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The Influence on Environmental Parameters on Chlorophycean Abundance: A Study from the Museum Lake in Thiruvananthapuram Kerala, India.

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Abstract

The interaction of environmental parameters with the planktonic Chlorophycean members has been carried out from the Thiruvananthapuram Museum Lake. A total of 54 species are recorded for a period of two years (February 2013-January 2015). *Chlorella* sp. was found throughout the study period. Among the total species, *Scenedesmus* was recorded as the major taxa with nine different species. *Scenedesmus quadricauda* and *S.dimorphus* were the dominant species among them. The Shannon-Wiener diversity index for the study period showed good diversity of the species for all the seasons (2.9-3.27). The Canonical Correspondence Analysis (CCA) between environmental variables and the dominant chlorophytes indicated an influence of the physical and chemical parameters on their distribution in the Museum Lake.

Key Words: Canonical Correspondence Analysis, Environmental Parameters, Kerala, Museum Lake, *Scenedesmus*, Shannon-Wiener Diversity, Thiruvananthapuram.

Introduction

Planktonic Chlorophytes compose the largest and the most varied phylum of algae (Perez *et al*., 2002) and are ubiquitous in aquatic and some terrestrial habitats. Being closely related to the higher plants, they have a crucial role in the global ecosystem for millions of years (Happey-Wood, 1988; Perez *et al.*, 2002; Falkowski *et al.*, 2004; O'Kelly, 2007; Leliaert *et al.*, 2011). For proper documentation, taxonomic identification of algal flora is essential and Chlorophycean members are difficult to describe taxonomically because many of them exhibit phenotypic plasticity (Shubert and Wozniak, 2003). Chlorophytes are the most diverse and widespread among the non-vascular plants that make them the largest class of algae approximately 7,000 species in number. The global value of green algae is incredibly important. They serve as the primary source of food for other aquatic organisms and they contribute largely to the supply of oxygen.

Taxonomical study of Chlorophycean algae was started in India earlier by Iyengar (1932) – The Father of Indian Phycology by studying the Zygnemales from India. Dixit (1937) studied the Chlorophyceae of Bombay Presidency. Subsequently, Philipose (1967), Kumar (1975), Krishnamurthy (2000), Rashmi (2004), Kumar and Rai (2005), Jena and Adhikari (2007), Keshri (2009), Deca *et al*., (2011) and Sikdar *et al*., (2012) made studies on the Chlorophycean classes. Recently Roy and Pal (2015) have studied the planktonic chlorophytes from the freshwater eutrophic wetland of Indian Ramsar Site- East Calcutta Wetland. A total of 61 taxa belonging to 17 different genera have been recorded. Gupta (2012) has worked on the algae of India and listed a total of 3745 taxa belonging to 328 genera which includes 62 families of Chlorophyceae 71 taxa and 25 genera particularly.

In spite of enormous biodiversity, little work has been done on phytoplankton diversity especially on Chlorophyceae in Kerala. Iyengar (1975) has made reports on the algae from South India. Patel *et al*., (1977) has studied on the Desmids from Kadaplamattom, Kottayam District of Kerala. They have extensively studied on the *Staurastrum*, *Cosmarium* and *Microsterias*. Panicker and Ampili (1988) analysed the Chlorophyceae from the flowing waters and reported a new species of *Temnogametum*. Shaji and Patel (1991) have worked on the Desmids from Kerala. *Microthamion stratissimum* Raberhorst (Chlorophyceae) from Kerala (1988) has been reported by the same authors. Jose and Patel (1992) have given a systematic account of Chlorococcales new to Kerala. Devi and Panikkar (1994) have studied on the Spirogyra new to Kerala. Maya *et al.*, (2000) studied on the algal flora of temple tanks of Southern Kerala. Cherian (2006) has made a study on the *Scenedesmus* varieties in the Poyyachira Pond at Thrikkakara. Radhika and Devi (2007) have investigated the phytoplankton diversity of the Vellayani Lake in Thiruvananthapuram District and they have observed 36 species of phytoplankton members. Paul and Sreekumar (2009) assessed the biodiversity and seasonal variation in freshwater algae in Thrissur Kol wetlands and reported 169 taxa of Phytoplankton. Manickam *et al.,* (2012) studied the phytoplankton diversity in the Parambikulam-Aliyar irrigation canals in Western Ghats and reported 22 species of phytoplankton. John and Francis (2013) have studied on the algal flora of Idukki District. They have identified 19 new taxa

belonging to Chlorophyceae which were new reports from Indian subcontinent and Kerala State. Nasser and Kumar (2014) analysed the freshwater micro algal richness of the Parambikulam Reservoir in Kerala. They recorded 89 taxa of phytoplankton. Kumar *et al*., (2014) has studied on the planktonic algae of temple ponds of Mahe and identified a total of 41 phytoplankton among them, chlorophyceae members were dominant. Krishnan and Kumar (2015) has assessed the trophic status of Aruvikkara reservoir using different algal indices. The Chlorophycean index for the reservoir revealed that most of the stations are in oligotrophic condition. Gopinath and Kumar (2015) has studied on the micro algal communities of Vellayani freshwater Lake of Thiruvananthapuram, Kerala and reported 13 genera of Chlorophyceae members.

A critical review of the available literatures on planktonic chlorophytes revealed that we do not have adequate information on the freshwater planktonic chlorophyta diversity in Kerala in spite of numerous water bodies yet to be explored. Only in the latter half of the last century some works were initiated in this interesting area. The algae are one of the least known and less documented groups of lower plants. Ajayan and Kumar (2015) studied the phytoplankton diversity of Museum Lake in which a total of 102 micro algal species were identified. The present paper is an updated list of 54 species of Chlorophycean members recorded from the Museum Lake in Thiruvananthapuram District. The environmental variables that influence the dominant phytoplankton are also discussed. There are scarce studies on temporal changes of chlorophytes and their relationships to environmental variables in worldwide water.

Materials and Methods

Study Area:

Thiruvananthapuram Museum and Zoo is one of the oldest of its kind in India located at the heart of the city (08˚30' N, 076˚57'E). The lake in the present study is situated inside the zoo (often known as Museum Lake) spreading over 2 acres (Fig: 1). The lake is a perennial and artificial lake is 157 year old one and right from its construction in 1859 has never lost its water level even in the scorching summers. About 60 species of resident water birds like Pond Herons, Oriental Darter, Cormorants and migrants like Asian Openbill Storks are some of them associated with the lake. The Central Zoo Authority (CZA) is the prime statutory body which regulates the Zoos in India.

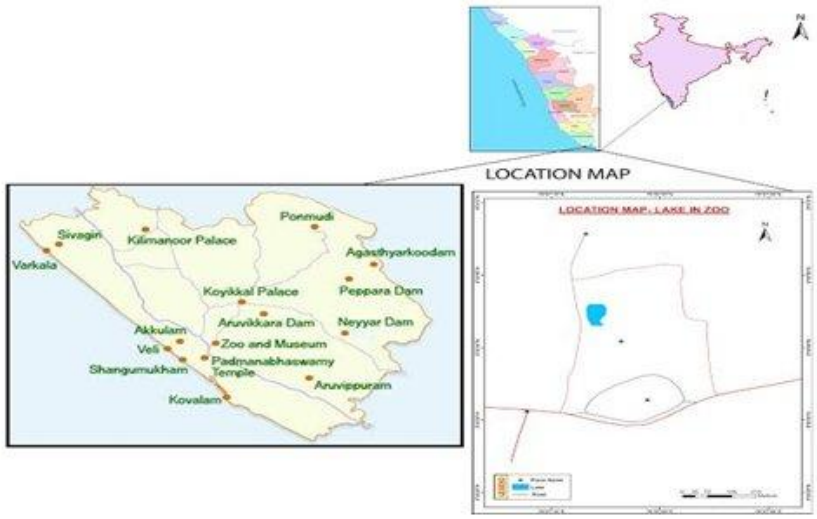


Fig:1, Location Map of the Museum Lake, Thiruvananthapuram

Sampling and Diversity Analysis:

The water samples for the phytoplankton analysis were collected monthly from selected sampling sites of the Museum Lake from February 2013 to January 2015. Seasonal data was obtained by dividing the annual monthly data into three seasons. The three seasons divided as; Pre Monsoon- PreM1: February 2013- May 2013& PreM2: February 2014- May 2014 Monsoon-Mon1: June 2013-September 2013 & Mon2: June 2014-September 2014 Post Monsoon- PoM1: October 2013-January2014 & PoM2: October 2014-January 2015.

Quantitative enumeration of phytoplankton was carried out by passing a known (1 litres) volume of sample water through a plankton net No. 25 (mesh size 22µm). The filtered samples were preserved by adding a

few drops of Lugol's solution. The samples were then reduced to a known volume of 15 ml in a centrifuge. Enumeration of phytoplankton was done by taking 1 ml of sub-sample in a Sedgwick Rafter cell and counting its entire contents up to the statistical accuracy. The plankton count less than 500 are assigned as rare (+), those which numbered greater than 500 are assigned as frequent (++) and the plankton that counted above 1000 are considered as abundant (+++). The plankton that were absent are marked as so (-). The works of Prescott (1964) and online websites like *Phycokey, Algaebase* and *Desmids* were considered for the identification of phytoplankton. The micro-photographs of each representative sample were taken using a camera attached microscope Leica DM 500 (with magnification 40X). The environmental parameters like Water Temperature (WT), pH, Dissolved Oxygen (DO), Total Alkalinity (TA), Nitrate-Nitrogen (NO_3^-N), Nitrite-Nitrogen (NO_2^-N), Calcium (Ca), Magnesium (Mg), Phosphate, Silicate, Sodium (Na), Potassium (K) were analyzed for the lake water following the procedures APHA (2005). Rainfall data was collected from the Indian Meteorological Department (IMD) Thiruvananthapuram.

Statistical Analysis:

The software program PRIMER v 6 (Plymouth Routines in Multivariate Ecological Research, version 6.1.9), was used for Multivariate analyses of data and for deriving the Community Structure-Diversity Indices and Similarity Indices- Non-metric Multi Dimensional Scaling (MDS); Dominance plot.

Community structure:

a) *Diversity Indices:* Five diversity indices were derived using PAST V 3.10. The formula designed for various indices are described below.

i) *Shannon-Wiener index (H')* (Shannon & Weaver 1949) calculated as,

$$H' = -\Sigma S\ Pi \log 2\ Pi \ldots\ldots$$
$$i = 1$$

This can be rewritten as,

$$H' = \frac{3.3219\ (N\ l0gN — \Sigma ni - \log ni)}{N}$$

Where, H'= species diversity in bits of information per individual
ni = proportion of the samples belonging to the i th species (number of individuals of the i th species)
N = total number of individuals in the collection and
Σ= Sum

ii) *Margalef Richness Index (d)*

$$d = (s-1) / \log N$$

iii) *Pielou's Evenness Index (J')*

The equitability (J') was computed using the following formula of Pielou (1966):

$$J' = \frac{H'}{\ln S}$$

where, J' = evenness

H'= species diversity in bits of information per individual and
S = total number of species

iv) *Simpson Index (D)*

$$D = 1-\lambda,$$

Where, $\lambda = \Sigma Pi2$

$$Pi = \frac{ni}{N}$$

ni = number of individuals of i, i2 etc. and N = total number of individuals.

Non-metric Multi Dimensional Scaling (MDS) ordination plot proposed by Shepard (1962) and Kruskal (1964) was used to find out the similarities (or dissimilarities) between each group of Chlorophyceans from all seasons for the two year study period which ideally represent the interrelationships of all in a graph.

Dominance plot

The *K*-dominance curve is a powerful tool for measuring abundance trends in communities over time. *K*-dominance curves are the cumulative ranked abundance against a log species rank (*ICES 2001A*, Jennings *et al*., 2001). Here, the numbers of individuals of each species are sorted in descending order, and the proportion of the total number of individuals for each species is then plotted on the log scale against the species rank. The shape of the abundance plot can provide an indication of dominance or evenness, for example, steep plots

signify assemblages with high dominance and shallower slopes indicate higher evenness. (Species Abundance Plot, 2016).

Chlorophycean Index (Rawson 1956)

Limnologists have proposed specific indices for the assessment of nutrient status for the water bodies. These indices use ratios of Chlorophycean algae as a trophic index.

The relative numbers of species of Chlorococcales and Desmidiaceae present in particular lakes have been used to recognize trophic types.

Chlorophycean Index= Number of species of Chlorococcales

Desmids

<1= Oligotrophy; >1 Eutrophy

Canonical Correspondence Analysis (CCA)

A Canonical Correspondence Analysis (CCA) method was explored to determine the relationship between dominant phytoplankton species and with the hydrographical parameters studied using the statistical software PAST ver.3.06.

Results and Discussions

In the present study we recorded 26 genera with 54 species representing the class Chlorophyceae (Table 1). During the study period *Chlorella* sp., *Crucigenia quadrata, Crucigenia tetrapedia, Didymocystis* sp., *Eudorina elegans, Kirchneriella lunaris, Pandorina morum, Scenedesmus dimorphus, Scenedesms quadricauda* were some of the abundant plankton recorded and represented in all seasons. The systematic enumeration of the planktons recorded during the study period is given below.

The species composition of the three seasons for the two consecutive years showed marked variations in distribution for the planktonic Chlorophytes in Museum Lake.

Table 1 Abundance of Chlorophyceans observed during the study period from Museum Lake

Serial No.	Phytoplankton	PreM1	Mon1	PoM1	PreM2	Mon2	PoM2
1.	*Ankistrodesmus falcatus* (Corda) Ralfs	++	+	+	+	+	++
2.	*Arthrodesmus convergens* Ehrenberg ex Ralfs	++	+	++	++	+	+
3.	*Chlorella* sp.	+++	+++	+++	+++	+++	+++
4.	*Closterium acerosum* Ehrenberg ex Ralfs	+	+	+	+	+	+
5.	*Closterium aciculare* T.West	+	+	+	+	+	+
6.	*Closterium attenuatum* Ralfs	+	+	+	+	+	+
7.	*Closterium eherenbergii* Meneghini ex Ralfs	+	+	+	+	+	+
8.	*Closterium macilentum* Brébisson	-	-	-	+	+	+
9.	*Closterium* sp.	+	+	+	+	+	+
10.	*Coelastrum microporum* Nägeli	+	+	+	+	+	+
11.	*Coelastum proboscideum* Bohlin	+	+	++	++	+	+
12.	*Cosmarium hammeri* var. *protuberens* West & G.S.West	+	-	+	+	+	+
13.	*Cosmarium maculatum* Turner	+	+	+	+	-	-
14.	*Crucigenia quadrata* Morren	+++	+	+++	+++	+	+++
15.	*Crucigenia tetrapedis* (Kirchner) Kuntze	++	+	++	+++	++	++
16.	*Desmodesmus communis* (E.Hegewald) E.Hegewald	+	+	+	+	+	+
17.	*Desmodesmus denticulatus* (Lagerheim) S.S.An, T.Friedl & E.Hegewald	+	+	+	+	+	+
18.	*Desmodesmus intermedius* (Chodat) E.Hegewald	+	+	+	+	+	+
19.	*Desmodesmus intermedius* (R. Chodat) Hegewald var. *acutispinus* (Roll) Hegewald	+	+	+	+	+	+
20.	*Dictyosphaerium* sp.	+	+	+	+	+	+

21.	*Didymocystis* sp.	++	+	++	++	++	++
22.	*Euastrum acanthophorum* W.B.Turner	+	+	+	+	+	+
23.	*Euastrum bidentatum* Nägeli	+	+	+	+	+	+
24.	*Eudorina elegans* Ehrenberg	++	+	++	++	++	++
25.	*Kirchneriella lunaris* (Kirchner) Möbius	+++	++	++	+++	+	++
26.	*Micractinum* sp.	+	+	+	+	+	+
27.	*Monoraphidium minutum* (Nägeli) Komárková-Legnerová	+	+	+	+	+	+
28.	*Pandorina morum* (O.F.Müller) Bory in J.V.Lamouroux, Bory & Deslongschamps	++	+	++	+++	++	++
29.	*Pediastrum duplex* Meyen	++	+	++	++	+	++
30.	*Pediastrum duplex* var. *gracillimum* West & G.S.West	+	+	+	++	+	+
31.	*Pediastrum tetras* (Ehrenberg) Ralfs	++	+	+	+	+	+
32.	*Roya obtuse* (Brébisson) West & G.S.West	+	+	+	+	+	+
33.	*Scenedesmus acunae* Comas	+++	+	++	++	+	++
34.	*Scenedesmus acuminatus* (Lagerheim) Chodat	+	+	+	+	+	+
35.	*Scenedesmus arcuatus* (Lemmermann) Lemmermann	+	+	+	+	+	+
36.	*Scenedesmua brasiliensis* Bohlin	+	+	+	+	-	+
37.	*Scenedesmus dimorphus* (Turpin) Kützing	++	+++	+++	+++	++	+++
38.	*Scenedesmus obliquus* (Turpin) Kützing	+	+	+	+	+	+
39.	*Scenedesmus obliquus var dimorphus* (Turpin) Hansgirg	+	-	-	+	-	-
40.	*Scenedesmus protuberens* F.E.Fritsch & M.F.Rich	+	+	+	+	-	+
41.	*Scenedesmus perforates* Lemmermann	+	-	-	+	-	-
42.	*Scenedesmus quadricauda* Chodat	+++	+	++	++	+	+
43.	*Schroederia* sp.	+	+	+	+	-	+
44.	*Spirogyra elongate* (H.C.Wood) H.C.Wood	+	+	+	+	-	-
45.	*Staurastrum anatinoides* var. *javanicum* A.M.Scott & Prescott	+	+	+	+	-	-
46.	*Staurastrum convergens* (Ehrenberg) Meneghini	+	-	+	+	-	-
47.	*Staurastrum dentatum* Willi Krieger	+	+	+	+	-	-
48.	*Staurastrum gracile* Ralfs ex Ralfs	+	+	+	+	-	+
49.	*Staurastrum inflexum* Brébisson	+	+	++	++	+	+
50.	*Staurastrum tetracerum* Ralfs ex Ralfs	+	-	-	+	-	-
51.	*Staurodesmus dejectus* (Brébisson) Teiling	+	+	+	+	-	-
52.	*Tetraedron trigonum* (Nägeli) Hansgirg	+	-	-	+	+	-
53.	*Tetrallantos lagerheimii* Teiling	+	+	+	+	+	+
54.	*Tetrastrum staurogeniiforme* (Schröder) Lemmermann	-	-	+	+	-	-

(- Absent; + Rare; ++ Frequent; +++ Abundant)

Community Structure:

The present study revealed a wide diversification of planktonic chlorophytes with *Scenedesmus* being dominant. A total 9 species of *Scenedesmus* has been recorded from the Museum Lake, Thiruvananthapuram. But recently in algal classification a polyphasic approach is being taken for identification, considering morphology, ultrastructure, biochemistry and molecular characters (Roy and Pal, 2015). Following this Hegewald (2000) and Tsarenko (2000) separated out the genus *Desmodesmus* from *Scenedesmus*. In our study also five *Desmodesmus* sp. *viz*. *D. communis, D. denticulatus*, *D. intermedius* and *D. intermedius* var. *acutispinus* were found. Besides these, 6 species of *Closterium*, 6 species of *Staurastrum* and 3 species of *Pediastrum* were also recorded. Diversity indices and similarity indices were calculated to interpret the community structure of planktonic chlorophytes from the Museum Lake.

Diversity Indices

The diversity indices of the Chlorophycean members recorded for the three seasons have been calculated. The results obtained are shown in Table 2.

Table 2 Diversity Indices of the Chlorophycean members recorded from Museum Lake.

	Richness (d)	Evenness (J')	Diversity(H')	Dominance (D)
PreM1	5.16	0.80	3.17	0.94
Mon1	5.07	0.75	2.9	0.90
PoM1	4.88	0.82	3.21	0.93
PreM2	5.33	0.81	3.27	0.94
Mon2	4.28	0.82	3.03	0.90
PoM2	4.33	0.84	3.16	0.94

Diversity indices are the relative abundance of different species at each site or time reduced to a single index. For the analysis of diversity indices Shannon Wiener diversity index is the most widely used diversity measure. Logarithmic base 2 is used here for the analysis as most of the tropical studies are using this pattern for comparison. Shannon and Weiner index represents entropy. It is a diversity index taking into account the number of individuals as well as the number of taxa. It varies from 0 for communities with only single taxa to high values for community with many taxa each with few individuals. Shannon's Diversity Index showed a value between 2.97- 3.27 with highest during PreM2. The data were selected on the seasonal scale. The seasonal variations in the plankton are greatly influenced by the nutrient status, physico chemical parameters and the environmental factors that are related to the lake water (Jithesh and Radhakrishnan, 2015). Longer days, higher water temperature (Altaf *et al*., 2016) and increased concentrations of nutrients like nitrates and phosphates (Ganai and Parveen, 2014) are the factors that determine the Chlorophycean abundance.

Evenness was similar during all the seasons except for a slight difference during Mon1. The Simpsons index is used to quantify the biodiversity of habitats. It takes into account the number of species and the abundance of the species. The greater the index value the greater the sample diversity. Species dominance showed values similar in all seasons (0.90-0.94) throughout the study period and it shows an even distribution of planktonic Chlorophytes in Museum Lake.

Similarity Indices

MDS

MDS plot for planktonic Chlorophycean density gave a good ordination having the stress value of 0 for seasonal distribution. The MDS plot of the planktons (Fig: 2), it clearly represents the distinct grouping for PreM1 and another group forming for Mon1 &2. This may be due to lowest density, despite maximum species richness, diversity and evenness. Mon1 and 2 formed a distinct group showing a similarity of 60%. While PoM1 & 2 and PreM2 the similarity was 80%. The similarity between phytoplankton compositions for the 3 seasons during 2 year study period was as high as 20%.

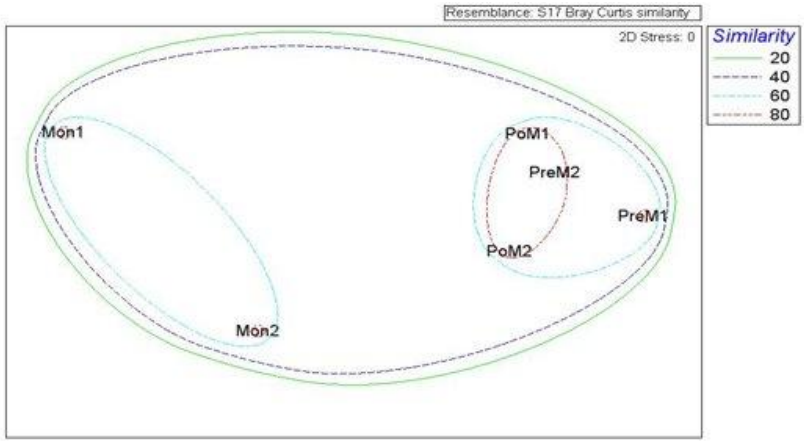


Fig: 2 Non-metric Multi Dimensional Scaling (MDS) ordination plot of planktons for the study period.

Dominance Plot:

Diversity profiles are also presented using k-dominance curves (Lambshead *et al*., 1983). The purpose of this distributional representation is to extract information on patterns of relative species abundance and dominance. This technique can be considered as intermediate between univariate summaries and full multivariate analyses (Clarke, 1990). The curves presented are cumulative ranked abundance plotted against species rank (logged axis). Shallow curves tend to correspond to communities with high levels of dominance, whereas steep curves reflect a more balanced, diverse community. Here, the percentage dominance of the organisms was plotted against their rank individually and cumulatively (Fig: 3). In this section, the figure represents the dominance plot for the three seasons during the study period. In the k-dominance curve for seasons showed an almost similar pattern with 'S' shaped curve. Here, from the figure the plot shows a shallower slope and this indicates a higher evenness of distribution among planktonic Chlorophytes from Thiruvananthapuram Museum Lake.

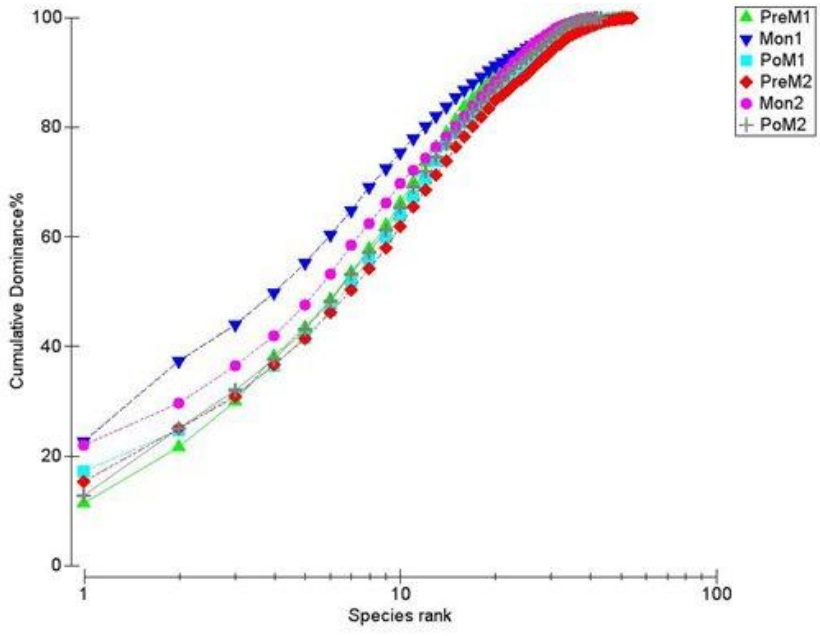


Fig: 3 k-dominance ranked curves for the study period of Museum Lake.

The relative numbers of species of Chlorococcales and Desmidiaceae present in particular lakes have been used to recognize trophic status. In practice the number of species of Chlorococcales is divided by the

number of desmids and the quotient, if less than one is said to indicate oligotrophy or if greater than one, eutrophy.

In the net plankton of Museum Lake, 32 species of Chlorococcales and 19 species of Desmids were recorded, and a quotient of 1.6 which would suggest a slight eutrophy is existed in the lake. The lake looks green almost all the seasons and is having good number of Chlorophycean members.

Canonical Correspondence Analysis (CCA)

In order to study the influence of environmental parameters with the plankton studied, CCA was carried out. The physical and chemical parameters studied are shown in the Table: 3. A low fluctuation of water temperature was observed in the study area. This is due to the shade provided by the riparian trees which prevents the sun's rays to hit the surface water and thus reduces the water temperature.

Table: 3 Physical and Chemical parameters recorded during the study period.

Season	WT	pH	DO	TA	NO_3-N	NO_2^-N	CaH	MgH	Phos	Na	Sili	K	Rainfall
PreM1	23.8	6.97	11.3	21.6	1.73	0.39	13.4	13.30	6.87	4.88	5.35	6.16	65.125
Mon1	23.3	6.79	8.3	16.6	3.99	0.90	18.65	14.11	3.46	4.94	8.06	12.24	267.5
PoM1	23	6.90	8.1	17.4	2.60	0.22	17.23	11.03	1.43	5.13	9.72	11.68	141.48
PreM2	24.3	7.05	6.1	15.2	4.10	0.38	13.28	4.52	2.79	4.17	8.30	4.82	100.85
Mon2	23	6.81	7.2	17.2	3.03	0.58	19.54	10.45	3.67	8.28	6.49	3.55	243.08
PoM2	23	6.60	4.9	16.7	2.88	0.14	13.79	11.32	1.66	6.31	6.27	13.31	140.03

(WT- ^{o}C; DO, TA, NO_3^-N, NO_2^-N, CaH, MgH, Phos, Na, Sili and K- mg/l; Rainfall- in mm)

Table: 4 List of Dominant Chlorophytes with the species code from Museum Lake for Canonical Correspondence Analysis (CCA)

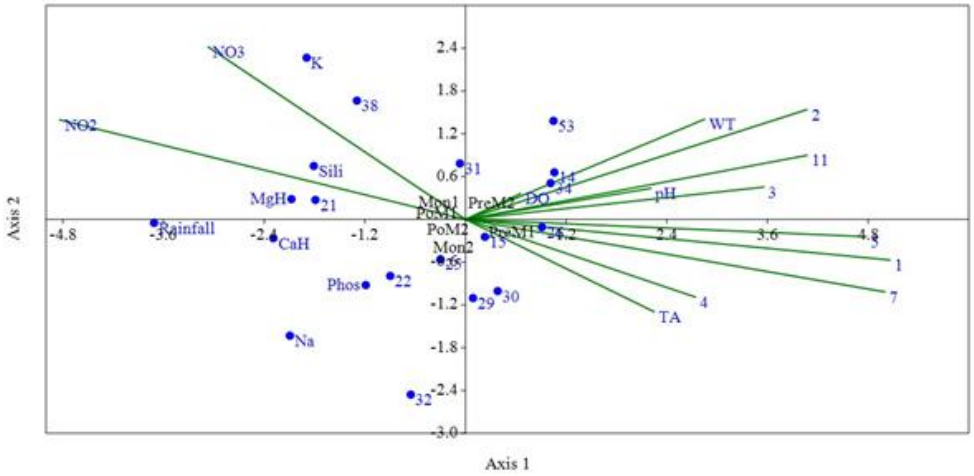
Phytoplankton	Species Code	Phytoplankton	Species Code
Ankistrodesmus falcatus	1	*Didymocystis sp.*	22
Arthrodesmus convergens	2	*Eudorina elegans*	25
Chlorella sp	3	*Kirchneriella lunaris*	26
Closterium acerosum	4	*Pandorina morum*	29
Closterium aciculare	5	*Pediastrum duplex*	30
Closterium eherenbergii	7	*Pediastrum duplex var.gracillimum*	31
Coelastum proboscideum	11	*Pediastrum tetras*	32
Crucigenia quadrata	14	*Roya obtuse*	34
Crucigenia tetrapedis	15	*Scenedesmus dimorphus*	38
Dictyosphaerium sp.	21	*Tetrallantos lagerheimii*	53

CCA method explored to determine the relationship between dominant phytoplankton species and with the hydrographical parameters studied revealed that, NO_3-N, NO_2-N, water temperature, K, phosphate, magnesium and pH are the influential environmental variables for Chlorophytes distribution in Museum Lake (Fig.4). The arrow length indicates the importance of variable and shows positive or negative correlations with axis (Abrantes *et al*., 2006; Liu *et al*., 2010).

The CCA triplot clearly represents the effect of environmental variables and the dominant phytoplankton species for the separate two years. Among the phytoplankton species identified *Chlorella* sp and *Crucigenia quadrata* were observed highest during the study period followed by *Scenedesmus dimorphus* and *Crucigenia tetrapedis.* Similar dominance pattern for phytoplankton were recorded in the year 2 also. A clear marked variation in the environmental variables is also recorded during the study period.

During the study period, the eigenvalues of Axes 1 and 2 were 0.065 and 0.02, which accounted for 56.65% and 23.13% of the total variance respectively with the environmental variables and the dominant phytoplankton species. Water temperature, pH, NO_3^--N, NO_2^--N, K, phosphate and magnesium showed strong relation with the phytoplankton species confirming their frequent distribution and can be considered as the limiting factors in Museum Lake. *Scenedesmus acunae* and *Crucigenia quadrata* showed strong influence with water temperature in its distribution in Museum Lake whereas DO have a strong influence on the distribution of *Arthrodesmus convergens*. *Closterium acerosum* and *Closterium eherenbergii* have shown a strong negative influence with NO_3^--N and NO_2^--N respectively. pH had a strong influence over *Coelastum proboscideum* and *Chlorella* sp. in Museum Lake. Phosphate had an influential distribution over *Didymocystis sp.* Potassium and NO_3-N had an influence over *Dictyosphaerium* sp. The CCA results also showed that rainfall, silicate, calcium hardness and sodium had no significant influence over the phytoplankton. The individual chlorophytes with its corresponding environmental variables reveals that they are the limiting factors that determine the distribution in Museum Lake and the exact reasons for this need a further study.

Fig: 4 Triplot of CCA depicting environmental variable - dominant planktonic chlorophytes species relationship of the year 2013-15 for Museum Lake, Thiruvananthapuram



Conclusion

From the present study it can be concluded that Museum Lake under the control of Department of Museums and Zoo, Thiruvananthapuram and the CZA is eutrophic in nature particularly due to planktonic Chlorophytes with the orders Chlorococcales and Desmidales recorded in all seasons. They were highest recorded during the PreM1 than that of the other studied seasons. The environmental parameters were highest during the PreM1 whereas, rainfall was recorded lowest. Thus, it can be confirmed that high nutrients with low rainfall influences the growth of green algae in the Museum Lake. Chlorophyceans can be considered in the prediction of trophic status of the water body. The enrichment due to the allochthonous nutrient sources like leaf litter from the riparian vegetation and the uprooted trees nearby causing the increased organic nutrients and destroying the beauty of this freshwater ecosystem. So regular cleaning and clearing of them can keep away from algal bloom in future and to preserve and conserve this beautiful perennial water source to enjoy the zoo tourism well.

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