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Seasonal variation in zooplankton community and environmental variables of sacred Lake Prashar Himachal Pradesh, India

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Abstract
In order to study the seasonal trends of zooplankton structure and community of the Prashar Lake, samples were collected in each month during one annual cycle (November 2014 to October 2015). A total of 27 genera of five zooplankton groups were identified during the study period. The zooplankton diversity belonging to five groups revealed 38% contribution of Rotifera followed by Cladocera (26%), Protozoa (25%), Copepoda (6%), and Ostrocoda (5%). The highest zooplankton abundance was observed in winter and the lowest in monsoon season. Among zooplankton, particularly Rotifera and Cladocera were the dominant groups throughout the study period. Maximum Shannon-Wiener diversity index was recorded at S_2 compared to both S_1 and S_3. Correlation coefficients between physicochemical variables and zooplankton groups were calculated for assessing interrelationships using SPSS software.

Keywords: Prashar Lake, variables, Shannon-Wiener diversity, correlation coefficients

1. Introduction
The lakes comprise the one of the most productive ecosystems. Lake ecosystems are made up of physical, chemical and biological properties contained within these water bodies. Mountain Lakes is a very important component of the water storage system [1]. Zooplankton community always acts as a key component which transfers the energy in different trophic level in an aquatic ecosystem and it helps to regulate the productivity of the water body. When any variation occurs in the physico-chemical variables, it will bring the comparing changes in the life forms dwelling in the aquatic ecosystem [2]. Zooplanktons are a significant indicator of change in any water quality, trophic status and pollution level. Mostly the population of fish depends on the dynamics of the plankton population especially the population of zooplankton community [3]. Lake Ecosystem is affected by various stresses which considerably changes the zooplankton biodiversity. To evaluate these changes various multivariate methods were applied by the use of different software to get better and appropriate results [4]. The present study was undertaken on the analysis of seasonal changes in the zooplankton structure and community influenced by the parameters in the sacred lake Prashar of Himachal Pradesh during the period of November 2014 to October 2015. Studies on zooplankton of lake have been done by some workers in different parts of the World [5-12]. Studies on lakes zooplankton have been done by some workers in different parts of India [13-18].

2. Materials and Methods
2.1 Study Area
The Prashar Lake is one of the important sacred lakes of Himachal Pradesh. It is located in the Mandi district of Himachal Pradesh (Latitude 31°45′30″N; longitude 77°06′04.30”E) at an altitude of 2,730 m above mean sea level in the western Himalaya. Prashar Lake comes under Trans-Hmalayan Zone. The climatic condition of the area is a dry and extremely cold condition. Rainfall recorded up to above and near to 500m. In this area winters are long as compare to other seasons. The lake is oval in shape with an area of 1.30 ha (Fig. 1). In this lake, there is a circular floating island, covered with dense macrophytic vegetation, which keeps changing its position throughout the year. The surrounded watershed area of the lake is a scrub land dominated by grasses and herbs. The sacred lake Prashar is surrounded by small mountain peaks.

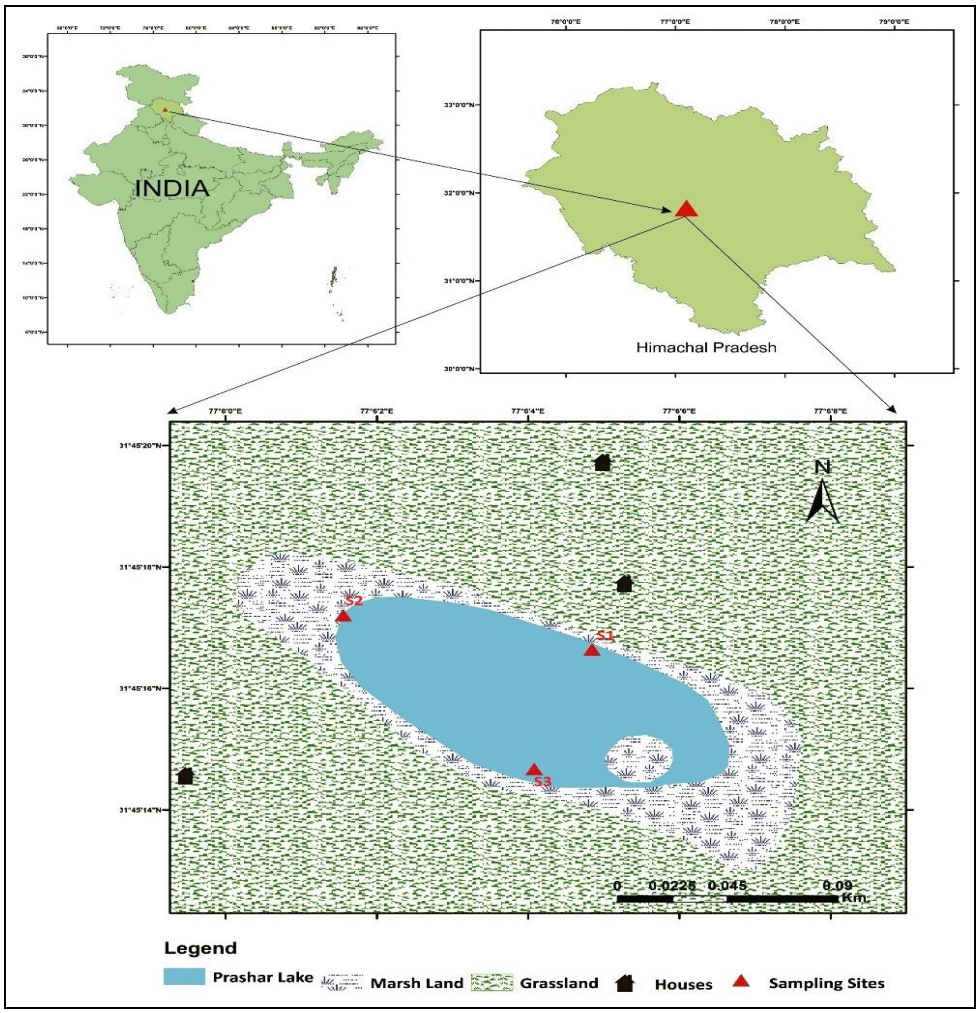

Fig 1: Location map of Prashar Lake with sampling sites (S1, S2, S3)

2.2 Collection of sample and Analysis

Three sampling sites S_1, S_2, and S_3 were selected to collect the sample from Prashar Lake. Monthly sampling was undertaken between 08:00 to 10:00 hrs during November 2014-October 2015, which include five seasons, winter season (November to February), spring season (March to April), summer season (May to June), monsoon season (July to August) and autumn season (September to October). From all the site minimum three replicates of water sample were collected. Standards methods were followed for the collection and analyses of parameters. The temperature of the water was measured with the help of the Centigrade Mercury thermometer (0-110 ˚C). Turbidity was measured with the help of the Deluxe Turbidity Meter (Model-335) and salinity, TDS and pH were measured with the Toshcon Multiparameter Analyser (Model-TPC-17). Dissolved Oxygen, alkalinity, BOD, hardness, nitrates, phosphates, Sodium and Potassium were analyzed by using the standard methods delineated in Wetzel and Likens, APHA [19-20]. A fine silk cloth (mesh size 25mm) Plankton net was used to collect the zooplankton sample. Total 10 liters of water was filtered from the plankton net from every sampling sites. The filtrates were diluted with distilled water up to 100 ml. Lugol's solution was used to preserve the sample and brought to the laboratory for identification. A subsample of 1ml is transferred to a Sedgewick-Rafter cell (SR cell) for the analysis under an inverted microscope (Olympus CH *20i*). Zooplanktons were counted individuals per liter (ind. l^{-1}) randomly [21]. Zooplankton was identified with the help of the manuals of Sarode and Kamat, Ward and Whipple, Munshi *et al*. and Bellinger and Sigee [22-25]. The Pearson's correlation coefficient was calculated using SPSS to find out the relationship among various variables and zooplankton community. The seasonal diversity of zooplankton was calculated for all the three sampling sites by Shannon Wiener diversity.

3. Results and Discussion

The data on seasonal variations in environmental variables of Prashar Lake have been presented in Table 1. Corelation between the environmental variables of Prashar lake have been presented in Table 3. The water temperature was recorded minimum (7.60 ˚C) during the winter season and maximum (19.70 ˚C) in summer season at S_1. Water temperature showed negative correlation with dissolved oxygen (r=-933), whereas it showed positive correlation with BOD (r=904). Minimum (6.90 $mg.l^{-1}$) concentration of Dissolved oxygen was recorded during summer season and maximum (11.85 $mg.l^{-1}$) recorded during winter season. Minimum concentration of dissolved oxygen during summer season may be due to a high metabolic rate of life forms during summer [26, 27]. Rawat and Sharma [28] also recorded high concentration of dissolved oxygen during winter months and low concentration during summer months in Deoria Tal. Concentration of salinity recorded maximum during summer (0.32 $mg.l^{-1}$) at S_1 and S_2, minimum (0.32 $mg.l^{-1}$) during winter at S_2 and S_3. The turbidity was recorded maximum

(2.78 NTU) at S_1 and S_2 during monsoon season and minimum (1.17 NTU) during winter season. Maximum concentration (93.23 mg.l^{-1}) of total dissolved solids was found in monsoon season at S_1 and minimum concentration (21.72 mg.l^{-1}) at S_1 and S_2. TDS showed positive correlation (r= 940) with turbidity. BOD of Prashar lake was found maximum (1.12 mg.l^{-1}) at S_1 and S_2 during monsoon season and minimum (0.41 mg.l^{-1}) at S_3 during winter season. BOD always showed negatively correlation with DO. The maximum pH value (7.39) was recorded at S_1 and S_2 during winter and minimum (6.51) during monsoon season at S_3. Dhanalakshmi *et al*. [29] found that the excessive microbial decomposition increased production of CO_2 which in turn decreases the pH of water mainly during monsoon season. Maximum concentration of alkalinity (85.32 mg.l^{-1}) was reported at S_1 and minimum (69.60 mg.l^{-1}) at S_2 in Prashar lake. The maximum concentration of (35.55 mg.l^{-1}) hardness was recorded in summer at S_1; whereas, minimum concentration (21.38 mg.l^{-1}) was recorded at S_2 during winter. The higher concentration of total hardness during summer may be due to higher temperature, resulting in the increased concentration of salts by excessive evaporation [30]. The nitrates concentration was found maximum (0.29 mg.l^{-1}) during monsoon season at S_1 and S_2 and minimum (0.072 mg.l^{-1}) at S_3 during winter season. In the Prashar lake, maximum concentrations.

Table 1 Seasonal variation of variables ($\bar{x}$ ±S. D.) of Prashar Lake during November 2014 to October 2015

Environmental variables	Sites	Winter	Spring	Summer	Monsoon	Autumn
		($\bar{x}$ ±S.D.)	($\bar{x}$ ±S.D.)	($\bar{x}$ ±S.D.)	($\bar{x}$ ±S.D.)	($\bar{x}$ ±S.D.)
Water Temperature (^{0}C)	S_1	7.6±1.53	14±3.11	19.7±0.99	17.7±1.56	15.15±3.04
	S_2	7.6±1.53	13.9±3.11	19.6±0.85	17.7±1.56	15.1±3.11
	S_3	7.6±1.53	13.9±3.11	19.6±0.56	17.75±1.62	15.1±3.11
Dissolved Oxygen (mg.l^{-1})	S_1	11.71±1.04	9.33±1.74	6.9±0.81	8.4±0.28	10.05±0.64
	S_2	11.82±1.06	9.03±1.24	7.07±0.72	8.7±0.55	10.09±0.69
	S_3	11.85±1.06	9.07±1.23	7.1±0.7	8.72±0.53	10.13±0.67
Salinity (mg.l^{-1})	S_1	0.16±0.02	0.24±0.05	0.32±0	0.21±0.01	0.21±0.01
	S_2	0.15±0.02	0.24±0.06	0.32±0.02	0.22±0.03	0.2±0.01
	S_3	0.15±0.02	0.24±0.05	0.31±0.02	0.22±0.02	0.2±0.01
Turbidity (NTU)	S_1	1.18±0.27	1.76±0.14	2.17±0.13	2.78±0.48	2.17±0.69
	S_2	1.19±0.25	1.6±0.09	2.22±0.13	2.78±0.53	2.13±0.83
	S_3	1.17±0.25	1.57±0.05	2.25±0.13	2.77±0.49	2.06±0.76
TDS (mg.l^{-1})	S_1	22±7.3	30.16±4.75	47.68±7.7	93.23±7.31	54.55±16.0
	S_2	21.72±6.79	30.08±4.8	48.05±8.25	92.34±8.49	54.00±16.65
	S_3	21.72±6.79	30.08±4.8	69.28±24.12	90.61±10.92	54.32±16.21
BOD (mg.l^{-1})	S_1	0.48±0.07	0.74±0.08	1.08±0.3	1.12±0.28	0.68±0.08
	S_2	0.5±0.56	0.76±0.09	1.05±0.28	1.12±0.35	0.68±0.05
	S_3	0.41±0.04	0.72±0.09	0.92±0.16	0.93±0.26	0.63±0.08
pH	S_1	7.39±0.37	6.96±0.08	6.69±0.22	6.54±0.02	6.68±0.08
	S_2	7.39±0.37	6.98±0.11	6.66±0.2	6.53±0.04	6.66±0.08
	S_3	7.38±0.37	6.96±0.06	6.65±0.23	6.51±0.02	6.66±0.10
Alkalinity (mg.l^{-1})	S_1	71.45±2.78	87.28±1.05	85.32±6.74	69.63±4.56	74.23±5.39
	S_2	71.48±2.84	87.12±1.3	85.27±6.74	69.6±4.53	74.45±5.87
	S_3	71.46±2.85	87.11±1.28	85.26±6.7	69.62±4.5	74.47±5.88
Hardness (mg.l^{-1})	S_1	22.93±1.1	29.43±7.67	35.55±2.46	28.83±1.73	24.83±0.98
	S_2	21.37±1.01	27.9±7.64	34.01±2.44	27.32±1.73	23.26±0.98
	S_3	21.38±1.02	27.92±7.63	33.99±2.45	27.36±1.74	23.29±0.99
Nitrates (mg.l^{-1})	S_1	0.08±0.02	0.08±0.01	0.11±0.03	0.29±0.09	0.20±0.07
	S_2	0.07±0.03	0.08±0.01	0.11±0.02	0.29±0.1	0.19±0.07
	S_3	0.07±0.02	0.07±0.01	0.11±0.01	0.28±0.09	0.20±0.07
Phosphates (mg.l^{-1})	S_1	0.02±0	0.02±0	0.02±0	0.04±0	0.02±0.01
	S_2	0.02±0	0.02±0	0.02±0	0.03±0	0.02±0.01
	S_3	0.02±0	0.02±0	0.02±0	0.03±0	0.02±0.1
Sodium (mg.l^{-1})	S_1	0.35±0.1	0.55±0.13	0.86±0.03	0.75±0.01	0.66±0.18
	S_2	0.34±0.1	0.53±0.15	0.84±0.03	0.74±0.01	0.64±0.16
	S_3	0.36±0.1	0.51±0.14	0.85±0.03	0.74±0.03	0.65±0.16
Potassium (mg.l^{-1})	S_1	0.25±0.07	0.43±0.08	0.59±0.06	0.75±0.05	0.5±0.06
	S_2	0.23±0.05	0.41±0.1	0.6±0.04	0.74±0.05	0.5±0.05
	S_3	0.23±0.05	0.37±0.06	0.56±0.06	0.74±0.01	0.5±0.07

(0.035 mg.l^{-1}) of phosphates was recorded in monsoon period at S_1 and minimum (0.015 mg.l^{-1}) during the winter season. The value of Sodium concentration was recorded maximum (0.86 mg.l^{-1}) at S_1 during summer season and minimum (0.23 mg.l^{-1}) at S_2 and S_3 during the winter season. The concentration of Potassium was found the maximum (0.75 mg.l^{-1}) at S_1 in monsoon season and minimum (0.23 mg.l^{-1}) found in the winter season at S_1 and S_2. Thus, the overall trend of physico-chemical parameters in the study area revealed that there was a little variation between the different sampling sites but there was a definite seasonal variation in the lake water.

3.1 Diversity Indices

Diversity indices are used as a tool to understand community structure and species richness. In this study, the Shannon-

Wiener diversity index was taken to explain the species diversity in zooplankton community. The seasonal variations of the species diversity index were computed for all the sampling sites (Table 2). Shannon-Wiener diversity index of zooplankton species diversity ranged from 2.80-3.16 at S_1, 2.84-3.17 at S_2 and 2.87-3.05 at S_3 of the Prashar Lake during the study period. Shannon-Wiener index showed maximum diversity in zooplankton community (3.17) during the winter season and minimum (2.80) during the monsoon season. The diversity of zooplankton species in aquatic ecosystems is also related to its abundance [31]. High diversity may also specify that the lake ecosystem has larger food chain, creates more inter-specific interaction and stability among the lake zooplankton community [32].

Table 2: Seasonal variations of Shannon weiner species diversity index at different sites (S_1-S_3) of the Prashar Lake

Shannon	Winter	Spring	Summer	Monsoon	Autumn
S_1	3.132	3.148	3.029	2.806	3.165
S_2	3.177	3.141	3.125	2.844	3.021
S_3	3.053	3.017	2.875	2.938	2.975
Total	3.121	3.102	3.010	2.863	3.054

3.2 Zooplankton community structure

The high abundance of zooplankton was also recorded in Prashar Lake during the winter season, when the species diversity of zooplankton was high. The similar structure was also recorded by the Krishnamoorthi and Selvakumar [33] in Veeranan Lake. Analysis of zooplankton community of Prashar lake revealed that the maximum contribution was made by Rotifera (38%) followed by Cladocera (26%), Protozoa (25%), Copepoda (6%) and Ostrocoda (5%). During the study, a total 27 species of five groups were identified. The Rotifer was the most dominant group having 10 species (*Anuraopsis* sp, *Keratella* sp, *Rotaria* sp, *Brachionus* sp, *Platyias* sp, *Lepadella* sp, *Lecane* sp, and *Trichocera* sp, *Monostyla* sp, *Philodina* sp,), representing 38% the total number of genera (Fig. 2). The second dominant group was Cladocera having 6 species including (*Alona* sp, *Bosmina* sp, *Daphnia* sp, *Moina* sp, and *Simocephalus* sp.), contributing 26% of the total number of genera. The third dominant group was Protozoa group, having 6 species (*Arcella sp, Centropyxis, Colpidium* sp, *Difflugia* sp. *Paramecium* sp, and *Paramecium caudatum)* contributing 25% of the total number of genera. Copepoda represented with three species, (*Cyclops* sp, *Mesocyclops* sp. *and Nauplii* sp.). Ostrocoda represented with two species, only (*Cypris* sp. and *Cypridopsis* sp.*)*.During the period of study, it was observed that the dominant group of Rotifera had shown a maximum number of individuals at S_1 and minimum at S_3. Rotifers act as natural water purifiers in both lentic and lotic aquatic ecosystem. *Platyias* sp. showed presence in Prashar lake from the end of monsoon season and attained its peak in the autumn season otherwise these were absent in rest the seasons. *Keratella* Sp. and *Anuraopsis* sp. were the common species which were present in all the seasons. *Brachionus sp.* and *Keratella* sp. were abundantly available in Prashar Lake during the summer season. These species were observed as an indicator of the rich nutrient condition of lake water during summer seasons [34].

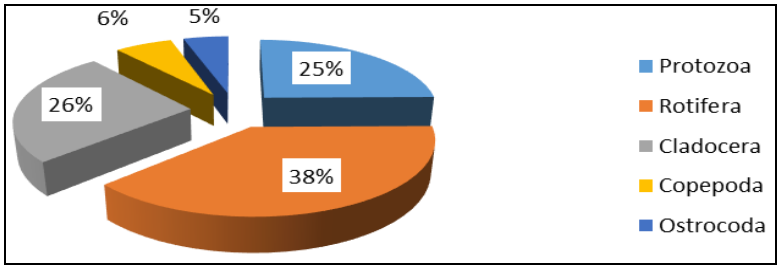

Fig 2: Percent composition of five zooplankton groups in Prashar Lake

Out of six species of Cladocera, *Bosmina sp.* and *Daphnia sp.* was recorded as most abundant. In many species of cladocera *Daphnia sp.* is one of the most common and mostly occurring in all types of environmental conditions. Cladocerans have high grazing efficiency this characteristics effects the dynamics of algal biomass. *Daphnia sp.* is herbivores in nature and also known as 'grazing cattle'. *Chydrorus sp.* was recorded as least abundant species in Prashar Lake. Maximum density was recorded during winter season and minimum during the monsoon season at S_3. The density of Cladocera was reported minimum during monsoon season. The same observation was made by Manickam *et al.* [35] On the perennial reservoir at Thoppaiyar lake. Protozoa group was the third dominated group in which two species of Paramecium (*Paramecium sp.* and *Paramecium caudatum)* were recorded *Diffligia sp.* was a fast most abundant maximum number of species at S_1 and minimum at S_3. The maximum numbers of individuals of Protozoa were observed during the winter season and minimum during the monsoon season. Whereas, *Paramecium caudatum sp.* was absent during the summer season at all the sites. *Centropyxis sp.* and *Paramecium sp.* were observed as a common species which showed their presence in all the seasons. A total of three species of Copepoda were recorded in Prashar Lake. The presence of Copepoda was observed highest during the winter month but the count of species density less as compare with other group [36]. *Mesocylops sp.* was recorded as the most common species present at all the sites in every season. Maximum species of Copepoda were observed during the winter season and minimum during the monsoon season. The minimum density of Copepoda during monsoon was also reported by Krishnamoorthi and Selvakumar [33] in the Veeranam Lake. Two species of Ostrocoda were recorded further in Prashar Lake. *Cypris sp.* was abundantly present winter season at S_1 and rarely present during monsoon season at S_3. Cypris species of ostracoda are usually presented in freshwater found along with the submerged plants the debris at the shallow edge less found in open water. *Cypridopsis sp.* was recorded during autumn to winter seasons only at all sites. Maximum density and diversity of Ostrocoda were recorded during winter season and minimum during monsoon season in Prashar Lake. This finding was supported by the findings of [37-39].

Table 3 Correlation coefficients computed between physico chemical variables and various zooplankton groups in Prashar lake during November 2014-October2015

	Roti	**Clado**	**Proto**	**Cope**	**Ostro**	**WT**	**DO**	**EC**	**SAL**	**Tu**	**TDS**	**BOD**	**pH**	**Al**	**Ha**	**Ni**	**Phos**	**Na**	**K**
Roti	1																		
Clado	0.442	1																	
Proto	0.286	.973**	1																
Cope	0.282	.940**	.954**	1															
Ostro	0.255	.884**	.874**	.952**	1														
WT	0.076	-.816**	-.888**	-.827**	-.746**	1													
DO	-0.28	.692*	.812**	.730**	.665*	-.933**	1												
EC	-0.079	-.855**	-.941**	-.907**	-.787**	.878**	-.872**	1											
SAL	0.506	-0.417	-0.563	-0.502	-0.446	.728**	-.805**	.672*	1										
Tu	-0.346	-.908**	-.916**	-.866**	-.751**	.865**	-.696*	.814**	0.478	1									
TDS	-0.484	-.929**	-.937**	-.921**	-.803**	.784**	-.634*	.862**	0.363	.940**	1								
BOD	-0.144	-0.343	-0.441	-0.493	-0.303	0.306	-0.336	.582*	0.232	0.418	.577*	1							
pH	0.186	.887**	.898**	.954**	.965**	-.800**	.743**	-.858**	-0.555	-.745**	-.806**	-0.367	1						
Al	.740**	-0.022	-0.111	-0.064	-0.129	0.333	-0.514	0.233	.687*	-0.089	-0.219	-0.314	-0.232	1					
Ha	0.512	-0.48	-.611*	-0.563	-0.498	.790**	-.887**	.725**	.727**	0.476	0.399	0.216	-0.546	.648*	1				
Ni	-.647*	-0.492	-0.439	-0.513	-0.519	0.239	-0.056	0.352	-0.241	0.434	.599*	0.159	-0.434	-0.499	-0.08	1			
Phos	-0.555	-.832**	-.835**	-.779**	-.661*	.586*	-0.504	.781**	0.219	.806**	.878**	0.509	-.619*	-0.249	0.334	.602*	1		
Na	0.08	-.806**	-.887**	-.836**	-.775**	.978**	-.931**	.864**	.720**	.856**	.788**	0.362	-.801**	0.284	.784**	0.218	.596*	1	
K	-0.261	-.946**	-.985**	-.944**	-.832**	.914**	-.815**	.946**	0.559	.934**	.956**	0.499	-.871**	0.062	.620*	0.458	.810**	.903**	1

Correlation is significant at the 0.01 level (2-tailed).

Correlation is significant at the 0.05 level (2-tailed).

Abbreviations: Roti: Rotifera, Clado: Cladocera, Proto: Protozoa, Cope: Copepoda, Ostro: Ostropoda, WT: Water temperature, DO: Dissolved Oxygen, SAL:Salinity, Tu: Turbidity, TDS: Total dissolved solids, BOD: Biochemical oxygen demand, pH, Al: Alkalinity, Ha: Hardness, Ni: Nitrates, Phos:Phosphates, Na: Sodium, K: Potassium

4. Conclusions

Microclimate and seasonal change in a particular area also play an important role in the presence and absence of some species. Zooplankton community always played an important quantitative role in net plankton by showing a diverse nature, with affluent diversity and the quantitative dominance of Rotifera and Cladocera. The present results on the Prashar Lake showed that the species diversity was influenced by the various environmental variables, seasonal variation influences these variables. In Prashar lake maximum density of zooplankton was recorded during the winter season (November-February). It starts declining during the spring season (March-April) onwards and attains the lowest ebb during monsoon months (July-August). Zooplankton showed an increase in their density in post monsoon season and attains peak in the winter season. The maximum diversity zooplankton was observed during the winter months. There is another region behind the maximum zooplankton growth in winter is the presence of predators were less observed during the winter season. Small plant growth always supports a

Habitat for a predator, but during winter these plants growth was reduced which support less population predator which enhances the population of zooplankton. The highest diversity of zooplankton was observed at S_2 as compare to S1, S_3 it may be due to the minimum growth of macrophytes was observed at these sites. In the Prashar lake zooplankton reduced in monsoon season due to heavy rainfall, high turbidity and temperature, reduced pH, and increased nutrient concentration due to run off entry into the lake. Usually rich species diversity thought to indicate a more convoluted and healthier community, because a larger diversity of species allows more species interactions and greater stability. So greater, the diversity, slighter the impact of environmental pollution were observed at the Prashar Lake. The present outcomes give valuable data on the zooplankton population especially in perspective of the scarcity in the data of zooplankton group in the Himalayan lakes.

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