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Interaction between microalgal species richness and environmental variables in Peringalkuthu Reservoir, Western Ghats, Kerala

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Abstract

Microalgae are the most diverse group of aquatic organisms and are the primary food source for animals of higher trophic levels in the aquatic food web. Biomonitoring the fresh water habitats in terms of phycological evaluation provide useful information about the pollution status of the water body. The present investigation aimed to delineate the interaction between microalgal species richness and environmental variables in Peringalkuthu Reservoir of Western Ghats, Kerala. Samples were collected during 2009-2011 for the analysis of environmental variables and microalgal community. Ninety four species of microalgae belonged to 42 genera under the classes Chlorophyceae, Desmidiaceae, Bacillariophyceae, Cyanophyceae and Euglenophycea were recorded from the samples. The dominant groups were desmids followed by diatoms. Factor analysis and multivariate analysis were applied to evaluate the extent of interaction between the microalgal species richness and the environmental variables. Temperature, total alkalinity, BOD, phosphate, silicate and chloride showed positive relationship with the species richness of the microalgae. While pH, total hardness, nitrate, fluoride, calcium and magnesium hinder the microalgal species richness. Elucidation of the interactions between microalgae and various environmental parameters suggested a control over the anthropogenic interventions to the reservoir to check the conversion of the lake oligotrophic to eutrophic condition.

Key words

Enviromental variables, Microalgae, Reservoir

Introduction

Microalgae are major producers in any aquatic ecosystem. Its community structure is important to higher trophic levels because it influences the efficiency of carbon and energy transfer between trophic level in any given system (Stevensen, 1996). Studies on microalgal community and its interaction to the physico-chemical factors are basic to the understanding of trophic dynamics of the aquatic ecosystem (Hulyal and Kaliwal, 2009). Microalgae play an important role in maintaining the equilibrium between living organism and abiotic factors. The microalgal community on which whole aquatic population depends is largely influenced by the interaction of a number of physico-chemical factors.

Several studies were conducted on microalgal diversity in India and abroad in water bodies like ponds, lakes and reservoirs. Tiwari and Chowhan (2006), Sridhar *et al.* (2006) and Senthilkumar and Sivakumar (2008) have made valuable contribution on the microalgae of lentic and lotic aquatic ecosystems. Lasker and Gupta (2009) revealed the diversity and dynamics of phytoplankton of Chatia floodplain lake, Barak Valley, Assam. Wang *et al.* (2007) studied the relationship of phytoplankton biomass and environmental variables of Taihu lake China. Hulyal and Kaliwal (2009) reported the dynamics of phytoplankton in relation to physico-chemical factors of Almatti reservoir of Bijapur. However, studies on microalgal population of lakes and reservoirs of Western Ghats are scanty except for stray references. Pramila *et al*. (1990) analysed the epiphytic and epiphyllous green algae from the water bodies of Nilgris. Madhusoodanan and Dominic (1996) studied the epiphytic Cyanobacteria on mosses from Western Ghats. Nasser and Sureshkumar (2012) analyzed the diversity of fresh water periphytons from high altitude areas of Western Ghats and reported 141 taxa of microalgae. For establishing the relationship between the environmental variable and community structure of microalgae, a backward multivariate regression analysis can be used taking species richness as dependent variable and the factors obtained by factor analysis as independent variables (Wang *et al.,* 2007). These techniques are made use of in the present study to discuss the interaction of environmental variables with microalgal diversity in the Peringalkuthu reservoir of Western Ghats region as there has been no earlier attempt in this line. This study will provide ample database for the understanding of the trophic status of the reservoir, as the microalgae are bio indicators of pollution.

Materials and Methods

The Peringalkuthu Reservoir is one of the hydro-electric reservoirs of Western Ghats located at $76^0$40'85"E and $10^0$20'11" longitude in Thrissur district of Kerala. This reservoir is constructed in the Chalakudy river basin. Water samples, in quadruplicate, were collected during post-monsoon, pre-monsoon and monsoon seasons for a period of two years from 2009 - 2011. A total of 24 samples were collected from the Peringalkuthu reservoir covering six seasons during 2009-2011 periods. Temperature and pH were measured in the field. Electrical conductivity, total alkalinity, total dissolved substances (TDS), total hardness, biological oxygen demand (BOD), dissolved oxygen (DO), nitrate, sulphate, phosphate, silicate chloride, fluoride, calcium, magnesium and iron were determined in the laboratory following the standard methods of APHA (2005). For periphytic microalgae, a stone from 10-15 cm water depth was collected and microalgae from 25cm^2 of the surface were scrapped out using a toothbrush and dispersed to 10ml distilled water and preserved in 5% formalin. Microalgae were identified using standard keys (Desikachary, 1989; Agarkar, 1979; Prescott, 1982; Sarode and Kamat, 1984; Anand, 1998, Kargupta 2004) and enumerated with the help of Haemocytometer and research microscope. Species richness was calculated as per the methods of Clark and Warwick (2001) using PRIMER 6.0 software. ANOVA, Regression analysis and factor analysis were carried out using SPSS 20.0 software. Species richness and environmental variables were tabulated for each sample. Preliminary analysis using ANOVA showed that mean species richness showed no significant (P>0.05) difference between the samples collected during the study and hence, the data collected during the present study is pooled and used for the analysis. Similarly data on physico-chemical parameters was also pooled for further analysis. Two parametric multivariate analysis (factor and regression analysis) were employed to examine the possible influence of environmental variables on the species richness of microalgae. Factor analysis was particularly useful for considering several related random environmental variables simultaneously to identify a new smaller set of uncorrelated variables that accounted for a large proportion of total variants in original variables (Lau and Lane, 2002; Wang *et al.,* 2007). Principal Component Analysis was adopted for deriving the factors following Varimax rotation with Kaiser Normalization. Procedure was fixed so that the rotation converged in 8 iterations (SPSS 20.0 software). In factor analysis, we are extracting factors that account for less variance. The variances extracted by the factors are called the *Eigen value*. Therefore, higher Eigen value means, higher percentage of variance exhibited by the factor (Wang *et al.,* 2007). Hence we are considered the first four factors with higher Eigen value for further analysis, which will cumulatively contribute much to the total variance.

Results and Discussion

94 species of microalgae belong to 42 genera under five classes (Table 1) were recorded from the samples. The algal community was represented by members of Chlorophyceae (24%), Desmidiaceae (32%), Bacillariophyceae (29%), Cyanophyceae (10%) and Euglinophyceae (5%).

Factor analysis of the environmental variables showed that the Eigen values for the first four factors are presented in Table 2. These four factors explained 93.4% variance of the environmental parameters. The loading of each environmental variable to the factors are summarized in Table 3. F_1, which captured 35.80% of total variance and was related to the electrical conductivity, TDS, DO, sulphate and iron, F_2 accounted for 28.16% of total variance related to total hardness, silicate, magnesium and calcium. F3 captured 17.44% of total variance and was related to temperature, pH, BOD, phosphate and chloride. F_4 accounted for 12.89 % of the variance and was related to total alkalinity, nitrate and fluoride. The relationship of these factors with the microalgal species richness was computed using stepwise regression analysis and worked out as

$$S = 46.58 - 11.20 \times F_2 + 16.05 \times F_3 - 12.11 \times F_4 \quad (R^2 = 0.815)$$

This model suggests that F_3 had significant and positive relationship with microalgal species richness while F_2 and F_4 had significant and negative relationship. F_2

Table 1 : Total number of genera of microalgae identified from the Peringalkoothu reservoir

Sl.No	Class	Genus	Sl.No	Class	Genus
1	**Chlorophyceae**	*Cheatophora* (1)*	22	**Bacillariophyceae**	*Melosira* (3)
2		*Tetraedron* (1)	23		*Achnanthes* (1)
3		*Coelastrum* (2)	24		*Cocconies* (1)
4		*Pediastrum* (3)	25		*Eunotia* (2)
5		*Chlorella* (1)	26		*Fragilaria* (2)
6		*Scenidesmus* (5)	27		*Synedra* (2)
7		*Ankistrodesmus* (3)	28		*Diploneis* (1)
8		*Geminella* (1)	29		*Frustulia* (1)
9		*Mougetia* (2)	30		*Gyrosigma* (2)
10		*Spirogyra* (1)	31		*Navicula* (5)
11	**Desmidiaceae**	*Arthrodesmus* (1)	32		*Pinnularia* (4)
12		*Closterium* (6)	33		*Hantzschia* (1)
13		*Cosmarium* (8)	34		*Nitzschia* (3)
14		*Desmidium* (1)	35		*Surirella* (2)
15		*Euastrum* (3)	36	**Cyanophyceae**	*Aphanocapsa* (2)
16		*Gonatozygon* (1)	37		*Gleocapsa* (1)
17		*Microsterias* (3)	38		*Mycrocystis* (1)
18		*Netrium* (1)	39		*Spirulina* (2)
19		*Penium* (1)	40		*Oscillatoria* (3)
20		*Pleurotaenium* (2)	41	**Euglenophyceae**	*Euglena* (2)
21		*Staurastrum* (4)	42		*Phacus* (2)

*Number of species

Table 2 : Total variance explained by the first four factors derived from the environmental variables

Factor	Total eigen value	% of variance	Cumulative %
1	6.088	35.813	35.813
2	4.787	28.160	63.973
3	2.965	17.441	81.414
4	2.192	12.893	94.306

showed positive relation between total hardness, calcium and magnesium and negative relationship with silicate. Temperature, BOD, phosphate, and chloride showed a positive relationship and pH showed negative relationship with F3. While F4 positively related to fluorides and nitrate and negative to total alkalinity. Therefore it is concluded that temperature, total alkalinity, BOD, silicate, chloride, and phosphate support algal species richness. However, pH, total hardness, nitrate, fluoride, calcium and magnesium hinder the algal species richness in Peringalkuthu reservoir. The predictability of the developed model was found to be very high as evidenced by the high R^2 values obtained from the p-p plot.

The quality and quantity of microalgae and their seasonal successional patterns have been successfully utilized to assess the quality of water and its capacity to sustain heterotrophic communities (Hulyal and Kaliwal, 2009). Dwivedi and Pandey (2003) studied the importance of algal dynamics and their response to nutrient fluctuations and noted that occurrence and growth of various species of algae in the water bodies are controlled by a single factor or a group of factors and these factors vary from one water body to another. The algal species richness of Peringalkuthu reservoir is found to be controlled by a number of environmental factors.

Factor analysis results of present investigation indicate that there is a positive correlation for temperature, total alkalinity, BOD, silicate, chloride, and phosphate (Table 3) with microalgal species richness. Wang *et al.* (2007) reported the factor analysis result in Taihu lake, China and found positive correlation of nitrate, phosphate, chloride, DO and temperature for the phytoplankton biomass. Babu *et al.* (2010) reported high factor loadings for conductivity, fluoride, calcium, magnesium, sulphate and pH in the water quality studies of Ashtamudi lake, Kerala. Moser *et al.* (2010) conducted similar studies and reported the positive correlation of alkalinity, DO and silicate for the diatom biomass in mountain lakes of U.S.A.

Desmidiaceae are the major groups of microalgae in all the sampling stations encountered throughout the period of study. According to Gerrath (1993) desmids are generally more common and diverse in oligotrophic lakes and ponds. However, they are highly sensitive to changes in the environmental parameters that could be considered as bio indicators for monitoring water quality (Coesel, 2008). Desmids are considered to be very sensitive group of microalgae as they are unable to withstand even slight changes in the quality of aquatic habitats (Hulyal and Kaliwal

Table 3 : Mean and Factor loading matrix for physico-chemical variables in samples collected from Peringalkuthu reservoir

Water quality parameters	**Mean±SD***	**Factor****			
		1	**2**	**3**	**4**
Temperature (°C)	25.83±2.33	-0.56	0.285	0.659	0.087
EC (µ mhos cm^{-1})	57.83±42.76	0.783	0.527	-0.226	0.197
pH	7.16±0.28	0.034	0.027	-0.932	0.162
Total alkalinity (mg l^{-1})	18.33±5.95	-0.137	0.264	0.162	-0.915
TDS (mg l^{-1})	40.33±29.99	0.785	0.525	-0.225	0.193
Total hardness (mg l^{-1})	16.33±4.16	0.057	0.963	0.206	-0.161
DO (mg l^{-1})	6.73±0.25	-0.67	-0.156	-0.263	0.652
BOD (mg l^{-1})	1.75±0.22	-0.347	-0.233	0.843	-0.268
Nitrate (mg l^{-1})	1.6±2.01	0.47	0.343	-0.553	0.591
Sulphate (mg l^{-1})	2.46±2.01	0.962	0.008	-0.255	-0.087
Phosphate (mg l^{-1})	0.03±0.01	0.132	0.153	0.527	0.499
Silicate (mg l^{-1})	3.28±1.18	-0.027	-0.996	-0.031	0.035
Chloride (mg l^{-1})	18.33±4.15	-0.51	0.308	0.727	0.202
Fluoride (mg l^{-1})	0.4±0.24	-0.111	-0.171	0.058	0.971
Calcium (mg l^{-1})	3.47±1.02	0.1	0.792	0.6	-0.025
Magnesium (mg l^{-1})	1.86±0.52	-0.008	0.908	-0.312	-0.278
Iron (mg l^{-1})	0.54±0.25	0.983	-0.167	-0.034	0.059

*Values are mean of 24 samples ± SD

2009). Ngearupat and Peeraporupisal (2007) studied the application of desmid diversity in assessing water quality of 12 fresh water reservoirs of Thailand and reported that eutrophic conditions do not support the growth of desmids. Wetzel (2001) reported that growth of desmids favours low nitrate concentration. These observations hold true for the present study also.

Bacillariophyceae members have also been considered as indicators of water quality. Ponader *et al*. (2007) explained the potential of using diatoms to assess and monitor nutrient enrichment in New Jersey rivers and opined that the diatoms usually favour neutral to alkaline pH. These findings hold true for the present investigation in Peringalkoothu reservoir where water is recorded to be alkaline and consequent occurrence of higher percentage of diatoms after desmids. Mohammed and Nabila (2006) reported the dominance of Bacillariophyceae in the Mediterranean Sea and attributed higher correlation of diatoms to high silicate concentrations. Silicate is positively correlated with microalgal species richness in Peringalkuthu reservoir.

The Chlorophyceae members have revealed its adaptability to different conditions. Tiwari and Chauhan (2006) observed the blooming of Chlorophyceae members in eutrophic lake of Kitham, Agra and Hulyal and Kaliwal (2009) reported its dominance in a water body with low pH. Shinde *et al*. (2012) observed the dominance of Chlorophyceae from Harsool-savegirin Dam, Aurangabad and concluded that the water body is slightly eutrophic. In the present investigation, Chlorophyceae represented only 24% of the total microalgal population and also showed negative correlation of magnesium, calcium and pH. This clearly indicates that the Peringalkuthu was almost free from pollution. The trophic status of Taihu, a fresh water lake in China has explained and the pattern of the phytoplankton variation and its relationship with environmental variables was brought out through multivariate analysis and nitrogen could identified as the limiting factor in phytoplankton biomass (Wang *et al.,* 2007). The present investigation also illustrates the correlation of temperature, total alkalinity, BOD, phosphate, silicate and chloride support algal species richness.

According to Kumar (2002), a positive correlation of nitrates and pH, favours the growth of Cyanophyceae. Hulyal and Kaliwal (2009) recorded maximum value for nitrate and pH and consequent increase of Cyanophyceae from Almatti reservoir. Nitrate is an important environmental variable for the proliferation of Cyanophyceae and Euglenophyceae (Shanthala *et al.,* 2009). In the present investigation, pH and nitrate was negatively correlated to the microalgal species richness in Peringalkuthu reservoir and this may be one of the reasons for the low percentage of the Cyanophyceae.

From the above observations, it is concluded that the condition of water in Peringalkuthu reservoir was oligotrophic and favoured the growth of microalgae. However, the occurrence of pollution indicator groups such as Euglenophyceae and Cyanophyceae pointed towards the possibility of eutrophication.

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