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MORPHOLOGY OF *PILA GLOBOSA* (GASTROPOD MOLLUSCA: AMPULLARIIDAE) WITHIN ENVIRONMENTAL VARIATION OF SOUTH-WESTERN BANGLADESH

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Abstract

Owing to the community engagement of the gastropod collection in the south western ecosystems in Bangladesh, the gastropod molluscs are getting important attention in terms of edible and non-edible purposes while detailed morphological information about the gastropods is scarce in this area. The present research has investigated the morphological variability of the gastropod molluscs (*Pila globosa*) in the six localities of south-western coastal Bangladesh (such as, *Khulna*, *Bagerhat*, *Satkhira*, *Gopalganj*, *Pirojpur* and *Jessore*). A total of 2160 gastropod samples (*Pila globosa*) were collected from July to December monthly over the two consecutive years of 2013 and 2014. The results of the analyses revealed that the maximum monthly mean values of the dry shell mass and the dry body mass were found in November, indicating the complete growth and development of the gastropods in the coastal environment. One-way ANOVA and ANCOVA show that there is a significant morphological variability of *Pila globosa* among different localities in the south-west coastal Bangladesh, while the covariate of water salinity significantly affects the aperture length of it; the covariate of electrical conductivity of soil significantly affects both the height and aperture length; the covariate of sodium contents of the soil significantly affects the aperture length of the gastropod mollusc. The results also revealed that the morphological variability of the mollusc *P. globosa* is linked to complex ecological systems and habitat variation.

Keywords: Morphology, variability, gastropod, snails, south-west, Bangladesh

Introduction

Gastropod molluscs are particularly important communities in many coastal ecosystems. Freshwater gastropod molluscs are important bio-indicators of aquatic pollution (Dalu & Chauke, 2020) and play a vital role in refining contaminated water of the aquatic environment. Understanding the environmental factors that control the abundance and distribution of freshwater gastropod molluscs is important because the knowledge of that factors will help policymakers to manage, conserve, monitor and restore the aquatic environmental quality (Bespalaya et al., 2021). The scientific knowledge about the information on gastropod molluscs is scarce in Bangladesh; however, the species at the coast of Bangladesh have socio-ecological emphasis for the edible and non-edible (e.g., for poultry and fish meal, ornaments) purposes.

However, survival of gastropods is regulated by various physico-chemical factors that play major roles in determining the ecological traits associated with a particular species (Dunithan et al., 2012; Begum et al., 2018). The ecology of these gastropod molluscs is chiefly altered by environmental factors like physico-chemical parameters of water and habitat's substrate and even, that environmental factors determine the mollusc richness and distribution in different areas (Dillon, 2000; Garg et al., 2009; Harayashiki et al., 2020; Colvin et al., 2022; Sandip et al., 2022). For a better understanding of the benthic ecosystem and coastal environmental changes, studies on the relationship between gastropod molluscs and environmental factors in terms of their physico-chemical parameters like water and

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habitat's substrate or sediment are very important (Lorencova´ & Horsa, 2019; Ganguly et al., 2020; Colvin et al., 2022).

But, investigations on the environmental factors that determine gastropod mollusc's richness and distribution in coastal wetland systems are scarce in south-western coastal area of Bangladesh and hence, it is important to investigate the morphological variability of gastropod molluscs and the relationship of environmental factors in terms of physico-chemical conditions of water and habitat's substrate/sediment with mollusc's morphological variability in the south-western coastal area of Bangladesh. It is also imperative to understand the morphological variability of molluscs (*Pila globosa*) under different environmental conditions because they act as an excellent environmental archive for predicting past environmental conditions including climate change. The results of the research will act as the baseline data of this region to understand the present and predict the future climate change and environmental reconstruction. So, the morphological data of this research will serve as the past baseline environmental achieve, which would have an important and significant impact in the field of functional ecology and environmental reconstruction research for the coastal ecosystem management of this south-western coastal region.

Therefore, the main goal of this study was to determine the morphological variability of *Pila globosa* in relation to environmental parameters and habitat variations (water and habitat's substrate/sediment) in the six localities of south-western coastal Bangladesh (such as, *Khulna*, *Bagerhat*, *Satkhira*, *Gopalganj*, *Pirojpur* and *Jessore*). The study will allow for the proper management of ecosystems and their services in the coastal area of Bangladesh. Even, the result of the study will form the baseline data for such macro-benthic invertebrates (gastropod molluscs) in this south-western coastal Bangladesh and finally, the results of this study can be used by policymakers of Bangladesh to evaluate environmental changes.

Materials and Method

Study Area

The study area of the research lies in the six localities of the six coastal districts of the south-western Bangladesh (*Khulna*, *Satkhira*, *Bagerhat*, *Gopalganj*, *Jessore* and *Pirojpur*), which receive discharges of water and sediment from the Ganges-Brahmputra-Meghna (GBM) river system and support rich wetland biodiversity including gastropod molluscs (*Pila globosa*) in the area (Figure 1).

The topography of the study area is very flat and consists of quaternary sediments, where clay soils in the low-lying areas and soils of medium textural compositions in the highland areas are predominant (Brammer, 2014). Climatically, the study area is located in a tropical zone with a dry winter period (December to March) and moist monsoon period (June-August), receiving an average minimum rainfall of about 1800 mm/yr (Azam, 2011).

Methods

With a view to analyzing the morphological variability of gastropods, a total of 2160 gastropod (*Pila globosa*) samples were collected for a consecutive six month period from July 1 to December 30, in a monthly basis over the two consecutive years of 2013 and 2014. The total of 2160 gastropod samples generated from: 30 samples from each locality*06 months = 180 samples, after two years, 180 samples*02 years*06 localities = 2160 samples. Considering the easy accessibility and availability with abundance of gastropod molluscs, the samples were collected within the six localities from the six south-west coastal districts in Bangladesh namely, *Khulna* (*Katkata Beel* of *Uttar Bedkashi* under *Koyra Upazila*; *Melakpuraikathi* of *Godaipur* and *Chandkhali union* under *Paikgacha Upazila*), *Satkhira* (*Paromanandakathi* of *Moutala* under *Kaliganj Upazila*, *Rudrapur* of *Vurulia*, *Hasarchalk Beel* of *Patchsatabigha* of *Iswaripur* and *Munshigonj Union* of *Shyamnagar Upazila*), *Bagerhat* (*Surigati Beel* under *Chitalmari Upazila*, *Borobondher Beel*, *Chuchramari*, *Malomgacha*, *Teligati* under *Morrelganj Upazila*, *Baniakhali Beel*, *Baniakhali*, *Khontakata* under *Sarankhola Upazila*), *Gopalganj* (*Chanda Beel* under *Muksudpur Upazila*), *Jessore* (*Borenga Beel*, *Borenga*, *5 no. Mangalkot*; *Pacaroi Beel*, *Pacaroi*; *Basuntia Beel*, *Basuntia* under *Keshabpur Upazila*) and *Pirojpur* (*Dakatia Beel*, *Dakatia*, *Durgapur*; ponds of *Pirojpur municipality*; *Dakkhin Gabtola Beel*, *Dakkhin Gabtola*, *Shikdar Mollik* under *Pirojpur Sadar Upazila*).

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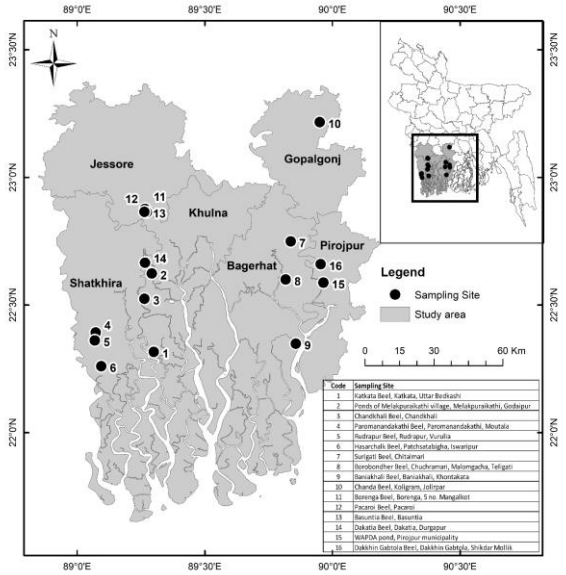

Figure 1. Sampling sites of the six localities (*Khulna*, *Satkhira*, *Jessore*, *Bagerhat*, *Pirojpur* and *Gopalganj*) in south-western Bangladesh.

The samples were collected following standard procedure using net and immediately brought to the laboratory for the analysis. The samples were preserved using 70% ethanol. The morphological parameters of the collected samples such as, height (L1), width (L2), aperture length (L3), aperture width (L4), dry shell mass, dry body mass and thickness of animals (Table 1) were determined in the laboratory by using slide-calipers and fine balance according to Begum el al. (2009).

The water samples from the habitat were collected monthly over six months from six sampling locations and the collected samples were analyzed for pH, temperature, DO (dissolved oxygen), EC (electrical conductivity), TDS (total dissolved solid) and salinity in the laboratory by following standard methods (APHA, 1995), while the soils of the *Pila* habitats were also collected from six sampling localities and analyzed for pH, EC, salinity, calcium, magnesium, phosphorous, sodium, potassium and organic carbon contents following the standard procedure as described in Ramesh and Anbu (1996).

Statistical analyses were performed to understand the spatial variability and relationships among morphological parameters, water and sediment quality parameters. The analysis of variance (ANOVA) was performed to understand the significant spatial variability of the morphological parameters of the gastropod molluscs in different parts of south-western Bangladesh, while the covariance analysis (ANCOVA) was performed to understand the significant influence of various covariates on morphological parameters in different localities. Moreover, factor analysis (FA) as a multivariate statistical tool was performed to assess the factors controlling the mollusc's variability in different localities of coastal Bangladesh.

Table 1. Measurement of individual morphological parameters.

Morphological Parameter	Definition	Figure
L1	Length-1/L1 is the height of *Pila globosa* measured from its apex to aperture in cm.	
L2	Length-2/L2 is the width of the gastropod (*Pila globosa*) in cm.	
L3	Length-3/L3 is the aperture length of the gastropod (*Pila globosa)* in cm.	
L4	Length-4/L4 is the aperture width of the gastropod (*Pila globosa*) in cm.	
Dry shell mass	After removing the soft parts of body from the gastropod shell and then the mass of the dry shell (gm) of the mollusc was measured.	
Thickness of Operculum	The measurement procedure of the thickness (cm) of the operculum with the slide calipers is shown.	
Dry body mass	After drying in oven for three days under 65-70^{0}C, the soft body dry mass (gm) was obtained.	

Results and Discussion

Morphological Variability of the Molluscs (Pila globosa)

The mean monthly variations of the morphological parameters of the gastropod molluscs (*Pila globosa*) are presented in Figure 2 and Figure 3. Moreover, the variability of the mean values of the morphological parameters of the gastropod molluscs (*Pila globosa*) from the six districts of the south-western coastal areas of Bangladesh is presented in Figure 4.

The figure (Figure 4) shows that the maximum mean value of the morphological parameter of L1 (height) is found to be 4.57 cm at *Satkhira* and the minimum value is 4.24 cm at *Khulna*. The maximum mean value of the thickness is found to be 0.14 cm at *Gopalganj* and the minimum value is 0.12 cm at *Jessore*. The maximum mean value of the dry shell mass is found to be 8.32 gm at *Satkhira* and the minimum value is 7.38 gm at *Jessore*, whereas the maximum mean value of the dry body mass is found to be 2.80 gm at *Satkhira* and the minimum value is 2.21 gm at *Khulna*.

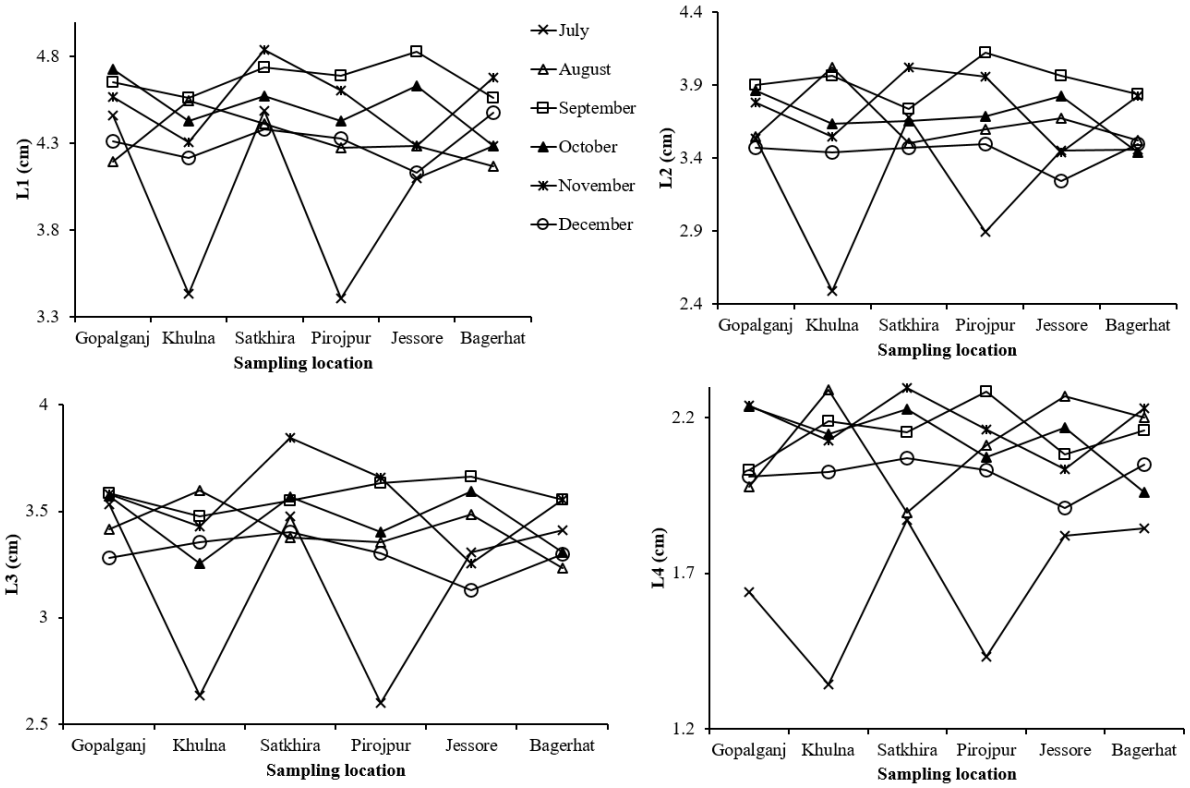

Figure 2. Variability of the monthly mean values of the morphological parameters (L1, L2, L3 and L4) of *P. globosa*.

The descriptive statistics of the morphological parameters of the gastropod molluscs for six districts show that in *Gopalganj* the dry shell mass of the gastropods varies from 2.01 to 23.65 gm with a mean of 7.87 gm and the standard deviation of 3.80. In *Khulna*, the dry shell mass varies from 1.38 to 22.70 gm with a mean of 7.39 gm and the standard deviation of 3.61. In *Satkhira*, it varies from 1.09 to 22.94 gm with a mean of 8.33 gm and the standard deviation of 4.08 and in *Pirojpur*, it varies from 1.42 to 21.93 gm with a mean of 7.51 gm and the standard deviation of 3.79.

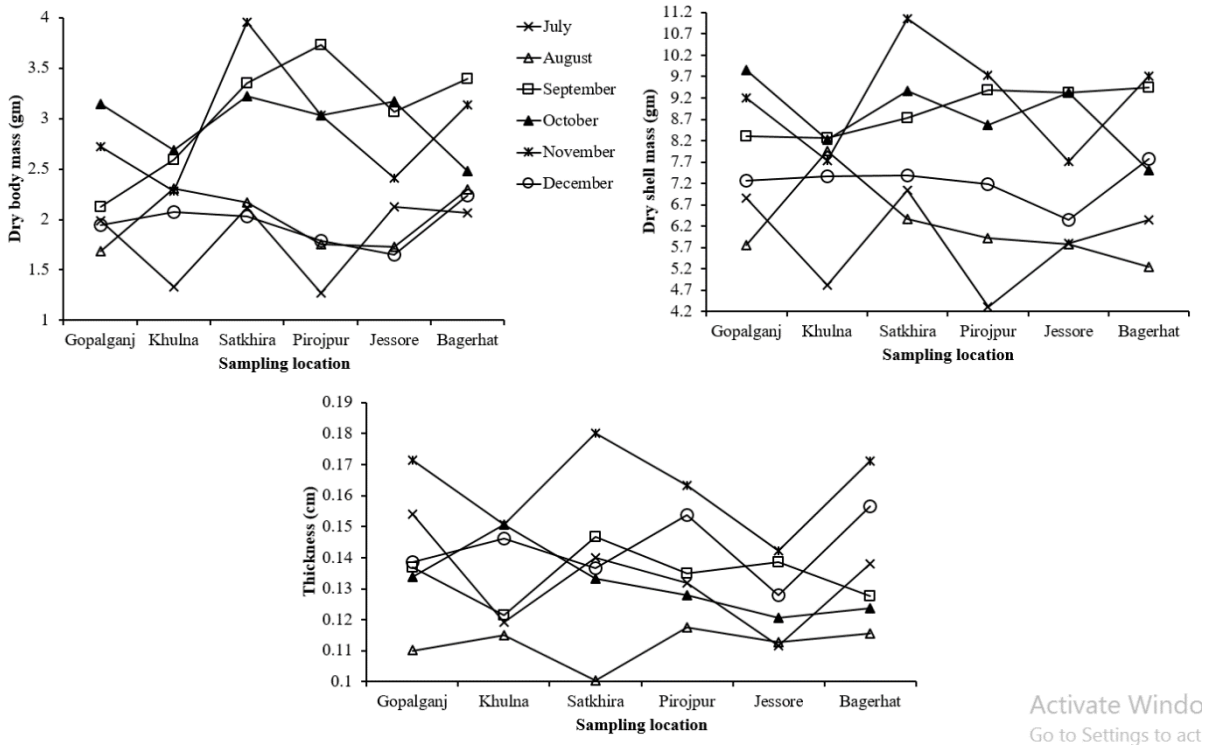

Figure 3. Variability of the monthly mean values of the morphological parameters (Dry body mass, dry shell mass and thickness) of *P. globosa*.

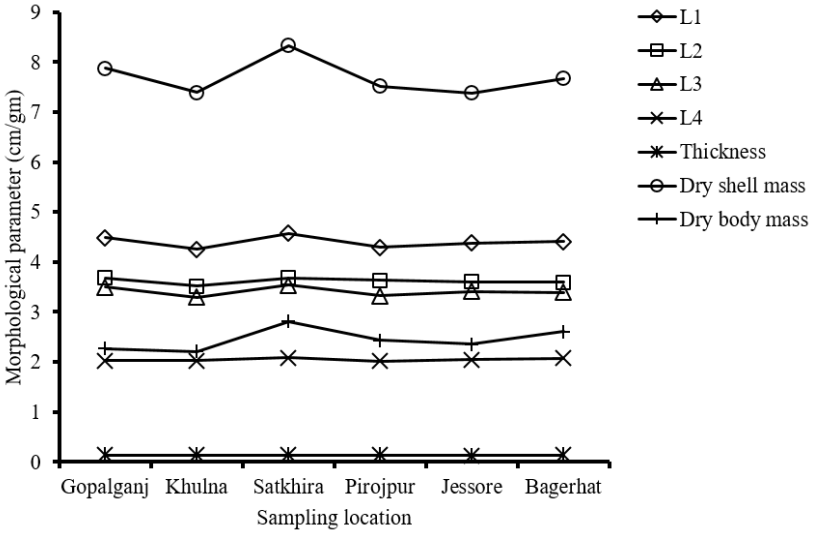

Figure 4. Variability of the mean values of the morphological parameters of *P. globosa* from six localities of the south-western coastal Bangladesh.

In *Jessore*, it varies from 1.23 to 25.62 gm with a mean of 7.38 gm and the standard deviation of 3.75 and in *Bagerhat*, it varies from 1.26 to 20.54 gm with a mean of 7.67 gm and the standard deviation of 4.08. These statistics of the dry shells mass show that *Satkhira* and *Bagerhat* have the highest variation in the dry shell mass of the gastropods. In *Gopalganj*, the dry body mass of the gastropods varies from 0.07 to 10.08 gm with a mean of 2.27 gm and a standard deviation of 1.48 and in *Khulna*, it varies from 0.24 to 6.93 gm with a mean of 2.21 gm and a standard deviation of 1.35. In *Satkhira*, the dry body mass of the gastropods varies from 0.39 to 8.30 gm with a mean of 2.81 gm and a standard deviation of 1.74 and in *Pirojpur*, it varies from 0.31 to 8.29 gm with a mean of 2.44 gm and a standard deviation of 1.53.

In *Jessore*, the dry body mass of the gastropods varies from 0.37 to 11.56 gm with a mean of 2.36 gm and a standard deviation of 1.64 and in *Bagerhat*, it varies from 0.28 to 9.78 gm with a mean of 2.60 gm and a standard deviation of 1.67. The statistics of the dry body mass show that *Satkhira* has the highest variation in the dry body mass of the gastropods among the six districts of the south-western coastal area of Bangladesh and this variability is due to the differences in their habitat composition and close connection to the sea as compared to the other districts in the south-western coastal area.

The morphological parameters also show that the maximum monthly mean value of L1 (height) is found to be 4.84 cm in November and the minimum monthly mean value is found to be 3.40 cm in July, whereas the maximum monthly mean value of thickness is found to be 0.18 cm in November and the minimum monthly mean value is found to be 0.10 cm in August. This variability is due to the occurrence of gastropod growth in November (Dunithan et al., 2012; Schöne et al., 2005; Colvin et al., 2022).

The one-way analysis of variance (ANOVA) shows that there is a significant spatial morphological variability of *P. globosa* in the morphological parameters such as heights (L1: $F_{(5, 2154)}$=10.29, P=0.000), width (L2: $F_{(5, 2154)}$=3.33, P=0.005), aperture lengths (L3: $F_{(5, 2154)}$=10.42, P=0.000), dry shell mass ($F_{(5, 2154)}$=3.16, P=0.008) and thickness of the molluscs ($F_{(5, 2154)}$=3.97, P=0.001) among different localities of the districts in the south-west coastal Bangladesh at 1% level of significance.

The analysis of covariance (ANCOVA) shows (Table 2) that the water salinity significantly affects the aperture length of the animal (L3: F=3.34, P=0.05); the electrical conductivity of soil significantly affect both the height (L1: F=3.32, P=0.05) and aperture length (L3: F=4.62, P=0.032); the sodium contents of the soil significantly affect the aperture length of the animal (L3: F=3.18, P=0.075) under different localities of the districts of the south-west coastal Bangladesh. It is found that both water salinity and electrical conductivity of the soil significantly affect the mollusc's shell morphology at 5% level while sodium contents of the soil significantly affect at 10% level. Bhuyain et al. (2020) also found similar results that the water salinity significantly affects the morphological structure of gastropod molluscs at the *Cox's Bazar* coast of Bangladesh. These results reveal that the morphological variability of the gastropod *P. globosa* is linked to complex ecological systems and habitat variation including the habitat's water and soil quality and it might be linked to many drivers such as temperature, food availability, intraspecific competition etc. (Márquez et al., 2015; Oteguia et al., 2019; Matos et al., 2020).

Factors Analysis of Environmental and Gastropod's Variability

R-mode factor analysis was performed on the mollusc morphological dataset, water quality dataset and soil quality dataset to explore the underlying factors controlling the animals morphological and environmental (soil and water) variability of the habitat from six coastal localities and the results of the factor analysis are given in Table 3. Table 3 shows only the parameters that have high factor loadings and the factors that have eigenvalues greater than 1. The results of the R-mode factor analysis show that the six factors explain more than 75% of the total variance in gastropod's morphological and environmental (soil and water) variations of the six coastal districts in south-west Bangladesh.

The variables such as soil pH, soil EC, soil salinity and sodium contents of the soil have high loadings on factor 1 (explaining 21.30% of the total variance) and factor 1 can be termed as 'soil salinity factor' of the mollusc habitats which delineates the spatial zoning of the coastal districts and thereby, the distribution of molluscs (Begum et al., 2009; 2010). The variables such as height (L1), width (L2), aperture length (L3) and dry shell mass of the gastropods have high loadings on factor 2 (explaining 17.55% of the total variance) and factor 2 can be termed as '*P. globosa* morphology' which advocates that the morphological variability of the mollusc is linked to the habitat's

ecological conditions and environmental quality (Dunithan et al., 2012; Márquez et al., 2015; Begum et al., 2018). The variables such as soil calcium and soil magnesium have high loadings on factor 3 and factor 3 can be termed as 'soil alkalinity' which advocates that the soil alkaline environment can influence the distribution of molluscs (Ganguly et al., 2020). The variables such as water EC and water TDS have high loadings on factor 4 and factor 4 can be termed as 'water salinity' which advocates that the water salinity can influence the distribution of gastropods.

Table 2**.** ANCOVA test for the morphological parameters of *P. globosa* from six localities in the south-west coastal Bangladesh.

Covariates	Dependent variable					
	Aperture length (L3)			Height (L1)		
	Mean square value	*F*-value	*P*-value	Mean square value	*F*-value	*P*-value
Water salinity	1.03	3.34	0.05	--	--	--
Soil's electrical conductivity (EC)	1.42	4.62	0.032	1.67	3.31	0.05
Soil's sodium contents	0.98	3.17	0.07	--	--	--

Table 3. Factor analysis for understanding the environmental and morphological variability.

Parameter	Factor 1	Parameter	Factor 2	Parameter	Factor 3
Soil Na	0.946	L1	0.918	Soil Ca	-0.802
Soil pH	0.861	L2	0.910	Soil Mg	0.868
Soil salinity	0.946	L3	0.878		
Soil EC	0.952	Dry shell mass	0.915		
Initial eigenvalue	4.687	*Initial eigenvalue*	3.863	*Initial eigenvalue*	3.067
Percentage of variance	21.303	*Percentage of variance*	17.557	*Percentage of variance*	13.940
Cumulative % of variance	21.303	*Cumulative % of variance*	38.860	*Cumulative % of variance*	52.800
Parameter	Factor 4	Parameter	Factor 5	Parameter	Factor 6
Water EC	0.919	Water temperature	0.767	Water pH	0.764
Water TDS	0.923				
Initial eigenvalue	2.441	*Initial eigenvalue*	1.379	*Initial eigenvalue*	1.183
Percentage of variance	11.095	*Percentage of variance*	6.266	*Percentage of variance*	5.378
Cumulative % of variance	63.895	*Cumulative % of variance*	70.161	*Cumulative % of variance*	75.539

The variable such as water temperature has high loadings on factor 5 and factor 5 can be termed as 'water physical quality' which advocates that the physical quality of water can influence the distribution of gastropods (Dunithan et al., 2012). The variable such as water pH has high loadings on factor 6 and factor 6 can be termed as 'water chemical quality' which advocates that the chemical quality of water can influence the distribution of gastropods.

Conclusion

Freshwater gastropods are important environmental archives and play a vital role in maintaining ecological balance in the complex south-west coastal system of Bangladesh. The analyses of gastropods (*P. globosa*) from the six

localities of the six coastal districts of south-west coastal Bangladesh revealed significant morphological variability among the localities and such morphological variability was largely influenced by environmental and habitat parameters and other ecological-ecosystem factors. However, more local data on the gastropod molluscs (*P. globosa*) over long period of time is required to acquire a detailed picture of the morphology and driving forces. This will enable researchers to calibrate the model animal so that this could act in climate reconstruction research and sustainable management of the complex coastal ecosystem.

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Conflicts of Interest
The authors declare no conflict of interest.

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