Ichthyofaunal Diversity and Limnological Characteristics of the Kakodonga River Flowing in Golaghat District Assam, India

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ABSTRACT

The present study investigates the ichthyofaunal diversity and distribution patterns in relation to various limnological parameters across five sites along the Kakodonga River in the Golaghat district of Assam, India. A total of 46 fish species, 36 genera, 21 families, and 9 orders were recorded. The family Cyprinidae exhibited the highest species richness (eight species), followed by Danionidae (five species) and Sisoridae (four species). Total suspended solids (TSS) and conductivity (Con) had a significant positive influence on the spatial fish abundance, while dissolved oxygen (DO) and water temperature (Tem) significantly affected temporal variations in fish abundance. Canonical Correspondence Analysis (CCA) based on site-wise data, revealed that TSS and conductivity were the primary environmental variables shaping the spatial distribution of fish species, collectively explaining 79.11% of the total variance across the first two ordination axes. Site- specific fish assemblages were identified through Bray-Curtis analysis. The Shannon-Weiner diversity index (H), Pielou's evenness index (J), Simpson's diversity index ($1–\lambda$), and taxonomic distinctness (Δ^*) did not exhibit significant seasonal variation ($p \geq 0.05$). However, Margalef's richness index (d) and abundance per sampling event showed significant seasonal differences. Site-wise comparisons revealed significant differences in all diversity indices except for Pielou's evenness index, which remained consistent across sites. These findings provide essential baseline data for fish assemblages and their environmental drivers that can support future monitoring and conservation of the Kakodonga River ecosystem.

Keywords: Fish diversity, Kakodonga River, Limnological parameters, Species abundance

INTRODUCTION

Rivers are typical aquatic environments exhibiting rich biological diversity (Kottelat and Whitten, 1996) and play a crucial role in ecological functioning (Brown, 2000; Rowe *et al*., 2009). In particular, rivers in tropical regions are considered highly productive, characterized by diverse microhabitats and environmental gradients (Horowitz, 1978; Bhat, 2003). Among aquatic fauna, fish are central not only as a vital source of life-sustaining food but also for their contribution to national economies (Ross *et al*., 2003). Ichthyofaunal diversity is influenced by various physicochemical factors such as temperature, pH, dissolved oxygen, alkalinity and hardness, which exhibit seasonal variations (Das *et al*., 2012; Sanches *et al*., 2016). However, increasing anthropogenic pressures have led to a decline in ichthyofaunal diversity, with many fish species becoming threatened. In this context, understanding fish assemblage patterns is essential for informing effective conservation strategies and formulating evidence based management policies for riverine ecosystems (Fischer, 2012; Yang *et al*., 2016).

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The north-eastern region of India is one of the major biodiversity hotspots and Assam holds particular importance due to its rich freshwater fish diversity (Kottelat and Whitten, 1996). The state is endowed with numerous lentic water bodies, primarily due to the presence of the Brahmaputra and the Barak River and their extensive tributary networks. The Brahmaputra River alone supports many tributaries, each rich in ichthyofaunal diversity and characterized by varied habitats and species interactions. These rivers not only sustain aquatic biodiversity but also support livelihoods, promote sustainable fisheries, preserve local economies, and maintain cultural practices. Several studies have documented the ichthyofaunal diversity of Brahmaputra tributaries, for instance, the Dhansiri River (34 species), Subhansiri River (204 species), Dihing River (50 species), Diyung River (81species) and the Jia Bharali River (69 species) (Acharjee *et al*., 2012; Bakalial *et al*., 2014; Deori *et al*., 2015; Ahmed *et al*., 2023; Chetry *et al*., 2023).

The Kakodonga River is an important southern sub-tributary of the Brahmaputra River originating in the Naga Hills and flowing through the Jorhat and Golaghat districts of Assam. It joins the Gelabil, Bhogdoi, and Dhanshiri Rivers before ultimately merging with the Brahmaputra River (Bora and Krishnaiah, 2015). The Kakodonga River supports a diverse ichthyofauna and provides a critical source of livelihood for local communities. It also contributes valuable information to the region's aquatic data bank and plays a role in supporting broader ecological frameworks.

Despite its ecological importance, no research has yet examined ichthyofaunal assemblage patterns in relation to physicochemical parameters in the Kakodonga River. Therefore, this study aims to document the diversity and distribution of fish species in relation to limnological variables across different seasons. It also seeks to provide essential baseline information to support the river in future ecological monitoring.

MATERIALS AND METHODS

Sampling of fish

To study the fish diversity of the Kakodonga River, five sampling sites were selected to represent a range of ecological conditions including variation in geographical locations, flow regimes and habitat characteristics. This design allows for a comprehensive assessment of fish diversity across varied environmental gradients and human influences.

The sites were designated as follows: S1 Mandalgaon (26°30'20.3112"N; 94°6' 14.6304"E), S2 Chabukdhara Gaon (26°32'50.892"N; 94°6' 29.1312"E), S3 Shitalpathar (26°33'37.2708"N 94°6'27.3204"E), S4 Neghereting (26°43'34.8564"N; 94°2'37.9212"E) and S5 Rangogori (26°40'55.1856"N 93°43'15.2364"E) (Figure1).

Fish sampling was conducted on the 15th and 16th of each month between January 2022 and December 2023. These fixed dates were selected to maintain temporal consistency and ensure standardized sampling efforts across all locations.

A combination of fishing gears was used to capture a broad spectrum of fish species and size classes including cast nets and lift nets (1–3 cm mesh size), drum-shaped trap boxes (sepa), and seine nets (1–2 cm mesh size). Each type of gear was used uniformly across all sampling sites to maintain methodological consistency.

At each site, key physiological parameters were measured following standard protocols (APHA, 2012) including total suspended solids (TSS), dissolved oxygen (DO), pH, conductivity (Con) and water temperature. Fish specimens were identified using standard taxonomic references (Talwar and Jhingran, 1991; Jayaram, 2010; Froese and Pauly, 2019). Data on fish diversity and abundance data were subsequently used to analyse patterns in fish assemblage structure.

Data analysis

Data on fish assemblages and water parameters from five sampling sites along the Kakodonga River were collected over two-year period and pooled for analysis across three different seasons: pre-monsoon, monsoon and post-monsoon. For each sampling event, the total abundance of fish was recorded. To assess species diversity and community structure, several diversity indices were calculated, including the Shannon Weiner Index (H), Margalef's Index (d), Pielou's Evenness Index (J) and Simpson's Diversity Index (1–λ). All analyses were performed using PAST 4.03 Software (available at https://www.softpedia.com/get/Science-CAD/PAST.shtml).

One-way ANOVA was performed using JAMOVI software (version 2.3.28) to assess significant differences in diversity indices among sampling sites and across seasons. Taxonomic distinctness (Δ*) (Clarke and Warwick, 1998) was calculated based on species occurrence data using PAST (4.03) software. To examine patterns in fish assemblage structure, Bray-Curtis similarity measures were applied and cluster analysis was conducted using PAST (4.03) software. Analysis of Similarity (ANOSIM) was performed to test for statistical differences in fish assemblages between sites and seasons. Similarity Percentages Breakdown (SIMPER) analysis was also used to identify species contributing most to dissimilarities. Canonical Correspondence Analysis (CCA) was conducted to explore the influence of physicochemical parameters on fish abundance, using PAST (4.03) software.

RESULTS AND DISCUSSION

Composition of fish

In the present study, a total of 13,384 fish were recorded, from the five representative sites along the Kakodonga River (Figure 1), comprising 46 species belonging to 36 genera, 21 families, and 9 orders (Table 1). The family Cyprinidae exhibited

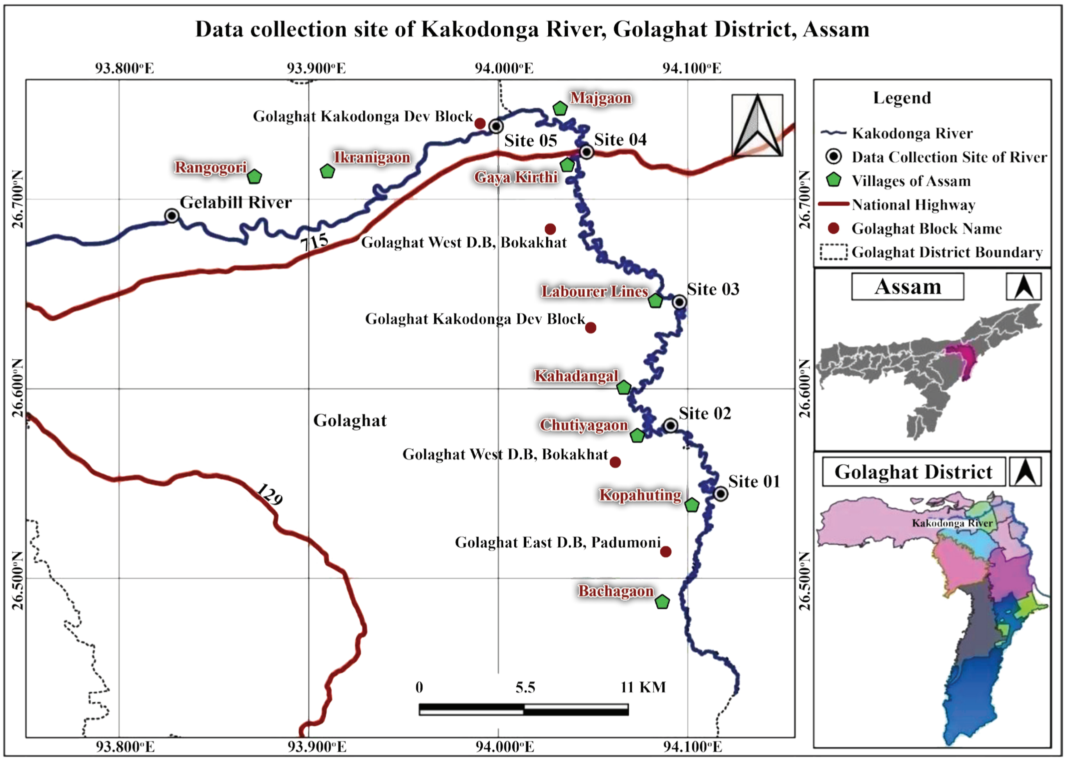

Figure 1. Map showing the sampling sites of Kakodonga River of Golaghat District, Assam.

Table 1. Fish species composition and frequency of occurrence (%) of each species across the five sampling sites in the Kakodonga River. Frequency values represent the proportion of sampling events in which each species was recorded at each site.

Family	Scientific name	Frequency of occurrence				
		Site 1	Site 2	Site 3	Site 4	Site 5
Mastacembelidae	*Macrognathus siamensis* (Gunther, 1861)	0.67	0.58	0.46	0.42	0.67
Mastacembelidae	*Mastacembelus armatus* (Lacepede, 1800)	0.67	0.58	0.46	0.38	0.58
Mastacembelidae	*Macrognathus pancalus* (Hamilton,1822)	0.83	0.94	0.83	0.94	0.88
Belonidae	*Xenentodon cancila* (Hamilton, 1822)	0.13	0.10	0.10	0.21	0.08
Ambassidae	*Parambassis ranga* (Hamilton, 1822)	0.42	0.42	0.38	0.46	0.50
Ambassidae	*Chanda nama* (Hamilton, 1822)	0.63	0.63	0.42	0.52	0.42
Xenocyprididae	*Ctenopharyngodon idella* (Valenciennes, 1844)	0.25	0.42	0.42	0.21	0.25
Cobitidae	*Canthophrys gongota* (Hamilton, 1822)	0.52	0.42	0.46	0.46	0.52
Danionidae	*Danio dangila* (Hamilton, 1822)	0.63	0.46	0.79	0.25	0.42
Danionidae	*Salmostoma bacaila* (Hamilton, 1822)	0.88	0.83	0.88	0.73	0.67
Danionidae	*Amblypharyngodon mola* (Hamilton, 1822)	1.00	0.94	1.00	0.83	0.94
Cobitidae	*Lepidocephalichthys guntea* (Hamilton, 1822)	0.58	0.29	0.25	0.38	0.46
Cyprinidae	*Cirrhinus mrigala* (Hamilton, 1822)	0.67	0.73	0.63	0.58	0.38
Cyprinidae	*Labeo gonius* (Hamilton, 1822)	0.83	0.63	0.52	0.31	0.63
Danionidae	*Esomus danrica* (Hamilton, 1822)	0.45	0.42	0.38	0.21	0.31
Danionidae	*Barilius bendelisis* (Hamilton, 1807)	0.42	0.21	0.21	0.21	0.17
Cyprinidae	*Pethia ticto* (Hamilton, 1822)	0.83	0.88	0.88	0.79	0.96
Cyprinidae	*Puntius sophore* (Hamilton,1822)	0.98	0.96	1.00	0.94	0.89
Cyprinidae	*Puntius chola* (Hamilton, 1822)	1.00	0.94	0.94	0.96	0.88
Cyprinidae	*Pethia conchonius* (Hamilton, 1822)	0.83	0.88	0.83	0.79	0.83
Cyprinidae	*Labeo bata* (Hamilton, 1822)	0.63	0.63	0.58	0.42	0.25
Cyprinidae	*Systomus sarana* (Hamilton, 1822)	0.27	0.21	0.06	0.02	0.00
Bagridae	*Mystus vittatus* (Bloch, 1794)	0.88	0.83	0.83	0.79	0.85
Bagridae	*Mystus bleekeri* (Day, 1877)	0.73	0.79	0.73	0.83	0.67
Bagridae	*Mystus cavasius* (Hamilton, 1822)	0.83	0.83	0.73	0.83	0.88
Sisoridae	*Gagata cenia* (Hamilton, 1822)	0.79	0.83	0.88	0.79	0.79
Sisoridae	*Gagata gagata* (Hamilton, 1822)	0.29	0.21	0.00	0.00	0.38
Ailiidae	*Clupisoma garua* (Hamilton, 1822)	0.27	0.31	0.25	0.17	0.21
Siluridae	*Wallago attu* (Bloch &Schneider, 1801)	0.31	0.29	0.31	0.38	0.42
Heteropneustidae	*Heteropneustes fossilis* (Bloch, 1794)	0.73	0.42	0.63	0.42	0.52
Schilbeidae	*Pachypterus atherinoides* (Bloch, 1794)	0.67	0.58	0.42	0.25	0.07
Sisoridae	*Glyptothorax telchitta* (Hamilton, 1822)	0.10	0.10	0.06	0.00	0.04
Sisoridae	*Hara jerdoni* (Day, 1870)	0.42	0.42	0.21	0.00	0.06
Siluridae	*Ompok pabo* (Hamilton, 1822)	0.31	0.38	0.42	0.67	0.42
Channidae	*Channa punctatus* (Bloch, 1793)	0.79	0.73	0.71	0.79	0.88
Anabantidae	*Anabas testudineus* (Bloch, 1792)	0.42	0.46	0.63	0.63	0.69
Nandidae	*Nandus nandus* (Hamilton, 1822)	0.31	0.33	0.25	0.25	0.46

Table 1. Cont.

Family	Scientific name	Frequency of occurrence				
		Site 1	Site 2	Site 3	Site 4	Site 5
Channidae	*Channa striata* (Bloch, 1793)	0.21	0.21	0.17	0.10	0.31
Channidae	*Channa orientalis* (Bloch & Schneider, 1801)	0.88	0.73	0.94	0.63	0.94
Badidae	*Badis badis* (Hamilton, 1822)	0.73	0.25	0.46	0.73	0.46
Osphronemidae	*Trichogaster fasciata* (Bloch & Schneider, 1801)	0.88	0.83	0.67	0.73	0.88
Osphronemidae	*Triochogaster chuna* (Hamilton, 1822)	0.31	0.25	0.21	0.21	0.25
Notopteridae	*Notopterus notopterus* (Pallas, 1769)	0.25	0.25	0.27	0.21	0.21
Notopteridae	*Chitala chitala* (Hamilton, 1822)	0.38	0.42	0.42	0.21	0.00
Gobiidae	*Glossogobius giuris* (Hamilton, 1822)	1.00	0.94	0.88	0.83	0.96
Tetraodontidae	*Leiodon cutcutia* (Hamilton, 1822)	0.38	0.00	0.00	0.00	0.25

Note: Sampling unit = 2; Sample size = 48

the highest species richness, with eight species, followed by Danionidae (five species) and Sisoridae (four species). In terms of relative abundance, Cyprinidae was also the most dominant family, representing 26.19% of the total catch, followed by Danionidae (14.08%) and Bagridae (11.21%). Cyprinidae family dominated the fish community across all five sampling sites.

Spatial and temporal nature of fish diversity

A one-way ANOVA of diversity indices (Table 2) indicated no significant seasonal variations ($p \geq 0.05$) in the Shannon-Weiner index (H'), Pielou's evenness index (J'), Simpson's diversity index (1–λ), or taxonomic distinctness (Δ*), indicating seasonal stability in diversity structure. However,

Table 2. One-way ANOVA of diversity indices and taxonomic distinctness with respect to sampling sites and seasons of the Kakodonga River.

Seasons	Sites	Shannon weiner index (H')	Margalef's index (d)	Pielou's evenness index (J')	Simpson's diversity index (1- λ)	Abundance per sampling event	Taxonomic distinctness Δ*
Main effects							
Seasons							
Pre-monsoon		3.44±0.06	6.23±0.19[b]	0.72±0.03	0.96±0.00	879.00±156.20[b]	3.89±0.03
Monsoon		3.45±0.05	6.54±0.31[a]	0.75±0.05	0.96±0.00	542.00±38.50[c]	3.89±0.02
Post-monsoon		3.49±0.08	6.02±0.12[b]	0.74±0.04	0.96±0.00	1,281.00±286.90[a]	3.89±0.02
p-value		0.540	0.010	0.650	0.000	0.001	0.917
Sites	1	3.52±0.05[a]	6.87±0.14[a]	0.74±0.03	0.96±0.00[a]	689.00±101.10[a]	3.88±0.01[b]
	2	3.45±0.07[b]	6.93±0.06[a]	0.69±0.04	0.96±0.01[a]	571.00±30.90[b]	3.87±0.02[c]
	3	3.41±0.04[c]	6.74±0.12[a]	0.71±0.04	0.96±0.00[a]	510.00±29.10[c]	3.88±0.02[b]
	4	3.34±0.05[d]	6.55±0.23[b]	0.69±0.04	0.96±0.00[b]	422.00±16.80[d]	3.89±0.02[b]
	5	3.45±0.03[b]	6.81±0.08[a]	0.72±0.04	0.96±0.00[a]	505.00±41.90[c]	3.91±0.01[a]
p-value		0.004	0.023	0.560	0.030	0.001	0.014

Note: Mean±SD in the same column followed by different superscript letters are significantly different ($p<0.05$).

Margalef's diversity index (d) ($p = 0.010$) and abundance per sampling event ($p = 0.001$) varied significantly across seasons. Tukey's post-hoc test showed that species richness was significantly higher during the monsoon (6.54±0.31) compared to the pre-monsoon (6.23±0.19) and post-monsoon (6.02±0.12) periods, which did not differ from each other. Abundance showed the most pronounced seasonal variation, with all three seasons forming distinct groups: monsoon (542±38.50), pre-monsoon (879±156.20), and post-monsoon (1,281±286.90), with the latter showing the highest value. Thus, while overall species diversity remained stable across seasons, the monsoon season stood out by exhibiting higher species richness and lower abundance.

However, significant site-wise variations were observed among the five study sites in almost all diversity indices except Pielou's evenness index (J') ($p = 0.560$). The Shannon- Weiner index differed significantly among sites ($p = 0.004$), with the highest value recorded at Site 1 (3.52± 0.05). Site 2 and Site 5 (3.45±0.07 and 3.45±0.03, respectively) formed a similar group, while Site 3 (3.41±0.04) was distinct, and the lowest value was recorded at Site 4 (3.34±0.05). For Margalef's index ($p = 0.023$), Site 1 (6.87±0.14), Site 2 (6.93± 0.06), Site 3 (6.74±0.12) and Site 5 (6.81±0.08) showed statistically similar richness, whereas Site 4 (6.55±0.23) exhibited significantly lower richness. Although Simpson's diversity index (1–λ) had an identical numerical value (0.96) across sites, it exhibited mild but significant variation ($p = 0.030$), with Site 4 differing from the others. Taxonomic distinctness also varied significantly ($p = 0.014$), with Site 5 (3.91±0.01) showing the highest distinctness and Site 2 (3.87±0.02) the lowest. Site 1 (3.88±0.01), Site 3 (3.88±0.02), and Site 4 (3.89±0.02) were intermediate in taxonomic distinctness.

Fish assemblage structure

Bray-Curtis's cluster analysis revealed distinct site-specific fish assemblages, forming two primary clusters: the first comprising Site 3, Site 4, and Site 5, while the second cluster comprised Site 1 and Site 2 (Figure 2). However, ANOSIM (Analysis of Similarity) indicated no significant differences in fish assemblage patterns across sites ($r = 0.18$, $p = 0.203$) or seasons ($r = 0.33$, $p = 0.133$). An r value close to 1.0 indicates strong dissimilarity between groups, whereas a value near 0 suggests uniform species distribution. These results suggest a relatively homogeneous fish composition across the study area. SIMPER analysis further supports this conclusion, showing a low average dissimilarity (1.50%) across sites. The species contributing to this slight variation were *Puntius chola* and *Glossogobius giuris*. For seasonal differences, SIMPER revealed a slightly higher average dissimilarity (2.40%), mainly influenced by *Puntius sophore* and *Amblypharyngodon mola* (Table 3).

Environmental parameters and fish assemblage

One-way ANOVA followed by Tukey's post hoc analysis revealed significant seasonal and site-wise variations in the physicochemical parameters. Seasonally, DO ($mg \cdot L^{-1}$) and water temperature (ºC) showed significant differences.

Table 3. Results of ANOSIM and SIMPER analyses showing the similarity composition in fish assemblages among sites and seasons of Kakodonga River.

Variables	**ANOSIM**		**SIMPER**	
	r-value	**p-value**	**Average dissimilarity (%)**	**Contributing species**
Sites	0.18	0.203	1.50	*Puntius chola*
			1.25	*Glossogobius giuris*
Seasons	0.33	0.133	2.40	*Puntius sophore*
			2.08	*Amblypharyngodon mola*

Table 4. One-way ANOVA of physicochemical parameters with respect to sampling sites and seasons of the Kakodonga River.

Seasons	Sites	Total suspended solid (mg·L^{-1})	Dissolved oxygen (mg·L^{-1})	pH	Conductivity (µS·cm^{-1})	Water temperature (ºC)
Main effects						
Seasons						
Pre-monsoon		59.70±15.70	7.75±0.18a	7.72±0.33	156.00±34.10	22.70±0.44^{c}
Monsoon		61.00±12.90	6.67±0.29b	7.77±0.22	153.00±32.10	29.80±1.19^{a}
Post-monsoon		69.40±17.90	7.51±0.23a	7.81±0.23	158.00±31.40	28.20±1.31^{b}
p-value		0.679	0.001	0.721	0.973	0.001
Sites	1	66.80±8.36^{a}	6.95±0.28	7.61±0.33	146.00±11.74^{c}	27.00±2.56
	2	61.40±5.81^{a}	7.35±0.35	7.48±0.22	125.00±0.83^{c}	25.80±2.30
	3	71.80±16.21^{a}	7.46±0.23	8.02±0.14	166.00±18.36^{b}	27.50±3.46
	4	76.60±7.62^{a}	7.37±0.32	7.89±0.18	205.00±21.85^{a}	27.40±2.31
	5	41.00±1.43^{b}	7.44±0.13	7.79±0.09	136.00±6.08^{c}	26.90±3.86
p-value		0.001	0.177	0.052	0.002	0.911

Note: Mean±SD in the same column followed by different superscript letters are significantly different ($p<0.05$).

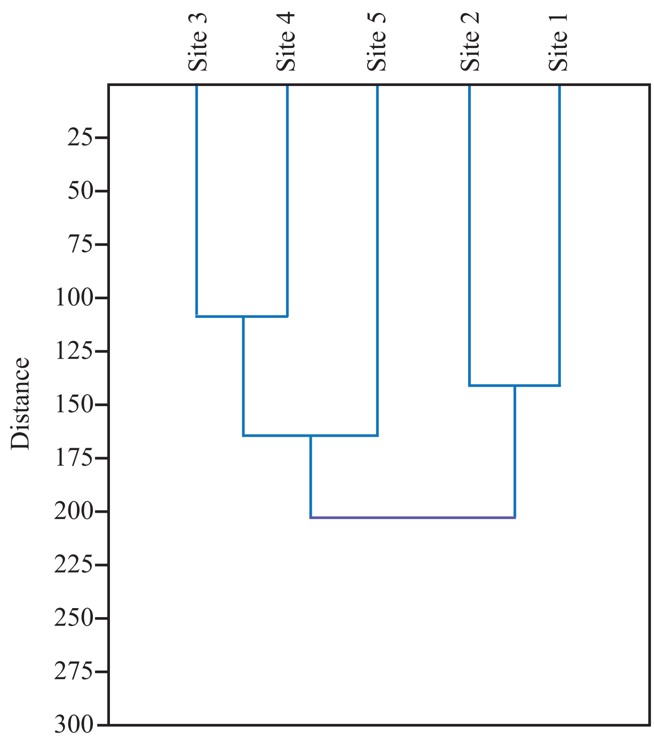

Figure 2. Cluster dendogram showing the similarity in fish species composition among the five sampling sites (Site 1–Site 5) based on hierarchical clustering using Bray-Curtis similarity index of fish species in Kakodonga River.

DO was significantly ($p = 0.001$) lower during the monsoon (6.67±0.29) compared to the pre-monsoon (7.75±0.18) and post-monsoon (7.51±0.23) seasons, which did not differ significantly. Water temperature also varied significantly ($p = 0.001$) across seasons, with the monsoon season exhibiting the highest temperature (29.80±1.19), followed by post-monsoon (28.20±1.31) and the lowest in the pre-monsoon season (22.70±0.44). However, TSS ($mg{\cdot}L^{-1}$), pH and conductivity ($\mu S{\cdot}cm^{-1}$) did not show statistically significant seasonal variations ($p \geq 0.05$), indicating temporal stability (Table 4).

Significant site wise variations were seen for TSS ($mg{\cdot}L^{-1}$) and conductivity ($\mu S{\cdot}cm^{-1}$). TSS was significantly ($p = 0.001$) lower at Site 5 (41.00±1.43) compared to the other four sites, which were statistically similar. Conductivity varied significantly among sites ($p = 0.002$), with the highest value recorded at Site 4 (205±21.85), followed by Site 3 (166±18.36). Site 1 (146±11.74), Site 2 (125±0.83), and Site 5 (136±6.08) formed a statistically similar group with lower conductivity. No significant variation ($p \geq 0.05$) was found in DO, pH or water temperature across the different sites, suggesting spatial consistency of these parameters.

Canonical Correspondence Analysis (CCA) revealed that the first two ordination axes collectively explained 79.11% of the total variation in fish species distribution across sites (Figure 3) indicating that the environmental variables play a substantial role in shaping assemblages. Axis 1 (41.88%) represents the primary environmental gradient, while Axis 2 (37.23%) captures additional variation (Table 5). ANOVA results (Table 4) indicate that total suspended solids (TSS) and conductivity differed significantly among sites ($p = 0.001$ and $p = 0.002$ respectively), suggesting that these factors are the main drivers of fish community structure. The ordination plot further supports this, as several species align along TSS and conductivity gradients. Although DO and pH exhibited moderate correlations with species distribution in the CCA, their lack of statistical significance in ANOVA across sites suggests a more secondary role. Overall, these findings highlight TSS and conductivity as the dominant environmental factors influencing fish community structure in the Kakodonga River. The ordination focuses on the spatial patterns. Environmental variations across seasons were addressed through univariate analysis involving ANOVA and Tukey's Post-Hoc test.

Table 5. Canonical Correspondence Analysis (CCA) results showing the correlations (canonical coefficients) of physicochemical parameters with the first four CCA axes. The table also includes eigenvalues, percentage of variance explained, cumulative variance, and p-values for each axis.

Parameters	CCA Axis 1	CCA Axis 2	CCA Axis 3	CCA Axis 4
Total suspended solid	-0.65	0.67	0.42	0.16
Dissolved oxygen	0.48	0.49	-0.60	0.19
pH	0.48	0.59	0.31	0.50
Conductivity	0.05	0.87	0.56	-0.08
Water temperature	0.37	0.45	0.72	0.38
Eigen value	0.02	0.01	0.01	0.00
Percentage of variance explained	41.88	37.23	15.30	5.59
Cumulative percentage	41.88	79.11	94.41	100.00
p-value	0.79	0.50	0.56	0.73

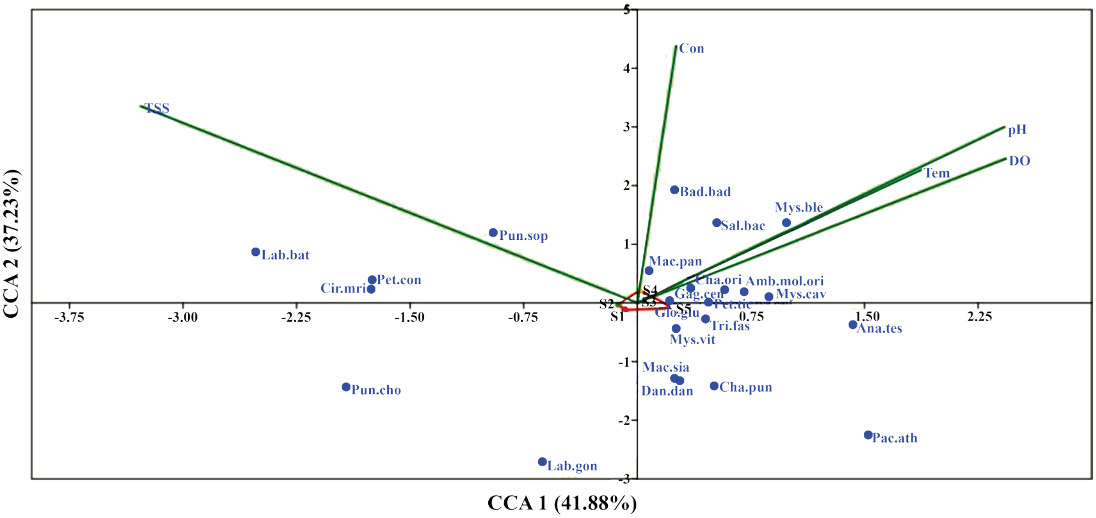

Figure 3. Canonical Correspondence Analysis (CCA) biplot showing the relationship between fish species abundance and their physicochemical parameters across sampling sites of the Kakodonga River. Fish species are represented by the points, abbreviated using the first three letters of their genus and species names. Abbreviations are as follows: *Puntius sophore* (Pun.sop), *Labeo bata* (Lab.bat), *Cirrhinus mrigala* (Cir.mri), *Pethia conchonius* (Pet.con), *Puntius chola* (Pun.cho), *Labeo gonius* (Lab.gon), *Badis badis* (Bad.bad), *Salmostoma bacaila* (Sal.bac), *Macrognathus pancalus* (Mac.pan), *Mystus bleekeri* (Mys.ble), *Channa orientalis* (Cha.ori), *Amblypharyngodon mola* (Amb.mol), *Gagata cenia* (Gag.cen), *Pethia ticto* (Pet.tic), *Mystus cavasius* (Mys.cav), *Glossogobius giuris* (Glo.giu), *Trichogaster fasciata* (Tri.fas), *Mystus vittatus* (Mys.vit), *Macrognathus siamensis* (mac.sia), *Danio dangila* (Dan.dan), *Channa punctatus* (Cha. pun), *Anabas testudineus* (Ana.tes), *Pachypterus atherinoides* (Pac.ath). The physicochemical parameters include total suspended solid (TSS), conductivity (Con), pH, temperature (Tem) and dissolved oxygen (DO).

DISCUSSION

A total of 46 fish species were recorded from the Kakodonga River, a richness level comparable to those reported in other Indian rivers such as the Gomti River (56 species; Sarkar *et al.*, 2010), the Kangsabati River (45 species; Kar *et al.*, 2017), and the Chambal River (56 species; Bose *et al.*, 2019). Similar levels of diversity have also been reported from the tributaries of the Brahmaputra including the Dhansiri River (34 species; Acharjee *et al.*, 2012), Dihing River (50 species; Deori *et al.*, 2015), and Jia Bharali (69 species; Chetry *et al.*, 2023). However, spatial variations in species richness and abundance was observed, with Site 1 (S1) exhibiting the highest diversity, while Site 4 (S4) exhibited the lowest. This difference could be attributed to differences in geomorphological and physicochemical characteristics among the sites (Pasquaud *et al.*, 2015).

The interplay between abiotic and biotic factors significantly impacts the distribution, abundance, and diversity of fish species (Chowdhury *et al.*, 2011). In this study, total suspended solids and conductivity varied significantly among sites and were found to be key environmental drivers influencing fish assemblages in the Kakodonga River. Conductivity, an indicator of ionic content and purity (Acharya *et al.*, 2008) along with TSS, which reflects turbidity and sediment load, may influence habitat quality and feeding opportunities for different fish taxa. Previous studies conducted in various tributaries of Brahmaputra River (e.g. Pagladia, Dihing, Ranganadi, Manas, Dibang, and Lohit) also reported variation in physicochemical parameters as an important determinant of fish community structure (Das *et al.*, 2015; Deori *et al.*, 2015; Bhattacharjya *et al.*, 2017).

The family Cyprinidae emerged as the most dominant taxonomic group in the study. Most cyprinids are herbivores, feeding primarily on plankton and periphyton, thus they play a foundational role in nutrient cycling and energy transfer within aquatic food web (Choudhury and Pal, 2012). Their dominance may also contribute to ecosystem stability by supporting trophic structure. The Shannon diversity index which ranged from 3.34 to 3.52, indicates a healthy ecosystem capable of supporting a diverse fish community (Clarke and Warwick, 1998).

Canonical Corresponding Analysis (CCA) based on 999 permutations, further demonstrated the ecological importance of TSS and conductivity. These two parameters showed strong correlations with the primary ordination axes, indicating their significant influence on fish species distribution patterns in the study area. Although, other variables such as dissolved oxygen (DO) and pH also showed moderate correlations with species assemblages, their lack of significant variation across sites suggests they may play a more secondary role.

Both spatial and seasonal dynamics influenced both fish diversity and water quality in Kakodonga River. Site specific differences in suspended solids and conductivity were key contributors to variation in species composition and evenness consistent with findings from other Indian rivers (Sarkar *et al*., 2012; Gogoi *et al*., 2022). Seasonal fluctuations particularly during the monsoon, led to increased turbidity and habitat disturbance reducing diversity. Conversely, cooler, oxygen rich conditions during the winter and post-monsoon seasons were associated with more stable fish assemblages (Dey *et al*., 2021). Water temperature is also stated to have a major influence on fish assemblage which is typically associated with the poikilothermic nature of fish (Vyas *et al*., 2012). Similar seasonal trends in diversity indices have been reported in other tropical rivers across Northeast India and elsewhere (Allan *et al*., 2021).

Finally, local observations from the fishing community point to a perceived decline in fish diversity and abundance highlighting the need to understand environmental and anthropogenic stressors. Although this study does not assess long term population trends, it provides insight into how water quality parameters influence fish diversity. Overfishing, habitat degradation and deforestation as reported in similar studies (Marsh-Matthews and Matthews, 2000; Kurup *et al*., 2004) may also be contributing to changes in community structure. Future conservation efforts should integrate physicochemical monitoring with ecosystem based management strategies to protect the ichthyofaunal diversity of the Kakodonga River.

CONCLUSIONS

Conserving biodiversity and ensuring the sustainability of aquatic ecosystems is crucial, particularly in ecologically sensitive rivers such as the Kakodonga. Achieving these objectives requires a thorough understanding of species diversity and the influence of physicochemical parameters on aquatic life. This study provides baseline insights into the spatial and seasonal patterns of fish diversity across five sites and highlights the role of water quality particularly total suspended solids, conductivity, dissolved oxygen and water temperature in shaping species distribution.

Although the river currently supports a substantial number of fish species, further research on reproductive biology and population dynamics is recommended to inform species-specific conservation strategies, particularly by identifying critical breeding seasons. In addition, routine monitoring of key physicochemical parameters is essential for early detection of environmental changes that may affect fish populations.

The findings presented here offer a scientific basis for future management efforts, including habitat conservation, water quality regulation and sustainable resource use thereby contributing to the long-term ecological health of the Kakodonga River ecosystem.

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LITERATURE CITED

Acharjee, B., P. Borah, M. Das and J. Purkayastha. 2012. Ichthyofaunal diversity of Dhansiri River, Dimapur, Nagaland, India. **Check List** 8(6): 1163–1165.

Acharya, G.D., M.V. Hathi, A.D. Patel and K.C. Parmar. 2008. Chemical properties of groundwater in Bhiloda Taluka Region. North Gujarat India. **Journal of Chemistry** 5(4): 792–796. DOI: 10.1155/2008/592827.

Ahmed, A.M., R. Dutta, H. Pokhrel, D. Nath, L. Mudoi, R. Sarmah, S. K. Bhagabati and I. Ahmed. 2023. Fish species composition, distribution, and community structure of a Himalayan biodiversity hotspot River Diyung, North East India. **Pakistan Journal of Zoology** 1–11. DOI: 10.17582/journal.pjz/20220312070327.

Allan, J. D., M.M. Castillo and K.A. Capps. 2021. **Stream Ecology: Structure And Function Of Running Waters.** Springer Nature, Cham, Switzerland. 485 pp.

American Public Health Association (APHA). 2012. **Standard Methods for the Examination of Water and Wastewater,** 22th ed. American Public Health Association, Washington, D.C., USA. 1360 pp.

Bakalial, B., S.P. Biswas, S. Borah and D. Baruah. 2014. Checklist of fishes of Lower Subansiri River drainage, northeast India. **Annals of Biological Research** 5(2): 55–67.

Bhat, A. 2003. Diversity and composition of freshwater fishes in the river systems of Central Western Ghats, India. **Environmental Biology of Fishes** 68: 25–38. DOI: 10.1023/A:1026017119070.

Bhattacharjya, B.K., U. Bhaumik and A.P. Sharma. 2017. Fish habitat and fisheries of Brahmaputra River in Assam, India. **Aquatic Ecosystem Health and Management** 20(1–2): 102–115. DOI: 10.1080/14634988.2017.1297171.

Bora, R. and Y.V. Krishnaiah. 2015. Temperature, rainfall, and rainfall recharge of the Kakodonga River Basin, India. **International Journal of Scientific Research** 4(2): 170–182.

Bose, R., A.K. Bose, A.K. Das, A. Parashar and K. Roy. 2019. Fish diversity and limnological parameters influencing fish assemblage pattern in Chambal River Basin of Madhya Pradesh, India. **Proceedings of the National Academy of Science, India Section B: Biological Science** 89: 461–473. DOI: 10.1007/s40011-017-0958-5.

Brown, L.R. 2000. Fish communities and their association with environmental variables, lower San Joaquin River Drainage, California. **Environmental Biology of Fishes** 57(3): 251–269. DOI: 10.1023/A:1007660914155.

Chetry, V., H. Das, P.K. Saikia, M.K. Saikia, B.P. Saikia and K. Sarma. 2023. Ichthyofaunal diversity in Jia Bharali River of north bank landscape of Assam in eastern Himalaya, Northeast India. **Ecology, Environment and Conservation** 29: S145–S157. DOI: 10.53550/EEC.2023.v29i01s.023.

Choudhury, A. and R. Pal. 2012. Understanding the seasonal dynamics of primary productivity in relation to phytoplankton populations from the Bhagirathi-Hooghly Estuary, Eastern Indian Coast. **Journal of Algal Biomass Utilization** 3(4): 80–88.

Chowdhury, M.S.N., M.S. Hossain, N.G. Das and P. Barua. 2011. Environmental variables and fisheries diversity of the Naaf River Estuary, Bangladesh. **Journal of Coastal Conservation** 15(1): 163–180. DOI: 10.1007/s11852-010-0130-3.

Clarke, K.R. and R.M. Warwick. 1998. Quantifying structural redundancy in ecological communities. **Oecologia** 113: 278–289. DOI: 10.1007/s004420050379.

Das, M.K., P.K. Srivastava, S. Dey and A. Rej. 2012. Impact of temperature and rainfall alterations on spawning behaviour of Indian major carps and consequence on fishers' income in Odisha. **Journal of the Inland Fisheries Society of India** 44(2): 1–11.

Das, U.K., S.K. Rout, N. Kumar, R.P. Mishra, B.K. Bhattacharjya and P. Gagoi. 2015. Limnochemistry of River Pagladia (a Major Tributary of the Brahmaputra River), Assam. **Environment and Ecology** 33 (2A): 863–866.

Deori, D.J., S, Abujam and S.P. Biswas. 2015. Fish diversity and habitat ecology of Dihing River-A tributary of Brahmaputra River. **International Journal of Fisheries and Aquatic Studies** 2(4): 190–197.

Dey, A., H. Choudhury., A. Mazumder., R.C. Bharali., K.K. Lal and D. Sarma. 2021. Spatial and temporal dynamics of fish species assemblage and distribution in the Kameng River, Northeast India. **Proceedings of the National Academy of Sciences, India Section B: Biological Sciences** 91: 123–130. DOI: 10.1007/s40011-020-01208-9.

Fischer, J.R. 2012. **Characterizing lentic fish assemblages and community environment relationships: an evaluation of natural lakes and reservoirs in Iowa, USA.** Graduate Theses and Dissertations, Iowa State University, Ames, USA. pp.

Froese, R. and D. Pauly 2019. **Fishbase.** www.fishbase.org. Cited 1 Nov 2024.

Gogoi, P., T.N. Chanu, A. Sinha, M.H. Ramteke, T. Tayung, A. Roy and B.K. Das. 2022. Fish assemblage pattern, seasonality and their interaction with environmental variables: Insights from canals of Sundarbans, India. **Tropical Ecology** 63(4): 626–643. DOI: 10.1007/s42965-022-00232-2.

Horowitz, R.J. 1978. Temporal variability patterns and the distributional patterns of stream fishes. **Ecological Monographs** 48(3): 307–321. DOI: 10.2307/2937233.

Jayaram, K.C. 2010. **The Freshwater Fishes of the Indian Region.** Narendra Publishing House, Delhi, India. 616 pp.

Kar, A., M. Bhattacharya, M. Ghorai, S. Patra and B.C. Patra. 2017. Ichthyofaunal diversity of Kangsabati River at Paschim Medinipur District, West Bengal, India. **Proceedings of the Zoological Society of India** 70: 165–173. DOI: 10.1007/s12595-016-0172-0.

Kottelat, M and T.Whitten. 1996. **Freshwater Biodiversity In Asia With Special Reference To Fish. World Bank technical paper.** The World Bank, Washington, D.C., USA. 343 pp.

Kurup, B.M., K.V. Radhakrishnan and T.G. Manojkumar. 2004. **Biodiversity status of fishes inhabiting rivers of Kerala (S. India) with special reference to endemism, threats and conservation measures.** Proceedings of the 2nd Large Rivers Symposium. Mekong River Commission and Food and Agricultural Organization 2004: 163–182.

Marsh-Matthews, E. and W.J. Matthews. 2000. Geographic, terrestrial and aquatic factors: which most in influence the structure of stream fish assemblages in the mid-western United States? **Ecology of Freshwater Fish** 9(1–2): 9–21. DOI: 10.1034/j.1600-0633.2000.90103.x.

Pasquaud, S., R.P. Vasconcelos, S. Franca, S. Henriques, M.J. Costa and H. Cabral. 2015. Worldwide pattern of fish biodiversity in estuaries: Effects of global vs. local factors. **Estuarine Coastal and Shelf Science** 154: 122–128. DOI: 10. 1016/j.ecss.2014. 12.050.

Ross, N., M. Islam and S.H. Thilsted. 2003. Small indigenous fish species in Bangladesh: contribution to vitamin A, calcium and iron intakes. **Journal of Nutrition** 133 (11): 4021–4026. DOI: 10.1093/jn/133. 11.4021S.

Rowe, D.C., C.L. Pierce and T.F. Wilton. 2009. Fish assemblage relationships with physical habitat in wadeable Iowa streams. **North American Journal of Fisheries Management** 29(5): 1314–1332. DOI: 10.1577/M08-192.1.

Sanches, B.O., R.M. Hughes, D.R. Macedo, M. Callisto and G.B. Santos. 2016. Spatial variations in fish assemblage structure in a south eastern Brazilian reservoir. **Brazilian Journal of Biology** 76(1): 185–193. DOI: 10. 1590/1519-6984.16614.

Sarkar, U.K., B.K. Gupta and W.S. Lakra. 2010. Biodiversity, ecohydrology, threat status and conservation priority of the freshwater fishes of river Gomti, a tributary of river Ganga (India). **The Environmentalist** 30: 3–17. DOI: 10.1007/s10669-009-9237-1.

Sarkar, U.K., A.K. Pathak, R.K. Sinha, K. Sivakumar, A.K. Pandian, A. Pandey and W.S. Lakra. 2012. Freshwater fish biodiversity in the River Ganga (India): changing pattern, threats and conservation perspectives. **Reviews in Fish Biology and Fisheries** 22: 251–272. DOI: 10.1007/s11160-011-9218-6.

Talwar, P.K. and A.G. Jhingran. 1991. **Inland Fishes Of India And Adjacent Countries.** Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, India. 1158 pp.

Vyas, V., D. Damde and V. Parashar. 2012. Fish biodiversity of Betwa River in Madhya Pradesh, India with special reference to a sacred ghat. **International Journal of Biodiversity and Conservation** 4(2): 71–77. DOI: 10.5897/IJBC10.015.

Yang, M.L., W.S. Jiang, W.Y. Wang, X.F. Pan, D.P. Kong, F.H. Han, X.Y. Chen and J.X. Yang. 2016. Fish assemblages and diversity in three tributaries of the Irrawaddy River in China: changes, threats and conservation perspectives. **Knowledge and Management of Aquatic Ecosystems** 417: 1–15. DOI: 10.1051/kmae/2015042.