

Original Research Article

<https://doi.org/10.20546/ijcmas.2018.707.317>

Ecological Assessment of Hooghly - Bhagirathi River System through the Study of Diversity of Bivalves and Gastropods in Relation to Physico-Chemical Parameters

Bhuban Mohan Majhi¹, Ashim Kumar Nath^{2*}, Chiranjeeb Dey¹,
Ayan Mondal³ and Nimai Chandra Saha⁴

¹Department of Zoology, Serampore College, Serampore, Hooghly, West Bengal, India

²Department of Zoology, Sidho-Kanho-Birsha University, Purulia, West Bengal, India

³Department of Environmental Science, University of Burdwan, West Bengal, India

⁴Vice Chancellor, University of Burdwan, West Bengal, India

*Corresponding author

ABSTRACT

Keywords

Gastropod, Bivalve,
Physico-chemical
parameters,
Principle
component analysis,
General linear
model

Article Info

Accepted:

20 June 2018

Available Online:

10 July 2018

It is generally considered that benthic organisms are good indicator of environmental condition of aquatic ecosystem. Present study focused on seasonal distribution of macrobenthic fauna and physico-chemical parameters of Hooghly-Bhagirathi river (part of Ganga river) during one year from June 2016 to May 2017. Total 16 species of mollusks (11 species of gastropods belonging to seven families and 4 species of bivalves belonging to the three families) have been found during study period. Among them *Tarebia lineata*, *Filopaludina bengalensis*, *Novaculina gangetica* and *Lamellidens marginalis* are found to be the most dominant species of the studied region of Ganga river. Four stations had been selected for the purpose of study (Station 1: Nabadwip, Station 2: Mayapur, Station 3: Khardaha, Station 4: Raichak) along the entire stretch of studied river. Gastropod and bivalves represent 43.59% and 56.41% of the total molluscs respectively. Principle component analysis (PCA) was done to determine the relationship among molluscan fauna and physico chemical variables of water. General linear model (GLM) was also done which gives a satisfactory result. Rarefaction curves confirmed the low probability of finding of addition of new species in station-1, whereas the probability of finding new species in case of station-2, station-3, station-4 are very low.

Introduction

In the world, fresh water ecosystem is being subjected to unexpected level of anthropogenic disturbance (Loh *et al.*, 1998). In the developing countries pollution of surface water as well as ground water is a major problem (Yan *et al.*, 2015). For

biological monitoring and risk assessment molluscs are used as indicator organism (Goldberg and Edward, 1986) because of their wide range of distribution and high adaptability. They react sharply to environmental change which makes them very suitable for studies of relationship between organism and environment (Ustaoglu *et al.*,

2001). Studies on benthic organism in natural water are of fundamental importance as they form the basic food for many fish species and invertebrate bottom dwellers of economic significance. Benthos have been employed to assess the past and present environmental condition of an ecosystem more efficiently than physical and chemical indices of water and soil (Hofmann, 1978) and are sedentary, sessile, long lived and easily collectable (Petersen, 1913). Hence it is prudent to study the relationship between organism and environment. Molluscs are second largest phylum after arthropod (Ellen *et al.*, 2008). Gastropods and Bivalves are the two major classes of this Phylum. Some molluscs are epifauna (living on mud or surface area of the land), some are infauna (burying themselves in the mud) and some are arboreal (attached to stem and roots of the vegetation and some are with overlapping habitat (Dey, 2006-2009; Kesavan *et al.*, 2009).

Molluscs play many vital roles in maintaining the ecosystem. They can degrade the organic detritus as they take living and decaying algae and plant material (Shanmugan and Vairmani, 2009; Kelaher *et al.*, 2007). Grazing gastropods are very efficient to control macro algal bloom and different epiphytes (Pace *et al.*, 1979; Geller, 1991; Hily *et al.*, 2004; Jenkins and Hartnoll, 2001). In the food web they place themselves in possible all the levels like predator, herbivores, detritus and filter feeder (Boodninathan *et al.*, 2012). Freshwater mussel (Class: Bivalvia, Family: Unionidae) play vital role by filtering and removing phytoplankton and other suspended particulate matter from the aquatic ecosystem (Hna *et al.*, 2004). The presence of both gastropods and bivalves are very significant in an aquatic ecosystem because they prepare food for fish and they connect an important link in the food chain. Molluscs are very sensitive indicator in localized condition, indicate the health of the ecosystem. It is a useful tool for monitoring

(biological) of river by using macro invertebrate especially for the assessment of water quality (Rosenberg and Resh, 1993; Hellowell, 1986). From the sea face to Nabadwip (latitude 23⁰24' and longitude 88⁰22') about 295 km. of the Hooghly Bhagirathi River is often referred as Hooghly estuary because of tidal influence due to its funnel shaped surface which is well suited for the optimum tidal flux (Menon *et al.*, 1972).

The Hooghly- Bhagirathi river in the studied area is affected due to abstraction of large amount of water for industrial uses. Sewer outlets and drainages, which open into the river directly cause resource deterioration. The present study is mainly concerned with the population dynamics of macrobenthos as related to certain hydrobiological condition of the studied portion of the river particularly in view of its organic and industrial pollution.

The main objective of this study is to highlight the ecological status in the studied area of Hooghly-Bhagirathi River, to study the macrobenthic community of the studied stations, to find out the influence of abiotic factor on the macrofauna using statistical methods and to assess the different population attributes with special reference to community diversity.

In the above context, an attempt was made to study the above factor in the Hooghly-Bhagirathi river in the areas from Nabadwip (latitude 23⁰ 24' and logitude 88⁰ 22') to Raichak (latitude 22⁰ 12' and longitude 88⁰ 07') of West Bengal, India from June 2016 to May 2017.

Materials and Methods

Study area

Station-1 (Nabadwip): This station is located in the latitude 23⁰ 24' and 88⁰ 22' longitude.

The river bed is not exposed except the summer season. Tidal flow is nearly absent.

Station-2 (Mayapur): This station is located in the latitude 23° 24' and 88° 22' longitude. The tidal influence is nearly absent in this station. Aquatic weeds mainly *Eichornia crassipes* is most dominant along the bank of the river. Here the river Jalangi meets with the main flow of the.

Station-3 (Khardaha): This station is located in between the latitude 22° 12' and longitude 88° 48'. The mud flat of this station is also inundated and exposed during tide. But the tidal influence is less than station-4.

Station-4 (Raichak): This station is located in between the latitude 22° 12' and 88° 07' longitude. The mud flat of this site gets inundated and exposed during tide. Along the mud flat the bank of the station is supported by cemented wall.

Collection of sample

Stratified random quadrat sampling method was followed for quantitative assessment of molluscan fauna (Christian and Harris, 2005). At each sampling station four replicates were performed to overcome the problem of random sampling. An Ekman dredge of 22 cm² was used for the collection of macrobenthic sample. Four samples were collected at random from studied area. All the samples collected were sieved through a standard sieve no. (256 mesh/cm²). The sample were preserved in 70% alcohol and used for identification. Molluscs were preserved in 75% alcohol and were identified (Ramakrishna and Dey, 2007). The density of molluscan species (number/m²) in each sample was calculated according to the following formula (Clark *et al.*, 1989).

$$D = (N/n \times 44)$$

Where 'D' is density, 'N' is the number of specimen collected and 'n' is the no of grab samples. The frequency of occurrence of macrobenthic molluscan species has been calculated using F index (Guille, 1970).

$$F = P_a / P \times 100$$

Where P_a = number of stations where the species occurred and P = total number of station. The macrobenthic molluscan species were classified as - constant species (F > 50%), common (10% < F < 49%) and rare (F < 10%) according to the above formula.

Physico- chemical analysis

Water parameters like DO, alkalinity, hardness, chloride, nitrate, phosphate were analysed seasonally following the standard method (APHA, 1989). Temperature were measured in the field with the help of thermometer (range 0°C - 60°C) while pH of water was determined by pH meter (Hanna, model no. H1 98107).

Statistical analysis

Different biological indices viz. Shannon-Wiener index (Shannon and Wiener, 1963), β diversity or heterogeneity index (d) (Whittaker, 1975), Evenness index of diversity (E) (Pielou, 1966), Berger-Parker index (Berger and Parker, 1970) of dominance (d) were calculated to interpret species richness, dominance and species abundance. The relationship between species and physicochemical variables were evaluated by applying Principle component analysis (Ter Braak and CJF, 1995). GLM were applying to denote the main physicochemical parameters (McCullagh and Nelder, 1989). The similarities of species assemblage among different sampling stations were determined using Brays-Curtis index (Krebs, 1999).

Results and Discussion

Species composition and abundance

The macrobenthic molluscan population in Hooghly-Bhagirathi River comprised 2 classes (Gastropoda and Bivalvia), 10 families and 16 species (Table 2). Gastropoda had 7 families and 12 species, while Bivalvia has 3 families and 4 species. Neritidae and Lymnaeidae had the highest species composition. Thiariidae and Unionidae has 2 species and all the other families had one species. The annual percentage contribution of malacofauna to the total molluscan species was higher in the class Bivalvia (56.41 %) than Gastropoda (43.59 %) (Fig. 2). This finding is very similar to the work of (Sakhare and Kamble, 2015). The annual percentage of species composition given in figure (Fig. 3 and 4). Among gastropoda dominant species shows that *Tarebia lineata* had (48.66 %) followed by *Filopaludina bengalensis* (24.51 %), *Brotia costula* (7.11 %), *Neritina smithii* (5.86 %) respectively. Among Bivalvia dominant species shows that *Novaculina gangetica* had (97.51 %) followed by *Lamellidens marginalis* (1.16 %). According to the frequency of occurrence (F value) eight gastropod species *Neripteron violaceum*, *Neritina smithii*, *Filopaludina bengalensis*, *Assiminea francesiae*, *Tarebia lineata*, *Brotia costula*, *Radix luteola*, *Indoplanorbis exustus* and three species of bivalves, viz, *Lamellidens marginalis*, *Parreysia favidens*, *Corbicula striatella* are considered as constant species. The remaining four species of gastropods *Septaria lineata*, *Melanoides tuberculata*, *Radix acuminata*, *Radix ovalior* and one species of bivalves *Novaculina gangetica* are classified as common species. The distribution of molluscan population in relation to station and season (Fig. 5, 6, 7, 8) showed that Station-2 had the highest number of species composition (10 species) and the dominant species *Novaculina gangetica* had the

abundance 414 nos./m² and the total average abundance was 453 nos./m². In case of station-1 total average abundance was 53 nos./m² and the dominant species *Tarebia lineata* has the abundance of 28 nos./m² followed by *Filopaludina bengalensis* (11 nos./m²). In case of Station-3 and station-4 total average abundance was 144 nos./m² and 115 nos./m² respectively.

Physico-chemical parameters

The pH of water was found to be alkaline in all stations varying from 7.2 to 8.05. Hooghly Bhagirathi River seems to have a good buffering capacity so it maintains the fluctuation in the entire stretch (Ray and Ghosh, 1976). The current in lotic environment tends to keep the pH uniform over certain distance (Welch, 1952). Maximum water temperature was recorded in the month of April - May (30⁰C - 34⁰C) and the minimum temperature in the month January and February (22⁰C - 26⁰C). The values of alkalinity varied from 91-335, 91-335, 97-231, 210-378 mg/l at station 1 - 4 respectively. High alkalinity is an indication of pollution (Kulshrestha *et al.*, 1989). Higher alkalinity noticed at station- 4 because of high concentration of sewage (Robert, 1977; Das and Sinha, 1994). Water Hardness varied from 90-274, 90-274, 97-174, 102-490 mg/l at station 1 - 4 respectively. Based on mean value of hardness station 1 - 3 fall under moderately hard water while station- 4 fall under moderately hard to hard water. The high value of hardness indicates the high pollution load of sewage (Sharma *et al.*, 1981). The value of dissolved oxygen varied from 7.0 - 9.2 mg/l at station- 1 and station- 2, 6.5 - 9.0 mg/l at station 3 and 6.5 - 8.0 mg/l at station-4. Chloride content of the river varied from 16-38 mg/l in station1 and 2, 18-39 mg/l at station 3, and 62-333 mg/l at station- 4. In general station- 4 showed high chloride content as the station is nearer to Bay of

Bengal. As nutrients are directly related to productivity concentration of nutrients like nitrogen and phosphate are important in lotic ecosystem. The phosphate content in the present study varied from 0.1 - 0.40 mg/l at station- 1, station- 2 and station- 3 and 0.05 - 0.45 mg/l at station- 4 respectively. Nitrate was not detectable at station- 3 and station- 4; on the other hand at station-1 and station- 2 the concentration of nitrate varied from 0 - 0.15 mg/l (Table 1).

Biological indices

The macrobenthic molluscan fauna was analyzed for species diversity, species dominance, species richness and evenness (Fig. 9). The value of Shannon-Wiener index ranged from 0.75 to 1.25 with an average of 1.0. The evenness index varied from 0.23 to 0.54 with an average of 0.43. The Berger-Parker dominance index varied from 0.52 to 0.83 with an average value of 0.66. Dominance index indicates the degree of predominance of one or a few species in an ecological habitat. As dominance index increases in an ecosystem, diversity index decreases which may be caused by increasing aquatic pollution. In higher level of pollution, only a few species can tolerate and survive and later flourish to increase their population abundance due to better adaptation to the changed environment and reduced competition from other species. β - diversity index ranged from 0.25 to 0.55 with average of 0.41. Overall, according to the result found low diversity index, the uneven distribution of species, low evenness value and moderate dominance showed an unstable community structure at the study sites of Hooghly - Bhagirathi River.

Statistical analysis

Cluster (Dendrogram) analysis of the selected stations (Fig. 11) showed one prominent

cluster and two intermediate cluster. Prominent cluster formed between station- 3 and station-4. Bray- Curtis index is 0.6 of these two stations in respect of their annual species assemblage. From the intermediate cluster it was seen that station- 1 exhibits less similarity to complete cluster and the Bray-curtis index is 0.38 in between Station-1 and the complete cluster. Station 2 has least similarity to other three stations with Bray-Curtis index 0.12. Cluster analysis has clearly shown affinities between sample and thus providing a baseline for monitoring programme.

Individual rarefaction estimates how many taxa is expected in a sample with smaller amount of individual. With this method (algorithm is from Krebs 1969), it can be compared the no. of taxa in sample of different size. Standard error are calculated and converted to 95 percent confidence interval. The rarefaction curve shows the possibility to find out maximum taxa in station-2 followed by station-3, station-2 and station-4. The highest species abundance is seen in station-2 followed by station-4, station-3 and station-1. Rarefaction curve indicate that the highest sampling is needed to find out the possible all taxa in case of station-2 followed by station-4, station-3 and station-1.

PCA analysis shows first two principle component 22.31% and 16.69% variability with eigenvalue 5.35 and 4.00 respectively. To form principle component 1 *Radix acuminata*, *Radix ovalior*, *Radix luteola* , *Lamillidens marginalis*, *Novaculina gangetica* contribute most and in case of component 2 *Septaria lineata*, *Filopaludina bengalensis*, *Assimineea francesiae*, *Brotia costula* has major responsibility. Among water parameter salinity contribute highest to component 1 and for component 2 it is hardness of water. From Biplot analysis phosphate, salinity and

alkalinity shows close association. *Neripteron violaceum*, *Neritina smithii* also makes a cluster with these factors. Especially *Neritina smithii* is very good indicator of phosphate and *Neripteron violaceum* for salinity. *Septaria lineata* and *Assiminea francesiae* are almost similar in relation with other factors. *Brotia costula*, *Filopaludina bengalensis*, *Melanoides tuberculata* are more or less similar with *Septaria lineata*, *Assiminea francesiae* group. pH and salinity shows inverse relation that is also consistent with *Neripteron violaceum*, *Neritina smithii* group. *Novaculina gangetica*, *Radix luteola*, *Lamillidens marginalis*, *Radix ovalior*, *Radix acuminata* are almost similar in terms of population variability with other factors; DO is the most sensitive factor for this large group. Water temperature and nitrate are clearly in inverse relationship.

GLM (General Linear Modelling) have been done in considering gastropod and bivalve

abundance as dependent variable and water parameter as independent variable. Univariate result shows that salinity (p= 0.03) and alkalinity (p= 0.01) is most important factor for gastropod species and for bivalve it is pH (p= 0.02) and phosphate (p= 0.03). The phosphate content of water influences the total benthic organisms which are in conformity with the findings of Adholia *et al.*, (1990). In case of multivariate test of significance, Wilks's lambda distribution found most significant (p= 0.04) for alkalinity. Sarkar (1989) reported a positive relation between alkalinity and molluscan population. Observed power for independent variables in an ascending order of temperature, DO, nitrate, hardness, salinity, pH, phosphate and alkalinity. Test result for whole model for gastropod and bivalve are well significant (Table 3) and shows R² value 0.42 and 0.36 respectively. Predicted vs. observed result according to derived linear equation (Chart-1) shows satisfactory result (Fig. 14 and 15).

Table.2 Mean ± Standard deviation of Physico - chemical parameters of Hooghly-Bhagirathi river

	Parameters	Station 1	Station 2	Station 3	Station 4
1.	Dissolved oxygen (mg/l)	7.9±0.66	7.9±0.66	7.6±0.722	7.9±.54
2.	Temperature (°C)	29.24±4.21	29.24±4.21	29.87±3.05	30.00±2.23
3.	Water pH	7.6±0.32	7.6±0.32	7.7±0.15	7.6±.16
4.	Salinity (mg/l)	24.62±7.37	24.62±7.37	25.83±7.27	208.36±106.48
5.	Hardness (mg/l)	128±54.17	128±54.17	121±33.50	232±.125.49
6.	Alkalinity (mg/l)	198.76±101.275	198.76±101.275	161.73±46.89	281.36±.66.02
7.	Phosphate (mg/l)	0.17±0.05	0.17±0.05	0.16±0.04	0.31±0.08
8.	Nitrate (mg/l)	0.014±0.04	0.014±0.04	0	0

Table.1 Species of Bivalves and Gastropods found at the studied sites

Class	Order	Family Genus Species	2016-2017			
			Site 1	Site 2	Site 3	Site 4
Gastropoda	Cycloneritimorpha	Neritidae				
		1. <i>Neripteron violaceum</i>	-	-	+	+
		2. <i>Neritina smithii</i>	-	-	+	+
		3. <i>Septaria lineata</i>	-	-	+	-
	Architaenioglossa	Viviparidae				
		4. <i>Filopaludina bengalensis</i>	+	+	+	+
	Littorinimorpha	Assimineidae				
		5. <i>Assiminea francesiae</i>	-	-	+	+
	Caenogastropoda	Thiaridae				
		6. <i>Melanoides tuberculata</i>	+	-	+	-
		7. <i>Tarebia lineata</i>	+	+	+	+
	Caenogastropoda	Pachychilidae				
		8. <i>Brotia costula</i>	+	+	+	-
	Hygrophila	Lymnaeidae				
		9. <i>Radix acuminata</i>	-	+	+	-
		10. <i>Radix ovalior</i>	-	+	+	-
		11. <i>Radix luteola</i>	+	+	-	-
	Hygrophila	Planorbidae				
		12. <i>Indoplanorbis exustus</i>	+	+	+	-
Bivalvia	Unionoida	Unionidae				
		13. <i>Lamellidens marginalis</i>	+	+	-	-
		14. <i>Parreysia favidens</i>	+	+	-	-
	Adapedonta	Pharidae				
		15. <i>Novaculina gangetica</i>	-	+	-	-
	Veneroida	Cyrenidae				
		16. <i>Corbicula striatella</i>	+	+	+	-

Table.3 Test of SS Whole Model vs. SS Residual (glm new.xlsx (C3:AX50))

Dependent variable	Multiple R	Multiple R square	Adjusted R square	SS	Df	MS	SS	df	MS	F	P
Gastropod	0.649695	0.422103	0.300441	736397.3	8	92049.66	1008194	38	26531.42	3.469459	0.004268
Bivalve	0.601829	0.362198	0.227924	791268.6	8	98908.58	1393359	38	36667.33	2.697458	0.018677

Fig.1 Map shows the study area

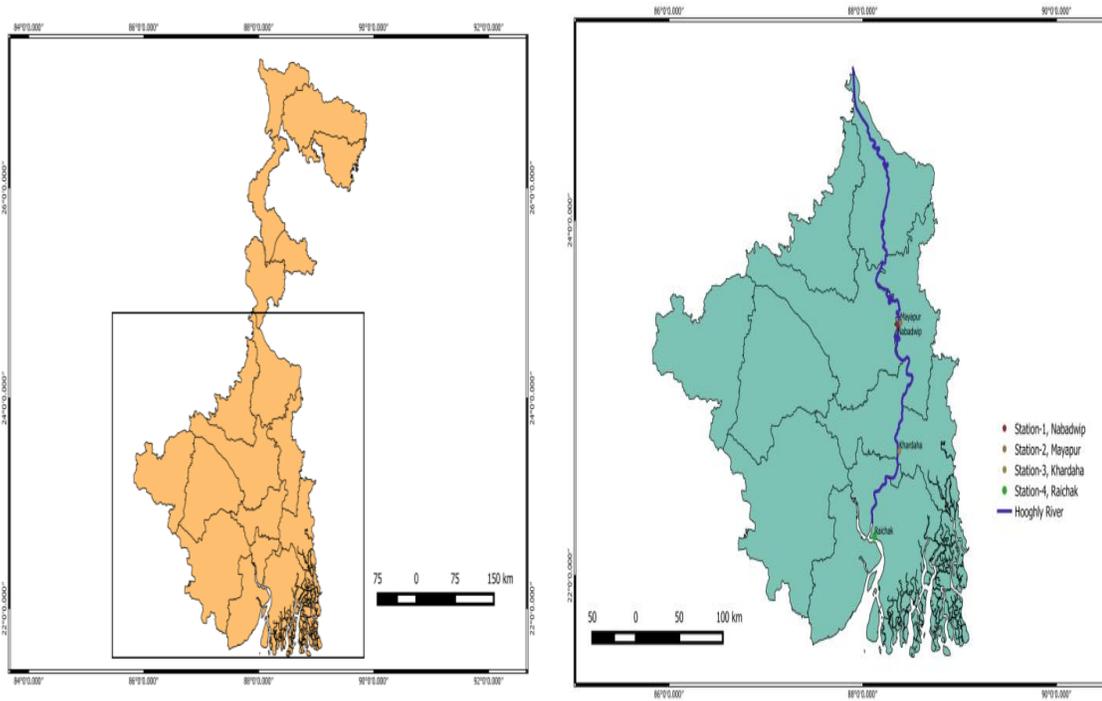


Fig.2 Total annual percentage composition of class Bivalvia and Gastropoda

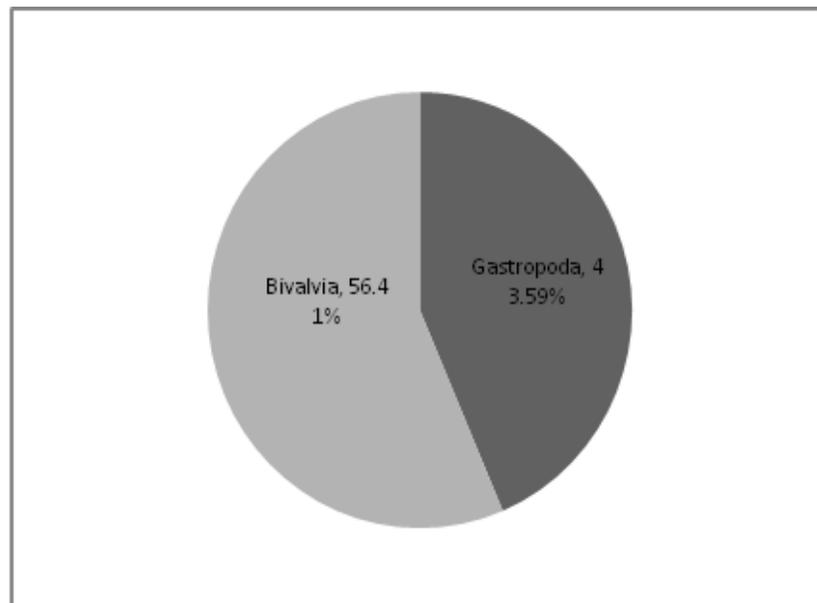


Fig.3 Percentage of annual composition of individual

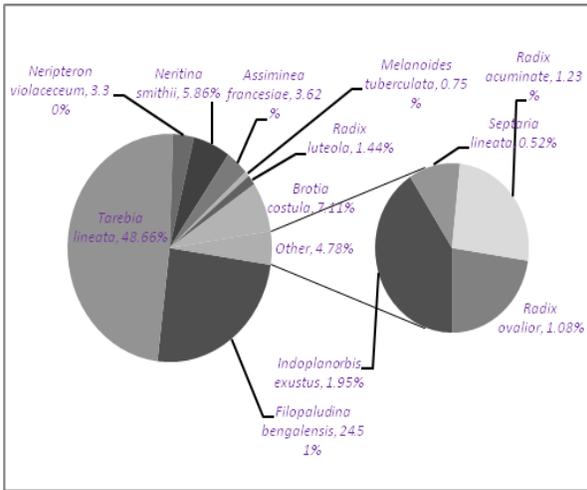


Fig.4 Percentage of annual composition of individual

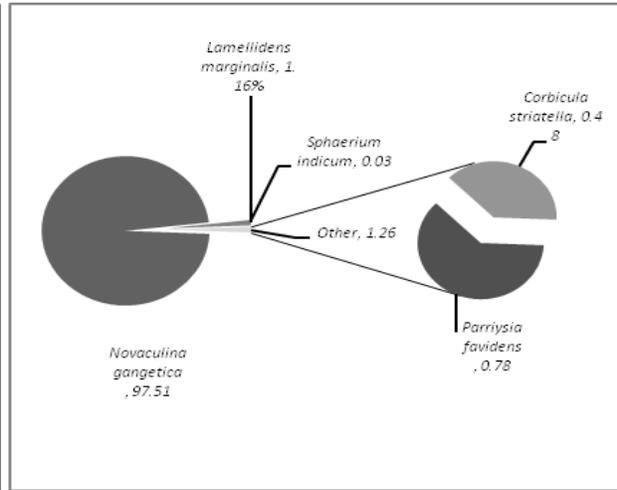


Fig.5 Abundance (nos./m²) of individual species at (Stn- 1) in different season

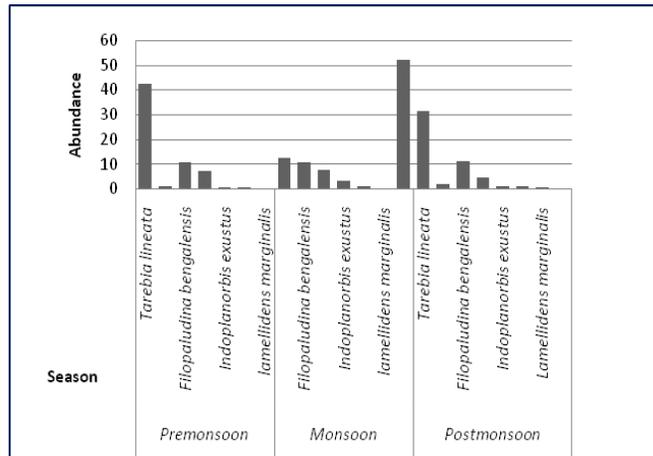


Fig. 6 Abundance (nos./ m²) of individual species at (Stn-2) in different season

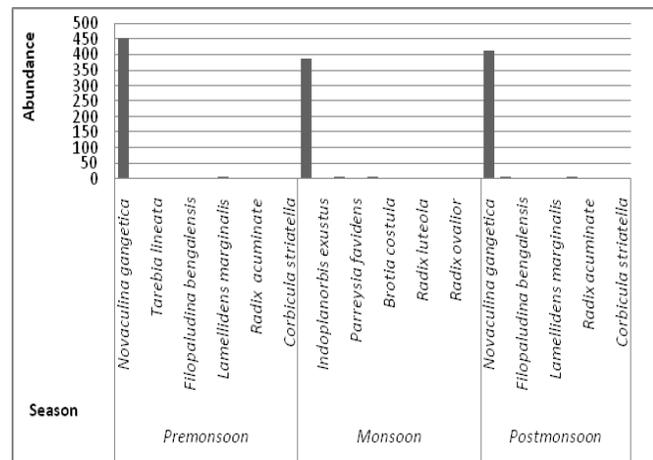


Fig.7 Abundance (nos./ m²) of individual species found in different season at (stn-3)

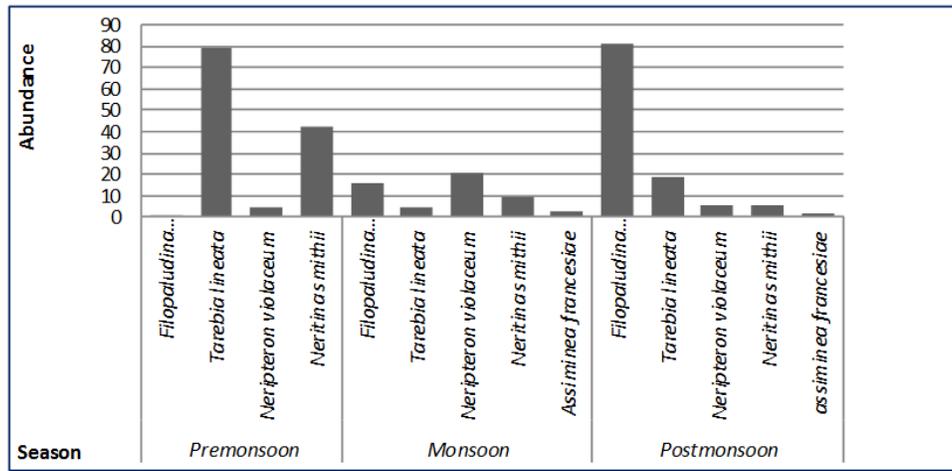


Fig. 8 Abundance (nos./ m²) of individual species found in different season at (Stn-4)

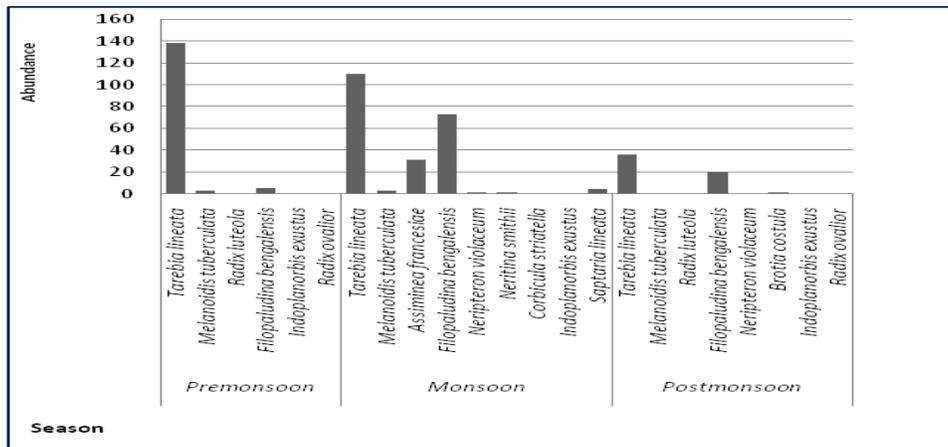


Fig. 9 Abundance (nos./ m²) of total Macrobenthic fauna (Gastropod and Bivalve) at four stations in different seasons

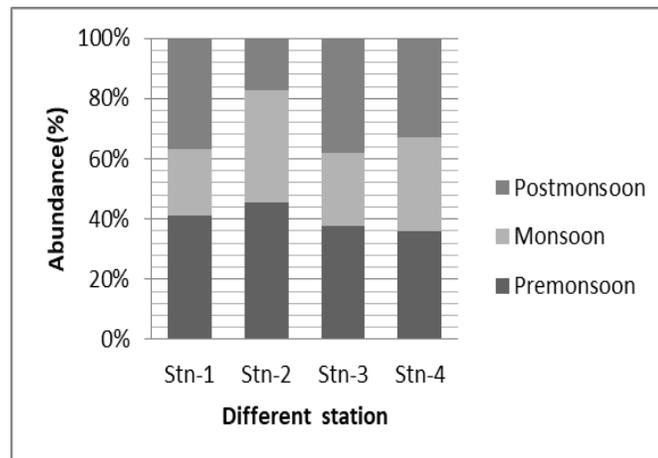


Fig.10 Mean value of different diversity indices at different sites in different month

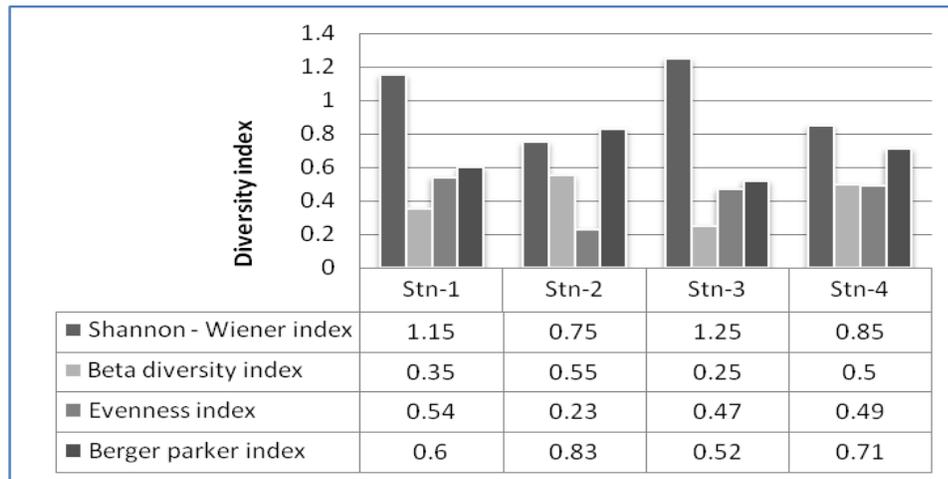


Fig.11 Dendrogram using Bray-Curtis coefficient and complete linkage clustering with the sampling stations

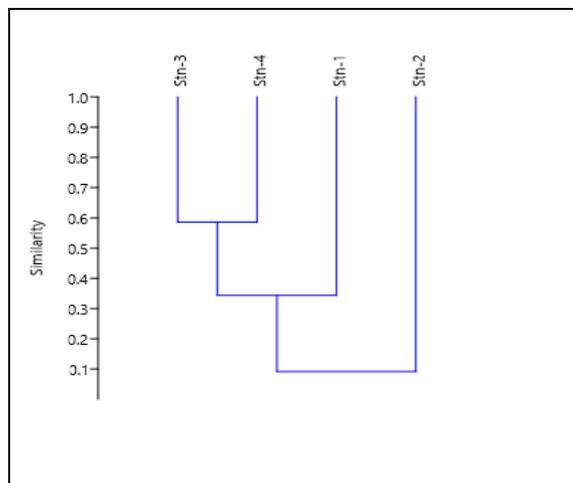


Fig.12 Rarefaction curve of sampling taxa at different sampling sites

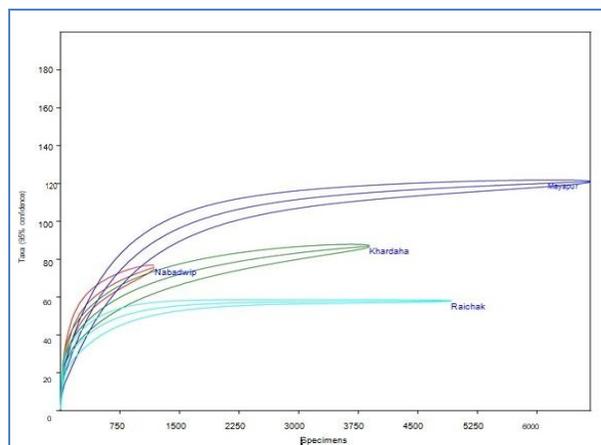


Fig.13 Principle Component Analysis of macrobenthic fauna as affected by different physico-chemical parameters of water of Ganga River. (Sp1-*Neripteron violaceum*, Sp2- *Neritina smithii*, Sp3-*Septaria lineata*, Sp4-*Filopaludina bengalensis*, Sp5-*Assiminea francesiae*, Sp6-*Melanoides tuberculata*, Sp7 -*Tarebia lineata*, Sp8-*Brotia costula*, Sp9-*Radix acuminata*, Sp10-*Radix ovalior*, Sp11-*Radix luteola*, Sp12- *Indoplanorbis exustus*, Sp13- *Lamillidens marginalis*, Sp14- *Parreysia favidens*, Sp15-*Novaculina gangetica*, Sp16-*Corbicula striatella*).

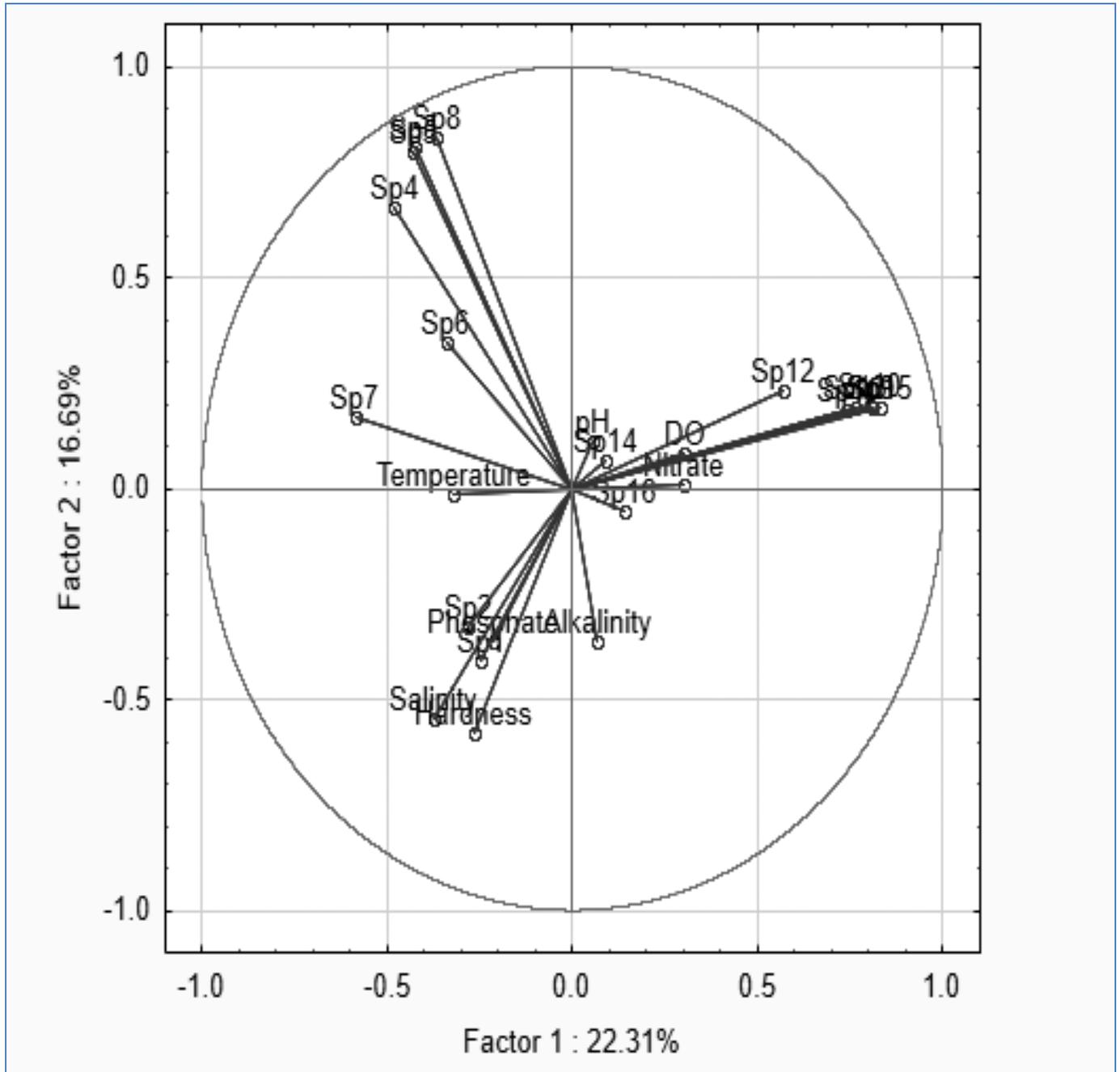


Fig.14 Graph of observed vs predicted for Gastropod ($R^2 = 0.42$)

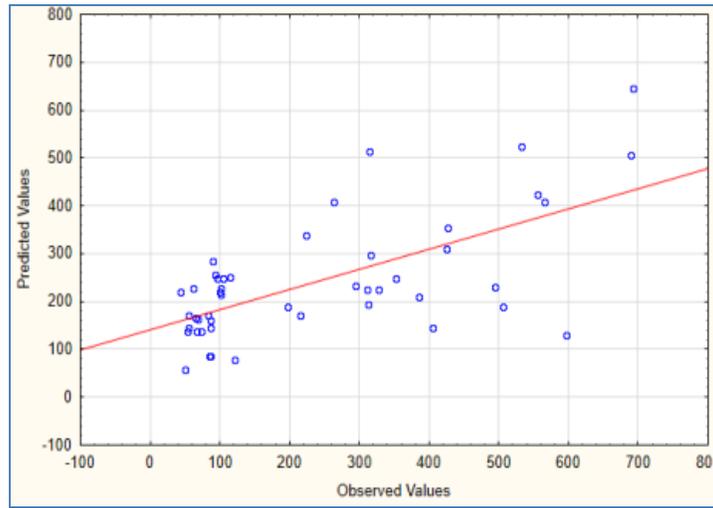
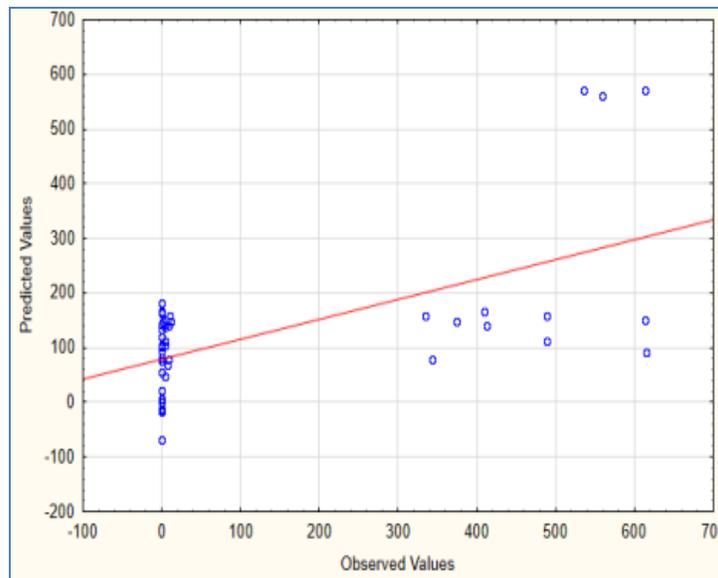


Fig.15 Graph of observed vs predicted for Bivalve ($R^2 = 0.36$)



In conclusion, the diversity of molluscs at four localities of Hooghly-Bhagirathi river varied significantly. During the study period 43.59% of gastropod species and 56.41% of bivalve species were recorded. *Tarebia lineata* and *Filopaludina bengalensis* were the most ubiquitous, being present in all stations. They are the indicator species because of their wide distribution and pollution tolerance level. *Neritina smithii* is primarily a brackish

water species occasionally extending in to fresh water and is found in station-4 and Station-3 probably due to habitat fragmentation. *Assiminea francesiae* is the only species of Assimineidae that is found in fresh water within the area of tidal influence (Ramakrishna and Dey, 2007) in our present study this is found in station- 4 and station- 3. Fresh water bivalves are very sensitive to salinity so the distribution of fresh water

bivalve (Family- Pharidae, Unionidae, Cyprinidae) are mainly found in station-1 and 2 due to absolutely fresh water habitat but they are not present in station- 3 and 4 as salinity gradually increases. As per the species diversity scale of Wilhm and Doris (1968) ($H > 3$ = clean water, $H = 1-3$ = moderately polluted, $H < 1$ = heavily polluted) station-1 and 3 are moderately polluted where as station-2 and 4 are heavily polluted. According to the Berger – Perker index if aquatic pollution increases dominance index increases but diversity index decreases. Higher Berger-Parker dominance index signifies higher level of aquatic pollution which is found at station-2 and 4 than station-1 and 3. The higher value of diversity index indicates greater perturbations due to environmental disturbances or pollution stress (Sharma *et al.*, 2005; Padmanabha and Belagali, 2007) which is found in station-2 and 4. This indicates that station-1 was with highest equal representation of species and station-2 with lowest equal representation or highest unequal representation of species (Padmanabha and Belagali 2006, 2007). Among the physico-chemical parameters salinity (mg/l) and alkalinity (mg/l) are the most dominant factor for distribution of gastropods where as pH and phosphate (mg/l) play the same role in case of bivalves. The present study shows that recorded all molluscan species in the category of indigenous species with valuable biodiversity potency which needs to be conserved in relation to maintain the ecological balance and their sustenance in the nature. The study focus in the interrelationship between the varied seasonal parameters with biodiversity context.

Aknowledgement

Authors are grateful to Department of Higher Education, Science and Technology and Biotechnology, Govt. of West Bengal for

providing fund in Major Research Project (Memo No. 696 (Sanc.) /ST/P/S and T/5G-1/2004) and to the Principal, Serampore College for giving permission to do the work. Thanks are due to Dr.Tulica Biswas, Zoological Survey of India (Molluscan Department), Kolkata for kind help.

References

- Adholia, U.N., Chakravarthy, A., Shrivastava, V., and Vyas, A. 1990. Community studies on macrozoobenthos with reference to limnochemistry of Manasarovar reservoir, Bhopal. *J. Nature C;on.*, 2(2): 139-154.
- APHA 1989. Standard Methods for the Examination of Water and Waste Water. 17th edition, Washington, DC
- Berger, W.H., and Parker, F.L. 1970. Diversity of planktonic Foraminifera in deep-sea sediments. *Science* 168: 1345-1347.
- Boodnathan, M., Ravikumar, G., Chandran, M.D.S., and Ramachandra, T. 2012. Mangrove associate molluscs of India. In. National Conference on Conservation and Management of wetland Ecosystem, Lake.
- Christian, A.D. and Harris, J.L. 2005. Development and assessment of a sampling design for mussel assemblages in large streams. *Am. Midl. Nat.*, 153: 284-92.
- Clark, F., Beeby, A., and Kirby, P. 1989. A study of the macroinvertebrates of Lakes Naivasha, Oloiden and Sonachi, Kenya. *Revue d'Hydrobiologie Tropicale.*, 22: 21–33.
- Das, N.K. and Sinha, R.K., 1994. Pollution status of river Ganga at Patna (Bihar) India. *J. Freshwater Bio.*, 6: 159-164.
- Dey, A. 2006-2009. Hand book on Mangrove Associate Molluscs of Sunderbans. Zoological survey of India, Kolkata .
- Ellen, E., Olivier, Gargominy, Wntston, F.P.,

- Philippe, Bouchet. 2008. Global diversity of gastropods (Gastropoda; molluscs) in freshwater. *Hydrobiologica.*, 595: 149-166.
- Geller, J.B. 1991. Gastropods grazer and algal colonization on the rocky shore in northern California; the importance of the body grazer. *J. Exp. Mar. Biol. Ecol.*, 150: 1-17.
- Goldberg and Edward, D. 1986. The mussel watch concept. *Environ Monit Assess.*, 7: 91-103.
- Guille, A. 1970. Benthic bionomy of continental shelf of the French catalane coast. II. Benthic communities of the macrofauna. *Vie Milie.*, 21: 239-25.
- Hellawell, J.M. 1986. Biological Indicators of Freshwater Pollution and Environment Management. Elsevier Applied Science., 14: 188.
- Hily, C., Connas, S., Raffin C Wyllie. and Echeverria, S. 2004. In vitro experiment assessment of the grazing marine L. epiphytic algae. *Aquat. Bot.*, 78:183-195
- Hna Louise, Mcivor, David Aldrige and Stephan Muller. 2004. Fresh water Mussel as Biofilters. PhD dissertation, Pembroke college. University of Cambridge.
- Hofmann, W. 1978. Analysis of animal microfossils from the Grosser Segebergersee (F. R. G.). *Arch. Hydrobiol.*, 82 (1-4): 316-346.
- Jenkins, B.R.. and Hartnoll, R.G. 2001. Food supply, grazing activity and growth rate in the limpet *Patella Vulgata* L , a comparison between exposed and sheltered shore. *J. Exp. Mar. Biol. Ecol.*, 258: 123-139.
- Kelaher, B.D., Casilla, J.C., ParboL, Yurk, P., Schiwin, dt E. and Bortolus, A. 2007. Spatial variation in molluscan assemblages from coralline Teerfs of Argentinean Patagonia. *J. Molluscan Stud.*, 73: 133-146.
- Kesavan, K., Palpandi, C. and Shanmugam, A. 2009. A Cheklist of malacofauna of the Vellar Estuarine Mangrove , India, *J Threat Taxa.*, 1: 382-384.
- Krebs, C.J. 1999. Ecological methodology. 2nd ed. Menlo Park: Benjamin Cummings.Total pages 620.
- Kulshresta, S.K., Adholia. U.N., Khan, A.A., Bhatnagar, A., Saxena, M. and Baghail, M. 1989. Pollution study on river Kshipra with special reference to macrozoobenthos. *Nature Con.*, 1: 285-292.
- Loh, J., Randers, J., MacGillivray, A., Kapos, V., Jenkins, M., Groombridge, B.,Cox, N. 1998. Living Planet Report. Gland, Switzerland, World Wide Fund for Nature., pp 56.
- McCullagh, P. and Nelder, J.A. 1989. Generalized linear models. Chapman and Hall, London.
- Menon, A.G.K., Rao, K.V. and Sen, T.K. 1972. The Hooghly and its fisheries in the past, the present and the future with special reference to the Farakka barrage on the Ganga. *Sci Cult.*, 38: 338-343.
- Pace, M.L., Shimmel, S. and Darley, W.M. 1979. The effect of grazing by gastropod, *Nassarius obosletus* on the benthic microbial community of a salt marsh mudflat. *Estuar. Coast. Mar. Sci.*, 2: 121-134.
- Padmanabha, B. and Belagali, S.L.2006. Comparative study on population dynamics of rotifers and water quality index in the lakes of Mysore. *Nat. Env. Poll. Tech.*, 5(1): 107-109.
- Padmanabha, B. and Belagali, S.L. 2007. Diversity indices of rotifers for the assessment of pollution in the lakes of Mysore city. India. *Poll. Res.*, 26(1): 65-68.
- Petersen, C.G.J., 1913. Valuation of the Sea. II. The animal communities of the sea

- bottom and their importance for marine zoogeography. Rep. Danish. Biol. Sta., 21: 1- 44.
- Pielou, E.C. 1966. The measurement of diversity in different types of biological collections. *J. Theor. Bio.*, 13: 131-144.
- Ramakrishna and Dey, A. 2007. Hand book on Indian freshwater molluscs. Zoological Survey of India, Kolkata.
- Ray, P. and Ghosh, B.B. 1976. Some ecological considerations of the Hooghly estuary polluted by domestic and industrial wastes under tropical environment. ACMRR/IABO Expert Consultation on Bioassays with Aquatic Organisms in relation to pollution problems, Dubranik, Yugoslavia, 16-19 November, 1976. PI: ACMR/BE/8, 29 September.
- Robert. and Ayers, S. 1977. Quality of water for irrigation and drainages. *J Irrig drain eng dev.*, 103(2): 125-154
- Rosenberg, D.M. and Resh, V.H. In *Freshwater Biomonitoring and Benthic Macroinvertebrate*, Chapman and Hall, New York.
- Sakhare, S.S. and Kamble, N.A. 2015. Diversified distribution of malacofauna from Hiranyakeshi river-A contemporary study. *Int. J. Pure App. Biosci.*, 3(5): 128-142.
- Shanmugan, A., Vairmani, S. 2009. Molluscs in Mangrove: A case Study, In *Training Course on Mangrove and Biodiversity.*, Pp 371-382.
- Shannon, C.E. and Wiener, W. 1963. *The mathematical theory of communications*, University of Illinois Press, Urbana. Illionis
- Sharma, K., Bharadwaj, S.M., Chaturvedi, R. and Sharma, K.P. 2005. Applicability of diversity indices for a comparative assessment of degree of pollution in lentic and lotic ecosystems and describing vegetation characteristics. *Nat. Env and Poll. Tech.*, 4(1): 101-106.
- Sharma, K.D., Lal, N. and Pathak, P.D. 1981. Water quality of sewage drains entering Yamuna at Agra. *Indian J. Environ. Hlth.*, 23: 118 – 122.
- Ter, Braak., C.J.F. 1995. Non-linear methods for multivariate statistical calibration and their use in palaeoecology: a comparison of inverse (k-nearest neighbours, partial least squares and weighted averaging partial least squares) and classical approaches. *Chemometr Intell Lab Syst.*, 28: 165-180
- Ustaoğlu, M.R., Balık, S. and Özbek, M. 2001. Işıklı Gölü (Çivril-Denizli)'nün Mollusca Faunası. *E.U. Journal of Fisheries and Aquatic Sciences.*, 18: 135-139.
- Welch, P. S. 1952. *Lilnnology*. Mc Grew Hill book Co., New York. Total pages:538
- Whittaker, R.H. 1975. *Communities and Ecosystems*. 2nd edn. MacMillan, New York.
- Yan, H., Cousins, I.T., Zhang C. and Zhou, Q. 2015. Perfluoroalkyl acids in municipal landfill leachates from China: Occurrence, fate during leachate treatment and potential impact on groundwater. *Sci. Total Environ.*, 524–525: 23–31.

How to cite this article:

Bhuban Mohan Majhi, Ashim Kumar Nath, Chiranjeeb Dey, Ayan Mondal and Nimai Chandra Saha. 2018. Ecological Assessment of Hooghly - Bhagirathi River System through the Study of Diversity of Bivalves and Gastropods in Relation to Physico-chemical Parameters *Int.J.Curr.Microbiol.App.Sci* 7(07): 2700-2715. doi: <https://doi.org/10.20546/ijcmas.2018.707.317>