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Taxonomic and Ecological Assessment of *Labeo rohita* in the Kali River System: Insights from Uttarakhand, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

In India, Uttarakhand is rich in its ichthyofaunal diversity, but in the Kali River system which is the largest in the Kumaun Himalaya, *Labeo rohita* has not been reported yet. This study investigates the taxonomy, morpho-biology, and habitat ecology of *Labeo rohita*. Taxonomic identification was conducted using diagnostic keys, fin formulae, and detailed descriptions, while morpho-biological analysis included 12 morphometric measurements, 6 meristic counts, and length-length relationships. Habitat ecology was assessed through 9 physicochemical parameters. The specimen

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was identified as *Labeo rohita* with negative allometric growth, supported by significant correlations between morphometric traits and physicochemical conditions which indicates healthy development. This first record of *Labeo rohita* in the Kali River system provides valuable insights into its taxonomy, growth, and ecological adaptations, contributing to the understanding and conservation of aquatic biodiversity in the Kumaun Himalaya.

Keywords: Labeo rohita; conservation; taxonomy; morphometric; physiochemical properties.

1. INTRODUCTION

In India, Uttarakhand harbours rich resource of fishes due to its specific biogeographic location, temperature and altitude gradients and the diverse habitat ecosystem (Jennings et al., 2008). In the present study the fish species *Labeo rohita* has been collected and identified on the basis of its systematics and taxonomy, which was further confirmed by studying its morpho-biology. This fish species is distributed all around the Uttarakhand but the available literature suggests that *Labeo rohita* has not been reported earlier from the Kali River system (Wing 2012; Pandey et al., 2018). Therefore, this study will be the first of its kind for the Kali River system, to do the taxonomy and morpho-biology of *Labeo rohita* with its relation to habitat ecology.

Analysis of physio-chemical parameters is also very essential for the study of the structure of riverine ecosystems, as they impact the aquatic environment and water asset from various perspectives (Colt et al., 2006; Gangwar et al., 2012). Therefore, this study is done to identify the fish specimen and to study its diverse habitat ecology, while morphometric statistics will help in the taxonomy and classification of *Labeo rohita*. Many scientists, researchers and other workers had studied and worked on different aspects of *Labeo rohita* in different aquatic habitat including morphological aspects like works of Negi (2013), Seth et al. (2014), Khati et al. (2015), Brraich and Akhtar (2015), Sharma et al. (2016), and Balai et al. (2017), are worth mentioning. As the literature on the habitat ecology and taxonomy of *Labeo rohita* is still very scarce from the Kali River is also lacking. Therefore, in this study, the main objectives were to identify the fish species *Labeo rohita*, and to determine the habitat ecology of the *Labeo rohita* from the Kali River system. Hence, this study will lead us to a new path and methods for the growth and development of this fish fauna, its habitat and will also try to cope up the literature gap in this matter. Ecological management will also be the resulting significance of our study.

2. MATERIALS AND METHODS

Study site and sampling: The study was done on the snow-fed river Kali (29.4° to 31° N latitude and 80° to 81° E longitude), that originate from Namik Glacier from the Kumaun Himalaya of Uttarakhand region, for a period of one year on a monthly basis from the local market. The sampling spots digitalized on the GIS platform by using remote sensing and GIS application (ArcGIS v.10.1).

Taxonomy: Fish samples were identified according to Jayaram (2010), and classified according to Nelson (2016). For taxonomical identification, a systematic key was prepared by using the standard method of Gopalji (1998) and www.fishbase.org (Yang et al., 2020).

Morpho-biology: All morphometric characters were measured using digital calipers and simple steel scales to the nearest 0.1 mm, as described in the methods of Sharma (2018) and Agnese et al., (1997). That includes total length (TL), forked length (FL), standard length (SL), pre-dorsal length (PDL), pre-orbital length (POL), eye diameter (ED), head length (HL), pre-pectoral length (PPL), pre-pelvic length (PPvL), pre-anal length (PAL), body depth (BD), and caudal length (CL). The meristic counts measured were dorsal fin rays (DFR), pelvic rays (PFER), pectoral fin rays (PFR), anal fin rays (AFR), caudal fin rays (CFR) and lateral line scales (LLS) (Fig. 1).

Habitat ecology: We analyzed the habitat ecology by estimating various physio-chemical parameters in different sampling spots of the Kali River. For this various parameter like water temperature (WT), air temperature (AT), hydrogen ion-concentration (pH), total dissolved solids (TDS), and electrical conductivity (EC) were estimated by using digital meters, while parameters like dissolved oxygen (DO), free CO_2, total alkalinity (TA), and total hardness (TH) were measured using the standard techniques and methods described in APHA (2012). Additionally, statistical analysis was done by using MS Excel data analysis software (Heiberger and Neuwirt, 2009) and PAST software (Hammer et al., 2001).

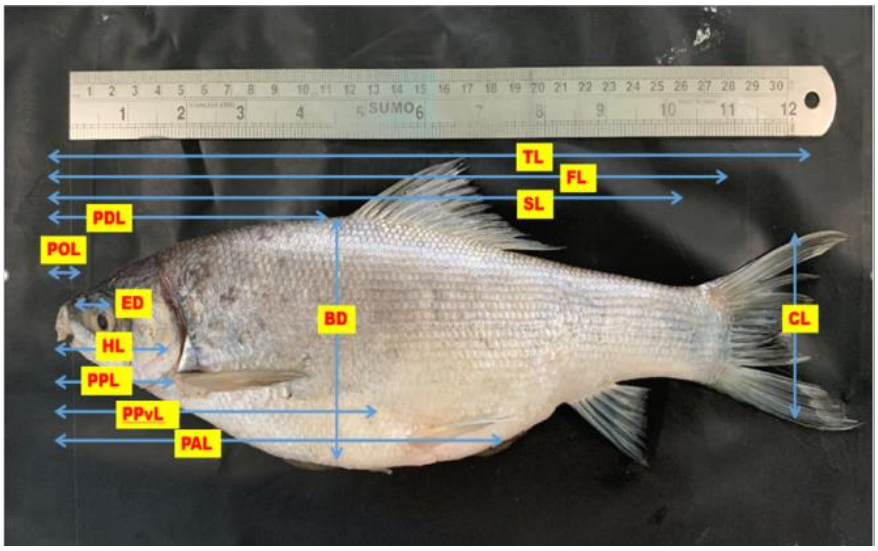

Fig. 1. Common morphometric data collected for identification of fish *Labeo rohita*

3. RESULTS AND DISCUSSION

Taxonomical data

Key to order of subclass Actinopterygii

1. Rounded or keeled abdomen,..Cypriniformes

Key to division of the order Cypriniformes

1. Body covered with scales …….Cyprini

Key to the family of the suborder Cyprinoidei

1. Scales are distinct, large and prominent……..Cyprinidae

Key to the subfamily of the family Cyprinidae

1. Scales are distinct, large and prominent……..…….....Cyprininae

Key to the genera of the subfamily Cyprininae

1. Fringed lips, rarely unfringed, if tubercles is provided on the dorsal surface of the lower lip ……*Labeo rohita*

Key to the species of the subfamily Cyprininae

1. Live body coloration is blackish above and sides, turning out to be silvery ventrally, ……*Labeo rohita*

Genus- *Labeo*
Species- *rohita*

Fin Formula: D. 13, P. 18, V. 9, A. 8, C. 18, L. I. 44, L. tr. 8.

Taxonomical description: The body of fish was moderately elongated, and the dorsal profile was more protruding than the ventral side. The snout was quite concave, protruding beyond the mouth. Big eyes and thick lower lip, covering two consecutive chins at the corners of the mouth, forming a lip fold. The upper jaw conceals a pair of small maxillary barbels. The dorsal fin is located between the snout tip and the base of the caudal fin. The head was longer than the pectoral fin. Deep forks could be seen on the caudal fin. Moderate scales, 40 to 44 scales on the lateral line, 6 to 6 1/2 rows of scales between the lateral line and the base of the pelvic fin, and 12 to 16 scales on the pre-dorsal surface. The body color is shiny, silvery and white on the abdomen.

3.1 Morphometric Observation

The morphometric and meristic data of *Labeo rohita* were observed and details are presented in Tables 1 and 2. Ten characters have been studied in percentage of total fish length (20.3±2.6) and head length (3.05±0.3) accordingly. Six distinct meristic characters were identified, each with a distinct variation. The meristic counts have also been observed to fall under some specific range in the fish *Labeo rohita* (Table 2). The total length was kept on the x-axis (independent variable), while other morphometric parameters were kept on the y-axis (dependent variables), observed that

significant correlations exist between (SL-TL), (FL-TL), (PVL-TL), and (PAL-TL). The correlation coefficient (r) was a minimum of 0.77 in (ED-HL) and (POL-HL), while it was a maximum of 1.00 in (SL-TL), respectively (Table 1). The regression coefficient (b) was also estimated and it was found to be a minimum of 0.1611 in (PPL-TL) and a maximum of 1.7622 in (SL-TL), respectively. In the study, value of 'b 'shows negative allometric growth (1.7622, i.e., b<3.0) in *Labeo rohita* (Table 1). Therefore, the relationship between different morphometric parameters was established and negative allometric growth (b<3.0) was reported in the studied fish.

3.2 Habitat Ecology

The mean values of each water quality parameter measured for the Kali River in this study are displayed in (Table 3), which falls under range of WT (12-27 °C), AT (14-33 °C), pH (6.0-7.0), TDS (152-389 ppm), EC (360-776 µs/cm), DO (4-7.6 mg/l), CO_2 (1-3 mg/l), TA (20 - 166 mg/l), and TH (80-204 mg/l) respectively. In Table 3, the summary statistics and in Table 4, the ANOVA test showed statistically significant differences ($P < 0.05$) for all physiochemical parameters, and the most highly significant value was found between (WT-EC). In Table 5, positive correlation was estimated 0.904 between (WT-AT), and 0.888 in between (WT-EC), while TDS, TH, and CO_2 did not show any significant correlation with any of the other parameters. In Fig. 3, a Correlation or Biplot Circle, the initial variables were projected into the factor space. The variables on the right side correlated positively among themselves but negatively with the variables on the left side. Similarly, the variables on the left side correlated positively among themselves but negatively with the variables on the right side. Table 6 provides details on the linear relationship among various physiochemical parameters with the water temperature of the Kali River system shown in Fig. 4.

3.3 Discussion

In this paper, taxonomical study offers valuable insights into the morphological characteristics of the observed fish, belonging to the species *Labeo rohita*. The results of taxonomical study were found similar to the results of Nelson (2016) and Sarma et al. (2017), who had reported the taxonomic account of *Labeo* species. For the identification of any species, key preparation plays an important role and is a useful tool for identifying any species all around the world (Sarma et al., 2017). Therefore, in this study, preparation of a systematic key was done by using the standard reference of Gopalji (1998) and www.fishbase.org (Yang et al. 2020), while identification was done according to Jayaram (2010).

Fig. 2. Meristic count of fish *Labeo rohita*

Table 1. Length-length relationship of *Labeo rohita*

S.No.	Parameter	Min	Max	Mean	Range	SD	r	Regression Equation	Correlation Coefficient
In the % of Total Length (TL)									
1	TL	16	23.2	20.3	7.2	2.6	-	-	-
2	SL	12.8	19.4	16.6	6.6	2.3	1.00	y = 0.9039x – 1.7622	1.00
3	FL	14.2	21.5	18.4	7.3	2.5	0.98	y = 0.9467x – 0.8004	0.98
4	PDL	6	8.5	7.5	2.5	0.9	0.90	y = 0.322x + 0.9357	0.90
5	PPL	2.7	3.8	3.3	1.1	0.5	0.84	y = 0.1686x – 0.1611	0.84
6	PVL	6.8	9.8	8.4	3	1.05	0.96	y = 0.3891x + 0.421	0.96
7	PAL	9.8	14.4	12.5	4.6	1.6	0.99	y = 0.6259x – 0.2603	0.99
8	CL	2.8	4.6	3.8	1.8	0.7	0.81	y = 0.2371x – 0.9873	0.81
9	BD	3	4.8	3.7	1.8	0.6	0.83	y = 0.2051x – 0.5039	0.83
In the % of Head Length (HL)									
10	HL	2.6	3.4	3.05	0.8	0.3	-	-	-
11	ED	0.5	0.8	0.6	0.3	0.1	0.77	y = 0.3158x – 0.3632	0.77
12	POL	1.0	1.6	1.3	0.6	0.2	0.77	y = 0.5263x – 0.3053	0.77

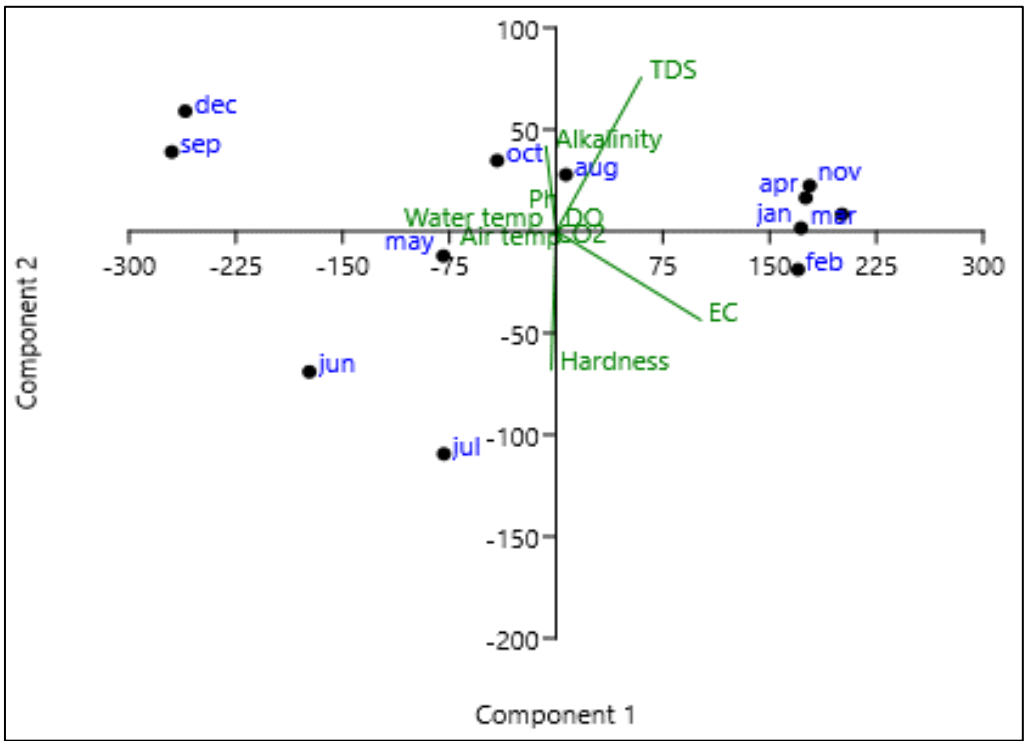

Fig. 3. Biplot or Correlation Circle of variables and observations

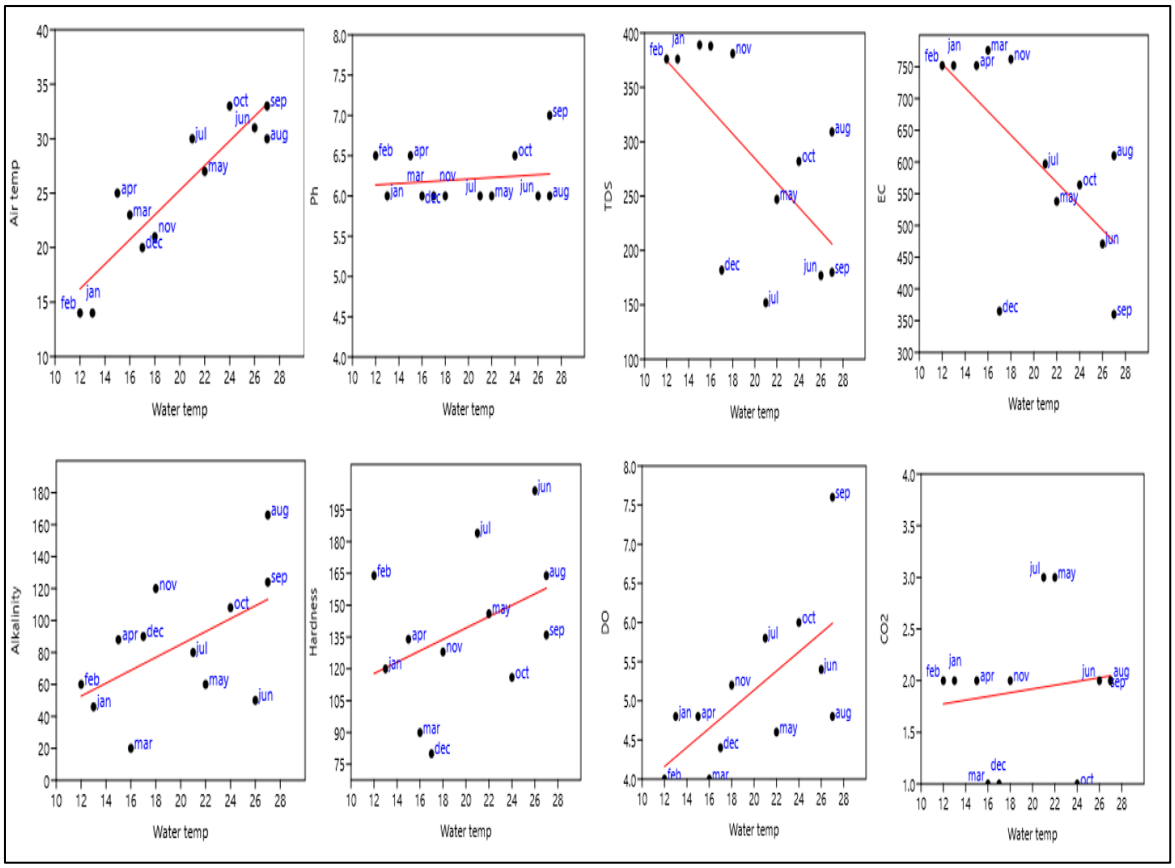

Fig. 4. Linear relation between various water quality parameters of Kali River system

Table 2. Meristic counts of studied fish *Labeo rohita*

S.No.	Parameters	Abbreviation	Fish description Ref. (Sharma et al. 2018)	In our study
1	Dorsal fin ray	DFR	14-16	14
2	Pelvic fin ray	PFER	9	8
3	Pectoral fin ray	PFR	17	16
4	Anal fin ray	AFR	7	6
5	Caudal fin ray	CFR	19	18
6	Lateral line scales	LLS	40-44	72

Table 3. Summary statistics of water quality parameters of Kali River system

S.No.		WT	AT	pH	TDS	EC	TA	TH	DO	CO_2
1	N	12	12	12	12	12	12	12	12	12
2	Min	12	14	6	152	360	20	80	4	1
3	Max	27	33	7	389	776	166	204	7.6	3
4	Sum	238	301	74.5	3439	7299	1012	1666	61.4	23
5	Mean	19.83	25.08	6.21	286.63	608.25	84.33	138.83	5.12	1.92
6	Std. error	1.56	1.95	0.1	27.55	44.42	11.71	10.47	0.29	0.19
7	Variance	29.24	45.90	0.11	9108.08	23675.48	1646.42	1315.97	1.01	0.45
8	Stand. dev	5.41	6.77	0.33	95.44	153.87	40.58	36.28	1.00	0.67
9	Median	19.5	26	6	295.5	603.5	84	135	4.8	2
10	25 prcntil	15.25	20.25	6	180.5	487.75	52.5	117	4.45	1.25
11	75 prcntil	25.5	30.75	6.5	379.75	752	117	164	5.7	2
12	Skewness	0.04	-0.52	1.45	-0.22	-0.46	0.45	0.14	1.40	0.08
13	Kurtosis	-1.48	-0.94	1.39	-1.85	-1.13	0.05	-0.29	2.55	-0.19
14	Geom. mean	19.13	24.12	6.20	270.61	588.33	74.23	134.31	5.03	1.80
15	Coeff. var	27.26	27.01	5.38	33.30	25.30	48.11	26.13	19.61	34.88

Table 4. Results of ANOVA test of seasonal variation in physiochemical parameters

Parameters	Between Groups (BG) Within Groups (WG) Total (T)	Sum of Squares	df	Mean square	F	P value	Sig.
AT	BG	165.375	1	165.375	4.401553	0.05	*
	WG	826.5833	22	37.57197			
	T	991.9583	23				
pH	BG	1113.844	1	1113.844	75.88999	1.39E-08	***
	WG	322.8958	22	14.67708			
	T	1436.74	23				
TDS	BG	426933.4	1	426933.4	93.44821	2.23E-09	***
	WG	100510.6	22	4568.663			
	T	527444	23				
EC	BG	2077405	1	2077405	175.2735	5.89E-12	***
	WG	260751.9	22	11852.36			
	T	2338157	23				
TA	BG	24961.5	1	24961.5	29.79292	1.75E-05	***
	WG	18432.33	22	837.8333			
	T	43393.83	23				
TH	BG	84966	1	84966	126.3236	1.38E-10	***
	WG	14797.33	22	672.6061			
	T	99763.33	23				
DO	BG	1299.482	1	1299.482	85.91786	4.71E-09	***
	WG	332.7433	22	15.1247			
	T	1632.225	23				
CO_2	BG	1926.042	1	1926.042	129.7461	1.07E-10	***
	WG	326.5833	22	14.8447			
	T	2252.625	23				

*Non-significant (P>0.05), * = low significant (P≤0.05),*
*** = intermediate significant (P≤0.01) and *** = highly significant (P≤0.001)*

Table 5. The correlation analysis of all the water quality parameters

	WT	AT	Ph	TDS	EC	TA	TH	DO	CO_2
WT	1								
AT	0.903623	1							
Ph	0.146683	0.252552	1						
TDS	-0.63641	-0.59214	-0.03693	1					
EC	-0.65571	-0.54488	-0.2238	0.887974	1				
TA	0.538056	0.425159	0.275914	-0.14495	-0.28319	1			
TH	0.400243	0.339249	-0.03061	-0.32256	-0.05747	0.080824	1		
DO	0.657276	0.677721	0.598487	-0.54053	-0.54058	0.451747	0.213855	1	
CO_2	0.146683	0.122095	-0.11864	-0.23711	0.033803	0.021224	0.685332	0.151316	1

- *Values significant at ($P < 0.05$)*

Table 6. Slope, intercept, and p-value of water sample collected from Kali River system

Variable	Slope	Error	Intercept	Error	r	p
Air temp	1.1321	0.1697	2.6295	3.4785	0.90362	5.56E-05
pH	0.009067	0.019337	6.0285	0.39636	0.14668	0.64918
TDS	-11.232	4.3049	509.34	88.241	-0.63641	0.026083
EC	-18.658	6.7936	978.29	139.25	-0.65571	0.020607
Alkalinity	4.0373	2.0001	4.2601	40.997	0.53806	0.071148
Hardness	2.685	1.944	85.581	39.849	0.40024	0.19732
DO	0.12197	0.044225	2.6976	0.90653	0.65728	0.020203
CO2	0.018135	0.038673	1.557	0.79272	0.14668	0.64918

During the study, the results showed slight variation from the previous studies of Sharma et al. (2018) in *Labeo rohita*. Generally, taxonomic variation is quite common in species to species, which may be due to the effect of the habitat ecosystem or to alteration in the hydrological condition of the river (Kamboj and Kamboj 2019). For the morphometric study of fish *Labeo rohita*, linear regression analysis and correlation analysis were performed, as shown in Table 1 and 2. The result of this statistical analysis was found to be similar to the results of Kaur et al. (2019) and Balai et al., (2017).

Various water quality parameters should be routinely monitored to understand the aquatic habitats for fish (APHA 2012). In results, our study showed annual variation in all the physio-chemical parameters. Similar observations on the Kali River system and the outer rivers of Uttarakhand by Ram et al. (2012) and Pramod et al. (2014), who have reported about the seasonal variation of habitat ecology in riverine ecology. During the study of habitat ecology, some statistical analyses were also done like ANOVA, correlation, Biplot curve, and linear regression, whose results are found to be similar to those of Hem (2017) and Tomar et al., (2016).

4. CONCLUSION

The studied fish was taxonomically identified as *Labeo rohita*, which was further confirmed by its morpho-biological study, which revealed a significant correlation between total length and other morphometric parameters. It was also concluded from the study of physio-chemical analysis that the aquatic habitat of the Kali River has a conducive environment and it is suitable for the growth of fish species like *Labeo rohita*. The current habitats are also undisturbed from environmental degradation point of view.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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