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A preliminary studies on diversity of algae from ubbalamadugu waterfalls, Eastern Ghats, Andhra Pradesh, India

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Abstract
A preliminary study was carried out between June 2018 and May 2019 to document the diversity of algae from Ubbalamadagu waterfalls of Chittoor district, Andhra Pradesh state, India. This scenic waterfall familiarly known as "*Tada Falls*" that falls from *Kaambakam* hills of Eastern Ghats at the height of 330 ft. A total number of 69 algae taxa belongs to three different classes Chlorophyceae, Bacillariophyceae and Cyanophyceae were documented during the study period. The study was dominated by class Chlorophyceae with thirty one taxa (45%) followed by Bacillariophyceae with twenty six taxa (38%) and Cyanophyceae with twelve taxa (17%). Diversity indices of the study area was found significant, in which the species abundance, richness and evenness were calculated. The Simpson Diversity Index, Shannon Wiener Index and evenness index of the study area is 0.624, 1.031 and 0.938 respectively. The study further revealed that this lotic ecosystem provides suitable environment for the luxuriant growth of algae. Studies on biodiversity provides an opportunity to know the different species in their natural habitat. Such studies also give a wide scope for the choice of other potential species which are available plenty in nature. Since only very few genera have so far been used in industry.

Keywords: Algae, diversity, tada falls, lotic ecosystem

Introduction

Algae defined as simple chlorophyll bearing organisms, where no differentiation on roots, stems and leaves. Fritsch (1935) [10] "Father of Phycology" was of the opinion that "Unless purely artificial limits are drawn the designation alga must include all holophytic organisms (as well as their numerous colorless derivatives) that fail to reach the higher level of differentiation characteristic of the archegoniate plants." They are distinguished on the basis of their photosynthetic pigments, food reserves and the number, position and fine structural details of flagella in the motile stages (Krishnamurthy, 2000) [19]. They play a vital role in maintaining proper equilibrium of both biotic and abiotic components of the aquatic ecosystem. Algae are usually omnipresent in nature, predominantly found in aquatic (fresh water and marine) as well terrestrial environment. Although they can tolerate extreme environment such as snow, desert soils and hot springs (Lee, 2008) [21]. Schlichting (1975) [36] highlighted that algae can also inhabit on unusual environment including surfaces of plants (epiphytic); leaves (epiphyllous); barks (corticolous); animals (epizoic); rock (lithophyte); metals (epimetallous) and so on.

Algae considered to be an important biotic factor that plays significant role in environment as well human economy. Algae are notable constituent of aquatic based food chain since they serve as primary producer (Browder *et al.* 1994) [6]. They play pivotal role in terms of reducing global warming as they perform roughly 50% of the overall photosynthesis on earth. (John, 1994) [15]. They are instrumental in converting solar energy and utilize the energy for the production of biomass through photosynthesis. Biomass of algae can be utilized for various source of food, feed, pharmaceuticals and fuel (Vonshak, 1990) [43]. Algal biofuel considered to be efficient, renewable and sustainable for aviation industry (Dagget, 2008) [7]. Essential human needs are fulfilled by many microalgae as they are important sources in the production of vitamins, minerals, proteins, polyunsaturated fatty acids (PUFA), antioxidants, and so on (Pulz and Gross, 2004) [30].

Studies on biodiversity help us to understand the fundamental for conservation and management of nature (Villasenor *et al*., 2007) [42]. Documentation of algal diversity in the waterfalls of Indian sub – continent is meticulously done by various phycologists including Gandhi (1960, 1966 & 1970) [11, 12, 13]– Jog Falls, Karnataka; Sankaran (1984 & 2005) [34, 35] – Anamalai hills, Tamil Nadu; Jose and Patel (1990) [16] – Athirapilly waterfalls, Kerala; Narwade *et. al*., (2014) [24] – Sahastrakund waterfalls of Maharashtra; Meeravali *et. al*., (2015) [23] Batrepalli waterfalls, Andhra Pradesh; Palanivel and Uma Rani (2016) [39] Kodiveri waterfalls, Tamil Nadu; Uma Rani *et. al*., (2016) [39] Theerthamalai falls, Tamil Nadu; Bhakta and Adhikary (2014) [5] Waterfalls of Eastern and North-Eastern Region of India and Palanivel (2018) [29] Waterfall of Eastern and Western Ghats of Tamil Nadu.

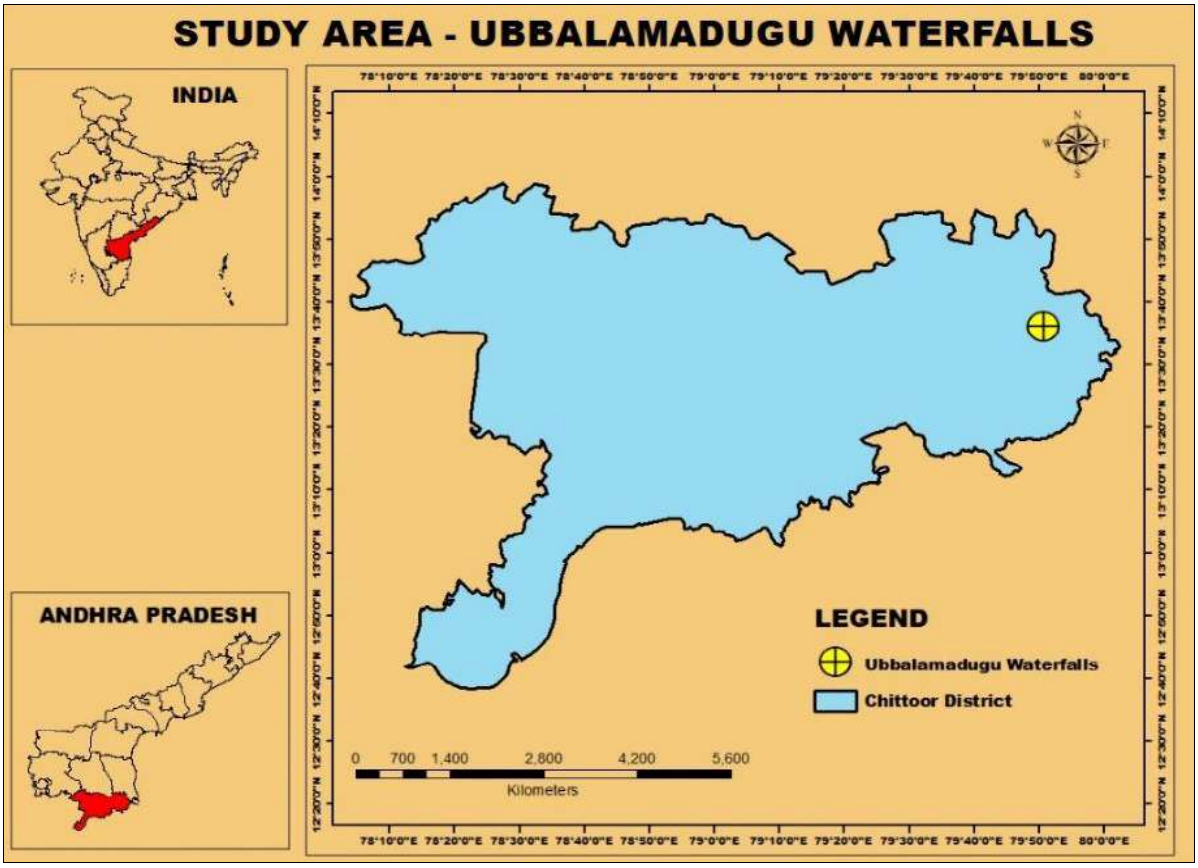
Although there is a paucity of information about Ubbalamadagu waterfalls (Andhra Pradesh) on diversity of algae. Hence this study seeks to fill the lacuna in knowledge and focused on conservation and management of natural sources.

Materials & methods

Study area

The study area Ubbalamadagu waterfalls is located inside the forest "*Siddulaiah Kona*" of Chittoor district, Andhra Pradesh state, India (Map.1). This scenic fall familiarly known as "*Tada Falls*" which is falls from *Kaambakam* hills, Eastern Ghats at the height of 330 ft. This location is found at 12 km distance from local village–*Varadaiahpalem* of Andhra Pradesh and 80 km from Chennai city of Tamil Nadu.

Tada falls is very familiar among the residents of Chittoor and Chennai (state capital of Tamil Nadu, India) for trekking and recreation purpose. This nature's beauty also functioned as "bio-hub" for various floral and faunal diversity. The location map of the study area was created using the software ArcGIS 10.3 Version 10.3.0.4322 © 1999 – 2012 Esri Inc.



Map 1: Study area

Collection, Observation and Identification

The study was carried out between June 2018 and May 2019 to document the diversity of algae from Ubbalamadagu waterfalls as primary objective. The collection of algal samples were focused with all the nook and corner of the waterfalls mainly lentic and lotic as well as terrestrial habitats. Planktonic, benthic, epiphytic and terrestrial algae from the study area was collected in sterile plastic bottles based on random selection.

The samples were brought to the laboratory. 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. 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. Identification was carried out with standard monographs and various published research articles (Krishnamurthy, 1954 [18]; Desikachary 1959 [8]; Philipose 1967 [30]; Prescott, 1982 [32] and Anand 1998 [3]).

Diversity Analysis

To analyze and evaluate the level of diversity from study area, the diversity indices such as Simpson's Diversity index; Wiener index and Evenness were derived. Simpson's index (D) - species abundance; Shannon's Wiener Index (H) –species richness and Evenness (E_H) – measurement of evenness was calculated.

The formulas are used as follows,

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

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

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

Results & discussions

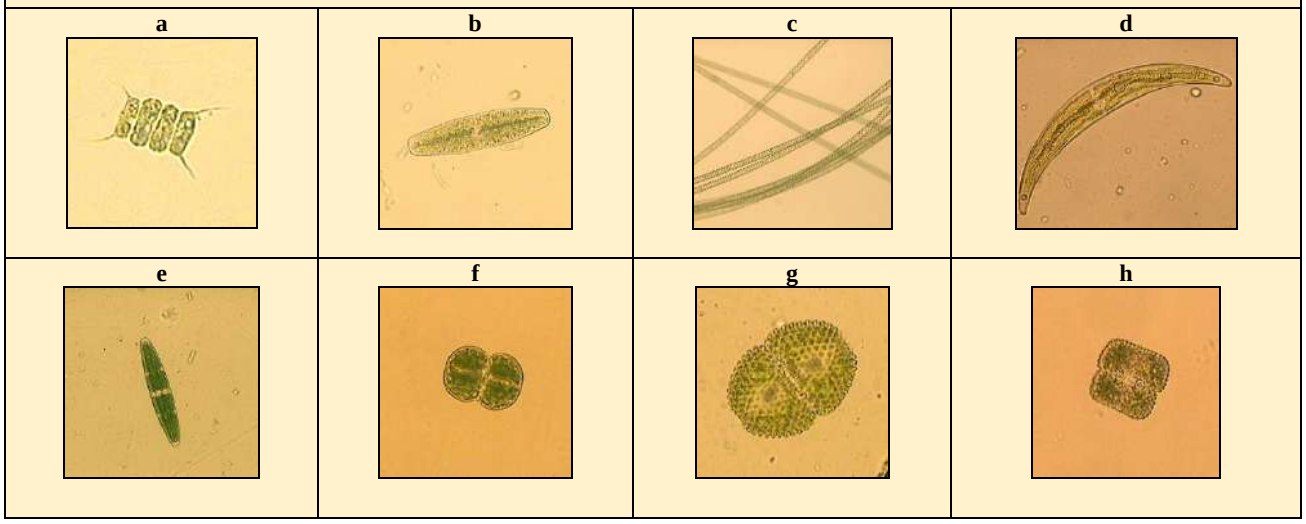
A total number of 69 algae taxa belongs to three different classes Chlorophyceae, Bacillariophyceae and Cyanophyceae were reported from Ubbalamadagu waterfalls, of Chittoor district, Andhra Pradesh, India (Table 1). Mahendra and Anand, (2008) [22] mentioned that the presence of Cyanophyceae, Chlorophyceae, Bacillariophyceae, and Euglenophyceae algae are common to freshwater environments.

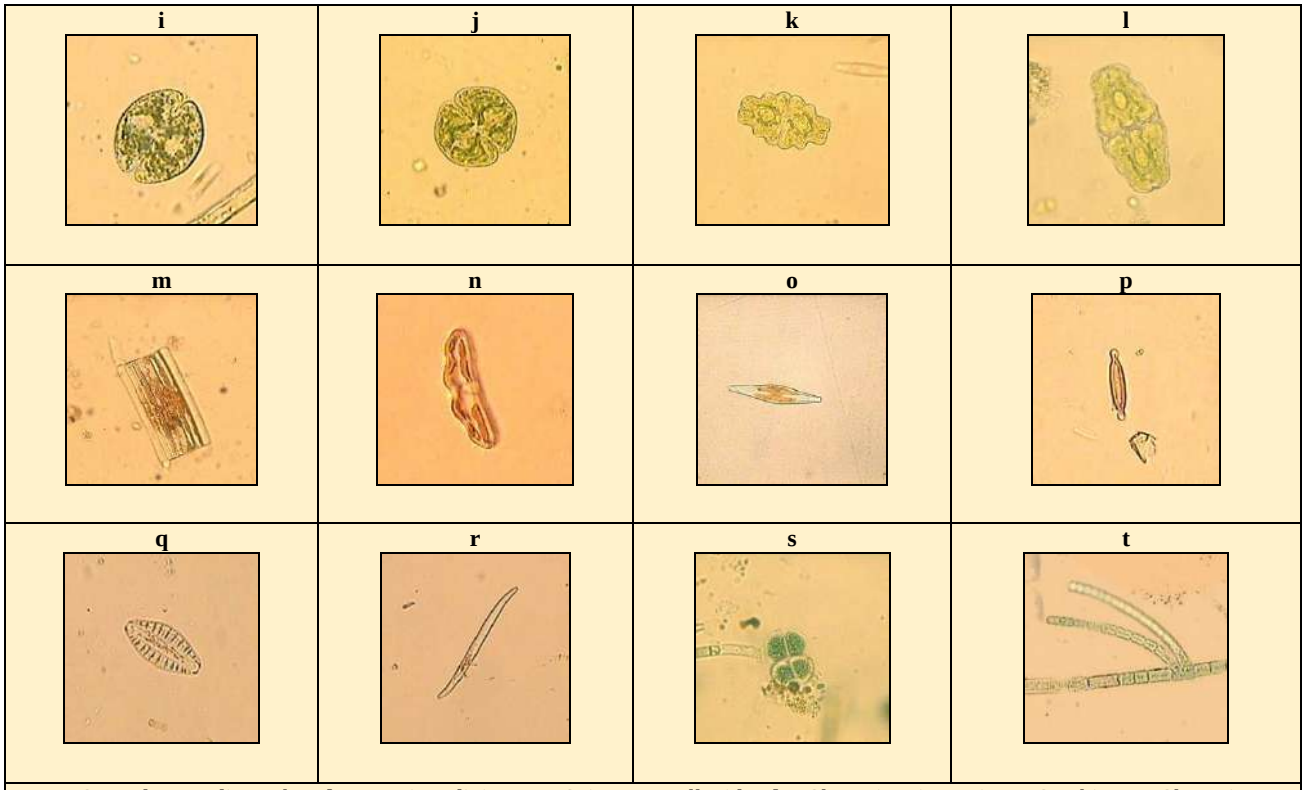
Table 1: Algal Diversity from the Study Area

S. No	Name of the Alga	S. No	Name of the Alga
Chlorophyceae		35	*Tabellaria fenstrata*
1	*Tetraedron muticum.*	36	*Eunotia fogedii*
2	*Desmodesmus abundans*	37	*Eunotia mucophila*
3	*Scenedesmus armatus*	38	*Eunotia naegelii*
4	*Scenedesmus dimorphus*	39	*Eunotia sioliopsis*
5	*Scenedesmus perforatus*	40	*Eunotia tropica*
6	*Uronema elongatum*	41	*Himantidium minus*
7	*Netrium digitus* var. *constrictum*	42	*Diadesmis confervaceae*
8	*Spirogyra pellucida*	43	*Diploneis subovalis*
9	*Closterium calosporum*	44	*Gamphonema clevei*
10	*Closterium jenneri* var. *cynthia*	45	*Gamphonema montanum* var. *genium*
11	*Closterium libilulla* var. *intermedium*	46	*Navicula viridis*
12	*Closterium navicula*	47	*Pinnularia braunii*
13	*Closterium peracerosum* var. *elegans*	48	*Pinnularia brevicostata*
14	*Closterium setaceum*	49	*Pinnularia platycephala*
15	*Cosmarium abbreviatum*	50	*Pinnularia stomatophora*
16	*Cosmarium connatum*	51	*Pinnularia viridis*
17	*Cosmarium contractum* var. *ellipsodium*	52	*Cymbella affinis*
18	*Cosmarium decoratum*	53	*Cymbella turgida*
19	*Cosmarium hammeri*	54	*Rhopalodia gibberula*
20	*Cosmarium maculatum*	55	*Nitzschia parvula*
21	*Cosmarium margaritiferum*	56	*Stenopterobia intermedia*
22	*Cosmarium obsoletum*	57	*Surirella capronii*
23	*Cosmarium ornatum*	**Cyanophyceae**	
24	*Cosmarium quadrum*	58	*Chroococcus turgidus*
25	*Cosmarium subauriculatum*	59	*Merismopedia elegans* var. *major*
26	*Euastrum anastum*	60	*Lyngbya lutea*
27	*Euastrum gemmatum*	61	*Lyngbya salina*
28	*Euastrum gnathophorum* var. *bulbosum*	62	*Microcoleus lacustris*
29	*Pleurotaenium trabecula*	63	*Oscillatoria formosa*
30	*Staurastrum recurvatum*	64	*Oscillatoria irrigua*
31	*Xanthidium antilopaeum*	65	*Oscillatoria jasorvensis*
Bacillariophyceae		66	*Phormidium autumnale*
32	*Fragilaria brevistriata.*	67	*Cylindrospermum musicola* var.*longispora*
33	*Fragilaria fusa*	68	*Syctonema schmidlei*
34	*Fragilaria virescens*	69	*Haplosiphon weleitschii*

The abundant algae taxa from the study area were displayed in Plate I. The results revealed that maximum number of species was recorded from the class Chlorophyceae with 12 genera and 31 taxa followed by Bacillariophyceae was documented with 14 genera and 26 taxa and Cyanophyceae with 9 genera and 12 taxa. Similarly, the dominance of Chlorophycean members were reported from Waterfalls of Eastern and North-Eastern Region of India (Bhakta and Adhikary, 2014) [5] and Sahastrakund Waterfall of Maharashtra Narwade *et al*. (2014) [24]. Whereas dominance of Bacillariophyceae was documented from Savica Waterfall at Slovenia by Krivograd and Vrhovšek (2003) [20]. The percentage composition of the study was dominated by Chlorophyceae - 45% followed by Bacillariophyceae– 38% and Cyanophyceae – 17% (Fig. 1). Hence the order of dominance from the study area is as follows,

Plate I





a – *Scenedesmus dimorphus*; **b –** *Netrium digitus*; **c –** *Spirogyra pellucida*; **d** – *Closterium jenneri* var. *Cynthia*; **e** – *Closterium navicular*; **f –** *Cosmarium connatum*; **g –** *Cosmarium decoratum*; **h** – *Cosmarium quadrum*; **i** – *Cosmarium obsoletum*;**j** – *Cosmarium subauriculatum*; **k** – *Euastrum gemmatum*; **l** – *Euastrum gnathophorum* var. *bulbosum*; **m** – *Fragilaria brevistriata*; **n** – *Eunotia tropica*; **o** – *Gamphonema clevei*; **p** – *Pinnularia braunii*; **q** – *Rhopalodia gibberula*; **r** – *Stenopterobia intermedia*; **s** – *Chroococcus turgidus* and **t** – *Haplosiphon weleitschii*.

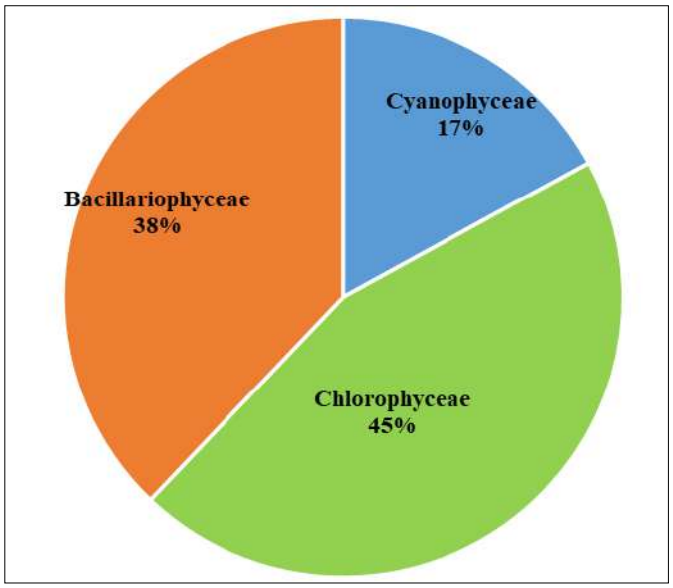


Fig 1

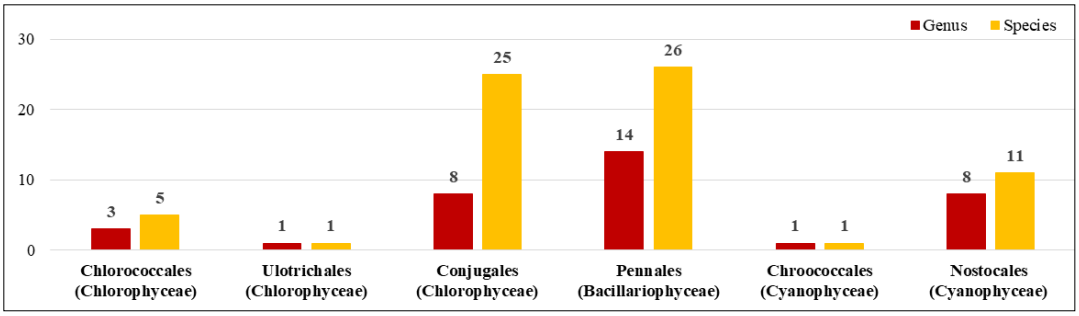


Fig 2

Chlorophyceae > Bacillariophyceae > Cyanophyceae

The taxonomic categorization of algal diversity from the study area was illustrated in Figure.2. This furtherly revealed that, the study area was dominated by the order Conjugales of Chlorophyceae with 25 taxa (36%) and Pennales of Bacillariophyceae was found dominant with 26 taxa (Fig. 3). The predominance of Chlorophyceae and Bacillariophyceae from the study area indicate the healthiness of water body (Palanivel, 2018) [29]

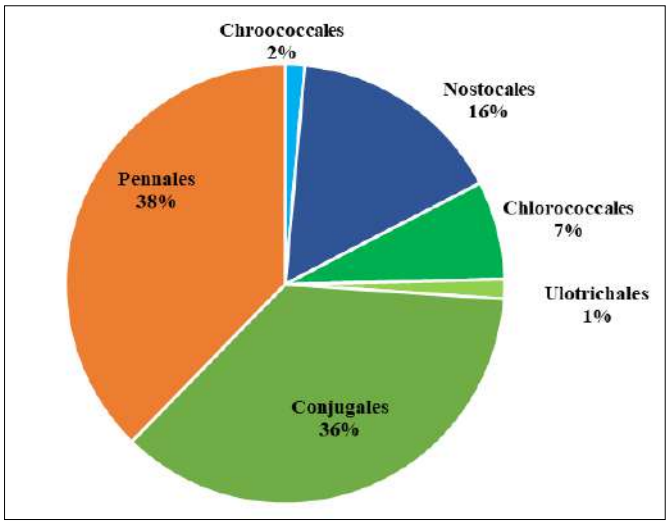


Fig 3

The dominance of Chlorophycean members from the waterbodies is directly related to good health of water (Descy, 1987) [9]. In the present study the class Chlorophyceae was recorded with 12 genera such as *Tetraedron, Desmodesmus, Scenedesmus, Uronema, Netrium, Spirogyra, Closterium, Cosmarium, Euastrum, Pleurotaenium, Staurastrum* and *Xanthidium*. Among which genus *Cosmarium* was found dominant with 11 taxa followed by *Closterium* with 6 taxa (Fig. 4a). Chlorophyceae play important role in freshwater ecosystem since they are found to be ecologically significant (Palmer, 1980) [27].

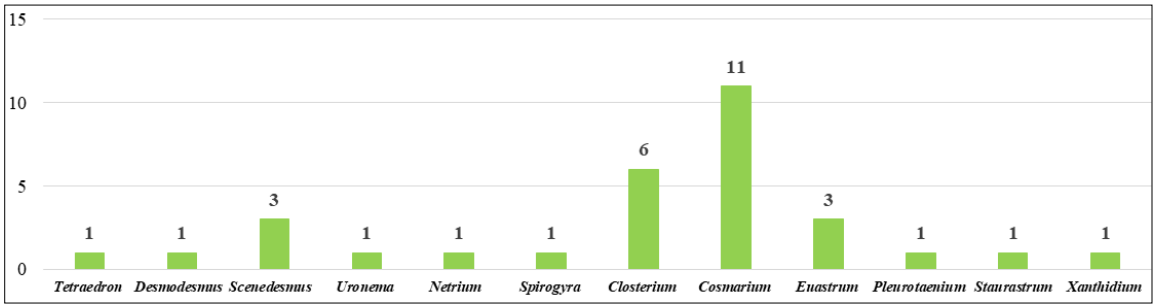


Fig 4a: Chlorophyceae

The members of bacillariophyceae are ecologically important organisms that play significant role in aquatic habitats such as primary producer (Urban *et. al.*, 1992) [40]; biogeochemical cycle (Tréguer *et. al.*, 1995) [38] and global carbon fixation (Battarbee *et. al.*, 2001) [4]. Maximum number of genera from the study area was reported in class Bacillariophyceae with 14 genera which includes *Fragilaria, Tabellaria, Eunotia, Himantidium, Diadesmis, Diploneis, Gamphonema, Navicula, Pinnularia, Cymbella, Rhopalodia, Nitzschia, Stenopterobia* and *Surirella*. Genera *Eunotia* and *Pinnularia* was found dominant among members of bacillariophyceae with 5 taxa each (Fig.4b). Diatoms are frequently employed in biomonitoring studies and they served as bio-indicators of organic pollutions of aquatic environments (Hosmani and Bharathi, 1980 [14]; Sudhakar *et al*., 1994 [37]; Acs, *et. al.*, 2004) [2].

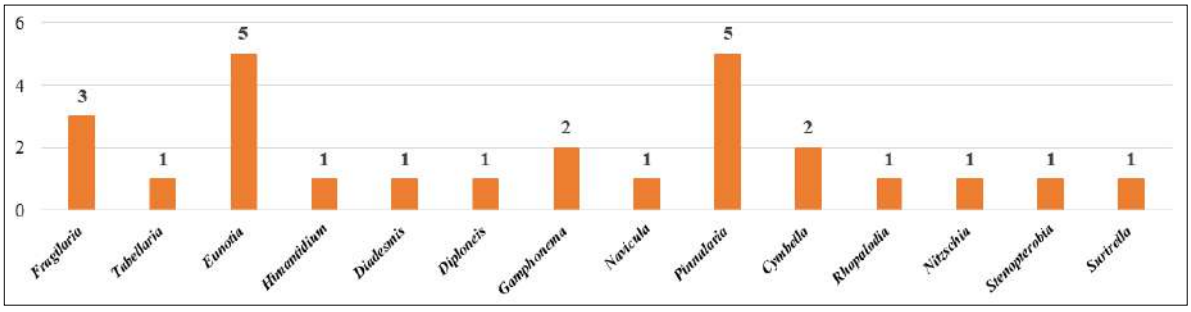


Fig 4b: Bacillariophyceae

Blue green algae are considered to be important biotechnological tool that are the source of many commercial products (Richmond, 1990). A total number of 9 genera was found in class Cyanophyceae, they are *Chroococcus, Merismopedia, Lyngbya, Microcoleus, Oscillatoria, Phormidium, Cylindrospermum, Syctonema* and *Haplosiphon.* Maximum number of 3 taxa was reported in genus *Oscillatoria* (Fig.4c). Most of the cyanobacteria play vital role in nitrogen fixation process (Fay, 1992) due to this they also served to be potential bio-fertilizer (Venkataraman, 1972 [41]; Kannaiyan, 1985) [17].

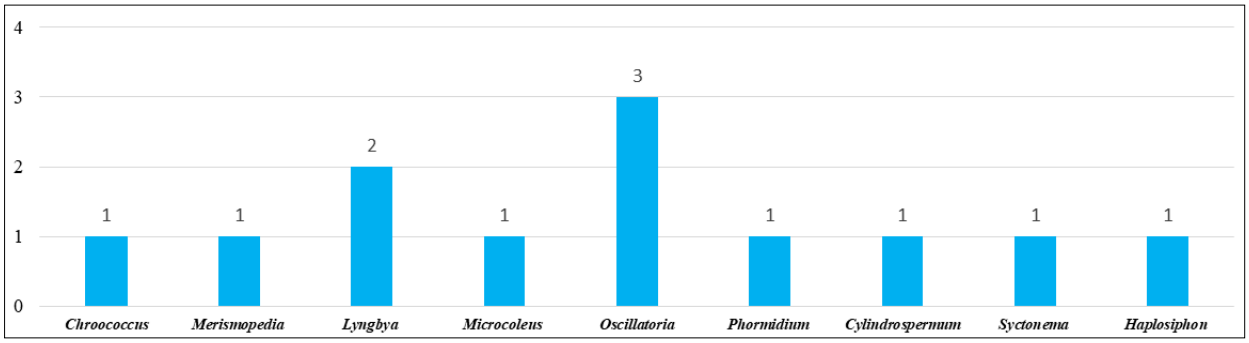


Fig 4c: Cyanophyceae

Previously dominance of genera including *Scenedesmus, Spirogyra, Closterium, Cosmarium, Eunotia, Diploneis, Gomphonema, Navicula, Cymbella, Rhopalodia, Nitzschia, Chroococcus, Oscillatoria* and *Lyngbya* were reported in various waterfalls including Madhabkunda waterfall of Bangladesh (Abdul, 2008) [1]; Agbokim Waterfalls in Nigeria (Offem and Ikpi, 2012) [26]; Waterfalls of Eastern and North-Eastern Region of India (Bhakta and Adhikary, 2014) [5]; Sahastrakund Waterfalls of Maharashtra (Narwade *et al.*, 2014) [24]; Batrepalli Waterfalls of Andhra Pradesh (Meeravali *et al.* 2015) [23].

In the present study the value of Simpson's Diversity Index is 0.624. The results showed that the study area has greater level of diversity (Fig.5). Shannon's Wiener Index is calculated to find out the species richness and species evenness as overall index of diversity. The value of Shannon's Wiener index also ranges between 0 and 1. Higher the value greater the species diversity. In this study the Shannon Wiener Index and evenness index is 1.031 and 0.938 respectively were derived (Fig.5). The present study divulges that diversity indices such as Simpson, Shannon – Wiener and Evenness showed moderate level of species abundance, richness and evenness in study area. These biological indices are very useful to present the data even for the people with little biological information and expertise (Norris, 1995) [25].

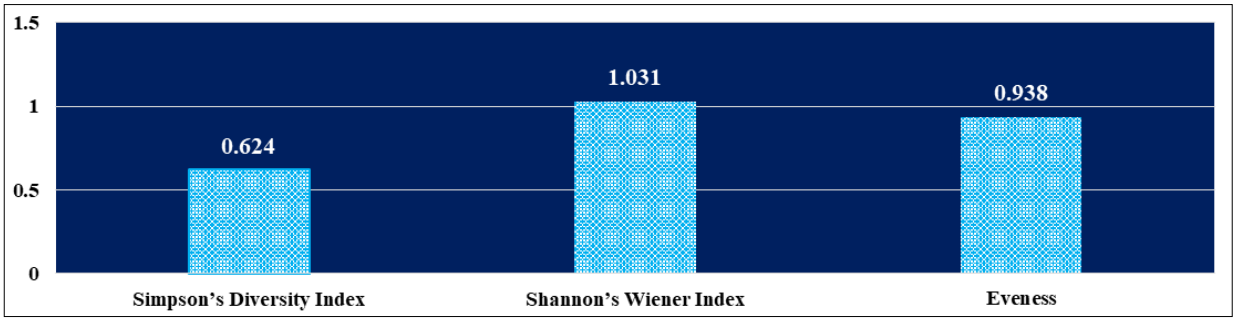


Fig 5

Ubbalamadagu waterfalls ("*Tada Falls*") of Chittoor district, Andhra Pradesh, India has been studied for its algal flora for the first time. This studies on biodiversity provides an opportunity to know the different species in their natural habitat. This kind of study also divulges that documentation of algal diversity is found substantial and can be used in conservation and management of aquatic ecosystems.

Conclusion

The study was conducted to explore the diversity of algae from the Ubbalamadagu waterfalls of Chittoor district, Andhra Pradesh state, India. It can be concluded that a total number of 69 algae taxa belongs to three different classes Chlorophyceae, Bacillariophyceae and Cyanophyceae were documented during the study period. This investigation further divulges that Chlorophyceae was found dominant class followed by Bacillariophyceae and Cyanophyceae. The species abundance, richness and evenness of the study area were calculated which was found also significant. This type of research can provide an opportunity to know the different algal forms in their natural habitat. Only very few resources have 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. Moreover, diversity studies may laydown the path to conservation of nature and natural resources.

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