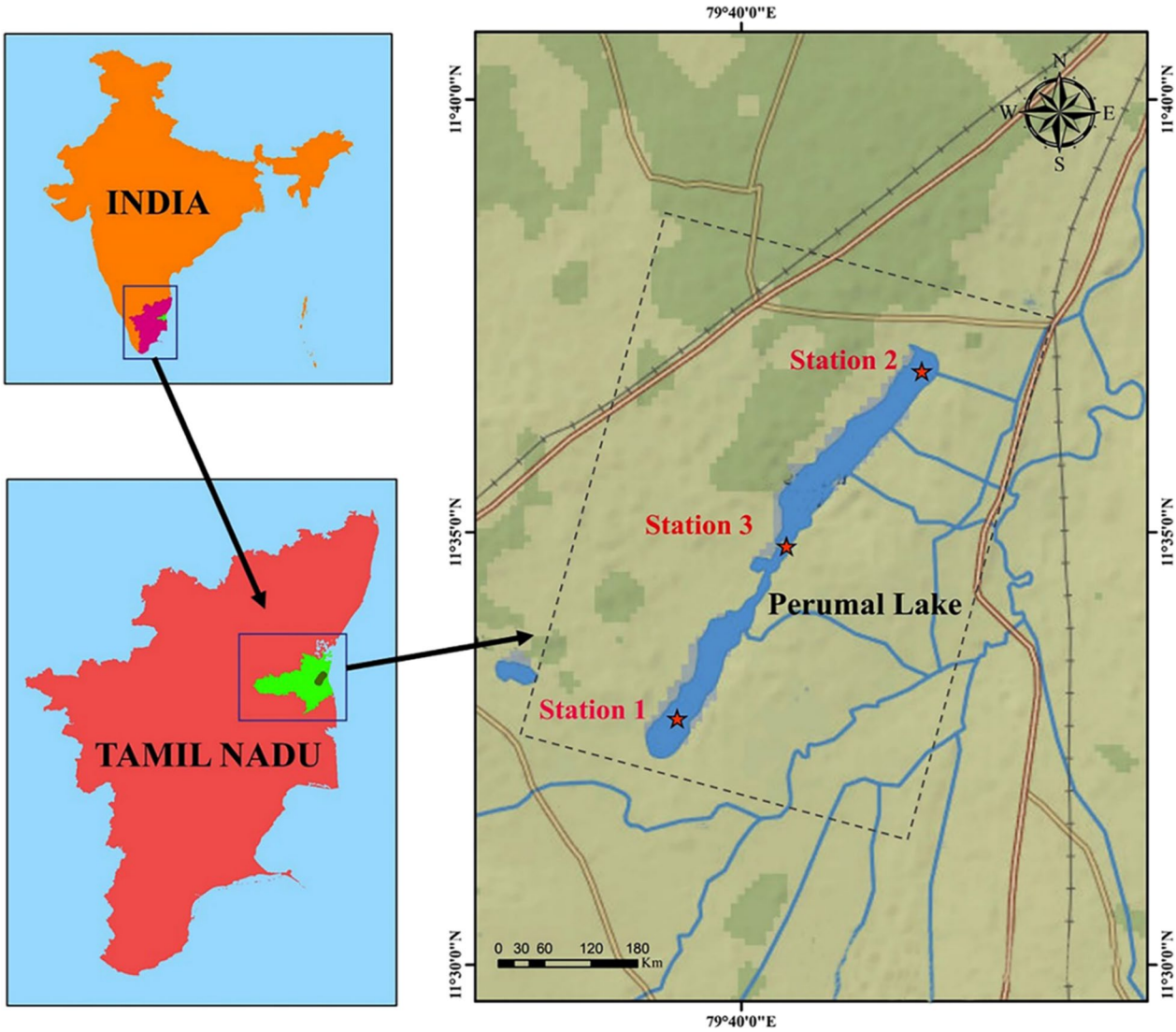

Fig. 1 Map showing the study area of Perumal Lake (Cuddalore District, Tamil Nadu, India)

n = average number of plankton in 1 ml of plankton sample; v = volume of plankton concentrated (ml); and V = volume of total water filtered (litre).

Statistical analysis and diversity indices

The population of each group of zooplankton was expressed in average (number of individuals per litre). The data between zooplankton versus physicochemical characteristics were subjected to correlation and linear regression analysis using IBM-SPSS (v20.0). The different diversity indices such as species dominance (D), Shannon's diversity index (H'), species evenness and species richness were calculated by using the PAST (Paleontological Statistics) software package (PAST, v2.02).

Results

Hydrographical features

The water temperature was recorded at three stations for 12 months, and the results are given in Fig. 2a. Water temperature varied from 24.2 to 29.9 °C at station1 followed by station 2 which ranged between 24.5 and 30.1 °C and at station 3, it ranged between 24.6 and 30.0 °C. The turbidity at station 1 was ranged between 10.46 and 38.6 NTU, and at station 2, it ranged between 11and 40 NTU. And at station 3, it varied from 11.2 to 43.2 NTU (Fig. 2b). Total suspended solids (mg/L) were: 455–1820 (Stn.1), 320.2–1800.8 (Stn. 2) and 300.2–1790.8 (Stn. 3) (Fig. 2c). The conductivity values ranges (mhos/cm) were: 3.4–10.54, 3.4–9.8 and 3.25–9.8 at stations 1, 2 and 3, respectively (Fig. 2d). The average pH value recorded at station 1 was 7.48

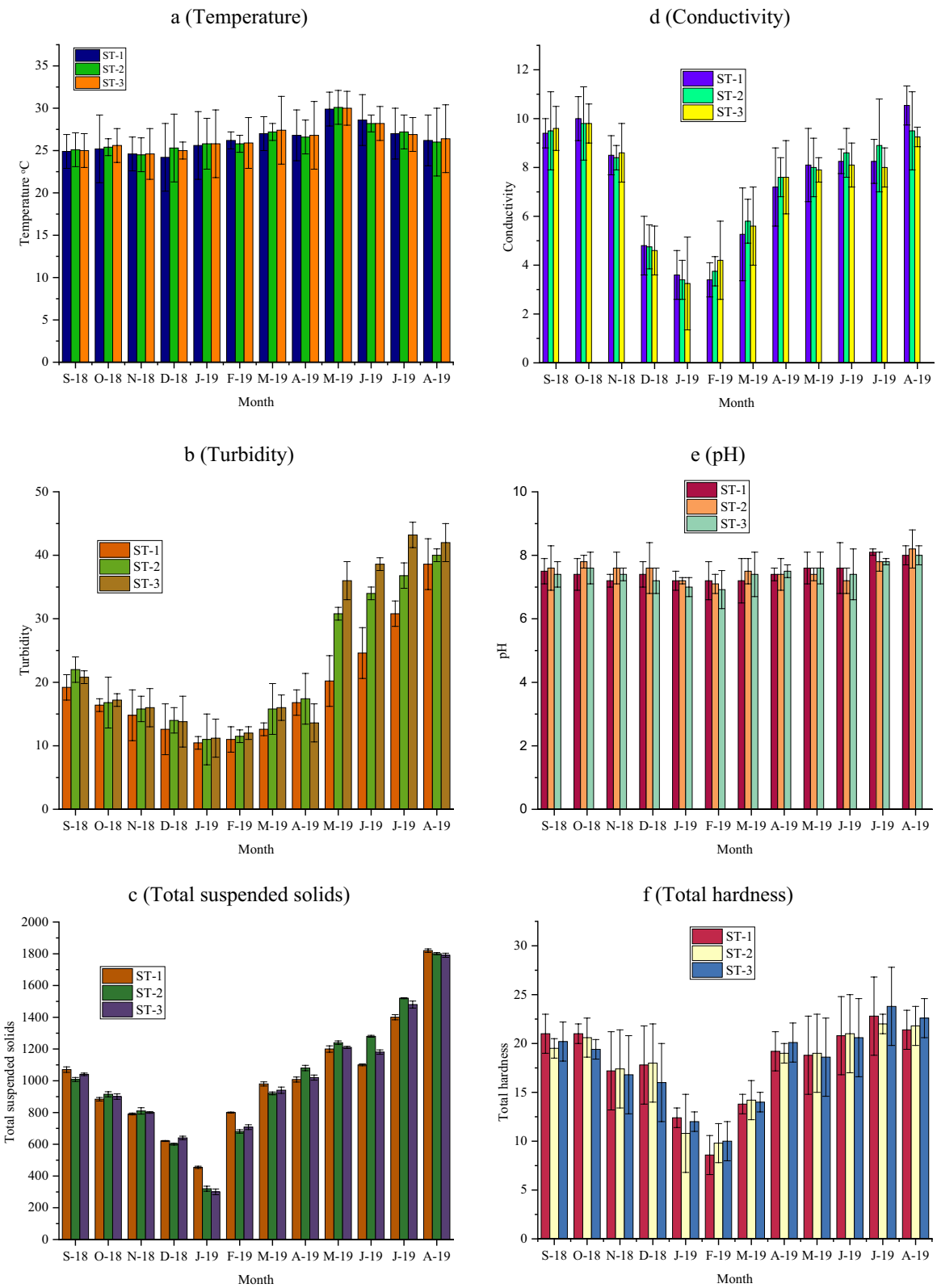

Fig. 2 Seasonal variations of physicochemical parameters in Perumal Lake during September 2018 to August 2019 (Temperature, Turbidity, Total Suspended Solids, Conductivity, pH and Total Hardness)

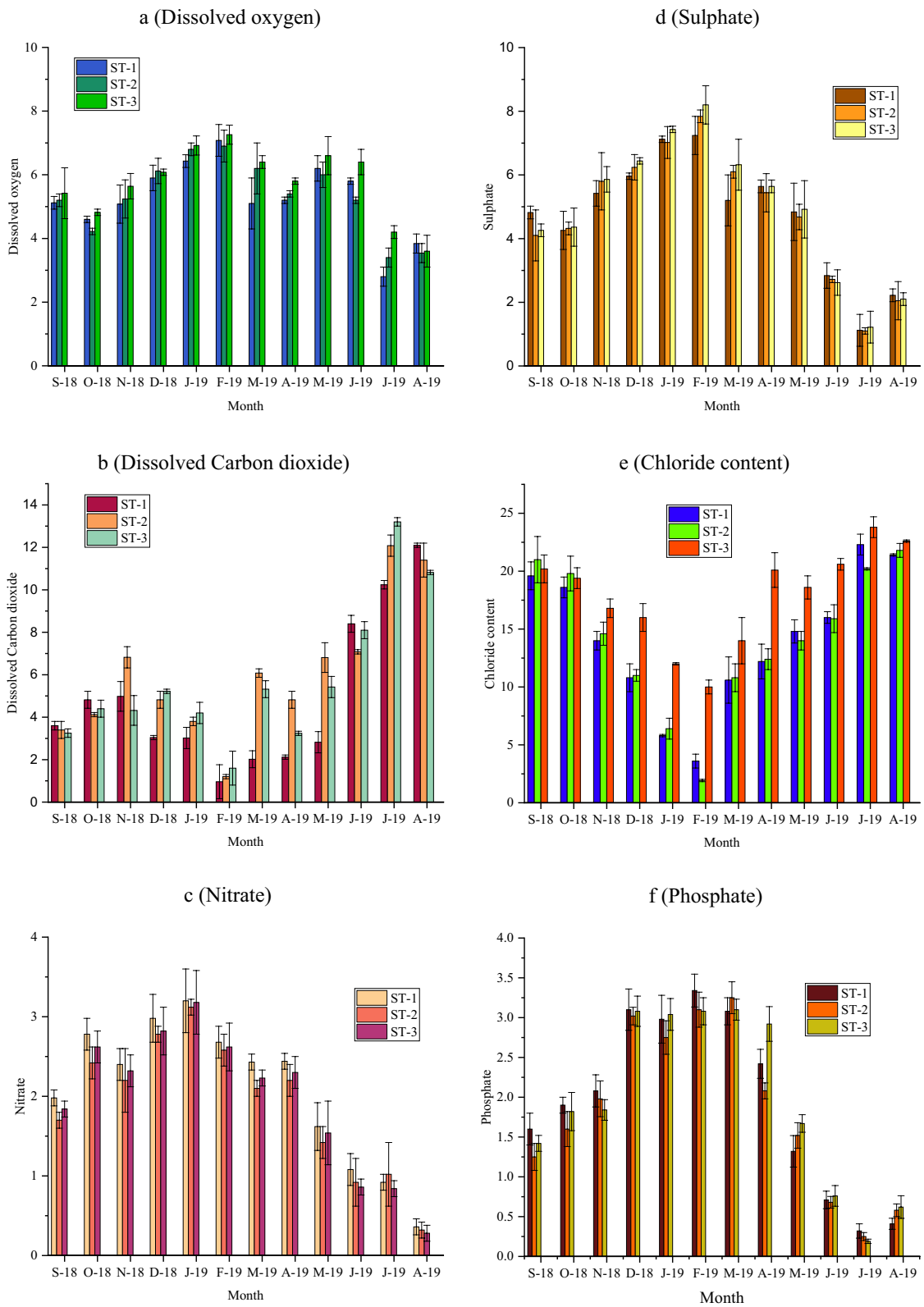

Fig. 3 Seasonal variations of physicochemical parameters in Perumal Lake during September 2018 to August 2019 (Dissolved Oxygen, Dissolved Carbon dioxide, Nitrate, Sulphate, Chloride content and Phosphate)

followed by stations 2 and 3 with 7.53 and 7.44, respectively (Fig. 2e). The total hardness values at station 1 were ranged between 8.58 and 22.8 mg/L, whereas at station 2 it was 9.8 and 22 mg/L and at site 3 it was 10 and 23.8 mg/L (Fig. 2f).

The dissolved oxygen concentration ranges (mg/L) were: 2.8–7.08, 3.4–6.9 and 3.6–7.26 at stations 1, 2 and 3 respectively (Fig. 3a). Dissolved carbon dioxide (mg/L) fluctuated from 0.96 to 13.2. The values at station 1 were ranged between 0.96 and 12.1, whereas at station 2 it was 1.2 and 12.08 and at station 3 it was 1.6 and 13.2 (Fig. 3b). Nitrate content (mg/L) varied from 0.28 to 3.20. The values varied from 0.36 to 3.2, 0.32 to 3.12 and 0.28 to 3.18 at stations 1, 2 and 3, respectively (Fig. 3c). The ranges of sulphate values (mg/L) were: 1.12–7.24; 1.1–7.84 and 1.22–8.2 at stations 1, 2 and 3, respectively (Fig. 3d), and correspondingly the chloride values were: 3.6–22.3, 1.92–22.3 and 10.0–23.8 (Fig. 3e). Phosphate values (mg/L) ranged between 0.32 and 3.3, 0.25 and 3.25 and 0.19 and 3.1 at stations 1, 2 and 3, respectively (Fig. 3f). The statistical - analytical values are presented in Tables 1, 2 and 3.

The identified phytoplankton and zooplankton species and their month-wise occurrence are listed in Tables 4, 5, 6 for the stations 1, 2 and 3 respectively. Presently, totally 15 species of phyto- and 15 zooplankters were found (Tables 7, 8). The total plankton volumes recorded during the study period at all the stations are presented in Table 9. The total count of phytoplankton (cells/m) at station 1 varied from 11 (February 2019) to 22 (August 2019) whereas at station 2 it was 18 (November) and 34 (July 2019) and at the sampling site 3 it was 12 (February 2019) to 32 (August 2019). The density of zooplankton (Ind/L) at station 1 fluctuated from 10 (February 2019) to 15 (September 2019), whereas at station 2 it was 14 (February) to 42 (August 2019) and at station 3 it was 16 (January 2019) to 24 (July 2019) (Fig. 4).

Discussion

The intensity and interval of occurrence of rainfall cause significant changes in the physical and chemical properties of the freshwater environments. Also, temperature variations in freshwater systems can have a major impact on the other physicochemical characteristics. The presently observed temperature variations could be related to the changes in the heat intensity of the sun. The range of temperature is basically important for its influence on the various biochemical events in the aquatic organisms (Gupta et al., 2012). The values of hydrographical features were found be to fluctuate greatly, during the different months presently, which might have been due to the changing environmental/climatic conditions. (Devika et al., 2006) reported that the physical–chemical conditions exhibited positive co-relationship with the phytoplankton diversity of aquatic ecosystems. Such a type of variations of hydrography and phytoplankton was reported earlier by Manickam et al. (2018).

Anil et al. (2023) have reported the influence of various ranges of hydrographical parameters on the density and composition of plankton and the recorded high temperature during the summer season could have been den to the non-monsoonal clear sky (Gupta et al., 2012). The variations in the pH, O_2, alkalinity and trace metals are having a major impact on phytoplankton productivity (Bais & Agarwal, 1990). The lake water's alkalinity could be due to the presence of carbonates. Currently, very little pH variation has been recorded, and the changes in pH could be caused by algae photosynthesis (Das and Srivastava, 1956). Various human activities like detergent usage and release of untreated sewages are also contributing to the raised pH level. In this study, the recorded higher pH (in summer and pre-monsoon) accounts for good primary and secondary productivity. An earlier investigation revealed that dissolved oxygen possesses an indirect relation with temperature (Ashok et al., 2015). The rate of dissolving capacity of oxygen is inversely related with the intensity of temperature of aquatic ecosystems (Zhang et al., 2019). Further, the concentration of water–oxygen is also influenced by the rate of atmospheric pressure and photosynthetic rate (Singh et al., 2008).

The highest values of dissolved oxygen are generally coincided with the lowest temperature. Dissolved oxygen exhibited positive correlation with pH value, as reported earlier by Sukhija (2007). The recorded low summer DO was because of dissolving of organic matter and the respiratory process of zooplankton. Electric conductivity (EC) is a numerical value of the capacity of aqueous solution to convey electric current (Joseph, 2017). Presently, the EC was noticed in the range of 3.4–10.54 (Stn. 1), 3.4–9.8 (Stn. 2) and 3.25–9.8 (Stn. 3). And interestigly high values of phosphate (3.25 mg/L) and nitrate (3.2, mg/L) were found during the month of January to May 2019, as reported earlier by Joseph, (2017) in artificial pond. Higher levels of total dissolved solids can often indicate pollution by an extraneous source (Aboo and Manuell, 1967). Earlier, Daoudi et al. (2013) highlighted the significant relationship between the phytoplankton density and nutrient concentration especially during summer months. And the high concentration of nutrients like phosphorus and sulphate is responsible for the algal blooms formation as reported earlier by many researchers. The atmospheric events and anthropogenic activities are the causes for the observed/recorded variation in hydrography. The phytoplankton is initiating the aquatic food chain, and the higher trophic organisms like zooplankters as well as the fishes are depending on

Table 1 Correlation matrix among the physicochemical and biological characteristics of Perumal Lake at station 1

Parameters	Temp	Turbidity	TSS	Conductivity	pH	TH	DO	DCO_2	Chloride	Nitrate	Sulphate	Phosphate	PP	ZP
Temperature	1													
Turbidity	0.30	1												
Total suspended solids	0.41	0.93*	1											
Conductivity	0.09	0.70*	0.69*	1										
pH	0.32	0.93*	0.85*	0.59*	1									
Total hardness	0.11	0.70*	0.60*	0.86*	0.73*	1								
Dissolved oxygen	0.08	−0.71*	−0.66*	−0.66*	−0.72*	−0.72*	1							
Dissolved carbon dioxide	0.11	0.91*	0.74*	0.63*	0.84*	0.66*	−0.73*	1						
Chloride	0.09	0.80*	0.74*	0.91*	0.79*	0.93*	−0.83*	0.75*	1					
Nitrate	−0.49	−0.94*	−0.93*	−0.64*	−0.87*	−0.62*	0.58*	−0.84*	−0.72*	1				
Sulphate	−0.31	−0.89*	−0.81*	−0.72*	−0.89*	−0.80*	0.82*	−0.89*	−0.88*	0.87*	1			
Phosphate	−0.40	−0.91*	−0.81*	−0.80*	−0.88*	−0.81*	0.66*	−0.86*	−0.87*	0.90*	0.91*	1		
Phytoplankton	0.02	0.80*	0.71*	0.88*	0.77*	0.93*	−0.80*	0.77*	0.92*	−0.66*	−0.83*	−0.80*	1	
Zooplankton	−0.40	0.26	0.22	0.40	0.15	0.43	−0.44	0.31	0.47*	−0.18	−0.32	−0.19	0.47	1

TSS, total suspended solids; TH, total hardness; DO, dissolved oxygen; DCO_2, dissolved carbon dioxide; PP, phytoplankton; ZP, zooplankton

Significance *($P < 0.05$; **$P < 0.02$; ***$P < 0.01$; ***$P < 0.001$)

Table 2 Correlation matrix among the physicochemical and biological characteristics of Perumal Lake at station 2

Parameters	Temp	Turbidity	TSS	Conductivity	pH	TH	DO	DCO_2	Chloride	Nitrate	Sulphate	Phosphate	PP	ZP
Temperature	1													
Turbidity	0.30	1												
Total Suspended Solids	0.41	0.93*	1											
Conductivity	0.09	0.70*	0.69*	1										
pH	0.32	0.93*	0.85*	0.59*	1									
Total hardness	0.11	0.70*	0.60*	0.86*	0.73*	1								
Dissolved oxygen	0.08	−0.71*	−0.66*	−0.66*	−0.72*	−0.72*	1							
Dissolved carbon dioxide	0.11	0.91*	0.74*	0.63*	0.84*	0.66*	−0.73*	1						
Chloride	0.09	0.80*	0.74*	0.91*	0.79*	0.93*	−0.83*	0.75*	1					
Nitrate	−0.49	−0.94*	−0.93*	−0.64*	−0.87*	−0.62*	0.58*	−0.84*	−0.72*	1				
Sulphate	−0.31	−0.89*	−0.81*	−0.72*	−0.89*	−0.80*	0.82*	−0.89*	−0.88*	0.87*	1			
Phosphate	−0.40	−0.91*	−0.81*	−0.80*	−0.88*	−0.81*	0.66*	−0.86*	−0.87*	0.90*	0.91*	1		
Phytoplankton	0.02	0.80*	0.71*	0.88*	0.77*	0.93*	−0.80*	0.77*	0.92*	−0.66*	−0.83*	−0.80*	1	
Zooplankton	−0.40	0.26	0.22	0.40	0.15	0.43	−0.44	0.31	0.47*	−0.18	−0.32	−0.19	0.47	1

TSS, total suspended solids; TH, total hardness; DO, dissolved oxygen; DCO_2, dissolved carbon dioxide; PP, phytoplankton; ZP, zooplankton

Significance *($P < 0.05$; **$P < 0.02$; ***$P < 0.01$; ***$P < 0.001$)

Table 3 Correlation matrix among the physicochemical and biological characteristics of Perumal Lake at station 3

Parameters	Temp	Turbidity	TSS	Conductivity	pH	TH	DO	DCO_2	Chloride	Nitrate	Sulphate	Phosphate	PP	ZP
Temperature	1													
Turbidity	0.51*	1												
Total suspended solids	0.41	0.93*	1											
Conductivity	0.10	0.65*	0.74*	1										
pH	−0.24	0.49*	0.60*	0.63*	1									
Total hardness	0.19	0.74*	0.76*	0.88*	0.66*	1								
Dissolved oxygen	0.04	−0.71*	−0.79*	−0.83*	−0.82*	−0.84*	1							
Dissolved carbon dioxide	0.30	0.83*	0.80*	0.52*	0.65*	0.65*	−0.75*	1						
Chloride	0.01	0.69*	0.72*	0.93*	0.77*	0.91*	−0.88*	0.62*	1					
Nitrate	−0.44	−0.96*	−0.96*	−0.70*	−0.50*	−0.71*	0.70*	−0.78*	−0.69*	1				
Sulphate	−0.29	−0.91*	−0.87*	−0.79*	−0.62*	−0.87*	0.89*	−0.81*	−0.86*	0.87*	1			
Phosphate	−0.26	−0.88*	−0.82*	−0.83*	−0.50*	−0.82*	0.84*	−0.70*	−0.82*	0.84*	0.94*	1		
Phytoplankton	0.72*	0.87*	0.88*	0.53*	0.35	0.64*	−0.59*	0.74*	0.52*	−0.82*	−0.78*	−0.70*	1	
Zooplankton	−0.25	0.60*	0.60*	0.70*	0.84*	0.67*	−0.83*	0.65*	0.83*	−0.62*	−0.74*	−0.68*	0.29	1

TSS, total suspended solids; TH, total hardness; DO, dissolved oxygen; DCO_2, dissolved carbon dioxide; PP, phytoplankton; and ZP, zooplankton

Significance *($P < 0.05$; **$P < 0.02$; ***$P < 0.01$; ***$P < 0.001$)

Table 4 List of freshwaters phytoplankton recorded in the Perumal Lake during September 2018–August 2019

Group	Family	Genus	Species
Chlorophycea (Willein Warming, 1884)	Hydrodictyaceae (Dumortier, 1829)	*Pediastrum* (Meyen, 1829)	*Pediastrum tetras* (Ehrenberg Ralfs, 1845)
			Pediastrum simplex (Meyen,1829)
			Pediastrum duplex (Meyen,1829)
	Scenedesmaceae (Oltmanns, 1904)	*Scenedesmus* (Meyen,1829)	*Scenedesmus abundans* (O. Kirchner Chodat, 1913)
			Scenedesmus quadricauda (Breb. in Breb. & Godey, 1835)
	Chlorellaceae (Brunnthaler, 1913)	*Actinastrum* (Lagerheim, 1882)	*Actinastrum hantzschii* (Lagerheim, 1882)
	Characiaceae (Guiry, G.M. 2007)	*Characium* (A. Braun In Kuetzing, 1849)	*Characium limneticum* (Lemmermann, 1903)
	Micractiniaceae (Guiry, M.D. & Guiry, G.M. 2007)	*Micractinium* (Fresenius, 1858)	*Micractinium pusillum* (Fresenius, 1858)
	Radiococcaceae (Guiry, M.D. & Guiry, G.M. 2007)	*Gloeocystis* (Nageli,1849)	*Gloeocystis ampla* (Rabenhorst, 1863)
Charophyta (Migula, 1897)	Closteriaceae (Ralfs, J,1848)	*Closterium* (Nitzsch ex Ralfs,1848)	*Closterium* venus (Kutzing ex Ralfs, 1848)
	Desmidiaceae (A Holzinger, 1999)	*Cosmarium* (Ralfs, 1848)	*Cosmarium contractum* (O. Kirchner, 1878)
	Dictyochaceae (Christensen, 1962)	*Dictyocha* (Ehrenb,1837)	*Dictyocha fibula* (Ehrenberg, 1837)
	Pedinellaceae (Pascher, 1910)	*Apedinella* (Throndsen, 1971)	*Apedinella radians* (P.H. Campbell, 1973)
Chlorophyceae (Warming, 1884)	Volvocaceae (Ehrenberg in 1834)	*Eudorina* (Ehrenberg, 1832)	*Eudorina* unicocca (G.M. Smith, 1931)
Euglenophyceae (Schoen., 1925)	Euglenaceae (Carter, 1859)	Euglena (Ehrenberg, 1830)	Euglena acus (O.F. Muller Ehrenberg, 1830)

the rate of primary productivity. The presently recorded maximum density of phytoplankton in summer might be due to the maximum sunlight besides conducive temperature, as reported earlier by Murugavel and Pandian (2000), Hujare (2005). The role of light and temperature in determining the density of phytoplankton promotion has been reported earlier by Nazneen (1980). Additionally, the shallowness of the lake water and the high temperature induced water evaporation might have caused phytoplankton aggregation. Murulidhar and Murthy (2014) opined that the higher pH (8.0) is favourable for the growth of phytoplankton and such observations were earlier recorded by Ekhande et al. (2013) in Yashwant Lake Toranmal, Maharashtra, India. The pH of water could be changed with the changes in the climatological and vegetational factors as discussed earlier by Tokatli et al. (2020).

Presently, the temperature and nutrients are positively correlated with the total density of phytoplankton. Available literature indicates that temperature is an important determining factor for phytoplankton productivity (Unni & Pawar, 2000). However, the thermal tolerance of phytoplankton is species dependent as discussed earlier by Christensen et al. (2004). The monsoonal heavy rainfall caused water stratification along with turbidity and reduced temperature, was the reason for the recorded lesser phytoplankton productivity. During the investigation period, the Chlorophyceae species group was found to be the dominant quantitative component of phytoplankton. The recorded pre-monsoonal stable hydrographical features were largely responsible for the good production of chlorophycean algae, as reported by earlier researchers (Islam et al., 2001; Kumar and Sahu, 2012). And the algal production was found to be low in monsoon season due to the water dilution. The Chlorophyceae was the dominant group recorded now, which coincided with the predominantly recorded diatoms, as repeated earlier by Ambili (2013). In cooler environs, the green and cyanophycean algae replace the diatoms because of intense incoming nutrients along the catchment area (due to anthropogenic activity). In the present study, diatom dominated over green algae quantitatively, as reported earlier by Giriayappanavar and Patil (2010) who have found it at Belgaum and Wadral Lake, Wadral, Karnataka, India.

Zooplankton consumes phytoplankton and then transfers the energy to higher-level organisms like fishes. Hence, more investigations on the various aspects of zooplankton are most essential that would forecast the future fish productivity potential. Further, some of the

Table 5 List of freshwaters zooplankton recorded in the Perumal Lake during September 2018–August 2019

Group	Family	Genus	Species
Protozoa	Euplotidae (Ehrenberg,1830)	*Euplotes* (Ehrenberg, 1830)	*Euplotes woodruffi* (Gaw, 1939)
			Euplotes vannus (Muller, 1786)
Arthropoda	Balanidae (Leach, 1817)	*Balanus* (Da Costa, 1778)	*Balanion* sp (Da Costa, 1778)
			Barnacle naupili (Da Costa, 1778)
			Balanus crenatus (Bruguiere, 1789)
Copepod	Diaptomidae (Baird, 1850)	*Heliodiaptomus* (Kiefer, 1932)	*Heliodiaptomus viduus* (Gurney, 1916)
		Sinodiaptomus (Kiefer, 1937)	*Sinodiaptomus (Rhinediaptomus) indicus* (Sewell, 1934)
Ciliophora	Condylostomatidae (Reichenow, 1929)	*Condylostoma* (Bory de Saint Vincent, 1826)	*Condylostoma tardum* (Penard, 1922)
Rotifera	Filiniidae (Harring and Myers, 1926)	*Filinia* (Bory de St. Vincent, 1824)	*Filinia longiseta* (Ehrenberg, 1834)
			Filinia brachiate (Rousselet, 1901)
			Filinia terminalis (Plate, 1886)
	Brachionidae (Ehrenberg, 1838)	*Keratella* (Bory de St. Vincent, 1822)	*Keratella americana* (Carlin, 1943)
Echinodermata	Echinoderms (Bruguiere, 1791)	*Echinodermata* (Echinus Linnaeus, 1758)	*Echinoderm* larva (Bruguiere, 1791)
Ciliophora	Acinetidae (Stein, 1859)	*Acineta* (Ehrenberg, 1834)	*Acineta papillifera* (Keppen, 1888)
Ostracoda	Cyprididae (Baird, 1845)	*Cypris* (Muller, 1776)	*Cypris protubera* (Muller, 1776)

Table 6 The occurrence of phytoplankton and zooplankton during the study period at station 1

S. no.	Name of the species	Month (2018–2019)											
		Monsoon			Post-monsoon			Summer			Pre-monsoon		
		Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.
Phytoplankton													
01	*Characium limneticum*	C	–	–	A	A	A	A	A	R	R	R	–
02	*Cosmarium contractum*	C	A	–	–	C	C	C	C	C	C	C	C
03	*Closterium venus*	C	A	C	C	C	C	C	A	A	C	R	R
04	*Euglena acus*	C	C	C	C	A	A	A	A	C	–	–	–
05	*Pediastrum tetras*	R	R	C	C	C	C	A	A	–	–	–	R
06	*Scenedesmus abundans*	A	–	C	C	C	A	A	A	R	R	R	R
07	*Apedinella radians*	A	C	C	C	A	A	A	A	R	R	–	–
Zooplankton													
08	*Acineta papillifera*	A	C	C	C	C	C	C	C	C	C	C	C
09	*Calanoid copepodite*	A	C	C	C	C	C	C	C	C	C	C	C
10	*Euplotes woodruffi*	C	C	R	R	–	–	R	–	R	–	A	C
11	*Filinia terminalis*	C	C	R	R	R	–	–	–	R	–	A	A
12	*Keratella americana*	C	C	R	R	R	–	–	–	–	R	C	A

A, Abundance; C, Common; R, Rare; and –, Absent

zooplankters are considered to be good indicator species (to assess the health of the aquatic ecosystems). The abundance of zooplanktonic population of an area largely depends upon the density of phytoplankton coupled with conducive hydrographical factors, and thus, the zooplankton coordinates a food chain between the fishes and phytoplankton. Presently, the high abundance of zooplankton was recorded at Perumal Lake during the winter season when the species diversity of zooplankton was high. A similar population structure was earlier recorded by Krishnamoorthi and Selvakumar (2012) in Veeranam Lake and Sharma and Rama Kumari (2018) in Sacred Lake Prashar, Himachal Pradesh, India. Presently recorded zooplankton included the groups like copepods, cladocerans, ostracods and similar plankton distributional pattern was earlier reported by many researchers (Gorsky et al., 2010; Halder et al., 2008). And the recorded temporal variation in the plankton density

Table 7 The occurrence of phytoplankton and zooplankton during the study period at station 2

S. no.	Name of the species	Month (2018–2019)											
		Monsoon			Monsoon			Monsoon			Monsoon		
		Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.
Phytoplankton													
01	*Actinastrum Hantzschii*	R	A	–	A	A	A	A	–	–	–	R	C
02	*Characium limneticum*	C	–	–	A	A	A	A	A	R	R	R	–
03	*Cosmarium contractum*	C	A	–	–	C	C	C	C	C	C	C	C
04	*Closterium venus*	C	A	C	C	C	C	C	A	A	C	R	R
05	*Eudorina unicocca*	C	A	C	A	R	R	R	C	C	C	C	C
06	*Gloeocystis ampla*	C	A	A	A	A	A	A	A	A	A	A	A
07	*Micractinium pusillum*	C	C	R	R	A	A	A	A	A	A	A	A
08	*Phacus orbicularis*	C	C	C	C	A	A	A	A	C	–	–	–
09	*Pediastrum duplex*	C	C	C	C	A	A	R	–	–	–	–	R
10	*Pediastrum simplex*	C	C	A	A	R	–	–	–	–	R	R	R
11	*Pediastrum tetras*	R	R	C	C	C	C	A	A	–	–	–	R
12	*Scenedesmus abundans*	A	–	C	C	C	A	A	A	R	R	R	R
13	*Scenedesmus quadricauda*	A	–	C	C	C	C	C	R	R	R	–	R
14	*Apedinella radians*	A	C	C	C	A	A	A	A	R	R	–	–
15	*Dictyocha fibula*	A	A	A	A	A	A	A	A	A	A	A	A
Zooplankton													
16	*Acineta papillifera*	A	C	C	C	C	C	C	C	C	C	C	C
17	*Euplotes vannus*	A	A	C	A	A	A	C	R	–	–	–	R
18	*Balanion* sp.	R	C	A	A	A	A	A	–	–	–	–	R
19	*Balanus crenatus*	A	C	A	A	A	C	R	–	–	–	–	–
20	*Barnacle*	A	C	C	C	C	C	C	C	C	C	C	C
21	*Sinodiaptomus*	A	C	C	C	C	C	C	C	C	C	C	C
22	*Heliodiaptomus viduus*	C	A	R	R	–	–	R	–	–	R	C	C
23	*Condylostoma tardum*	C	R	R	R	R	–	–	–	–	R	A	A
24	*Echinoderm larva*	C	A	R	R	–	–	R	R	R	R	A	C
25	*Euplotes woodruffi*	C	C	R	R	–	–	R	–	R	–	A	C
26	*Cypris protubera*	C	C	R	R	R	–	–	–	R	–	A	A
27	*Filinia brachiata*	C	C	R	R	R	–	–	–	R	–	A	A
28	*Filinia longiseta*	C	R	R	R	R	–	–	–	–	R	A	A
29	*Filinia terminalis*	C	C	R	R	R	–	–	–	–	R	A	C
30	*Keratella americana*	C	C	R	R	R	–	–	–	–	R	C	A

A, Abundance; C, Common; R, Rare; –, Absent

could be related to the seasonal oscillation of the hydrographical parameters. And the observed predominance of Copepods (in relation to rotifers) could be considered to be an acceptable water quality (Ravichandran, 2003; Sladeck, 1983). The results of the present study indicate that the Perumal Lake located in warm rural area is quite productive one with sufficient nutrient input (through monsoonal-rains), which can be utilized for planning aquaculture practices also.

Conclusions

Freshwater ecosystems are providing essential resources to humans, and they are the only home to a diverse range of endemic and sensitive biota. Aquatic organisms, particularly, the plankton, are the most sensitive component of such ecosystem, as they are sensitive to the environmental disturbances. Moreover, the primary production/phytoplankton serves as food for herbivorous animals and also serve as a biological indicator of environmental quality. In view of importance of zooplankton, more studies are essential for clear understanding of the process of ecosystems. Studies on the assessment of plankton

Table 8 The occurrence of phytoplankton and zooplankton during the study period at station 3

S. no.	Name of the species	Month (2018–2019)											
		Monsoon			Post-monsoon			Summer			Pre-monsoon		
		Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.
Phytoplankton													
01	*Actinastrum Hantzschii*	R	A	–	A	A	A	A	–	–	–	R	C
02	*Characium limneticum*	C	–	–	A	A	A	A	A	R	R	R	–
03	*Closterium* sp.	C	A	C	C	C	C	C	A	A	C	R	R
04	*Eudorina* sp.	C	A	C	A	R	R	R	C	C	C	C	C
05	*Gloeocystis ampla*	C	A	A	A	A	A	A	A	A	A	A	A
06	*Euglena acus*	C	C	C	C	A	A	A	A	C	–	–	–
07	*Pediastrum simplex*	C	C	A	A	R	–	–	–	–	R	R	R
08	*Pediastrum tetras*	R	R	C	C	C	C	A	A	–	–	–	R
09	*Scenedesmus quadricauda*	A	–	C	C	C	C	C	R	R	R	–	R
10	*Dictyocha fibula*	A	A	A	A	A	A	A	A	A	A	A	A
Zooplankton													
11	*Acineta papillifera*	A	C	C	C	C	C	C	C	C	C	C	C
12	*Euplotes vannus*	A	A	C	A	A	A	C	R	–	–	–	R
13	*Balanion* sp.	R	C	A	A	A	A	A	–	–	–	–	R
14	*Balanus crenatus*	A	C	A	A	A	C	R	–	–	–	–	–
15	*Heliodiaptomus viduus*	C	A	R	R	–	–	R	–	–	R	C	C
16	*Echinoderm* larva	C	A	R	R	–	–	R	R	R	R	A	C
17	*Filinia brachiata*	C	C	R	R	R	–	–	–	R	–	A	A
18	*Filinia longiseta*	C	R	R	R	R	–	–	–	–	R	A	A
19	*Filinia terminalis*	C	C	R	R	R	–	–	–	–	R	A	C
20	*Keratella americana*	C	C	R	R	R	–	–	–	–	R	C	A

A, Abundance; C, Common; R, Rare; –, Absent

Table 9 Phytoplankton volumes (cells/ml) and zooplankton volumes (Ind./l) recorded during the period of study

Month (2018–2019)	Phytoplankton (cells/mL)			Zooplankton (Ind./L)		
	S 1	S 2	S 3	S 1	S 2	S 3
September 2018	18	22	30	15	30	18
October 2018	20	24	22	13	32	20
November 2018	16	18	20	12	30	18
December 2018	16	20	18	13	24	20
January 2019	13	19	16	12	18	16
February 2019	11	20	12	10	14	16
March 2019	14	26	24	14	22	18
April 2019	18	28	26	12	14	16
May 2019	16	32	30	10	18	20
June 2019	18	30	28	13	28	20
July 2019	20	34	30	12	32	24
August 2019	22	32	32	14	42	20
Mean value	16.83	25.42	24	12.5	25.33	18.83
Minimum	11	18	12	10	14	16
Maximum	22	34	32	15	42	24
SD	3.16	5.97	6.44	1.51	8.50	2.33

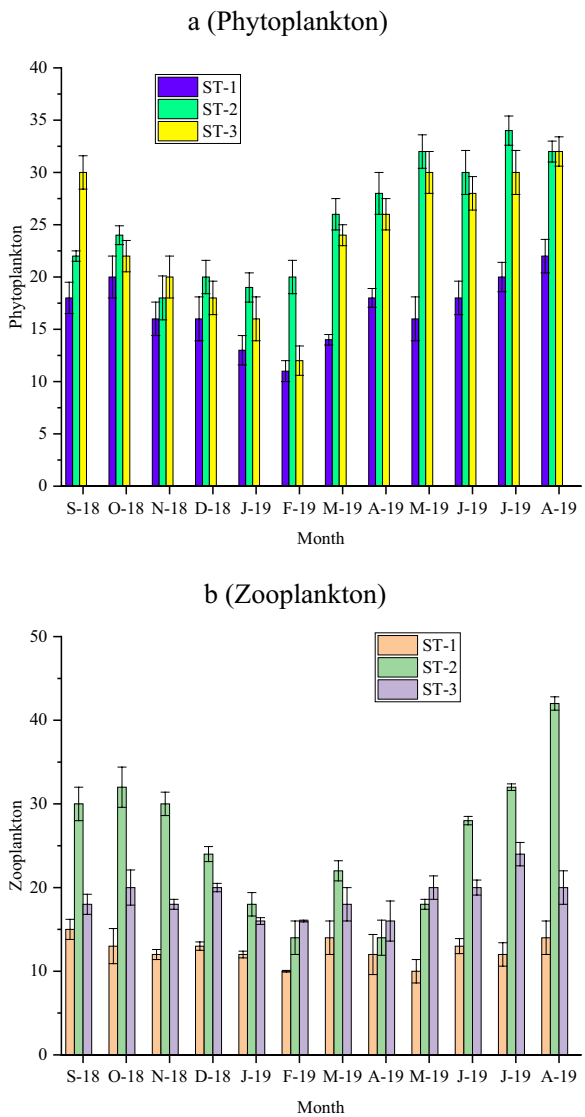

Fig. 4 Seasonal variations of plankton abundance in Perumal Lake during September 2018 to August 2019

diversity regularly in the freshwater system are critical for determining the status of water quality that supports the productivity of fishes.

Abbreviations

EC	Electrical conductivity
N	North
TH	Total hardness
DO	Dissolved oxygen
DCO_2	Dissolved carbon dioxide
PP	Phytoplankton
ZP	Zooplankton
TSS	Total suspended solids
NTU	Nephelometric turbidity unit

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Author contributions
AA contributed to methodology, investigation, conceptualization and writing—review and editing—original, draft, RK was involved in writing—review and editing, data curation and formal analysis, and GC contributed to formal analysis, resources and data curation. NM, PR and PS were involved in writing—review and editing and data curation, and PP contributed to writing—review and editing, and data curation. All authors have read and approved the manuscript.

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Availability of data and materials
The datasets generated and analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
We declare that we do not need an ethics approval regarding our work on the freshwater Plankton.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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