Factors influencing zooplankton density and diversity in Thirumeni Lake, Tamil Nadu, India.

V. Dhivaharan

https://doi.org/10.56343/STET.116.014.002.001
http://stetjournals.com

Article History
Received: 04-12- 2019
Revised and Accepted : 15-12-2020
Published: 28-12-2020

Abstract

The influence of water quality and bottom soil quality on the zooplankton of Thirumeni Lake, Thiruvarur District, Tamilnadu, India is described in this paper. Protozoans have dominated the zooplankton community followed by crustaceans. Water pH, hardness (total, calcium and magnesium), iron, nitrate and sulphate levels in water and soil phosphorus have been the most significant factors that influence the zooplankton volume, density and diversity in Thirumeni lake.

Key words: density, diversity, soil factors, water quality, zooplankton

INTRODUCTION

The zooplankton in freshwater comprise principally protozoans, rotifers, cladocerans and copepods. Zooplankton are major herbivores as well as important predators in aquatic ecosystems. Therefore, to understand the lake metabolism it is necessary to evaluate the biomass and the rate of zooplankton productivity in this ecosystem. Accoþrding to Sinha and Islam (2002) in lentic ecosystem zooplankton constitutes a vital link in the food chain and an understanding of their composition, abundance and variation helps in proper management of lentic ecosystems. Zooplankton forms an important intermediary step in the grazing food chain in aquatic biota in any ecosystem. Analysis at specific level cannot entirely disclose the functional mechanism of the aquatic ecosystem, unless the dynamics of zooplankton community is adequately known. The distribution pattern of zooplankton in lentic systems þhas been well been documented by several workers (Das and Shrivastava, 1956; Vasisht and Dhir, 1970; Vasisht and Sharma, 1975; Awtramani, 1980; Sharma, 1983; Vasisht and Jindal, 1980; Saxena, 1982). Fluctuation of zooplankton in space and time is controlled by a combination of physico-chmical and biological factors (Dijk and Zanten, 1995).

Significant correlations have been established between zooplankton density and physico-chemical parameters of water by Prakash *et al.* (2001) with rotifers showing highly significant positive correlation with temperature, free CO_2, pH, chloride and nitrogen, cladocerans showing highly significant and positive correlation with temperature, free CO_2, pH, chlorides and nitrogen whereas negative correlation with dissolved oxygen and copepods showing highly positive correlation with dissolved oxygen. Similar observations have been made by Ismail (1997), Ansari and Prakash (2000), Prakash (2001) and Prakash *et al.* (2001) also. Multiple regression analyses by Davis (1954), Ruttner and Kolisko (1974), Gupta (1989), Sharma (1995) and Sharma and Hussain (2001) have shownþ that a number of abiotic and biotic environmental circumstances act simultaneously on zooplankton productivity. Thus, it may be concluded that the density and biomass of Zooplankton are also dependent on different abiotic factors either directly or indirectly.

The influence of water quality and bottom soil quality on the zooplankton of Thirumeni Lake, Thiruvarur District, Tamilnadu, India is described in this paper.

STUDY AREA

The Thirumeni Lake

Thirumeni lake (10° 33′ 28" to 10° 34′ 30.9" N and from 79° 26′ 17.7" to 79° 27′ 54.1" E) is one of the major freshwater habitats and resources of old Thanjavur District, Tamil Nadu, Southern India After trifurcation

V. Dhivaharan

email: *cvdkar@rediffmail.com*

Dean, PG and Research Department of Microbiology, Sengamala Thayaar Educational Trust Women's College, Sundarakkotta, Mannargudi - 614 016, Thiruvarur District, Tamil Nadu, South India.

P - ISSN 0973 - 9157
E - ISSN 2393 - 9249

of the old Thanjavur District it now comes under the Thiruvarur District.

Sampling Stations

For recording periodically the various physico-chemical and biological fluctuations in the lake, three stations were selected. The stations were located nearby the villages Thirumakkottai, Painganadu and Paravakkottai.

Station I : (10° 33′ 46.44" N; 79° 27′ 18.36" E) was at the southern part of the lake near Thirumakkottai.

Station II : (10° 34′ 17.4" N; 79° 27′ 5.4" E) was at the Northern side of the lake near Painganadu.

Station III : (10° 34′ 0.48" N; 79° 26′ 40.56" E) was at the western part of the lake near Paravakkottai.

METHODS

Study Period

Data were collected from October 2000 to May 2001 and November 2001 to April 2002, during three seasons *viz.*, Monsoon (October, November and December) and Post Monsoon (January, February and March) and Summer (April and May) of two successive years (during the months in an year when water was available in the lake which varied depending on the variations on water inflow from the feeder canals and rains). Data were collected on calm, sunny days and days with high wind, heavy rain and dense fog were avoided.

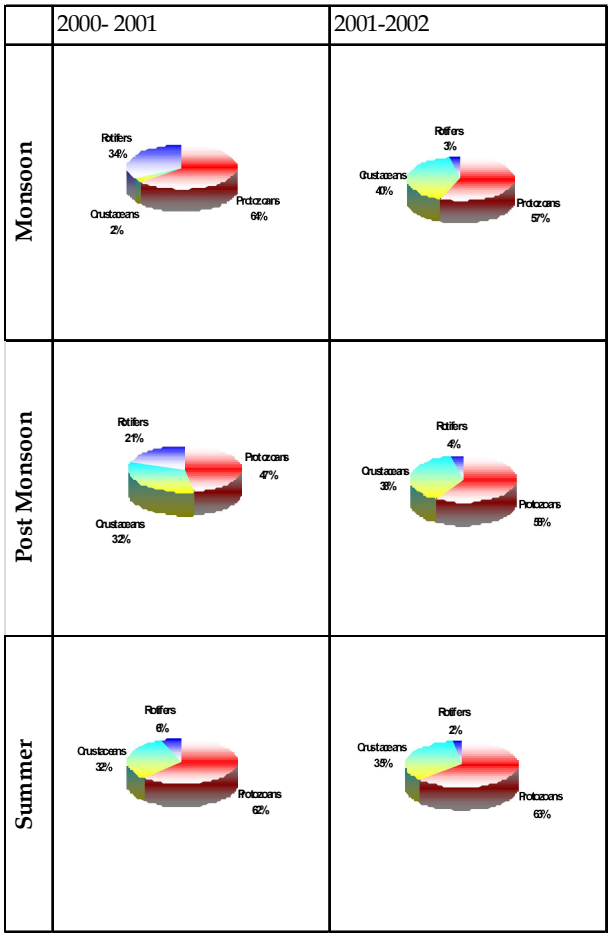


Fig. 1. Season-wise zooplankton composition in Thirumeni lake during the study period

Measuring Water Quality Variables

The following water quality factors were measured once in a week from the three stations. Sample collections and preservation were as per the specifications of APHA (1995).

Physical Factors

Surface water temperature was measured at 8.00 a.m. It was measured in centigrade (C) with a LCD-portable digital Multi-Thermo meter with external sensor probe in all the three stations 0.1m below the water level (Danel1 and Sjoberg, 1982) with 0.1°C accuracy. Turbidity was measured by using the Nephelometer and expressed as NTU. Total dissolved solids were measured using Standard TD Scan I pocket TDS tester (10-1990 ppm range).

Chemical Factors

Fifteen chemical factors *viz.*, pH., dissolved oxygen, total alkalinity, carbonate alkalinity, bicarbonate alkalinity, total hardness, calcium hardness, magnesium hardness, chloride, iron, ammonia, nitrite, nitrate, sulphate and phosphate were assessed. The water samples were collected from the three stations in pre-cleaned separate water cans (1-2 L capacity) and were analyzed separately (Murphy *et al.*, 1984). The water samples were collected and preserved for later analyses as per the procedures described in APHA (1995). The methods used to measure the water chemistry variables were as follows.

pH of the water samples were determined by portable pen type electronic pH meter. The pH meter was immersed in the water and pH values were read directly from the digital screen (Nagarajan and Thiyagesan, 1996). The dissolved oxygen content was estimated by the standard volumetric Winkler method. The water samples were collected in narrow mouthed glass stoppered amber coloured bottles without air bubbles and fixed in the field (Nagarajan and Thiyagesan, 1996). The alkalinity of water sample was estimated by Acid-Base titrimetric method (Trivedy *et al.*, 1987). Hardness was measured by the complexometric titration using EDTA (Trivedy and Goel, 1986).

Calcium was estimated by the complexometric titration using EDTA (Trivedy and Goel, 1986) Magnesium hardness was calculated as follows : Magnesium

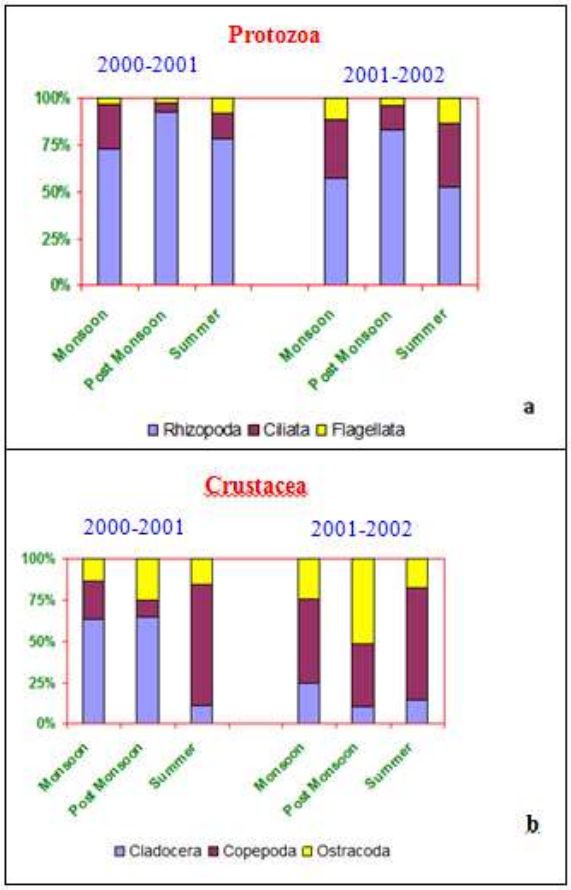


Fig. 2. Seasonal variations in the composition of a) Protozoans and b) Crustaceans in the Thirumeni lake during the study period.

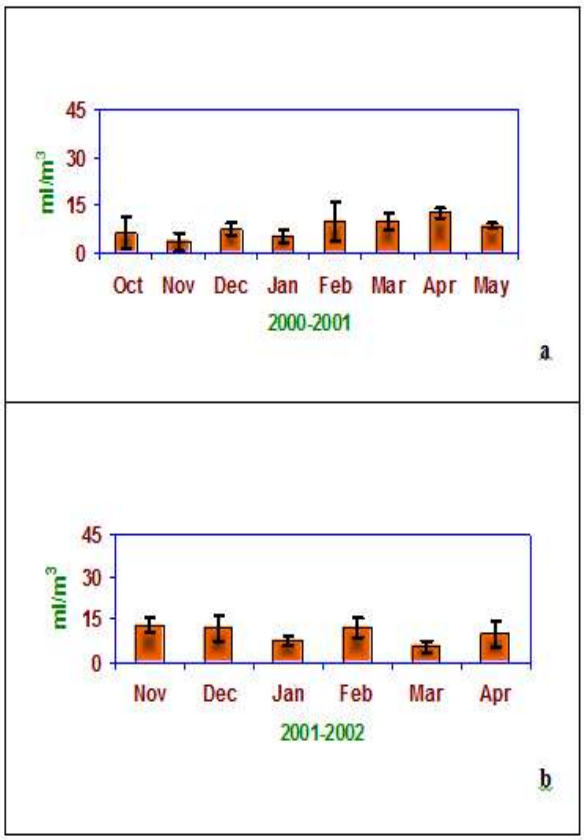


Fig. 3. Monthly variations in the volume of zooplankton in Thirumeni lake during a) First Year (2000-2001) and b) Second Year (2001-2002) of the study period. Values are $\overline{X}$±1SD.

Hardness = Total Hardness - Calcium Hardness. Estimation of chloride was by following Trivedy and Goel (1986). Iron was estimated by the Phenanthroline method (APHA, 1995). Ammonia was estimated by the Nesslerization method described by Trivedy and Goel (1986).The nitrite content was estimated by the colorimetric Griess – Ilosvay method described by Klein (1973). Determination of nitrate was based on the phenol disulfonic acid colorimetric method described by Trivedy and Goel (1986). Sulphate level was estimated by the barium chloride Turbidimetric method (Trivedy and Goel, 1986). The determination of phosphate was made by the colorimetric method of Trivedy *et al*. (1987).

Plankton Studies

Sampling

The plankton samples were collected once in a fortnight by filtering 50 litres of surface water at different sites using a standard plankton net (No.20) and were fixed and preserved in modified Lugol's solution (Pandit, 1980) and also in 4% formalin for later identification (Michael, 1986). The plankton sample was also allowed to settle overnight in a measuring cylinder and the sedimented volume was taken to calculate the volume of plankton per cubic metre of water. Identification of the plankton organisms was done out by referring to relevant works (Desikachary 1959a,b; Ward and Whipple 1959; Philipose 1967; Sreenivas and Duthie 1973; Adoni *et al.,* 1985; Battish, 1992).

Counting

For counting the plankton, a modification of Lackey drop method (Lackey, 1938) was used. It is a simple method of obtaining counts of considerable accuracy with samples containing dense planktonic populations (APHA, 1995). The plankton was quantified with the help of the formula given by Welch (1952).

i.e., Organisms / l = (N*A/V)/L

A = Number of organisms per drop

L = Volume of original sample

V = Volume of one drop

N = Total volume of the sedimented sample

Table 1. Zooplankton recorded in Thirumeni lake during the study period.

I. PROTOZOA		
A) Rhizopoda	**B) Ciliata**	*6. Stylonychia* sp.
1. *Amoeba* sp.	*1. Flexiphyllum* sp.	7. Euplotes sp.
2. Difflugia sp.	2. Lacrymaria sp.	
3. Hyalosphenia sp.	3. Mesodinium sp.	**C) Zoo Flagellata**
4. Pelomyxa sp.	4. Enchelys sp.	1. Mallomonas sp.
5. Platoum sp.	5. Hastatella sp.	
II. ROTIFERA		
1. Ephydatia sp.	8. *Kellicottia* sp.	
2. Heteromeyenia sp.	9. Lacane sp.	
3. Brachionus sp.	10. Pompholyx sp.	
4. Keratella sp.	11. Platyias sp.	
5. Monostyla sp.	12. Ploesoma sp.	
6. Notholca sp.	13. Rattulus sp.	
7. Asplanchna sp.	14. Trichocerca sp.	
III. CRUSTACEANS		
A) Cladocera	*9. Macrothrix* sp.	
1. Daphnia sp.	10. Simocephalus sp.	
2. Moina sp.	**B) Copepoda**	
3. Holopedium sp.	1. Cyclops sp.	**C) Ostracoda**
4. Ceriodaphnia sp.	2. Mesocyclops sp.	1. Cypris sp.
5. Bosmina sp.	3. Diaptomus sp.	2. Notodromas sp.
6. Diaphanosoma sp.	4. Calanus sp.	
7. Chydorus sp.	5. Eucalanus sp.	
8. Eurycercus sp.	6. Pseudodiaptomus sp.	

In the text, quantity of plankton has been expressed as number per cubic meter (APHA, 1995).

Bottom Soil Analysis

Bottom samples were collected at three different stations in each region in each month by using Petersen grab. It was towed slowly for a distance of one foot (Wetzel and Likens, 1979; Nagarajan and Thiyagesan, 1996).

Soil Textural Analysis

Soil textural analysis was done at the Tamilnadu Agricultural University, Soil Testing Laboratory, Aduthurai. Soil analyses were by mechanical analysis as per the international pipette method (Piper, 1966).

Soil Macronutrient Analysis

For the estimation of the level of soil macronutrients like nitrogen, phosphorus and potassium, soil pH and soil electrical conductivity, the soil samples collected were sent to the Tamilnadu Agricultural University Soil Testing Laboratory, Aduthurai and the results were obtained directly from them.

Data Analysis

Diversity Index

The species-diversity (H′) was calculated using the Shannon Weiner index (Shannon and Weiner, 1949).

$$H = -\sum_{I=1}^{S} pi \ln ip$$

Where pi = ni/N; ni = proportion of individual in each category; N=total number observed and s=number of categories).

Statistical Analyses

Basic statistics *viz.*, arithmetic mean, standard deviation and standard error were calculated for all the replicate variables and are given as $\overline{X} \pm 1$ SD or

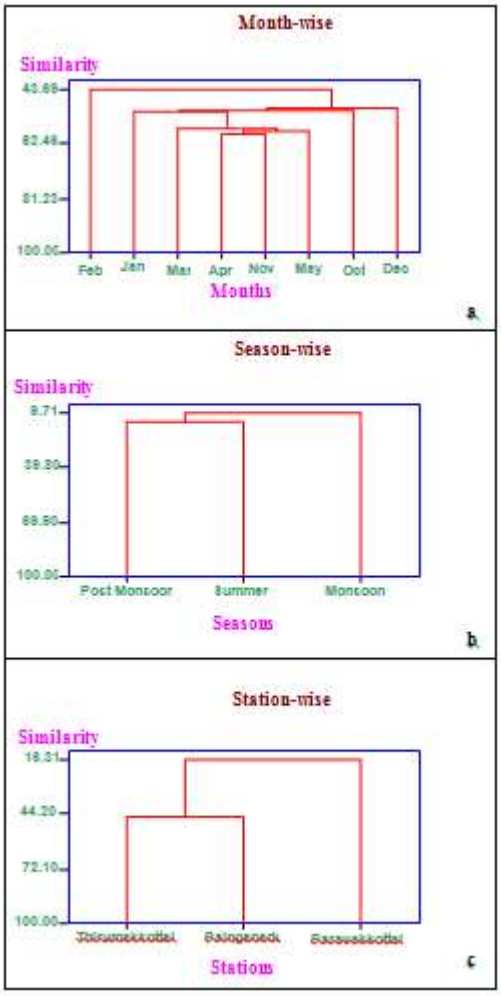


Fig. 4. Dendrograms to show the similarities among the **a)** months and **b)** seasons of the study period and **c)** sampling stations of the lake with regard to volume of zooplankton.

$\overline{X}$ ± 1 SE. Statistical analyses were performed by using Window based statistical packages *viz*., Microsoft Excel, MINITAB (Ryan *et al*., 1992) and SPSS (Statistical Package for Social Science; Nie *et al*., 1975). Mainly parametric tests *viz*., Analysis of Variance (ANOVA), Cluster Analysis, and Multiple Regression equations were used to test hypothesis. Appropriate data transformations were made wherever needed. For hypothesis testing $P < 0.05$, $P < 0.01$ and $P < 0.001$ were considered and these levels of significance were indicated at appropriate places. Statistical inferences were made by following Sokal and Rohlf (1995) and Zar (2003).

RESULTS

Forty-five genera of zooplankton with the following break up were recorded from the Thirumeni lake during the study period (Table 1).

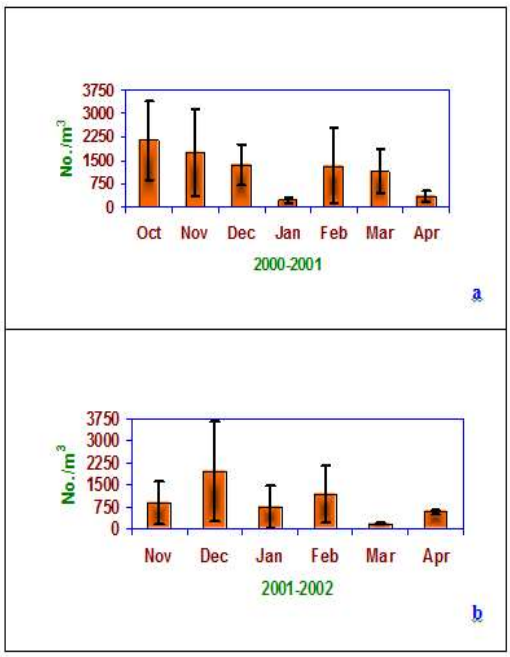


Fig. 5 : Monthly variations in the density (No./m^3) of zooplankton during a) First Year (2000-2001) and b) Second Year (2001-2002) of the study period. Values are $\overline{X}$±1SD.

(i) Protozoa : 13 (5 Rhizopoda, 7 Ciliata, 1 Zooflagellata)

(ii) Rotifera : 14

(iii) Crustacea : 18 (10 Cladocera, 6 Copepoda, 2 Ostracoda)

The per cent composition of various groups of zooplankton during different seasons of the study period is shown in fig. 1. Protozoans dominated the zooplankton community followed by Crustaceans in all the seasons of both the years except during monsoon of 2000 – 2001 when Rotifers were more then Crustaceans (Fig. 1).

Per cent composition of various groups of protozoans during the different seasons of the study period is shown in Fig. 2a and that of the Crustaceans in Fig. 2b.

Volume of Zooplankton

Month–wise variations in the volume of zooplankton recorded in the lake during the study period are shown in figs. 3a and b. April happened to be the month of highest zooplankton volume in the first year (2000 – 2001) while it was highest in November in the second year of study (2001 – 2002) (Fig. 3a and b). On the other hand, the zooplankton volume was lowest during November in the first year (Fig. 3a), while March was the month with lowest zooplankton volume (Fig. 3 b) in the second year.

Table 2. Multiple regression equation model to predict the influence of water quality parameters and soil characteristics on the volume (ml / m^3) of zooplankton

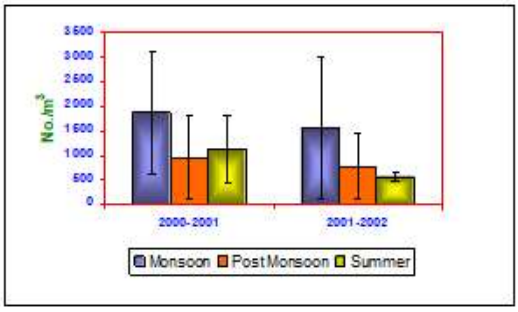
Variables Model F Model P and R2	Predictor	Coefficient	Standard Deviation	t	P
Zooplankton volume(ml/m3) F=4.30 P<0.05 R2 = 13.7%	Constant	10.499	2.153	4.88	0
	Total Hardness	-0.03674	0.01878	-1.96	0.056
	Magnesium	0.08223	0.02803	2.93	0.005

Table 3. Multiple regression equation model to predict the influence of water quality parameters and soil characteristics on the density (No./m^3) of zooplankton.

Variables Model F Model P and R2	Predictor	Coefficient	Standard Deviation	t	P
Zooplankton density (No./m3) F=4.03 P<0.001 R2 = 43.6%	Constant	123.65	34.03	3.63	0.001
	Chlorides	-0.09926	0.04774	-2.08	0.043
	Chlorides^2	0.00017222	0.00008118	2.12	0.039
	Iron	19.389	6.404	3.03	0.004
	Iron^2	-13.376	4.172	-3.21	0.002
	Nitrate	481.9	165.5	2.91	0.005
	Nitrate^2	-7595	2649	-2.87	0.006
	Nitrate^3	25581	9192	2.78	0.008
	Phosphorus	-12.323	3.948	-3.12	0.003
	Phosphorus^2	0.347	0.1123	3.09	0.003

Table 4. Multiple regression equation model to predict the influence of water quality parameters and soil characteristics on the diversity (H′) of zooplankton.

Variables Model F Model P and R2	Predictor	Coefficient	Standard Deviation	t	P
Zooplankton diversity (H′) F=5.72 P<0.001 R2 = 52.3%	Constant	3.2918	0.8636	3.81	0
	pH	-0.06624	0.02914	-2.27	0.028
	Calcium Hardness	0.0019712	0.0009531	2.07	0.044
	Iron	0.5662	0.1637	3.46	0.001
	Iron^2	-0.4228	0.1124	-3.76	0
	Sulphate	0.26907	0.06051	4.45	0
	Sulphate^2	-0.08553	0.02167	-3.95	0
	Sulphate^3	0.006202	0.001686	3.68	0.001
	Phosphorus	-0.2844	0.105	-2.71	0.009
	Phosphorus^2	0.008113	0.003003	2.7	0.01



ANOVA for Sooplankton density

Source	DF	SS	MS	F*	P*
Year	1	202.77	202.77	3.30	0.075
Season	2	411.28	205.64	3.34	0.043
Year*Season	2	172.30	86.15	1.40	0.256
Error	51	3135.79	61.49		

* Significant values are indicated by bold types

Fig. 6 : Seasonal variations in the density (No./m^3) of zooplankton in Thirumeni lake during the study period. Values are $\overline{X}$±1SD.

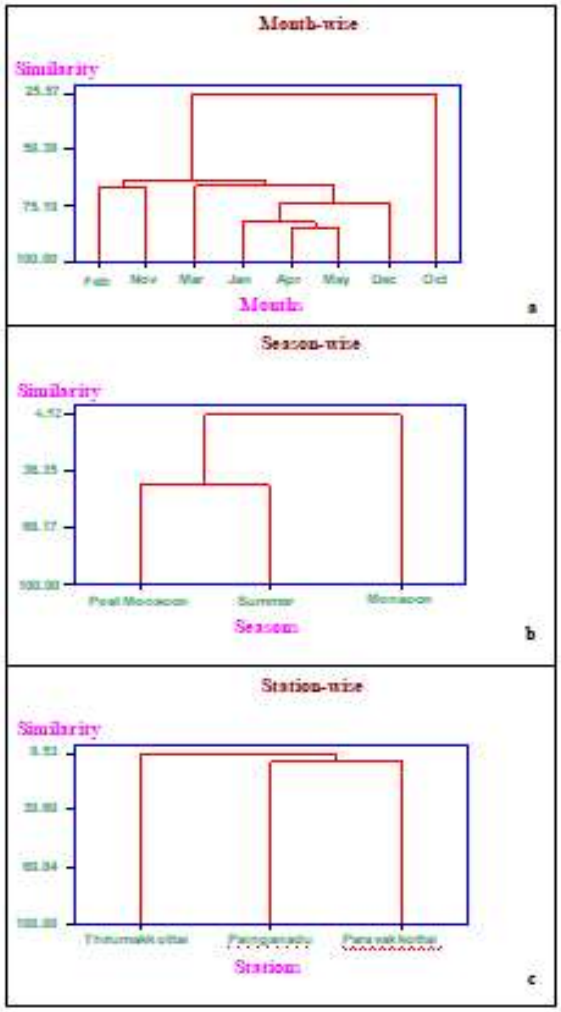


Fig.7 Dendrograms to show the similarities among the **a)** months and **b)** seasons of the study period and **c)** sampling stations of the lake with regard to density of zooplankton.

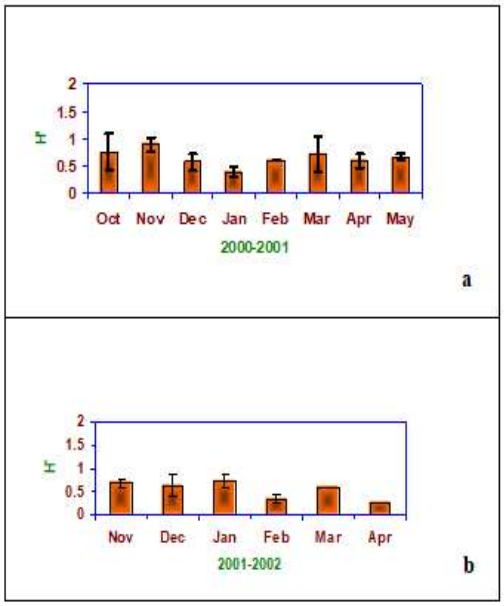


Fig. 8 : Monthly variations in the diversity (H') of zooplankton during a) First Year (2000-2001) and b) Second Year (2001-2002) of the study period. Values are $\overline{X}$±1SD.

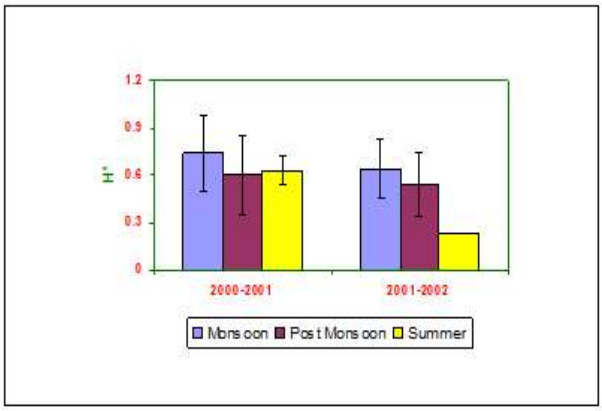
Dendrograms obtained as a result of cluster analysis to find out the similarities in zooplankton volume with regard to months, seasons and stations are shown figs. 4 a, b and c. The months, January, February, October and December were unique in their zooplankton volume during the study period (Fig. 4a). The zooplankton volume during post monsoon and summer seasons was similar, while monsoon happened to be unique in zooplankton volume (Fig. 4 b). The stations Thirumakkottai and Painganadu had highest similarity with regard to zooplankton volume, while the Paravakkottai lake was unique in zooplankton volume during the study period (Fig. 4 c).

Factors Influencing Volume of Zooplankton

Levels of total hardness and magnesium in the lake waters entered into the multiple regression equation derived to predict the variation in the zooplankton productivity. Both the variables had linear relationship with zooplankton volume and magnesium had positive effect whereas total hardness had negative effect. The model was highly significant ($F=4.30$; $P<0.05$; $R^2=13.7\%$) (Table –2).

Density of Zooplankton

Month – wise variations in the density of zooplankton recorded in the lake during the study period are shown in figs. 5a and b. The zooplankton density was highest during October (2000 – 2001) and thereafter it showed a declining trend up to January, shot up during the next month i.e. February and once again declined in



ANOVA for diversity of Zooplankton

Source	DF	SS	MS	F*	p*
Year	1	0.41739	0.41739	10.07	0.003
Season	2	0.45553	0.22776	5.49	0.007
Year*Season	2	0.22533	0.11266	2.72	0.076
Error	51	2.11485	0.04147		

* Significant values are indicated by bold types

Fig. 9 : Seasonal variations in the diversity (H') of zooplankton in the Thirumeni lake during the study period. Values are X±1SD.

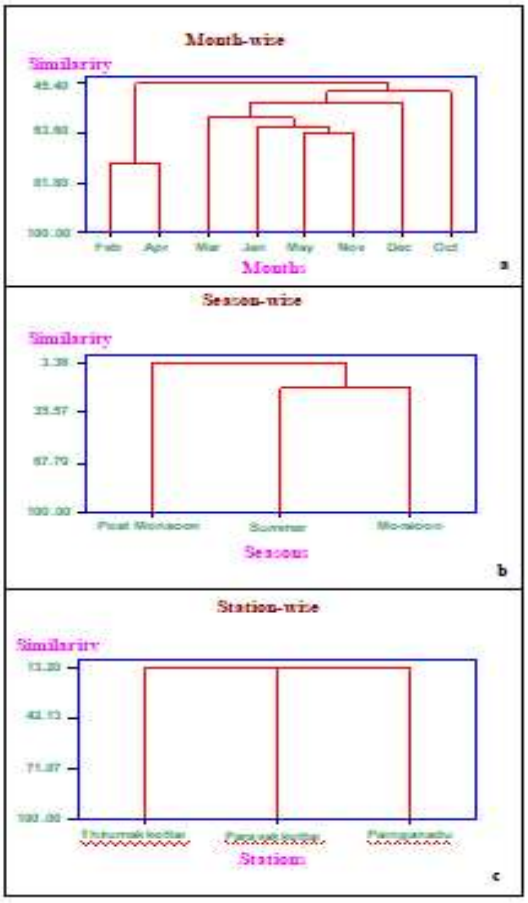


Fig. 10. Dendrograms to show the similarities among the **a)** months and **b)** seasons of the study period and **c)** sampling stations of the lake with regard to diversity of zooplankton.

the remaining months of the first year i.e. March and April (Fig. 5a). However, no such clear trend could be discerned in the second year of study (2001 – 2002) as it fluctuated with alternate rise and fall in successive months from November to April (Fig. 5b).

Season–wise variations in the density (no./m^3) of the zooplankton are shown in fig. 6. The zooplankton density was highest during the monsoon season in both years of study (Fig. 6). The season - wise variations in the zooplankton density in the lake are statistically significant (ANOVA; $F_{2, 51} = 3.34$; $P<0.05$).

Cluster analysis showed that the zooplankton density was similar during (i) February and November and (ii)January, March, April and May while October was unique in zooplankton density during the study period (Fig. 7a). When grouped by cluster /analysis, the zooplankton density was similar during post monsoon and summer seasons, while monsoon happened to be the season with characteristic zooplankton density (Fig. 7b). The station Painganadu and Paravakkottai were similar in zooplankton density (Fig. 7 c).

Factors Influencing Zooplankton Density

Variation in the zooplankton density in Thirumeni lake could be attributed to chlorides, iron and nitrates levels of water and phosphorus of bottom soil as they accounted for 43.6% variations in zooplankton density. All the variables had quadratic relationship except nitrates, which had cubic relationship ($F = 4.03$; $P<0.001$; Table - 3).

Diversity of Zooplankton

Month – wise variations in zooplankton diversity (H') recorded in the lake during the study period are shown in figs. 8a and b. The zooplankton diversity (H') was highest during November and lowest during January in the first year (2000 – 2001) of the study period (Fig. 8a). Contrastingly, January happened to be the month with the highest zooplankton diversity (H') and April with the least during the second year of study (i.e. 2001 – 2002) (Fig. 8 b).

Season – wise variations in the zooplankton diversity (H') are shown in fig. 9. Monsoon season happened to be the season with the highest zooplankton diversity in both the years of study (Fig. 9). The zooplankton diversity (H') was lowest in the post monsoon during the first year (2000 – 2001) and summer during the second year (2001 – 2002) (Fig. 9). Both the annual and seasonal effects on zooplankton diversity in the lake were statistically significant (ANOVA; year $F_{1, 51} = 10.07$; season $F_{2, 51} = 5.49$; $P<0.01$).

Clustering of months, seasons and stations based on their zooplankton diversity has been shown in figs. 10 a, b and c. Two clusters i) February and April and ii) November, January, March and May could be discerned

in the month-wise dendrograms developed, while December and October showed unique pattern in the zooplankton diversity (Fig. 10a). The zooplankton diversity was similar during the summer and monsoon seasons and the zooplankton diversity in the lake during post monsoon season was quite different from that of the other two seasons (Fig. 10b). But, no clear differentiation of stations of the lake could be discerned from the dendrogram with regard to zooplankton diversity (Fig. 10c).

Factors Influencing Zooplankton Diversity

Water pH, calcium hardness, iron and sulphates levels and soil phosphorus entered into the multiple regression model developed to predict the variation in zooplankton diversity in Thirumeni lake and they collectively explained for 52.3% of the total variation ($F = 5.72$; $P<0.001$). pH and calcium hardness had linear relationship, iron and phosphorus had quadratic and sulphates had cubic relationship with zooplankton diversity (Table 4).

DISCUSSION

Zooplankton Composition

Protozoans have dominated the zooplankton community followed by crustaceans in all the seasons of both the years except during monsoon of 2000- 2001, when rotifers have been found to be higher than crustaceans (vide Fig.1). Variation in zooplankton composition in freshwater ecosystems in different seasons has been reported by Jha *et al.* (1931), Govind (1969), Sreenivasan (1970), Ayyappan *et al.* (1980), Dad (1981), Rao (1987), Gupta (1989) and Kumar (2002). According Pandit (1999), the rich crop of protozoa may be attributed to the higher amounts of organic matter providing the basic source of food and the higher percentage of rotifers may be attributed to the availability of rich protozoan food. However, according to George (1966) numerical superiority of rotifers is an indication of the eutrophic nature of the waterbody.

Seasonal Variations in Zooplankton

In the present study, the zooplankton volume has been observed to be highest in summer during the first year (2000-2001) and during the monsoon in the second year . The zooplankton density has been highest during the monsoon season in both years of study (vide Fig. 6). Monsoon happens to be the season with the highest zooplankton diversity in both the years of study (vide Fig. 4.107). On the contrary, Michael (1969), Baruah *et al.* (1993) and Kumar and Gupta (2002) have observed maximum zooplankton density during summer in various freshwater bodies and have opined that such a summer increase in zooplankton might be due to favourable water conditions and high phytoplankton density upon which they depend for their food. There has been only a single peak in April during the first year, while there have been three peaks in November, February and April during the second year with regard to zooplankton volume (vide Fig. 3). There have been two peaks in the density of zooplankton, in October and February, in the first year and in December and February in the second year (vide Fig. 5). There were two peaks in zooplankton diversity in the first year in November, March and a single peak in January during the second year (vide Fig. 4.106). Cluster analyses (vide Figs. 4, 7 and 10) have also showed that there are clear variations due to months. Temporal variations in zooplankton periodicity with unimodal peak (Sumitra, 1969), bimodal peak (Das and Shrivastava, 1956; Vasisht and Dhir, 1970; Vasisht and Sharma, 1975; Bohra, 1977; Awtramani, 1980; Vashist and Jindal, 1980; Sharma, 1983; Kumar, 2002) and trimodal periodicity (Tandon and Singh, 1972) have been reported earlier. In the present study, the pattern of zooplankton volume, density and diversity have been found to be broadly similar to that of phytoplankton. This relationship i.e. the zooplanktonic peaks coinciding with phytoplanktonic peaks, has also been reported by Shetty *et al.* (1961), Pahwa and Mehrotra (1966), Tandon and Singh (1972), Bhatnagar (1982) Sharma (1983) and Kumar (2002), also. But on the other hand, according to theory, zooplankton and phytoplankton should show an inverse relationship (Anderson *et al.,* 1955). Porter (1973, 1977) explains that this anomaly is due to the fact that the zooplankton consume only a certain portion of total phytoplanktonic community and therefore the above relationship is restricted primarily to the nanoplankton, because of easy grazing on small sized plankton. Furthermore, Saunders (1969) Ruttner and Kolisko (1974) and Moore (1978, 1981) have found the dependence of zooplankton on detritus and associated bacterial flora also. Davis (1954), Ruttner and Kolisko (1974) and Gupta (1989) have stated that a number of abiotic and biotic environmental circumstances act simultaneously to shape the planktonic community and according to Kumar (2002) the maximum plankton yield is governed mainly by favourable balance between various ecological and biological conditions.

Water Quality Factors Influencing Zooplankton

Water pH, hardness (total, calcium and magnesium), iron, nitrate and sulphate levels in water and soil phosphorus have been the most significant factors that influence the zooplankton volume, density and diversity in Thirumeni lake as inferred from the multiple regression analyses (vide Tables 2-4). pH has been reported to directly or indirectly affect the production of aquatic organisms (Odum, 1996; Das,

1978; Minns, 1989). Significance of hardness values on zooplankton production has been reported by Sharma and Hussain (2001). Iron plays an important part in the metabolism of organism (Maitland, 1990). Saha (1980) has found an inverse relationship between nitrate and zooplankton. According to Dijk and Zanten (1995) fluctuation in zooplankton in space and time is controlled by a combination of physico-chemical and biological factors. Prakash *et al*. (2002) have also observed significant correlations between zooplankton and levels of pH and nitrogen. Sharma and Hussain (2001) have found that a multiple regression predictor with the ecological variables, namely, specific conductivity, pH, dissolved oxygen, transparency, free carbon-di-oxide, total alkalinity, hardness, chlorides, net primary production and potassium together account for 99.96% of variations in zooplankton, thereby indicating the combined influence of various factors.þþþ Earlier Sharma (1995) and Yadava and Dey (1990) have also reported the collective influence of water quality variables on zooplankton densities. Prakash *et al.* (2002) have also established significant correlations between zooplankton groups, such as, rotifers, cladocerans and copepods and water quality factors *viz*., water temperature, free Co_2, pH, dissolved oxygen, chlorides and nitrogen. Similar observations have been reported by Ismail (1997), Ansari and Prakash (2000), Prakash (2001) and Prakash *et al.* (2001). Thus it may be concluded that the dynamics of zooplankton communities in Thirumeni lake is greatly influenced by the variation in its water quality factors discussed above.

REFERENCES

Adoni, A.D., Joshi, G., Ghosh, K., Chourasia, S.K., Vaishya, A.K., Yadav, M. and Verma, H.G. 1985. Work book on limnology. Pratibha Publishers, Sagar.

Anderson, G.C., Comita, G.W. and Engston, H.V. 1955. A note on the phytoplankton, zooplankton relationship in two lakes in Washington. *Ecology* 36: 756-759. https://doi.org/10.2307/1931314

Ansari, K.K. and Prakash, S. 2000. Seasonal variations in Rotifer population and some physico-chemical factors of motisagartal of Tarai region, Balrampur, U.P. p. 11. *In:* Proc. of first national conference on recent trends of life management at Jhansi.

APHA. 1995. Standard methods for the examination of water and wastewater. American Public Health Association, Washington D.C.

Awatramani, G.M. 1980. Limnological studies of Sagar lake. Ph.D. Thesis, University of Sagar, Sagar, India.

Ayyappan, S., Gupta, T.R.and Chandrashekhran. M. 1980. Limnology of Ramasamudra tank. *J. Inland Fish. Soc. India* 12(2): 1-12.

Baruah, A., Singh, D.K., Sinha, A.K. and Sharma, U.P. 1993. Plankton variability of a tropical wetland, Kawar lake (Begusarai), Bihar. *J. Fresh. Biol*.5: 27-32.

Bhatnagar, G.P. 1982. Limnology of lower lake Bhopal with reference to sewage pollution and entrophication. N.A.B. project report 1979-1982. 77pp.

þBhattish, S.K. 1992. Freshwater zooplankton of India. Oxford and IBH Publishing Co., New Delhi.

Bohra, O.P. 1977. Observations on the diel cycle of abionic parameters at Jatabera, Jodhpur. *Comp. Physiol. Ecol.* 2(3): 115-118.

Dad, N.K. 1981. Limnological studies on Chambal river with reference to pollution. Ph.D. Thesis, Vickram University, India.

Danell, K. and Sjoberg, K. 1982. Seasonal and diel changes in the feeding behavior of some dabbling duck species on a breeding lake in northern Sweden. *Ornis Scand* https://doi.org/10.2307/3676199 13(2): 129-134.

Das, S.M. 1978. High pollution in lake Nainital, U.P. as evidenced by biological indicators. *Sci. Cult.* 45(5): 236-237.

Das, S.M. and Shrivastava, V.K. 1956. Quantitative studies on fresh water plankton II. Correlation between plankton and hydrological factors. *Proc. Nat. Acad. Sci. India* 24 (4): 243-254.

Davis, C.C. 1954. A preliminary study of the plankton of Cleaveland harbour area Ohio. II. The distribution and quantity of the phytoplankton. *Ecol. Monogr*. 23: 321-347. https://doi.org/10.2307/1943235

Desikachary, T.V. 1959a. Cyanophyta. Indian Council of Agricultural Research, New Delhi.

Desikachary, T.V. 1959b. A monograph on Cyanophyta. Indian Council of Agricultural Research, New Delhi.

Dijk, G.M.V. and Zanten, V. 1995. Seasonal changes in zooplankton abundance in the lower Rhine during 1987-1991. *Hydrobiologia* 304: 29-38. https://doi.org/10.1007/BF02530701

George, M.G. 1966. Comparative plankton ecology of five fish tanks in Delhi, India. *Hydrobiologia* 27(1-2): 81-108. https://doi.org/10.1007/BF02530701

Govind, B.V. 1969. Bottom fauna and macrovegetation in the Tungabhadra reservoir and their role in the food chain of fish communities. p. 27-29. *In:* Proc. Sem. Ecol. Fish Fresh Water Reservoir. CIFRI, Barrackpore.

Gupta, S. 1989. Pollution ecology of some ponds in urban vicinity of Jodhpur. Ph.D., Thesis, University of Jodhpur, Jodhpur, India.

Ismail, Q. 1997. Seasonal variation of rotifers and certain physio-chemical factors Pipliya Pala Tal Indore. *Proc. Acad. Environ. Biol.* 6(2): 139-144.

Jha, B.C., Kaushal, D.K, Rao, Y. and Rama, N.M. 1931. Observations on qualitative abundance of plankton and periphyton in Gobind Sagar reservoir. *J. Inland. Fish. Soc. India* 13(2): 126-129.

Klein, L. 1973. River pollution 1. Chemical analysis. Butterworths, London.

Kumar, A. 2002. The ecology of aquatic biota in thermal springs. p.1-53. *In:* Ecology and ethology of aquatic biota. Daya Publishing House, New Delhi.

Kumar, A. and Gupta, H.P. 2002. Ecobiodiversity of aquatic biota in certain freshwater ecosystems of Santal Pagana (Jharkhard). p. 1-70. *In*: Ecology and ethology of aquatic biota (Vol. I). Data Publishing House, Delhi.

Lackey, J.B. 1938. The manipulation and counting of river planktons and changes in some organisms due to formalin preservation. *Pub. Health Rep*. 53: 2080.
https://doi.org/10.2307/4582717

Maitland, P.S. 1990. Biology of freshwater. 2nd edition. Champan and Hall, New York.

Michael, P. 1986. Ecological methods for field and laboratory investigations. Tata- McGraw-Hill Publishing Company Limited, New Delhi.

Michael, R.G. 1969. Seasonal trends in physico-chemical factors and plankton of a fresh water fish pond and their role in fish culture. *Hydrobiologia* 33(1): 144-160.
https://doi.org/10.1007/BF00181684

Minns, C.K. 1989. Factors affecting fish species richness in Ontario lakes. *Trans. Am. Fish. Soc.* 118: 533-545.
https://doi.org/10.1577/1548-8659(1989)118%3C0533:FAFSRI%3E2.3.CO;2

Moore, W.J. 1978. Distribution and abundance of phytoplankton cycles in 153 lakes, rivers and pools in the Northwest Territories. *Can. J. Biol.* 56:765-1173.
https://doi.org/10.1139/b78-210

Moore, W.J. 1981. Influence of temperature photoperiod and tropic conditions on the seasonal cycles of phytoplankton and zooplankton in two deep subarctic lakes on Northen Canada. *Int. Rev. Gesamten Hydrobiol.* 66(5): 745-770.
https://doi.org/10.1002/iroh.19810660512

Nagarajan, R. and Thiyagesan, K. 1996. Waterbird population and substrate quality of the Pichavaram wetlands, Southern India. *Ibis* 138: 710-721.
https://doi.org/10.1111/j.1474-919X.1996.tb04773.x

Nie, N.H., Hull, C.H., Jenkins, J.G., Steinbrenner, K. and Bent, D.H. 1975. Statistical package for the social sciences. McGraw-Hill, New York.

Odum, E.P. 1996. Fundamentals of ecology. Natraj Publishers, Dehra Dun.

Pahwa, D. and Mehrotra, S.N. 1966. Observation on fluctuations in the abundance of plankton in relation to certain hydrobiological conditions of river Ganga. *Proc. Natl. Acad. Sci.* 96: 157-189.

Pandit, A.K. 1980. Biotic factors and food chain in some tropical wetlands of Kashmir. Ph.D. Thesis, University of Kashmir, Srinagar, India.

Pandit, A.K. 1999. Tropic structure of plankton community, in some typical wetlands of Kashmir, India. p. 190-224. *In*: Mishra, S.R., editor. Limnological research in India, Daya Publishing House, Delhi.

Philipose, M.T. 1967. Chlorococcales. Indian Council for Agricultural Research, New Delhi.

Piper, C.S. 1966. Soil and plant analysis, Hans Publishers, Bombay.

Porter, K.G. 1973. Selective grazing and differential digestion of algae by zooplankton. *Nature* 244: 179-180.

Porter, K.G. 1977. The plant animal interface in fresh water ecosystem. *Am. Sci.* 65: 159-170.
https://doi.org/10.1038/244179a0

Prakash, S. 2001. Seasonal dynamics of plankton in a fresh water body at Balrampur. *Geobios* 28(1): 36-39.

Prakash, S., Ansari, K.K. and Shrivastava, R.R. 2001. Effects of hydrological parameters on the population of Cladoceran and Copepods of Motisagar, Tal, Balrampur, U.P. *Acta. Ecol.Sinc.* 23(1): 121-132.

Rao, M.G. 1987. Synecology of the lake Ranasagar in relation to limnology and eutrophication. Ph.D. Thesis, Sukhadia University, Udaipur, India.

Ruttner, F. and Kolisko, A. 1974. Plankton Rotifers. Biology and taxonomy. *Die Binnen. Gerasser Suppl.* 26: 1-146.

Ryan, F.B., Joiner, B.L. and Ryan, A.J. 1992. MINITAB Hand book. PWS-KENT Publishing Company, Boston.

Saha, S.K. 1980. Limnological survey of thermal springs of Bhimbandh, Monghyr. Ph.D. Thesis, Bhagalpur University, India.

Saunders, G.W. 1969. Some aspects of feeding in zooplankton. p. 556-573. *In*: eutrophication-causes, consequences, correctives. Nat. Acad. Sci., Washington.

Saxena, M.M. 1982. Limnological studies of freshwater reservoir, Sardarsamand. Ph.D. Thesis, University of Jodhpur, Jodhpur, India.

Shannon. C.E. and Wiener, W. 1949. The mathematical theory of communication. Illinoss Univ. Press, Urban III.

Sharma, B.K. 1995. Limnological studies in a small reservoir in Meghalaya (N.E., India). p. 187-197. *In:* Timotius, K.H. and Goltenboth, F.S., editors. Trophical limnology, Wacana Christian University Press, Salatiga, Indonesia..

Sharma, B.K. and Hussain, M.D. 2001. Abundance and ecology of zooplankton in a tropical floodplain lake, Assam [N.E. India]. *Eco. Env. and Cons.* 7(4):397-403.

Sharma, N. 1983. Investigations on the limnology of tank ecosystem near Allahabad with particular reference to the abundance and seasonal distribution of plankton and benthos. Ph.D. Thesis, Sagar University, Sagar, India.

Shetty, H.P., Saha, S.B. and Ghosh, B.B. 1961. Observations on the distribution and fluctuation of plankton in the Hooghly Mattah estuarine system, with notes on their relation to commercial fish landings. *Indian J. Fish.* 8(2): 326-363.

Sinha, B. and Islam, M.R. 2002. Seasonal variation in zooplankton population of two lentic bodies at

Assam state Zoo cum Botanical Garden, Guwahati, Assam. *Eco. Env. and Cons.* 8(3): 273 – 278.

Sokal, R.R. and Rolf, F.J. 1995. Biometry. W.H. Freeman and Company, New York.

Sreenivasan, A. 1970. Limnological studies on Parambikulam Aliyar project. I Aliyar reservoir (Madras state), India. *Schewiz. Hydrol.* Birkhauserverlog *Basel* 32: 405-417. https://doi.org/10.1007/BF02502556

Sumitra, V. 1969. Limnological studies on some tropical ponds. Ph.D. Thesis, Madurai Kamarajar University, Madurai, India.

Tandon, K.K. and Singh, H. 1972. Effect of certain physico-chemical factors on the plankton of the Mangal lake. *Proc. Ind. Acad. Sci.* 76(1-8): 15-25. https://doi.org/10.1007/BF03050732

Trivedy, R.K. and Goel, R.K. 1986. Chemical and biological methods for water pollution studies. Environmental Publications, Karad. India.

Trivedy, R.K., Goel. P.K. and Trisal, C.L. 1987. Practical methods in ecology and environmental science, Environmental Publications, Karad, India.

Vasisht, H.S. and Dhir, S.C. 1970. Seasonal distribution of freshwater zooplankton of four tanks, Chandigarh (India). *Ichthyologica*10: 44-56.

Vasisht, H.S. and Jindal, R. 1980: Rheological survey of a pucca stream of Patiala (Punjab, India). *Limnologica* (Berlin) 12(1): 77-83.

Vasisht, H.S. and Sharma, B.K. 1975. Ecology of a tropical urban pond in Ambala city of the Haryana State. *Indian J. Ecol.* 2(1): 79-86.

Ward, H.B. and Whipple, G.C. (editors). 1959. Fresh water Biology. John Wiley and Sons. Inc. New York.

Welch, P.S. 1952. Limnology, 2nd Edition, McGrew Hill Book Company, NewYork. https://doi.org/10.2307/1439300

Wetzel, R.G. and Likens, G.E. 1979. Limnological analysis. W.B. Saunders Co., Philadelphia.

Yadava, Y.S. and Dey, S.C. 1990. Impact of physico-chemical complexes on plankton density in Dhir beel of Assam. *Limnologica* (Berlin) 21: 287-292.

Zar, J.H. 2003. Biostatistical analysis. Pearson Education Pvt. Ltd., Singapore.