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Insights into the Diversity and Distribution of Gastropods in River Kana Damodar (Kaushiki), West Bengal, India: A Spatial Perspective

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ABSTRACT

This study aimed to assess the spatial distribution, diversity, and community composition of gastropods in the anthropogenically altered Kana Damodar River (Kaushiki), West Bengal, India. Monthly collections of gastropods were conducted at five sampling sites (KD1-KD5) during the 2019-20 and 2021-22 sampling periods using various sampling methods. Three diversity indices were computed: dominance index, Shannon-Weiner index, and Margalef's richness index. Hierarchical cluster analysis using the Bray-Curtis similarity matrix and one-way analysis of similarities (ANOSIM) were employed to evaluate the spatial organization and dissimilarity of gastropod assemblages across the sampling sites. Eleven (11) gastropod species, distributed across eight (8) families, were recorded from five sampling stations. The study revealed significant spatial variability in species composition, with *Filopaludina bengalensis* and *Radix rufescens* being the most dominant species. The dominance index showed a prevalence of a few opportunistic species, with values ranging from 0.24 to 0.46. The Shannon-Weiner index (H') ranged from 0.55 to 1.98, indicating low species diversity across all stations, which suggests potential vulnerabilities in ecosystem stability of the studied river. Margalef's richness index showed notable variation in species richness, with values ranging from 0.79 to 1.55, suggesting reduced gastropod diversity in the studied river. Hierarchical cluster analysis and ANOSIM further underscored the spatial heterogeneity of gastropod communities across the studied river. The findings of this study highlight the urgent need for targeted conservation and site-specific management strategies to address the unique ecological challenges at each sampling station in the River Kana Damodar (Kaushiki).

INTRODUCTION

Gastropods are a ubiquitous group of macrobenthic fauna in aquatic ecosystems, playing a crucial role in freshwater habitats. They typically reside in sediment-rich bottom zones, where they exhibit strong responses to environmental changes. This sensitivity makes them invaluable for studying the intricate relationships between organisms and their environment, highlighting their significance in biological monitoring **(Zeybek Yünlü *et al.*, 2012; Ghosh & Panigrahi, 2018; Ghosh *et al.*, 2021a)**.

The community structure of gastropods is influenced by a variety of factors related to water and soil quality, the presence of macrophytes, and the shading provided by riparian areas **(Ghosh & Panigrahi, 2018; Lewin *et al.*, 2023)**. Most snails are adapted to lentic (still water) environments, with only a limited number of species found in lotic (flowing water) habitats **(Strzelec & Królczyk, 2004)**.

Freshwater gastropods, though constituting only about 5% of the global gastropod fauna, are experiencing significant declines in diversity due to habitat alteration, pollution, and climate change **(Bae & Park, 2020)**. These threats are particularly pronounced in developing countries, where rapid urbanization and industrialization often coincide with poor environmental regulations. This makes river systems in regions such as India particularly prone to biodiversity loss, with freshwater molluscs, including gastropods, being among the most affected groups.

The River Kana Damodar (Kaushiki) in West Bengal, India, exemplifies this vulnerability. As an eastern distributary of the Damodar River, it plays a crucial role in the Damodar River Basin but has been heavily impacted by pollution and anthropogenic pressures over the years **(Rao & Mamatha, 2004)**. The ongoing degradation of water and sediment quality results from both point (PS) and non-point sources (NPS) **(Singh *et al.*, 2005; Ghosh & Panigrahi, 2024)**. The Kana Damodar flows through densely populated areas, where industrial effluents, agricultural runoff, and sewage disposal have significantly degraded its water and sediment quality. As a result, the local gastropod populations in this river may provide key insights into the broader ecological health of the river system and its ability to support biodiversity **(Strong *et al*., 2008)**. However, to date, no comprehensive assessment has been made of the gastropod community in this anthropogenically altered river. Therefore, this study aimed to assess the diversity and abundance of gastropod species along the Kana Damodar (Kaushiki) River, providing valuable insights into the overall ecosystem health of the river.

MATERIALS AND METHODS

Monthly collections of gastropod specimens were conducted at specified sampling sites (KD1-KD5) along the Kana Damodar River during two sampling periods: 2019-20 and 2021-22 (Fig. 1). These sites experience varying degrees of ecological stress primarily due to human activities. KD1 and KD4 are heavily impacted by agricultural runoff and macrophyte congestion, indicating nutrient enrichment and water quality degradation. KD2 and KD3 face significant pollution from waste disposal and commercial activities, with additional stress from nearby crematoriums. KD5 suffers the most severe contamination, driven by industrial discharge, commercial waste, and domestic sewage, resulting in severe water quality degradation and ecological imbalance. To ensure comprehensive sampling, various sampling methods were employed based on site-specific conditions. In deeper areas, a grab sampler was used, and soil samples were sieved to extract gastropods. In shallow regions, a surber sampler was utilized for effective sampling of benthic organisms. A D-frame net was employed in macrophyte-infested areas to collect gastropods among aquatic plants. Moreover, handpicking was occasionally performed to ensure thorough sampling in inaccessible areas. At each sampling site, three replicates were collected during each visit to ensure data accuracy and reliability. The collected data were then converted into gastropod abundance per square meter to facilitate further analysis. The identification of the gastropod specimens followed the guidelines and keys provided by **Rao (1989)** and **Ramakrishna and Dey (2007)**.

In this research, three diversity indices were computed: dominance index, Shannon-Weiner index, and Margalef's richness index using PAST software version 4.11.

Dominance index

The dominance index is a quantitative measure utilized to evaluate the prevalence of particular species within a specific community. This index was calculated using the following equation **(Simpson, 1949)**:

$$D = \sum_{i=1}^{s} n(n-1)/N(N-1)$$

Where, n is the total number of individuals of a specific species, and N is the total number of individuals of all species.

Shannon-Weiner index

The Shannon-Wiener index (H') is a widely utilized measure in community ecology that integrates both species richness (the number of various species present) and species evenness (the relative abundance of each species) within a community. This index was calculated through the following equation **(Shannon, 1948)**:

$$H' = \sum_{i=1}^{s} -(P_i * \ln P_i)$$

$$Where, \quad P_i = \frac{n_i}{N}$$

Where, P_i = proportion of the sample made up of species i; N = total number of individuals of all species in community; n = number of individuals of species i; S = numbers of species encountered; $\sum$ = sum from species 1 to species S.

Margalef's Richness index

Margalef's index, developed by Spanish ecologist Ramon Margalef, is a measure of species diversity that emphasizes species richness.

The formula for Margalef's richness index (R) was calculated as follows **(Margalef, 1968)**:

$$R = \frac{(S-1)}{lnN}$$

Where, S is the total number of species observed, N is the total number of individuals sampled, and ln(N) is the natural logarithm of the total number of individuals.

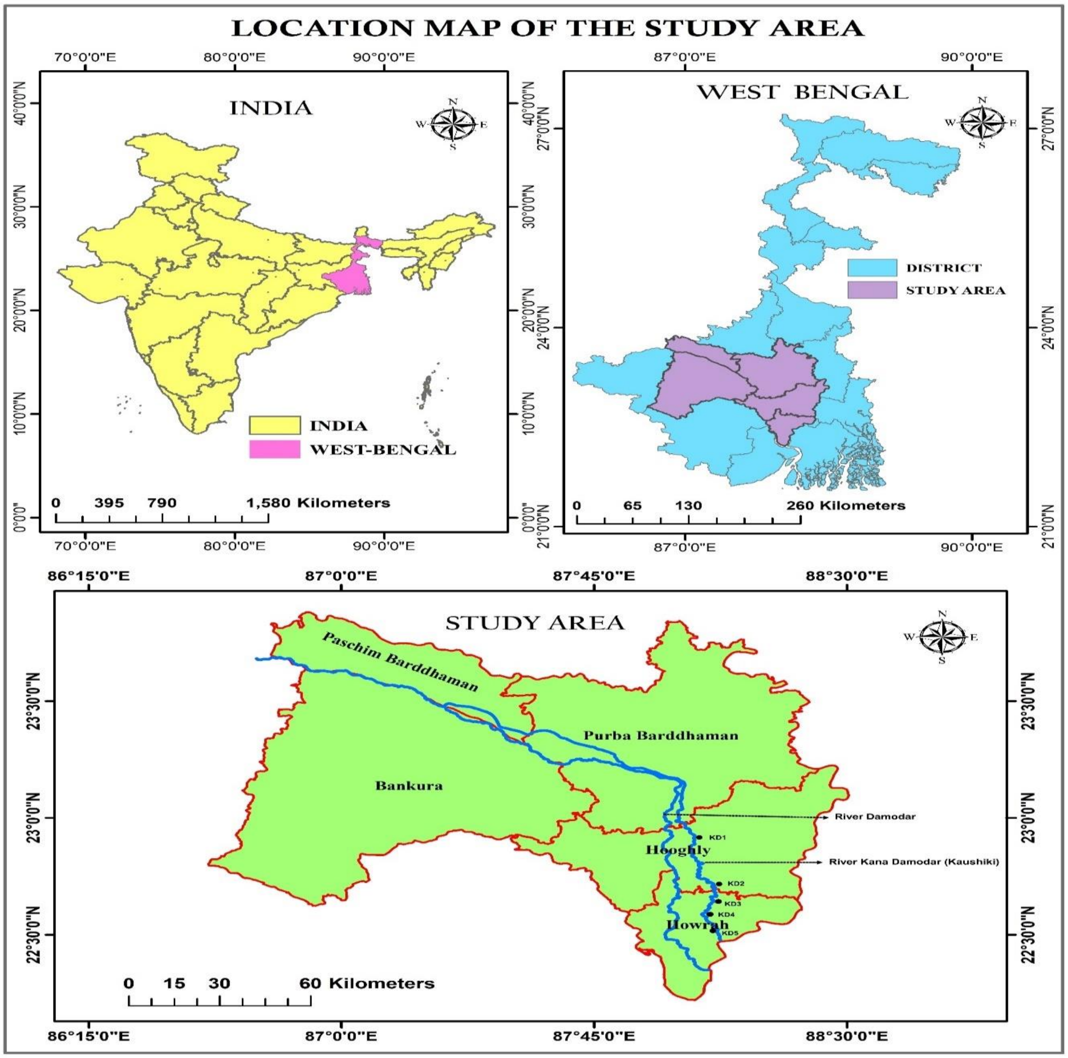

Fig. 1. Study area map showing the location of the gastropod sampling sites along the River Kana Damodar (Kaushiki)

Hierarchical cluster analysis and ANOSIM

To gain insight into the spatial organization of gastropod assemblages, a hierarchical cluster analysis was conducted using the Bray-Curtis similarity matrix. This matrix was derived from log (x+1) transformed species abundance data (No. of snails: 3476). Furthermore, one-way analysis of similarities (ANOSIM) was employed to statistically evaluate the dissimilarity and variation in gastropod community composition across the different sampling sites along the Kana Damodar (Kaushiki). A high ANOSIM R-value close to 1 indicates distinct differences between groups, while a value close to 0 suggests no difference.

ANOSIM was conducted using PAST software version 4.11, while hierarchical cluster analysis was performed using R.

RESULTS

A total of eleven gastropod species, distributed across eight families, were recorded from the Kana Damodar (Kaushiki) River (Table 1). Among these, *Filopaludina bengalensis* exhibited the highest abundance with 728 individuals, followed by *Radix rufescens* with 447 individuals. On the lower end of the abundance spectrum, *Tarebia granifera* and *Bithynia (Digoniostoma) pulchella* were the least abundant, with 8 and 3 individuals, respectively.

The study revealed significant spatial variability in the abundance and diversity of gastropod species across the five sampling stations (KD1 to KD5) along the Kana Damodar River. At KD1, six species were identified, with *Brotia costula* (G2) being the most abundant, while *Pila globosa* (G1) and *Tarebia granifera* (G4) were the least abundant. KD2 had seven species, with *Radix rufescens* (G10) as the most abundant, and *Pila globosa* (G1) as the least abundant. KD3 exhibited the highest species richness, with eight species, where *Filopaludina bengalensis* (G7) was the most abundant and *Pila globosa* (G1) the least. KD4 had seven species, with *Radix rufescens* (G10) being the most abundant, while *Bithynia (Digoniostoma) pulchella* (G6) had the lowest abundance. Finally, KD5, the site with the lowest species richness, had five species, with *Radix rufescens* (G10) as the most abundant and *Melanoides tuberculata* (G3) as the least abundant.

Table 1. Checklist of available gastropod species recorded in the River Kana Damodar (Kaushiki)

Family	Species	Code
Ampullariidae	*Pila globosa (Swainson, 1822)*	G1
Pachychilidae	*Brotia costula (Rafinesque, 1833)*	G2
Thiaridae	*Melanoides tuberculata (O. F. Müller, 1774)*	G3
	Tarebia granifera (Lamarck, 1816)	G4
	Tarebia lineata (Gray, 1828)	G5
Bithynidae	*Bithynia (Digoniostoma) pulchella (Benson, 1836)*	G6
Viviparidae	*Filopaludina bengalensis (Lamarck, 1822)*	G7
Bulinidae	*Indoplanorbis exustus (Deshayes, 1833)*	G8
Planorbidae	*Gyraulus convexiusculus (T. Hutton, 1849)*	G9
Lymnaeidae	*Radix rufescens (J. E. Gray, 1822)*	G1
	Racesina luteola (Lamarck, 1822)	G1

A one-way ANOVA, followed by post-hoc analysis, revealed significant differences (at the 0.05 significance level) in various diversity indices of the gastropod community across different sampling stations of the River Kana Damodar (Kaushiki).

The mean dominance index during the first year of study (2019-2020) showed significant variation across the sampling stations. KD1 had the highest mean dominance index (0.45 ± 0.07), which was significantly different from KD2 and KD3 ($P < 0.05$). KD5 had the second-highest mean dominance index (~0.40), not significantly different from KD1 but distinct from KD2 and KD3. KD2 and KD4 had similar mean dominance index values, ranging from 0.28 to 0.30, with no significant difference between them or with KD3. KD3 had the lowest mean dominance index (0.24 ± 0.09). During the second year of study (2021-22), KD1 exhibited the highest mean dominance index (0.46 ± 0.05) and was significantly different from KD2, KD3, and KD4. KD5, with the second highest mean dominance index (0.41 ± 0.1), was not significantly different from KD1 but was distinct from KD2, KD3, and KD4. KD4, KD3, and KD2 were not significantly different from each other ($P < 0.05$) (Fig. 2a, b).

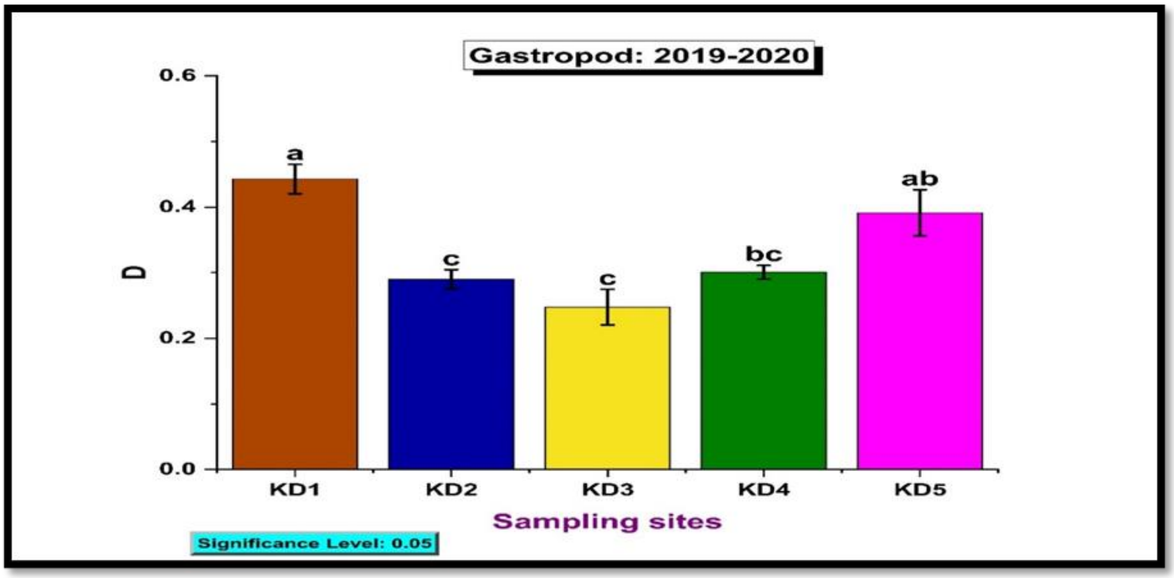

Fig. 2a. Spatial variation in the dominance index of gastropod communities in River Kana Damodar (Kaushiki) during 2019-20

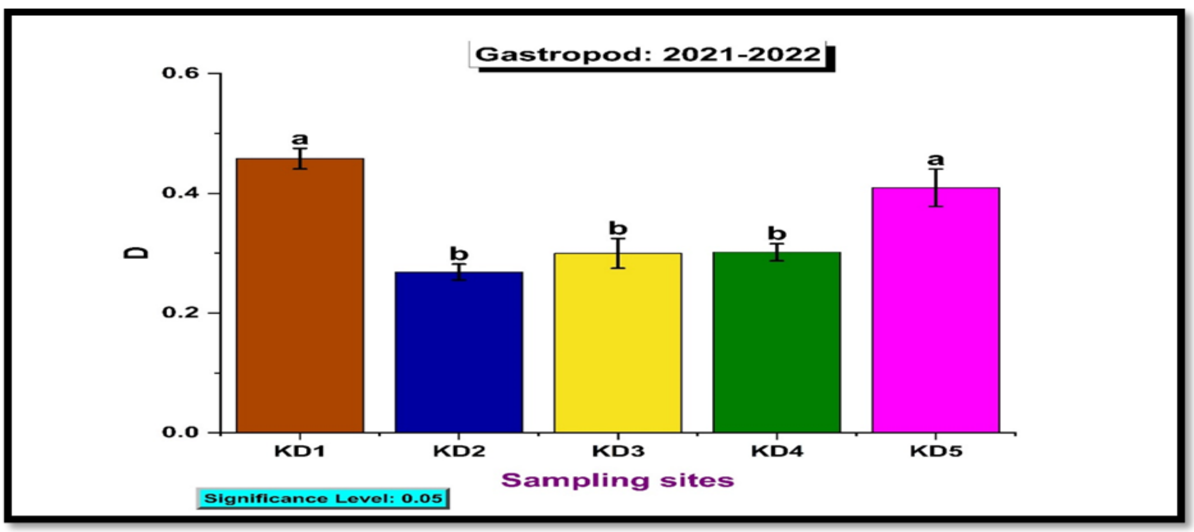

Fig. 2b. Spatial variation in the dominance index of gastropod communities in River Kana Damodar (Kaushiki) during 2021-22

The Shannon-Weiner diversity index also varied significantly across the sampling stations. KD3 had the highest mean value (1.58 ± 0.23), significantly higher than KD1 (0.92 ± 0.17). KD2 had a mean value of 1.36, not significantly different from KD3 but higher than KD1. KD4 and KD5 had similar mean values (around 1.3), which were not significantly different from each other or from KD2, but both were higher than KD1. KD1 had the lowest mean value, which was significantly lower than all other stations. During the second sampling period (2021-2022), KD3 had the highest mean value (1.61 ± 0.29) and was significantly higher than KD1, KD4, and KD5 ($P < 0.05$). KD2 had a mean value of 1.41, not significantly different from KD3 but higher than KD1 and KD5 ($P<$ 0.05). KD4 had a mean value of 1.32, not significantly different from KD2 and KD5 but higher than KD1 ($P<$ 0.05). KD5 had a mean value of 1.14, which was significantly different from KD3 but not from KD2 and KD4 ($P<$ 0.05). KD1 had the lowest mean value (0.85 ± 0.18) and was significantly lower than all other stations ($P<$ 0.05) (Fig. 3a, b).

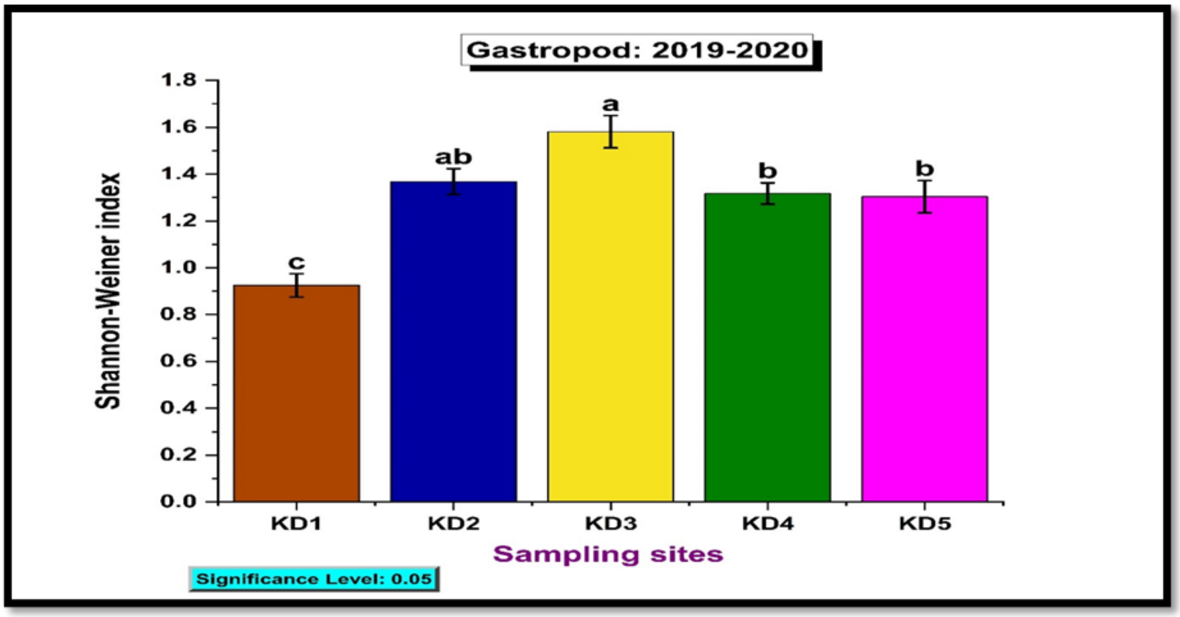

Fig. 3a. Spatial variation in the Shannon-Weiner index of gastropod communities in River Kana Damodar (Kaushiki) during 2019-20

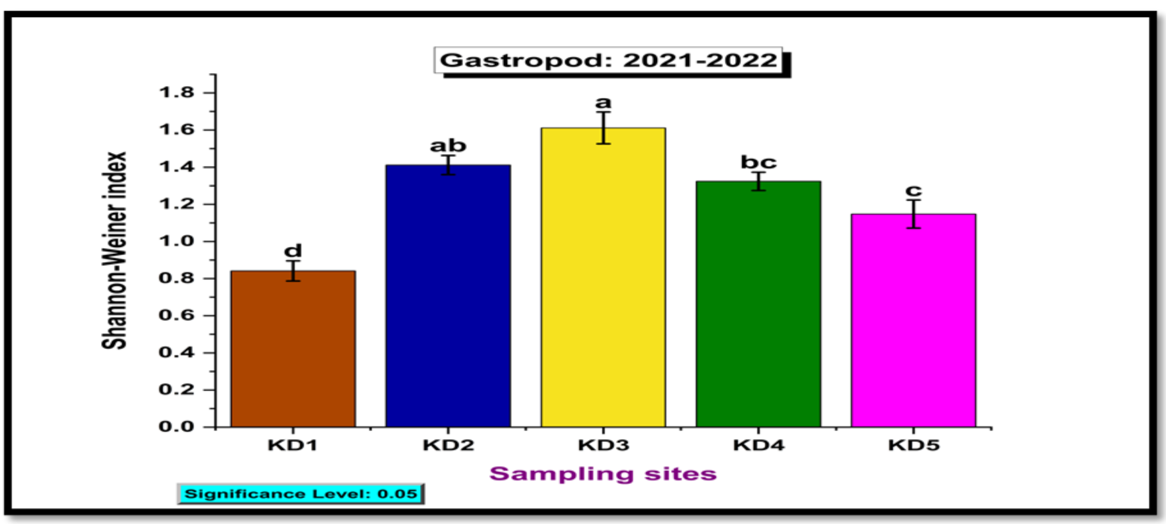

Fig. 3b. Spatial variation in the Shannon-Weiner index of gastropod communities in River Kana Damodar (Kaushiki) during 2021-22

Margalef's richness index also revealed significant variations across the five sampling stations (KD1 to KD5). During the first-year of study (2019-20), KD3 stood out with the highest mean value (1.55 ± 0.31), distinguishing itself from all other stations. In contrast, KD1 had the lowest mean value (0.69 ± 0.24), significantly lower than the others. The mean values for KD2 (1.12 ± 0.29), KD4 (1.04 ± 0.31), and KD5 (1.06 ± 0.22) were similar to each other, not showing significant differences among them but notably higher than KD1. During the 2021-2022 sampling period, Margalef's richness index showed significant variations across the five stations (KD1 to KD5), based on Tukey's post-hoc test at a 0.05 significance level. KD2 had the highest mean value (1.19 ± 0.35), similar to KD3 (1.19 ± 0.28) and KD4 (1.11 ± 0.36), with no significant differences among them. KD5 had a mean of 0.91 ± 0.22, not significantly different from KD2, KD3, and KD4. KD1 had the lowest mean value (0.79 ± 0.13), significantly lower than KD2 and KD3 ($P < 0.05$) (Fig. 4a, b).

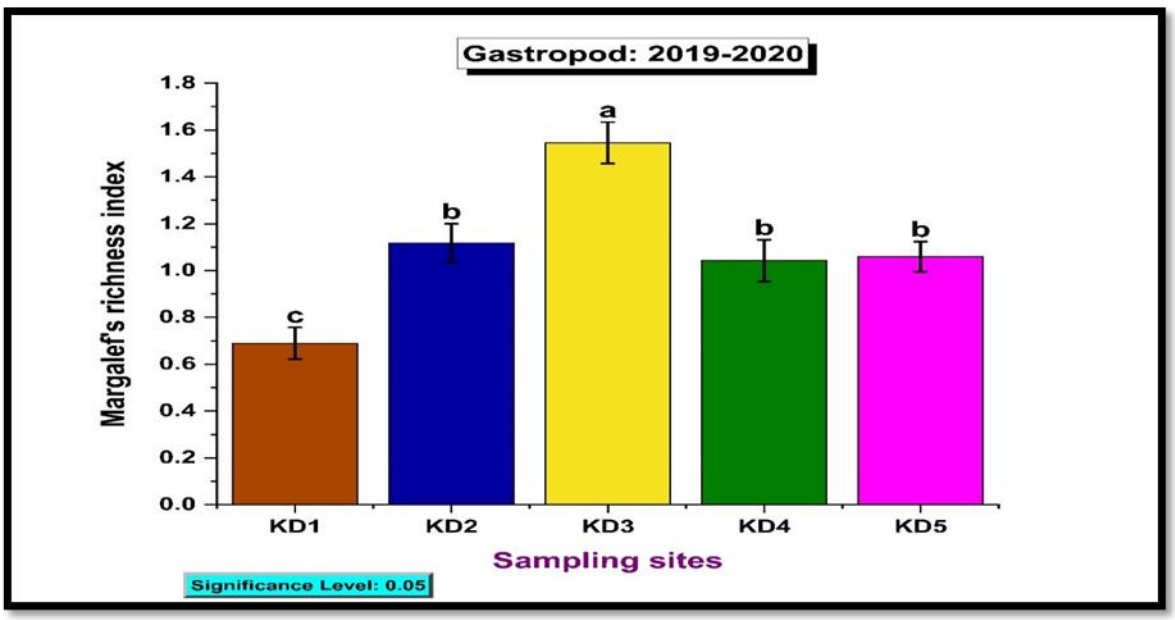

Fig. 4a. Spatial variation in the Margalef's richness index of gastropod communities in River Kana Damodar (Kaushiki) during 2019-20

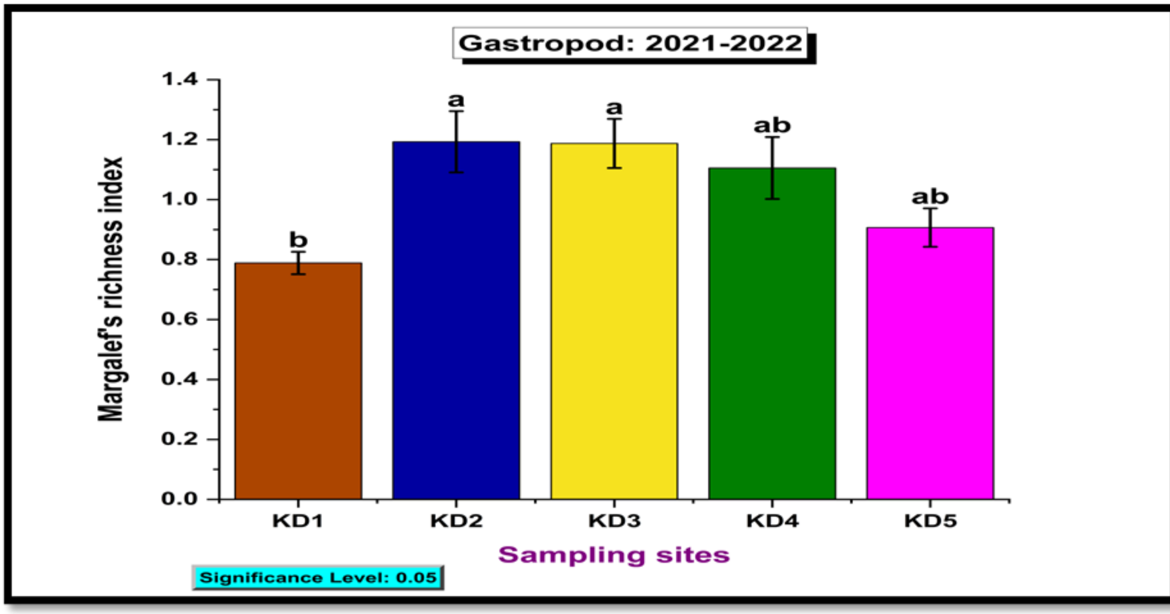

Fig. 4b. Spatial variation in the Margalef's richness index of gastropod communities in River Kana Damodar (Kaushiki) during 2021-22

Hierarchical cluster analysis of gastropod data from the five sampling stations of the River Kana Damodar (Kaushiki) revealed three distinct clusters, indicating significant heterogeneity in the composition of the gastropod community (Fig. 5). KD1 and KD3 formed a separate cluster at a high dissimilarity level, suggesting unique environmental characteristics or disturbance regimes at these stations. KD2 and KD4 clustered together at a low dissimilarity level, indicating similar habitat conditions or gastropod assemblages. KD5 joined the KD2-KD4 cluster at a moderate dissimilarity level, sharing some characteristics with KD2 and KD4 but also exhibiting distinct features.

The analysis of similarities (ANOSIM) showed substantial differences in community composition among the sampling sites, with a global R value of 0.5844 and a highly significant *P*-value (< 0.01). KD1 showed strong dissimilarity with all other sites, indicating distinct community compositions. KD2 and KD4, as well as KD2 and KD5, did not show significant differences, suggesting similar community structures. KD3 exhibited significant dissimilarity with KD4 and KD5, while KD4 and KD5 displayed marginal dissimilarity.

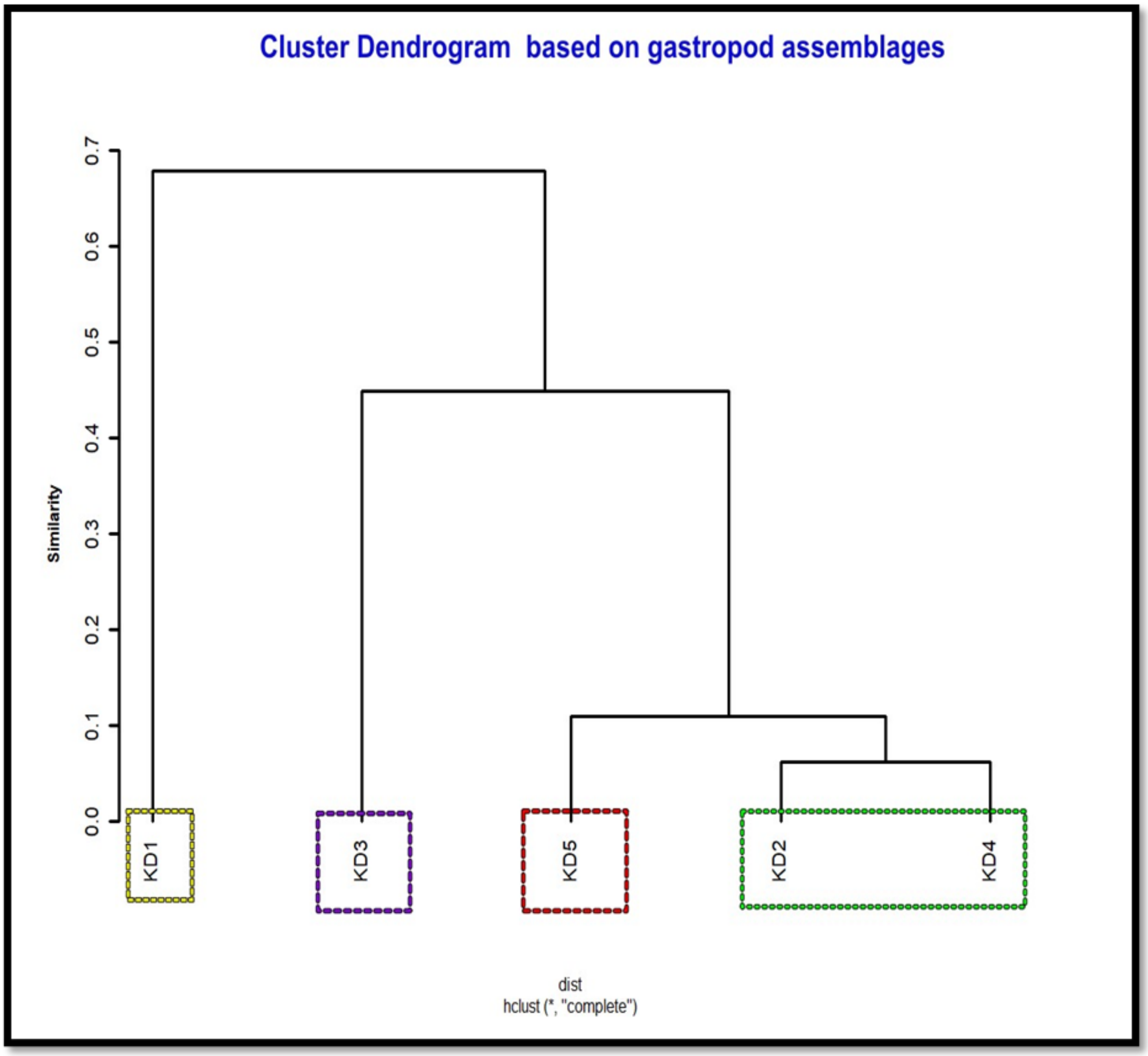

Fig. 5. Cluster dendrogram of sampling stations based on gastropod assemblages

DISCUSSION

The observed variability in gastropod abundance and diversity in the studied river is consistent with findings from previous studies conducted in other Indian rivers. For instance, **Roy and Gupta (2010)** identified 13 gastropod species from the Barak River and its tributaries in eastern India. **Kumar and Vyas (2012)** and **Raina *et al.* (2016)** similarly recorded 11 and 13 gastropod species in the Sip and Narmada rivers, respectively, consistent with the findings of the present study. In southern Bengal**, Majhi *et al.* (2018)** recorded 11 species of gastropods within the Bhagirathi-Hooghly River system upon which Kana Damodar River (Kaushiki) converges. Conversely, **Roy *et al.* (2022)** reported greater diversity, identifying 18 freshwater gastropod species along the entire stretch of the Ganga River. In contrast, **Sharma *et al*. (2013)** recorded a lower number of gastropod species in the Gho-Manhasan River in Jammu and Kashmir cities.

The dominance of *Filopaludina bengalensis* and *Radix rufescens*, as observed in the present study, corroborates the findings from other regions, such as the Sip River in central India **(Raina *et al.*, 2016)** and the Subarnarekha River in eastern India **(Pakhira & Chakraborty, 2018)**. A considerable number of air-breathing gastropods from the Lymnaeidae and Bulinidae families were observed at the most of the sampling stations. *Pila globosa* had low abundance in the studied River. The overexploitation for food could potentially explain the lower abundance of *Pila globosa* throughout the entire study period **(Chutia & Kardong, 2021)**.

A high value of the dominance index in a gastropod community indicates that certain opportunistic species have higher abundance or prevalence within the community compared to others **(Gallmetzer *et al.*, 2017; Rahmawati *et al.*, 2021)**. A high dominance index can lead to a shift in the overall species composition of the gastropod community, with a few dominant species overshadowing the others. The dominance of certain gastropod species can affect ecosystem stability **(Rahmawati *et al.*, 2021)**.

The Shannon-Weiner index (H') measures species diversity within a community, where lower values ($H' < 1$) indicate low diversity and vulnerability to environmental changes. Communities with moderate diversity ($1 < H' \leq 3$) are still at risk of instability, while those with high diversity ($H' > 3$) are highly resilient and stable **(Wilhm & Dorris, 1968; Roy *et al.*, 2014; Ghosh *et al.*, 2021b)**. In this study, the Shannon-Weiner index ranged from 0.55 to 1.98, indicating low diversity across all sampling stations. Low diversity in gastropods can result from habitat degradation, invasive species, pollution, and competition, leading to decreased ecosystem resilience and health **(Setyono *et al.*, 2019; Raković *et al.*, 2022)**.

The cluster dendrogram underscores the spatial heterogeneity of the Kana Damodar River (Kaushiki), with gastropod communities reflecting localized environmental gradients. The observed clustering patterns highlight the influence of site-specific factors on gastropod distribution and community composition. The ANOSIM results reinforce the findings from hierarchical cluster analysis, which also revealed similar spatial variation and grouping of sampling stations. This complementary analysis further supports the distinct community compositions identified across different sites.

In line with the observed variability in gastropod abundance and diversity, the ecological stress at the sampling sites plays a crucial role in shaping community composition. The extreme contamination at KD5 due to industrial discharge and waste pollution likely contributes to the dominance of opportunistic species, while agricultural runoff, macrophyte congestion, and low water level for most of the year at KD1 and KD4 may drive the reduced species diversity and ecosystem instability seen at these stations. In contrast, KD3 exhibited relatively better species richness, likely due to its consistently high-water levels throughout the year, which prevent it from drying up, and its relatively lower pollution levels.

CONCLUSION

The study reveals the precarious state of the gastropod community in the River Kana Damodar (Kaushiki), particularly at several sampling stations where low diversity and the dominance of a few opportunistic species indicate ecological imbalance and heightened vulnerability to environmental stressors, such as habitat degradation and overexploitation. The low Shannon-Weiner index values indicate possible risks to ecosystem stability, and the changes in community composition highlight the need for targeted conservation efforts. To maintain biodiversity and ecological health, the findings of this study emphasize the importance of developing site-specific river management strategies that account for the unique ecological conditions at each station. These strategies are crucial for ensuring long-term ecological balance and resilience in the river system.

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