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# ENVIRONMENTAL CORRELATES OF MICROALGAL DIVERSITY IN THE HIGH RANGES OF THE BIODIVERSITY HOTSPOT, WESTERN GHATS, INDIA

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**Abstract:** This study explains the environmental correlates of microalgal diversity in high range regions of one of the most important biodiversity hotspots, Western Ghats. Samples were collected from Nelliampathy (76°67.25′E 10°47.94′N), Valpara (76°93.97′E 10°32.18′N) and Malakkappara (76°32.18′E 10°25.62′N) of the Anamalai region of the southern Western Ghats. Environmental variables and microalgal community structure were estimated for three different seasons viz., post-monsoon, pre-monsoon and monsoon for two years (2009-2011). Diatoms were the dominant group in all the seasons followed by desmids. Cyanophytes represented only during pre-monsoon and monsoon while euglenophytes represented during post-monsoon period only. Factor analysis and multivariate analysis were applied to evaluate the interaction between microalgal diversity and environmental variables. Sulphate and silicate were the environmental variables determining algal diversity in all the seasons in high range regions of the Western Ghats. The relationship between the environmental variables and microalgal diversity indices such as total number of microalgae, species richness, Shannon diversity index and taxonomic distinctness were established for different seasons and discussed.

Keywords: Western Ghats, Microalgae, Diversity, Environmental Variables

# INTRODUCTION

The Western Ghats represents one of the four biodiversity hot spots from the Indian region, extended over 1,400 km along the states of Maharashtra, Goa, Karnataka, Tamil Nadu and Kerala. According to Devagiri (2004), 23% of biodiversity in India occurs in the Western Ghats. This account does not include the microalgal diversity of the aquatic systems of the region. Negligible are the literature available on the diversity of microalgae of fresh water bodies in this region. Microalgae constitute the primary producers in aquatic ecosystem and form essentials of the food web in terms of energy and material input. Hence any environmental variations that affect the integrity of the algal community structure may impact higher trophic levels as well. Microalgae play an important role in maintaining the equilibrium between living organisms and abiotic factors (Hulyal and Kaliwal, 2009). The microalgal community on which whole aquatic population depends is largely influenced by the interaction of a number of physico-chemical factors (Davis,1995). Because of the rapid response of microalgae to the environmental changes, they are also useful as an indicator of stream water quality. Bio-monitoring of these freshwater habitats in terms of phycological evaluation provides useful information about the pollution status of the water body. Microalgae, the primary producers of stream ecosystem in a very important biodiversity hotspot needs special attention because it forms the initial feed for a large number of endemic aquatic organisms and also fix the water quality perturbations in this fragile ecosystem (Nayar, 1996).

Extensive works have been carried out in different habitats of the Kerala focused on understanding the ecology of microalgae. Importance of microalgae is highlighted both as fish diet and indicator of pollution (Nair et al., 1983). Microalgae were also employed to assess the trophic status of water body (Naik and Neelakandan, 1990). However studies on microalgal population in the high ranges of Western Ghats are scanty except for stray references such as Goyal (1982) in Silent Valley, Sankaran (1984) in Aliyar Dam and Chandra (2004) in Yercaud Hills. Pramila et al (1990) analysed the epiphytic and epiphyllous green algae from Nilgris. Madhusoodanan and Dominic (1996) studied the epiphytic Cyanobacteria on mosses from Western Ghats. Jithesh (2010) analyzed the effect of environmental parameters on phytoplankton of Mullaperiyar Dam. Nasser and Sureshkumar (2012) analyzed the diversity of fresh water periphytons from high altitude areas of Western Ghats and reported 141 taxa of microalgae.

Therefore an attempt has been made to study the microalgal correlation with the environmental variables of Chalakkudy river basin which is exclusively within the Anamalai landscape unit of southern Western Ghats, a very significant biodiversity hotspot showing high degree of endemism. This paper describes quantitative variation of species abundance, species richness, diversity and taxonomic distinctness of microalgae in respect to physico-chemical parameters of the high range region of the Western Ghats.

# MATERIALS AND METHODS

## Study area and sampling sites

Threedifferenthighrangeareasinthe Anamalaipart of Western Ghats (76°59'85"E and 10°20'11"N;

Fig. 1) namely Nelliampathy (76067.25'E 10<sup>0</sup> 47.94'N; 1260 m), Valpara (76<sup>0</sup>93.97'E 10<sup>0</sup> 32.18'N; 1220 m) and Malakkappara (76<sup>0</sup>32.18'E 10<sup>0</sup>25.62'N; 920m) were selected for the present investigation. These areas are parts of Anamalai landscape and designated as one of the three hot spots of entire Western Ghats region (Sing, 1977). At every station a transect of 15m was laid and systematic random sampling (Trivedi and Goyal, 1986) was adopted for the collection of water and algal samples by generating first sampling unit by random numbers.



Fig. 1. Map of Anamalai part of Western Ghats showing the study sites

### Sample analysis

Water samples in quadruplicate were collected during three seasons viz. post-monsoon, premonsoon and monsoon for a period of two years (2009-2011). Temperature, pH, rate of flow, turbidity, dissolved oxygen (DO) and altitude were measured in the station itself. Electrical conductivity, acidity, total alkalinity, total dissolved substances (TDS), total hardness, biological oxygen demand (BOD), nitrate, phosphate, sulphate, silicate, chloride, fluoride, calcium, magnesium and iron were determined in the laboratory following APHA (2001). Periphytic microalgae were sampled by scraping 15cm<sup>2</sup> of the surface of pebble/rock collected from 15cm depth in flowing stream and dipped in 100 ml distilled water, 4% formalin used for preservation and later reduced to 10ml concentrate which is used for enumeration (Trivedi and Goyal, 1986). The samples Microalgae were identified using standard keys (Venkataraman, 1961; Desikachary, 1989; Agarkar *et al.*, 1979; Prescott, 1982; Sarode and Kamat, 1984; Anand, 1998; Wolowski, 1998; Kargupta, 2004) and enumerated with the help of haemocytometer and research microscope. All the preserved samples are kept in the museum of Postgraduate Department and Research Centre of Aquaculture and Fishery Microbiology, MES Ponnani College, Kerala for further verification.

## Data preparation and analysis

Microalgal diversity and environmental variables were tabulated for each sample. Preliminary data analysis showed that, means of microalgal diversity and environmental variables did not vary significantly (P<0.05) between stations in a given season. However, the parameters showed a significant (P<0.05) variation between seasons studied. Therefore, the data collected during the present study are pooled with respect to stations and used for the analysis. Diversity indices viz. Total number of individuals (N), Margalef's species richness (d), Shannon diversity index (H') and Taxonomic distinctness on abundance  $(\Delta^*)$  were worked out for each sample using the software Primer 6.0 (Clark and Warvick, 2001). Two parametric multivariate analysis (factor and regression analysis) were employed to examine the possible influence of environmental variables on the diversity 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). To establish the relationship between the environmental variables and microalgal diversity, a backward multivariate regression analysis was employed using diversity indices as dependent variable and the factors obtained by factor analysis as independent variables using SPSS v17.0.

## RESULTS

A total of 72 samples were collected from the three study sites covering three seasons during the study period. 112 species of microalgae were recorded from the samples. The mean values of various diversity indices worked out from the collected samples are presented in the Table 1. The mean and standard deviation (SD) of the environmental variables recorded during the present study is shown in Table 2.

Factor analysis of the data showed that Eigen values for the first four factors were high, which accounted for 96.15, 92.25 and 92.91% variance respectively for post-monsoon, pre-monsoon and monsoon seasons (Table 3).

The factors loading of different environmental variables to the first four selected factors are given in the Table 4. The relationships of microalgal diversity indices to these factors during different seasons were computed using stepwise regression analysis. Subsequently regression equations to correlate each microalgal diversity indices and related environmental variables were developed for each season.

Diversity indices	Post-mon- soon	Pre-mon- soon	Monsoon		
Total number of Microal- gae (no./ mm <sup>2</sup> )	626.58± 84.51	274.37± 8.07	75.20± 20.60		
Species Richness	8.18±0.72	4.84± 0.67	3.08± 0.50		
Shannon index	5.61±0.14	4.62± 0.27	3.71± 0.18		
Taxonomic distinct- ness.	65.82± 1.10	65.87± 4.33	66.70±1.95		

Table 1. Diversity indices of microalgae collected from the high ranges of the Western Ghats during different seasons during 2009-2011. (Values are mean  $\pm$ SD of 24 observations)

	Post-monsoon	Pre-monsoon	Monsoon			
	Mean± Std. Deviation	Mean± Std. Deviation	Mean± Std. Deviation			
Temperature <sup>o</sup> C	19.75±0.82	21.17±0.70	19.08±1.33			
Rate of flow m/sec	0.24±0.01	0.22±0.03	0.33±0.02			
Turbidity ( NTU)	1.16±0.65	0.11±0.05	1.45±1.41			
Electrical conductivity (micro mhos/cm)	56.83±16.92	60.17±14.8	39.17±12.03			
рН	7.18±0.11	7.1±0.22	7.62±0.12			
Acidity (mg/l)	4.0±2.89	2.33±0.76	4.0±2.89			
Total Alkalinity (mg/l)	20.33±4.32	21.33±5.23	13.33±2.81			
TDS (mg/l)	39.83±11.93	41.17±10.56	27.67±8.42			
Total hardness (mg/l)	24.33±9.39	22±4.25	12.33±1.83			
DO (mg/l)	8.02±0.07	7.98±0.07	8.23±0.26			
BOD (mg/l)	1.82±0.07	1.32±0.14	0.56±0.1			
Nitrate (mg/l)	1.28±2.23	0.62±1.42	3.07±2.65			
phosphate (mg/l)	0.17±0.18	0.04±0.01	0.04±0.01			
Sulphate (mg/l)	5.93±8.78	2.08±2.52	1.63±0.43			
Silicate (mg/l)	11.16±4.99	5.57±1.6	3.97±1.15			
Chloride (mg/l)	21.67±5.06	22.83±4.51	16.33±3.21			
Fluoride (mg/l)	5.73±1.79	4.82±1.11	2.93±0.39			
Calcium (mg/l)	2.43±1.97	2.26±0.62	1.22±0.25			
Magnesium (mg/l)	0.36±0.2	0.54±0.56	0.49±0.13			
Iron (mg/l)	0.72±0.36	0.36±0.04	0.69±0.17			
Altitude (m)	1133.33±154.99					

 Table 2. Physico-chemical parameters recorded from the high ranges of the Western Ghats in different seasons during 2009-2011(Values given are mean and SD for 24 samples)

# Total number of Microalgae (N)

N (Post-Monsoon)= 626.58 - 66.20 X F1 - 37.71 X F3 - 21.31 X F4 (R<sup>2</sup>=0.875)

This result suggested that F1, F3 and F4 had significant negative relationship with total number of microalgae. F1 positively correlated with temperature, rate of flow, pH, total alkalinity, and negatively correlated with BOD and phosphate (Table 4). While F3 is positively related with, acidity, TDS, calcium, iron, and altitude and F4 is positively correlated with electrical conductivity, total hardness, nitrate and magnesium, and negatively correlated with silicate. Therefore it is concluded that BOD, phosphate and silicate are the important factors supporting the total production of microalgae during post-monsoon season in higher attitude regions of the Western Ghats.

N (Pre-monsoon) = 274.37- 65.9 X F2 +28.58 X F1-25.34 X F3 -17.82 X F4 (R<sup>2</sup>=0.967)

This multiple regression equation showed that F1 had significant positive correlation while, F2, F3 and F4 had negative correlation with total number of microalgae during pre-monsoon season. F1 is positively correlated with rate of flow, acidity, TDS, nitrate and sulphate and

**Table 3.** Total variance explained by the first fourfactors derived from the environmental variables indifferent seasons.

Factor	Total Eigen value	% of Variance	Cumulative %						
Post-monsoon									
1	8.29	39.49							
2	5.90	28.13	67.62						
3	4.51	21.51	89.14						
4	1.40	7.01	96.15						
Pre-monsoon									
1	8.07	38.44	38.44						
2	5.83	27.78	66.23						
3	3.14	14.98	81.23						
4	2.31	11.03	92.25						
Monsoon									
1	7.47	35.60	35.60						
2	5.18	24.68	60.29						
3	4.49	21.39	81.69						
4	2.35	11.22	92.91						

negatively with phosphate. F2 is positively correlated with chloride and negatively with pH, BOD, and silicate, F3 positively related to electrical conductivity, total alkalinity, total hardness, magnesium and altitude and negatively with iron only While F4 positively correlated with temperature, turbidity and fluoride Therefore the supporting variables for total number of microalgae during pre-monsoon are rate of flow, pH, acidity, TDS, BOD, nitrate, sulphate, silicate, and iron.

N (Monsoon) =75.208 – 17.40 × F1 -6.18 × F3 -4.60 × F4 ( $\mathbb{R}^2 = 0.854$ )

The regression equation for total number of microalgae during monsoon illustrated that F1, F3 and F4 were related to the total number of microalgae negatively. The physico chemical parameters backs the total number of microalgae during monsoon are temperature, total alkalinity, DO, silicate and fluoride.

# Species Richness (d)

d (Post- monsoon) =  $8.18 - 0.524 \times F3 - 0.26 \times F^2(\mathbb{R}^2=0.667)$ 

It is found that F2 and F3 had significant negative correlation with species richness. From the results it is derived that DO and fluoride are the supporting environmental parameters for species richness during post-monsoon.

d (Pre- monsoon) =  $4.84 - 0.481 \times F2 - 0.265 \times F3 + .217 \times F1$  (R<sup>2</sup>=0.785)

The regression analysis showed that F1 is positively correlated and F2 and F3 are negatively correlated with species richness during premonsoon. Therefore, rate of flow, pH, acidity, TDS, BOD, nitrate, sulphate, silicate and iron favours species richness during pre-monsoon.

d (Monsoon) =  $3.08+ 0.316 \times F3+0.203 \times F1+$ 0.141 ×F4 (R<sup>2</sup>=0.728)

This regression equation showed that during monsoon F1, F3 and F4 are positively correlated with species richness. The positively correlated variables are turbidity, electrical conductivity, acidity, TDS, total hardness, nitrate, sulphate, calcium, magnesium and iron. It could be observed that a variety of environmental parameters positively influence the species richness of microalgae of the high ranges of Western Ghats.

## Shannon index (H')

H'(Post- monsoon) =  $3.87-0.069 \times F3$  (R<sup>2</sup>= 0.510)

The results of the regression analysis showed that F3 is the only parameter determines diversity of microalgae in the study area during post-monsoon. The environmental variables positively related are acidity, TDS, calcium, iron, and altitude

H (Pre- monsoon) =  $3.202 - 0.153 \times F2 - 0.063 \times F3 + 0.055 \times F1$  (R<sup>2</sup>=0.849).

**Table 4.** Factor loading matrix for physico-chemical variables after varimax rotation in samples collected from high ranges of the Western Ghats during three seasons of 2009-2010. Variables with highest factor loading are highlighted.

SI. No.	Water Quality Parameters	Post-n	nonsoon				Pre-mons	soon			Mons	oon	
L	Factors	1	2	3	4	1	2	3	4	1	2	3	4
1	Temperature	0.98	0.17	-0.11	-0.02	-0.06	0.14	0.02	0.99	-0.77	-0.56	-0.20	0.17
2	Rate of flow m/sec	0.89	0.22	0.28	-0.22	0.66	-0.14	-0.43	0.55	0.14	0.94	0.27	0.15
3	Turbidity	0.06	0.91	0.37	-0.17	-0.07	0.03	-0.33	0.54	0.71	0.10	0.33	0.61
4	Electrical conductivity(micro mhos/cm)	0.10	0.18	0.67	0.68	0.70	0.07	0.71	-0.08	0.03	0.14	0.97	0.20
5	рН	0.96	0.09	0.22	0.11	0.17	-0.77	-0.02	-0.61	0.19	-0.13	-0.10	0.30
6	Acidity (mg/l)	0.22	0.57	0.75	-0.09	0.99	-0.04	0.12	-0.04	0.95	0.25	-0.15	-0.06
7	Total Alkalinity (mg/l)	0.75	-0.32	0.55	-0.06	0.51	-0.34	0.73	-0.10	-0.16	-0.19	-0.37	-0.9
8	TDS (mg/l)	0.09	0.18	0.69	0.67	0.75	0.1	0.65	0.07	0.03	0.13	0.97	0.21
9	Total hardness (mg/l)	-0.14	-0.01	0.53	0.79	-0.07	0.5	0.82	-0.21	0.07	-0.18	0.69	0.17
10	DO (mg/l)	-0.26	-0.88	-0.13	-0.29	0.07	-0.22	-0.34	0.11	-0.87	0.09	-0.03	-0.47
11	BOD (mg/l)	-0.59	0.53	0.36	0.42	0.60	-0.74	-0.04	-0.25	0.27	0.84	0	-0.33
12	Nitrate (mg/l)	-0.38	-0.10	-0.08	0.92	0.99	-0.04	0.12	-0.04	0.91	0.10	0.12	0.09
13	Phosphate (mg/l)	-0.94	0.22	-0.22	0.10	-0.59	0.04	-0.52	0.3	0.17	-0.95	0	-0.26
14	Sulphate (mg/l)	-0.02	0.96	0.16	-0.11	0.82	-0.40	0.03	-0.39	0.76	-0.52	0.03	-0.01
15	Silicate (mg/l)	-0.41	0.08	0.07	-0.9	0.27	-0.88	-0.04	-0.32	-0.69	-0.1	-0.28	-0.09
16	Chloride (mg/l)	-0.18	0.95	0.09	-0.22	0.35	0.83	0.27	-0.09	0.04	0.78	0.27	0.55
17	Fluoride (mg/l)	0.47	-0.68	-0.46	-0.31	-0.37	0.60	-0.02	0.66	-0.74	-0.06	0.49	-0.42
18	Calcium (mg/l)	0.28	0.27	0.92	0.05	0.02	0.10	0.07	-0.06	0.01	-0.55	0.55	0.10
19	Magnesium (mg/l)	-0.31	-0.16	0.11	0.88	0.02	0.09	0.96	0.25	0.11	0.19	0.72	0.21
20	Iron (mg/l)	0.29	0.59	0.73	-0.01	-0.15	0.61	-0.77	0.02	0.62	-0.09	0.26	0.73
21	Altitude (m)	0.06	0.28	0.74	0.48	0.15	0.4	0.78	-0.41	0.28	0.75	-0.21	-0.49

The equation illustrated that F1 is positively correlated to the diversity of microalgae; however, F2 and F3 are negatively correlated. The rate of flow, pH, acidity, TDS, BOD, nitrate, sulphate, silicate, and iron are the supporting variables for microalgal diversity during pre-monsoon.

 $H'(Monsoon) = 2.57 + 0.080 \times F3 - 0.46 \times F^2$ 

#### $(R^2 = 0.538)$

A positive correlation was observed between F3 and microalgal diversity during monsoon and negative correlation with F2. The supporting environmental variables for microalgal diversity are electrical conductivity, TDS, total hardness, phosphate, calcium and magnesium.

## Taxonomic distinctness ( $\Delta^*$ )

 $\Delta^*$ (Post- monsoon) = 66.20+ 1.10 × F2 -0.44 × F3 (R<sup>2</sup> = 0.618)

The regression calculation illustrated that F2 is positively and F3 is negatively correlated with taxonomic distinctness. Therefore turbidity, sulphate and chloride are the environmental variables supporting the taxonomic distinctness

 $\Delta^*$  (Pre- monsoon) =69.17 -1.89 × F4 -1.17 × F3 (R<sup>2</sup>= 0.679)

This result suggested that factor F4 and F3 are negatively correlated with the taxonomic distinctness. F3 positively correlated to electrical conductivity, total alkalinity, total hardness, magnesium and altitude and negatively with iron. F4 is positively correlated with temperature, turbidity and fluoride. Hence the supporting variable for taxonomic distinctness during premonsoon is iron only.

 $\Delta$ \*(Monsoon) =66.89 +1.07 × F3 (R<sup>2</sup>=0.495)

The regression analysis showed that the significant relationship only existed between F3 and Taxonomic diversity. The supporting variables are electrical conductivity, TDS, total hardness, calcium and magnesium.

## DISCUSSION

In general the micro algal diversity primarily indicates the state of environmental conditions in aquatic systems. To better understand the annual pattern of microalgal assemblages, it is important to examine the linkage between the environmental variables and microalgal variations. Phytoplankton in ponds, lakes and reservoirs normally showed a periodic and cyclic response to physico-chemical factors (Hujare, 2005). Lasker and Gupta (2009) 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 present study also establishes that the algal species diversity of the high ranges is controlled by a combination of environmental factors.

The total microalgal population in the study area was found to be maximum during postmonsoon and moderate during pre-monsoon and minimum during monsoon. Varma and Singh (2001) reported the phytoplankton diversity in different seasons in the order postmonsoon > pre-monsoon > monsoon. During post- monsoon seasons there will be a chance for the release of nutrients, from the sediments from the adjacent forest, deposited in the streams during strong monsoon surface run off. This release of the nutrients can be attributed to the higher diversity and productivity of algae during post monsoon period. The variation in productivity and diversity with respect to the seasons can further be attributed to the higher solar illumination during post-monsoon and pre-monsoon when compared to the cloudy and rainy monsoon season. The decrease in the diversity of algae during monsoon months may be due to the dilution of the nutrients (Nair et al., 1988) and during dry seasons the water become concentrated due to the decrease in the water level, with rich amounts of nutrients especially nitrate and phosphate (Jithesh, 2010).

The major environmental variables support the microalgal diversity during post- monsoon in the study area are turbidity, DO, BOD, phosphate, sulphate, silicate, fluoride and chloride. The dominant microalgae during this period was the members of Bacillariophycea. Diatoms are considered as the best indicators of trophic status of water (Hencock, 1973). Sing and Balsing (2011) reported that maximum population of Bacillariophyceae in Kodaikanal lake was recorded during summer and minimum during winter. Mohammed and Nabila (2005) reported the dominance of Bacillariophyceae in the Mediterranean Sea and attributed higher correlation of diatoms to high silicate concentrations. High count of diatoms recorded during the present study may be attributed to the high silicate concentration, as silicate is the main components of diatom frustules (Donoso and Phinnes, 1988 and Gouni and Tsekos, 1989). In the present study the dominance of Bacillariophyceae is positively correlated with silicate load during post-monsoon.

Desmids are the second major microalgal group from all the three seasons of the study area. They are the markers of clarity and purity of water and their dominance indicate the oligotrophic nature of the water body (Venketeshwarlu, 1983).

During pre-monsoon the major supporting environmental variables are rate of flow, pH, acidity, TDS, BOD, nitrate, sulphate, silicate and iron. In pre-monsoon season diatoms form the dominant microalgal group from the study area. Along with diatoms (62%) and desmids (14%) chlorophytes (12%), cyanophyceae (8%) and euglinophytes (4%) are also observed. Shinde et al. (2012) reported the maximum population density of diatoms in pre-monsoon period. In the present investigation also diatoms were the dominant group of microalgae both in the post-monsoon and pre-monsoon seasons. Naik et al. (2005) showed positive correlation of temperature, pH, nitrates, and phosphates during pre-monsoon season trigger the growth of Cyanophyceae from Kaly River, west coast of India. In the present investigation temperature, pH, nitrate and phosphate showed a positive correlation with the algal production and consequent occurrence of Cyanophyceae members were also recorded. Kumar (2002) reported the higher concentration of organic matter in tropical oxidation ponds supports the development of Cyanophyceae. The important factors responsible for the formation of a blue green algal bloom are nitrate, phosphate, CO2 and calcium (Ramaswamy and Somashekar, 1982).

During monsoon temperature, turbidity, electrical conductivity, acidity, total alkalinity, TDS, total hardness, DO, nitrate, phosphate, sulphate, silicate, fluoride, calcium, magnesium and iron are the environmental variables contribute to a great extend to the total variability of physicochemical parameters in the study area. In monsoon the diversity of microalgae was very low and desmids are the major group among the microalgae observed. The decrease in the diversity of microalgae may be due to the dilution of nutrients and high turbulence during monsoon months (Nair et al., 1988). Euglinophytons were totally absent and Cyanophycean members are represented only the 5% of the total microalgal community during monsoon seasons. Lasker and Gupta (2009) reported the maximum diversity of desmids during monsoon season in Chatla reservoir and found that soft water with low turbidity and low nutrients favour the growth of Desmids. In the present investigation also the water turbidity is high and the nutrient load is low during monsoon favours the growth of desmids.

In stream water flow conditions, the nutrient variables did not show a visible relationship to the microalgal biomass however, nutrients were limiting resources for the rapid colonization and proliferation of microalgae. In this study we explained the interaction between phytoplankton and environmental variables in the high range areas of Western Ghats with respect to different seasons. The statistical evidence suggested that there exists a special heterogeneity among the relationship between environmental variables and microalgal diversity. In general sulphate and silicate are having a positive correlation on microalgal diversity during all the three seasons. The trophic status of Taihu, a fresh water lake in China, has explained trough the pattern of the phytoplankton variation and its relationship with environmental variables and nitrogen could be identified as the limiting factor in phytoplankton biomass (Wang et al., 2007). Similar observations were made by Ponader et al. (2007) of New Jersey streams and found the positive interaction of nitrate and phosphates with Diatoms. The present investigation also illustrates the correlation of sulphate and silicate to the algal diversity in all seasons.

Dominant microalgal representatives during all the seasons were diatoms and desmids. The percentage of Euglenoids and Cyanophytes were very low throughout the period of study as these groups are indicators of eutrophication. The higher content of silicate throughout the season favours the growth of Bacillariophyceae, which is considered to be the best indicators of trophic status of water. Therefore the present investigation gives the impression that an oligotrophic condition is prevailing in the high ranges of the Western Ghats as evidenced from the oligotrophic indicators. In conclusion, the present result revealed that water quality in the region is not seriously affected by the anthropogenic drivers acting in the region; however, there is an indication of its conversion to eutrophic state. Since these areas are habitats of many endemic fauna, algal production and diversity profile suggests that the ecological ambience is enough to provide microalgae for herbivorous larvae and young ones of these fishes. The distribution pattern of these fishes is also depends on the microalgal community structure which further influenced by physico-chemical factors of the environment. The information generated from this investigation may be useful for the decision makers for conservation and effective utilization of the water bodies of the high range area. It is concluded from the present investigation that there is least chance of eutrophication in the high range regions of Western Ghats.

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