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Seasonal Trends of Freshwater Gastropods in Relation to Physicochemical Variables in the Upper Brahmaputra Basin, Assam, India

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ABSTRACT

Background: Limited scientific exploration and documentation have been conducted on the diversity, morphology, physiology, biochemical characteristics and nutritional value of gastropods in this region. The study attempts to present an outline of freshwater gastropods and highlight the significance of physicochemical variables in clarifying their distribution patterns in the upper Brahmaputra Basin of Assam.

Methods: Nine physicochemical parameters were analyzed across 20 sampling stations in four seasons: Pre-monsoon, monsoon, post-monsoon and winter, over three consecutive years, from 2022 to 2024. The Quadrat sampling method (quadrat size-1m^2) was followed by taking 10 random sampling sites in each sampling station for sampling across different stations. Diversity indices, principal component analysis (PCA), canonical correspondence analysis (CCA) and linear regression analysis were performed to explore the correlations between physicochemical parameters, sampling stations and freshwater gastropod assemblage.

Result: A total of 16,124 gastropod samples were collected, representing 18 species from three orders-Archaetaenioglossa, Sorbeoconcha and Hygrophila-and six families-Viviparidae, Ampullaridae, Thiaridae, Pachychilidae, Lymnaeidae and Planorbidae. One-way ANOVA substantiated that multiple physicochemical parameters were considerably distinct and Pearson correlation coefficients showed mild to strong links with the distribution of gastropods. Strong positive correlations were found for pH (r = 0.55), DO (r = 0.64) and TA (r = 0.75), while chloride content showed a negative connection (r = -0.30). Principal component analysis (PCA) and canonical correspondence analysis (CCA) revealed that pH, DO, TDS, TA and TH all play important roles in influencing gastropod distribution.

Key words: Endemic, Population density, Species diversity.

INTRODUCTION

The Brahmaputra river basin, with its vast habitat diversity and varied microclimates, hosts endemic freshwater mollusc species (Bolotov *et al.,* 2024; Sonowal *et al.,* 2021; Kardong *et al.,* 2016; Budha *et al.,* 2010). This basin is bestowed with range of habitats such as streams, wetlands, seagrass meadows and oxbow lakes. The diversity and richness of species in an aquatic ecosystem are influenced by factors such as resource availability, habitat structure and physicochemical properties as well as other factors affecting species dispersal and colonization (Kohler *et al.,* 2012). Temperature, dissolved oxygen, pH and salinity are the chief factors that mould the composition, distribution and abundance of gastropods and to evaluate the functionality of an ecosystem, monitoring these variables is essential (Salawu *et al.,* 2014). It has been observed that some physicochemical parameters influence the distribution and abundance of molluscan populations in Poba Reserve, Assam, India (Chutia and Kardong, 2021).

Gastropods are highly diversified class of phylum Mollusca that includes a broad taxonomic group of invertebrates (Lydeard *et al.,* 2004). They occupy a pivotal position in the food chain and it is known to configure the benthic macroinvertebrates (Strong *et al.,* 2008). Many freshwater gastropods are highly sensitive to pollutants and human impact on aquatic ecosystems, making them valuable indicators of biodiversity and ecosystem health (Bogan *et al.,* 2008). In northeastern India, freshwater ecosystems face threats from pollution, dam construction and habitat destruction. Additionally, various freshwater gastropod species have served as traditional food sources for indigenous communities in the Northeast. Certain snail gastropods serve as intermediate hosts for various parasitic diseases that affect both livestock and humans (Alam *et al.,* 2010). Despite their critical ecological

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significance, limited scientific research has been conducted on freshwater molluscs in the northeast region (Kardong *et al.,* 2016). It was reported that the studies on freshwater molluscs are restricted mostly to diversity, distribution and nutritional values, but the studies are confined to the southern peninsula as well as the Indo-Burma region (Budha, 2005; Ramesha *et al.,* 2013; Subavathy, 2020; Jesintha *et al.,* 2022). Despite the ecological and cultural significance of freshwater gastropods in the Brahmaputra River basin, there is a lack of comprehensive studies on their distribution and response to environmental changes. This study aims to assess the distribution and habitat preferences of freshwater molluscs in the Brahmaputra basin, with a focus on understanding how physicochemical parameters influence their populations.

MATERIALS AND METHODS

Sampling

20 distinct sampling stations were established across various major aquatic bodies in the upper Brahmaputra basin of Assam (Fig 1). Within each station, 10 random sampling sites were selected for sampling. The Quadrat method (quadrat size-1 m^2) was followed for sampling. The sampling was carried out during four different seasons: pre-monsoon, monsoon, post-monsoon and winter, over three consecutive years: 2022 to 2024.

Collection of samples and laboratory analysis

Large samples were handpicked, while a Surber net sampler with a mesh size of 0.5-1 mm^2 was used for smaller samples. The collected samples were sorted into representative morphotypes and their quantities were recorded before being transported to the laboratory for further examination. Water samples from each sampling site were collected seasonally using Tarsons PP/HDPE-100 containers to assess nine different physicochemical variables: pH, water temperature (WT), free carbon dioxide (FCO_2), dissolved oxygen (DO), total alkalinity (TA), total dissolved solids (TDS), total hardness (TH), chloride content (Cl^-) and nitrate content (NC). pH was measured with a digital pH meter and water temperature was measured with a mercury bulb thermometer. The remaining variables were analyzed according to APHA standards (Sorensen, 2007).

Identification

The morphological identification of the collected specimens was done following Preston, (1915); Subba Rao, (1989); Ramakrishna and Dey, (2007) and the literature available in the molluscabase.org.

Statistical analysis

A one-way ANOVA was conducted using GraphPad Prism 8 software to assess the significance of differences in physicochemical variables. Diversity indices, principal component analysis (PCA) and canonical correspondence analysis (CCA) were performed with paleontological statistics software (PAST version 4.03) to explore the correlations between physicochemical parameters, sampling stations and gastropods. Linear regression analysis was employed to evaluate the relationship between physicochemical variables and taxa richness by using GraphPad Prism 8 software and MS-Excel. During this process, variables with insignificant p-values were progressively removed from the regression model, leaving only those variables that were significantly related to taxa richness ($p<0.05$).

RESULTS AND DISCUSSION

Effects of physicochemical variables on the distribution pattern of freshwater gastropods

The One-way ANOVA of nine variables were carried out to check the significant difference at $p<0.05$ (Table 1).

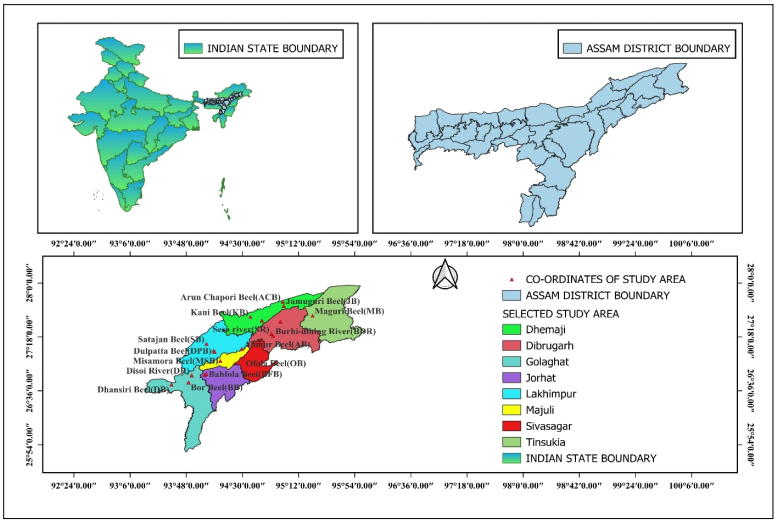


Fig 1: Map of study area with co-ordinates.

The present study detailed the particulars of the influence of physicochemical parameters on the seasonal distribution pattern of gastropods along the upper Brahmaputra basin. The study recorded the highest pH value of 8.36±0.2 during the monsoon season at sampling station MB and the lowest pH value of 6.9±0.5 at KB and SN during post-monsoon, with an average pH value of 7.59±0.12 across all the stations. A significant difference was observed in pH, p = 0.04 at all sampling stations and the Pearson coefficient (r)= 0.55, which infers that gastropods can endure reasonable pH variations and this result coincides with the previous finding as noted by Dodiya and Poriya (2024).

The essence of water temperature in the growth and development of a macro-benthic organism in an aquatic ecosystem can be understood from the study of Nirar and Valparai (2017). The present study recorded maximum WT at MSB (31.4°C±0.5) during the monsoon and the minimum was recorded at TB (18.1°C±0.7) during winter, resulting in a mean temperature of (27.09±0.18). The observations of the present study are consistent with the result of Vase *et al.* (2018), which recorded maximum temperature during summer and lowest during winter. The recent study recorded a statistically significant difference of p<0.0001 in temperatures in all the twenty sampling stations and Pearson coefficient (r) value of 0.49, which indicates a moderate correlation between the two.

DO was recorded highest at JB during the monsoon and lowest at DR during winter with, a mean value of 8.74±0.2. The collective consequence of higher wind rate, heavy precipitation, freshwater influx, influence of deposits and high biological activity (Garg *et al.,* 2009) are the reasons for high values observed during monsoon. The Pearson coefficient (r)=0.64 value indicates a moderate positive correlation with the gastropod community, which is in accordance with Satheeshkumar and Khan (2012). The TDS were highest at OB and lowest at BB during pre-monsoon, with a mean value of 186.15±0.8. The p-value = 0.009 was statistically significant and the Pearson coefficient (r) = 0.57 implies moderate positive correlation with the gastropod community, which is in accordance with the results as detailed by PIP (1987).

TA was highest at MSB (68±0.18) during pre-monsoon and lowest at BDR (19.4±0.72) during monsoon, with an average of 44.87±1.6 during pre-monsoon. The reason for the elevated values of DO during the pre-monsoon season may be due to increased biological activity, decreased dilution and evaporation concentration. During the study, significant difference in p value = 0.04 was observed and TA was found to have strong positive correlation with the gastropod population with Pearson coefficient (r = 0.75), which is parallel with the finding as documented by Hoverman *et al.* (2011). Maximum chloride content was recorded at SR (32.4±1.2), (38.5±1.5) and (40.5±0.9) during pre-monsoon, post-monsoon and winter, respectively, while during monsoon it was recorded highest at MB (31.4±0.5). Minimum value was recorded at BFB (1.4±0.2), (2.5±0.8), (3.2±0.5) and (5.8±1.1) throughout the four seasons with a mean value of (16.33±1.5). Recorded P value = 0.03. The present study showed that chloride content was found to be negatively correlated (r = -30), which coincides with previous studies which have shown that high concentration of chloride has negative effect on unionid mussels, particularly, glochidia (Gills, 2011). The maximum total hardness (TH) was recorded at MB (234.5±0.6) and the lowest at SB (91.4±85), with average values of (151.14±4.6) and p value = 0.04, during pre-monsoon and winter, respectively. The recorded Pearson coefficient (r)=0.70 during the study period shows a strong positive correlation with the gastropod population. Some previous findings on the effect of total hardness on gastropods distribution conform with the present result, excluding the findings as documented by Strzelec (2014). P values for free carbon dioxide and nitrate content were found to be insignificant and they were discarded from further analysis and discussion.

Abundance and density

A total of 16,124 specimens of freshwater gastropods were collected across four seasons from 20 different sampling stations over two years. The study identified 18 species of freshwater gastropods from six families across the various sampling stations throughout the different seasons (Table 2 and Fig 2). During the study period, it was found that

Table 1: Range of physicochemical parameters across different sampling stations with Pearson correlation coefficients (p-value<0.05 indicates significance).

Physicochemical variables	Range (min-max)	Pearson coefficient (r)	P-value
pH	6.9±0.5-8.36±0.2	0.55	0.04
WT (°C)	18.1±0.7-31.4±0.5	0.49	0.0001
FCO_2 (mgL^{-1})	0.74±0.08-3.4.8±0.3	-0.01	0.21
DO (mgL^{-1})	4.2±0.8-12.5±0.4	0.64	0.007
CL^- (mgL^{-1})	1.4±0.7-38.5±0.9	-0.30	0.03
TH (mgL^{-1})	91.4±0.6-234.5±0.8	0.70	0.04
TA (mgL^{-1})	19.4±0.72-68±0.2	0.75	0.04
TDS (mgL^{-1})	150.4±1.1-245±0.9	0.57	0.009
NC (mgL^{-1})	0.15-0.92±0.06	0.27	0.208

Table 2: Seasonal variation of abundance and density (pre-monsoon, monsoon, post-monsoon and winter).

Genus/Species	Pre-monsoon		Monsoon		Post-monsoon		Winter	
	Abundance	Density	Abundance	Density	Abundance	Density	Abundance	Density
Mekongia crassa	0.33±0.51	0.28±0.03	0.23±0.11	0.08±0.01	0.34±0.16	0.17±0.1	0.26+0.12	0.17±0.05
Filopaludina bengalensis	1.86±0.12	1.43±0.32	0.76±0.21	0.30±0.12	2.1±0.12	1.22±0.15	2.1±0.06	1.58±0.02
Filopaludina micron	1.13±0.26	1.06±0.27	0.27±0.22	0.06±0.03	0.89±0.14	0.58±0.13	1.9±0.11	1.06±0.07
Idiopoma dissimilis	0.42±0.17	0.14±0.02	0.24±0.17	0.11±0.04	0.46±0.08	0.23±0.09	0.60±0.07	0.24±0.04
Angulyagra microchaetophora	0.86±0.15	0.51±0.19	0.26±0.15	0.06±0.03	0.74±0.07	0.53±0.8	1.05±0.06	0.39±0.06
Angulyagra oxytropis	0.97±0.13	0.55±0.17	0.14±0.10	0.03±0.01	0.82±0.06	0.20±.08	1.2±0.14	0.44±0.12
Pila globosa	1.24±0.12	0.69±0.16	1.25±0.09	0.61±0.03	1.29±0.05	0.66±0.2	1.4±0.05	5.52±0.03
Pila olea	0.81±0.11	0.5±0.15	0.30±0.12	0.09±0.02	0.68±0.07	0.41±0.07	0.59±0.04	0.46±0.11
Pila theobaldi	0.43±0.10	0.41±0.14	0.29±0.08	0.13±0.02	0.73±0.07	0.41±0.05	0.59±0.06	0.23±0.02
Mieniplotia scabra	0.54±0.14	0.32±0.1	0.15±0.05	0.08±0.04	0.63±0.05	0.34±0.05	0.71±0.04	0.42±0.03
Melonoides tuberculata	0.41±0.11	0.28±0.11	0.08±0.02	0.05±0.02	0.32±0.07	0.16±0.03	0.38±0.02	0.21±0.08
Tarebia lineata	0.76±0.15	0.39±0.13	0.11±0.09	0.10±0.02	0.18±0.06	0.11±0.02	0.47±0.04	0.27±0.02
Brotia costula	0.72±0.10	0.39±0.11	0.50±0.11	0.17±0.02	0.88±0.06	0.63±0.07	1.11±0.10	0.73±0.08
Radix rufescens	0.51±0.02	0.24±0.11	0.41±0.11	0.18±0.02	0.75±0.03	0.26±0.07	0.87±0.05	0.46±0.5
Racesina ovalior	0.47±0.12	0.33±0.12	0.40±0.10	0.21±0.05	0.61±0.08	0.30±0.06	0.79±0.05	0.39±0.04
Indoplanorbis exustus	1.12±0.09	0.55±0.13	0.51±0.09	0.27±0.02	0.66±0.06	0.28±0.06	0.80±0.05	0.38±0.09
Gyraulus convexiusculus	0.81±0.13	0.55±0.12	0.14±0.05	0.06±0.01	0.40±0.05	0.18±0.05	0.47±0.04	0.21±0.02
Intha umbilicalis	0.72±0.12	0.45±0.12	0.27±0.09	0.09±0.02	0.42±0.01	0.22±0.05	0.43±0.02	0.24±0.06

Values are expressed in mean ± SE.

throughout the four seasons, the abundance of *Filopaludina bengalensis* was recorded highest: Pre-monsoon (1.86±0.12), monsoon (0.76±0.21), post-monsoon (2.1±0.0.06) and winter (2.1±0.0.06) with mean value of 1.73±0.48, while *Mekongia crassa was* recorded lowest during the pre-monsoon (0.33±0.11) and winter (0.26+0.12) with mean value of 0.46±0.04. During monsoon and post-monsoon, the lowest values were recorded with *Tarebia lineata* (0.11±0.09 and 0.18±0.06, respectively) among all the recorded species.

Density was recorded highest with *Filopaludina bengalensis* (1.43±0.32), (1.22±0.15*),* (1.58±0.02) during pre-monsoon, post-monsoon and winter, respectively, while *Pila globosa* was recorded maximum (2.1±0.3) during monsoon and it was recorded lowest with *Idiopoma dissimilis* (0.14±0.02), *Gyraulus convexiusculus* (0.06±0.01, *Tarebia lineata* (0.11±0.02), respectively, among all the recorded species. Density was recorded highest with *Filopaludina bengalensis* (1.43±0.32), (1.22±0.15*),* (1.58±0.02) during pre-monsoon, post-monsoon and winter, respectively, while *Pila globosa* was recorded maximum (2.1±0.3) during monsoon and it was recorded lowest with *Idiopoma dissimilis* (0.14±0.02), *Gyraulus convexiusculus* (0.06±0.01), *Tarebia lineata* (0.11±0.02) and *Mekongia crassa* (0.17±0.05) during pre-monsoon, monsoon, post-monsoon and winter, respectively. Increase in water temperature, pH, dissolved oxygen, alkalinity and dissolved solids was correlated with high occurrence of density and abundance (Bath and Dhillon, 1999). The collective consequence of the alkaline nature of water, dissolved oxygen, chloride content and dissolved solids might be ascribed to the present study on the richness of gastropods, which afford them an upright habitat to dwell in. During the study period, the seasonal values of abundance and density were found to be statistically significant, where p=0.0003 (abundance) and p = 0.0002 (density).



A. *Mekongia crassa* B. *Filopaludina bengalensis* C. *Filopaludina micron* D. *Idiopoma dissimilis* E. *Angulyagra microchaetophora* F. *Pila globosa* G. *Pila olea* H. *Pila theobaldi* I. *Mieniplotia scabra* J. *Melonoides tuberculata* K. *Tarebia lineata* L. *Brotia costula* M. *Radix rufescens* N. *Racesina ovalior* O. *Indoplanorbis exustus* P. *Gyraulus convexiusculus*. Photo: J. Sanong.

Fig 2: Shells of some of the recorded freshwater gastropods from upper Brahmaputra Basin (dorsal and ventral view).

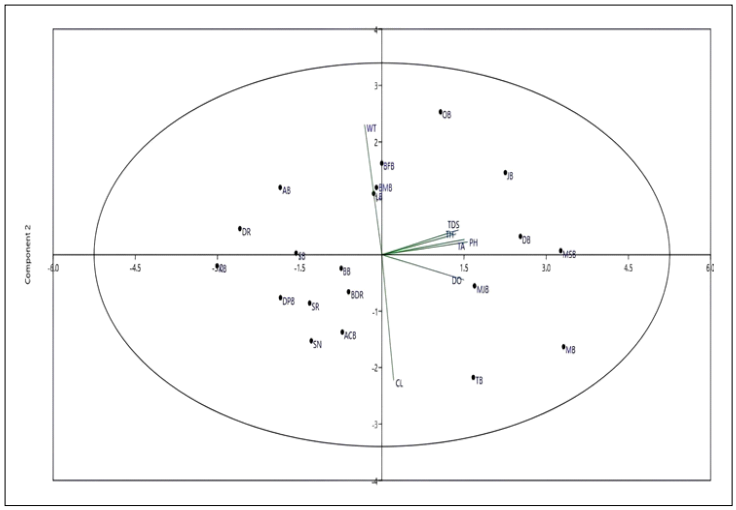


Fig 3: Scatter plot of PCA using seven statistically significant physicochemical variables of water: pH, WT, DO, Cl^-, TA, TH and TDS.

Table 3: Diversity indices among the (pre-monsoon, monsoon, post-monsoon and winter).

Sampling	Pre-monsoon			Monsoon			Post-monsoon			Winter		
stations	S	1-D	H	S	1-D	H	S	1-D	H	S	1-D	H
MB	12±2.1	0.90±0.02	2.4±0.14	8±0.82	0.88±0.05	2.18±0.24	13±1.5	0.91±0.05	2.48±0.5	14±1.3	0.92±0.14	2.59±0.52
MJB	8.75±1.4	0.84±0.03	2.1±0.99	6±0.54	0.79±0.06	1.65±0.64	9±0.9	0.86±0.05	2.06±0.6	10±0.2	0.89±0.01	2.25±0.9
SR	2.5±0.3	0.43±0.09	0.80±0.42	2±1.12	0.30±0.05	0.51±0.43	2±0.7	0.65±0.02	1.07±0.5	3±0.7	0.65±0.04	1.07±0.3
BDR	2.25±0.7	0.51±0.01	0.75±0.35	2±0.62	0.41±0.09	0.60±0.24	2±0.2	0.47±0.04	0.66±0.7	3±0.5	0.65±0.03	1.07±0.8
BMB	1.25±0.6	0.77±0.01	1.58±0.31	3±0.23	0.70±0.12	0.35±0.09	6±0.4	0.80±0.05	1.70±0.1	6±0.3	0.80±0.04	1.68±0.6
OB	9±0.6	0.85±0.09	2.03±0.28	7±0.71	0.83±0.15	1.87±0.81	8±0.7	0.83±0.12	1.90±0.6	11±0.5	0.89±0.05	2.25±0.7
LB	7.75±0.6	0.83±0.02	1.96±0.27	6±0.54	0.79±0.32	1.66±0.97	9±0.3	0.87±0.08	2.12±0.3	8±0.7	0.86±0.02	1.98±0.3
BFB	7.71±0.2	0.80±0.08	1.88±0.25	5±0.35	0.70±0.08	1.40±0.28	9±0.5	0.84±0.03	1.94±0.7	9±0.3	0.88±0.06	2.15±0.5
DB	7.25±0.5	0.81±0.05	1.88±0.24	5±0.34	0.79±0.21	1.74±0.34	7±0.6	0.80±0.06	1.76±0.5	9±0.3	0.86±0.08	2.03±0.9
BB	7.5±0.6	0.82±0.09	1.92±0.23	7±0.81	0.82±0.56	1.82±0.46	8±0.8	0.81±0.07	1.80±0.3	7±0.6	0.86±0.05	1.99±0.2
DR	2.5±0.5	0.45±0.08	0.86±0.22	2±0.63	0.31±0.12	0.32±0.14	3±0.2	0.71±0.04	1.30±0.8	3±0.3	0.65±0.12	1.08±0.4
JB	8.5±0.4	0.87±0.08	2.22±0.21	4±0.51	0.83±0.09	1.92±0.91	11±0.7	0.88±0.02	2.25±0.5	9±0.6	0.91±0.13	2.45±0.5
TB	9.25±0.4	0.85±0.04	2.09±0.22	5±0.48	0.78±0.05	1.67±0.36	8±0.2	0.87±0.05	2.17±0.6	13±0.8	0.90±0.04	2.35±0.7
ACB	4±0.4	0.51±0.08	1.16±0.20	2±0.32	0.24±0.07	0.31±0.14	7±0.6	0.71±0.03	1.31±0.6	4±0.2	0.83±0.08	1.77±0.6
KB	4.25±0.4	0.74±0.08	1.56±0.20	3±0.25	0.63±0.08	1.03±0.53	3±0.3	0.77±0.04	1.58±0.8	5±0.5	0.84±0.07	1.87±0.4
SB	2.25±0.5	0.47±0.08	0.67±0.20	2±0.11	0.45±0.02	0.64±0.24	3±0.6	0.49±0.06	0.68±0.2	2±0.5	0.50±0.03	0.69±0.7
DPB	5.75±0.4	0.80±0.07	1.71±0.19	3±0.35	0.69±0.05	1.27±0.85	7±0.4	0.85±0.05	1.95±0.3	8±0.8	0.87±0.03	2.05±0.5
SN	1.5±0.3	0.29±0.07	0.43±0.18	1±0.62	0.14±0.09	0.20±0.05	1±0.6	0.33±0.07	0.51±0.2	2±0.8	0.43±0.05	0.62±0.7
AB	3±0.42	0.68±0.06	1.36±0.18	1±0.27	0.43±0.11	0.69±0.25	2±0.2	0.84±0.05	1.85±0.4	4±0.2	0.79±0.02	1.59±0.3
MSB	9.25±0.41	0.85±0.08	2.13±0.16	6±0.38	0.79±0.34	1.65±0.39	10±0.8	0.88±0.03	2.21±0.6	10±0.8	0.89±0.05	2.32±0.4

Taxa richness (S), Simpson index (1-D) and Shannon-Weiner index (H) were highest at MB (12±2.10), (0.90±0.02) and (2.4±0.14) during pre-monsoon; (8±0.82), (0.88±0.05) and (2.18±0.24) during monsoon; (13±1.5), (0.91±0.05) and (2.48±0.53) during post-monsoon; and (14±1.3), (0.92±0.14) and (2.59±0.52) during winter respectively (Table 3). The lowest taxa richness (S) was observed at BMB, AB, SN and SB with (1.25±0.6), (1±0.27), (1±0.6), (2±0.5) during pre-monsoon, monsoon, post-monsoon and winter, respectively. The Simpson index(1-D) and Shannon-Weiner index (H) and Shannon-Weiner index (H) were count least at SN with (0.29±0.07), (0.14±0.09), (0.33±0.07), (0.43±0.05) and (0.43±0.18), (0.20±0.05), (0.51±0.2), (0.62±0.7) during pre-monsoon, monsoon, post-monsoon and winter respectively (Table 3).

The present study found a pattern of low species diversity during monsoon and high diversity during pre-monsoon, post-monsoon and winter across the sampling stations, which is in accordance with previous studies (Raut *et al.,* 2005). Maximum diversity and richness during pre-monsoon, post-monsoon and winter may be due to steady physicochemical variables such as pH, WT, DO, TA and TDS during these seasons. Earlier observation (Field *et al.,* 1982) noted that diversity of a species is governed chiefly by the variations of physicochemical variables, wherein the present observations conform with it. The scatter plot diagram of PCA (Fig 3) depicts that the sampling stations are of different environmental conditions since there is no overlapping of the physicochemical variables. It can be drawn from the ordination diagram (Fig 4) that *P. globosa*, *R. ovalior, I. dissimilis*, *A. microchaetophora*, *I. umbilicalis* were associated with moderate to high concentration of pH, DO and TA than other physicochemical variables, whereas *B. costula, P. olea, A. oxytropis, F. bengalensis* and *F. micron* flourished under high concentration of TH and TDS. Furthermore, *M. scabra, M. tuberculata* and *T. lineata* were linked to WT. It was found that out of the seven physicochemical variables, the taxa richness was negatively

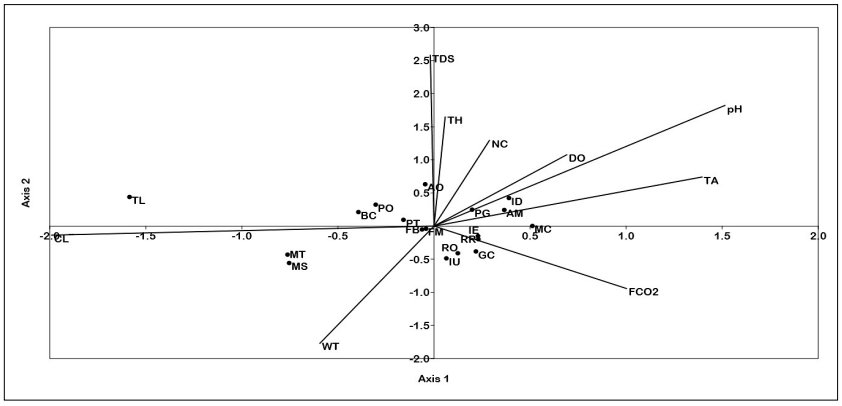


Fig 4: Ordination diagram of physicochemical variables and taxa richness.

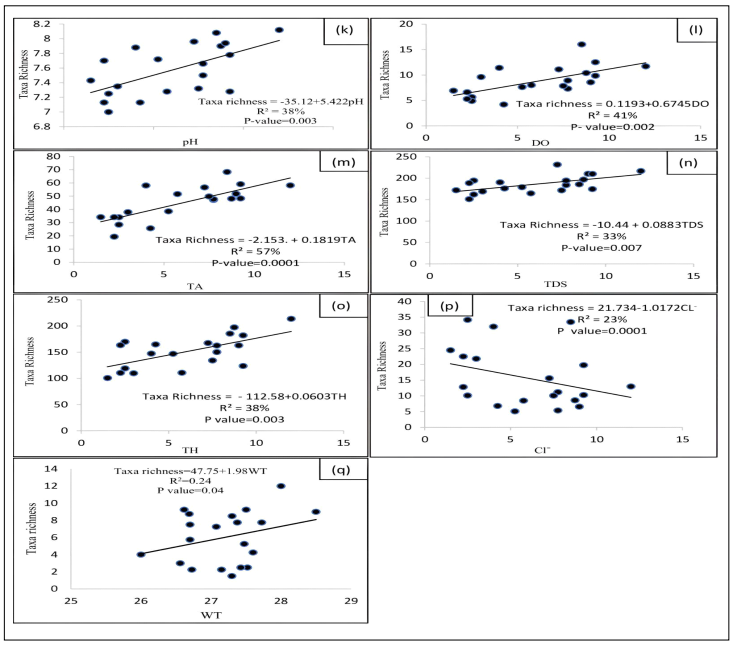


Fig 5: Linear regression equation for the (k) pH (l) DO (m) TA (n) TDS (o) TH (p) Cl^- (q) WT.

correlated to chloride content (R^2 = 23%, p = 0.0001; Fig 5), which conforms with the finding as documented by (Uttam *et al.,* 2022), while the rest are positively correlated.

CONCLUSION

The current study highlights the significance of environmental factors in determining freshwater gastropod abundance and dispersion. Different gastropod species exhibited varying levels of tolerance to specific physico-chemical conditions. Findings revealed that freshwater gastropods diversity and distribution in the upper Brahmaputra basin are influenced by a combination of factors, with species-specific responses. Key parameters affecting these patterns included water temperature (WT), pH, dissolved oxygen (DO), chloride (Cl^-), total alkalinity (TA), total hardness (TH) and total dissolved solids (TDS). Our study revealed that the sampling stations SR, BDR and AB had high concentrations of chloride ions, which could explain the reduced taxa richness and densities at these locations. Moreover, linear regression analysis showed no significant relationship between taxa richness and taxa density.

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Authors' contributions

This work was carried out in collaboration between the three authors. Author James Sanong originated the research ideas, drafted the manuscript and analyzed and interpreted the data. Author(s) Devid Kardong and Jyotish Sonowal did the idea formulation, data analysis and reviewed and edited the manuscript. The three authors read and finalized the manuscript.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

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