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Depiction of Microalgal Diversity in Gundur Lake, Tiruchirappalli District, Tamil Nadu, South India

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ABSTRACT

The biodiversity study was executed to reveal the microalgal population in the Gundur Lake located in the southern part of Tiruchirappalli in Tamil Nadu, India. The samples were collected from the six chosen sites in the lake as algal mats and plankton samples during March 2014. In total, 81 species were reported which includes 35 species belongs to Chlorophyta, 9 species belongs to Bacillariophyta and 37 species belongs to Cyanophyta. Eight microalgal genera such as *Pediastrum, Cosmarium rhophalodia, Microcystis, Chroococcus, Oscillatoria, Scytonema* and *Gloeotrichia* were found predominant in the lake. Physicochemical parameters of the water samples were also analysed to evaluate the algal diversity. The suitable trophic condition and eutrophic nature of the lake favoured the algal dominance and bloom formation.

Key words: Microalgae, biodiversity, Gundur Lake, algal dominance, bloom formation

INTRODUCTION

Microalgae are a group of photosynthetic algae which are very tiny in size to be able to identify only under microscopy. It also includes the photosynthetic bacterial taxon cyanobacteria (formerly known as Blue-Green Algae) closely related to the Chloroplasts of the algae and plants. Microalgae are of economic importance as they produce many biotechnological and industrial products (Wijffels *et al.*, 2013; Borowitzka, 2013; Praveenkumar *et al.*, 2012a, b; Milledge, 2011; Thajuddin and Subramanian, 2005). Microalgae are dominant group of organism in aquatic habitats with sufficient nutrients and light available for their luxury and they tend to form a bloom by a single or a few species when there are eutrophication and favourable conditions (Anahas *et al.*, 2013; Zhang *et al.*, 2012; Oliver *et al.*, 2012; Tang *et al.*, 2010; Muthukumar *et al.*, 2007; Thajuddin and Subramanian, 2002). They are one of the major primary producers in the freshwater aquatic ecosystem such as rivers, lakes, ponds and canals.

Tiruchirappalli district representing the central region of Tamil Nadu in Tropical India is rich in fresh water aquatic ecosystems enriched by the river Cauvery delta and warm condition. Tiruchirappalli city is bifurcated by passage of River Cauvery and there are numerous canals exist around the delta region of the river to store water in reservoirs nearby the city. Mayanur barrier canal is one such canal used to collect the river water in the reservoir lake known as "Gundur Lake". Gundur Lake is a biotic rich water reservoir (except in summer) located in the Trichy-Pudukkottai Highway.

Although, a few reports have been made on the Cladocerans and bacterial count in the lake, there was no extensive study made on microalgal population and its diversity (Sivakami *et al*., 2011; Mohideen *et al*., 2007). The present study was aimed to collect the microalgal and water samples from the Gundur Lake and to identify the microalgal species to make a record on its diversity and compare them with the physico-chemical parameters evaluated from the sampling sites of the lake.

MATERIALS AND METHODS

Sampling area: Gundur Lake is located in southern outer region of Tiruchirappalli city near Gundur with exact Latitude -10°43' N and Longitude -78°43' E in the central Tamil Nadu (Fig. 1).

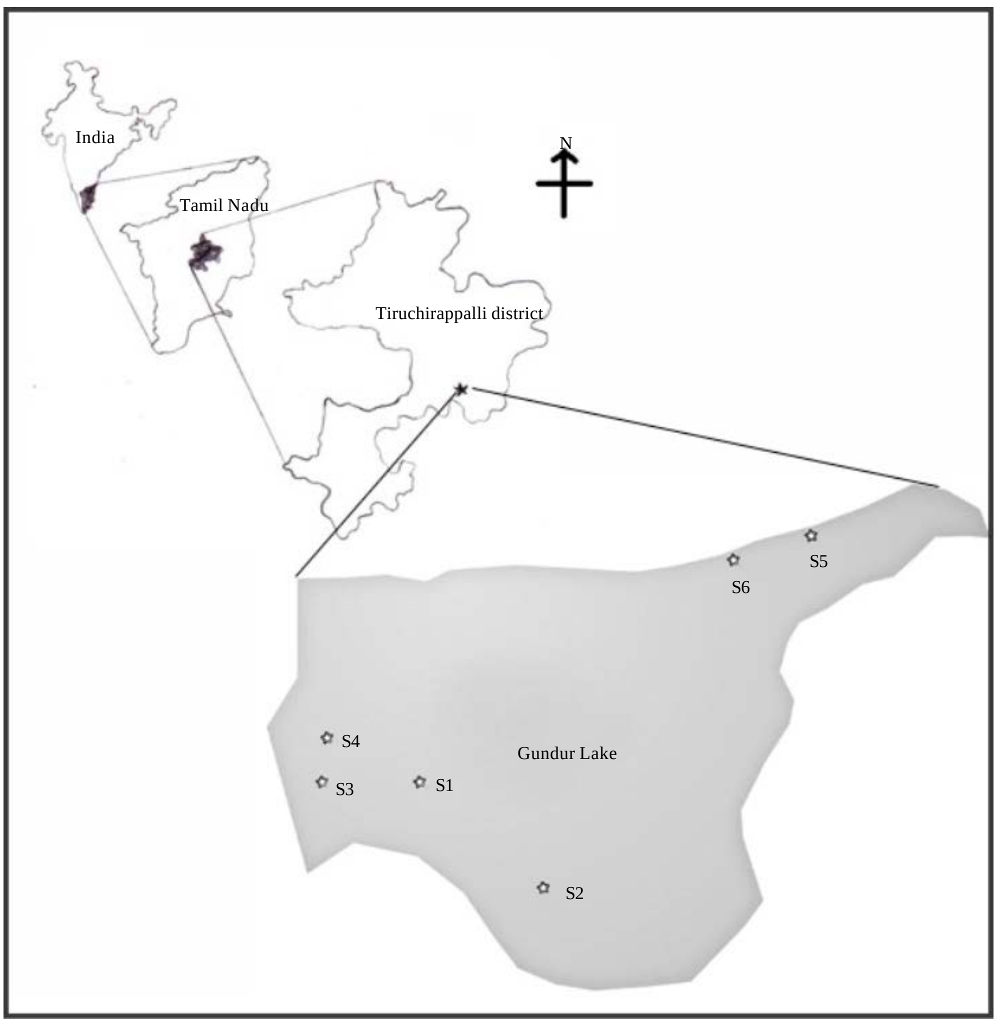

Fig. 1: Map showing the location of sampling sites in Gundur Lake

The lake extends approximately 1 km^2 and its average annual rainfall was drastically reduced to <600 mm in recent years. The reservoir is used for rice crop irrigation and drinking water needs of the surrounding places.

The samples were collected during early summer (March 2014) from the Gundur Lake and the sampling sites were spotted out sporadically based on the location and intense microalgal population. The samples were collected as algal mats, plankton epiphytic microalgae. The samples were rinsed and tilted with water using plankton nets with mesh size of 200 and 42 μm sequentially. Phytoplankton and epiphytic microalgal samples were collected from the residues of the 42 μm mesh sized filtration. Parts of the samples were fixed using the formalin (5%) for biodiversity analysis and other parts were used for the isolation and purification of microalgae for the further application studies.

Physico-chemical parameters: Water samples from each sampling site were also collected to study the physico-chemical parameters. Physical parameters namely temperature, pH, light intensity in terms of photon intensity (μmol m^{-2} sec^{-1}) using quantum meter (Spectrum Technologies, USA) and in terms of illumination (Lux) using illuminometer (Kyoritsu, Japan) were collected at the sampling sites. Chemical parameters such as calcium, magnesium, chloride, nitrate, nitrite, Dissolved Oxygen (DO), carbonate and bicarbonate (Alkalinity) and sulphate were determined from the water samples of the sites using standard methods (APHA, 1989). The experiments were done in triplicate for each sampling sites and the average values of the chemical parameters were recorded.

Identification and cultivation: The samples collected from the sites were subjected to morphological identification based on the published reports and standard monographs (Taylor *et al*., 2007; Van Vuuren *et al*., 2006; Ling and Tyler, 1986; Philipose, 1967; Desikachary, 1959; Prescott, 1954, 1962; West and West, 1904). Microphotographs of the samples were taken using photomicroscopic system (Micros, Austria) and the biodiversity in each samples were recorded. The identified taxa were subjected to purification using BG 11 medium (Rippka *et al*., 1979), F/2 medium (Guillard, 1975; Guillard and Ryther, 1962) and Chu 10 medium (Chu, 1942).

RESULTS

In total, six sampling sites were spotted out namely S1-S6 in Gundur Lake to record the microalgal diversity. The sampling sites S1, S2, S5 and S6 were dominated by microalgae with lush growth and it was hard to see visible clear water and the sampling site S3 was dominated by a dense *Microcystis* bloom. In comparison, S4 was the deepest sample site where clear water was visible but there were no weeds but showed well distributed microalgae population. The planktonic water sample of the S4 site showed domination of unialga indicating the possibility of a bloom in successive weeks. Spherical balls of cyanobacterial dark brownish thallus (*Gloeotrichia pisum* colonies) were collected in sites S4 and S5 adhered to aquatic plants.

Under morphological observation, eight microalgal genera were found commonly in lake (at least in 3 sites) which includes two Chlorophytes namely *Pediastrum* and *Cosmarium*, one Bacillariophyte namely *Rhophalodia* and five Cyanophytes namely *Microcystis, Chroococcus, Oscillatoria, Scytonema* and *Gloeotrichia* (Table 1). In total, 81 species belongs to 35 genera were

Table 1: Diversity of microalgae in Gundur Lake observed during early summer 2014

	Sampling site in the Gundur Lake					
Organism's name	S1	S2	S3	S4	S5	S6
Chlorophyta						
Ankistrodesmus sp.	-	+	-	-	-	-
Chlorococcum humicola (Naeg.) Rabenhorst (Strain 01)	+	-	-	-	-	-
Chlorococcum humicola (Naeg.) Rabenhorst (Strain 02)	+	-	-	-	-	-
Closterium leibleinii Kütz. (Strain 01)	+	-	-	-	-	-
Closterium leibleinii Kütz. (Strain 02)	+	+	-	-	-	-
Closterium leibleinii Kütz. (Strain 03)	+	+	-	-	-	-
Coelastrum sp.	+	-	-	-	-	-
Coelastrum sphaericum Naegeli	+	-	-	-	-	-
Cosmarium meneghinii Breb.	+	-	-	-	-	-
Cosmarium Phaseolus Breb. (Strain 01)	+	-	-	-	-	-
Cosmarium Phaseolus Breb. (Strain 02)	+	-	-	-	-	-
Cosmarium sp. (Strain 01)	+	+	-	-	-	-
Cosmarium sp. (Strain 02)	+	+	-	-	-	-
Cosmarium sp. (Strain 03)	-	+	-	+	-	-
Cosmarium sp. (Strain 04)	+	+	-	-	-	-
Cosmarium sp. (Strain 05)	+	+	-	-	-	-
Dictyosphaerium sp.	-	-	-	-	+	+
Euastrum sp.	-	+	-	-	-	-
Nephrocytium obesum West and West (Strain 01)	-	+	-	-	-	-
Nephrocytium obesum West and West (Strain 02)	-	+	-	-	-	-
Oedogonium sp. (Strain 01)	+	+	-	-	-	-
Oedogonium sp. (Strain 02)	-	+	-	-	-	-
Oocystis sp.	+	-	-	-	-	-
Pandorina sp.	-	-	-	-	+	-
Pediastrum duplex var. *rotundatum* Lucks (Strain 01)	+	-	-	+	-	-
Pediastrum duplex var. *rotundatum* Lucks (Strain 02)	-	+	-	-	-	-
Pediastrum duplex var. *rotundatum* Lucks (Strain 03)	-	-	-	-	-	+
Pediastrum sp.	-	+	-	-	-	-
Scenedesmus acuminatus var *tetradesmoides* G. M. Smith	+	-	-	-	-	-
Scenedesmus arcuatus Lemmermann	-	+	-	-	-	-
Scenedesmus bernardii G. M. Smith	+	-	-	-	-	-
Staurastrum sp. (Strain 01)	+	-	-	-	-	-
Staurastrum sp. (Strain 02)	-	+	-	+	-	-
Staurastrum sp. (Strain 03)	-	+	-	-	-	-
Staurastrum sp. (Strain 04)	-	-	-	+	-	-
Bacillariophyta						
Amphipluera pellucida (Kützing) Kützing	-	+	-	-	-	-
Craticula cuspidate (Kützing) DG Mann Syn.	-	-	-	-	+	-
Navicula cupsidata (Kützing) Kützing	+	-	-	-	-	-
Frustulia saxonica Rabenhorst	-	+	-	-	-	-
Hyalodiscus sp. Ehrenberg	+	+	-	-	-	-
Navicula radiosa Kützing	+	-	-	-	-	-
Nitzschia palea (Kützing) W Smith	-	+	-	-	-	-
Rhophalodia gibba (Ehrenberg) Müller	+	+	-	-	+	-

Table 1: Continue

Organism's name	Sampling site in the Gundur Lake S1	S2	S3	S4	S5	S6
Synedra ulna Ehrenberg (Strain 01)	+	+	-	-	-	-
Synedra ulna Ehrenberg (Strain 02)	+	+	-	-	-	-
Cyanophyta						
Aphanocapsa koordersi Strom	+	-	-	-	-	-
Aphanocapsa pulchra (Kütz.) Rabenh. (Strain 01)	+	-	-	-	-	-
Aphanocapsa pulchra (Kütz.) Rabenh. (Strain 02)	+	-	-	-	-	-
Aphanocapsa roeseana De Bary (Strain 01)	-	-	-	+	-	-
Aphanocapsa roeseana De Bary (Strain 02)	+	-	-	-	-	-
Aulosira prolifica Bharadwaja	+	-	-	-	-	-
Calothrix sp.	+	-	-	-	-	-
Chroococcus minutus (Kütz.) Näg. (Strain 01)	+	+	-	-	-	-
Chroococcus minutus (Kütz.) Näg. (Strain 02)	+	-	-	-	-	-
Chroococcus turgidus (Kütz.) Näg. (Strain 01)	-	+	-	-	-	-
Chroococcus turgidus (Kütz.) Näg. (Strain 02)	+	-	-	-	+	-
Gloeocapsa rupestris Kütz.	+	-	-	-	-	-
Gloeotrichia pisum Thuret ex Born. et Flah	+	-	-	+	+	+
Lyngbya hieronymusii Lemm.	+	-	-	-	-	-
Lyngbya hieronymusii Var. *crassivaginata* Ghose (Strain 01)	+	-	-	-	-	-
Lyngbya hieronymusii Var. *crassivaginata* Ghose (Strain 02)	-	+	-	-	-	-
Merismopedia elegans A. Br.	-	+	-	-	-	-
Microcystis aeruginosa Kütz.	+	-	-	-	+	+
Microcystis robusta (Clark) Nygaard	-	-	+ + +	+	-	-
Myxosarcina spectabilis Geitler (Strain 01)	+	-	-	-	-	-
Myxosarcina spectabilis Geitler (Strain 02)	-	+	-	-	-	-
Myxosarcina spectabilis Geitler (Strain 03)	+	-	-	-	-	-
Oscillatoria paucigranata Bruhl et Biswas	+	-	-	-	-	-
Oscillatoria chalybea (Mertens) Gomont	-	-	-	-	+	-
Oscillatoria decolorata West, G.S. (Strain 01)	-	+	-	-	-	-
Oscillatoria decolorata West, G.S. (Strain 02)	+	-	-	-	-	-
Oscillatoria limosa Ag. Ex Gomont (Strain 01)	+	-	-	-	-	-
Oscillatoria limosa Ag. Ex Gomont (Strain 02)	-	+	-	-	-	-
Oscillatoria limosa Ag. Ex Gomont (Strain 03)	-	+	-	-	-	-
Oscillatoria princeps Vaucher ex Gomont	+	-	-	-	-	-
Oscillatoria sancta (Kütz.) Gomont (Strain 01)	+	-	-	-	-	-
Oscillatoria sancta (Kütz.) Gomont (Strain 02)	-	+	-	-	-	-
Phormidium abronema Skuja	+	-	-	-	-	-
Scytonema bohneri Ghose	-	+	-	-	-	-
Scytonema hofmanni Ag. Ex Born. Et Flah.	+	-	-	-	-	-
Scytonema simplex Bharadwaja	-	+	-	-	-	-
Scytonema sp.	-	-	-	+	-	-

+: Presence, -: Absence, +++: Abundance

recorded which includes 35 species (14 genera) of Chlorophyta, 9 species (8 genera) of Bacillariophyta and 37 species (13 genera) of Cyanophyta (Table 1). Desmids were the dominant Chlorophytes in the lake with more than 15 strains of *Closterium*, *Cosmarium*, *Staurastrum* and *Euastrum*. Similarly unicellular/colonial Chroococcales were the dominant Cyanophytes with more than 15 strains of *Chroococcus*, *Microcystis*, *Merismopedia*, *Aphanocapsa*, *Gloeocapsa* and *Myxosarcina* (Table 1).

Highest phytoplankton diversity was recorded in sampling site S1 with 46 species followed by S2 with 36 species and lowest phytoplankton diversity was recorded in S6 with 4 species, S4 and S5 with 8 species in each (Table 1). S3 was recorded with dense unialgal bloom of *Microcystis robusta*. Microphotographs of some of the microalga observed under microscope were documented (Plate 1 and 2).

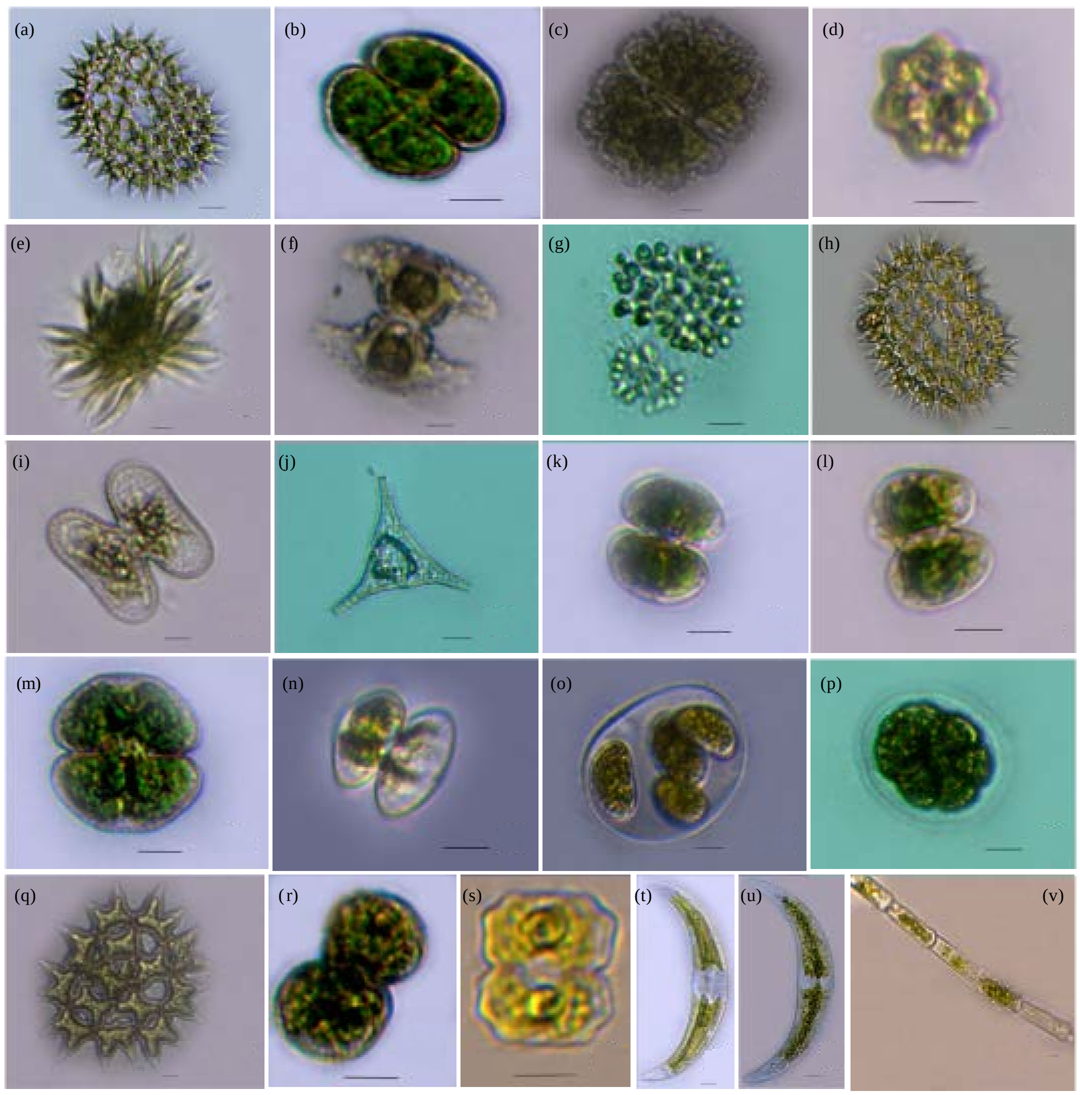

Plate 1(a-v): Microphotography of Microalgae-Chlorophytes (scale bar measures 10 μm), (a) *Pediastrum duplex* var. *rotundatum*, (b) *Cosmarium phaseolus*, (c) *Euastrum* sp., (d) *Coelastrum sphaericum*, (e) *Ankistrodesmus* sp., (f) *Staurastrum* sp., (g) *Dictyosphaerium* sp., (h) *Pediastrum duplex*, (I) *Cosmarium* sp., (j) *Staurastrum* sp., (k) *Cosmarium* sp., (l) *Cosmarium* sp., (m) *Cosmarium phaseolus*, (n) *Cosmarium* sp., (o) *Nephrocytium obesum*, (p) *Pandorina* sp., (q) *Pediastrum* sp., (r) *Cosmarium* sp., (s) *Cosmarium meneghinii*, (t-u) *Closterium leibleinii* and (v) *Oedogonium* sp.

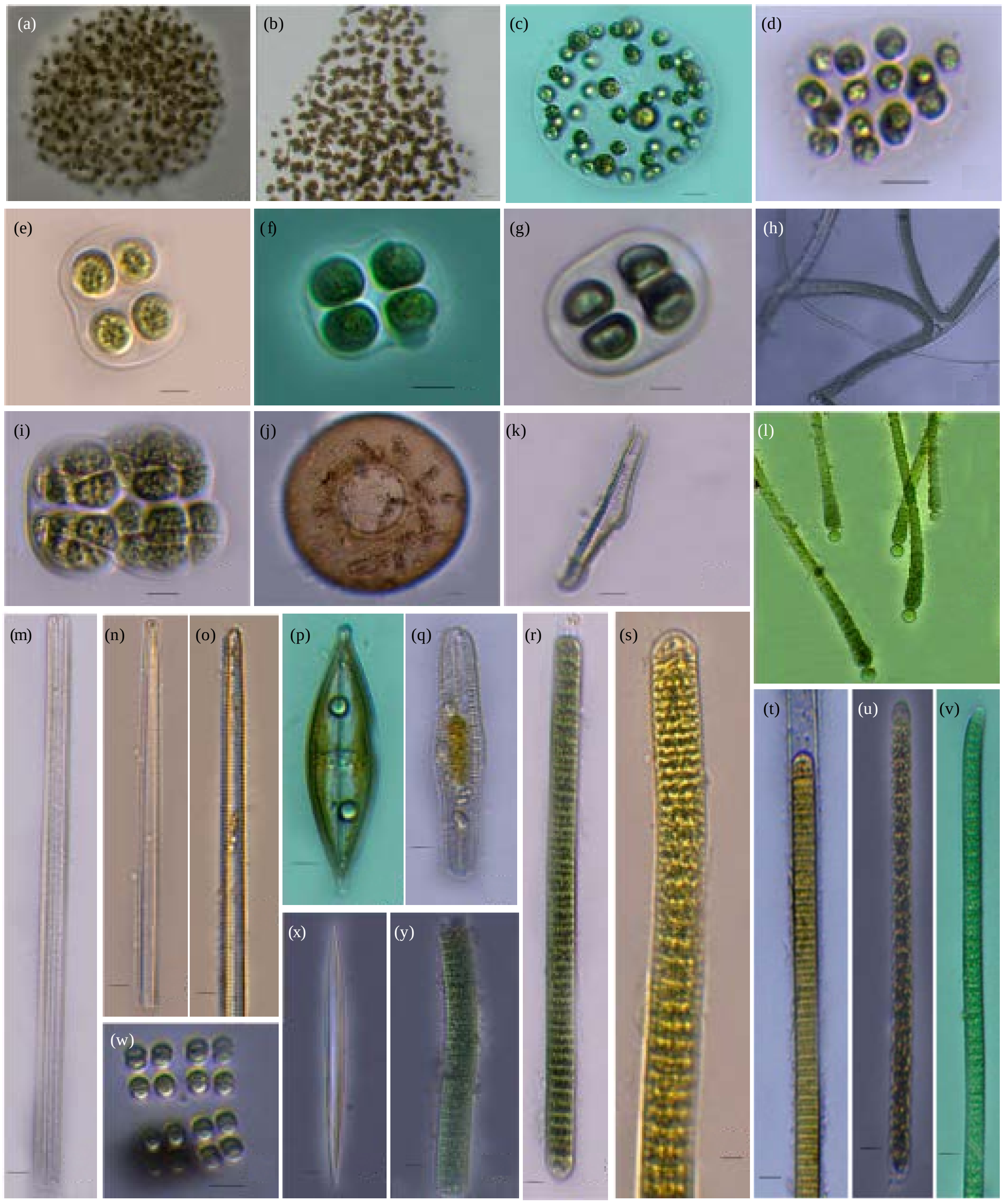

Plate 2(a-y): Microphotography of Microalgae-Bacillariophytes and Cyanophytes (Scale bar measures 10 µm), (a) *Microcystis robusta*, (b) *Microcystis auroginosa*, (c-d) *Aphanocapsa roeseana*, (e-g) *Chroococcus turgidus*, (h) *Scytonema bohneri*, (i) *Myxosarcina spectabilis*, (j) *Hyalodiscus* sp., (k, q) *Rhophalodia gibba*, (l) *Gloeotrichia pisum*, (m-o) *Synedra ulna*, (p) *Craticula cuspidate* syn. *Navicula cuspidate*, (r) *Oscillatoria sancta*, (s) *Oscillatoria princeps*, (t) *Lyngbya hieronymusii*, (u) *Oscillatoria* sp., (v) *Oscillatoria chalybea*, (w) *Merismopedia elegans*, (x) *Amphipluera pellucida* and (y) *Oscillatoria limosa*

Table 2: Physico-chemical parameters of the samples in each site at the time of collection

Time and physico-chemical parameters	Sampling sites at Gundur Lake S1	S2	S3	S4	S5	S6
Time of sample collection (on 17 March 2014) (IST)	8:10 h	8:45 h	9:30 h	9:45 h	10:35 h	11:00 h
pH	7.5	7.5	7	7.5	8.5	8
Light in photon intensity unit (μmol m^{-2} sec^{-1})	820	1100	1440	1850	1950	>1999
Dissolved Oxygen (DO) (mg L^{-1})	4.8±0.3	5.1±0.3	3.6±0.1	5.7±0.7	7.1±0.4	4.3±0.2
Chloride (mg L^{-1})	449.99±50	316.66±28.87	266.66±28.87	249.99±50	216.66±28.87	283.33±28.87
Nitrate (mg L^{-1})	20.5±0.4	23.8±0.3	30.3±0.4	26.6±0.3	24.5±0.3	27.3±0.3
Nitrite (mg L^{-1})	17.4±0.4	15.3±0.3	21.1±0.3	19.4±0.6	17.7±0.6	25.5±0.5
Magnesium (mg L^{-1})	13.21±0.6	20.12±0.5	30.06±3.2	26.93±0.5	27.09±0.2	30.53±3.1
Calcium (mg L^{-1})	43.90±1.4	66.73±0.7	99.47±10.2	88.83±1.2	89.13±0.7	97.37±11.3
Carbonate (mg L^{-1})	28.00±1.8	30.00±1.8	23.33±2.7	27.33±1.0	32.00±1.8	40.00±1.8
Bicarbonate (mg L^{-1})	6.00±0.9	3.33±0.5	8.67±0.5	4.33±0.5	10.33±0.5	5.00±0.9
Sulphate (mg L^{-1})	15.28±0.6	15.54±0.7	39.22±2.4	16.03±1.2	14.61±0.4	14.18±0.8

Physico-chemical parameter analysis of water samples from each sites at the time of sample collection were recorded (Table 2). It showed that the temperature ranges from 28-36°C (in water 25-34°C); pH ranges from 7-8.5, light intensity in terms of photon intensity ranges from 820-1999 μmol m^{-2} sec^{-1}, light intensity in terms of illumination ranges from 8000 to undetectable (by instrument) >10000 Lux; Dissolved Oxygen (DO) ranges from 3.6±0.1-7.1±0.4 mg L^{-1}; chloride ranges from 216.66±28.87-449.99±50 mg L^{-1}; Nitrate ranges from 20.5±0.4-30.3±0.4 mg L^{-1}; Nitrite ranges from 15.3±0.3-25.5±0.5 mg L^{-1}; Calcium ranges from 43.90±1.4-99.47±10.2 mg L^{-1}; Magnesium ranges from 13.21±0.6-30.53±3.1mg L^{-1}; Carbonate ranges from 23.33±2.7-40.00±1.8 mg L^{-1}; Bicarbonate ranges from 3.33±0.5-10.33±0.5 mg L^{-1} and Sulphate ranges from 14.18±0.8-39.22±2.4 mg L^{-1}.

DISCUSSION

Microalgae dominate the aquatic habitats as one of the major primary producers and they found to be distributed in diverse pattern. In freshwater aquatic habitats, the nutrient levels were often found in excess leading to eutrophic conditions due to drainage of rainwater, industrial wastes, agricultural wastes and household wastes through sewage. Eutrophication often succeeded in rich aquatic ecosystem with weeds and algal blooms (Khan and Mohammad, 2014).

For the current study, Gundur Lake was selected as it possesses abundant algal diversity often evident with bloom formation due to eutrophication and there were no previous reports on algal diversity in the area. Moreover, the tropical conditions of the lake favour the algal population with abundant light, temperature and nutrients. The samples were collected during early summer (March 2014) when the condition suited the algal population with intense light, temperature and nutrient could be witnessed from lush algal growth.

Physico-chemical parameter analysis showed the pH around neutral to slightly above neutral favouring the microalgae dominance. Temperature around 35°C and high light intensity observed during sampling time represented the typical high photosynthetic condition. Dissolved oxygen around 4-7 mg L^{-1} and chloride around 200-500 mg L^{-1} also favours the algal population. Nitrate and Nitrite contents were found literally very higher than that of the earlier reports by Mohideen *et al.* (2007). The high nitrate content leads to the eutrophication possibly favouring the algal dominance and bloom formation in the lake.

The sample collection sites were chosen carefully to represent at least half the area of the reservoir and a few hundred meters apart from each other. During collection, the plankton net with mesh size 200 μm was used to trap debris, macroalgae and large zooplanktons whereas the net with mesh size 42 μm was used to trap microalgae which were collected as samples.

The sample sites S1, S2, S5 and S6 were shallower with maximum half meter depth whereas the sites S3 and S4 were deeper sites susceptible to bloom formation. Sampling site S1 and S2 were recorded with more number of microalgae due to its location where other photosynthetic partners sharing the habitat with intense light and abundant nutrient availability. Higher diversity rate of S1 and S2 may also be due to the possible beneficial interaction among the algae, bacteria, weeds and other plants in the habitats.

Even though the sites S5 and S6 were shallower, it was reported with low number of algae diversity since it's located near the north shore of the lake and less accessibility to light due to shadow of the competing land plants on the shore. S4 and S3 were bloom prone sites with high nutrient and intense light availability. The low number of algal population in the sites may possibly due to less macroalgae or plants to compete and obviously due to *Microcystis* bloom. The thallus of *Gloeotrichia pisum* was found as spherical balls in S4 and S5 along the shore and as adherent to the plants reported similarly by Prescott (1954). The diversity pattern almost showed equal dominance of cyanophytes and chlorophytes followed by bacillariophytes as similar to the earlier reports (Suresh *et al.*, 2012; Ratha *et al.*, 2012; MubarakAli *et al.*, 2012).

Overall, the biodiversity analysis showed that the Gundur Lake was rich in microalgae especially with high abundance of unicellular/colonial forms. Cyanophytes and Chlorophytes were found to be dominant in the study area. Physico-chemical analysis also revealed the eutrophic nature of the lake favouring the microalgal dominance often evident from lush algal growth and bloom formation. However, more extensive and seasonal studies needed to understand the algal diversity, distribution and the factors responsible for the indicator of blooms.

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REFERENCES

APHA, 1989. Standard Methods for the Examination of Water and Wastewater. 17th Edn., American Public Health Association, Inc., Washington, DC., USA.

Anahas, A.M.P., M. Gayathri and G. Muralitharan, 2013. Isolation and Characterization of Microcystin-Producing *Microcystis aeruginosa* MBDU 626 from a Freshwater Bloom Sample in Tamil Nadu, South India. In: Microbiological Research in Agroecosystem Management, Velu, R.K. (Ed.). Springer, India, ISBN-13: 9788132210863, pp: 235-248.

Borowitzka, M.A., 2013. High-value products from microalgae-their development and commercialisation. J. Appl. Phycol., 25: 743-756.

Chu, S.P., 1942. The influence of the mineral composition of the medium on the growth of planktonic algae: Part I. Methods and culture media. J. Ecol., 30: 284-325.

Desikachary, T.V., 1959. Cyanophyta. 1st Edn., Indian Council of Agricultural Research, New Delhi, India, Pages: 686.

Guillard, R.R.L. and J.H. Ryther, 1962. Studies of marine planktonic diatoms: I. *Cyclotella nana* hustedt and *Detonula confervacea* (Cleve) gran. Can. J. Microbiol., 8: 229-239.

Guillard, R.R.L., 1975. Culture of Phytoplankton for Feeding Marine Invertebrates. In: Culture of Marine Invertebrate Animals, Smith, W.L. and M.H. Chanley (Eds.). Springer, USA., ISBN-13: 9781461587163, pp: 29-60.

Khan, M.N. and F. Mohammad, 2014. Eutrophication: Challenges and Solutions. In: Eutrophication: Causes, Consequences and Control, Ansari, A.A. and S.S. Gill (Eds.). Springer, Netherlands, ISBN-13: 9789400778139, pp: 1-15.

Ling, H.U. and P.A. Tyler, 1986. A limnological survey of the alligator rivers region: Part II. Freshwater algae, exclusive of diatoms. Research Report No. 3, Australian Government Publishing Service, Canberra.

Milledge, J.J., 2011. Commercial application of microalgae other than as biofuels: A brief review. Rev. Environ. Sci. Biotechnol., 10: 31-41.

Mohideen, B.M.G., P.S. Hameed and C. Shajitha, 2007. Studies on the diversity and abundance of cladocerans in Guntur pond (Tiruchirappalli, Tamilnadu). Proceedings of the 12th World Lake Conference, October 28-November 2, 2007, Jaipur, India, pp: 470-476.

MubarakAli, D., M.I. Ershath and N. Thajuddin, 2012. Biodiversity and molecular evolution of microalgae on different epiphytes and substrates. Pak. J. Biol. Sci., 15: 813-820.

Muthukumar, C., G. Muralitharan, R. Vijayakumar, A. Panneerselvam and N. Thajuddin, 2007. Cyanobacterial biodiversity from different freshwater ponds of Thanjavur, Tamil Nadu (India). Acta Bot. Malacitana, 32: 17-25.

Oliver, R.L., D.P. Hamilton, J.D. Brookes and G.G. Ganf, 2012. Physiology, Blooms and Prediction of Planktonic Cyanobacteria. In: Ecology of Cyanobacteria II, Whitton, B.A. (Ed.). Springer, Netherlands, ISBN-13: 9789400738546, pp: 155-194.

Philipose, M.T., 1967. Chlorococcales. Indian Council of Agricultural Research, New Delhi, India, Pages: 365.

Praveenkumar, R., K. Johncy, D. MubarakAli, D. Vijayan, N. Thajuddin and M. Gunasekaran, 2012a. Demonstration of increased lipid accumulation potential of *Stigeoclonium* sp., Kutz. BUM11007 under nitrogen starved regime: A new source of lipids for biodiesel production. J. Biobased Mater. Bioenerg., 6: 209-213.

Praveenkumar, R., K. Shameera, G. Mahalakshmi, M.A. Akbarsha and N. Thajuddin, 2012b. Influence of nutrient deprivations on lipid accumulation in a dominant indigenous microalga *Chlorella* sp., BUM11008: Evaluation for biodiesel production. Biomass Bioenergy, 37: 60-66.

Prescott, G.W., 1954. How to Know the Freshwater Algae. W.C. Brown Co., USA., Pages: 211.

Prescott, G.W., 1962. Algae of the Western Great Lakes Area. W.C. Brown Co., USA.

Ratha, S.K., R. Prasanna, V. Gupta, D.W. Dhar and A.K. Saxena, 2012. Bioprospecting and indexing the microalgal diversity of different ecological habitats of India. World J. Microbiol. Biotechnol., 28: 1657-1667.

Rippka, R., J. Deruelles, J.B. Waterbury, M. Herdman and R.Y. Stanier, 1979. Generic assignments, strain histories and properties of pure cultures of cyanobacteria. J. Gen. Microbiol., 111: 1-61.

Sivakami, R., P.S.R. Macherla and G. Premkishore, 2011. Bacterial enumeration in surface and bottom waters of two different freshwater aquatic systems in Tamil Nadu. J. Curr. Sci., 16: 91-95.

Suresh, A., R.P. Kumar, D. Dhanasekaran and N. Thajuddin, 2012. Biodiversity of microalgae in Western and Eastern Ghats, India. Pak. J. Biol. Sci., 15: 919-928.

Tang, Y.Z., F. Koch and C.J. Gobler, 2010. Most harmful algal bloom species are vitamin B1 and B12 auxotrophs. Proc. Natl. Acad. Sci. USA., 107: 20756-20761.

Taylor, J.C., W.R. Harding and C.G.M. Archibald, 2007. An illustrated guide to some common diatom species from South Africa. WRC Report No. TT 282/07, Water Research Commission (WRC), Pretoria, South Africa, January 2007.

Thajuddin, N. and G. Subramanian, 2002. The Enigmatic Bloom Forming Marine Cyanobacterium *Trichodesmium*. In: Advances in Marine and Antarctic Sciences, Sahoo, D. and P.C. Pandey (Eds.). APH Publishing Corporation, New Delhi, India, ISBN-13: 9788176483476, pp: 57-89.

Thajuddin, N. and G. Subramanian, 2005. Cyanobacterial biodiversity and potential application in biotechnology. Curr. Sci., 89: 47-57.

Van Vuuren, S.J., J. Taylor, A. Gerber and C. van Ginkel, 2006. Easy Identification of the Most Common Fresh Water Algae: A Guide for Identification of Microscopic Algae in South African Freshwater. Resource Quality Services (RQS), Vanderbijlpark, South Africa, ISBN-13: 9780621354713, pp: 111-193.

West, W. and G.S. West, 1904. A Monograph of the British Desmidiaceae. The Ray Society, London, UK.

Wijffels, R.H., O. Kruse and K.J. Hellingwerf, 2013. Potential of industrial biotechnology with cyanobacteria and eukaryotic microalgae. Curr. Opin. Biotechnol., 24: 405-413.

Zhang, P., C. Zhai, R. Chen, C. Liu, Y. Xue and J. Jiang, 2012. The dynamics of the water bloom-forming *Microcystis aeruginosa* and its relationship with biotic and abiotic factors in Lake Taihu, China. Ecol. Eng., 47: 274-277.