Seasonal Changes in Zooplankton Community Thriving in Wastewater - Fed Fish Ponds

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ABSTRACT

East Calcutta Wetlands, Ramsar site No 1208, receive domestic and industrial wastes of Kolkata city both in solid and liquid forms. In the wetlands several small and large ponds are excavated which receive the raw wastewater and apply them in pisciculture. Zooplankton plays a major role in pisciculture, as they are the primary food for juvenile fishes. Present study records the aspects of zooplankton diversity for 12 months in relation to physico-chemical environment of four selected fishponds comprising of 3 nursery tanks (Site 1, 2 and 3) and a large stocking pond (Site 4). The study revealed the occurrence of 45 species of zooplankton, among these 12 species of Cladocera, 4 species of Copepoda, 27 species of Rotifera, and 2 species of Ostracoda were recorded. *Mesocyclops leuckarti* was the most frequently encountered zooplankton. *Paracyclops* sp. was very rare, encountered only in five occasions at Site 2 and Site 3. Among the cladocerans *Moina brachiata* and *M. micrura* were most abundant. *Diaphanosoma sarsi*, *Ceriodaphnia cornuta* and *Daphnia* sp. were also found in adequate numbers. The genus *Moinodaphnia sp.* was very rare, found only twice at Site 2 and Site 3. *Brachionus calyciflorus*, *B. quadridentatus* & *B. urceolaris* were more frequent among the rotifers and were found in all the sites. Abundance of different groups of zooplankton was correlated with the physico-chemical parameters of the pond water. Total zooplankton showed significant negative correlation with Total Dissolved Solids ($r = -0.98$; $p < 0.05$) and significant positive correlation with DO($r = 0.98$; $p < 0.05$). Total copepods and total cladocerans separately exhibited significant positive correlations with Gross Primary Productivity ($r = 0.99$ and 0.97 respectively; $p < 0.05$). Site wise variation in dominance, diversity, evenness and richness were also calculated.

INTRODUCTION

Zooplankton are cosmopolitan in nature and they inhabit all freshwater habitats as well as the municipal and industrial wastewaters (Mukhopadhyay *et al.* 2007). They are used as bioindicators for the detection of pollution load and also take part in the amelioration of polluted wastewater (Mukhopadhyay *et al.* 2007). East Calcutta wetlands (ECW), a Ramsar site (No 1208) located in the eastern fringe of Kolkata city is the biggest urban wetland ecosystem of the world covering an area of 12,500 ha, which includes 286 wastewater-fed fishponds sprawled over 3,832.27 ha (over 30% of the total wetland area), and producing 10,915 metric tonnes of fish annually (Chattopadhyay *et al.* 1999). Huge composite effluent mixed city sewage is discharged to the Storm Water Flow (SWF) and the Dry Weather Flow (DWF) canals, the two main wastewater carrying canals that pass through this wetland area. Many small and large ponds are excavated in this area where wastewater from the two canals referred earlier is used for pisciculture. Zooplankters occupy the place preceding to the fishes in the food chain and are basically served as food for the juvenile fishes. The traditional pisciculture practiced in the ECW for nearly a century involves rearing of a particular group of zooplankton before the release of the fish eggs. The community structure of zooplankton in respect to the physico-chemical parameters in the wastewater along the SWF canal has already been reported by Mukhopadhyay *et al.* 2007. The present study aims to record the changes in the zooplankton community structure; both spatial and temporal in the pisciculture ponds that are fed with the composite wastewater.

MATERIALS AND METHODS

The sampling area is located at Chowbaga about 4 kilometers east of Science city in Kolkata. The spot is situated beside the Kolkata- Basanti highway which traverses through the East Calcutta Wetlands, running parallel to the DWF and SWF canals. The sampling area comprises of four ponds, three of which are stocking ponds where fingerlings are developed from eggs, and a very large nursery pond where fingerlings reared in the stocking ponds are released. Water and zooplankton samples were collected from the three stocking ponds named Site I, II and III, and also from the large nursery pond named Site IV. Sampling was done once in a month, on the last week of every month, between 10.00 hrs to 16 hrs. In each site water and plankton samples are collected following Eaton *et al.* 1995.

Conductivity, pH, Total Dissolved Solids (TDS) and Dissolved Oxygen (DO) were measured potentiometrically on the spot using Mettler Checkmate 90 Toledo. Nitrate (NO_3), phosphate (PO_4), chloride (Cl), Total hardness, alkalinity and acidity were analyzed on the spot titrimetrically using E. Merck (Germany) Field testing devices (Aquaquant/ Merckoquant/ Aquamerck Kits). After determination, collected samples were acidified by 1N HNO_3 (AR) at pH <2.5 and brought to the laboratory in 500 ml glass stoppered bottles. All metals were detected by AAS (Perkin Elmer AAnalyst100). Total Suspended Solid (TSS) was estimated gravimetrically using Mettler AE240 electronic balance. BOD_5, COD and primary productivity were analyzed following Eaton *et al.* 1995.

Collection (using No.25 conical silk bolting cloth net), narcotisation (adding 5 drops of 5% formalin in 50ml sample volume) and preservation (in 70 parts 70% alcohol+25 parts distilled water+5parts 5% formalin) of zooplankters were made following

Mukhopadhyay and Rao, 1982. Organisms were counted, in a Sedgwick-Rafter counting cell following Eaton *et al* 1995.Zooplankters were studied and photographed using Leica DM LB2 Microscope fitted with Leica DFC 320 camera. Narcotization, preservation and identification of the rotifers were made following Arora 1962; Battish 1992; Dhanapati 1974; Edmondson 1992; Sharma 1979a; Sharma 1979b. For statistical computation, data presentation and community structure analyses, Statistical computer software (Statistica for Windows, Version 5.1A, Statsoft Inc., 1996) and Community Analysis Package (IRS, UK, 2000) were used.

RESULTS AND DISCUSSION

The mean values (and standard deviation) of different physicochemical conditions including the metal loads and the primary productivity of the four selected fishponds are depicted in Table 1. Most of these values were much different from the relatively uncontaminated ponds of West Bengal as reported by Sharma 1992 and Michael 1968. The four selected ponds are found to be predominantly alkaline having the mean pH values ranging from 7.53 ± 0.67 mgL^{-1} in Site 4 to 8.13±0.42 mgL^{-1} in Site 1. Mean DO content was highest in site 1 (7.02±2.77 mgL^{-1}) and lowest in site 44.63±3.69 mgL^{-1}. Mean TDS values are as high as 475.42±115.65 mgL^{-1} (at site 4) to 382.83±60.79 mgL^{-1} (in site 3). Conductivity showed a similar pattern having the highest mean value at site 4 (0.95± 0.23ms) and lowest at site 1 (0.77± 0.12 ms). Similar kind of fluctuation of mean values TDS and conductivity was also reported by Chattopadhyay *et al.* 2004.The mean values for TSS was higher at sites 1& 4 (166.83± 11.38mgL^{-1} and 153.33± 38.57mgL^{-1} respectively and lower at sites 2 &3 (136.50± 21.38 mgL^{-1}& 123.92± 36.50 mgL^{-1}). The mean chloride concentration for the fishponds (132.68± 65.34mgL^{-1} to 152.50± 44.08 mgL^{-1}) are complying with the values obtained for the sewage fed fisheries in East Calcutta Wetlands (Khan 2003) but lower in comparison with tannery effluent stabilization pond (Mukhopadhyay *et al.* 2000). This may be due to the use of high concentration of salts in tanning operations (Chattopadhyay *et al.* 2004). The total hardness values for the wastewater in the fish culture ponds (mean value ranging form 185.71± 39.43 mgL^{-1} to 227.69± 39.02 mgL^{-1}) is complying with the values obtained for water in sewage fed fish culture ponds in the ECW as depicted by Khan 2003. This similarity in the physicochemical parameters can be attributed to the similar nature of pisciculture technique practiced in the area. The mean BOD concentrations for the water samples were found to be fairly high ranging from 58.04± 11.93mgL^{-1} to 88.29± 21.39mgL^{-1}. The high BOD values can be due to the fact that the raw composite effluent having the mean BOD value of approximately 260 mgL^{-1} (Chattopadhyay *et al.* 2004) is allowed in the fishponds for certain duration (7-8 hours a day), as a natural food for the fishes. The mean phosphate and nitrate content in the water samples collected from the fishponds ranges from 2.74 ± 0.50 mgL^{-1} to 7.53 ± 1.54 mgL^{-1} and 11.25 ± 3.78 mgL^{-1} to 15± 4.05 mgL^{-1} respectively. The high phosphate and nitrate content in the pond water is due to the admixture of phosphate and nitrate rich municipal wastewater. The toxic heavy metals like Cr and Pb were absent in the

Table 1 : Mean and standard deviation of physico-chemical parameters of water in the selected sites[1]

	SITE I		SITE II		SITE III		SITE IV	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
AT (^{o}C)	31.75	2.12	31.63	2.34	31.53	1.76	31.18	1.71
WT (^{o}C)	28.71	3.79	28.93	3.30	28.08	3.79	29.99	2.13
pH	8.13	0.42	7.68	0.42	7.53	0.67	7.62	0.61
DO (mgL^{-1})	7.02	2.77	5.39	2.20	4.96	3.95	4.63	3.69
TDS (mgL^{-1})	382.83	60.79	421.50	119.02	447.83	96.39	475.42	115.65
COND(ms)	0.77	0.12	0.84	0.23	0.84	0.18	0.95	0.23
TSS(mgL^{-1})	166.83	11.38	136.50	21.38	123.92	36.50	153.33	38.57
ACID(m mol L^{-1})	0.10	0.02	0.08	0.03	0.13	0.08	0.15	0.06
ALK(m mol L^{-1})	3.38	0.44	3.58	1.04	4.35	1.35	4.56	1.40
HARD(mgL^{-1})	185.71	39.43	197.05	39.33	210.04	38.76	227.69	39.02
CO_3(mgL^{-1})	151.30	30.11	166.63	38.87	194.32	39.51	220.03	45.24
CL(mgL^{-1})	138.17	48.83	145.83	48.86	132.68	65.34	152.50	44.08
PO_4(mgL^{-1})	2.74	0.50	5.97	1.25	7.53	1.54	6.24	0.91
NO_3(mgL^{-1})	15.00	4.05	11.25	3.78	11.88	3.00	12.50	3.83
BOD_5(mgL^{-1})	85.28	14.33	58.04	11.93	86.16	25.81	88.29	21.39
COD(mgL^{-1})	101.00	26.95	96.02	27.94	112.48	26.85	82.80	24.48
Cr(mgL^{-1})	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mn(mgL^{-1})	0.35	0.07	0.20	0.07	0.23	0.02	0.25	0.O4
Fe(mgL^{-1})	1.47	0.20	1.50	0.28	1.37	0.23	1.04	0.33
Cu(mgL^{-1})	0.11	0.03	0.00	0.00	0.00	0.00	0.51	0.23
Zn(mgL^{-1})	0.11	0.03	0.15	0.03	0.13	0.03	0.16	0.04
Pb(mgL^{-1})	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NPP (mgC m^{-2}h^{-1})	430.24	123.10	211.05	83.86	202.82	89.95	74.89	15.24
GPP (mgC m^{-2}h^{-1})	598.98	110.69	346.93	121.31	297.25	36.63	129.39	29.20

[1] AT= Air Temperature WT= Water Temperature; DO= Dissolved Oxygen; TDS= Total Dissolved Solids; COND= Conductivity; TSS= Total Suspended Solids; ACID= Acidity ALK= Alkalinity; HARD= Total Hardness; CO_3= Carbonate Hardness; CL= Chloride; PO_4= Phosphate; NO_3 = Nitrate; BOD_5= Biochemical Oxygen Demand COD= Chemical Oxygen Demand NPP = Net Primary Productivity; GPP= Gross Primary Productivity

pond water samples at all the four sites. Other heavy metals like Mn (0.35 ± 0.07 mgL^{-1} to 0.23± 0.02 mgL^{-1}), Fe (1.04±0.33 mgL^{-1} to 1.47 ±0.20 mgL^{-1}), Cu (0.11±0.03 mgL^{-1} to 0.51±0.23 mgL^{-1}) and Zn (0.11± 0.03 mgL^{-1} to 0.16± 0.04 mgL^{-1}) are present in almost all the sites. The mean GPP and NPP values for the pond water samples range from 129.39 ±26.20 mg Cm^{-2} h^{-1} to 598.98 ± 110.69 mg Cm^{-2} h^{-1}and 74.89 ±15.24 mg Cm^{-2} h^{-1}to 430.24±153.10 mg Cm^{-2} h^{-1} respectively. The high productivity at the fishponds is again due to the admixture of composite effluent which contains large amount of organic matters and nutrients favoring the growth of phytoplankton.

In the current study area a total of 45 species of zooplankton were observed in the study ponds; comprising of 4 species of copepods, 12 species of cladocerans, 2 species of ostracods and 27 rotifer species. The mean abundance of different zooplanktonic species has been depicted in Table 2. Among the copepods the immature cyclopods are most numerous (mean densities 8.75 nos L^{-1} to 83.99 nos L^{-1}). immature calanoids (mean densities 0.33 nos L^{-1} to 32.79 nos L^{-1}) and *Mesocyclops leuckarti* are also the dominant zooplanktonic species in the selected ponds. *Heliodiaptomus viduus* represented the only calanoid species that was obtained from the study sites having mean density as high as 30.87 nos L^{-1} at site 1. Among the cladocerans *Moina brachiata* and *M. micrura* were most frequently encountered (mean densities 1.70 nos L^{-1} to 45.14 nos L^{-1} and 1.07 nos L^{-1} to 16 nos L^{-1} respectively) and *Ilyocryptus sordidus*, *Kurzia longirostris*, *Moinodaphnia macaleayi* and *Macrothrix goeldii* are encountered in very few samples. Among the ostracods *Cyclocypris globosa* was more abundant (mean densities 2.94 nos L^{-1} to 8.44 nos L^{-1}) than *Stenocypris malcolmsoni*(mean densities 0.00 nos L^{-1} to 0.85 nos L^{-1}). Though 27 species of rotifers were found in the samples collected from the sites, *Brachionus calyciflorus* var. *anuraeiformis* (mean densities 0.52 nos L^{-1} to 4.75 nos L^{-1}), *B. quadridentatus* (mean densities 0.65 nos L^{-1} to 2.02 nos L^{-1}) and *B. urceolaris* (mean densities 0.11 nos L^{-1}-4.47 nos L^{-1}) were the rotifers most frequently encountered.

The seasonal trend in zooplanktonic abundance in the selected sites has been shown in Tables 3-6. All the sites followed a definite pattern having peak periods at spring summer (March- April- May) and lean periods during September when maximum rainfall occurs in the area as recorded from the meteorological data. Site 2 had high mean zooplanktonic densities at December (223.04 nos L^{-1}), January (298.74 nos L^{-1}) February (217.29 nos L^{-1}) and in May (264.42 nos L^{-1}). It is to be noted that site 2 is used as the egg pond where eggs are released and spawns are reared. Every year prior to the release of eggs an extensive pond preparation is undertaken (Mukhopadhyay *et al.* 2000). Raw effluent is allowed to enter into a previously dried pond which results in a phyplanktonic bloom, the bloom is due to the appearance of blue green algae. The phyplanktonic bloom is followed by appearance of zooplankton. So pond preparation process is invariably accompanied by increased densities of zooplankton. Site 1 had peak abundance of zooplanktons (mean density 684.95 nos L^{-1}) at March and lowest abundance (mean density 84.75 nos L^{-1}). Site 1 is used to nurture the spawns until they grow upto the fingerling stage. Pond preparation is also done in site 1 prior to the release of spawns. The succession of zooplankton in site 3 reaches peak values at March having mean density 212.80 nos per litre and the rainy seasons viz. July, August and September showed the minimum abundance of zooplankton. Site 4 is used for the nurturing of the fingerlings until they grow as adult fishes. High mean zooplanktonic densities were recorded in October (277.68 nos L^{-1}), November (241.02 nos L^{-1}) and December (285.48 nos L^{-1}) from site 4 whereas, low densities were recorded in the rainy seasons viz. June (29.25 nos L^{-1}) and July (15.21 nos L^{-1}).

Table 2: Mean densities of different zooplanktonic species in the four selected fishponds

COPEPODA	SITE I	SITE 2	SITE 3	SITE 4
Nauplius	4.03	1.77	0.71	0.91
Immature Cyclopods	83.99	46.10	40.05	8.75
Immature calanoids	32.78	21.03	2.89	0.33
Mesocyclops hyalinus male	1.14	0.46	0.20	0.39
M. hyalinus female	2.68	0.00	1.04	0.42
M. leuckarti male	20.58	2.24	17.63	2.02
M. leuckarti female	27.54	2.60	18.43	3.15
Paracyclops poppei	0.00	12.58	1.10	0.00
Heliodiaptomus viduus male	10.78	12.90	0.36	0.20
H. viduus female	20.13	0.13	0.72	0.10
CLADOCERA				
Immature *Moina sp.*	3.10	0.36	0.20	0.23
Immature *Daphnia sp.*	1.17	1.04	0.00	0.00
Alona quadrangularis	0.00	0.40	0.75	0.72
A. rectangula rectangula	0.20	0.00	0.22	0.13
Ceriodaphnia cornuta	0.14	0.43	2.11	0.88
Daphnia carinata	1.37	0.76	0.26	0.13
D. lumholtzi	0.46	0.00	0.03	0.00
Diaphanosoma sarsi	0.65	4.02	0.85	0.91
Ilyocryptus sordidus	0.00	0.20	0.00	0.13
Kurzia longirostris	0.00	0.20	0.13	0.33
Macrothrix goeldii	0.00	0.00	0.85	0.46
Moina brachiata	45.14	11.74	3.87	1.70
M. micrura	16.53	11.59	4.74	1.07
Moinodaphnia macaleayi	0.00	0.20	0.26	0.00
OSTRACODA				
Cyclocypris globosa	2.97	3.55	3.16	8.44
Stenocypris malcolmsoni	0.85	0.26	0.07	0.00

Table 2: Mean densities of different zooplanktonic species in the four selected fishponds (contd..)

ROTIFERA				
Asplanchna brightwelli	0.52	0.72	13.52	0.69
A. priodonta	0.07	0.00	0.20	1.17
Brachionus angularis	0.46	0.00	0.46	0.13
B. bidentata	0.20	0.23	0.00	0.46
B. budapestinensis	0.00	0.00	0.07	0.65
B. calyciflorus var. anuraeiformis	4.75	0.52	2.21	2.93
B. calyciflorus f. borgerti	3.37	0.00	0.00	0.00
B. calyciflorus var. dorcas	5.98	1.69	0.65	0.00
B. calyciflorus var. dorcas f. spinosa	0.00	0.00	1.82	0.00
B. calyciflorus var. pala	9.14	0.26	0.00	0.00
B. caudatus var. personatus	0.85	0.13	0.00	0.20
B. diversicornis	0.59	0.20	0.00	0.13
B. falcatus	2.11	0.00	0.00	0.00
B. patalus	0.00	0.00	2.41	1.37
B. pterodinoides	0.10	0.00	0.00	0.00
B. rubens	0.55	0.00	2.18	0.72
B. quadridentatus	1.35	2.02	0.65	0.72
B. urceolaris	3.98	0.11	6.31	4.57
Filinia longiseta	0.00	0.00	0.07	0.13
Keratella tropica	0.00	0.20	0.00	0.00
Lecane pleonensis	0.00	0.00	0.10	0.00
Lecane sp.	0.00	0.00	0.33	0.00
Lepadella patella	0.00	0.00	0.20	0.13
Monostyla clostocerca	0.00	0.00	0.00	0.26
M. lunaris	0.00	0.00	0.37	0.13
Platyias quadricornis	0.00	0.00	0.49	0.20
Squartinella sp.	0.00	0.00	0.20	0.20

Table 3: Seasonal abundance of the zooplanktonic groups in Site 1

Zooplankton	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT
Copepoda	113.62	267.36	456.48	208.26	262.86	250.04	120.12	224.64	71.37	109.20	283.14	76.56
Cladocera	16.12	28.08	1.72	35.88	0.78	222.11	315.90	166.14	3.51	3.12	30.42	1.17
Ostracoda	0.00	0.00	1.72	0.00	0.78	2.66	10.14	21.06	2.34	0.00	0.00	7.02
Rotifera	0.00	12.48	0.00	0.00	8.58	210.14	74.46	53.82	37.44	0.00	10.53	0.00
Total Zooplankton	129.74	307.92	459.92	244.14	273.00	684.95	520.62	465.66	114.66	112.32	324.09	84.75

Table 4: Seasonal abundance of the zooplanktonic groups in Site 2

Zooplankton	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT
Copepoda	19.24	167.44	213.88	261.30	180.63	26.52	46.02	102.96	12.87	62.01	89.98	14.82
Cladocera	0.78	18.98	7.34	33.54	31.20	0.00	78.78	114.66	7.02	0.00	77.22	1.56
Ostracoda	0.00	0.00	0.52	1.56	3.90	31.20	2.34	0.00	0.00	0.00	0.00	6.24
Rotifera	0.00	3.90	1.30	2.34	1.56	9.36	5.46	46.80	0.00	0.00	0.00	1.95
Total Zooplankton	20.02	190.32	223.04	298.74	217.29	67.08	132.60	264.42	19.89	62.01	167.20	24.57

Table 5: Seasonal abundance of the zooplanktonic groups in Site 3

Zooplankto	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT
Copepoda	195.00	156.78	221.52	186.42	107.64	20.28	18.09	30.42	5.85	4.68	9.36	41.34
Cladocera	61.62	38.22	1.56	3.51	1.56	0.00	3.35	4.68	22.23	10.53	19.89	3.90
Ostracoda	0.78	0.78	0.00	0.00	6.24	7.80	8.71	11.70	1.17	0.00	0.00	1.56
Rotifera	20.28	45.24	62.40	13.65	7.80	170.82	1.34	7.02	0.00	0.00	16.38	41.34
Total Zooplankton	277.68	241.02	285.48	203.58	123.24	198.90	31.49	53.82	29.25	15.21	45.63	88.14

Table 6: Seasonal abundance of the zooplanktonic groups in Site 1

Zooplankton	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT
Copepoda	17.16	3.63	41.34	31.20	0.00	1.56	4.68	7.80	4.68	12.87	11.70	58.50
Cladocera	0.00	6.75	7.02	3.12	1.56	3.12	4.68	4.68	14.04	16.38	9.36	9.36
Ostracoda	0.00	4.17	1.56	4.24	0.00	0.00	1.56	87.36	2.34	0.00	0.00	0.00
Rotifera	6.24	10.92	19.50	9.36	0.00	7.80	68.64	21.84	0.00	2.34	4.68	25.74
Total Zooplankton	23.40	25.47	69.42	47.92	1.56	12.48	79.56	121.68	21.06	31.59	25.74	93.60

Table 7: Correlation coefficients (significant at $p<0.05$) between the zooplankton communities and the physicochemical environment of their habitat (*marked correlations were significant).

Parameters	Copepoda	Cladocera	Ostracoda	Rotifera	Total Zooplankton
WT	-0.53	-0.31	0.93	-0.58	-0.50
pH	0.84	0.95*	-0.18	0.40	0.88
DO	0.95*	0.99*	-0.44	0.48	0.98*
TDS	-0.99*	-0.97*	0.64	-0.36	-0.98*
Cond	-0.96*	-0.86	0.84	-0.53	-0.95*
TSS	0.39	0.62	0.40	0.16	0.46
Acid	-0.94	-0.83	0.85	-0.26	-0.89
Alk	-0.93	-0.90	0.58	-0.05	-0.88
Hard	-0.98*	-0.91	0.75	-0.29	-0.95*
CO_3	-0.97*	-0.91	0.72	-0.22	-0.93
CL	-0.52	-0.34	0.83	-0.78	-0.53
PO_4	-0.78	-0.92	0.08	-0.30	-0.82
NO_3	0.61	0.77	0.02	0.65	0.71
BOD5	-0.21	-0.09	0.38	0.71	-0.08
COD	0.45	0.24	-0.88	0.65	0.44
GPP	0.99*	0.97*	-0.65	0.52	0.99*
NPP	0.98*	0.97*	-0.60	0.56	0.99*
Cr	--	--	--	--	--
Mn	0.61	0.76	0.01	0.68	0.71
Fe	0.84	0.67	-0.93	0.17	0.77
Cu	-0.74	-0.54	0.99*	-0.32	-0.68
Zn	-0.83	-0.80	0.64	-0.85	-0.88
Pb	--	--	--	--	--
Copepoda	1.00	0.96*	-0.68	0.42	0.99*
Cladocera	0.96*	1.00	-0.46	0.41	0.98*
Ostracoda	-0.68	-0.46	1.00	-0.36	-0.63
Rotifera	0.42	0.41	-0.36	1.00	0.52
Total zooplankton	0.99*	0.98*	-0.63	0.52	1.00

The copepods exhibited a significant positive correlation with DO ($r=0.95$; $p<0.05$), a significant negative correlation with TDS ($r=-0.99$; $p<0.05$) and a insignificant positive correlation with chloride ($r=0.52$; $p<0.05$), similar relationship of copepod with DO, TDS and chloride was also reported by Mukhopadhyay *et al* 2007. The copepods exhibited a significant positive relationship ($r=0.96$; $p<0.05$) with the cladocerans, this might be attributed to the coexistence of immature cyclopods, *M. leuckarti* with the cladocerans like *M. brachiata*, *M. micrura* in almost all the sites. Cladocerans also exhibited similar positive correlation with DO ($r=0.99$; $p<0.05$) and negative correlation with TDS ($r= -0.97$; $p<0.05$). Total zooplankton exhibited a significantly positive correlation with the GPP($r=0.99$; $p<0.05$) which can corroborated to the fact that influx of raw municipal wastewater into the ponds induce rapid growth of the green algae (Mukhopadhyay *et al.* 2000). The abundance of phytoplankton provides more food for the zooplankton and thus higher zooplanktonic densities attain much higher values.

The site wise variations in diversity, evenness, richness and dominance of zooplanktonic communities are represented in Table 8. The Shannon Weiner's (H') species diversity index was almost similar for all the sites viz.2.17 (site 1), 2.11 (site 2), 2.26 (site 3) and 2.18 (site 4) which might be due to the fact that similar kind of pond preparation is practiced in the selected fishponds resulting in the similar nature and densities of the zooplankton in the ponds. Simpson's

Table 8: Different diversity indices for determination of the community structure of the zooplankton

DIVERSITY INDICES	Site-1	Site-2	Site-3	Site-4
Shannon-Wiener Species Diversity Index $[H' = -\sum_{i=1}^{OS} pi \ln pi]$	2.17	2.11	2.26	2.18
Pielou's Evenness Index $[J' = \frac{H'}{\ln OS}]$	0.66	0.65	0.65	0.64
Margalef's Richness Index $[D_{MARG} = \frac{OS-1}{\ln N}]$	3.38	3.43	4.45	4.20
Simpson's Dominance Index $[D_{SIMP} = \sum_{i=1}^{OS} (pi)^2]$	0.17	0.17	0.15	0.16

dominance index (D_{SIMP}) also showed similar trends in all the sites but lowest values of D_{SIMP} (0.15)was observed at the highest H' values which is in compliance with the findings of Mukhopadhyay *et al.* 2007. Margalef's richness index (D_{MARG}) which takes into account both abundance and species numbers varied between 3.38 (in site 1) and 4.45 (in site 3).

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