International Journal for Environmental Rehabilitation and Conservation

essence

ISSN: 0975 — 6272
XI (SP2): 183 — 197
www.essence-journal.com

Original Research Article

A Comparative study of Zooplankton diversity and abundance of two Ramsar sites (Lake Mansar and Lake Surinsar) of Jammu Region, J & K

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A R T I C L E I N F O

Received: 14 July 2020 | Accepted: 15 August 2020 | Published Online: 30 September 2020

EOI: 10.11208/essence.20.11.SP2.143

A B S T R A C T

Studies were carried out so as to compare the diversity of zooplankton along with physico-chemical parameters in two Ramsar sites (Lake Mansar and Lake Surinsar) of Jammu region. From the survey, 50 species of zooplankton were enlisted from Lake Mansar and 47 species were from Lake Surinsar. Lakes were also investigated for various physico-chemical parameters which interestingly showed some variability, an important reason presently estimated to be responsible for variation in diversity and abundance of inhabitant zooplankton in these two sister Lakes. Presently collected data on qualitative and quantitative aspects of zooplankton community were subjected to correlation studies and statistical diversity which proved that although Lakes showed some similarity in their zooplanktonic fauna and have good percentage of Similarity Index yet there exist some difference in their abiotic environment which leads to the dissimilarity in the composition and distribution of biotic micro fauna.

K E Y W O R D S

Community | Zooplankton | Correlation | Ramsar | Micro Fauna

C I T A T I O N

Antal, Neha; Kour, Sarbjeet and Sharma, Kuldeep K. (2020): A Comparative study of Zooplankton diversity and abundance of two Ramsar sites (Lake Mansar and Lake Surinsar) of Jammu Region, J & K. ESSENCE Int. J. Env. Rehab. Conserv. XI (SP2): 183 — 197.
https://eoi.citefactor.org/10.11208/essence.20.11.SP2.143

Introduction

Aquatic habitat endowed with a vast network of lentic water bodies like lakes, reservoirs, ponds, paddy fields, ditches, tanks etc., which harbor variety of plants and animals, from primary producers to tertiary consumers, intermittently occupied by zooplankton, macrobenthic invertebrates, small fishes, aquatic insects, reptiles, amphibians and even mammals. These aquatic organisms serve as important indicators of water quality and ecosystem health. Among all these aquatic inhabitants zooplankton are the central link between primary producers and higher trophic levels. Jammu region has rich biological heritage that qualifies it, as one of greatest diversity regions of the country. And this region has vast network of lentic water bodies like lakes, reservoirs, ponds, paddy fields etc. Keeping in view the importance of diversity, the present work has been designed to identify, inventorize and compare the zooplanktonic diversity of two important Ramsar sites (Lake Mansar and Lake Surinsar) of Jammu region. This will help to generate the basic information of zooplankton ecology and the present status of these lakes and it will also help in preparation of effective strategies for conservation and management of these twin lakes.

Study Area

Lake Mansar is situated in lower Shivalik hills of Jammu and Kashmir in northern part of India located at 75° 5' 11.5" E to 75° 5' 12.5" E longitude and 32° 40' 58.25" N to 32° 40' 59.25" N latitude and 666 m above mean sea level. The lake along with its twin Lake Surinsar which is located in the lower Shivalik ranges of the Western Himalayas about 40 km to the northeast of Jammu city at an elevation of 605 m above mean sea level and lies at 75° 02' 30" East Longitude and at 32° 46' 30" North Latitude, was declared as Ramsar site in 2005. Lakes experience pollution due to tourist activities, idol immersion, siltation, addition of wheat flour, cattle bathing, washing clothes, domestic waste discharge from local inhabitants.

Material and Methods

Analysis of Physico-Chemical Parameters: Measurement of parameters like depth, transparency, air temperature, water temperature, pH, DO, FCO2, CO32-, HCO3-,Cl-, Ca2+, Mg2+ and total hardness was done on the spot while BOD, nitate, phosphate ans sulphate was done in the laboratory by following the standard methodology of Adoni (1985) and A.P.H.A (1985).

Analysis of Zooplankton: The zooplankton samples were collected by filtering 20 litres of water through the standard plankton net (25 mesh bolting silk). Finally the volume of planktonic concentrate was filtered to 20 ml and preserved by adding 5% formalin. Zooplankton species identification was done with the help of standard references (Adoni, 1985; Battish, 1992; Pennak, 1978). The number of plankton per ml of the concentrate was calculated by using the formula:

Organism/litre $= A \times 1/L \times n/V$

Where,

V = Volume of 1 drop (ml)

A = Number of organism per drop (ml)

n = Total volume of concentrated sample

L = Volume of original sample (l)

Statistical Analysis: Correlation studies were carried out using SPSS software and PAST Software (version2.17c) was used for calculation of various diversity Indices.

Results

Zooplankton: During the present period of investigations extending from August, 2013 to July, 2015, a total of 50 zooplanktonic taxa were recorded from Lake Mansar and 47 zooplanktonic taxa were recorded from Lake Surinsar. The recorded zooplankton species were observed to belong to five taxonomic groups viz. Protozoa, Rotifera, Cladocera, Copepoda and Ostracoda with the contribution of 7, 20, 15, 7 and 1 species in Lake Mansar and contribution of 6, 20, 12, 6 and 3 species in Lake Surinsar respectively (Table 1, Fig. 1-4). As indicated from the Table 1 group Rotifera with a representation of 20 species dominated the zooplanktonic community of both the Lakes while Ostracoda exhibited a rare contribution with only 1 species in Lake Mansar and 3 species in Lake Surinsar.

Protozoa: In Lake Mansar Protozoan acquired a peak in the month of July during both the years followed by a fall during winter and reached minima in spring. And in Lake Surinsar the total protozoan count acquired a peak in the month of June during both the years of present study followed by a fall or absence during winter months.

Rotifera: The rotifer population recorded a peak during the spring (March) in Lake Mansar and during the autumn in first year and in spring in the second year in Lake Surinsar. Minima of rotifer population were recorded in the monsoon months in both the Lakes during study years.

Cladocera: Cladoceran population showed maxima in the winter months (January, 2014 and February, 2015) in Lake Mansar and in the post monsoon months in Lake Surinsar during both the years of investigation. Lakes showed decline in cladoceran population in the monsoon season during both the years.

Copepoda: Copepods registered population maxima in the winter season and minima in the monsoon seasons in both the lakes for both the study years.

Ostracoda: Higher values of ostracod population were recorded in summer and lower in winter months in both the lakes during both the years.

Physico-chemical parameters

During the present investigation Lake Mansar and Lake Surinsar were analyzed for various abiotic parameters viz., air temperature, water temperature, depth, transparency, pH, DO, BOD, FCO_2, CO_3^{2-}, HCO_3-, Cl, Ca, Mg, total hardness, NO_3-, PO_4^{3-} and SO_4^{2-}(Table 2).

Statistical Analysis

Correlation between physico-chemical parameters of water and biotic components: Correlation between physico-chemical parameters of water and biotic components

Statistical analysis between abiotic and biotic factors showed both positive and negative correlation. In Lake Mansar Rotifera, Cladocera and Copepoda showed positive correlation with FCO_2, HCO_3^-, Cl and Ca and negative with air temperature, water temperature, transparency, pH, CO_3^{2-}, NO_3^- and SO_4^{2-}. Protozoa showed positive correlation with air temperature, water temperature, CO_3^{2-}, NO_3^-, PO_4^{3-} and SO_4^{2-}

while negative correlation with depth, FCO_2, HCO_3^- and Cl. Ostracoda recorded positive correlation with air temperature, water temperature, NO_3^-, PO_4^{3-} and SO_4^{2-} whereas negative with depth, FCO_2, HCO_3^-, Cl, Ca, Mg and total hardness.

Zooplankton (No./l)	**Lake Mansar**		**Lake Surinsar**	
	1st Year	**2nd Year**	**1st Year**	**2nd Year**
Protozoa				
Class: Ciliata				
Order: Peritrichida				
Family: Vorticellidae				
Vorticella campanula	0.15	1.65	-	1.95
Class: Rhizopoda				
Order: Testacea				
Family: Difflugiidae				
Centropyxis hemisphaerica	0.35	0.5	-	-
Centropyxis ecornis	0.05	0.3	-	0.15
Centropyxis aculeata	0.25	0.65	1.55	0.55
Difflugia oblonga	0.15	0.25	-	-
Difflugia lebes	1.0	1.2	-	0.1
Difflugia corona	-	-	-	0.15
Difflugia acuminata	-	-	0.9	0.4
Family: Euglyphidae				
Pareuglypha reticulata	0.1	-	-	-
Total Protozoa	2.05	4.55	2.45	3.3
Rotifera				
Class: Monogonota				
Order: Ploima				
Family: Brachionidae				
Brachionus calyciflorus	1.35	1.65	4.9	2.75
Brachionus falcatus	5.2	1.15	-	-
Brachionus quadridentata	1.05	17.0	1.4	2.35
Brachionus rubens	1.0	0.95	-	-
Brachionus caudatus aculeatus	-	0.2	4.95	0.85
Brachionus forficula	-	-	0.1	-
Brachionus angularis	-	-	-	0.4
Keratella tropica	1.25	0.65	2.85	0.4
Keratella cochlearis	0.1	0.15	1.35	1.2
***Anuraeopsis* sp.**	-	-	0.05	-
Scaridium longicaudum	-	0.05	-	-
Family: Euchlanidae				
Euchlanis dilatata	9.0	1.95	11.75	6.55
Family: Colurellidae				
Lepadella bicornis	-	0.1	-	-
Lepadella patella	-	0.05	0.1	0.05
Family: Mytilinidae				
Mytilina ventralis	-	0.6	0.05	0.1
Family: Lecanidae				
Lecane luna	-	0.35		0.1
Lecane inopinata	0.15	-	-	-
Monostyla bulla	-	0.1	-	-
Monostyla lunaris	-	-	0.2	0.1
Family: Trichocercidae				
***Trichocerca* sp.**	-	-	0.2	-
Family: Asplanchnidae				
***Asplanchna* sp.**	3.65	0.3	1.55	0.55
Family: Synchaetidae				
***Polyarthra* sp.**	-	-	1.1	0.1
Order: Flosculariacea				
Family: Testudinellidae				

***Testudinella* sp.**	3.85	0.75	0.05	1.15
Filinia opoliensis	4.9	1.85	-	0.35
Filinia longiseta	0.35	0.05	0.15	0.1
Order: Bdelloidea				
Family: Philodinidae				
***Philodina* sp.**	1.5	1.25	14.95	1.25
Total Rotifera	33.35	29.15	45.70	19.20
Cladocera				
Family: Chydoridae				
Chydorus sphaericus	8.15	19.75	2.5	3.85
Chydorus ciliatus	-	0.95	-	-
Pleuroxus aduncus	-	0.3	-	-
Alona pulchella	-	0.1	0.15	0.3
Alona guttata	0.1	1.2	0.8	0.55
Alona costata	0.15	1.4	0.55	0.45
Alona rectangula	1.45	5.15	4.85	3.5
Alona monacantha	0.05	0.85	0.25	3.75
Alona affinis	-	0.25	1.0	1.5
Camptocercus rectirostris	-	0.15	0.05	0.55
Camptocercus kapuri	-	-	0.15	0.05
Family:Macrothricidae (Lyncodaphnidae)				
Macrothrix rosea	0.25	0.55	0.15	0.15
Macrothrix laticornis	1.6	0.1	-	-
Family: Daphnidae				
Daphnis similis	0.35	0.4	0.05	1.1
Cerodaphnia cornuta		0.55	-	-
Cerodaphnia reticulata	3.5	0.95	0.3	0.65
Total Cladocera	15.6	32.65	10.8	19.9
Copepoda				
Order: Cyclopoida				
Family: Cyclopidae				
Mesocyclops leuckarti	18.55	8.48	19.6	14.1
Mesocyclops hyalinus	1.1	0.5	3.55	0.2
***Mesocyclops* sp.**	0.5	0.7	-	-
***Halicyclops* sp.**	-	-	-	0.5
Cyclops nanus	1.55	4.8	0.1	1.8
***Eucyclops* sp.**	3.1	0.8	2.1	0.3
***Tropocyclops* sp.**	3.15	3.05	1.1	1.3
***Nauplius* larvae**	19.3	9.75	16.25	8.9
Order: Calanoida				
Family: Diaptomidae				
***Diaptomus* sp.**	1.05	1.0	-	-
Total Copepoda	48.3	29.08	42.7	27.1
Ostracoda				
Order: Podocopa				
Family: Cypridae				
***Cypris* sp.**	2.85	2.95	-	-
***Stenocypris* sp.**	-	-	0.35	-
***Eucypris* sp.**	-	-	0.1	0.4
Onchocypris pustulata	-	-	2.6	2.8
Total Ostracoda	2.85	2.95	3.05	3.2
Total Zooplankton	102.15	98.38	104.7	72.7
Total (two years)	200.53		177.4	

Table 1: Qualitative and Quantitative abundance of Zooplankton in Lake Mansar and Lake Surinsar

Parameters	**Lake Mansar**		**Lake Surinsar**	
	1st Year	**2nd Year**	**1st Year**	**2nd Year**
Air Temperature	16 °C (Dec,13) - 34°C (May,14)	16 °C (Dec,14; Jan,15) - 33°C (May,15)	15 °C (Dec,13) - 34°C (May,14)	11.5 °C (Jan,15) - 32.5°C (May,15)
Water Temperature	17 °C (Jan,14) - 30°C (May,14)	14.5 °C (Jan,15) - 31°C (Jun;Aug,15)	14.5 °C (Dec,13) - 29.5°C (May,14)	12.5 °C (Jan,15) - 30°C (Jun,15)
Depth	75 cm (Jun,14) - 135 cm (Dec,13)	73 cm (May,15) - 130 cm (Dec,14)	71 cm (Jul,14) - 125 cm (Sep,13)	78 cm (Jul,15) - 106 cm (Sep,14)
Transparency	30 cm (Nov,13) - 79 cm (Jan;Mar,14)	30 cm (Mar,15) – 87.5 cm (Feb,15)	48.5 cm (Sep,13) - 86 cm (Dec,13)	41 cm (Aug,14) - 82.5 cm (Feb,15)
pH	6.7 (Jan; Feb, 14) -8.6 (Aug,13)	6.7 (Mar,15) - 8.8 (Aug,14)	6.8 (Dec, 13) - 8.6 (Aug,13)	6.8 (Dec,14; Jan,15) - 9.5 (Aug,14)
Dissolved Oxygen	2.8 mg/l (Jan,14) - 9.6 mg/l (Mar;Jul,14)	2.4 mg/l (Jan,15) -12.8 mg/l (Apr,15)	3.6 mg/l (Dec,13) -8.4 mg/l (Mar;Jul,14)	2.0 mg/l (Jan,15) - 9.2 mg/l (Apr,15)
BOD	1.5 mg/l (Jan,14) - 4.4 mg/l (Oct,13;Jul,14)	0.8 mg/l (Jan,15) -3.6 mg/l (Aug, 14)	1.2 mg/l (Dec,13) -5.2 mg/l (Aug, 13)	0.4 mg/l (Jan,15) – 4.4 mg/l (Aug, 14)
Free Carbon Dioxide	0 - 12 mg/l (Feb,14)	0- 14 mg/l (Jan,15)	0 – 10 mg/l (Jan; Feb,14)	0- 10 mg/l (Jan; Feb,15)
Carbonate	0 - 9.6 mg/l (Apr,14)	0- 16.8 mg/l (Jul,15)	0 – 14.4 mg/l (May,14)	0- 16.8 mg/l (Jun,15)
Bicarbonate	29.28 (Aug,13; Jul,14) - 170.8 mg/l(Feb,14)	48.8 mg/l (Aug,14) -183 mg/l (Jan,15)	39.4 mg/l (Aug,13) - 158.44 mg/l (Jan,14)	51.24 mg/l (Aug,14) - 200.8 mg/l (Jan,15)
Chloride	6 mg/l (Oct, 13) - 78 mg/l (Mar,14)	18 mg/l (Nov, 14) -78 mg/l (Mar, 15)	8 mg/l (Oct,13) -75 mg/l (May, 14)	10 mg/l (Oct,14) -102 mg/l (May,15)
Calcium	16.82 mg/l (Aug,13; Jul,14)-41.2 mg/l (Feb,14)	14.3 mg/l (Aug,14) -37 mg/l (Dec, 14)	11.77 mg/l (May,14) - 42.05 mg/l (Jan,14)	8.41 mg/l (May,15) - 52.98 mg/l (Dec, 14)
Magnesium	16.4 mg/l (Jun,14) - 64.92 mg/l (Jan,14)	17.37 mg/l (Aug, 14) - 36.69 mg/l (Dec, 14)	9.96 mg/l (May, 14) - 85.65 mg/l (Jan,14)	12.49 mg/l (Aug, 14) - 67.69 mg/l (Jan, 15)
Total Hardness	86 mg/l (Aug, 13) - 158 mg/l (Jan,14)	90 mg/l (Aug; Oct, 14) - 188 mg/l (Dec,15)	62 mg/l (Aug,13) -236 mg/l (Jan, 14)	64 mg/l (Aug, 14) - 292 mg/l (Jan, 15)
Nitrate	0.08mg/l (Sep, 13) -0.82 mg/l (May, 14)	0.11 mg/l (Apr,15) - 0.62 mg/l (May, 15)	0.13 mg/l (Sep, 13)- 0.72 mg/l (May, 14)	0.11 mg/l (Apr,15) - 0.59 mg/l (Jun, 15)
Phosphate	0.01 mg/l (Oct, 13) -0.50 mg/l (Jun, 14)	0.07 mg/l (Oct, 14) -0.37 mg/l (Jun, 15)	0.0 mg/l (Oct, 13)-0.52 mg/l (Jun, 14)	0.0 mg/l (Oct, 14) -0.56 mg/l (Jun, 15)
Sulphate	1.3 mg/l (March, 14) -5.7 mg/l (July, 14)	1.1 mg/l (Feb, 15) -4.7 mg/l (July, 15)	1.9 mg/l (Feb, 14)-6.2 mg/l (Aug, 13)	1.1 mg/l (Feb, 15)-5.8 mg/l (Jul, 15)

Table 2: Variation in Physico-chemical parameters in Lake Mansar and Lake Surinsar

Diversity Indices of Zooplankton in Lake Mansar								
	Simpson Index		**Shannon Index**		**Margalef's Richness Index**		**Equitability Index**	
	1st Year	2nd Year	1st Year	2nd Year	1st Year	2nd Year	1st Year	2nd Year
Protozoa	0.296	0.240	1.529	1.579	8.36	3.3	0.785	0.881
Rotifera	0.151	0.358	2.112	1.699	3.42	5.337	0.823	0.577
Cladocera	0.343	0.397	1.376	1.485	2.912	4.016	0.626	0.548
Copepoda	0.317	0.239	1.415	1.634	1.805	2.077	0.680	0.786
Ostracoda	1.0	1.0	0	0	0	0	0	0
Diversity Indices of Zooplankton in Lake Surinsar								
	Simpson Index		**Shannon Index**		**Margalef's Richness Index**		**Equitability Index**	
	1st Year	2nd Year	1st Year	2nd Year	1st Year	2nd Year	1st Year	2nd Year
Protozoa	0.535	0.397	0.658	1.252	1.116	4.188	0.949	0.699
Rotifera	0.204	0.172	1.899	2.146	4.186	5.415	0.670	0.757
Cladocera	0.272	0.157	1.708	2.209	5.043	3.678	0.666	0.816
Copepoda	0.366	0.386	1.188	1.191	1.332	1.818	0.663	0.612
Ostracoda	0.741	0.781	0.497	0.377	1.793	0.860	0.452	0.544

Table 3: Diversity indices of Zooplankton in Lake Mansar and Lake Surinsar during the period August, 2013 to July, 2015

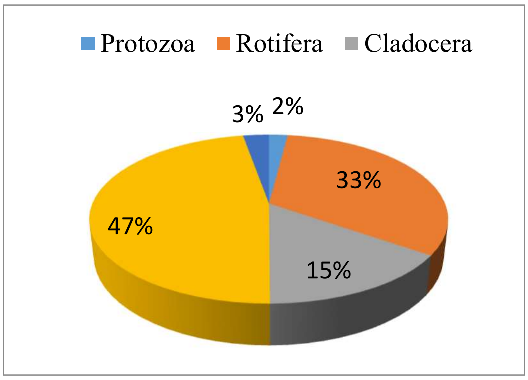

Fig 1: Percentage contribution of zooplankton of Lake Mansar during the period August, 2013 to July, 2014

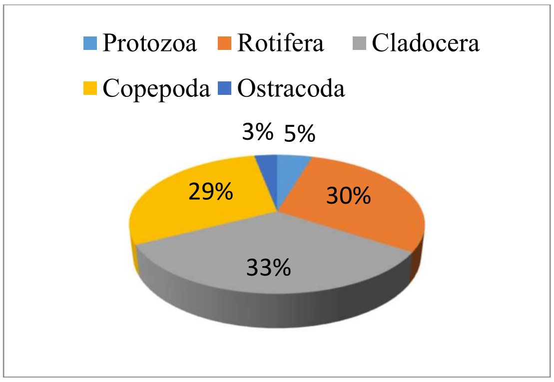

Fig 2: Percentage contribution of zooplankton of Lake Mansar during the period August, 2014 to July, 2015

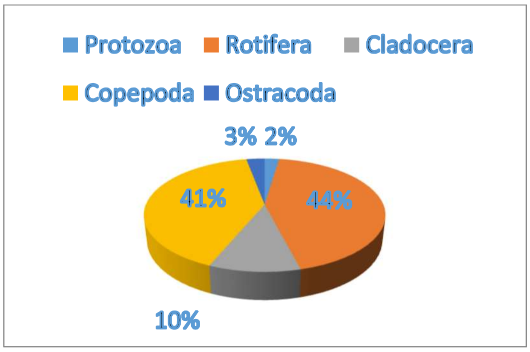

Fig 3: Percentage contribution of zooplankton of Lake Surinsar during the period August, 2013 to July, 2014

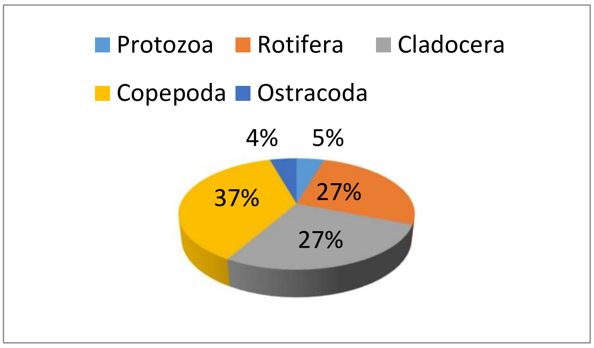

Fig 4: Percentage contribution of zooplankton of Lake Surinsar during the period August, 2014 to July, 2015

While In Lake Surinsar, Protozoa and Ostracoda showed positive correlation with air temperature, water temperature, CO_3^{2-}, NO_3^-, PO_4^{3-} and SO_4^{2-} while they showed negative correlation with depth, FCO_2, HCO_3^- and Ca. Rotifera showed positive correlation with HCO_3^-, Cl and total hardness while negative with water temperature, DO, BOD, NO_3^- and PO_4^{3-}. Cladocera showed positive correlation with Cl and total hardness and negative with NO_3^-. Copepoda showed positive correlation with HCO_3^- and Cl and negative correlation with air temperature, water temperature, pH, DO, CO_3^{2-}, BOD and SO_4^{2-}.

Correlation among biotic groups

Correlation studies among zooplanktonic groups showed positive correlation among Protozoa-Ostracoda, Rotifera-Cladocera, Rotifera-Copepoda & Cladocera-Copepoda and negative correlation Protozoa-Rotifera, Protozoa-Cladocera, Protozoa-Copepoda and Ostracoda showed negative correlation with Rotifera, Cladocera and Copepoda in both the Lakes.

Correlation between physico-chemical parameters

Physico-chemical parameters were also analyzed for correlation studies and these parameters also recorded positive and negative values. Parameters which were strongly positively correlated during both the years of investigation in both the lakes were air temperature-water temperature, air temperature-pH, air temperature-NO_3^-, water temperature-pH, water temperature-DO, water temperature-CO_3^{2-}, water temperature-

SO_4^{2-}, DO-BOD, FCO_2-Ca, FCO_2-HCO_3^-, Cl-total hardness, Ca-Mg, Ca-total hardness, Mg-total hardness and NO_3^--PO_4^{3-}. Whereas strongly negatively correlated parameters were water temperature-FCO_2, water temperature-HCO_3^-, water temperature-Ca, water temperature-total hardness, depth-PO_4^{3-}, pH-FCO_2, pH-HCO_3^-, pH-Cl, pH-Ca, FCO_2-CO_3^{2-}, FCO_2-SO_4^{2-} and HCO_3^--SO_4^{2-}.

Parameters which were strongly positively correlated in lake Mansar were air temperature-CO_3^{2-}, air temperature- PO_4^{3-}, water temperature-transparency, depth-FCO_2, depth-HCO_3^-, transparency- PO_4^{3-}, pH-CO_3^{2-}, FCO_2-Cl, CO_3^{2-}- PO_4^{3-}, HCO_3^--Cl, HCO_3^--Ca and Cl-Ca Whereas strongly negatively correlated parameters were air temperature-depth, air temperature-FCO_2, air temperature-Ca, air temperature-Mg, air temperature-total hardness, water temperature-depth, water temperature-Cl, water temperature-Mg, depth-transparency, depth- NO_3^-, transparency-HCO_3^-, transparency-Ca, DO-Mg, pH-Mg, pH-total hardness, CO_3^{2-}-total harness, Cl- SO_4^{2-} and Ca-SO_4^{2-}. In Lake Surinsar, parameters which were significantly positively correlated during both the years of investigation were air temperature-DO, air temperature-CO_3^{2-}, air temperature-BOD, water temperature-BOD, transparency-Cl, pH-DO, pH-BOD, pH-sulpahte, DO-CO_3^{2-}, FCO_2-Mg, CO_3^{2-}-BOD, HCO_3^--Mg, HCO_3^--total hardness, Cl-PO_4^{3-}, total hardness-BOD and total hardness- SO_4^{2-} Whereas negatively correlated parameters were air temperature-FCO_2, air temperature-HCO_3^-, air temperature-Ca, depth-CO_3^{2-}, DO-FCO_2, DO-Cl, DO-Ca, FCO_2-BOD, CO_3^{2-}-Ca, HCO_3^--BOD, Cl- NO_3^-, Ca-BOD and total hardness-BOD.

Discussion

Protozoa : From the present data collected from water bodies protozoan showed their maximum presence in the warmer months of May, June and July. Interestingly, they acquire a peak in the summer months at Lake Surinsar, and in July in case of Lake Mansar during both the years of present study followed by a fall during winter. Total protozoan count was mainly contributed by Centropyxis sp. and Difflugia sp. which may be due to their high tolerance to organic content (Kaushik and Saksena, 1995; Slathia and Dutta, 2009). Summer rise and winter fall in protozoa population could be attributed to:

- Corresponding fall and rise in the copepod count. Importance of protozoan as food for the copepod has been already discussed by Welch (1952).
- Increased availability of food due to higher rate of decomposition at increased temperature results in plentiful organic matter and detritus on which these protozoans can feed (Chandrakiran, 2011; Sharma et al., 2014).

In Lake Mansar, peak of protozoa shifted slightly towards early monsoon in July (Bera et al., 2014; Sharma et al., 2013) which may be attributed to the combination of two important factors, accumulation of organic matter which is brought by surface runoff and the higher rate of decomposition of this organic matter due to higher temperature as this being a bigger Lake in volume and depth is usually self regulatory.

Rotifera: Rotifer population recorded their maximum presence in the months of January-April and October-November in both the lakes when temperature ranged between 12.5

to 28°C. Maxima of rotifers appear to be influenced by various factors like: Increased DO level (Sehgal, 1980), increased transparency (Sharma, 2001), high macrophytic and algal growth (Bonecker and Lansac-Taho, 1996) and increased alkalinity (Edmondson, 1992). Monsoon minima was observed in both the lakes due to high turbidity which restricts the light penetration and thereby suppress the growth and dilution of water resulting in less nutrients, reduced DO and change in pH (Kumar, 2001). Similar monsoon minima was observed by various workers like Bhat et al., 2014 & Korgaonkar and Bharamal, 2016.

A careful analysis showed two interesting and important phenomenon among rotifers. Firstly, the observed maxima in the total rotifer population has been the result of the sudden outburst in the population of Brachionus sp., Keratella sp., Philodina sp. and Euchlanis sp. Such sudden numerical increase in 2-3 species of rotifers (Sehgal, 1980; Singh, 2004). Secondly during the present study, maximum coexistence of four species of genus Brachionus were observed. Such simultaneous occurrence of 3-6 species of a single genus have been observed by various scientists in different water bodies (Sharma, 1995; Verma, 2009).

Cladocera: Cladoceran population shows their maximum presence in post-monsoon and winter months (September-October and January-February). This rise among cladoceran is an outcome of the successive increase of different species rather than any single species. But mainly the maxima was contributed by Chydorus sphaericus. Various reasons which could be held responsible for rise were favourable breeding at low temperature (Sharma, 2007), increased DO and decreased FCO2 at low temperature (Sehgal, 1980), increase in pH (Nyberg, 1998) and luxuriant growth of phytoplankton due to increase amount of nutrients and organic matter brought by rains (Battish and Kumari, 1986). Cladoceran population showed decline in the monsoon season for both the investigative years which may be attributed to dilution effect caused by rains, scarcity of food due to reduction in phytoplanktonic growth and increased turbidity.

Copepoda: Copepods registered population maxima in the winter months and minima in the monsoon season at both the study sites. Copepod maxima in winter may be attributed to their ability to adapt to low temperature, preference for high DO, total alkalinity and presence of phytoplankton (Rajashekhar et al., 2010). Presently, maxima in winter was mainly contributed by Mesocyclops leuckarti and also by large number of Nauplius larvae which were fertilized after monsoon breeding season. Similar trend of copepods population dynamics has been already pointed out by workers (Korgaonkar and Bharamal, 2016 & Verma, 2009). Minima in copepod population in monsoon season in both the water bodies may be due to high turbidity which restricts the light penetration and thus growth and dilution of water resulting in less nutrients, low transparency, reduced DO and pH.

Ostracoda: Higher values of ostracod population were recorded in summer and lower in winter months (Korgaonkar and Bharamal, 2016 & Sontakke and Mokashe, 2014). Summer rise in ostracods may be due to availability of food in the form of detritus and organic matter due to high rate of decomposition and favourable temperature. Low winter ostracod population at both the study sites may be attributed to less availability of food and low input of organic matter and slow decomposition due to temperature fall (Chaitram, 2014).

Statistical Analysis

Correlation between physico-chemical parameters of water and biotic components

Correlation studies between biotic and abiotic parameters of water showed well marked interdependence and interactions. Protozoa showed positive correlation with air temperature, water temperature and NO_3^- and negative with Ca in the studied water bodies. Two of the protozoan species *Centropyxis* sp. and *Difflugia* sp. which dominated the protozoan biota also showed maxima in temperature range between 17 to 35°C but maximum growth was observed above 29.5°C, range of NO_3^- between 0.59 to 0.98 mg/l and PO_4^{3-} ranged between 0.25 to 0.56 mg/l. Such positive correlation between protozoa with temperature and NO_3^- is well documented by earlier workers (Bera *et al*., 2014; Sharma *et al*., 2013). Positive correlation between carbonate and PO_4^{3-} with protozoans (Sharma *et al*., 2013) whereas negative correlation between FCO_2 and HCO_3^- was also recorded from lakes. This means increased values of carbonate and PO_4^{3-} and decreased value of FCO_2 and HCO_3^- in summer play a crucial role in the development of this group. Group Rotifera showed positive correlation with Ca and negative with air temperature, water temperature and NO_3^-. Maximum contribution among rotifers was by *Brachionus calyciflorus* in the present study which showed their presence at temperature range of 13-37°C, pH range of 6.6 to 10 and DO level always remained above 1.6 mg/l. Coinciding with the earlier report by Halbach that maximum density of *B. calyciflorus* was found at 20-28°C (Halbach, 1970). Ludwig (1993) also recorded favorable condition for *B. calyciflorus* was temperature 15-31°C, pH 6-8 and DO minimum upto 1.2 mg/l. In the present observation of Lake Mansar *Filinia* sp. showed its presence only in October, November and December months when temperature ranged between 15 to 27.8 and DO value was comparatively less, George and Fernando also postulated that number of *Filinia* sp. increases with decrease in DO content(George and Fernando, 1970).

Cladocera showed positive correlation with FCO_2, HCO_3^-, Cl and Ca and negative with pH, carbonates, NO_3^- and SO_4^{2-} in Lake Mansar. In Lake Surinsar showed positive correlation with Cl and total hardness and negative with NO_3^-. Cladoceran species like *Chydorus sphaericus* and *Alona* sp. in the presently studied Lakes were mainly dominated the cladoceran population, this shows that the range of various physico-chemical parameters in the present study were suitable for their growth (Langer *et al*., 2007). Interestingly, *Camptocercus* sp. mainly occurred in winter months (12.5-15°C) in both the presently studied Lakes which may be because at that time the ecological and limnological components of Lake favor their growth and development. Copepods showed positive correlation with Ca and negative with air and water temperature. Group Copepoda was mainly dominated by *Mesocyclops leuckarti* at temperature range of 12.5°C to

37°C, DO range of 1.6 to 14.4 mg/l and pH 6.6 to 10. *Mesocyclops* sp. was present even at low DO condition of 1.6 mg/l during the study as already on record in literature by Aycock (1942) that *Mesocyclops* sp. can tolerate low level of oxygen indicating organic pollution. Furthermore, positive correlation of Ostracoda with air temperature, water temperature and SO_4^{2-} and negative correlation with HCO_3^- and Ca (Sebastian, 2012). Presently, most of the Ostracods (*Onchocypris pustulata*, *Cyprinotus* sp., *Stenocypris* sp. and *Eucypris* sp.) showed their presence and maxima in monsoon season and this maxima is directly correlated with decreased concentration of Ca in water which might be because of important role of Ca in the formation and growth of calcareous shell (Iglikowska and Pawlowska, 2015).

Correlation among various biotic groups

Among these Rotifera showed positive correlation with Copepoda and Cladocera because they showed coexistence and synchronized minima and maxima (Sharma et al., 2017). Cladocerans and copepods also showed positive correlation among themselves may be due to different niches preferences but negative with Protozoa as they both share common food (Protozoa). Ostracoda recorded negative correlation with group Rotifera, Cladocera and Copepoda this might be because Ostracoda was both quantitatively and qualitatively poorly represented as compared to other zooplanktonic groups and this tilt towards negative correlation is supported by the fact that presently ostracods showed summer maxima, when all the other zooplanktonic groups were less.

Correlation between physico-chemical parameters

Air temperature showed significant positive correlation with water temperature, pH, carbonate, DO and negative correlation with FCO_2, HCO_3^-, Ca, Mg and total hardness. Water temperature registered positive correlations with pH, DO, carbonate, BOD and negative correlation with FCO_2, HCO_3^-, Ca, Mg and total hardness. DO showed positive correlation with BOD and carbonate and negative with HCO_3^-, Mg and total hardness while pH recorded positive correlation with DO, BOD and carbonate and negative with FCO_2, HCO_3^-, Ca, Mg and total hardness (Pattan and Sunkad, 2017). Mohamed and Mostafa (2009) while working on water quality of Lake Nasser recorded positive correlation between carbonate and pH and suggested that carbonates act as main component which contributes alkalinity of Lake. FCO_2 showed positive correlation with HCO_3^- and negative correlation with CO_3^{2-} and SO_4^{2-} (Singh, 2004; Verma, 2009). HCO_3^- showed positive correlation with Ca, Mg and total hardness and negative correlation with SO_4^{2-}. Cl recorded positive correlation with NO_3^- and PO_4^{3-}. Ca, Mg and total hardness showed significant positive correlation with each other but Ca and total hardness showed negative correlation with BOD (Pattan and Sunkad, 2017). NO_3^- and PO_4^{3-} also registered significant positive correlation due to simultaneous rise or fall during the study months (Zubair and Ahrar, 2013).

Diversity Indices

Comparative study of various diversity indices (Table 3) revealed high Simpson and Shannon diversity for rotifers in Lake Mansar during first year (maximum contribution was given by Euchlanis sp) and Cladocera (Alona sp.) of Lake Surinsar showed high diversity in second year of study. Margalef richness index was high for Protozoa (Lake Mansar) and Rotifera (Lake Surinsar) in two years of study period. Protozoa showed higher value for equitability index in Lake Surinsar in first year and in Lake Mansar in the consecutive year. Ostracoda showed least value for all the diversity indices in Lake Mansar.

Conclusion

From the comparative study of lake Mansar and lake Surinsar, it can be concluded that lake Mansar has high qualitative and quantitative diversity as compared to lake Surinsar. Sorenson's similarity index results revealed similarity index in zooplanktonic fauna is 59.74% during first year and 74.73% during the second year of study period between the two lakes. This showed that although both the studied lakes are lentic water bodies but their exist some differences in abiotic conditions which are responsible for variation in zooplankton diversty and abundance.

Acknowledgements

The authors are grateful to UGC for help and encouragement and providing financial assistance under UGC-SAP. We also sincerely thank Department of Zoology, University of Jammu for providing lab facilities to conduct the work successfully.

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