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Analysis of zooplankton diversity and physico-chemical conditions in three perennial ponds of Darbhanga district, Bihar

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Abstract
Present study revealed that zooplankton species richness (R1 and R2) was comparatively higher (R1: 4.39; R2: 2.13) in Dighi pond. The species diversity was higher in the Dighi pond (H': 2.53; N1: 15.05; N2: 15.75) as compared to other ponds. The water samples were analyzed for temperature, pH, electrical conductivity, alkalinity, salinity, phosphate, hardness, dissolved oxygen and biological oxygen demand. Higher value of physico-chemical parameters and zooplankton diversity were recorded in Dighi pond as compared to other ponds. The zooplankton population shows positive significant correlation with physico-chemical parameters like, temperature, alkalinity, phosphate, hardness and biological oxygen demand, whereas negatively correlated with rainfall and salinity. The study revealed that the presence of certain species like, Monostyla sp., Keratella sp., Lapadella sp., Leydigia sp., Moinodaphnia sp., Diaptomus sp., Diaphanosoma sp., Mesocyclopes sp., Cypris sp. and Brachionus sp. is considered to be biological indicator for eutrophication.

Keywords: Psychiatric disorders, suicide, suicide attempt; first admission; recurrent admission; schizophrenia; bipolar disorder; depression; substance abuse disorder

Introduction
Most of the ponds are getting polluted due to domestic waste, sewage, and agricultural effluents. The requirement of water in all lives, from micro-organisms to man, is a serious problem today because all water resources have reached to a point of crisis due to unplanned urbanization and industrialization. Water quality assessment generally involves analysis of physico-chemical, biological and microbiological parameters and reflects on abiotic and biotic status of the ecosystem. In ecologically, zooplankton are one of the most important biotic components influencing all the functional aspects of an aquatic ecosystem, such as food chains, food webs, energy flow and cycling of matter. The distribution of zooplankton community depends on a complex of factors such as, change of climatic conditions, physical and chemical parameters and vegetation cover. Most of the species of planktonic organisms are cosmopolitan in distribution.

A number of study have been carried out on ecological condition of freshwater bodies in various parts of Bihar, but southern part of Darbhanga, the ecological studies of freshwater body is very scanty. However, relationship between physico-chemical parameters and planktonic fauna is very limited (Ahmad and Siddiqui, 1995; Choudhary and Singh, 1999) [6, 7, 10]. Therefore, the present investigation attempts to study the zooplankton species richness, diversity and evenness in relationship between physico-chemical parameters in three perennial ponds of Darbhanga district.

Materials and Methods
Three perennial ponds were selected for this investigation, in which Dighi pond (Pond I) is situated on the way to Station Road, Shastri Chowk to Bhatiyari Sarai, about 0.1 km away from Donar, Bhatiyarisarai Road.

A match factory and automobile workshop situated near the pond, dump the waste material and people who are unmindful of the environmental conservation, defecate near the pond. Harahi pond (Pond II) is situated at C.M. Law College, Darbhanga. This pond is misused for dumping the germinated grams after the Mirzakhan pond (Pond III) is located at adjoining L.Sarai. Darbhanga, about 6 kms away from Darbhanga and it receives domestic effluents from surface run off from nearby agriculture field during raining season.

Collection of samples: The pond survey was carried out from June 2000 to December 2000. Water samples were collected periodically in each second Saturday from the three selected ponds, during the early hours between 7.00-10. 00 am. The plankton samples were collected by filtering 50 litters of water through standard plankton net (77 mesh bolting silk) and the concentration samples were fixed in 5% of formalin.

Physico-chemical analysis: Temperature (air and surface water) was recorded on the spot using Centigrade Thermometer. The pH of the water samples was measured by using the gun pH meter on the spot. Physico-chemical analysis (electrical conductivity, alkalinity, salinity, phosphate, calcium hardness, magnesium hardness, total hardness, dissolved oxygen and biological oxygen demand) of the sample was done according to standard methods (APHA, 1975).

Biological analysis: Zooplankton species identification was done with the help of standard references (Alfred *et al*., 1973; Adoni *et al*., 1985). The quantitative analysis of planktonic organisms was carried out using Sedgwick Rafter plankton counting cell in accordance to Welch (1948).

Community structure analysis: Three indices were used to obtain the estimation of species diversity, species richness and species evenness.

1. Shannon and Weaver (1949) and Simpson (1949) diversity index value was obtained using the following equation:

$D = \Sigma Pi^2 (\log Pi)$ (Shannon's index)
i = I
$D = \Sigma Pi^2$ (Simpson index)
i = I
Where
Pi = is the proportion of the first species. The proportions are given Pi = ni/N

2. Species richness (R1 and R2) was obtained using the equation.

$R_1 = (S - 1) / \log N$ (Margalef, 1951)
$R_2 = S \sqrt{n}$ (Menhinick, 1964)
Where:
R = is the index of species richness
S = total number of species
N = total number of individuals

3. Species equitability or evenness was determined by using the expression of Pielou (1966) and Sheldon (1969).

$E1 = \frac{N_1}{N_0}$ (Pielou evenness)

$E1 = \frac{N_1}{N_0}$ (Sheldon evenness)

Where:
N_0 = number of species on the sample
N_1 = number of abundant species in the sample

4. The correlation co-efficient "r" is calculated by the method of Birader (1988).

$$R = \frac{(1/n)\Sigma xy - \overline{X}\overline{Y}}{oX\sqrt{oY}}$$

Where:
x = mean of x
y = mean of y
σx = standard deviation of x
σy = standard deviation of y
n = number of paired observation

Results and Discussion

Species diversity indices such as species richness and evenness were studied in order to measure the status of water quality in three perennial ponds and relationship that exists between the physico-chemical characteristics. Data obtained from the study indicates that a total of 47 zooplankton species were recorded in three ponds comprising of 24 species of rotifers, 9 copepods, 8 cladocerans, 4 ostracods and 2 species of protozoa. High number of zooplankton species was observed in the Dighi pond (47 species) followed by Harahi pond (39 species) and Harai pond (24 species) (Table 1).

Table 1: Zooplankton density in the water sample of three perennial ponds during the study period

Zooplankton (Unit l^{-1})	Pond I							Pond II							Pond III						
Protozoa																					
Vorticella sp.	+	+	+	-	-	+	+	+	+	-	-	-	-	+	+	+	+	-	-	+	+
Euglypha sp.	-	+	+	-	-	-	+	+	+	-	-	-	-	+	-	-	-	-	-	-	-
Rotifera																					
Brachionus calyciflorus	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-
B. quadridentatus	+	+	+	+	+	-	+	+	+	+	+	+	+	+	-	+	+	-	+	+	+
B. forticula	+	+	+	+	-	+	+	+	+	+	-	-	+	+	+	+	-	+	-	+	+
B. angularis	+	+	+	+	+	+	+	+	+	-	+	+	-	+	+	+	+	+	+	+	+
B. falcatus	+	+	+	-	-	+	+	+	+	-	+	-	-	+	-	-	-	-	-	-	-
B. caudatus	+	+	-	-	-	+	+	-	+	-	-	+	-	+	-	-	-	-	-	-	-
B. urceolaris	+	+	+	-	-	-	+	-	+	-	-	-	-	+	-	-	-	-	-	-	-
Euchlanis sp.	+	+	-	+	-	+	-	+	+	+	-	+	-	+	+	+	+	-	-	+	+
Horella brehmi	+	+	+	+	+	-	-	-	+	+	+	-	+	-	+	+	+	+	+	+	+
Keratella tropica	+	+	+	-	+	-	+	+	+	+	-	+	+	+	-	-	-	-	-	-	-
K. cochlearis	-	+	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lepadella sp.	+	+	+	-	-	+	+	+	+	+	+	+	-	+	-	-	-	-	-	-	-
Monostyla quadridentatus	-	+	+	+	-	+	+	-	+	+	+	-	+	+	+	+	+	-	+	+	-
Mytilina sp.	+	+	-	-	-	+	-	+	+	+	-	+	-	-	-	-	-	-	-	-	-
Notholca sp.	+	+	+	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-
Trichotria sp.	+	+	-	+	+	+	-	+	+	+	-	-	+	+	+	+	+	+	-	+	+
Trichocera rattus	+	+	+	-	-	-	+	+	+	+	-	-	-	-	+	+	+	-	-	+	+
Testudinella patina	+	+	+	-	-	-	+	+	+	+	-	+	-	-	+	+	-	-	-	+	+
Asplanchna brightwelli	+	+	-	-	-	-	+	-	-	-	-	-	-	-	-	+	-	-	+	-	+
Lecane lunaris	+	+	-	-	-	-	+	+	+	+	+	-	+	+	+	+	-	+	+	-	+
L. papuana	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L. bulla	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Platyias patulus	-	+	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Conochilus sp.	-	+	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cladocera																					
Alonella sp.	+	+	-	-	+	-	+	+	+	-	-	+	-	+	+	+	+	-	+	-	+
Bosmina longirostris	+	+	+	+	-	+	-	+	+	+	+	+	+	+	+	-	+	+	-	+	+
Daphnia carinata	+	+	+	+	+	+	+	+	+	+	-	-	+	-	-	-	-	-	-	-	-
D. similes	+	+	-	-	-	+	-	+	+	+	+	-	+	+	+	+	+	-	-	+	+
Diaphanosoma sp.	+	+	+	+	+	+	+	-	+	+	-	+	-	+	-	-	-	-	-	-	-
Leydigia sp.	+	+	-	+	-	+	+	+	+	+	-	-	-	+	+	+	-	-	-	+	-
Moina sp.	+	+	+	-	-	+	+	+	+	-	-	-	+	+	+	+	-	+	-	-	+
Moina daphnia	+	+	+	-	+	+	+	+	+	-	-	+	+	+	+	-	+	-	+	-	+
Copepoda																					
Calonoid copepod	+	+	+	-	-	+	-	+	+	-	+	-	+	+	-	-	-	-	-	-	-
Heleodiaptomus viduus	+	+	-	+	-	-	+	-	+	-	-	-	-	+	+	+	+	-	-	+	+
Mesocyclops hyalinus	+	+	-	+	-	-	+	-	+	-	-	-	-	+	+	+	+	-	-	+	+
M. leuckartii	+	+	+	+	-	-	+	+	+	-	+	-	+	+	+	-	+	-	+	-	+
Diaptomus sp.	+	+	-	+	-	+	+	+	+	-	-	-	+	+	-	-	-	-	-	-	-
Tropocyclops sp.	+	+	+-	-	-	+	+	+	-	+	-	-	-	-	-	-	-	-	-	-	-
Spicodiaptomus chilospinus	+	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thermocyclops sp.	+	+	+	-	-	-	+	+	+	-	+	-	-	+	-	-	-	-	-	-	-
T. crassus	+	+	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ostracoda																					
Cypris sp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Stenocypris malcolmsoni	+	+	-	+	-	-	+	+	+	-	-	-	-	+	+	+	+	+	-	-	+
Cyprinotus sp.1	+	+	+	+	-	-	+	+	+	+	+	+	+	+	+	-	+	-	-	-	+
Cyprinotus sp.2	+	+	-	-	-	-	+	-	+	-	-	-	+	+	-	-	-	-	-	-	-
Total number of species	**41**	**46**	**33**	**19**	**11**	**25**	**34**	**31**	**38**	**21**	**15**	**15**	**19**	**32**	**22**	**20**	**18**	**9**	**10**	**17**	**22**

J = June, J = July, A = August, S = September, O = October, N = November, D = December

Higher number of zooplankton species were recorded during June and July 2010 (summer), whereas low during September and October (monsoon). Rotifer is the richest group with 24 species, which accounts for 51% of total zooplankton population (Table 2).

Table 2: Monthly variation of species content belonging to the different group of zooplankton in three perennial ponds

Months	Pond I					Pond II					Pond III				
	Class					Class					Class				
	PR	RO	CL	CO	OS	PR	RO	CL	CO	OS	PR	RO	CL	CO	OS
June	1	19	8	9	4	2	14	7	5	3	1	9	6	3	3
July	2	24	8	8	4	2	18	8	6	4	1	11	4	2	2
August	2	18	5	6	2	0	13	5	1	2	1	7	4	3	3
September	0	8	4	4	3	0	8	2	3	2	0	5	2	0	2
October	0	6	4	0	1	0	9	4	0	2	0	6	2	1	1
November	1	12	7	4	1	0	8	5	3	3	1	10	3	2	1
December	2	15	6	7	4	2	13	7	6	4	1	10	5	3	3

PR = Protozoa, RO = Rotifera, CL = Cladocera, CO = Copepoda, OS = Ostracoda

In all ponds, rotifer population was most abundant during June and July 2010. Singh *et al*. (2012) [10] reported that higher rotifer populations occurs during summer and winter might be dominant due to hypertrophical conditions of the pond at high temperature and low level of water.

About 1700 species of rotifers have been described from the different parts of the world and 500 species (only 330 species belonging to 63 genera and 25 families have so far been authenticated) was described from Indian water bodies (Arora and Mehra, 2013; Kiran *et al*., 2017) [9]. During observation, in rotifers population the numerical superiority was found to be high in the case of Brachionus species (7 spp.), which are considered typical for and most frequent in tropical environment (Nogueira, 2001; Mulani *et al*, 2019) [4]. Genus Brachionus is one of the most ancient genus of monogonont rotifers and is represented by 46 species in India (Harikrishnan, 1995; Sharma and Sharma, 2011).

High mean value of Shannon's index (H') was recorded in Dighi pond (2.53±0.03) as compared to Harahi (2.31±0.22) and Mirzakha pond (1.92±0.62) (Table 3).

Table 3: Zooplankton species richness, diversity and evenness of three perennial ponds

Diversity indices Mean ± SE	Pond I		Pond II		Pond III	
	Range	Mean ± SE	Range	Mean ± SE	Range	
Richness						
Number	27.85 ± 4.36	13 - 45	22.71 ± 3.11	12 - 36	17.28 ± 1.85	13 – 25
R1 (Margalef's index)	4.39 ± 0.11	4 - 4.91	3.82 ± 0.24	2.57 - 4.44	3.35 ± 0.35	2.11 - 4.47
R2 (Menhinick's index)	2.13 ± 0.04	2 - 2.99	1.90 ± 0.17	1.12 - 2.32	1.70 ± 0.18	1.12 - 2.29
Diversity						
Lambda	6.38 ± 0.19	5 - 7.22	4.11 ± 1.08	0.06 - 6.69	1.30 ± 1.16	0.12 - 5.31
H' (Shannon's index)	2.53± 0.03	2.42 - 2.69	2.31 ± 0.22	1.58 - 2.86	1.92 ± 0.62	1.58 - 2.76
N1	15.05 ± 0.49	13.20 - 17.48	13.97 ± 0.40	13.16 - 15.88	12.44 ± 0.62	10.06 - 14.83
N2	15.75 ±0.47	13.83 - 17.48	14.21 ± 0.82	9.36 - 15.44	8.18 ± 0.82	5.6 - 12.02
Evenesse						
E1	0.93 ± 0.01	0.85 - 0.95	0.91 ± 0.01	0.83 - 0.96	0.59 ± 0.03	0.47 - 0.78
E2	0.83 ± 0.1	0.75 - 0.88	0.79 ± 0.05	0.53 - 0.88	0.56 ± 0.03	0.44 - 0.76

Dash (1996) [11] reported that high value of Shannon's index (H') the greater is the planktonic diversity. Low value of Shannon's index were recorded during September and October 2000 at Dighi and Harahi ponds, this may be due to high downpour recorded as 244.2 mm and 100.9 mm.

Out of the three perennial ponds, the zooplankton species richness (R1 and R2) was found to be high in Dighi pond (R1: 4.39±0.11; R2: 2.13±0.04) followed by Harahi (R1: 3.82±0.24; R2: 1.90±0.17) and Mirzakha ponds (R1: 3.35±0.35; R2: 1.70±0.18). High Margalef's (R1) and Menhinick's index (R2) value was observed during June and July 2010. Mukherjee (1997) [5] reported that the higher species richness (R1 and R2) is characterized by larger food chain (Dumont, 1999). The mean value of the evenness index ranges between E1= 0.85 to 0.95 and E2= 0.75 to 0.88 at Dighi pond, E1=0.88 to 0.96 and E2= 0.53 to 0.88 at Harahi and E1=0.47 to 0.78 and E2= 0.44 to 0.76 at Mirzakhan pond. Equitability (evenness) was relatively high during the raining season indicating a reduction in the plankton diversity at this period (Adesalu and Nwankwo, 2008). Peet (1974) has reported that species diversity implies both richness and evenness in the number of species and equitability for the distribution of individual among the species.

The physico-chemical parameters of water at three perennial ponds have been given in the Tables 4a, b and c.

Table 4a: Correlation coefficient values among certain physico-chemical parameters at Dighi pond

	AT	WT	pH	EC	RF	AK	SA	P	CH	MH	TH	DO	BOD	ZOOP
AT	-													
WT	0.87*	-												
pH	0.46	0.20	-											
EC	0.54	0.74*	0.64	-										
RF	-0.66	-0.51	-0.70*	-0.49	-									
AK	0.56	0.78*	0.54	0.94*	-0.79*	-								
SA	-0.87*	-0.48	-0.70*	-0.96*	0.73*	-0.91*	-							
P	0.48	0.06	0.52	0.54	-0.52	0.49	-0.63	-						
CH	0.49	0.42	0.61	0.41	-0.49	0.61	-0.44	0.87*	-					
MH	0.61	0.53	0.49	0.48	-0.87*	0.53	-0.52	0.93*	0.94*	-				
TH	0.49	0.44	0.51	0.37	-0.82*	0.57	-0.70*	0.88*	0.73	0.97*	-			
DO	-0.60	-0.42	-0.37	-0.56	0.80*	-0.58	0.63	-0.55	-0.31	-0.54	-0.37	-		
BOD	0.35	0.51	0.19	0.65	-0.37	0.55	-0.51	-0.04	-0.09	0.04	-0.08	-0.55	-	
ZOOP	0.45	0.43	0.50	0.20	-0.58	0.49	-0.24	0.79*	0.85*	0.76*	0.84*	-0.30	-0.21	-

Table 4b: Correlation coefficient values among certain physico-chemical parameters at Harahi pond

	AT	WT	pH	EC	RF	AK	SA	P	CH	MH	TH	DO	BOD	ZOOP
AT	-													
WT	0.96*	-												
PH	0.12	0.25	-											
EC	0.51	0.55	0.71*	-										
RF	0.28	0.12	-0.74	-0.24	-									
AK	0.25	0.26	0.86*	0.68*	-0.45	-								
SA	0.17	0.10	-0.87*	-0.39	0.77*	-0.84*	-							
P	0.34	0.34	0.44	0.14	-0.52	0.68*	-0.42	-						
CH	0.02	0.03	0.56	0.11	-0.74	0.61	-0.55	0.54	-					
MH	0.09	0.15	0.73*	0.36	-0.51	0.66*	-0.71*	0.46	0.94*	-				
TH	0.06	0.10	0.66*	0.25	-0.73*	0.65	-0.69*	0.51	0.98*	0.98*	-			
DO	0.72	0.63	-0.30	0.35	0.63	-0.15	0.56	-0.12	-0.51	-0.54	-0.58	-		
BOD	-0.03	0.19	0.60	0.26	-0.64	0.28	-0.35	0.40	0.38	0.50	0.45	-0.42	-	
ZOOP	0.36	0.38	0.53	0.22	-0.55	0.66*	-0.46	0.87*	0.84*	0.77*	0.81*	-0.28	0.51	-

Table 4c: Correlation coefficient values among certain physico-chemical parameters at Mirzakha pond

	AT	WT	pH	EC	RF	AK	SA	P	CH	MH	TH	DO	BOD	ZOOP
AT	-													
WT	0.95*	-												
pH	0.78*	0.73*	-											
EC	0.76*	0.75*	0.45	-										
RF	-0.53	-0.83	-0.95*	-0.52	-									
AK	0.93	0.91	0.60	0.77*	0.09	-								
SA	-0.46	-0.48	-0.83*	-0.24	0.66*	-0.23	-							
P	0.45	-0.16	0.50	-0.45	-0.53	0.45	-0.38	-						
CH	0.82*	0.88*	0.79*	0.81*	-0.92*	0.85*	-0.41	0.81*	-					
MH	0.47	0.40	0.44	0.40	-0.76*	0.24	-0.93*	0.43	0.45	-				
TH	0.70*	0.58	0.97*	0.64	-0.67*	0.55	-0.77*	0.67*	0.33	0.4 1	-			
DO	0.07	0.73*	0.31	0.71	-0.51	0.87*	0.14	0.10	0.46	-0.12	0.28	-		
BOD	0.35	0.38	0.45	0.72	0.43	0.32	-0.06	-0.17	0.49	-0.25	0.42	0.42	-	
ZOOP	-0.25	-0.19	0.43	-0.07	-0.25	-0.43	-0.63	0.35	0.29	0.41	0.71*	-0.18	0.15	-

The air and surface water temperature ranged from 29-32 ºC at Dighi pond, 28-31ºC at Harai pond and 26-27 ºC at Mirzakha pond. Temperature is one of the essential and changeable environmental factors, since it influences the growth and distribution of flora and fauna. Water temperature ranging between 13.5 and 32 ºC is reported to be suitable for the development of the planktonic organisms (Kamat, 2000; Gaikwad *et al*., 2008). Among the three ponds, the populations of zooplanktons are positive correlated with water temperature. Similar observation were made by Bhuiyan and Gupta (2007) and Park and Shin (2007). The increase in zooplankton population with the rise in temperature was observed during the recent investigation.

The pH value ranges between 7.00-8.70 at Dighi pond, 6.53-8.20 at Harahi pond and 6.50-7.20 at Mirzakha pond, it indicates alkaline nature. High pH value was recorded during June and July 2010 (summer). This may be due to low level of water and high photosynthesis of micro- macro organism resulting in high production of free carbon dioxide during the equilibrium towards alkaline side (Trivedy, 1989; Shiddamallayya and Pratima, 2008) [2, 3]. According to Kurbatova (2005) and Tanner *et al*. (2005) the pH range between 6.0 and 8.5 indicates medium productive nature of a reservoir; more than 8.5 highly productive and less than 6.0 low productive nature of a reservoir. In the case of Dighi pond the average pH value observed during the study period was 8.2 which indicates that the water is a highly production of zooplankton population.

In the present investigation, Electrical conductivity (EC) value ranged from 806 to 145 Rmhos cm^{-1} among the three ponds. High value of EC was recorded during June (summer) whereas low during September 2000 (monsoon) at Dighi and Harahi ponds. The high Electrical conductivity value was observed during June 2000, and this might be due to high temperature at less solubility and high degradation of organic substances. Among the three ponds, Electrical conductivity values showed positive correlation with zooplankton production, while negative correlation with dissolved oxygen. EC is found to be good indicators of the water quality (Abbassi *et al*., 1996; Gaikwad *et al*., 2008). According to Gaikwad *et al*. (2008) the dilution of solid substance in turn reduces the EC value alkalinity and zooplankton production.

Total alkalinity in three ponds ranged from 50-185 ppm. Maximum value was recorded at Dighi pond (range: 85-185 ppm), followed by at Harahi (range: 70-125 ppm) and Mirzakha pond (range: 50-87 ppm). High alkalinity values were recorded during June and July 2000, which is probably due to reduction of water. Alkalinity showed significant positive correlation with zooplankton diversity suggested that high value of total alkalinity coinciding with the high planktonic yield (Singh *et al*., 2002; Sachidanandamurthy and Yajurvedi, 2006; Kiran *et al*., 2007) [10].

The value of total hardness fluctuation from 150-70 ppm at Dighi pond, 105-60 ppm at Harahi pond and 85-50 ppm at Mirzakha pond. High value of hardness was recorded during June and July 2000 (summer) whereas low during September and October 2000 (monsoon). High range of total hardness obviously was due to high loading organic substance, detergents, chlorides and other pollutants. Among three ponds, the total hardness showed significant positive correlation with zooplankton production, water temperature, alkalinity and phosphate, whereas significant negative correlation with salinity and rainfall. Similar findings were observed by Ratushnyak *et al*. (2006), Mathivanan *et al*. (2007) and Park and Shin (2007).

Meshram (2005) has reported that calcium hardness is essential for normal growth and development of many aquatic ecosystems. Estimation of biological oxygen demand (BOD) is an important measure to the oxygen required for the degradation of organic matter. The BOD value ranged from 1.5-3.75 ppm at Dighi pond, 1.00-2.5 ppm at Harahi pond and 0.8-2.00 ppm at Mirzakha pond. High BO value was recorded during June and July 2000. In Dighi pond BOD values noted negative correlation with zooplankton, whereas in Harahi and Mirzakha ponds BOD showed positive correlation with zooplankton production. Dissolved oxygen (DO) is an important aquatic parameter whose measurement is vital in the context of culture of any aquatic animal as oxygen plays a crucial role in its life processes.

Dissolved oxygen ranged from 2.5-7.5 ppm at Dighi pond, 2.0-7 ppm at Harahi pond and 2.12-5 ppm at Mirzakha pond. High concentration of DO was recorded during June and July 2000. This may be due to low solubility at high temperature and high degradation of organic substances. In Harahi pond DO value showed significant positive correlation with zooplankton, while negative correlation with zooplankton at Dighi and Mirzakha ponds. Ahmad and Krishnamurthy (1990) [6, 7] and Singh and Singh (1993) [10] drew similar conclusion.

Conclusion

The findings of the present study indicate that the Dighi pond exhibited higher levels of zooplankton species density as well as physico-chemical parameters than that of Harahi and Mirzakha ponds. This may be depends upon the levels of organic enrichment. This relatively high zooplankton

species density could be explained by eutrophication effect. Monostyla sp., Keratella sp., Lapadella sp., Moinadaphnia sp., Diaptomus sp., Mesocyclopes sp., Cypris sp., Diaphanosoma sp., Brachionus calyciflorus, B. quadridentatus, B. forficula, B. angularis, B. falcatus, B. urceolaris and B. caudatus species were predominant at Dighi and Harahi ponds. On the other hands, the absence of above certain species like Brachionus calyciflorus, B. falcatus, B. urceolaris, Keratella sp., Lapadella sp., Diaphanosoma sp. and Diaptomus sp. at Mirzakha pond was noted. Nogueira (2011) [4] reported that above 15 species is the index of eutrophic waters and its abundance is considered as a biological indicator for eutrophication. Brachionus calyciflorus species was frequently observed during all months in the Dighi and Harahi ponds. This species is considered to be the indicators of eutrophication (Sampaio *et al*., 2012) [1]. The results indicate that the Dighi and Harahi ponds water have already reached the eutrophication stage. Nogueira (2011) [4] reported that Brachionus calyciflorus as indicators of sewage and industrial pollution. This study concluded that the water of Dighi pond and Harahi pond is highly polluted by directed contamination of sewage and other industrial effluents. Therefore, the water body has to be preserved for their intended use, a sustainable and holistic management planning is necessary for conservation of this pond.

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