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Freshwater Gastropoda Diversity and their Population Abundance as Bioindicators of Water Quality in Three Perennial Ponds of Howrah District, West Bengal

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Abstract

Studies were carried out on natural populations of the freshwater benthic gastropods at Howrah district for two years in three perennial ponds. Gastropod community of these ponds are represented by seven species like *Bellamya bengalensis, Terabia lineate, Bithynia (Digoniostoma) pulchella, Melanoides tuberculata, Indoplanorbis exustus, Lymnaea (Pseudusuccinea) acuminate* and *Pila globosa. Bellamya* is the dominant member among the benthic Prosobranch. Average season wise population pattern, Shannon-Wiener diversity Index, Simpson's Dominance Index, Pielou's Evenness Index and Margalef's Richness Index were studied in seven species in relation to nine physico-chemical parameters. The average density of *Bellamya* was highest i.e. 444.67 ± 304.93 ind/m^2 with a minimum and maximum values of 393.5 ± 70.22 ind/m^2 to 133.75 ± 59.36 ind/m^{2}during rainy season. Whereas the average density of *Terabia* was 161.33 ± 129.46 ind/m^2 in another pond with highest i.e. 117.25 ± 44.43 ind/m^2 and with a lowest values of 1.25 ± 0.96 ind/m^2 during summer season. Maximum seven number of gastropod species was observed in the one pond followed by five type of species in other two ponds. Present study revealed that the Gastropoda species richness and diversity index were comparatively higher (1.72 ± 0.29 and 2.83 ± 0.09 respectively) in Kulgachia pond as compared to other ponds. High values of Simpson's Dominance Index were 0.96 ± 0.01 and 0.91 ± 0.03 in Uluberia and Deulti pond respectively. The Gastropoda population shows positive correlation with water temperature, pH, COD, alkalinity, hardness, conductivity and soil organic carbon. The study revealed that some of the physico-chemical characters of water are within desirable limits and these gastropods have highest adaptability of the utilization of some water parameters. Among gastropods *Bellamya* and *Terabia* can be considered as bioindicators for pond water quality through evaluation of physico-chemical characters.

Key words : Gastropoda, Abundance, Shannon diversity, Species richness, Bioindicator.

Freshwater Prosobranch snails are among the dominant members of the benthic fauna at the second trophic level in mesotropic lakes of New York. Macrobenthic fauna are important components as natural food for secondary consumers and their population reflects the productive potential of a freshwater pond (1, 2). Ramakrishna and Dey (3) have revealed that molluscs are an important members of macrobenthic fauna and represented by a diverse species group of freshwater Gastropoda. Molluscs need to be considered as a part of the whole freshwater community, particularly in its role in the food chains linking up to the edible fish. The members belonging to the families Viviparidae, Ampillaridae, Planorbidae and Lymnacidae live in stagnant freshwater and not only many aquatic animals thrive on them but they also serve as food for human in many parts of the India (4). Gastropods in general are found attached to the submerged vegetation or to the substratum of the water bodies or crawl in the mud. The freshwater molluscan shells exhibit a great variation depending on the ecology of the species and may produce ecophenotypes (3). Hynes (5) revealed that the density of molluscan population fluctuates widely with the change in the season. Finally Italo Braga et al. (6) reported that gastropod is considered to be the indicator of water quality. Therefore the present study was under taken to identify different freshwater gastropod species present in pond habitat and also to evaluate their diversity, abundance, species richness, dominance, evenness and seasonal fluctuation in relation to physico-chemical parameters of ponds. Study

was initiated in three different location from March 2007 to February 2009 at three big ponds of south-west of Howrah district. West Bengal, India. Literature showed that similar work was not carried out so far in freshwater pond of West Bengal. This study revealed that the presence of gastropod population may reflect the water quality of the pond.

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Methods

Names of the three sample sites (ponds) selected for this study, their approximate pond size in hectares (ha), latitude and longitude are as follows : ULU—Uluberia pond : 0.12 ha ; $22^0 28' 11''$ latitude and $88^0 6' 9''$ longitude ; KUL—Kulgachia pond : 0.11 ha ; $22^0 8' 15''$ latitude and $88^0 2' 10''$ longitude ; DEL—Deulti pond : 0.14 ha ; $22^0 27' 28''$ latitude and $87^0 58' 6''$ longitude.

All the sites located at the south-west part of Howrah district and the location of ULU, KUL and DEL are 41, 52 and 63 km away respectively from western part of second Hooghly river bridge of Kolkata city. All the three ponds are located in remote village and naturally well maintained by the surrounding villagers.

Physico-Chemical Analysis

The pond survey was carried out from March 2007 to February 2009. Water samples were collected fortnightly from the selected ponds during the early hours between 8.00 to 9.00 am. Physical parameters of the water and soil were measures monthly throughout the year at all the three sites including water temperature (C), pH, dissolved oxygen (mg/liter), biological oxygen demand (mg/liter) for five days, chemical oxygen demand (mg/liter), alkalinity (mg/liter), hardness (mg/liter), conductivity (μ Sc/m) and soil organic carbon (%). The water samples were analyzed and soil organic carbon was estimated according to standard methods of APHA et al. (7).

Collection of Samples

The gastropod samples were collected from these village ponds during the study period. In every pond gastropod sample were taken after every fortnight for two successive years. The benthic fauna present on and within the soft clay at the periphery of the pond, where water touches the shoreline and samples were collected from this area. The sampler was 1 meter × meter (m^2) in size area with four replication/pond. The collected sedimented samples of each zone were taken individually in polythene bags with respective tagging. The collected gastropod population were carried to the laboratory and then species wise isolated and counted for computation. The quantitative study of the benthic fauna were computed and the pooled value were expressed as number/sq m. Identification of gastropods was made by the Malacological Department, Zoological Survey of India, Kolkata. The values are represented through mean ± SD.

Community Structure Analysis

Four indices were studied to obtain the estimation of species diversity, species richness, species evenness and dominance. The quantative analysis of freshwater gastropod was carried out through Shannon-Wiener diversity index (8), Simpson dominance index (9), Pielou evenness index (10) and Margalef species richness index (11). The correlation coefficient *r* was calculated by the method of Birader (12).

Results and Discussion

Ramakrishna and Dey (3) have been identified about 156 species of freshwater gastropod from different parts of the Indian water bodies. In our studies we have recorded and identified seven species and they are *Bellamya bengalensis* (Lamarck, 1822), *Terabia lineate* (Gray, 1828), *Bithynia (Digoniostoma) pulchella* (Benson, 1836), *Melanoides tuberculata* (Mueller, 1974), *Indoplanorbis exustus* (Deshayes, 1834), *Lymnaea* (Pseudusuccinea) *acuminate* Lamark, 1822 and *Pila globosa* (Swainson, 1822). The species *Bellamya*, *Terabia, Bithynia, Melanoides* and *Pila* were identified under the sub-class Prosobranchia whereas the rest two are under Pulmonata. Except *Lymnaea* all the six species are partly submerged into the soft clay of the ponds at shoreline level of the surface water.

Table 1. Monthly average water parameters (for two years) of the three ponds in Howrah district (±SD).

Months	Water temp. (C)	pH	DO (mg/l)	BOD (mg/l)	COD (mg/l)	Alkali-nity (mg/l)	Hardness (mg/l)	Condu (μ Sc/m)	Org car (%)
Mar	27.95 ± 1.5	7.2 ± 0.1	7.6 ± 0.7	6.1 ± 1.1	68 ± 4.7	148 ± 0.3	74 ±2.2	208.7 ± 10.3	2.276 ± 0.8
Apr	29.8 ± 0.8	7.3 ± 0.1	5.8 ± 1.0	5.8 ± 0.9	75 ± 5.1	134 ± 1.1	80 ± 0.9	245.5 ± 8.5	1.945 ± 1.2
May	30.03 ± 1.0	7.4 ± 0.1	4.7 ± 0.5	3.6 ± 1.3	42 ± 5.7	152 ± 1.5	68 ± 0.5	329.1 ± 4.3	2.332 ± 0.6
Jun	30.8 ± 0.8	7.5 ± 0.1	3.6 ± 0.4	2.18 ± 1.5	82 ± 2.7	140 ± 2.1	76 ± 1.6	218.3 ± 11.1	3.371 ± 0.3
Jul	29.55 ± 0.9	7.6 ± 0.1	4.9 ± 1.1	2.82 ± 1.1	94 ± 1.5	156 ± 1.8	82 ± 2.0	310.2 ± 9.1	3.545 ± 0.5
Aug	28.8 ± 0.5	7.6 ± 0.2	4.3 ± 0.3	2.05 ± 1.7	106 ± 2.5	164 ± 1.9	92 ± 1.7	342.2 ± 10.7	3.487 ± 0.7
Sep	28.5 ± 0.8	7.7 ± 0.1	4.6 ± 1.1	1.65 ± 2.1	71 ± 3.8	130 ± 2.2	86 ± 1.1	303.7 ± 8.5	3.312 ± 0.5
Oct	26.9 ± 0.5	7.5 ± 0.2	3.3 ± 0.9	2.11 ± 2.2	54 ± 3.1	144 ± 2.0	80 ± 1.9	316.5 ± 2.9	2.112 ± 0.9
Nov	24.25 ± 1.0	7.4 ± 0.1	3.5 ± 0.5	1.92 ± 1.6	62 ± 5.3	122 ± 1.7	66 ± 2.4	260.7 ± 7.5	1.833 ± 0.8
Dec	18.5 ± 1.1	7.2 ± 0.1	6.7 ± 0.3	2.77 ± 1.5	32 ± 6.7	126 ± 1.2	68 ± 2.3	184.8 ± 8.5	1.856 ± 1.1
Jan	16.4 ± 0.9	7.2 ± 0.1	6.1 ± 0.2	4.33 ± 0.9	48 ± 4.3	108 ± 2.2	62 ± 2.1	154.4 ± 12.7	1.533 ± 1.4
Feb	23.9 ± 1.1	7.1 ± 0.1	7.2 ± 0.5	4.18 ± 1.3	86 ± 2.2	142 ± 2.1	60 ± 3.3	124.6 ± 13.5	1.642 ± 1.3

Ramakrishna and Dey (3) reported that *Lymnaea* resides in permanent water bodies with abundant vegetation. Scudo (13) also reported that major freshwater gastropods are bottom feeders which lead to their sedentary habit. Survey report in India revealed that (3, 4) *Bellamya* population have the numerical superiority of 14 species in freshwater condition, which they considered as typical for and most frequent in tropical environment. In our present study we got only one type i.e. *Bellamya bengalensis* (Lamarck, 1822). Genus *Terabia* and *Bythynia* are also common freshwater gastropod in West Bengal and is represented by three species and six species in India (3). On the other hand, genera *Melanoides*, *Indoplanorbis, Lymnaea* and *Pila* are represented by five species, 1 species, 19 species and eight species respectively in India (3).

During two years study period the month-wise average physico-chemical characteristic features of three perennial ponds (ULU, KUL and DEL) of Howrah district are presented in Table 1.Data indicate that out of seven gastropod species i.e. *Bellamya, Terabia, Bithynia, Melanoides, Indoplanorbis, Lymnaea* and *Pila,* maximum number (seven) of gastropod species was observed in the KUL pond followed by ULU and DEL with five species respectively (Table 2). Among the seven species *Bellamya, Terabia* are the two most dominant species. The average density of *Bellamya* in DEL pond was highest i.e. 444.67 ± 304.93 ind/m^2 (Table 2) with a minimum and maximum values are 393.5 ± 70.22 to 133.75 ± 59.36 ind/m^2 during rainy season (Table 3). Brown (1) also observed that the viviparous is usually found on the bottom of lakes and ponds and are often numerically and functionally dominant member of the second trophic level of macrofauna. Abundance of *Terabia* comes next to *Bellamya.* The average density of *Terabia* was 161.33 ± 129.46 ind/m^2 in KUL pond (Table 2) with highest i.e. 117.25 ± 44.43 ind/m^2 and a lowest values of 1.25 ± 0.96 ind/m^2 during summer season (Table 4). Hynes (5) reported that the density of some benthic invertebrates fluctuates widely with the season but research

Table 2. Average abundance (two years) of seven gastropod species in the three ponds of Howrah districts (ind/m^2 ± SD).

Species	Ponds ULU	KUL	DEL
Bellamya	286.5 ± 198.92	110 ± 139.15	444.67 ± 304.93
Terabia	21.17 ± 28.07	161.33 ± 129.46	11.03 ± 3.11
Bithynia	1.67 ± 3.05	8.75 ± 12.49	1.55 ± 2.09
Melanoide	0	25.0 ± 20.97	7.83 ± 8.16
Indoplanorbis	1.08 ± 2.02	9.5 ± 13.78	0
Lymnaea	0	2.75 ± 4.03	0
Pila	3.67 ± 4.47	3.0 ± 4.49	3.17 ± 4.36

Table 3. Average season wise population pattern (ind/m^2 ±SD) of *Bellamya* at three ponds of Howrah district. Number in the parentheses represented the minimum and maximum number of individuals/m^2.

Seasons	Ponds ULV	KUL	DEL
Summer	124.08 ± 60.57 (66.5—193)	25.75 ± 32.32 (0—67)	152.875 ± 80.39 (93.5—264)
Rainy	240.5 ± 36.05 (210—290)	133.75 ± 59.36 (53.5—192)	393.5 ± 70.22 (297.5—462.5)
Winter	45.625 ± 52.74 (7.5—123.5)	1.5 ± 2.1 (0—4)	101.125 ± 100.39 (33.5—250.5)

findings on population fluctuation of *Terabia* is still lacking. The mean high density of *Bellamya* and *Terabia* attained a peak density during rainy and summer season was characterized by prevailing moderate water temperature, high dissolved oxygen, alkalinity, hardness, conductivity and organic carbon (Table 1). Raut (14) reported that *Viviparous bengalensis* reproduces throughout the year but the rate of breeding is rather variable from season to season. Ward and Stanford (15) have also the openion that occurrence and abundance of different macrobenthic fauna depend on substrate characteristics, food quality, quantity, thermal regime, habitat complexity and biological interactions.

The mean density of Bithynia in KUL pond was highest i.e. 8.75 ± 12.49 ind/m^2 with a lowest population of 1.55 ± 2.09 ind/m^2 in pond DEL, whereas *Melanoides* was also found in KUL and DEL ponds with 25.0 ± 20.97 to 7.83 ± 8.16 ind/m^2 respectively (Table 2). The average density of *Indoplanorbis, Lymnaea* and *Pila* ranged from 9.5 ± 13.78 to 1.08 ± 2.02, 2.75 ± 4.03, 3.67 ± 4.47 to 3.17 ± 4.36 ind/m^2 respectively in all the three ponds (Table 2). As their abundance is significantly low (Table 2), we did not represent their average season wise population pattern. Correlation coefficient among the seven species regarding their abundance in three ponds revealed that for *Bellamya* the correlation with *Terabia* is significant ($P < 0.0001$) (Tables 5 to 7), but its correlation with *Bithynia, Indoplanorbis* and *Pila* is highly significant ($P< 0.0001$). It revealed that population of *Bellamya* had no effect on the population abundance of *Terabia, Bithynia, Indoplanorbis* and *Pila*. Again *Terabia* is significantly correlated ($P < 0.0001$) with all the four species except *Bithynia*. So, there is evidence of habitat coexistance among *Bellamya, Terabia* and *Bithynia* rather than competition. Interestingly *Bithynia, Indoplanorbis* and *Lymnaea* are negatively correlated with each other, which revealed that an inter species competition among them may influenced on their reduced population (Table 6). Olive and Dambasch (16) was also made similar observation in hill stream of kumaon and according to them the magnitude of freshwater benthic invertebrate community changes according to inter and intra species competition and also with the change in the water and soil quality. However literature on the biology and diversity of *Terabia, Bythynia, Melanoide, Indoplanorbis, Lymnaea* and *Pila* were still lacking which did not help us to make a conclusive remark regarding their less population.

Only two species i.e. *Bellamya bengalensis* and

Table 4. Average season wise population pattern (ind/m^2 ± SD) of *Terabia* at three ponds of Howrah district. Number in the parentheses represented the minimum and maximum number of individuals/m^2.

Seasons	Ponds ULU	KUL	DEL
Summer	3.37 ± 6.75 (0—13.5)	117.25 ± 44.43 (69—156)	1.25 ± 0.96 (0—2)
Rainy	22.125 ± 15.77 (8—40.5)	84.25 ± 25.68 (55—117.5)	2 ± 1.15 (0—3)
Winter	1.5 ± 0.58 (0—2)	21.25 ± 21.91 (8—54)	1 ± 0.82 (0—2)

Table 5. Shannon-Wiener diversity Index, Simpson's dominance index, Pielou's evenness index and Margalef's richness index of Gastropoda species in three perennial ponds of Howrah district. OS = Observed number of species ; pi = Proportional abundance of species 1 ; N = Total number of individuals per sample.

Indices	Ponds ULU	KUL	DEL
Shannon-Wiener species diversity [$H = \sum_{i=1}^{05} pi\ in\ pi$]	1.09 ± 0.06	1.53 ± 0.09	1.19 ± 0.02
Pielou's evenness index [J = H'/In OS]	0.34 ± 0.05	0.92 ± 0.03	0.41 ± 0.03
Margalef's richness index [DMARG = (OS-1)/In N]	1.04 ± 0.69	1.72 ± 0.29	1.36 ± 0.13
Simpson's dominance index [$HSIMP = \sum_{i=1}^{05} (pi)^2$]	0.91 ± 0.03	0.55 ± 0.04	0.96 ± 0.01

Terabia lineate are recorded most abundantly in ULU and DEL ponds compared to five other species. In this regard Negi and Mallick (2) have the opinion that the factors singly or in combinations that limit the production of one species may not hold good for the others. We found again that the species *Bellamya bengalensis* may have the more adaptive diversity in DEL and ULU freshwater habitat in compare to other six species and as a result the species dominance Index of both ponds become 0.96 ± 0.01 and 0.91 ± 0.03 respectively (Table 5), which indicate that *Bellamya* in DEL and ULU pond are dominating species over other six species. However the species *Terabia* have more abundance over other six species in pond KUL but due to moderate density of *Bellamya* the species dominance index came down to 0.55 ± 0.04. McMohan (17) reported that *Viviparus* have more productivity power than the others when he studied the interspecific comparisons of productivity between *Viviparus* and other molluscan species (*Bithynia, Lymnaea* etc.). In this regard Kiss (18) also revealed that the number of species and individuals have changes depending on the ecological factors and food availability in the aquatic system. Pooled annual abundance (%) of seven gastropods in three perennial ponds are illustrated in Figure 1. *Bellamya* contributed the largest proportion (74.57%) of gastropod, followed by *Terabia* (15.15%), *Melanoides* (4.47%), *Bythynia* (2.40%), *Indoplanorbis* (1.67%), *Lymnaea* (0.73%) and *Pila*

Table 6. Correlation coefficient among the seven species regarding their abundance in three ponds. Parentheses represented the *P* -value.

Species	*Bellamya*	*Terabia*	*Bithynia*	*Melanoide*	*Indoplanorbis*	*Lymnaea*	*Pila*
Bellamya	*						
Terabia	0.608 (0.001)	*					
Bithynia	0.717 (< 0.0001)	0.102 (0.628)	*				
Melanoide	0.333 (0.104)	0.877 (< 0.0001)	-0.082 (0.697)	*			
Indoplanorbis	0.745 (< 0.0001)	0.716 (<0.0001)	-0.203 (0.330)	-0.534 (0.006)	*		
Lymnaea	0.342 (0.094)	0.830 (<0.0001)	-0.225 (0.280)	-0.314 (0.094)	-0.494 (0.012)	*	
Pila	0.816 (< 0.0001)	0.676 (<0.0001)	0.612 (0.001)	0.482 (0.015)	0.730 (< 0.0001)	0.691 (< 0.0001)	*

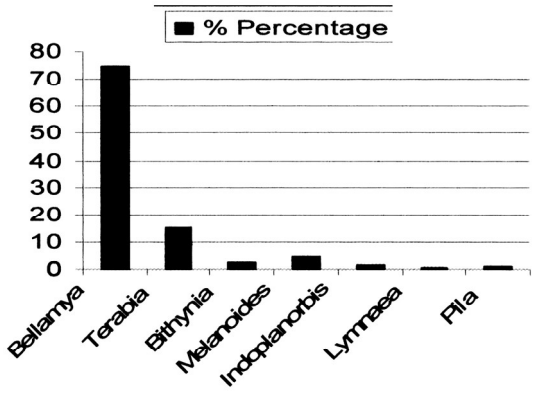

Figure 1. Pooled annual abundance (%) of seven species of gastropods in three perennial ponds.

(1.01%) during the study period. Russel-Hunter and Eversole (19) reported that the life cycle and growth of Viviparus (Bellamya) is continuous throughout the year but decreases during winter, in contrast the Pulmonates experience little growth during summer and no growth during winter.

Biological Analysis

We used Shannon's diversity index to measures biodiversity for a greater number of species and a more even distribution of species. High mean value of Shannon-Wiener index (H) was recorded in KUL (1.53 ± 0.09) as compared to ULU (1.09 ± 0.06) and DEL (1.19 ± 0.02) pond (Table 5). Dash (20) reported that the high value of Shannon's index (H) indicate greater species diversity. The maximum Shannon's diversity for a sample is found when all species are equally abundant and values of the Shannon's diversity index for real communities typically fall between 1.5 and 3.5. Here the index at pond KUL is 1.53 ± 0.09, which indicate that diversity in terms of gastropod population is more evenly distributed in this pond than the other two ponds. This result also supported the observation we obtained in case of average abundance of seven gastropod organisms (Table 2).

Margalef's species richness or alpha-diversity is the simplest measure of biodiversity with simply a count of the number of different species in a given area. Of the three perennial ponds, the gastropod species richness was found to be high in the pond KUL (1.72 ±0.29) followed by DEL (1.36 ± 0.13) and ULU pond (1.04 ± 0.69) (Table 5). So there are higher species richness in KUL in compare to DEL and ULU ponds. Mukherjee (21) and Dumont (22) reported that the higher species richness is also indicates a high level of ecosystem stability. In KUL pond highest seven types of species were observed and this result confirmed the values of species richness.

Simpson's dominance index ranges from 0 (when all taxa are equally present) to 1.0 (one taxon dominates the community completely). In our study Simpson's Dominance Index in pond ULU and DEL become 0.91 ± 0.03 and 0.96 ± 0.01 respectively, which indicate that in the ponds DEL and ULU, *Bellamya* is dominating species over other six species (Table 5).

The mean value of Pielou's evenness index ranged between 0.92 ± 0.03 to 0.34 ± 0.05. Evenness is a measure of how similar the abundances of different species and when there are similar proportions of all species present, evenness approaches a value of 1.0. In the pond KUL evenness (0.92 ± 0.03) approaches the value of 1.0. Here the abundance was dissimilar in ponds ULU and DEL, so the value for evenness decreases. Our findings exhibit the similar views like Peet (23), who have opinioned that species diversity implies both richness and evenness in the number of species and equitability for the distribution of individual among the species.

Physico-Chemical Analysis

Average physico-chemical characteristic features of three perennial ponds (ULU, KUL and DEL) of Howrah district during the study period are presented in Table 1. The average maximum and minimum water temperature ranged from 30.8 ± 0.8 C in June to 16.4 ± 0.9 C in January. The temperature of the three sampling sites vary little due to their same exposure to the sunlight in different seasons. Rajagopal et al. (24) reported that temperature is one of the essential and changeable environmental factors, since it influence the growth and distribution of fauna. The increase in gastropod population with the rise in temperature was observed during this investigation. Kamat (25) and Gaikwad et al. (26) also reported that water temperature ranging between 13.5 to 32 C are reported to be suitable for the development of freshwater organism.

The pH is a good indicator of determining the quality of water. Here pH value is more or less neutral

Table 7. Correlation coefficient between the seven Gastropoda species population and nine water parameters. *P*-value within the parentheses.

Species	Temp (C)	pH	DO (mg/l)	BOD (mg/l)	COD (mg/l)	Alk (mg/l)	Hard (mg/l)	Cond (μ Sc/m)	Org car (%)
Bellamya	0.601 (0.001)	0.921 (<0.0001)	0.665 (<0.0001)	0.570 (0.003)	0.561 (0.004)	0.620 (<0.0001)	0.799 (<0.0001)	0.748 (<0.0001)	0.852 (<0.0001)
Terabia	0.823 (<0.0001)	0.650 (<0.0001)	0.568 (<0.0001)	0.228 (0.274)	0.333 (0.104)	0.646 (<0.0001)	0.524 (0.007)	0.689 (<0.0001)	0.741 (<0.0001)
Bithynia	0.218 (0.295)	0.736 (<0.0001)	-0.466 (0.019)	0.616 (0.001)	0.268 (0.195)	0.116 (0.581)	0.660 (<0.0001)	0.648 (<0.0001)	0.675 (<0.0001)
Melanoide	0.784 (<0.0001)	0.437 (0.029)	-0.411 (0.041)	-0.041 (0.846)	0.111 (0.598)	0.540 (0.005)	0.305 (0.139)	0.575 (0.003)	0.607 (0.001)
Indoplan-orbis	0.567 (0.003)	0.686 <0.0001)	-0.476 (0.016)	-0.319 (0.120)	0.609 (0.001)	0.609 (0.001)	0.618 (0.001)	0.561 (0.004)	0.855 (<0.0001)
Lymnaea	0.587 (0.002)	0.402 (0.046)	-0.462 (0.020)	-0.194 (0.352)	0.271 (0.190)	0.487 (0.014)	0.216 (0.300)	0.347 (0.089)	0.509 (0.010)
Pila	0.551 (0.004)	0.859 (<0.0001)	-0.567 (0.003)	-0.592 (0.002)	0.415 (0.039)	0.487 (0.013)	0.702 (<0.0001)	0.673 (<0.0001)	0.856 (<0.0001)

having the maximum pH value was 7.7 ± 0.1 in September and minimum 7.2 ± 0.01 during December—January period. According to Siddamallayya and Pratima (27) the low level of water and high photosynthetic activity of microorganism during mid summer resulting in high production of free carbon di oxide during the equilibrium towards alkaline side (7.4 ± 0.1 to 7.6 ± 0.1) (Table 1). From the present study we revealed that pH have high direct positive relationship ($P < 0.0001$) with the population of *Bellamya, Terabia*, *Bythynia, Indoplanorbis* and *Pila* (Table 7). Welch (28) reported that free dissolved oxygen (DO) is essential to maintain variety of fauna in the water. However the average values of DO in these three ponds was relatively higher in March (7.6 ± 0.7 mg/liter) while it is much lesser i.e. 3.3 ± 0.9 to 3.5 ± 0.5 mg/l during October-November. Oxygen is generally reduced in the water due to respiration of biota, decomposition of organic matter, rise in temperature and oxygen demanding wastes. From the Table-6 it was revealed that DO have an positive relationship ($P <$ 0.0001) with *Bellamya* and *Terabia* species only (Table 7). Singh and Singh (29) have also concluded similar observation but in river conditions.

Biological oxygen demand (BOD) relates to the amount of oxygen needed to support the aquatic life ranged from 1.65 ± 2.1 to 6.1 ± 1.1 mg/liter and this value is far below from danger limit as mentioned by Mondal et al. (30). BOD have negative correlation with *Melanoides, Indoplanorbis, Lymnaea* and *Pila* population (Table 7), as a result of which their population may be recorded insignificant in three sampling sites. In our study the COD value is always higher than BOD values which indicates that the COD value include substances that are chemically as well as biologically oxidized. According to IS : 10500 (31) the general standard of COD for environmental pollutants is 250 mg/liter and in our studies the COD range in three ponds are withen the safe limit i.e. 32 ± 6.7 to 106 ± 2.5 mg/liter. Although COD is not significantly correlated with any of the seven species (Table 7).

Alkalinity reflects the buffering capacity of the three pond water and expressed as mg/liter of calcium carbonate. It is the measurement of carbonate and bicarbonate ions which dissolved in water and help to form the hard shell of the gastropod. According to IS : 10500 in (31), the desire limit of alkalinity is 200 mg/l and the average alkalinity in the three ponds ranged from 108 ± 2.2 to 164 ± 1.9 mg/l (Table 1), which indicate that it is safe for living organisms in all the three ponds. Alkalinity shows high positive correlation at 1% level with *Bellamya* and *Terabia* species (Table 7). This finding indicates that *Bellamya* and *Terabia* may utilized the dissolved carbonate and bicarbonate ions successfully. McMohan (17) indirectly confirmed this studies because he reported that *Viviparus* have more productivity power (mgC/m^2 per day) than *Bithynia, Lymnaea* in lake water. Hardness of water is caused by the presence of multivalent metallic cations like calcium, magnesium ions and is

essential specially in the freshwater medium where several Gastropoda species were cultured. Hardness in three ponds ranged from 60 ± 3.3 to 92 ± 1.7 mg/liter. Welch (28) reported that this range of values are quite desirable for the different fauna. Hardness also have positive correlation with all the seven species (Table 7) but significantly ($P < 0.0001$) with *Bellamya, Bithynia* and *Pila.* However Sharma et al. (32) observed similar results in aquatic macroinvertebrate diversity in Nanda Devi Biosphere Reserve. Conductivity denotes the capacity of water to conduct the electric current due to presence of ions and in our study the values vary from 124.6 ± 13.5 to 342.2 ± 10.7 μ Sc/m (Table 1). This can be classified as very soft category of pond water (30). Conductivity shows high positive correlation ($P < 0.0001$) with *Bellamya, Terabia, Bithynia* and *Pila* species (Table 7). According to Gaikwad et al. (26) electric conductivity found to be a good indicator of the water quality. In our present studies we recorded the above mentioned four species in all the three ponds all through the years , which indicates that conductivity have direct relation with the survivability of dominant gastropod species.

Freshwater gastropods (except *Lymnaea*) are bottom dwellers, they considered pond organic matter as their primary food sources which are originates from decaying plant tissue, leaves. The organic carbon present in the sampling ponds shows high values (ranges 1.533 ± 1.4 to 3.545 ± 0.5 %), this result indicate that it can provide a large amount of food to the benthic fauna present in the soft clay at the periphery of the pond, where water touches the shoreline. Organic carbon has a high correlation ($P < 0.0001$) with *Bellamya, Terabia, Bithynia, Indoplanorbis* and *Pila* species (Table 7) i.e. with important abundant and survival species. Mondal et al. (30) have also the opinion that organic matter is one of the important controlling factor as food sources for maximum abundance of benthic invertebrates.

Therefore two Prosobranch gastropods i.e. *Bellamya* (as major species) and *Terabia* (comparatively smaller abundance) are dominating in the freshwater ponds by maximum utilization of desirable physico-chemical characters of water and soil organic contents. Hawkins (33) and Angradi (34) reported that physically complex organic soil and water quality generally support the benthic diversity along with inter species competition. Present studies reported that water conditions like pH, dissolved oxygen, alkalinity, hardness, conductivity and soil organic carbon concentrations also have the desired limits in three ponds and statistical analysis indicated that certain range of physico-chemical characters of water and soil also help the gastropods population to survive. So this study also may give the direction that the physico-chemical parameters of water and soil influence the benthic freshwater gastropod population diversity. Dumont (22) enlighted that Shannon's diversity index is a suitable indicator for water quality assessment and higher species richness is characterized by large food chain and a high level of physico-chemical characters stability in terms of alpha-diversity. From our observation we also came to similar conclusion in KUL pond. As the *Bellamya* and *Terabia* species supported maximum dominance and evenness index by utilizing the above mentioned physico-chemical qualities so they may be considered to be the indicators of water quality. Balloch et al. (35) and Islam et al. (36) also found that the diversity index (Shannon's) is a suitable indicator for water quality assessment. If we consider our result in biotic index score methods of Barbour et al. (37) i.e. through biological monitoring working party average score per taxon methods (BMWP-ASPT), we will place gastropod species in the scoring rank of 8. Which indicates that the water quality of these ponds are considerably better (average polluted) and a high range of gastropod diversity may possibly act as bioindicator of better water quality in three ponds of Howrah districts. In this regard Hynes (5) also concluded that the density of molluscan invertebrates in a water body is a useful index of water quality. So, the present study indicates that the freshwater Gastropoda diversity and their population abundance may act as bioindicators of water quality in three perennial ponds.

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