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A treatise on diversity of algae from the Western Ghats, Tamil Nadu, India

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Abstract
The Western Ghats of India functions as reservoir for many life forms including giant elephant to quaint hummingbird. Western Ghats is endowed with several waterbodies which backbones micro-floral diversity too. This investigation was aimed to document algal diversity along with physico-chemical analysis of nine different waterfalls located in Western Ghats of Tamil Nadu. The study was resulted with 117 algal species belongs to the class Cyanophyceae, Chlorophyceae, Bacillariophyceae, Euglenophyceae and Rhodophyceae. Documentation of Rhodophycean members from freshwater environment is quite infrequent. It was found that the study was dominated by Chlorophycean and Bacillariophycean members that indicate healthiness of the water. The various physicochemical parameters were analyzed in which most of the parameters were found within in permissible limits recommended by WHO and BIS for drinking water specifications. This assessment on algae and water quality may helpful in ecological conservation studies and management.

Keywords: Algae, physicochemical analysis, lotic habitats, western ghats

Introduction

The Western Ghats is considered as one of the world's ten hottest biodiversity hotspots and major tourists' attraction. It is known for its high diversity and endemism of flora and fauna. Though only five percent of the total land area of India is covered by Western Ghats, it has twenty seven percent of higher plant species of the country. It is also known for its diversity in ecosystem and ethnic group of indigenous people. The fresh water ecosystem can be categorized into lentic (stagnant) and lotic (running) water bodies. Among lotic ecosystem waterfalls are always unique as it is physiologically rich in nutrients and occupy a pivotal position on earth. Waterfalls are also considered as natural monuments for revenue generation, because of their ecotourism potentials and as source for drinking, irrigation, and other domestic purposes (Offem and Ikpi 2012) [30].

Algae are ubiquitous in nature occupy dominant position in aquatic environments. They represent large group of oxygen-evolving photosynthetic autotrophs. They are ecologically important and often form conspicuous feature of waterbodies (Vymazal, 1994) [44] and serve as a primary producer in all aquatic based food chain (Browder *et. al.*, 1994) [8]. Algae have long been utilized as biotic indicators mainly as means for measuring and evaluating overall condition of water bodies because algae exhibit wide range of ecological tolerance and directly response to many changes in the environment (Stoermer, 1998) [39]. Utilizing algae in biomonitoring process was done by researchers from in mid of the 20th century onwards.

Documenting biodiversity forms the fundamental and also helpful in the conservation and management actions (Villasenor *et al.*, 2007) [43]. Only few research work has been carried out exclusively on algal diversity of waterfalls from Western Ghats (Gandhi, 1970; Jose and Patel 1990 and Narwade *et. al.*, 2014) [15, 20, 26]. Although documenting the algal diversity on waterfalls and it is environs from Western Ghats is found still lacuna. Moreover, Tamil Nadu is one of the southern states of India and is known for its natural wealth endowed with several waterfalls. Only very few resources of natural wealth has been utilized so far in agriculture, medicine, food and so on. Most of the potential algae are available in plenty which has wide spectrum of benefits.

The most important step for conservation of water bodies is to maintain a proper water quality (Smitha and Shivashankar, 2013) [38]. The study on physicochemical and biological characteristic of standing and running water resources reveals the pollution level (Trivedy and Goel 1986) [41]. Mohamad (2020) [25] emphasis the important of water management and rehabilitation plans for waterbodies for the sustainable management. Hence an attempt was made with an aim to explore the status of water quality from the waterfalls and its surroundings of Western Ghats, Tamil Nadu through the algal diversity along with its physico – chemical properties of water.

Materials & methods

Study Area

The Western Ghats of India is characterized by a chain of highlands running along the Western edge of the country with series of valleys and dense forest. Western Ghats endowed with several waterfalls that are often referred for it is gigantism and elegance. The study area was framed with nine different waterfalls and its surroundings located on Western Ghats of Tamil Nadu, India (Map.1). The sampled locations are Kovai Kutralam, Law's Falls, Moyar Falls, Pykara Falls, Chinna Suruli Falls, Kumbakarai Falls, Sokkanalai Falls, Kutladampatti Falls and Suruli Falls. All the sampled locations were chosen based on random selection. The details about each location was given in Table.1.

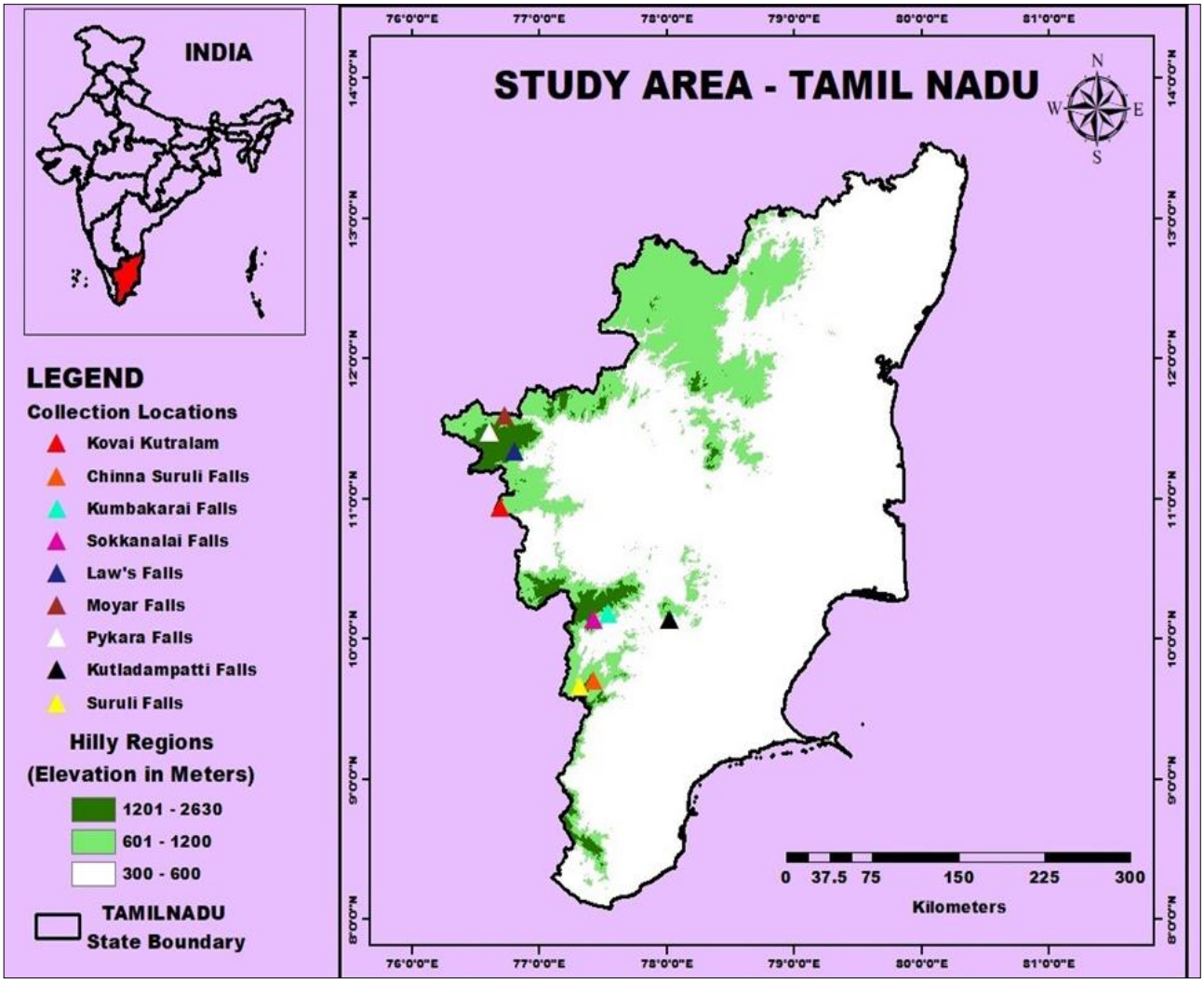
Table 1: Details of Collection Locations

S. No	Name of the Location	District	Taluk	Nearest known area	Geo – Coordinates		Elevation (MASL)
					Latitude (N)	Longitude (E)	
1	Kovai Kutralam.	Coimbatore	Coimbatore South	Aalandurai	10.93907°	76.68927°	519
2	Law's Falls.	The Nilgiris	Coonoor	Coonoor	11.33231°	76.80087°	1512
3	Moyar Falls.	The Nilgiris	Ooty	Masinagudi	11.59400°	76.71765°	791
4	Pykara Falls.	The Nilgiris	Ooty	Pykara	11.47277°	76.60413°	2037
5	Chinna Suruli Falls.	Theni	Aandipatti	Kadamalaigundu	09.70000°	77.41660°	596
6	Kumbakarai Falls.	Theni	Periyakulam	Periyakulam	10.18005°	77.53055°	512
7	Sokkanalai Falls.	Theni	Bodi	Periyakulam	10.13210°	77.42086°	774
8	Kutladampatti Falls.	Madurai	Vaadipatti	Vaadipatti	10.13371°	78.01776°	478
9	Suruli Falls.	Theni	Uthamapalayam	Cumbum	09.65496°	77.30896°	529
N – North; E – **East** & **MASL** – Meters above sea level							

Table 2: List of algal species documented in study area.

S. No	Name of the Species	S. No	Name of the Species
CYANOPHYCEAE		33	*Tetraedron regulare* var. *granulata* Prescott.
1	*Aphanocapsa banaresense* Bharadwaja.	34	*Ankistrodesmus falcatus* var. *Acicularis* (A. Br.) G. S West.
2	*Aphanothece castagnei* (Breb.) Rabenh.	35	*Westella botryoides* (W. West) De Wildeman.
3	*Aphanothece naegelii* Wartm.	36	*Pediastrum duplex* Meyen.
4	*Chroococcus pallidus* Nageli.	37	*Pediastrum tetras* var. *apiculatum* Fritsch.
5	*Chroococcus turgidus* (Kuetz.) Nageli.	38	*Crucigenia tetrapedia* (Kirch.) W. & W.
6	*Gloeocapsa crepidinum* Thuret.	39	*Desmodesmus armatus* (Chodat) Hegew.
7	*Gloeocapsa nigrenscens* Nageli.	40	*Desmodesmus opoliensis* Richter.
8	*Gloeothece linearis* Nageli.	41	*Scenedesmus acumintus* (Largerh.) Chod.
9	*Merismopedia tenuissima* Lemm.	42	*Scenedesmus acutiformis* Schoreder.
10	*Microcystis flos - aquae* Wittr.	43	*Scenedesmus bijugatus* (Turpin) Kutz.
11	*Synechocystis crassa* Woronich.	44	*Scenedesmus carinatus* (Lemm.) Chod.
12	*Arthospira jenneri* Stizenb ex Gomont.	45	*Scenedesmus dimorphus* Kutz.
13	*Lyngbya ceylanica* Wille.	46	*Scenedesmus longus* var. *brevispina* G.M.Smith.
14	*Lyngbya confervoides* Ag.	47	*Scenedesmus longus* var. *minutus* G.M.Smith.
15	*Lyngbya laxespiralis* Skuja.	48	*Scenedesmus obliqus* (Turpin) Kütz.
16	*Oscillatoria acuminata* Gomont.	49	*Scenedesmus obtusus* Meyen.
17	*Oscillatoria curviceps* Ag.	50	*Scenedesmus smithii* Teiling.
18	*Oscillatoria perornata* Skuja.	51	*Ulothrix subconstricata* G. S. West
19	*Oscillatoria vizagapatensis* Rao, C.B.	52	*Uronema africanum* Borge.
20	*Phormidium ambiguum* Gomont.	53	*Microspora crassior* Hazen.
21	*Phormidium ambiguum* var. *major* Lammermann.	54	*Microspora floccosa* Thuret.
22	*Phormidium purpurascenhs* (Kutz) Gomont.	55	*Microspora stagnorum* Lagerheim.
23	*Anabaena doliolum* Bharadwaja.	56	*Cladophora glomerata* (Linn.)Kutz.
24	*Anabaena laxa* (Rabenh) Born *et* Flah.	57	*Rhizoclonium hookeri* Kutz.
25	*Anabaena naviculoides* Bory.	58	*Oedogonium brittonii* Tiff.
26	*Nostoc calcicola* Breb.	59	*Oedogonium subareolattum* Tiffany.
27	*Nostoc humifusum* Carm *ex* Born *et* Flah.	60	*Spirogyra jogensis* Iyengar.
28	*Nostoc rivulare* Kuetz. *ex* Born. *et* Flah.	61	*Spirogyra pellucida* (Hassall.)Kutz.
CHLOROPHYCEAE		62	*Zygnema pectinattum* (Vaucher) C. Agardh.
29	*Gonium pectorale* Muller.	63	*Closterium dianae* var. *arcuatum* (Breb.) Rabenh.
30	*Chlorella vulgaris* Benyerinck.	64	*Closterium monilferum* (Bory) Her.
31	*Tetraedron minimum* (A. Br.) Hansg.	65	*Cosmarium blytii* Wille.
32	*Tetraedron muticum* (A. Br.) Hansg.	66	*Cosmarium cyllicum* Turner
67	*Cosmarium inane* Turner.	97	*Pinnularia brevicostata* Cleve.
68	*Cosmarium mansangense* W. & W.	98	*Pinnularia gibba* Ehernb.
69	*Cosmarium microsphinctum* var. *majus* Roy & Biss.	99	*Pinnularia nodosa* (Ehrenb.) W. Smith.
70	*Cosmarium pachdermum* Lundell.	100	*Sellaphora pupula* (Kutz.) Mereschkowsky.
71	*Cosmarium polygonnum.* (Nageli) W. Archer.	101	*Amphora bigbba* Grun.
72	*Cosmarium trachypleurum* Lund.	102	*Amphora ovalis* Kutz.
73	*Staurastrum bieneanum* var.*ellipticum* wille.	103	*Amphora proteus* Greg.
74	*Staurastrum paradoxum* mayen.	104	*Cymbella affinis* Kutz.
BACILLARIOPHYCEAE		105	*Cymbella ehrenbergii* Kutz.
75	*Cyclotella glomerata* H. Bachm.	106	*Cymbella tumida* Breb.
76	*Melosira granulata* var. *angustissima* O. Mull.	107	*Nitzschia obtusa* W. Smith.
77	*Fragilaria capucina* Desmazie.rs.	108	*Nitzschia parvula* W. Smith.
78	*Fragilaria fonticola* Hust.	109	*Nitzschia sociablilis* Hust.
79	*Subsilicea fragilarioides* Von Stock & Reimann.	110	*Surirella nervosa* (A.S.) May.
80	*Gramatophora undulata* Ehrenb	EUGLENOPHYCEAE	

81	*Synedra dorsventralis* O. Mull.	111	*Euglena gracilis* Kelbs.
82	*Tabellaria fenstrata* (Lyngb) Kutz.	112	*Euglena lepocincloides* Drez.
83	*Tabellaria flocculosa* (Roth.) Kutz.	113	*Euglena mutabilis* var. l*efevrei* Chadef.
84	*Achnanthes brevipes* Agardh.	114	*Euglena sanguinea* Ehrenb.
85	*Achnanthes inflata* Kutz.	115	*Phacus unguis* Pochm.
86	*Calonies bacillum* (Grun.) Cleve.	116	*Astasia vacuolata* Skuja.
87	*Craticula buderi* (Hustedt) Lange - Bretlot.		RHODOPHYCEAE
88	*Diploneis puella* (Schum.) Cleve.	117	*Audouinella indica* (Raikwar) Garbary
89	*Diploneis subovalis* Cleve.		
90	*Gamphonema clevei* Fricke.		
91	*Gamphonema olivaceum* (Lyngb.) Kutz.		
92	*Gamphonema parvulum* Kutz.		
93	*Gyrosigma acuminatum* (Kutz.) Rabenh.		
94	*Navicula heimansioides* Lange - Bertalot.		
95	*Navicula towutiensis* Cholnoky.		
96	*Navicula viridis* Kutz.		



Map 1: Showing the study area

The location map of the study area is created using the software ArcGIS 10.3 Version 10.3.0.4322 © 1999 – 2012 Esri Inc.

Phycological analysis

Planktonic, benthic, epiphytic and terrestrial algae were collected from the study area between March 2014 and December 2017. Algal species were collected in different spots around the waterfalls including top of the waterfall, water flowing area, water diverging points, waterfall – pool, tourists bath area, water dripping on rock, wet rock, rock slits, rock pool, running water, standing water, soil and plants etc., The samples were studied under light microscope for their morphological characters such as color, size and shape of the cell, nature of the filament etc., Photomicrographs were taken with the help of HOVERLABS Research Photo Microscopic Unit. One portion of the sample was fixed in 4% formalin for microscopic studies and the other portion was used for isolation and culturing of algae. Identification was carried out with standard monographs and various published research articles (Desikachary, 1959 & 1986; Desikachary

et. al., 1990; Krishnamurthy, 1954 & 2000 and Philipose, 1967 & 1988) [12, 13, 14, 22, 23, 32, 33].

Diversity indices such as Simpson's Diversity index; Shannon Wiener index and Evenness were calculated to measure the species abundance, richness and evenness of the study area respectively. The formula are used as follows,

$$\text{Simpson's Index } (\mathbf{D}) = \mathbf{1} - \frac{\sum \mathbf{n(n-1)}}{\mathbf{N\,(N-1)}}$$

$$\text{Shannon's index } (\mathbf{H}) = -\sum_{i=1}^{S} \boldsymbol{pi\ In\ pi}$$

$$\text{Evenness } (\mathbf{E_H}) = \mathbf{H} / \mathbf{H_{max}}$$

Physico – chemical analysis

Three litters of water samples were collected from all the nine waterfalls with clean sterile plastic container. The analysis of water samples were carried out in Tamil Nadu Water Supply and Drainage Board (TWAD) laboratory, Chennai using standard analytical procedures IS 10500: 2012; IS 456: 2000; APHA (2012) [4] prescribed by Bureau of Indian Standard (2012) approved by Ministry of Drinking Water and Sanitation, Government of India. The physico – chemical parameters includes, appearance, odor, electrical conductivity, turbidity, total dissolved solids, ambient temperature, water temperature, pH, calcium, sodium, nitrate, chloride, fluoride, phosphate, sulphate, BOD and COD.

Karl Pearson correlation co efficient was carried out to find out the relationship of water quality parameters with each other. The Pearson correlation was calculated by using software SPSS 15.0 for windows evaluation version © SPSS Inc. 1989 – 2006.

Result & discussion

Phycological analysis

A total number of one hundred and seventeen algal species belonging to five classes namely Cyanophyceae, Chlorophyceae, Bacillariophyceae, Euglenophyceae and Rhodophyceae were recorded in nine different waterfalls from the Western Ghats of Tamil Nadu, India (Table.2). The most abundant algal species documented from the study area was given in PLATE 1 and PLATE 3. It was recorded that class Cyanophyceae with 14 genera and 28 species; Chlorophyceae with 20 genera and 46 species; Bacillariophyceae with 20 genera and 36 species; Euglenophyceae with 3 genera and 6 species and Rhodophyceae with single species. Class Chlorophyceae – 39.32% found to be dominant class followed by class Bacillariophyceae – 30.77% and Cyanophyceae – 23.94% (Fig.1).

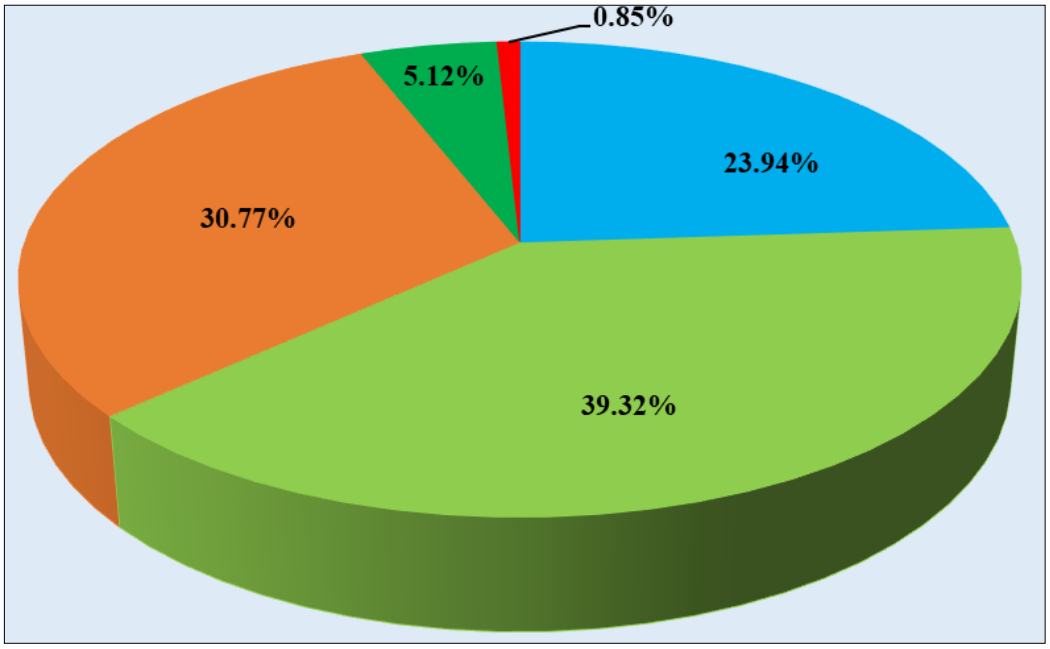
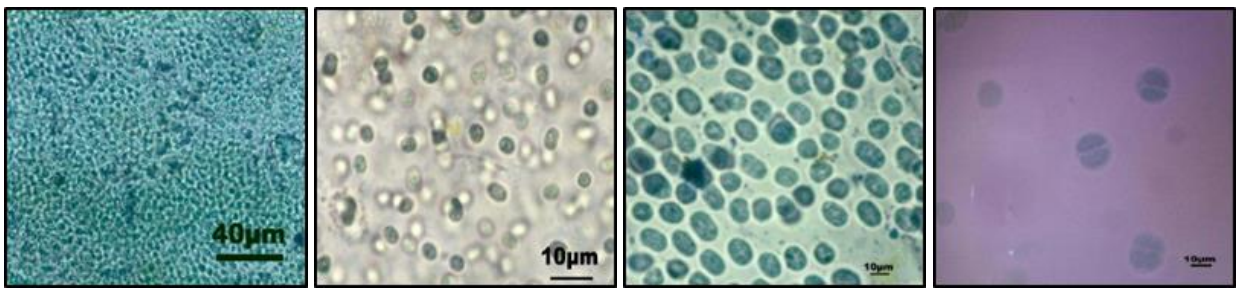
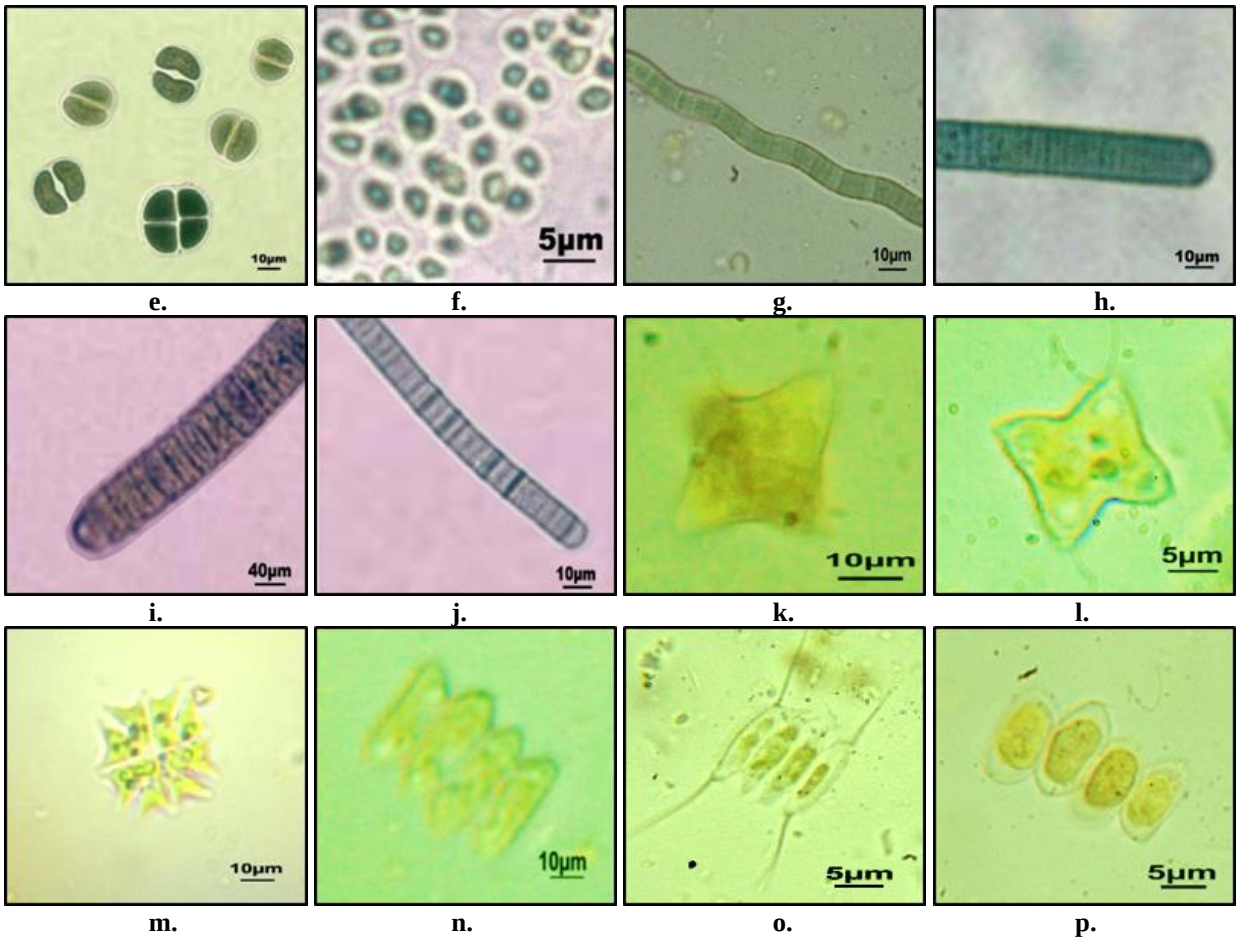


Fig 1: Class wise distribution of algae in the study area

Plate 1

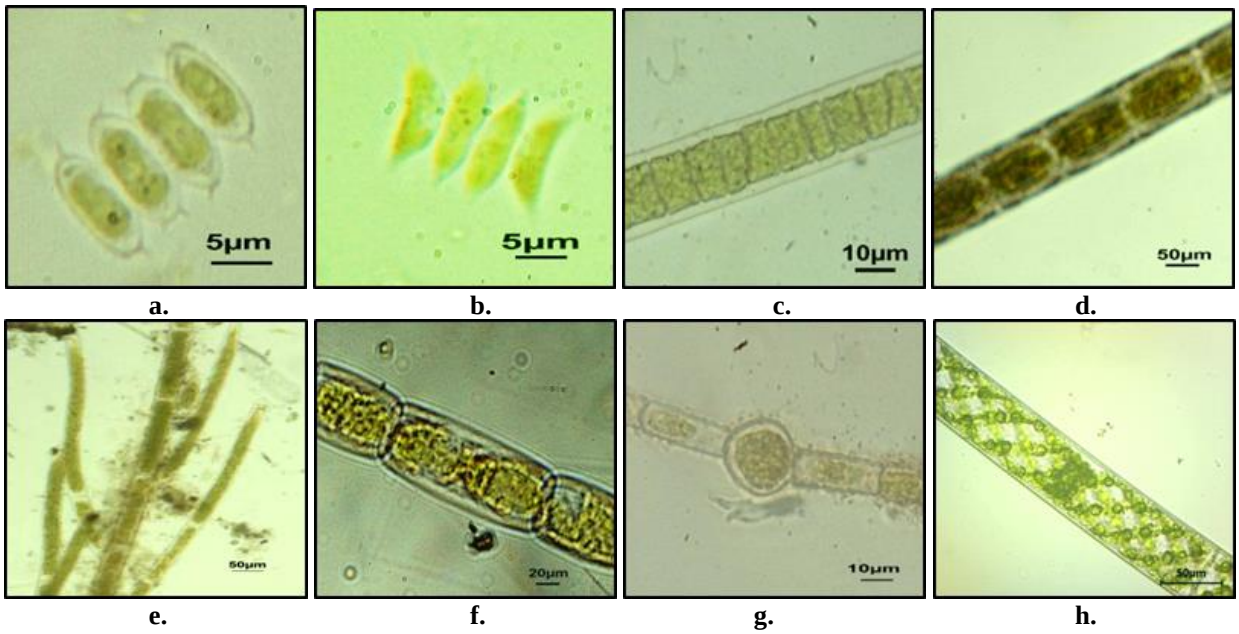


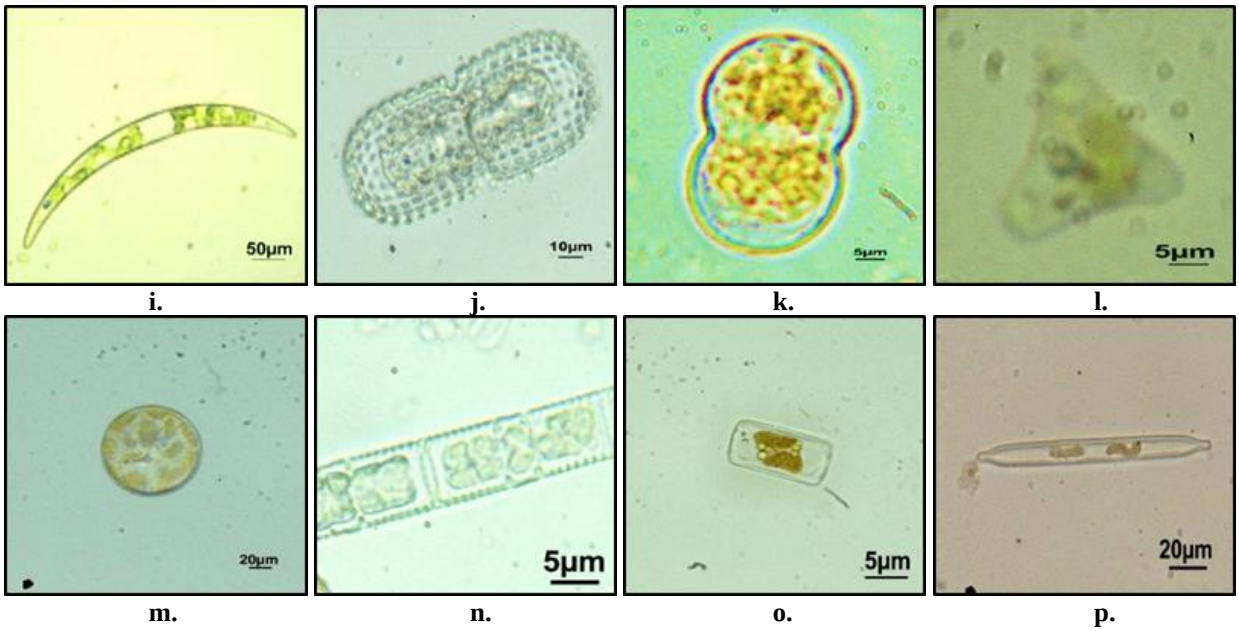
a. **b.** **c.** **d.**



a – *Aphanocapsa banaresense* Bharadwaja; **b –** *Aphanothece castagnei* (Breb.) Rabenh; **c –** *Aphanotheceae naegelii* Wartm; **d –** *Chroococcus pallidus* Nageli; **e –** *Chroococcus turgidus* (Kuetz.) Nageli; **f –** *Gloeocapsa crepidinum* Thuret; **g –** *Arthospira jenneri* Stizenb *ex* Gomont; **h –** *Oscillatoria curviceps* Ag; **i –** *Oscillatoria perornata* Skuja; **j –** *Phormidium ambiguum* Gomont; **k –** *Tetraedron minimum* (A. Br.) Hansg; **l –** *Tetraedron regulare* var. *granulata* Prescott; **m –** *Pediastrum tetras* var. *apiculatum* Fritsch; **n –** *Scenedesmus acutiformis* Schoreder; **o –** *Scenedesmus carinatus* (Lemm.) Chod and **p –** *Scenedesmus longus* var. *brevispina* G.M. Smith.

Plate 2





a –*Scenedesmus longus* var. *minutus* G.M. Smith; **b** – *Scenedesmus obliqus* (Turpin) Kütz; **c** – *Uronema africanum* Borge; **d** – *Microspora floccosa* Thuret; **e** – *Cladophora glomerata (Linn.)Kutz*; **f** – *Rhizoclonium hookeri* Kutz; **g** – *Oedogonium subareolattum* Tiffany; **h** – *Spirogyra Pellucida* (Hassall.) Kutz; **i** – *Closterium dianae* var. *arcuatum* (Breb.) Rabenh; **j** –*Cosmarium mansangense* W. & W; **k** – *Cosmarium microsphinctum* var. *majus* Roy & Biss; **l** – *Staurastrum bieneanum* var. *ellipticum* wille; **m** – *Cyclotella glomerata* H. Bachm; **n** – *Melosira granulata* var. *angustissima* O. Mull; **o** – *Gramatophora undulata* Ehrenb and **p** – *Synedra dorsventralis* O. Mull

Thus, the order of dominance is Chlorophyceae > Bacillariophyceae > Cyanophyceae > Euglenophyceae > Rhodophyceae.

Furtherly, it was reported that the species of five classes were found under twelve orders such as Chroococcales and Nostocales of Cyanophyceae; Volvocales, Chlorococcales, Ulotrichales, Cladophorales, Oedogoniales and Conjugales of Chlorophyceae; Centrales and Pennales of Bacillariophyceae; Euglenales of Euglenophyceae and Acrochaetiales of Rhodophyceae. Maximum representation was found in order Pennales with 34 species which accounting 29.05% of total species (Fig.2)

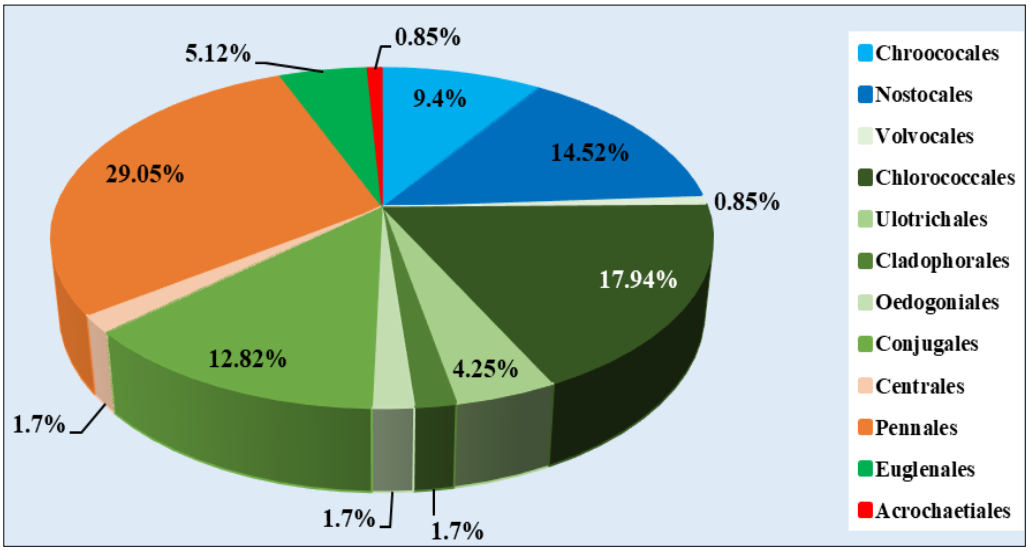
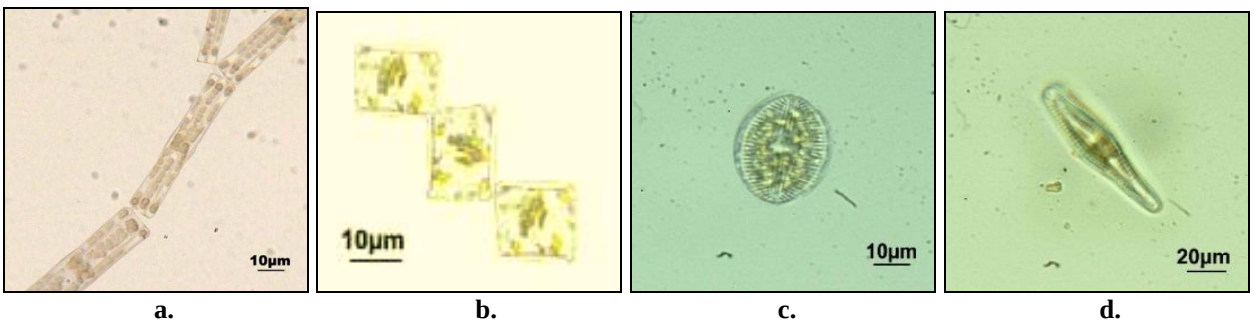
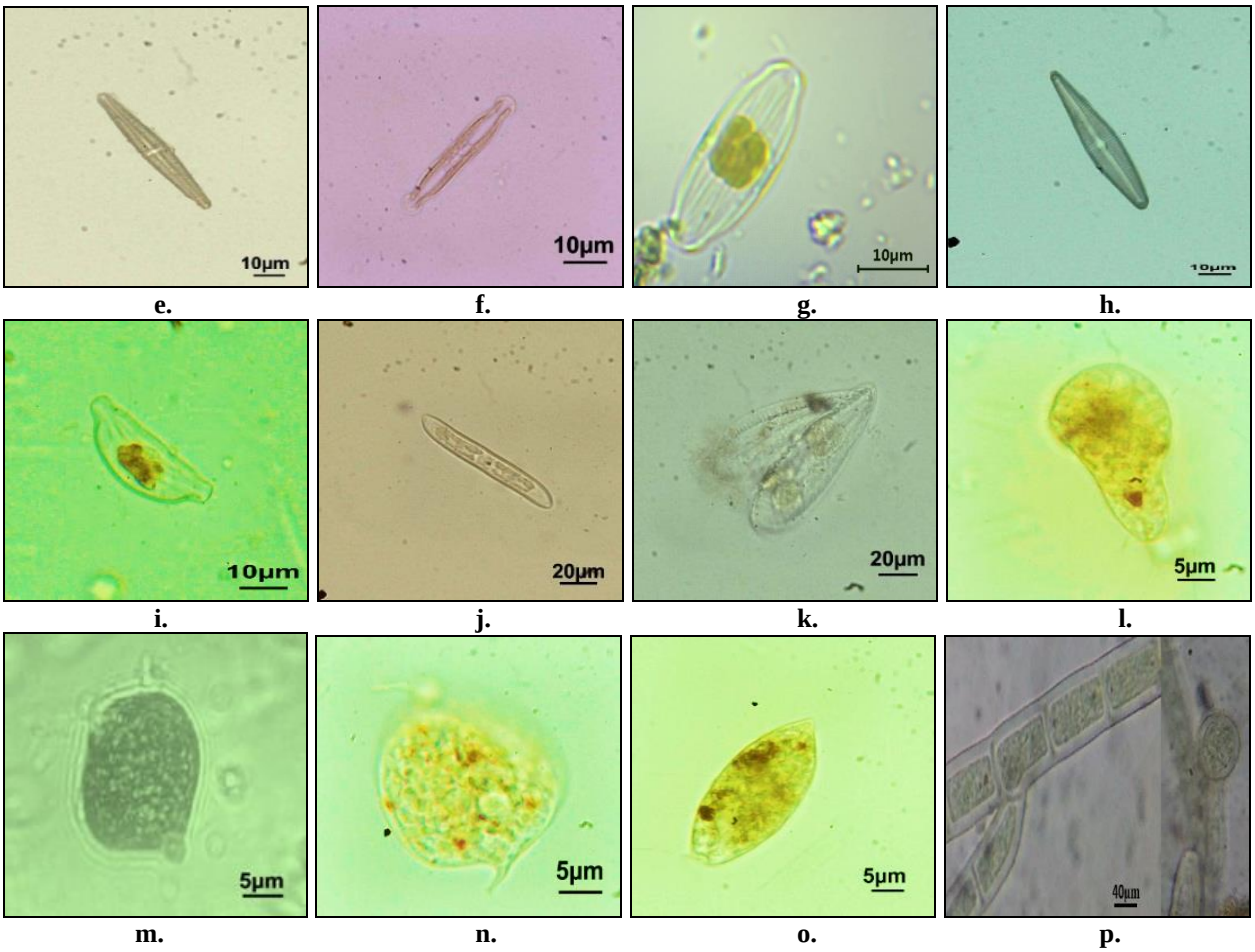


Fig 2: Distribution of Algae under each order in the study area

Plate 3





a – *Tabellaria fenstrata (Lyngb) Kutz*; **b –** *Tabellaria flocculosa* (Roth.) Kutz; **c –** *Diploneis subovalis* Cleve; **d –** *Gamphonema clevei* Fricke;**e –** *Navicula heimansioides* Lange – Bertalot; **f –** *Pinnularia nodosa* (Ehrenb.) W. Smith; **g –** *Amphora ovalis* Kutz; **h –** *Cymbella affinis* Kutz; ; **i –***Cymbella tumida* Breb ; **j** – *Nitzschia sociablilis* Hust; k **–** *Surirella nervosa* (A.S.) May; **l –** *Euglena lepocincloides* Drez; ; **m –** *Euglena sanguinea* Ehrenb; **n –** *Phacus unguis* Pochm; **o –** *Astasia vacuolata* Skuja and **p –** *Audouinella indica* (Raikwar) Garbary

The class Chlorophyceae has traditionally been taken to include almost all the green algae (Bold and Wynne, 1985) [7]. A total number of 20 genera and 46 species were reported in class Chlorophyceae was found dominant from the study area. Similarly, the dominant of Chlorophycean members were documented in several research *viz.* temple tanks of Kerala state (Arulmurugan *et. al.*, 2010) [5]; Kwan Phayao (Lake) of Thailand (Kanthana and Siripen, 2012) [21] and selected freshwater ponds in Mahe – Puducherry Union Territory (Harsha *et. al.*, 2017) [17].

Six orders namely Volvocales (1 species), Chlorococcales (21 species), Ulotrichales (5 species), Cladophorales (2 species), Oedogoniales (2 species) and Conjugales (15 species) were reported from this class. Members of Chlorophyceae plays significant role in freshwater ecosystem as most of them considered to be ecologically important (Palmer, 1980) [31]. The Chlorophycean genera reported from the study area includes *Gonium, Chlorella, Tetraedron, Ankistrodesmus, Westella, Pediastrum, Crucigenia, Desmodesmus, Scenedesmus, Ulothrix, Uronema, Microspora, Cladophora, Rhizoclonium, Oedogonium, Spirogyra, Zygnema, Closterium, Cosmarium* and *Staurastrum*.

Chlorophycean algae considered as fundamental in the food chain due to they are direct or indirect food sources for various heterotrophic forms (Rao, 1975) [35]. Among the genera, genus *Scenedesmus* was documented with maximum 10 species and genus *Cosmarium* with 8 species. Genera *Tetraedron* and *Microspora*, were reported with three species each. Wherein genera *Pediastrum, Desmodesmus, Oedogonium, Spirogyra, Closterium,* and *Staurastrum* was found with 2 species each. The highest diversity of Chlorophycean members directly related to good health of water (Descy, 1987) [11].

It was found that Bacillariophyceae as second dominant class from the study area with 20 genera and 36 species. Similarly, diatoms was found second dominant class in Umiew River of Meghalaya (Hygina, 2013) [19]; Tamraparni river of Tamil Nadu (Priya, *et. al.*, 2016) [34]; and Biodiversity survey of Hawaiian freshwater algae (Alison *et. al.*, 2014) [2]. It is revealed that two orders namely Centrales (2 species) and Pennales (34 species) of Bacillariophyceae were reported from the study area. While the genera includes *Cyclotella, Melosira, Fragilaria, Subsilicea, Gramatophora, Synedra, Tabellaria, Achnanthes, Calonies, Craticula, Diploneis, Gamphonema, Gyrosigma, Navicula, Pinnularia, Sellaphora, Amphora, Cymbella, Nitzschia* and *Surirella.*

Occurrence of more diatoms in the waterbodies may be due to deposition of silica in the water which helped in the formation of frustule (Wetzel and Likens, 2006) [45]. During this investigation six genera namely *Gamphonema, Navicula, Pinnularia, Amphora, Cymbella* and *Nitzschia* were documented with three species each. Wherein *Cyclotella, Melosira, Subsilicea, Gramatophora, Synedra, Calonies, Craticula, Gyrosigma, Sellaphora,* and *Surirella*

were found with single species each. Diatoms has received attention of many researcher for water quality monitoring program (Acs, *et. al.*, 2004) [1].

Most of the BGA are capable of living in the soil and other terrestrial environs, where they play significant role in the functional processes of ecosystems (Whitton, 1992) [46]. Class Cyanophyceae was found third dominant class from the study area with 14 genera and 28 species. Members of BGA was found under two orders namely Chroococcales (11 species) and Nostocales (17 species). Genus *Oscillatoria* was recorded with 4 species wherein genera *Lyngbya*, *Phormidium*, *Anabaena* and *Nostoc* was reported with 3 species each. Blue greens are found to be source for many biotechnologically applied commercial products (Richmond, 1990) [36]. Occasionally BGA produce substances that are injurious to biodiversity of water bodies as well as human health. The correlation between toxicity produced by algae and human health effects were reviewed by Nick *et. al* (2020) [28].

Members of Euglenophyceae occurs mostly in freshwater habitats as well as in contaminated water too (Buetow, 1968) [9]. In class Euglenophyceae a total number of six species were reported from the study area. Furtherly it was revealed that three genera namely *Euglena*, *Phacus* and *Astasia* were documented under order Euglenales. Among which genus *Euglena* was found with 4 species. Presence of less number of Euglenoids is often indicated to low organic pollution (Hosmani sss Rhodophyceae was recorded with single species – *Audouinella indica*. In the entire study area this was the only red alga recorded from Kumbakarai Falls. Biological indices are a useful way to summarize data even for the people with little biological information and expertise (Norris, 1995) [29]. The diversity indices such as Simpsons Diversity index; Shannon – Wiener index and Evenness were calculated (Fig. 3).

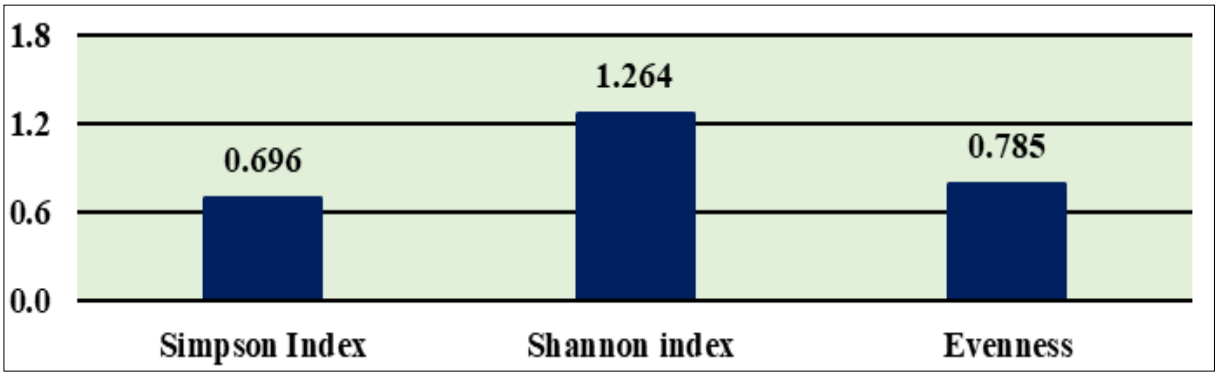


Fig 3: Diversity Indices

The results shows that the study has moderate level in terms of species abundance, richness and evenness.

Physico – chemical analysis

Biological diversity and physico – chemical properties contribute the healthiness of an aquatic ecosystem (Venkatesharaju *et. al.*, 2010) [42]. The result of physico – chemical analysis of water sample from the study area was given in Table.3. The water quality is generally assessed by its appearance, odor and other parameters. Fluctuation among water quality parameters can be vary and subject to increase *i.e.* Electrical Conductivity – higher concentration of ions; Turbidity – many suspended particles; Total Dissolved Solids – salinity of water and Temperature – sampling time and seasonal effect (Tiwari *et. al.*, 2004) [40]. The results of physical parameters of water sample from the study area such as Electrical Conductivity, Turbidity, Total Dissolved Solids, Ambient Temperature and Water Temperature showed greater variation. Due to anthropogenic activities the physico – chemical properties of water may altered that leads to affects the planktonic flora (Mishra *et. al.*, 1992) [24].

Table 3: Result of Physico – Chemical Analysis from the study area

Physical Examination								
S. No	**Name of the Location**	**APR**	**ODR**	**EC**	**TBTY**	**TDS**	**AT**	**WT**
1	Kovai Kutralam	Clear	Agreeable	114	3.8	80	29	26
2	Law's Falls	Turbid	Agreeable	282	16.4	197	24	22
3	Moyar Falls	Turbid	Agreeable	122	13.4	85	29	24
4	Pykara Falls	Clear	Agreeable	245	4.4	172	21	19
5	Chinna Suruli Falls	Clear	Agreeable	108	2	76	31	25
6	Kumbakarai Falls	Clear	Agreeable	93	2.8	65	29	26
7	Sokkanalai Falls	Clear	Agreeable	87	2.4	61	29	24
8	Kutladampatti Falls	Clear	Agreeable	140	0.5	98	32	28
9	Suruli Falls	Clear	Agreeable	61	2.6	43	27	23

Chemical Examination											
S. No	**Name of the Location**	**pH**	**Ca**	**Na**	**No_3**	**Cl**	**F**	**PO_4**	**SO_4**	**BOD**	**COD**
1	Kovai Kutralam	7.14	7	14	6	16	0.11	0.68	4	4.8	12.8
2	Law's Falls	7.09	23	29	18	33	0.24	0.2	8	3.8	13.1
3	Moyar Falls	7.53	13	12	4	13	0.12	0.09	2	4	10.2
4	Pykara Falls	7.06	32	11	2	52	0.24	0.06	10	4.4	11.2
5	Chinna Suruli Falls	6.87	14	5	2	14	0.11	0.17	2	3	14.2
6	Kumbakarai Falls	6.82	10	5	2	14	0.11	0.17	2	3	12.8

7	Sokkanalai Falls	6.78	12	5	2	12	0.11	0.16	2	2	12.6
8	Kutladampatti Falls	8.24	12	18	0	19	0.5	0.1	1	3	12.4
9	Suruli Falls	6.66	6	5	3	11	0.08	0	2	2	9.6

APR – Appearance**, ODR** – Odor**, EC** – Electric Conductivity (Micro mhos/cm), **TBTY** – Turbidity (NT Units), **TDS** – Total Dissolved Solids (mg/L), **AT** – Ambient Temperature (˚C), **WT –** Water Temperature (˚C), **Ca** – Calcium (mg/L), **Na** – Sodium (mg/L), **No3**- Nitrate (mg/L), **Cl** – Chloride (mg/L), **F** – Fluride (mg/L), **PO4** – Phosphate (mg/L), **PO4** – Sulphate (mg/L), **BOD** – Biological Oxygen Demand (mg/L), **COD** - Chemical Oxygen Demand (mg/L).

Wider variation among chemical parameter of the water sample from the study area was also seen *viz*. pH, Calcium, Sodium, Nitrate, Chlorides, Fluoride, Phosphate, Sulphate, BOD and COD. The concentration of chemical ions is due to industrial discharge, organic waste (Chintan and Vasant, 2014) [10]. Physico-chemical parameter of the water sample incase exceeds the permissible amount will leads into ecological and human health concerns *i.e.* TDS – disorders of alimentary canal, respiratory system, nervous system, coronary system besides, causing miscarriage and cancer; pH – lethal to fish; Calcium – influencing growth of fish; Sodium – cardiovascular diseases and toxemia in women; Nitrate – toxicity in drinking water; Chloride – hypertension, risk for stroke, osteoporosis, renal stones and asthma; Fluoride – bone problem; Sulphate – gastrointestinal irritation and BOD & COD – Indicate the organic load (Ndimele, 2012) [27].

All the physico – chemical parameters were analyzed with Karl Pearson correlation co-efficient. The result revealed that significance was documented in Total Dissolved Solids with Calcium, Sodium, Chloride and Sulphate; Electric Conductivity with Total Dissolved Solids, Calcium, Sodium, Chloride and Sulphate; Sulphate with Electric Conductivity, Total Dissolved Solids, Calcium and Chloride; Water Temperature with Ambient Temperature; Fluride with pH and so on. (Table. 4). Most of the parameters such as Odor, Total Dissolved Solids, pH, Calcium, Nitrate, Chloride, Fluride, Sulphate and Phosphate were found within in permissible limits recommended by WHO (1996, 2011) and BIS (2012) [6] for drinking water specifications.

Table 4: Karl Pearson correlation co-efficient

	EC	**TBTY**	**TDS**	**AT**	**WT**	**pH**	**Ca**	**Na**	**No3**	**Cl**	**F**	**PO4**	**SO4**	**BOD**	**COD**
EC	1														
TBTY	.592	1													
TDS	1.000**	.588	1												
AT	-.713*	-.412	-.715*	1											
WT	-.581	-.391	-.583	.930**	1										
pH	.200	.066	.198	.337	.438	1									
Ca	.875**	.363	.877**	-.775*	-.756*	.043	1								
Na	.773*	.660	.770*	-.284	-.086	.500	.391	1							
No3	.645	.806**	.642	-.436	-.313	-.121	.290	.775*	1						
Cl	.871**	.251	.873**	-.838**	-.729*	.070	.940**	.432	.276	1					
F	.437	-.072	.437	.065	.218	.834**	.313	.567	-.031	.371	1				
PO4	-.043	-.019	-.043	.178	.335	-.019	-.285	.197	.246	-.139	-.191	1			
SO4	.877**	.428	.878**	-.922**	-.810**	-.156	.869**	.482	.521	.933**	.112	.045	1		
BOD	.560	.418	.560	-.362	-.209	.285	.426	.486	.328	.527	.110	.546	.583	1	
COD	.153	-.142	.153	.303	.359	-.028	.056	.162	.187	-.024	.118	.445	-.003	.077	1

EC – Electric Conductivity, TBTY – Turbidity, TDS – Total Dissolved Solids, AT – Ambient Temperature, WT – Water Temperature, Ca – Calcium, Na – Sodium, No3- Nitrate, Cl – Chloride, F – Fluride, PO4 – Phosphate, SO4 – Sulphate, BOD – Biological Oxygen Demand, COD - Chemical Oxygen Demand.

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

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

Conclusion

Biodiversity research can provide an opportunity to know the different algal forms in their natural habitat and their numbers. Though there were few findings made earlier in the waterfalls, this is the first ever attempt to explore the algal diversity in waterfalls located exclusively on Western Ghats of the state along with its physico – chemical properties of water. The dominance of Chlorophyceae and Bacillariophyceae and lower level of Cyanophyceae and Euglenophyceae in the study area indicate the healthiness of water body. The physico – chemical analysis results were also affirm the same. Most of the physico- chemical parameters of the study area was found within the permissible limit as prescribed WHO.

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