

# Macrozoobenthic Community and Assessment of Aquatic Ecosystem Health of three Waterbodies of East Calcutta Wetlands, India

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Received: 1 November 2012 / Revised: 18 May 2013 / Accepted: 3 June 2013 / Published online: 23 July 2013  
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**Abstract** The present study was aimed to understand the diversity, abundance and distribution of macrozoobenthic community of three selected fishponds differing in sewage intake and culture practices of East Calcutta Wetlands of Kolkata, India, as well as the aquatic ecosystem health of these waterbodies considering benthos as the best indicator of pollution. One year seasonal samplings were done to study the diversity and distribution of macrozoobenthos along with 12 water quality parameters to reflect the ecological conditions and aquatic ecosystem health of these waterbodies through biodiversity indices and statistical analysis (SPSS 10). A total of 27 species of macrozoobenthic organisms belonging to 18 families under four phyla comprising eight major groups viz. Polychaeta, Oligochaeta, Hirudinea, Diptera, Odonata, Gastropoda, Bivalvia and Pisces have been recorded. The diversity of macrozoobenthic fauna of these three waterbodies revealed that Ruby wetland had the highest representation of 24 species followed by Sukantanagar pond (17 species) and Sukantanagar bheri (16 species). The result of Pearson's correlation coefficient showed that amongst the collected macrozoobenthos the gastropod species, *Bellamya bengalensis* and *Lymnaea acuminata* were wetland site-wise significant.

The total benthic population and biomass have positive correlation with water transparency and organic enrichment of the waterbody. Shannon Weiner and Margalef's indices have revealed higher values for Ruby wetland. Biodiversity indices and BMWP Score System designated to benthic organisms, suggested Ruby wetland is healthier than the other two waterbodies, differing in sewage intake and culture practices.

**Keywords** Biodiversity indices · Distribution · Ecosystem health · Macrozoobenthos · Sewage fed fishery

## Introduction

Conceptually, ecosystem health defines the status and quality of environmental conditions of ecosystem as life support system for which quantification of biodiversity and its related indices provide significant clues in assessing ecosystem health. Biodiversity index and biomonitoring of benthic organisms act as important tool for obtaining an impression about the ecosystem health (Moretti and Callisto 2005; Sultana and Seshi Kala 2012) and productivity of wetland ecosystem, while limnological parameters are widely used as an important indicator of aquatic ecosystem health and environmental changes. As such, the macrobenthic community that gives a precise idea of the wetland condition, is studied from three fishponds of East Calcutta Wetlands (ECWs), presently recognized as a Ramsar site for its wise use of wastewater. The ECW, now stretching about 12,500 ha in area, has 286 fishponds supporting sustainable fish production and rich biodiversity of fish food organisms. Information on the faunal exploration on ECWs is scanty (Ghosh 1990; Chattopadhyay et al. 1999, 2000) and no information is available on the

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community structure of macrozoobenthos of these fishponds of ECWs differing in sewage intake. The present study is therefore, made to understand the distribution and abundance of macrobenthic diversity of three different fishponds and to assess the aquatic ecosystem health using indicator species.

## Materials and Methods

### Study Area

Out of 286 fishponds of ECWs only three fishponds were selected and surveyed that differ in sewage intake and also in fishery practices. The brief descriptions of these fishponds that were surveyed seasonally in the year 2005–2006, are as follows:

#### *Sukantanagar Bheri (SB)*

It is one of the semi-intensive sewage-fed fishery systems of ECWs, almost a rectangular in shape and about 25 acres in area with a mean depth of 1.5 m. The littoral region of this fishpond is covered with water hyacinth which acts as biofilter for natural purification of sewage water taken through inlet for fish culture.

#### *Sukantanagar Pond (SP)*

It is a semi-managed, square-shaped small pond, with much less marginal macrophytes. It has no inlet or outlet, but in which wastewater is pumped in as and when required from the adjoining canal on its southern part. This pond constitutes 4 acres in water area with an average depth of 1 m. It is devoid of water hyacinth.

#### *Ruby Bheri (RB)*

This wetland is of about 48 ha water area comprising of 108 small ponds. Of these ponds, two large interconnected fishponds with average depth of 2 m and 35 acres of water area are surveyed and pooled data are presented. These two fishponds are traditionally managed with no intake of sewage water through inlet though are highly used for bathing and washing purpose of local peoples. Both these ponds are littorally vegetated with macrophytes other than water hyacinth.

### Sampling Methods

Qualitative as well as quantitative samplings were made from different sites of the selected wetlands using a box-

type sampler, 15 cm × 15 cm (Mukherji and Nandi 2004), drag net and also by hand picking. The collected organisms were sieved, sorted and preserved in 4 % formalin or 70 % alcohol. Water quality parameters were analyzed following APHA (1998) and Mukherji and Nandi (2004).

### Data Analysis

Two biotic indices viz. (i) Shannon–Weiner index and (ii) Margalef's index were calculated to determine the aquatic health of these ponds.

**Margalef's Index** Species diversity comprises of a number of components that respond differently to geographical, developmental or physical factors (Odum 1971). One of the major components of species diversity is called the 'species richness' or variety components or Margalef's diversity index (d) and is expressed by simple ratio between total species (s) and total number or importance value (N).  $d = s - 1 / \log N$  (Margalef 1958).

This index commonly varies between 1 and 5 and larger the index a more healthy body of water. When it tends towards one pollution is thought to increase and damage should be suspected.

**Shannon–Weiner Index** In estimating species diversity probably the most widely used index is the Shannon–Weiner (1949) index given by the formula.

$$H = \sum (n_i / N) \log(n_i / N)$$

where H = Shannon–Weiner index,  $n_i$  = importance value of each species, N = total of importance values.

The value of this index can theoretically range from 0 to infinity. However, values normally range from 0 to 4. Wilhm and Dorris (1968), after examining diversity in a range of polluted and unpolluted streams, concluded that the value of H' greater than three indicated clean water, values in the range of 1–3 were characterized by moderately polluted conditions and values less than one characterized heavily polluted conditions. Nowadays various biological indices have been invented depending on the organisms and analysis methods such as relative purity, saprobic index, saprobic valency, indicative weight, Trent biotic index, score system, Hilsenhoff biotic index, etc. (Yoon et al. 2001). In the present investigation, saprobic index or Bio Monitoring Working Party (BMWP) score methodology that involves inventory of the presence of benthic macroinvertebrate fauna up to the family level with taxonomic precision was followed. All possible families having saprobic indicator value are classified on a score-scale of 1–10 according to their preference for saprobic water quality. The saprobic scores of all the families are

registered to produce BMWP score. The biological water quality evaluation of the selected wetlands was done through saprobic score and diversity score.

In statistical analysis, a one way analysis of variance (ANOVA) and Pearson's correlation coefficients were calculated through SPSS10 version to evaluate the parametric relationships between the sites, seasons, limnological parameters and macrozoobenthic groups and species. The two tailed t test was used to test the correlation coefficients at 5 and 1 % level of significance.

## Results and Discussion

### Water Chemistry

Twelve water quality parameters of the three selected water bodies have seasonally tested and presented in Table 1. The range values of water temperature have been found more or less moderate. The pH levels reveal that these wetlands are of calcareous or alkaline in nature. Dissolved oxygen (DO), which reflects a physical and biological processes occurring in the water remained high in Ruby Bheri and Sukantanagar Pond. The ionic content of the wetlands so far as the conductivity is

concerned is less. Chloride content and nutrient concentration were recorded higher in Ruby Bheri and Sukantanagar Pond.

Based on the data of water chemistry, all the three fishponds of ECWs are considered relatively clean. Considering the Spence's criteria (1964) the total alkalinity values of the wetlands indicate the nutrient rich condition. Relatively untreated sewage intake in Sukantanagar Pond made the water highly alkaline (Munawar 1970). Ruby Bheri showed higher values of chloride content which may be due to greater anthropogenic activities like bathing and washing. The total hardness and chloride content of these wetlands also indicate higher rate of anthropogenic activities and eutrophication (Varghese et al. 1992). High amount of hardness of the selected fishponds indicates higher productivity (Barrett 1957). The phosphate, nitrate and nitrite levels of the wetlands, however, show much eutrophic status of these wetlands. On the basis of nutrient contents these three fishponds may be categorized as organically rich wetlands (Bath and Singh 1998). Nutrient contents of Ruby Bheri attained its maximum values during the monsoon due to inflow of rain water from the surrounded slum areas. The transparency became lower in Sukantanagar Bheri, presumably due to higher density of phytoplankton as evident from green colouration of water.

**Table 1** Range values with mean, initial reading and standard deviation of water parameters of the selected wetlands

Parameters	SB	RB	SP
Temperature (°C)	26.5–35.6 (35.1) (30.93 ± 3.87)	25.2–33.0 (33.0) (29.9 ± 4.13)	27.2–37.6 (36.5) (33.51 ± 5.55)
DO (mg/l)	4.0–4.8 (4.3) (4.49 ± 0.44)	2.6–6.3 (4.7) (4.52 ± 1.88)	5.1–7.5 (5.1) (6.11 ± 1.22)
BOD (mg/l)	1.92–2.21 (2.1) (2.03 ± 0.16)	0.91–2.3 (1.5) (1.41 ± 0.77)	1.56–2.28 (1.56) (1.77 ± 0.45)
pH	8.1–8.7 (8.6) (8.36 ± 0.33)	8.2–8.8 (8.4) (8.47 ± 0.31)	8.3–9.5 (9.3) (8.83 ± 0.57)
Alkalinity (mg/l)	254.4–490.9 (280.3) (375.52 ± 118.34)	60.1–350.5 (140.1) (238.02 ± 106.64)	321.6–528.5 (350.4) (443.95 ± 108.53)
Hardness (mg/l)	210.1–305.4 (298.4) (265.41 ± 49.44)	321.3–446.3 (354.6) (374.85 ± 64.36)	281.8–512.4 (287.9) (379.64 ± 119.22)
Conductivity (mS/cm)	7.7–15.0 (14.3) (10.58 ± 3.88)	9.8–18.6 (11.9) (14.92 ± 4.61)	8.8–15.5 (13.2) (11.64 ± 3.44)
Transparency (cm)	11.4–17.5 (11.5) (13.99 ± 3.14)	36.7–71.2 (59.5) (55.8 ± 17.54)	19.5–34.2 (12.7) (28.38 ± 7.84)
Chloride (mg/l)	184.8–275.6 (238.8) (222.22 ± 47.44)	100.0–398.0 (360.0) (286 ± 162.2)	201.8–300.8 (270.0) (256.77 ± 50.41)
PO <sub>4</sub> (mg/l)	0.3–0.4 (0.75) (0.37 ± 0.05)	0.3–2.0 (0.35) (1.42 ± 1.01)	0.6–2.8 (0.25) (1.63 ± 0.97)
NO <sub>2</sub> (mg/l)	0.01–0.6 (0.01) (0.22 ± 0.3)	0.01–1.0 (0.7) (0.57 ± 0.51)	0.1–0.2 (0.15) (0.10 ± 0.07)
NO <sub>3</sub> (mg/l)	0.01–1.4 (0.01) (0.77 ± 0.67)	0.01–2.5 (1.0) (1.35 ± 0.97)	0.1–1.3 (0.02) (0.49 ± 0.72)

**Table 2** Diversity of macrozoobenthos in the selected East Calcutta Wetlands

Sl. no.	Groups and species	SB	SP	RB
<b>I. Annelida</b>				
<b>Polychaeta</b>				
Family Nereididae				
1.	<i>Nephtys</i> sp.	–	–	+
2.	<i>Namalycastis</i> sp.	–	+	+
<b>Oligochaeta</b>				
Family Tubificidae				
3.	<i>Tubifex</i> sp.	+	+	–
<b>Hirudinea</b>				
Family Glossophonidae				
4.	<i>Hemiclepsis marginata asiatica</i> Morre	–	+	+
<b>II. Arthropoda</b>				
<b>Diptera</b>				
Crustacea				
Family Gecarcinucidae				
5.	<i>Sartoriana spinigera</i> (Wood Mason)	–	+	+
Family Chironomidae				
6.	<i>Chironomus</i> sp.	+	–	+
<b>Odonata</b>				
Family unidentified				
7.	Damselfly larvae	–	–	+
Family unidentified				
8.	Dragonfly larvae	–	–	+
<b>III. Mollusca</b>				
<b>Gastropoda</b>				
Family Viviparidae				
9.	<i>Bellamyia bengalensis</i> (Lamarck)	+	+	+
Family Bithyniidae				
10.	<i>Bithynia (Digoniosstoma) cerameopoma</i> (Benson)	+	+	+
11.	<i>Gabbia orcula</i> (Nevill)	+	+	+
Family Thiaridae				
12.	<i>Thiara tuberculata</i> (Mueller)	+	+	+
13.	<i>Tarebia lineata</i> (Gray)	+	+	+
14.	<i>Tarebia granifera</i> (Lamarck)	+	+	+
15.	<i>Thiara scabra</i> (Müller)	+	–	+
Family Planorbidae				
16.	<i>Indoplanorbis exustus</i> (Deshayes)	+	+	+
17.	<i>Gyraulus convexiusculus</i> (Hutton)	+	+	+
18.	<i>Gyraulus labiatus</i> (Benson)	–	–	+
Family Lymnaeidae				
19.	<i>Lymnaea accuminata</i> (Lamarck)	+	+	+
20.	<i>Lymnaea luteola</i> (Lamarck)	+	+	+
Family Pilidae				
21.	<i>Pila globosa</i> (Swainson)	+	–	+
Family Physidae				
22.	<i>Physa acuta</i> (Draparnaud)	+	+	–

**Table 2** continued

Sl. no.	Groups and species	SB	SP	RB
<b>Bivalvia</b>				
Family Unionidae				
23.	<i>Lamellidens marginalis</i> (Lamarck)	+	+	+
24.	<i>Lamellidens corrianus</i> Lea	–	–	+
Family Pisidiidae				
25.	<i>Pisidium (Afropisidium) clarkeanum</i> G and H Nevill	–	–	+
Family Amblenidae				
26.	<i>Parreysia (Parreysia) corrugata</i> (Mueller)	–	–	+
<b>IV. Pisces</b>				
Family Platycephalidae				
27.	Unidentified species	+	–	–
Total 27 species		17	16	24

In overall, based on water chemistry Ruby Bheri appears to be healthier than the other two wetlands.

#### Macroinvertebrate Faunal Diversity

Quantitative as well as qualitative sampling of macrozoobenthic organisms revealed the presence of 27 species belonging to four phyla comprising eight major groups, viz., Polychaeta, Oligochaeta, Hirudinea, Diptera, Odonata, Gastropoda, Bivalvia and Pisces under 18 families (Table 2). Of these eight groups, only gastropod molluscs occurred more or less throughout the year in all the selected wetlands, whereas all other groups were rare in occurrence. Only one species of Pisces under the family Platycephalidae was occasionally recorded in Sukantanagar Bheri, for using a small box-type sampler. The number and composition of macrozoobenthic fauna revealed that Ruby wetland had the highest diversity of species (24 species), followed by Sukantanagar Bheri 8 (17 species) and Sukantanagar pond (16 species). The diversity of species appears to be similar in Sukantanagar Bheri and Sukantanagar Pond under Sukantanagar fishery system depending on sewage intake. A wide variety of organisms, namely, *Nephtys* sp., *Gyraulus labiatus*, *Parreysia (Parreysia) corrugata*, *Pisidium (Afropisidium) clarkeanum* and *Lamellidens corrianus* as well as damselfly larvae and dragonfly larvae were encountered in the Ruby Bheri probably due to no intake of sewage water and for its better ecosystem health as evidenced from water chemistry.

According to the BMWP score system (Table 3) abundance of *Bellamya bengalensis* under Viviparidae family and *Lamellidens* spp. under Unionidae family will be more abundant in mesotrophic wetland; aquatic polychaeta *Namalycastis* sp. of Nereidae family lives in mesotrophic waterbody; *Lymnaea* spp. under Lymnaeidae and

**Table 3** Modified bio monitoring working party (BMWP) score system

Order	Families	Score
Mollusca	Naritidae Viviparidae Ancyliidae Unionidae	6
Polychaeta	Nereidae Nephthyidae	6
Odonata	Platynemididae Coenagriidae	6
Mollusca	Valvatidae Hydrobiidae Lymnaeidae Physidae Planorbidae	3
Chironomid	Chironomidae	2
Oligochaeta	Oligochaeta (all families)	1

*Indoplanorbis exustus* under Planorbidae family can withstand pollution. Chironomid larvae and Oligochaeta species indicate eutrophic wetland.

In the present investigation this score system suggests that Ruby Bheri represents more or less mesotrophic condition followed by Sukantanagar Pond. Macroinvertebrate faunal composition in Sukantanagar Bheri exhibits eutrophic condition of the wetland which is due to the regular sewage intake.

#### Population Density

Population density of macrozoobenthic groups in the selected fishponds are presented in Table 4. Among major groups of macrozoobenthos, gastropods were predominant

**Table 4** Average variation of major groups, total benthos and biomass in the selected wetlands

Site	Mollusca	Annelida	Arthropoda	Total benthos	Biomass
SB	468.0767	–	5.76	474.2494	168.3213
RB	4721.297	103.7033	7.406667	5984.253	4668.76
SP	3467.077	4.32	–	3482.508	1164.258

**Table 5** Biotic indices of the selected East Calcutta Wetlands

Site	Biotic indices	
	H	d
SB	1.91	2.76
RB	4.38	2.84
SP	2.38	2.13

in all the water bodies. Annelids were abundant mainly in Ruby Bheri and Sukantanagar Pond. The highest density of gastropod molluscs was, however, recorded in Ruby Bheri. The chironomid larvae were highly abundant in Sukantanagar Bheri. In overall, total population density was recorded highest in Ruby Bheri and lowest in Sukantanagar Bheri throughout the year.

A number of macrobenthic fauna, particularly oligochaetes and chironomids found in these wetlands, are usually inhabit polluted water conditions. According to BMWP Score System (Table 3), oligochaete species *Tubifex* sp. and chironomid larvae indicate eutrophic condition of water due to sewage. Mesotrophic water quality indicator species namely, *Namalycastis* sp. (Nereidae: Polychaeta), *Bellamyia bengalensis* (Viviparidae: Gastropoda), *Lamellidens* sp. (Unionidae: Bivalvia) and odonate larvae were abundant in Ruby Bheri. The pulmonate snails like *Lymnaea* spp. and *Indoplanorbis exustus* were present in both Ruby Bheri and Sukantanagar Bheri for their tolerance to pollution. *Lymnaea luteola* and *Bellamyia bengalensis* occurred in higher abundance in Ruby Bheri, perhaps preferring organic enrichment (Sampath et al. 1981).

### Community Analysis

Mean values of Shannon–Weiner and Margalef's indices of the three wetlands are presented in Table 5. It is evident that the mean value of diversity index was highest in Ruby Bheri (4.38), while lowest in Sukantanagar Pond.

Biotic indices like H' revealed that the Ruby Bheri is much healthier than the other two as the index exceeded the value 4. The Sukantanagar Pond showed polluted condition of the waterbody with respect to H' (Wilhm and Dorris 1968). Margalef's index was also highest in Ruby Bheri indicating it's healthier and clean condition than Sukantanagar Bheri and Sukantanagar Pond.

### Statistical Analysis

ANOVA analysis (Table 6) reveals that the limnological parameters like temperature, conductivity and transparency are site wise significant whereas temperature and conductivity along with pH and alkalinity are season wise significant. This indicates significant variation of water chemistry in the three different kinds of fishery systems selected from

**Table 6** Results of one way analysis of variance (ANOVA) of limnological parameters and biotic components against site and season

Source	SS	df	MS	F	p
Dependent variable: temperature					
Site	20.75	2	10.38	8.10	0.04
Season	120.72	2	60.36	47.12	0.00
Error	5.12	4	1.28		
Total	9046.63	9			
Dependent variable: pH					
Site	0.36	2	0.18	4.16	0.11
Season	0.88	2	0.44	10.30	0.03
Error	0.17	4	0.04		
Total	659.42	9			
Dependent variable: alkalinity					
Site	14889.10	2	7444.55	1.01	0.44
Season	145865.76	2	72932.88	9.92	0.03
Error	29421.26	4	7355.32		
Total	1550866.29	9			
Dependent variable: conductivity					
Site	30.63	2	15.32	6.67	0.05
Season	87.11	2	43.56	18.96	0.01
Error	9.19	4	2.30		
Total	1507.03	9			
Dependent variable: transparency					
Site	2706.67	2	1353.34	7.63	0.04
Season	48.86	2	24.43	0.14	0.88
Error	709.33	4	177.33		
Total	13102.54	9			
Dependent variable: <i>Bellamyia bengalensis</i>					
Site	10612341.03	2	5306170.52	47.88	0.00
Season	285046.27	2	142523.14	1.29	0.37
Error	443252.87	4	110813.22		
Total	33080611.12	9			
Dependent variable: <i>Lymnaea acuminata</i>					
Site	1223.17	2	611.59	11.16	0.02
Season	3.32	2	1.66	0.03	0.97
Error	219.27	4	54.82		
Total	4356.37	9			
Dependent variable: Mollusca					
Site	28656949.18	2	14328474.59	9.88	0.03
Season	855377.18	2	427688.59	0.30	0.76
Error	5801721.39	4	1450430.35		
Total	110248174.35	9			
Dependent variable: total benthos					
Site	126894104.83	2	63447052.42	13.73	0.02
Season	9309412.88	2	4654706.44	1.01	0.44
Error	18483616.77	4	4620904.19		
Total	350829428.06	9			
Dependent variable: biomass					
Site	33527352.65	2	16763676.33	128.78	0.00
Season	273941.27	2	136970.63	1.05	0.43
Error	520679.36	4	130169.84		
Total	70338012.53	9			



**Table 7** Correlation coefficients between biotic components and abiotic factors in selected wetlands

Biotic components	Site	DO	Alk	Cond	Trans	Cl <sub>2</sub>	PO <sub>4</sub>	NO <sub>2</sub>	NO <sub>3</sub>
Annelida					0.07 <sup>a</sup>			0.71 <sup>a</sup>	0.92 <sup>b</sup>
Mollusca					0.90 <sup>b</sup>				0.71 <sup>b</sup>
<i>Bellamya bengalensis</i>	0.67 <sup>a</sup>				0.86 <sup>b</sup>		0.68 <sup>b</sup>		
<i>Bithynia cerameopoma</i>	0.84 <sup>b</sup>						0.69 <sup>a</sup>		
<i>Gabbia orcula</i>					0.82 <sup>b</sup>			0.79 <sup>b</sup>	0.97 <sup>b</sup>
<i>Thiara tuberculata</i>							0.85 <sup>b</sup>		
<i>Thiara scabra</i>				0.75 <sup>a</sup>	0.88 <sup>b</sup>	0.77 <sup>a</sup>		0.88 <sup>b</sup>	0.98 <sup>b</sup>
<i>Gyraulus convexiusculus</i>					0.73 <sup>a</sup>				0.86 <sup>b</sup>
<i>Lamellidens marginalis</i>			−0.78 <sup>b</sup>						
<i>Lamellidens corrianus</i>		−0.67 <sup>a</sup>			0.69 <sup>a</sup>				0.93 <sup>b</sup>
<i>Parrysia corrugata</i>				0.68 <sup>a</sup>	0.81 <sup>b</sup>	0.69 <sup>a</sup>		0.83 <sup>b</sup>	0.99 <sup>b</sup>
<i>Pisidium clarkeanum</i>					0.84 <sup>b</sup>			0.79 <sup>b</sup>	0.97 <sup>b</sup>
Total benthos					0.96 <sup>b</sup>			0.68 <sup>a</sup>	0.86 <sup>b</sup>
Biomass					0.90 <sup>b</sup>				0.72 <sup>a</sup>

<sup>a</sup> Correlation is significant at the 0.05 % level (2-tailed)

<sup>b</sup> Correlation is significant at the 0.01 % level (2-tailed)

ECWs. Among molluscan macrobenthos, site wise significance is shown by *B. bengalensis*, indicating its adaptation to mesotrophic condition, while *L. acuminata* shows its tolerance to eutrophic condition through its site wise significance. Molluscan group as a predominant macrozoobenthic group in the selected wetlands exhibits site wise significance along with other biotic components viz. total benthos and biomass.

Pearson's correlation coefficient was calculated between sites, abiotic factors (water parameters) and biotic components viz. major groups (Annelida, Arthropoda, Mollusca), total benthos, biomass and also with some gastropod species, which occurred frequently in these wetlands. Only values indicating significant correlations are presented in the Table 7. It revealed that the effects of individual water parameter on the benthic fauna were at different levels of probability. The calculated *r*-values between physico-chemical parameters and frequently occurring species suggest that *B. bengalensis* and *Bithynia cerameopoma* have positive correlation with the sites ( $r = 0.67$ ,  $p < 0.05$  and  $r = 0.84$ ,  $p < 0.01$  respectively). Population density of all the molluscan species (*B. bengalensis*, *Bithynia cerameopoma*, *Gabbia orcula*, *Thiara tuberculata*, *T. scabra*, *G. convexiusculus*, *L. marginalis*, *L. corrianus*, *Parrysia corrugata*, *P. clarkeanum*), however, had positive correlation with water transparency. Similar trend is shown for the abundance of major groups, total benthos and biomass in relation to transparency. *L. corrianus* is negatively ( $r = -0.67$ ,  $p < 0.05$ ) influenced by DO in the Ruby wetland which might be due to habitat preference. Total alkalinity of water showed a negative relationship ( $r = -0.78$ ,  $p < 0.01$ ) with respect to variation in the density of *L. marginalis*, while *T. scabra* and *P. corrugata* showed significant positive effects with conductivity and chloride content of water. The abundance of *B. bengalensis*, *B. cerameopoma* and *T. tuberculata* expressed positive relationship with phosphate. The abundance of annelids, *G. orcula*, *T. scabra*,

*P. corrugata*, *P. clarkeanum* and total benthos had strong positive correlation with NO<sub>2</sub>. Nitrate was also showed strong influence on the biotic components of these wetlands.

Correlation coefficient showed (Table 7) that most of the macrozoobenthos (7 species) were significantly positively correlated with transparency of the water body because of their epibenthic nature and direct relation to suspended particles of the water. *L. marginalis* is significantly negatively correlated with BOD and alkalinity, which reflects that with the increase of BOD and alkalinity or increased pollution level, the abundance of this species is declined. These corroborate with the BMWP score assigned to these molluscan species.

## Conclusion

Differences in hydrological regimes of the fisheries in ECWs affected the diversity and distribution of the macrozoobenthic community as well as ecological balances and functions. BMWP scores based on the bioindicator organisms, evaluated different situations and cost effectively gave clues about the moderate to highly polluted conditions of the wetland ecosystem health. In natural pond or at the most traditionally cultured fish ponds benthos can reflect the water condition or aquatic ecosystem health as there is less man managed interference or treatment. Ecological benefits with high biodiversity of mesotrophic fishponds are to be recognized with sufficient importance and should be implemented also in sewage fed fisheries of ECWs. Local anthropogenic impacts which could alter vegetation structure of the wetland contributing reduced habitat quality of benthic organisms and nutrient contents of the pond should be managed properly.

Several palliative measures like shoreline management, de-weeding or water hyacinth control or removal, implementation of cost-effective technology for cleaning up

pollutants, introduction of composite fish culture or larvivorous fish species, should be taken to remove eutrophication and improve ecosystem health irrespective of sewage-fed and natural fish ponds of ECWs.

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