Original Research Article

Diversity of Freshwater Microalgae from Selected Regions of Central Western Ghats, Karnataka

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Abstract: Exploring algal diversity principally offers the availability, identification and documentation of varieties of species at the site, allowing understanding the organization level of the biological elements in an ecosystem. Current research aimed at the exploration of microalgae species in freshwater bodies of the central Western Ghats, Karnataka between January-2019 to December-2019. The samples were collected, processed and observed under light microscope followed by culturing in a broad range of media. The physico-chemical analysis of the samples was performed using the standard titrimetric methods and an association between abiotic factors and microalgal population was statistically evaluated. The diversity of the microalgae was assessed with the help of five diversity indices followed by Pearson's correlation. A total of 46 species, belonging to 4 different classes was identified in 7 selected study sites. Amongst all, *Chlorophyceae* class dominated with 24 species and *Zygnematophyceae* with a four species was the least. The Pearson's correlation matrix of all seven study sites with their physico-chemical parameters had a significant correlation between pH, TDS, and EC. The substantial association of Mg^{++}, Ca^{++} and DO with Temperature too existed. The diversity indices *viz.* Dominance index (D), Simpson diversity index (1-D), Shannon diversity index (H), Species Evenness and Margalef diversity index (d) showed a noteworthy diversity status of the study area. But, the instability among the water bodies and their microalgal species composition remained evident in the present work.

Key words: Diversity, Ecology, Microalgae, Phycology, Western Ghats.

Introduction

Algae with their multiple capabilities in plentiful dimensions remained as the utmost attentive phytoplankton for the ecological assessment of lakes, ponds and reservoirs by means of water quality indicator (Bharati and Hosmani, 1973; Ryabushko *et al.,* 2019). Beside these facts, algae have become an economically prominent microbial community and turn out to be factories, accomplishing modern-day human needs (Fu *et al.,* 2016; Vetriselvi and Sivakumar, 2012). In an aquatic ecosystem, these groups of organisms serve to be a primary producer; constitute a major food web that helps in establishing a healthy aquatic environment which forms a stable ecosystem around. Slight variations in a water body can be detected by the presence of the microalgae which serves as an excellent biosensor (Protasov *et al.,* 2019).

The Western Ghats are one of the diversity hotspots spread across 6 Indian states and Karnataka is one among them. It is treasure for 23% of the overall diversity of India. Conversely, this account does not comprise algal diversity, because algae being primitive plants gain a very less attention (Myers *et al.,* 2000; Suresh *et al.,* 2012; Nasser and Suresh

Kumar, 2013). The increased developmental activities around Western Ghats may pose threat to the vegetative diversity of this region and at the mean time least attention to the phycological studies may lead to the loss of algal species

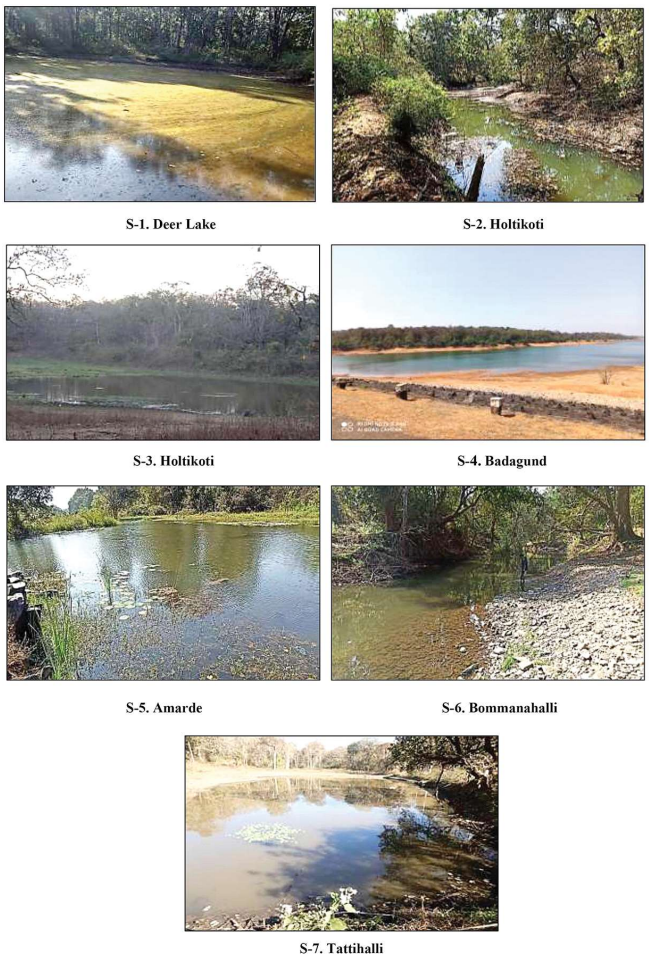

Fig. 1A. Study/Sampling Sites: S-1: Deer Lake an extremely eutrophicated, remote lentic water body throughout the study period which could be because of dense growth of microalgae; S-2: Holtikoti isolated lotic water body with solid green colour appearance of water indicating presence of the microalgae; S-3: Holtikoti one of the largest lakes found in the study area which is at high risk of anthropogenic activity due to easyaccessibilityfor visitors; S-4: Badagund is a backwater resource which is lentic in nature surrounded with thick forest; S-5: Amarde is an isolated lentic water body with an unique visible phytoplankton growth, important water source for wild animals; S-6: Bommanahalli a lotic water body, the water flows from the Bommanahalli reservoir which pass through a villageand gets contaminated; S-7: Tattihalli completely inaccessiblewater and one of a water resource to wild animals. All the aboveselected sites are integral parts of central Western Ghats, which are found to be exposed to anthropogenic activity randomly.

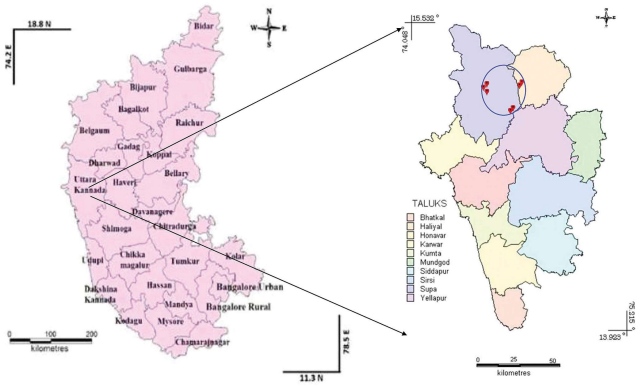

Fig. 1 B. The study area is confined to the Supa taluk and Haliyal taluks of the Uttar Kannada district, Karnataka, India which falls under central Western Ghats of Karnataka. It covers an approximately 255 Km^2 area and around 75 Km of perimeter. The sites are distant apart and found to be different water systems (lentic, lotic, reservoirs, ponds, lakes etc).

(Ramachandra and Karthick, 2009). Reports says 15-20% of all species cease to exist over a 12-year period (Lugo, 1988). Hence, conservation strategies need to be implemented for the protection of undocumented algae from extinction.

As per the available data from diversity board of Karnataka, in India 7284 algal species were documented till today, which is 15.33% of the total Indian flora and there are 1761 taxa have been reported from the Karnataka state so far (Gupta and Das, 2018). Significant work on marine algae been done in the coastal Karnataka by Agadi (1985), freshwater algae of Karnataka by Hegde and Isaacs, (1988) and Hosmani (2014), Freshwater algae of Uttar Kannada district Karnataka by Isaacs and Hegde (1986). Physical and chemical parameters of lentic water bodies of Uttara Kannada district with special concern of zooplankton were carried by Kudari *et al.,* in 2006 and major contribution to the eco-hydrology of rivers in central Western Ghats along with the diatom diversity were reported by the Ramachandra in 2015. According to Guiry (2012), ~10 lakh species of algae exist on planet earth. So far, in India only 0.17 % of the global algal taxa have been documented. With an increased importance and widespread applications of these species, to cope up with the elevating demand at industrial level, exploring, identifying, documenting and reporting a potential algal bio-diversity from unexplored

geographical areas is a prime responsibility of the phycologists (Barinova *et al.,* 2010).

Under the shadow of available literature, the present study aims at exploring and documenting the freshwater microalgal diversity of selected regions of central Western Ghats, Karnataka, along with evaluation of abiotic factors and their correlation with microalgal diversity.

Materials and methods

Study sites

This time bound study was carried out between January - 2019 to December – 2019 in the following locations as given in Fig.1A, Fig.1B and Table 1. The selected sites were the locations around the Western Ghats regions in the Uttara Kannada district of Karnataka. The study area covers an approximately 255 Km^2 and around 75 Km of perimeter. The water bodies targeted in this study are major reservoirs, ponds and lakes.

Table 1. List of study sites with the geographical coordinates.

Sampling Sites	Latitude	Longitude
S-1 (Deer Lake)	15°21′ 0″N	74°53′ 39″ E
S-2 (Holtikoti)	15°21′ 5″ N	74°53′ 8″ E
S-3 (Holtikoti)	15°18′ 21″ N	74°37′ 43″ E
S-4 (Badagund)	15°16′ 35″ N	74°32′ 9″ E
S-5 (Amarde)	15°12′ 21″ N	74°31′ 42″ E
S-6 (Bommanahalli)	15°10′ 31″ N	74°41′ 19″ E
S-7 (Tattihalli)	15°08′ 18″ N	74°47′ 43″ E

Sample collection

The microalgal and the water samples were collected twice in a month by grab and scoop method at the depth of 15cm, in a sterile plastic bottle. Later, microalgal samples were processed and observed under 40X magnification of light microscope at the Environment and Sustainable Technology Laboratory, Department of Microbiology and Biotechnology, Karnatak University, Dharwad. The microalgal samples were cultured in BG-11 media (Stanier *et al.,* 1971), BBM media and for diatoms f/2 media (Guillard and Ryther, 1962; Guillard, 1975). With the help of standard monographs and research papers, identification of microalgae was accomplished (Prescott, 1964; Andersen, 1992; Vuuren*et al.,* 2006; Stastny *et al.,* 2013; Bellinger and Sigee, 2015; Kim, 2018). The counting of the microalgae was carried out as per the Lackey's drop method (Lackey, 1938).

Physico - chemical analysis

The samples collected from the study sites were subjected to the physicochemical analysis using the standard titrimetric methods. The physical parameters like- pH (GE Filtration pH meter), Shatech Digital Purity tester was used to measure temperature, total dissolved solids (TDS) and electric conductivity (EC), at the site while collecting the sample. Further, the chemical parameters like- dissolved oxygen (DO), Mg^{++}, Ca^{++}, and total hardness (TH)were analyzed by standard titration methods at the laboratory of Biochemistry, Department of Geology, Karnatak University, Dharwad (Suresh *et al.,* 2012).

Diversity and statistical analysis

Diversity indices *viz.,* Dominance index (D), Simpson diversity index (1-D), Shannon diversity index (H), Species Evenness and Margalef diversity index (d) were calculated using Paleontological Statistics Software Package (PAST version 3.0 for Windows) (Hammer *et al.,* 2001). Descriptive analysis *viz.,* mean, standard error, and standard deviation of the physico-chemical parameters of water samples along with the Pearson's correlation were calculated with IBM SPSS Statistics software Inc., version 20.0 (Armonk, NY: IBM Corp.).

Results

Microalgal diversity

A total of 46 microalgal species belongs to the class *Chlorophyceae*, *Bacillariophyceae*, *Cyanophyceae* and *Zygnematophyceae* were found in seven study sites (Table. 2) (Fig. 2A and 2B). The class *Chlorophyceae* encompassed highest number (24) of species, followed by *Bacillariophyceae* (12), *Cyanophyceae* (6) and *Zygnematophyceae* (4) species were documented during the study period. Out of 46 species, S-1 sheltered 29 and S-4 had only 10 species. Totally 1,65,942 individuals of 46 species were

Table 2. Diversity of microalgal species in study sites.

Sl. No.	Species	Study Sites						
		1	2	3	4	5	6	7
1	*Amphora ovalis*	+	+	+	-	+	-	-
2	*Coelastrummicroporum*	+	-	+	+	+	-	-
3	*Synedra ulna*	+	+	+	-	+	-	+
4	*Scenedesmus acutus*	-	+	-	-	-	-	-
5	*Merismopedia punctata*	-	-	-	+	-	-	+
6	*Crucigeniatetrapedia*	+	-	+	-	+	-	+
7	*Actinocyclus litoralis*	-	-	-	-	-	-	+
8	*Pediastrum tetras*	-	-	-	-	-	+	+
9	*Naviculasubtilissima*	+	-	+	+	-	+	+
10	*Coscinodiscus radiatus*	-	+	-	-	-	-	-
11	*Chroococcussubnudus*	+	+	-	-	+	-	-
12	*Ulothrix aequalis*	-	+	+	-	+	-	-
13	*Aulacoseiragranulata*	+	+	+	-	+	+	+
14	*Oedogoniumvaucherii*	-	+	-	-	-	+	+
15	*Dictyochloropsissplendida*	+	+	-	-	-	-	-
16	*Cymbella lanceolata*	-	-	+	-	+	+	-
17	*Closterium moniliferum*	+	+	-	-	+	-	+
18	*Oscillatoria limosa*	+	+	-	-	-	+	-
19	*Spirogyra porticalis*	+	+	-	-	+	+	-
20	*Staurastrumvestitum*	-	-	-	-	+	-	-
21	*Gyrosigmaobtusatum*	+	+	+	-	-	-	-
22	*Tetrastrum elegans*	+	-	+	-	+	-	-
23	*Gyrosigma acuminatum*	+	+	+	-	-	-	+
24	*Monoraphidiumcontortum*	+	+	-	-	-	-	-
25	*Haematococcuspluvialis*	-	-	-	-	+	-	+
26	*Crucigeniacrucifera*	+	-	+	+	+	+	+
27	*Scenedesmus dumorphus*	+	+	+	-	+	+	+
28	*Scenedesmus armatus*	+	+	+	+	+	-	-
29	*Tetrastrumheterocanthum*	+	+	-	+	+	-	+
30	*Actinastrumgracillimum*	-	-	-	-	+	-	-
31	*Crucigeniafenestrata*	+	+	+	-	+	-	+
32	*Scenedesmus acuminatus*	+	+	+	+	+	+	+
33	*Coelastrumreticulatum*	+	-	-	-	-	-	-
34	*Actinastrumhantzschii*	+	+	+	+	+	-	-
35	*Pediastrum duplex*	+	+	-	-	+	-	-
36	*Tetraedranlaboratum*	+	-	+	-	-	-	-
37	*Thallasiorapacifica*	+	+	+	-	-	-	-
38	*Closterium striolatum*	-	+	+	-	-	-	+
39	*Tetraedron minimum*	+	-	+	-	-	-	-
40	*Microcystis aeruginosa*	-	+	-	-	-	-	+
41	*Staurastrumsexangulare*	-	-	-	+	-	-	-
42	*Fragilaria striolata*	+	-	+	-	+	+	-
43	*Eudorinaunicocca*	-	+	+	-	-		+
44	*Pandorina morum*	-	+	-	-	-	-	+
45	*Oscillatoria princeps*	-	+	-	-	-	+	+
46	*Chlorella vulgaris*	+	+	+	-	+	+	+

observed in all seven study sites amongst which, S-2 registered highest individuals (72,710) and S-4 with lowest individuals (7995). The most abundant group was *Chlorophyceae* (73.91%) **(Fig.3)** *viz., Coelastrum microporum*, *Scenedesmus acuminatus*, *Crucigenia tetrapedia, Actinocyclus litoralis, Pediastrum tetras*, *Crucigenia fenestrata, Scenedesmus dumorphus*, *Scenedesmus armatus*, *Tetrastrum heterocanthum, Actinastrum gracillimum, Crucigenia crucifera*, *Coelastrum reticulatum*, *Actinastrum hantzschii, Pediastrum duplex*, *Tetraendran laboratum, Thallasiora pacifica, Closterium striolatum, Tetraedron minimum, Microcystis aeruginosa, Eudorina unicocca, Pandorina morum, Chlorella vulgaris.*

Physico-chemical analysis

The physico-chemical analysis of water samples showed satisfactory outcomes represented in **Table-3,** as mean and standard error. The mean value of all seven-water body temperature was ranging between 24ÚC to 26ÚC, pH values were between 6.5 to 7.5, total dissolved solids was 29 to 42 PPM, Mg^{++} was 1.5 mg/l to 5.85 mg/l, Ca^{++} was ranging between 6.87mg/l to 20.34mg/l, electric conductivity assorted between 64.82 to 99.26mS/cm, total hardness of the water body was between 24.60 to 69.10 mg/l $CaCO_3$, and dissolved oxygen level was between 3.0 to 12.99mg/l. The Pearson's correlation matrix of all seven study sites with their physico-chemical parameters were performed, in which the significant correlation was found between pH, TDS, and EC. The significant association between Mg^{++} and Ca^{++} followed by DO with Temperature was also existed **(Table-4).** Later, to understand the association between composition of habitat and microalgal population, correlation matrix was produced **(Table-5).** Amongst all, the *Cyanophyceae* showed a slightly significant correlation with total hardness (TH) of water. Most of the internal composition of water body were found to be negatively correlating with rest other microalgae.

Diversity indices

The statistical findings of the current study showed significant results. There were five different diversity indices applied to understand the diversity status of the study area. The Dominance index (D) values were between 0.04 and 0.4, 0.62

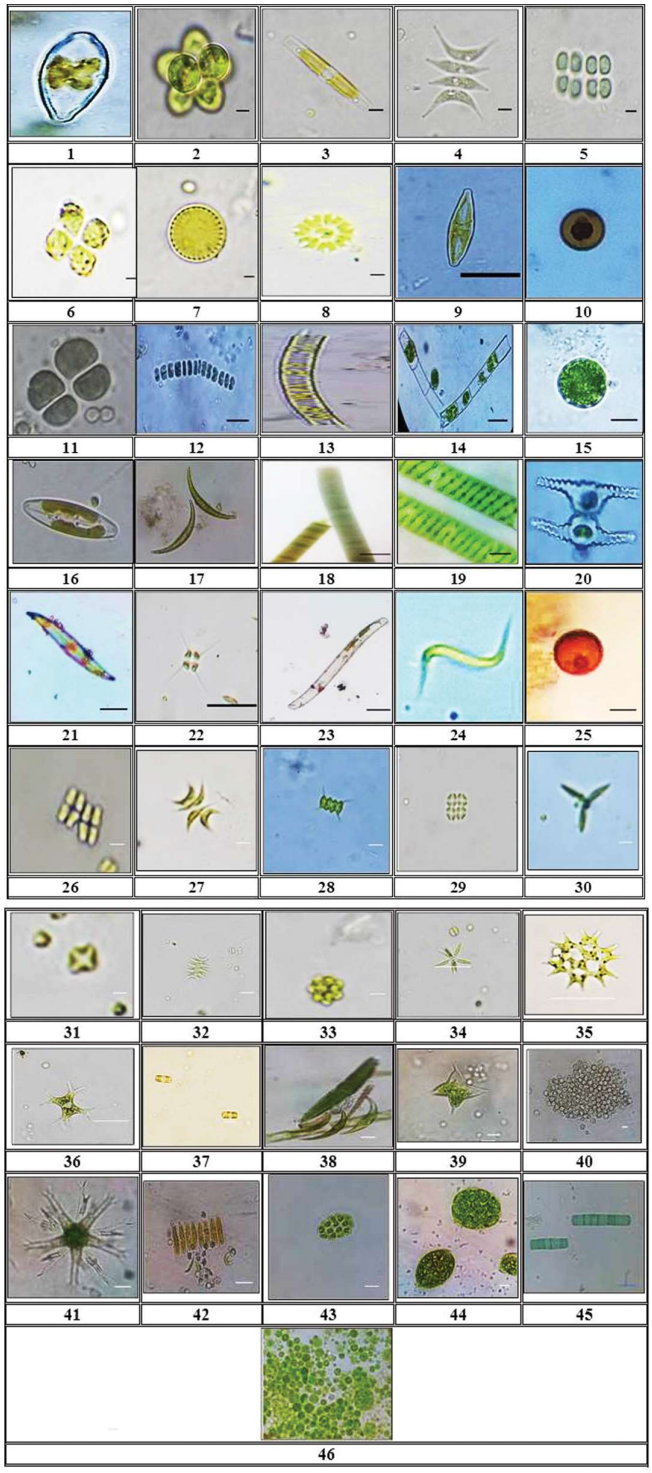

Fig. 2. Microalgal species from the study sites: 2A) 1-*Amphora ovalis*; 2-*Coelastrum microporum*; 3-*Synedra ulna*; 4-*Scenedesmus acutus*; 5-*Merismopedia punctata*; 6-*Crucigenia tetrapedia*; 7-*Actinocyclus litoralis*; 8-*Pediastrum tetras*; 9-*Navicula subtilissima*; 10-*Coscinodiscus radiatus*; 11-*Chroococcus subnudus*; 12-*Ulothrix aequalis*; 13-*Aulacoseira granulate*; 14-*Oedogonium vaucherii*; 15-*Dictyochloropsis splendida*; 16-*Cymbella lanceolata*; 17-*Closterium moniliferum*; 18-*Oscillatoria limosa*; 19-*Spirogyraporticalis*; 20-*Staurastrum vestitum*; 21-*Gyrosigma obtusatum*; 22-*Tetrastrum elegans*; 23-*Gyrosigma acuminatum*; 24-*Monoraphidium contortum*; 25-*Haematococcus pluvialis*; 26-*Crucigenia crucifera*; 27-*Scenedesmus dumorphus*; 28-*Scenedesmus armatus*; 29-*Tetrastrum heterocanthum*; 30-*Actinastrum gracillimum*. **2B)** 31-*Crucigenia fenestrate*; 32-Scenedesmus acuminatus; 33-Coelastrum reticulatum; 34-*Actinastrum hantzschii*; 35-Pediastrum duplex; 36-Tetraendran laboratum; 37-Thallasiora pacifica; 38-*Closterium striolatum*; 39-*Tetraedron minimum*; 40-*Microcystis aeruginosa*; 41-*Staurastrum sexangulare*; 42-*Fragilaria striolata*; 43-*Eudorina unicocca*; 44-*Pandorina morum*; 45-*Oscillatoria princeps*; 46-*Chlorella vulgaris*.

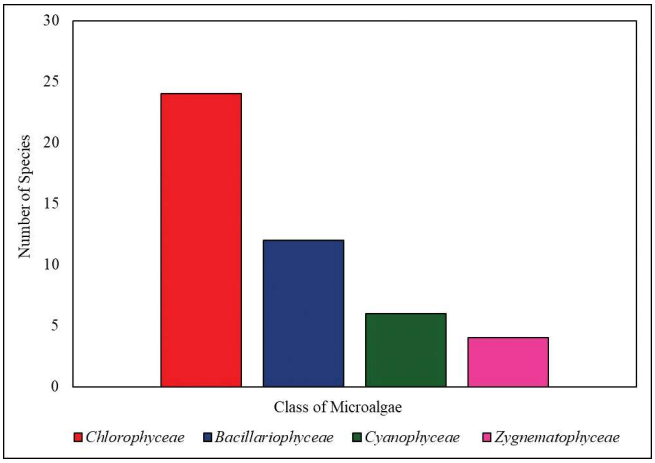

Fig. 3. The Graph represents the class level distribution of microalgae found in this study. Amongst 46 microalgal species, class *Chlorophyceae* has 24 species, followed by *Bacillariophyceae* with 12 species, *Cyanophyceae* with 6 species and *Zygnematophyceae* had only 4 species. In this study, class *Chlorophyceae* members found abundant and dominated the diversity data.

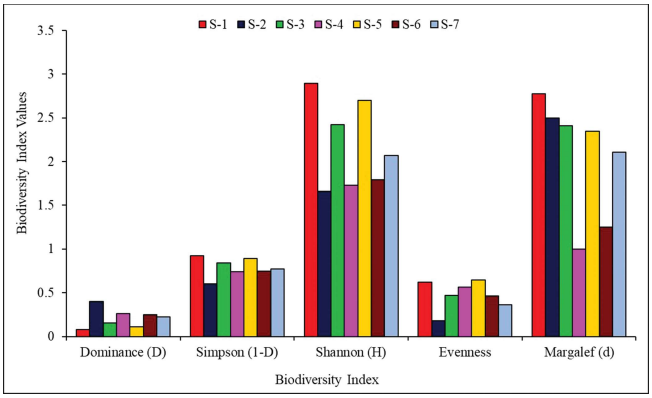

Fig. 4. The Graph represents diversity status amongst seven study sites. The Dominance index indicates "diversity richness" and in present study S-2 has maximum diversity richness. The Simpson diversity index indicates "higher/ lower diversity" and present study showed higher diversity amongst all sites. The Shannon-Wiener diversity index indicates "health status of study site" and present study S-1, S-3, S-5 and S-7 registered stable and healthy status. The species evenness index indicates "even distribution of species" and in present study S-1 and S-5 showed even distribution of the species compared to other sites. The Margalef diversity index indicates "species variation" and S-4 and S-6 had a significant variation of species number and individuals.

and Margalef diversity index (d) values varied from 1.001-2.77 (Table 6) (Fig. 4).

Discussion

We were able to report totally 46 microalgal species from seven selected study sites. Earlier, 97 microalgal species from Western Ghats of Maharashtra (Nikam *et al.,* 2010), Eastern Ghats (Suresh *et al.,* 2012) and 24 microalgal species at the foot hills of eastern Himalayas (Das and Keshri, 2017) have been reported. In this study, class *Chlorophyceae* members found abundant and hence, dominated the diversity data (Panda *et al.,* 2011; Sankaran and Thiruneelagandan, 2015; Halder *et al.,* 2019). Altogether, life forms exist and subsist in the definite site which directly implicates the importance of the environment which they live in. When it comes to the aquatic environment various parameters governs life forms present in it (Ratha *et al.,* 2012). The mean temperature of all seven study sites was optimal, which is moderate enough for microalgal growth (Adhikary and Sahu, 1992). It is crucial for water bodies to hold lesser temperature than that of the atmospheric temperature, which helps in the survival of aquatic ecosystem (Vetriselvi *et al.,* 2011). The main reason for the moderate temperature in the sites is, the highest forest cover and low rate of evaporation, which keeps the water bodies cool for longer period (Rao and Jaya, 2001). The mean pH values of all sites didn't show periodic variation adjoining to the neutral, it may be because of the other biological activities

Table 3. Physical and chemical parameters of the study sites.

Site No.	Temp (C°).	pH	TDS	EC	Ca^{++}	Mg^{++}	TH	DO
1	25±0.58	6.57±0.35	35.83±1.97	76.24±6.67	13.40±2.67	3.46±0.36	30.46±3.0	4.73±0.3
2	24.9±0.52	6.57±0.29	36±2.18	83.33±4.40	20.34±1.72	5.82±1.56	69.1±14.6	3.10±0.12
3	26±0.45	6.92±0.30	32.33±2.63	83.44±3.25	6.90±1.70	2.37±0.61	25.93±6.47	6.13±0.06
4	25.96±0.59	6.73±0.19	31.66±1.63	77.47±5.49	9.18±1.70	1.64±0.24	37.5±3.44	10.80±1.71
5	26.46±0.87	6.78±0.19	29.16±0.48	64.81±1.06	16.61±0.29	1.52±0.11	41.01±1.03	12.98±0.35
6	25.58±0.83	7.43±0.10	44.66±1.20	99.25±2.67	23.76±0.56	6.27±0.20	24.7±1.07	6.96±0.31
7	24.93±0.60	7.53±0.13	42.5±1.09	94.44±2.42	5.04±0.26	2.55±0.11	24.60±0.92	6.20±0.29

Values are mean ± SE. Temp – Temperature; TDS – Total Dissolved Solids; EC – Electric Conductivity; TH – Total Hardness of water; DO – Dissolved Oxygen.

Table 4. Pearson's correlation of physical and chemical parameters.

	Temp	pH	TDS	EC	Ca^{++}	Mg^{++}	TH	DO
Temp	1							
pH	-.106	1						
TDS	-.627	.757*	1					
EC	-.507	.778*	.915**	1				
Ca^{++}	-.029	-.119	.231	.077	1			
Mg^{++}	-.540	.148	.655	.600	.758*	1		
TH	-.185	-.624	-.321	-.335	.423	.301	1	
DO	.851*	.004	-.500	-.524	-.086	-.648	-.194	1

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).

Temp – Temperature; TDS – Total Dissolved Solids; EC – Electric Conductivity; TH – Total Hardness of water; DO – Dissolved Oxygen

Table 5. Pearson's correlation matrix of the species-environmental variables of the study sites (*p<0.05; **p<0.01).

	Chl.	Bac.	Cyan.	Zygn.
Temp.	-.518	-.029	-.584	-.124
PH	-.575	.397	-.205	-.166
TDS	-.161	.085	.231	-.153
EC	-.298	.215	.225	-.046
Ca^{++}	.132	-.535	.469	.152
Mg^{++}	.232	-.240	.681	.224
TH	.506	-.396	**.822***	.706
DO	-.611	-.237	-.611	-.293

Temp – Temperature; TDS – Total Dissolved Solids; EC – Electric Conductivity; TH – Total Hardness of water; DO – Dissolved Oxygen; Chl – *Chlorophyceae*; Bac -*Bacillariophyceae*; Cyan – *Cyanophyceae*; Zygn – *Zygnematophyceae*.

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

at the study sites (Gupta *et al.,* 1996; Parikh and Mankodi, 2012). This also helps in the over growth of certain algae resulting in the bloom formation thus, leading to noxious condition for the other aquatic creatures as well (Choi *et al.,* 2014). Amongst seven study sites, frequent bloom formation was observed within S-2, notably it embraces highest number of individual microalgal species. The TDS values of a water body generally varies due to detergent use or other domestic activity (Vetriselvi *et al.,* 2011). The optimal total hardness of water was between 24 and 69 mg/l, where the growth of *phytoplankton* found abundant (Parikh and Mankodi, 2012). The mean values of TDS in all sites were normal, which obviously facilitated the growth of microalgae. The EC of the site S-5 was minimum when compared to other sites, where unique microalgal species *Staurastrum* was found. The similar reports were found with respect to *Desmids* occurrence in water bodies with low EC (Gerrath, 1993; Ngearnpat and Peerapornpisal, 2007). The presence of Ca^{++} and Mg^{++} is important for an aquatic creature to carry out certain metabolic activities. The highest concentration of Ca^{++} in a water body is an indication of an increased rates of evaporation which was acceptable in S-2, S-5 and S-6 (Prasad *et al.,* 1985). In case of phytoplankton, Mg^{++} acts as a central metal ion and hence, presence of elevated Mg^{++} concentration in S-2 is true. According to Gautama *et al.,* (1993), the aeration rate plays a key role in the DO value and in case of reservoirs (S-4 and S-5), they spread across the wide area henceshowing the higher DO values than others (Gautama *et al.,* 1993; Vetriselvi *et al.,*

Table 6. Diversity indices of the study sitesof central Western Ghats.

Study Site (n)	No. of Species (n)	Dominance Index (D)	Simpson Index (1-D)	Shannon Index (H)	Species Evenness ($e^{H/S}$)	Margalef Index (d)
S-1	29	0.0780	0.9220	2.895	0.6238	2.775
S-2	29	0.3998	0.6002	1.660	0.1814	2.501
S-3	24	0.1567	0.8433	2.425	0.4708	2.413
S-4	09	0.2623	0.7377	1.731	0.5647	1.001
S-5	24	0.1086	0.8914	2.699	0.6465	2.350
S-6	13	0.2518	0.7482	1.793	0.4621	1.250
S-7	22	0.2261	0.7739	2.071	0.3604	2.111

2011). Whereas, lowest DO values amongst S-1 and S-2 are an indication of high degree of pollution due to consumption of dissolved oxygen by aquatic ecosystem (Sangu *et al.,* 1987). The frequent occurrence of *Oscillatoria* species in study site S-1, S-2, and S-6 give us the indication of growing pollution at the site (Ray and White, 1976). To understand the diversity and fitness of selected study sites, the microalgal data was subjected for diversity indices assessment (Davari *et al.,* 2011). The Dominance (D) value for the species diversity ranges from 0 to 1, where 0 specifies infinite diversity and 1 means low diversity. The D values of all study sites were below 1 and hence, showing rich diversity. In Simpson diversity index, the value 0 indicates less diversity and value 1 indicates the higher diversity (Turkmen and Kazanci, 2010). In this report, all study sites were having values nearer to 1, indicating the optimum diversity richness. General values for Shannon index assorted between 1.5 - 3.5, where values less than 1 indicates pollution and degradation of the water body (Halder *et al.,* 2019) and values above the limit value indicates healthy and stable ecosystem (Mandaville, 2002). In our study, S-1, S-3, S-5 and S-7 registered stable and healthy status, but S-2, S-4 and S-6 found to be nearly polluted. The Species evenness index values fell between 0 and 1, where a value nearing to 1 indicates the even distribution of species (Pielou, 1966). In current study the S-1 and S-5 sites showed even distribution of the species compared to other sites. The Margalef diversity index helps us to compare the variation of the species among the different study sites (Kocatas, 1992). According to the values there is a significant variation noted at the S-4 and S-6 in terms of species number and individual compared to other sites.

Conclusion

The diversity and species composition are the part and parcel of the planet earth, which together establish a healthy and balanced ecosystem. In current study, site S-2 and S-4 showed highest and lowest microalgae population respectively. Subsequently, site S-1 and S-5 enumerated as most stable and healthy whereas, S-2 found to be most polluted. There was no novel strain found during this study. The diversity indices and correlation matrix studies evidently indicate the instability among the water bodies and their microalgal species composition. Hence, adaptation of proper management strategies in conserving these water bodies as well as microalgal diversity is crucial.

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