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Study on Pelagic Copepods from Pipnakha Village, District Gujranwala, Pakistan

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Abstract.- Seasonal variations, density and diversity of fresh water copepods were investigated from October 2011 to August 2012. In total, 20 copepod species were identified. Density of copepods was high in spring and low in winter. *Mesocyclops edax* was the dominant species in summer, monsoon and fall, while *Ectocyclops phaleratus* and *Eucyclops agilis* were dominant in winter and spring respectively. Impact of selected physico-chemical parameters on population dynamics of copepods was also studied. Copepods density was positively correlated with temperature, pH, total dissolved solids (TDS) and turbidity and negatively correlated with dissolved oxygen (DO). Shannon-Weaver diversity index, Simpson index, Pielou's evenness index, and Margalef index were calculated to find out diversity of copepods. Analysis of variance (ANOVA) showed significant difference (F=22.36, P=0.000) in copepods density of all seasons. Principal component analysis (PCA) was used to find out correlation between copepod species and seasons.

Key Words: Zooplankton, physico-chemical parameters, copepods, diversity indices.

INTRODUCTION

Ponds are rich in biodiversity of fauna and flora. They are socioeconomically and commercially important (Ghanai *et al*., 2010). Copepods are the most abundant metazoans on earth (Ka and Hwang, 2011). They are food source of fish, shrimps and larvae of molluscs (Sakthivel and Fernando, 2012). Zooplankton are responsible for energy flow in water body (Medeiros and Arthington, 2011).

Copepods are one of the most important components of zooplankton in freshwaters and they have an important role in the trophic state of inland water ecosystems (Bozkurt and Akın, 2012). And, they are the significant part of zooplankton in the sense of diversity, abundance and distribution (Hsieh and Chiu, 1997). Also, Apaydın Yağcı (2013) stated that Cyclopoid (especially, *Cyclops abyssorum*) and Harpacticoid copepods are determinant as indicators in decision of trophic state.

Crustacean succession is largely found by the interactions and the seasonal cycles of physico-chemical parameters (Shah and Pandit, 2013). Florescu *et al*. (2013) studied diversity of zooplankton of Danubi Delta, Romania, in relation to physico-chemical parameters and showed that the copepods and cladocerans were dominant and great difference was observed in spring, summer and autumn. Naz *et al*. (2012) reported 21 species of copepods from mangrove creek area along Karachi coast, Pakistan. No work has been done on seasonal variations, density and diversity of copepods in Punjab. The aim of the study was to determine seasonal variation, density and diversity of copepods in a pond of Pipnakha village, District Gujranwala.

MATERIALS AND METHODS

Study area

This study was carried out to study fresh water copepods from October 2011 to August 2012 in a pond in Pipnakha village, which is located at latitude of 32.17º N and longitude of 74.04º E at the distance of 14 km on the western side of the city. Pond length is 234 ft and width is 150 ft.

Water sampling

Water samples were taken just beneath the water surface from three selected sites of the pond between 10:00 A.M to 1:00 P.M. Samples were collected in 1 liter bottles to determine physico-

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chemical parameters. The water temperature, pH and dissolved oxygen (DO) were measured with HANNA HI-8053, YSI-Eco Sense pH 100 and YSI-Eco Sense DO 200 respectively. The other parameters including total dissolved solids (TDS) and turbidity were measured using classical methods (by their respective meters YSI-Eco Sense EC 300 and HANNA HI-93703) on the spot.

Copepods sampling, counting and identification

For copepods sampling, 50 L water was passed through plankton net with a mesh size 70µm and contents were preserved in 50 mL plastic bottles with 4-5% formalin (Koste, 1978).

Copepods were counted by using Sedgwick rafter chamber (APHA, 2005) at 60-100x using an inverted Olympus microscope. Copepods were identified by observing their body shape, segments of antenna and caudal rami (Ward and Whipple, 1959; Pennak, 1978; Yunfang, 1995).

Diversity indices

Shannon-Weaver diversity index was calculated by using the following formula;

$$H = -\sum P_i (\ln P_i)$$ (Shannon and Weaver, 1949)

where Pi is the proportion of each species in the sample. Pi = ni/N (Omori and Ikeda 1984), where n is the number of individuals of a particular species. N is the total number of individuals of all the species in the sample.

Simpson index was calculated by following formula;

$$D = \sum n (n-1)/N (N-1)$$ (Simpson, 1949),

Where D is Simpson's index of Dominance, N denotes total number of individuals of all the species and n is the number of individuals of specific species per samples.

Species richness was calculated by given formula;

$$SR = (S - 1)/\log N$$ (Margalef, 1951),

Where S is total number of species and N denotes total number of individuals present in the sample.

Species evenness was determined by the following equation;

$$E = H/\log S$$ (Pielou, 1966),

Where S is total number of species and H is Shannon- Weaver diversity index

Analysis of variance (ANOVA) and Pearson correlation were calculated by software The Minitab 13. Principal component analysis (PCA) was calculated by XL stat 13.

RESULTS AND DISCUSSION

As a result, a total of 20 species of fresh water copepods were identified. Highest population density of copepods was noted in spring and lowest in winter (Fig. 1). Similar findings were reported by Shah *et al*. (2013) while working on copepods distribution and diversity in Wular lake Kashmir. *Mesocyclops edax* (Forbes, 1891) was the dominant species in summer (12.6%), monsoon (15%) and fall (17.17%), while *Ectocyclops phaleratus* (Koch, 1838) and *Eucyclops agilis* (Koch, 1838) were dominant in winter (21.04%) and spring (9%) respectively (Table I).

Values of Shannon-Weaver (1.56-2.84), Simpson index of dominance (0.06-0.22) and species richness (0.49-1.82) were highest in April and lowest in January (Fig. 2) indicating high diversity in spring and lower in winter. This was attributed to high photosynthetic activity and favorable physico-chemical parameters for the growth of organisms. Mohan *et al.* (2013) also reported similar results. Species evenness ranged between 0.91 and 0.97 showing even distribution and homogeneity in organisms throughout all the seasons. Copepods density showed positive correlation with temperature, pH, TDS and turbidity and negative correlation with DO (Table II).

The water temperature ranged from 12.65±1.56 to 36.35±1.11 (Table III) during the study period. The highest water temperature was recorded during summer while the lowest was recorded in winter. Sulehria and Malik (2012) reported the same trend. This was attributed to the photoperiod. Longer photoperiod in summer

Table I.- Relative percentage of copepods.

Copepod species	Fall	Winter	Spring	Summer	Monsoon
Acanthocyclops viridis (Jurine, 1820)	8.08	8.78	6.60	2.30	0
Acanthocyclops brevispinosus (Herrick, 1884)	0	0	2.83	0	0
Cyclops strenuus (Fischer, 1851)	0	0	3.77	6.90	2.98
Diacyclops bicuspidatus (Claus, 1857)	9.09	8.78	6.60	9.20	7.47
Diacyclops nanus (Sars, 1863)	5.05	12.28	3.77	6.90	8.95
Diacyclops navus (Herrick, 1882)	2.025	0	2.83	3.45	2.98
Eucyclops agilis (Koch, 1838)	7.07	0	9.43	10.34	13.43
Ectocyclops phaleratus (Koch, 1838)	5.05	21.04	6.60	5.75	8.95
Macrocyclops albidus (Jurine, 1820)	6.06	10.53	4.72	8.05	10.45
Macrocyclops fuscus (Jurine, 1820)	3.03	7.89	7.55	3.45	4.48
Mesocyclops aspericornis (Daday, 1906)	7.07	0	7.55	0	0
Mesocyclops edax (Forbes, 1891)	17.17	12.28	7.55	12.64	14.93
Microcyclops rubellus (Lilljeborg, 1901)	6.06	0	1.88	4.60	7.47
Microcyclops varicans (Sars, 1863)	6.06	7.89	5.66	4.60	5.97
Thermocyclops hyalinus (Rehberg, 1880)	4.04	0	5.66	0	0
Paracyclops affinis (Sars, 1863)	4.04	10.53	3.77	4.60	0
Leptodiaptomus siciloides (Lilljeborg, 1889)	4.04	0	5.66	3.45	0
Skistodiaptomus oregonesis (Lilljeborg, 1889)	4.04	0	5.66	4.60	2.98
Skistodiaptomus pallidus (Herrick, 1879)	2.02	0	1.89	4.60	2.98
Skistodiaptomus pygmaeus (Pearse, 1906)	0	0	0	4.60	5.97

Table II.- Correlation (Pearson) between Copepods and physico-chemical parameters.

	Significance	Copepods	Temp	pH	DO	TDS
Temp	p<0.05	0.568				
pH	p>0.05	0.570	0.672			
DO	p<0.05	-0.372	-0.872	-0.853		
TDS	p<0.05	0.280	0.701	-0.044	-0.314	
Turb	p<0.05	0.172	0.838	0.335	-0.777	0.713

Temp, temperature; DO, dissolved oxygen; TDS, total dissolved solids; Turb, turbidity; level of significance=0.05

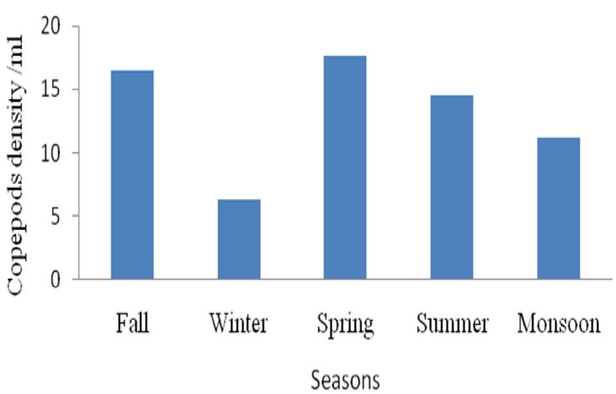

Fig. 1. Seasonal variations in density of copepods.

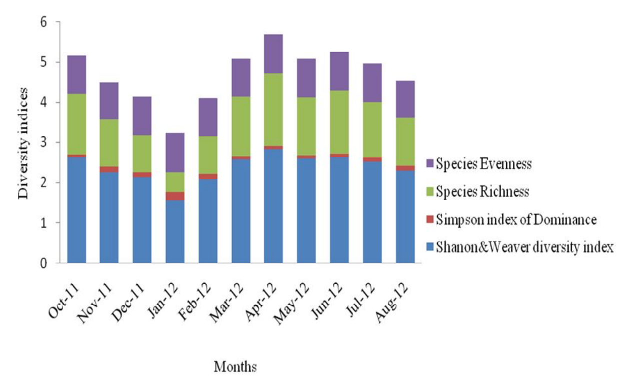

Fig. 2. Seasonal variation in diversity indices.

Table III.- Seasonal variations in Physico-chemical parameters.

Parameters	Fall	Winter	Spring	Summer	Monsoon
Temp (ºC)	25.45±0.99	12.65±1.56	26.34±1.05	36.35±1.11	31.85±0.63
pH	7.37±0.14	7.08±0.38	8.17±0.34	8.8±0.1	7.27±0.13
DO (mg/L)	9.7±0.1	9.95±0.03	8.4±0.2	7.03±0.53	8.33±0.0.08
TDS (mg/L)	534±10.53	377.±40.6	427±15.46	496±46.22	593±4.48
Turb (FTU)	191.33±10.03	178.56±4.77	210.5±5.19	232.67±4.35	253.84±0.84

Temp, temperature; DO, dissolved oxygen; TDS, total dissolved solids; Turb, turbidity.

resulted in high temperature while shorter photoperiod caused low temperature in winter. These findings were matched with findings of Odum (1971).

In the present study, pH ranged from 8.8±0.1 to 7.08±0.38 (Table III). Lowest pH was recorded in winter then pH started to increase in spring and summer. This increased pH in warm months was attributed to high concentration of carbonates. Kamble *et al.* (2009) had given the same results. Decline in pH was observed in monsoon which may be attributed to dilution effect due to rain water. Aquino *et al*. (2008) reported similar findings.

Value of dissolved oxygen was high (9.95±0.03) during winter and low (7.03±0.53) during summer (Table III). This might be due to the fact that solubility of oxygen in water increased with the decrease in temperature (winter) and low DO in summer was explained by low solubility level of oxygen and its utilization by microorganisms in decomposition. Hussain *et al.* (2013) had shown the same results.

Total dissolved solids were highest (593±4.48) in monsoon and lowest (377±40.6) in winter (Table III). This might be due to the fact that increases in temperature increased decaying process resulting in increased total dissolved solids in water. This can also be due to the entry of muddy water. These results are in accordance with work done by Ahmad *et al.* (2011). Turbidity was highest (253.84±0.84) during monsoon while the lowest (178.56±4.77) was observed in winter (Table III), which was due to settlement of suspended particles in winter resulting in least turbidity. Kedar *et al.* (2008) showed similar findings.

During study two maxima in population density of copepods were observed in spring and fall indicating the fact that all parameters in these seasons were in favorable range for the growth of copepods. Shah *et al.* (2013) has also reported similar results. Decline in population density in summer was attributed to downward migration of copepods at very high temperature. This is in conformity with the findings of Islam and Bhuiyan (2007). Further decline in copepods in monsoon was attributed to high TDS and turbidity. High turbidity restricted the growth of copepods in monsoon. Kumar *et al.* (2011) informed similar findings. High TDS resulted in suffocation in aquatic organism. Maqbool *et al*. (2014) reported the same results. Decline in copepods density in monsoon might also be due to the low photosynthetic activity. Joshi (2011) had given the same results. Further decline in population density of copepods in winter was due to low temperature because low temperature slowed down the metabolic activities of organisms resulting in decreased growth rate and population density (Fig. 1).

Table IV.- Analysis of variance between copepods and seasons (p<0.05).

Source	DF	SS	MS	F	P
Factor	1	261.9	261.9	22.36	0
Error	8	93.7	11.7		
Total	9	355.7			

DF, degree of freedom; SS, sum of squares; MS, mean of squares; F, F ratio; P, probability.

Outcomes of analysis of variance showed significant difference in copepods density of all seasons (Table IV) showing that seasonal changes in zooplankton density were due to significant changes in physico-chemical parameters. These results were matched to the work of Imoobe (2011).

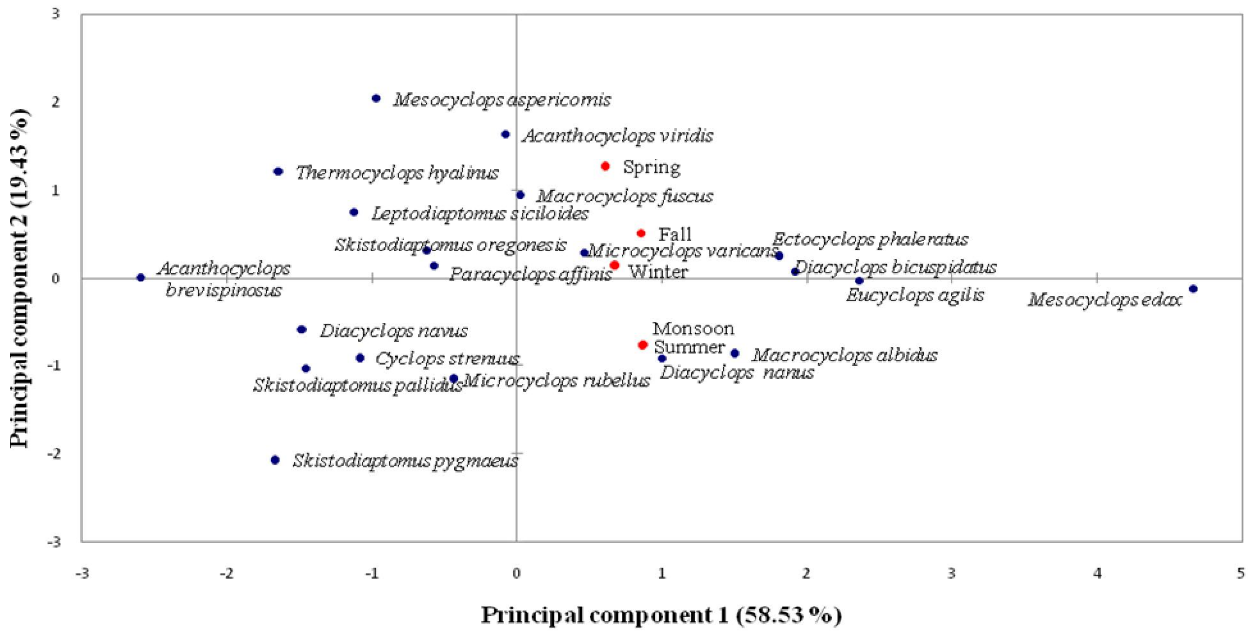

Fig. 4. Biplot of variables and observations.

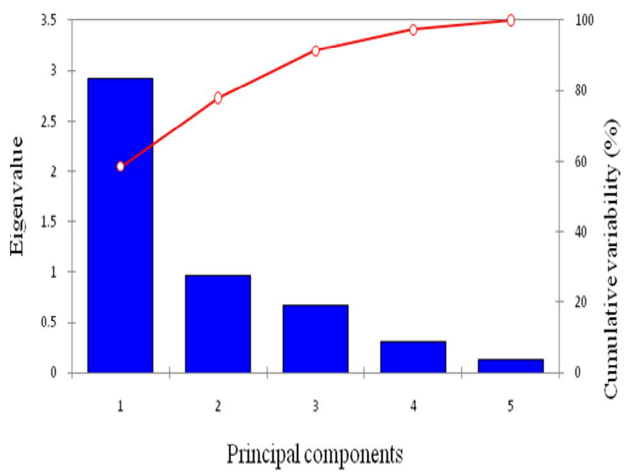

Fig. 3. Scree plot of principal components, their given values and cumulative variability (%).

Principal component analysis (PCA) was used to analyze the data. Data was divided into five principal components (Table V). Scree plot indicated that three components having high eigenvalues 2.92, 0.97 and 0.6 can be used to analyze the data (Fig. 3). It was shown from table that *M. edax E. agilis* had loaded heavily on 1st component, *Mesocyclops aspericornis* (Daday, 1906) had loaded heavily on 2nd component and *E. phaleratus* had loaded heavily on 3rd component (Table VI). Biplot showed that copepod species present on the right side of the plot were positively correlated among themselves and with the seasonal changes, while species on the left side showed negative correlation with seasonal changes and species present on the central vertical line of biplot were not affected by seasonal changes. Species present close to the centre were strongly affected by seasonal changes while species present away from the central points were least affected by the seasonal changes (Fig. 4).

Table V.- Principal components and their Eigenvalues.

Components	Eigenvalue	Variance (%)	Cumulative (%)
1	2.926	58.53	58.53
2	0.972	19.433	77.963
3	0.666	13.316	91.279
4	0.306	6.118	97.397
5	0.13	2.603	100

Table VI.- Principal components and their loadings.

Copepod species	Components				
	1	2	3	4	5
A. viridis	-0.082	1.635	0.590	0.599	-0.209
A. brevispinosus	-2.595	0.005	0.206	-0.032	0.306
C. strenuus	-1.080	-0.906	-0.439	-0.733	-0.718
D. bicuspidatus	1.915	0.077	-0.150	0.134	-0.525
D. nanus	1.002	-0.911	0.969	-0.047	0.164
D. navus	-1.484	-0.584	-0.210	0.089	0.040
E. agilis	**2.357**	-0.033	-1.950	-1.179	0.202
E. phaleratus	1.808	0.253	**2.053**	-0.732	0.346
M. albidus	1.503	-0.857	0.433	-0.160	0.165
M. fuscus	0.020	0.946	0.369	-0.934	0.216
M. aspericornis	-0.970	**2.040**	-0.634	0.372	0.337
M. edax	**4.662**	-0.118	-0.574	1.090	-0.078
M. rubellus	-0.438	-1.147	-0.521	0.909	0.520
M. varicans	0.464	0.291	0.307	0.021	0.224
T. hyalinus	-1.646	1.210	-0.289	0.168	0.323
P. affinis	-0.570	0.146	1.199	0.264	-0.736
L. siciloides	-1.124	0.748	-0.511	-0.008	-0.421
S. oregonesis	-0.622	0.309	-0.684	-0.197	-0.203
S. pallidus	-1.453	-1.035	-0.182	0.249	-0.206
S. pygmaeus	-1.669	-2.069	0.016	0.128	0.254

Value in the bold show high loadings for each component.

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