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Seasonal variations of phytoplankton community structure in relation to Physico-chemical factors in Lake Kolleru, Andhra Pradesh, India

Bhanu Prakash. M, Jyothi Kaparapu and *Narasimha Rao G. M.
Department of Botany, Andhra University, Visakhapatnam 530003, India.
*Correspondance: gmnrao_algae@hotmail.com

Abstract:

In order to study the seasonal variations in the structure and dynamics of phytoplankton community of the Kolleru lake in Andhra Pradesh, water samples were collected in each season during January to December 2009. Seasonal variations, biodiversity indices and correlation coefficient of phytoplankton were studied during the period. Fifty six species of phytoplankton belonging to Chlorophyceae (35 species), Bacillariophyceae (6 species), Cyanophyceae (12 species) and Euglenophyceae (2 species) were identified. The highest phytoplankton abundance was observed in summer and the lowest in winter. The maximum and minimum species richness (Menhinick index R_2) were found to be 1.25 at station 2 and 1.13 at station 3 respectively. Maximum and minimum species diversity (H^1) were found at station 4 and station 5 (3.85) and station 2 (3.67). Maximum species evenness (0.94) was recorded at stations2 and 4 and minimum species evenness was recorded at station 1 (0.89). The preponderant and sub-preponderant species changed in accordance with the seasons. Pearson correlation analysis was used to investigate the relationship between environmental factors and phytoplankton community. The present investigation revealed that the distribution of plankton species depended upon the environmental and physicochemical parameters.

Keywords: Phytoplankton, physicochemical parameters, Seasonal variations, Kolleru Lake, Pearson correlation analysis.

Introduction:

PHYTOPLANKTON contributes about half of the global primary production, the other half being due to terrestrial plants. According to NASA, phytoplankton produces 50–90% of all the oxygen in the air, depending on the seasons. They are important contributors to global carbon fluxes through photosynthetic carbon fixation, which leads to the formation of ~45 Gt of organic carbon per annum[1]. Phytoplankton is an assemblage of heterogeneous microscopic algal forms of aquatic systems whose movement is more or less dependent upon water currents[2]. Besides serving as a primary producer, the free-living phytoplankton serves as feed and caters for the energy needs of planktonivorous organisms and is the key factor capable of determining the fishery potential of the region[3]. As phytoplankton assemblages are at the base of the food web, changes in phytoplankton biomass, species composition and pattern of primary production have implications for the whole community[4,5].

The distribution of phytoplankton is not always uniform and varies spatially and also at time scales. Phytoplankton dynamics or the time dependent changes in phytoplankton biomass are the result of a complex interplay of physical, chemical and biological processes, among all nutrient availability plays a key role in determining the phytoplankton population density[6,7]. By removing carbon-dioxide from the atmosphere and releasing oxygen influenced by available nutrients in the ambient water column, phytoplankton plays more subtle but extremely important role on global biogeochemistry[8]. It has been well documented that initial changes in aquatic communities due to increasing eutrophication begin with the successions in the species composition and abundance of phytoplankton[9]. Understanding the links between nutrient concentration and algal biomass is important in the efforts for eutrophication management[10]. Nutrient enrichment typically stimulates phytoplankton growth in lakes. Some genera of phytoplankton, such as *Microcystis*, *Anabaena*, *Nostoc* and *Aphanizomenon*, usually breakout and stand stably, leading to problems with hypoxia, toxins and changes in the structure of biological communities[11,12]. Major interest on phytoplankton investigation is raised to understand environmental factors that influence their diversity and density, as phytoplankton occupies the starting point of the food chain of the aquatic environment[13]. Phytoplankton population largely dependent on nutrient availability, light penetration and mixing with in the water column however nutrient availability is frequently referred as key

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factor regulating phytoplankton biomass and species composition[14] . The quality and quantity of phytoplankton and their seasonal patterns have been successfully utilized to assess the quality of water and its capacity to sustain heterotrophic communities[15]. Trophic linkages exist, between the phytoplankton as primary producers and populations of consumer organisms including bacteria, zooplankton, benthic invertebrates, and fish [16]. The objective of this study was to assess the seasonal changes in physicochemical parameters, seasonal variation, total percentage, species richness, species diversity, species evenness of phytoplankton and correlation coefficient in the Kolleru Lake, Andhra Pradesh, India.

Study sites and Methods:

Kolleru Lake is largest freshwater lake located in Andhra Pradesh state, India. This is the biggestfresh water ecosystem spreading in an area about 300 Sq.km located in Krishna and Godavari Rivers. It is also known for the famous Kolleru Bird Sanctuary. It is located between the deltas of Godavari & Krishna with very rich and varied of flora and fauna.It receives water from four rivers, namely Budameru, Ramileru, Tammileru and Errakalva and 18 drains. This lake empties its water into the Bay of Bengal, through an outlet called 'upputera'. Its majestic beauty comes alive during monsoons when it spans nearly 260-sq-kms. Kolleru lake lies between longitude 81°5' and 81°20' East and latitudes of 16°32' and 16°51' North in the districts of Krishna and West Godavari districts. In the present investigation, six sampling stations were selected, viz. Kalaparu (S1), Penumakalanka (S2), Venkatapuram (S3), Pulaparru (S4) Chintapadu(S5) Pratikollalanka (S6). Surface water samples were collected from these study sites for collection of hydgrographical chemical and chemical features. Temperature and pH were measured with a thermometer and portable pH meter respectively; transparency was estimated by the Secchi disc.

Plankton net (mesh size 25 µm) was swept on surface water and plankton was collected and transferred in to plastic container and fixed in 4% formalin. Then plankton samples were centrifuged at 1500–2000 rpm for 10–12 min. The phytoplanktons settled were diluted to a desirable concentration in such a way that they could be easily counted individually under compound binocular microscope and phytoplankton were measured and multiplied with the dilution factors and the physico–chemical variables were estimated as per the standard method[17-22]. Pearson correlation matrix was used to establish the relationship among various environmental variables and phytoplankton density with the help of SPSS 16.0 for windows. Three indices were used to obtain estimation of species diversity, species richness and species evenness.

1. Shannon and Weaver and Simpson diversity index values were obtained by using the following equation[23,24]:

$$H^1 = -\sum_{i=1}^{S} \left(Pi \ln Pi\right) \text{(Shannon's index)}$$

$$\lambda = \frac{-\sum_{i=1}^{S} n_i (n_i - 1)}{n\,(n-1)} \text{ (Simpson index)}$$

Where,

Pi = Proportion of the first species.

The proportions are given Pi=ni/N

2. Species richness (R_1 and R_2) obtained using the following equation[25,26].

$$R_1 = \frac{\left(S-1\right)}{\ln\left(n\right)} \text{ (Margalef, 1958)}$$

$$R_2 = \frac{S}{\sqrt{n}} \text{ (Menhinick, 1964)}$$

Where,

R = Index of species richness

S = Total number of species

N = Total number of individuals

3. Species evenness was determined by using the following expression.

Shannon's equitability (E_H) can be calculated by dividing H by H_{MAX} (here H_{MAX} =lnS). Equitability assumes a value between 0 and 1 with 1 being complete evenness.

$$\left(E_H\right) = \frac{H}{H_{MAX}} = \frac{H}{\ln S}$$

H= Shannon diversity index

S = number of species in sample

Results and discussion

Physico-chemical features of the Kolleru lake was presented in the Table.1. Surface water temperature of the this aquatic ecosystem was varied seasonally with maximum water temperature (26˚C) and minimum (18˚C) were reported.

Table-1. Physicochemical parameters of Lake Kolleru during January –December, 2009.

	Station1		Station2		Station3		Station4		Station5		Station6	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Temperature(^{0}C)	18	25	19	26	21	25	19	26	18	24	19	24
Transparency (cm)	8	28	8	27	8	27	8	29	8	27	8	28
Salinity (ppt)	0	0	0	0	0	0	0	1.5	0	1.5	0	1.5
pH	6.6	7.6	6.5	7.5	6.7	7.4	6.7	7.5	6.6	7.5	6.7	7.6
D.O (mg/l)	4.5	7.8	4.7	7.5	4.9	7.7	4.6	7.7	4.6	7.7	4.8	7.7
Alkalinity (mg/l)	250	450	280	460	290	450	280	460	280	450	290	450

Temperature showed a significant inverse relationship with dissolved oxygen. Such an inverse relationship was observed by many authors[27-30]. The pH ranges from 7.6 at stations one and six in September to 6.5 at station two in November (Table-1). The pH values of all the water samples are acceptable for drinking, irrigation and aquaculture purpose. Dissolved oxygen varied from 7.8 mg/l at station one in March to 4.5 mg/l at station one in May. These values are in well agreement with the findings of some authors [31,32]. During the present investigation, the negative correlation of DO with temperature at all sampling sites is in agreement with researchers [27-30,33,34]. Alkalinity ranges from 460 mg/l at stations two and four in June to 280 mg/l in March at station one. This alkalinity limit is not harmful to human beings and other living organisms [35,36]. It has also been concluded that high alkalinity indicates pollution [37]. Alkalinity showed significant negative relationship with dissolved oxygen (r= -0.65). (Table-2).

Transparency of the Kolleru lake was varied from 8 to 29cm in different stations. Water clarity and the ecological quality of shallow lakes could be predicted quite well from water transparency[38,39]. In the present investigation, the transparency values were maximum during summer and minimum during monsoon. Low values of transparency in monsoon may be due to influx of rain water from catchments area, cloudiness, less penetration of light and high turbidity due to suspended inert particulate matter. However, high values of transparency in summer may be due to clear atmosphere and high light penetration.

Similar results have been reported[39-41]. It showed significant positive relationship with dissolved oxygen (r=0.262613), Alkalinity(r= 0.5) and showed significant negative relationship with total phytoplankton (r= -0.59827). Maximum Salinity of surface water was 1.5 ppt in the months of April and May at stations 4, 5 and 6 while 0 ppt salinity observed in October and November months. This may be due to the shrimp culture in nearby regions and some major canals are connected to the sea. Salinity showed significant positive relationship with temperature (r= 0.471405), pH (r=0.242536), dissolved oxygen (0.185695) and total phytoplankton (r=0.015875).

Table-2. Correlation Coefficient (r) among the physico-chemical properties and phytoplankton of Kolleru Lake during January 2009-December2009.

	Transparency	Salinity	pH	D.O	Alkalinity	Temperature	Phytoplancton
Transparency	1						
Salinity	0	1					
pH	-0.08575	0.242536	1				
D.O	0.262613	0.185695	0.315264	1			
Alkalinity	0.5	0	-0.1715	-0.65653	1		
Temperature	-0.125	0.471405	-0.68599	-0.39392	0.25	1	
Phytoplanktonon	-0.59827	0.015875	-0.67557	-0.15283	-0.42491	0.654648	1

Microscopic examination of phytoplankton revealed that there were 4 groups consisting of 32 genera and 56 species of phytoplankton in order Chlorophyceae (19 genera, 35 species), Bacillariophyceae (3 genera, 6species), Cyanophyceae (9 genera 12 species) and Euglenophyceae (1 genus, 2 species). The phytoplankton identified were: *Ankisrodesmus convolutes, Chlamydomonas globosa, Chlorella vulgaris, Chlorococcus varians, Closterium ehernbergi, C. parvulum, C. obsoletum, Cosmarium psedobiramum, C. contractum, Cladophora glomerata, Chara spinosa, Cladophora sps., Chetophora attenuate, C. elegans, Hydrodictyon reticulam, Pandorina morum, Pediastrum ovatum, P.simplex, Pithophora oedogonium, P.varia, Scenedesmus denticulatum, S.abundans, S. dimorphus, S. longus, Spirogyra singularis, S.accidentalis, S.communis, Oedogonium biformae, O.globusum, Ulothrix zonata, U.variabilis, U.cylendricus, Zygnema pectinatum ,Z.sterile., Z.gangeticum* (Chlorophyceae); *Navicula bacilliodes, N.cincta, N.mutoca, Melosira sps., Melosira varians, Astsrionella formosa*. (Bacillariophyceae); *Anabaena constrica, Gloeocapsa granosa, Microcystis elegans, Nostoc commune, Oscilllototia chlorine, O.cortica,O.proboscidea, Lyngbya epiphytica, L.nigra, Gleotheca rupestris, Synechococcus cedrorum, phormidium fragile,* (Cyanophyceae); *Euglene viridis, Euglena caudate* (Euglenophyceae). Chlorophyceae were dominant followed by Bacillariophyceae, Cyanophyceae and Euglenophyceae. Similar observations were made by others [42-45]. Maximum and minimum abundance of phytoplankton observed at station three and one. Physical facors such as temperature and light intensity also regulated seasonal appearance of algal forms[46]. Total phytoplankton abundance showed significant positive correlation with Temperature (r=0.654648), and showed significant negative relationship with dissolved oxygen (r= -0.15283), Transparency (r= -0.59827), pH (r= -0.67557), alkalinity (r= -0.42491) respectively. Maximum abundance was reported for the species *Melosira varians* and minimum abundance for the species *Scenedesmus abundans.* Bacillariophyceae members are dominant in winter and monsoon months[46].

Diversity indices can serve as a good indicator of the overall pollution of water body. Bioindices of species diversity can be derived from species counts and are of three main categories: species richness (Margalef index), species evenness/dominance (Simpson index), and a combination of richness and dominance (Shannon–Wiener index) [47]. These diversity indices have been developed by taking into account of the number of species and their relative abundances, which means the higher the values of these diversity indices, the more the oligotrophic state of water bodies.

Table-3. Annual variations of phytoplanktons's, biodiversity indices at Kolleru Lake during January -December2009.

Indices	Index	Station1	Station2	Station3	Station4	Station5	Station6
Species Richness	N_0	36	38	40	36	39	39
	R_1	8.73	7.56	7.72	8.67	8.32	7.84
	R_2	1.19	1.25	1.13	1.18	1.22	1.19
Species Diversity	λ	0.04	0.03	0.05	0.04	0.04	0.05
	H^1	3.84	3.67	3.74	3.83	3.85	3.78
Species Evenness	E	0.89	0.94	0.92	0.94	0.92	0.91

(N_0):No. of all species (λ):Simpson's index
(R_1):Margalef's index (H^1):Shannon - Weiner index
(R_2):Menhinick index E:Evenness index

Maximum species richness was recorded 8.73 Margalef's index (R_1) and 1.25 Menhinick index (R_2) at station one and station two, minimum Species richness was recorded 7.56 Margalef's index (R_1) and 1.13 Menhinick index (R_2) at station two and station three. Maximum species diversity was recorded 0.05 Simpson's index (λ) at station three and minimum species diversity was recorded 0.03 Simpson's index (λ) at station two. Maximum of 3.85 Shannon - Weiner index (H') at station one and station four; and minimum of 3.67 Shannon - Weiner index (H') at station two. Maximum species evenness was recorded at stations two and four; minimum species evenness was recorded at station one (Tab. 3).

A comparison of the biodiversity indices in the lake suggested that the diversity indices were higher. Such relationship is well documented in the literature and is related to the extreme restrictive environmental conditions associated with the eutrophication process[48]. Seasonal variations in abundance and composition of lake phytoplankton are usually affected by the discharge, morphometry, hydrology, trophic status, and light availability[49-54]. This diversity indices showed that the reservoir under study have a well balanced phytoplankton community that enjoyed an even representation of several species indicating the dynamic nature of aquatic ecosystem.

Conclusion:

Quantitative counts showed clear seasonal variation in phytoplankton cell numbers with maximum during early summer and autumn. The present basic information of the phytoplankton distribution and abundance would form a useful tool for further ecological assessment and monitoring of the ecosystem of Kolleru Lake.

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