Journal of Aquatic Biology & Fisheries | 2023 | 11(1) | pp. 78-86
ISSN 2321–340X
OPEN ACCESS
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University of Kerala, INDIA

Morphometric variation of selected barbs from Koraput district, Eastern Ghats, southern Odisha, India

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ABSTRACT

Among the fishes, Barbs are a diverse group under the family Cyprinidae, inhabiting all types of freshwater bodies, are potentially important as many of them are ornamental species, some are of medicinal value and others are used as food and for oil extraction purposes. Koraput district of southern Odisha in Eastern Ghats is a storehouse of rich biodiversity of endemic and threatened flora and fauna including a large variety of fishes. The undulating hilly landscape of the district is provided with a variety of water bodies, such as rivers, hill streams, reservoirs, and manmade tanks. Morphometric studies were carried out using 21 quantitative body parameters of five species of barbs (*Puntius sophore, Puntius dorsalis, Puntius amphibius, Pethia ticto,* and *Pethia conchonius*) collected from both lentic and lotic water bodies of Koraput to identify morphometric variation in them. All measurements were standardised and when subjected to ANOVA and LDA showed that all the sampled species were different from each other based on morphometric parameters which were found to have significant variation ($p<0.05$) among the species and multivariate cluster analysis showed the maximum closeness between *P. amphibius* and *P. ticto* (0.968). This will aid to the identification of fish resources, which can contribute to conservation and management.

ARTICLE HISTORY

Received on: 29-06-2023
Revised on: 27-10-2023
Accepted on: 04-12-2023

KEYWORDS

Smiliogastrinae, Cyprinidae, Meristic characters, *Pethia, Puntius,* Freshwater body

1. Introduction

The distribution of freshwater fishes is found to be worldwide constituting 18,642 of species (Eschmeyer et al., 2023) with Cyprinidae being the largest and most diverse family, consisting of 367 genera and 3006 species (Nelson, 2016). In India, the family is well-represented and accounts for nearly 33.59% (345 species) of total freshwater fish (Gopi et al., 2017). Barbs are the most diverse freshwater fishes under Cyprinidae (Kumar et al., 2019) distributed in both lentic and lotic ecosystems (Bhat, 2004; Chakraborty et al., 2006; Jena et al., 2007) and have a higher demand for aquarium, food, medicine, and oil extraction purposes (Singh et al., 2013).

The fishes of the two genera *Puntius* and *Pethia* under the Sub-family Smiliogastrinae (Family: Cyprinidae) are of small size and with beautiful colour patterns and thereby are very much popular as aquarium fishes and have been traded internationally (Collins et al., 2012). The species of *Pethia* and *Puntius* are highly adaptive to different aquatic habitats such as streams, rivers, canals, lakes, reservoirs, and other wetlands. The species of both genera are almost distributed throughout India except in higher altitudes of the Himalayan ranges (Talwar and Jhingran, 1991).

The shape and structure are unique to the species and considered to be the most significant and integrative aspect of an organism's morphology (Adams et al., 2013; Ingram, 2015). The variations in its features are probably related to the habits and habitat of the species (Cavalcanti et al., 1999). Morphological diversification is a significant process that plays an essential role in the fitness consequences of organisms in an environmental gradient (Langerhans, 2009; Cucherousset et al., 2011). As the phenotypic plasticity of fish is very high, they adapt quickly by modifying their physiology and behaviour to environmental changes. These modifications ultimately change their morphology also (Stearns, 1983). Studies of the differences in morphology and regular performance among related species provide information on the process and magnitude of such differences, which helps in comprehending the natural control of biological diversity (Schoner, 1974; Karr and James, 1975; Bock, 1977). Though morphological plasticity is quite widely evident among all fishes, in barbs plasticity exists even among the individuals as well as sexes making it too difficult to identify the species (Kortmulder et al., 1983; Kottelat and Pethiyagoda, 1989; Jayaram, 1991; Kullander and Fang, 2005; Kullander, 2008). Morphological characters have long been used to study the diversity and taxonomy of these cyprinids (Mohsin and Ambak, 1983). Studies have also been carried out on morphometric plasticity in various species of barbs in different parts of India, in North-East (Choudhury and Dutta, 2011; Choudhury et al., 2011; Jha et al., 2013; Manorama and Ramanujam, 2016; Kumar et al., 2019), East (Kapuri et al., 2011), North (Joshi et al., 2019), Central (Saroniya et al., 2013; Gupta et al., 2018; Bano and Serajuddin, 2021) and South India (Rajasekaran and Sivakumar, 2014; Edwinthangam et al., 2015; Sreelekshmi et al., 2017).

Odisha an eastern state of India is blessed with 52,5248 ha of freshwater resources in the form of rivers, reservoirs, and tanks (Panigrahy et al., 2011), which contributes 13.92% of India's freshwater fish population (Mogelaker and Cancyial, 2018). In Odisha, though some studies on morphometrics have been carried out on marine fishes, particularly in mudskippers (Das and Palita, 2018) and ponyfishes (Seth et al., 2019), flatfishes (Tripathy et al., 2022), there is almost no morphometric study on freshwater fishes in general and *Puntius* and *Pethia* genera in particular from this region of India. Koraput district in southern Odisha in the Eastern Ghats is endowed with a large number of waterbodies, both lentic and lotic. In the present study, an attempt has been made to identify morphometric variation and taxonomic relationships among five species of barbs from waterbodies of Koraput.

2. Materials and Methods

Koraput district (18°14′ to 19°14′ N and 82°05′ and 83°25′ E), a part of Eastern Ghats in Southern Odisha is rich in faunal and floral diversity (Panda et al., 2014; Palita, 2015) with altitude ranging between 500 m to 1600 m AMSL covering an area of 8,807 sq. km. The land is dominated by mountains with hill streams, rivers, reservoirs, and waterfalls (Palita et al., 2016) which harbour various types of freshwater fishes.

Barb specimens were collected from four study sites- Jagannath Sagar (18º55′7.68″N, 82º22′50.16″E), a lentic waterbody and three different lotic sites of Kolab River i.e. Ghatguda (18º45′30″N, 82º49′17″E), Duruguda (18º46′25″N, 82º45′24″E), Kanheiput (18º47′54″N, 82º42′37″E) of Koraput district (Fig. 1) from May 2020 to July 2020. From these sites, a total of 171 specimens were sampled under five barbs species including *Puntius sophore* (n=42), *Puntius dorsalis* (n=30), *Puntius amphibius* (n=30), *Pethia ticto* (n=35), and *Pethia conchonius* (n=34). The fish samples were collected during morning hours (0700 hrs to1100 hrs) with the help of scoop nets, cast nets as well as from local fishers. The sampled barbs were identified based on Jayaram (1991), Talwar and Jhingram (1991), and Froese and Pauly (2010). Photographs of specimens were captured through a Nikon Coolpix camera (Model P900). Specimens were preserved in 10% formalin for future reference.

Twenty-one morphometric parameters, which were studied (Fig. 2) includes - TL-Total Length; SL-Standard Length; HL-Head Length; PrOL-Pre Orbital Length; PsOL-Post Orbital Length; PDL- Pre Dorsal Length; PODL- Post Dorsal Length; DFL- Dorsal Fin Length; PAL- Pre Anal Length; POAL- Post Anal Length; AFL- Anal Fin Length; PPL- Pre Pectoral Length; POPL- Post Pectoral Length; PFL-Pectoral Fin Length; CFL- Caudal Fin Length; CPDL-Caudal Peduncle Length; MBW- Maximum Body Width; BD-Body Depth; ED-Eye Diameter; IOW-Inter Orbital Width; HCPD-Height of Caudal Peduncle. The measurements were taken from the lateral side of the fish on a continuous scale using a digital Vernier calliper. All lengths (in mm) were taken parallel to the anterior-posterior body axis except for the body depth that was taken perpendicular to the body axis between dorsal and ventral margins (Manimegalai et al., 2010). The mean of the data for each species was calculated along with the standard deviation (Table 1). The thirteen meristic characters of the selected five species are DFR-Dorsal Fin Rays; PFR-Pectoral Fin Rays; PLFR- Pelvic Fin Rays; AFR-Anal Fin Rays; CFR-Caudal Fin Rays; LLS-Lateral Line Scale; ALLS -Scales above lateral line; BLLS -Scales below lateral line; PRDS- Pre dorsal scale; POAS- Post anal scale; CPED- Circumpeduncular scales; CFER- Circumferential scales; NOB- Number of Barbels present (Table 2). No significant sexual dimorphism with respect to the selected morphometrics was observed; therefore, the data analysis was performed without taking the sex of the individual and the maturation stage into consideration.

The descriptive statistics i.e. mean, standard deviation and range were analysed by considering the morphometric parameters. The quotients of Total Length and Head Length with other body and head parameters were computed by taking the ratio of morphometric data for all samples of each species. Boxplot analysis had been undertaken by considering Total Length and Head Length quotients with other body and head parameters. Besides effects from the environment and evolutionary history, morphometric characters may contain growth and/or allometric trends. To correct (relative) differences in size, all body and head measurements were transformed into ratios with respect to Total length (TL) and Head length (HL) respectively (Table

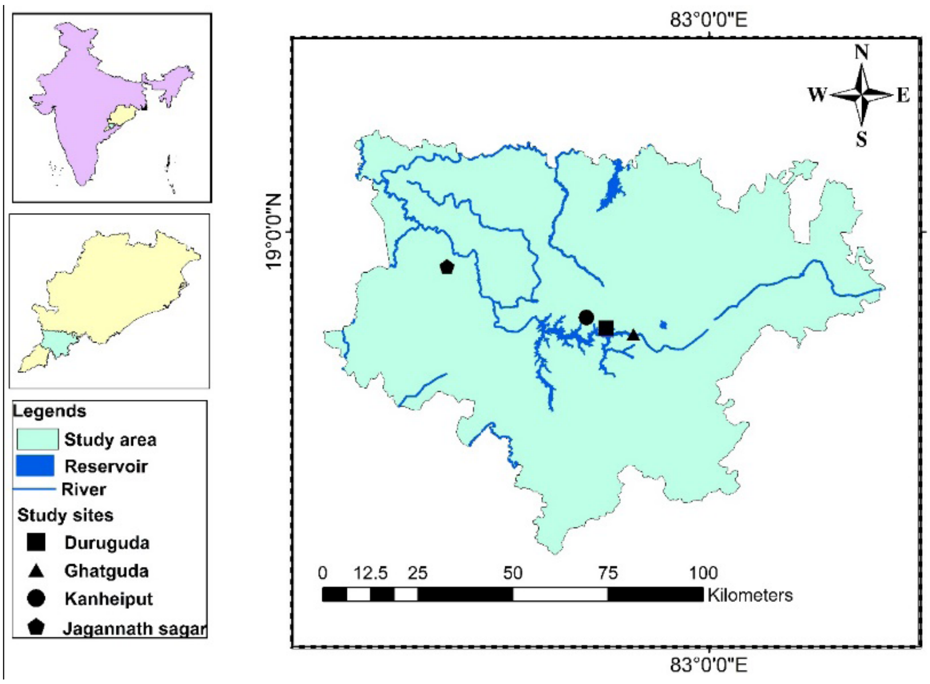

Fig. 1. Map showing location of study sites of Koraput district, Eastern Ghats, Southern Odisha

Table 1. Average (Mean± SD), Range of morphometric data and Quotients of TL and HL with other parameters of five species of Barbs (*Puntius sophore, Puntius dorsalis, Puntius amphibious, Pethia ticto and Pethia conchonius*) sampled from freshwater bodies of Koraput, Odisha.

Measure-ments (mm)	*Puntius sophore*			*Puntius dorsalis*			*Puntius amphibius*			*Pethia ticto*			*Pethia conchonius*		
	Mean± SD	Range	Quotients of TL and HL	Mean± SD	Range	Quotients of TL and HL	Mean± SD	Range	Quotients of TL and HL	Mean± SD	Range	Quotients of TL and HL	Mean± SD	Range	Quotients of TL and HL
TL	81.036± 12.578	63-120	-	89.6 ± 11.457	71-110	-	71.633 ± 11.571	51-89	-	70.428 ± 9.356	56-87	-	62.294± 7.42	50-79	-
SL	62.738± 11.99	26-97	1.283± 0.029	70.05 ± 10.144	55-89	1.281±0.032	53.493 ± 9.112	38.2-67.5	1.341± 0.042	53.971± 7.402	42-68	1.315±0.027	48.117± 5.6	39-60	1.296± 0.039
HL	15.988± 2.610	9.0-24	4.989± 0.277	18 ± 2.939	14.5-23	4.998±0.314	13.883 ± 2.476	Oct-17	5.173± 0.306	14.185 ± 1.839	Nov-17	4.981±0.291	11.676 ± 1.618	Sep-15	5.347± 0.344
PDL	32.666± 5.168	25-48	2.488± 0.1255	34.9 ± 4.801	28-43	2.499±0.394	26.273 ± 5.113	18-34	2.754± 0.256	27.657 ± 4.739	21-35	2.555±0.134	24.91± 2.632	20-30	2.512± 0.077
PODL	33.011± 4.837	25-48	2.465± 0.147	36.7 ± 4.778	29-48	2.446±0.082	28.2 ± 4.999	20-36	2.551± 0.125	29.065 ± 4.506	23-36	2.430±0.105	26.558 ± 3.23	22-33	2.360± 0.101
DFL	13.369± 1.743	Oct-17	5.947± 0.677	14.466 ± 2.599	Oct-20	6.244±0.52	10.233 ± 2.095	6.0-14.0	7.091± 1.088	10.828 ± 1.882	Aug-16	6.534±0.464	9.352± 1.097	06-Nov	6.757± 0.852
PAL	45.976± 7.732	35-72	1.770± 0.069	51.833 ± 8.021	43-67	1.728±0.077	37.51 ± 7.913	22.9-50	1.937± 0.222	39.914 ± 6.089	31-51	1.776±0.08	34.308 ± 4.711	28-42.5	1.829± 0.150
POAL	17.857± 4.528	Nov-29	4.636± 0.944	17.9 ± 2.901	14-24	5.027±0.473	16.366 ± 2.697	12.0-22.0	4.418± 0.458	15.057 ± 2.248	Nov-20	4.757±0.492	15.470 ± 4.086	Oct-25	4.132± 0.780
AFL	8.678± 1.947	05-Dec	9.259± 2.513	10.7 ± 2.167	Aug-14	8.460±0.793	7.92 ± 1.787	5.0-11.0	9.152± 1.068	7.3 ± 1.51	05-Oct	9.983± 2.00	7.441 ± 4.668	5.0-33	9.378± 1.942
PPL	17.202± 2.66	12.5-25	4.753± 0.375	19.25 ± 2.815	16-24	4.644±0.296	14.983 ± 3.201	Oct-20	4.872± 0.66	14.971 ± 1.806	Dec-19	4.720±0.318	13.235 ± 2.585	Apr-17	5.086± 2.114
POPL	47.476± 9.345	31-75	1.737± 0.134	52.166 ± 7.153	42-64	1.715±0.074	38.1 ± 6.567	27-49	1.881± 0.124	40.028 ±6.337	30-51	1.763± 0.077	36.661 ± 4.688	30-47	1.710± 0.091
PFL	11.333± 1.934	Jul-16	7.086± 0.992	12.666 ± 1.773	Oct-17	7.151± 0.419	9.3 ± 1.803	6.0-13.0	7.735± 0.534	10.2 ± 1.663	Aug-14	6.969± 0.544	8.485± 1.509	06-Nov	7.498± 0.825
CFL	17.25± 2.783	13-27	4.643± 0.696	20.333 ± 2.698	17-25	4.390±0.220	14.866 ± 2.658	10.0-20.0	4.828± 0.235	15.171 ± 3.314	Jan-19	4.626±0.489	14.323± 1.87	12-18.5	4.366± 0.244
CPDL	17.19± 5.170	Jun-29	5.551± 2.291	17.666 ± 2.708	13-21	5.347±1.391	16.733 ± 3.453	Nov-22	4.319± 0.415	14.585 ± 3.006	Sep-19	5.429±1.665	16.191± 3.064	Jul-21	3.895± 0.887
HCPD	10.5± 2.018	Jun-15	7.912± 1.399	10.733 ± 0.639	10-Dec	8.388± 0.786	8.633 ± 1.809	05-Nov	8.356± 1.008	7.957 ± 2.143	4.5-12	9.056±1.675	8.220 ± 0.719	06-Sep	7.664± 0.744
MBW	13.273± 13.954	6-9.5	7.828± 2.0203	12.683 ± 2.309	9.0-17.0	7.127± 0.736	8.78 ± 1.71	06-Nov	8.265± 0.795	10.014 ± 5.008	Apr-20	7.902±2.596	6.75± 1.149	04-Sep	9.568± 1.426
BD	19.833± 3.998	Nov-31	4.232± 1.125	23.783 ± 4.72	18.5-38	3.797±0.349	16.433 ± 3.202	Dec-20	4.400± 0.370	20.2 ± 4.137	13 -28	3.523±0.354	16.955 ± 2.441	14-22	3.664± 0.184
PrOL	5.059± 0.983	3.5-7	3.265± 0.415	5.833 ± 1.493	4-8.5	3.111±0.405	3.333 ± 1.028	2.0-6.0	4.354± 0.777	4.9 ± 1.11	3.0-7.0	2.950±0.536	3.794± 0.946	2.0-5.5	3.067± 0.655
PsOL	7.476± 1.645	05-Nov	2.253± 0.359	8.1 ± 1.482	6.0-11.0	2.199±0.197	6.133 ± 1.407	4.0-8.0	2.329± 0.402	6.228 ± 1.133	05-Sep	2.273±0.220	5.117± 0.591	4-6.5	2.239± 0.385
ED	5.0714± 0.874	3.5-8	3.222± 0.512	5.25 ± 0.583	4-6.5	3.455±0.594	3.2 ± 0.97	02-Jun	4.513± 0.698	4.457 ± 0.679	03-Jun	3.318±0.536	3.823 ± 0.534	3.0-4.5	3.115± 0.447
IOW	7.083± 0.89	05-Sep	2.260± 0.199	7.78 ± 1.148	6.0-10	2.267±0.432	5.716 ± 0.906	4.0-8.0	2.449± 0.29	5.985 ± 0.988	05-Aug	2.394±0.276	5.161± 0.342	05-Jun	2.512± 0.077

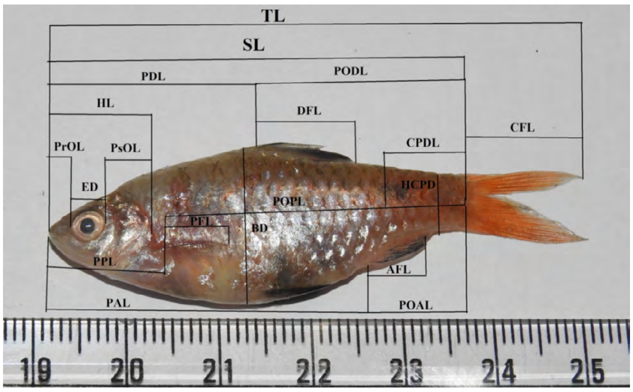

Fig. 2. Lateral view of *Pethia ticto* with various morphometric parameters

TL-Total Length; SL-Standard Length; HL-Head Length; PrOL-Pre Orbital Length; PsOL-Post Orbital Length; PDL- Pre Dorsal Length; PODL- Post Dorsal Length; DFL- Dorsal Fin Length; PAL- Pre Anal Length; POAL- Post Anal Length; AFL- Anal Fin Length; PPL- Pre Pectoral Length; POPL- Post Pectoral Length; PFL-Pectoral Fin Length; CFL- Caudal Fin Length; CPDL-Caudal Peduncle Length; MBW-Maximum Body Width; BD-Body Depth; ED-Eye Diameter; IOW-Inter Orbital Width; HCPD-Height of Caudal Peduncle

1, Fig. 3). Moreover, selecting specimens from a specific size range may also contribute to the elimination of growth trends (Choudhury et al., 2011). Standardized parameters were subjected to descriptive analysis-Correlation and Regression Analysis done by taking TL and HL as independent variables for body and head parameters respectively, One-way Analysis of variance (ANOVA), Linear Discriminant Analysis (LDA), and Bray-Curtis cluster analysis to detect the interspecies variations among the sampled barbs species. For statistical analysis, PAST software Vers 3.3 (Hammer et al., 2001) was used.

3. Results and Discussion

The result of the present study constituting of mean, standard deviation, range, and ratio value of each morphometric parameter in relation to Total Length (TL) and Head Length (HL) were summarised in Table 1. The present findings were observed to have similarity with the findings of Choudhury *et al.* (2011) and Choudhury and Dutta (2013) on the morphometric variation in six species of barbs (*P. chonchonius, P. ticto ticto, P. sarana sarana, P. sophore, P. chola* and *P. gelius*).

Saroniya et al. (2013) found that in *P. ticto,* the quotient of TL and other body parameters like standard length, body depth, head length and depth of caudal peduncle was 1.31, 3.40, 4.78, and 8.91 times in total length respectively, whereas in the present study, it was 1.31, 3.52, 4.98 and 9.06 respectively (Table 1). Similarly in *P. sophore,* for the above parameters values obtained were 1.29, 3.27, 4.71 and 7.99 respectively (Saroniya et al., 2013). However, the values obtained in the present study showed them to be 1.28, 4.23, 4.98 and 7.91 respectively. In case of *P. conchonius,* Saroniya et al. (2013) found the values of quotient of TL and other body parameters as 1.29, 2.81, 4.77, and 8.37 respectively, while the values obtained in the present study were 1.29, 3.66, 5.34 and 7.66 respectively (Table 1).

Choudhury and Dutta (2013) explained that the quotients of TL and PAL, PDL, PPL, BD, HL in *P. conchonius* to be

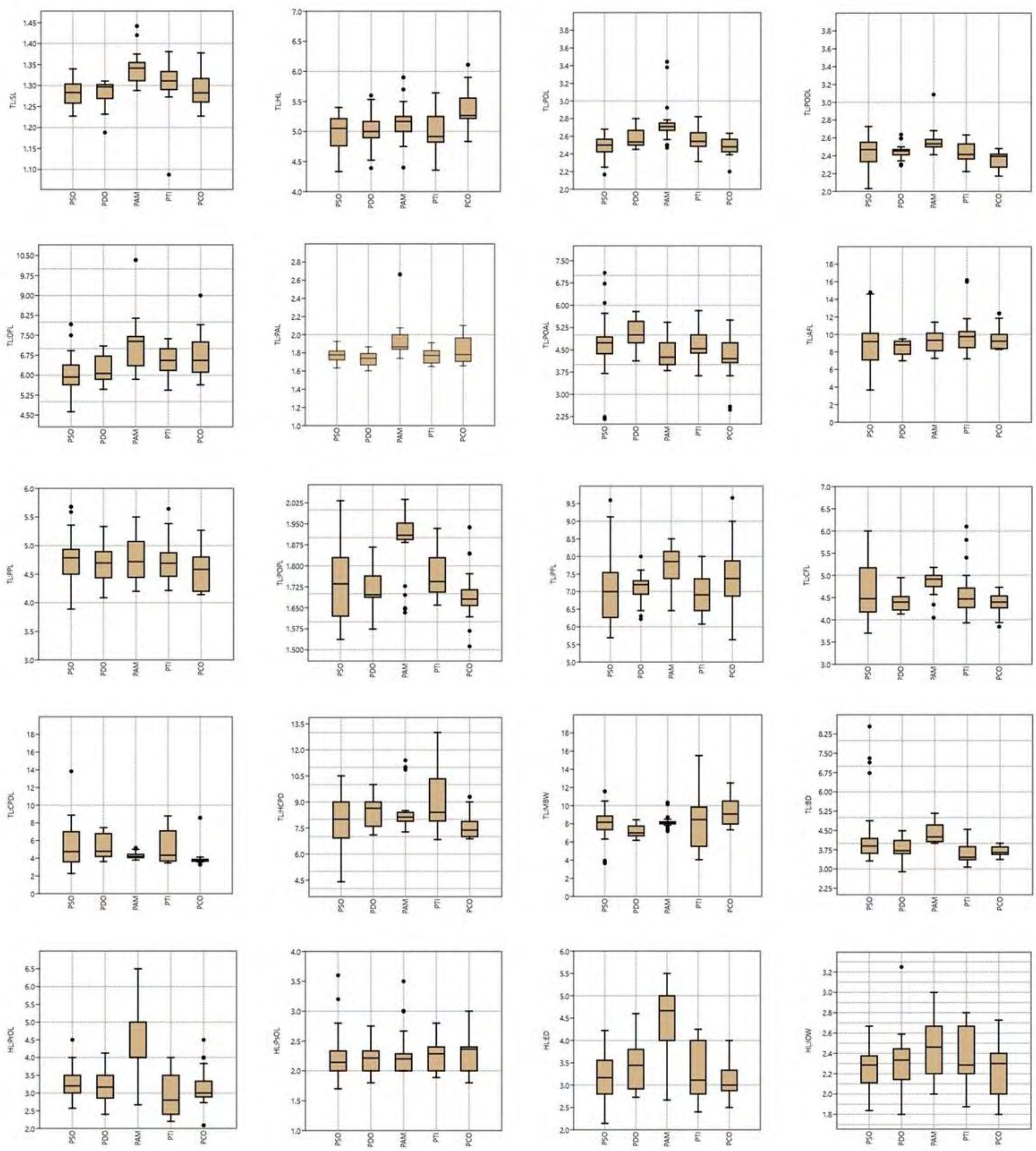

Fig. 3. Box plots of selected barbs- PSO (*Puntius sophore*), PDO (*Puntius dorsalis*), PAM (*Puntius amphibius*), PTI (*Pethia ticto*), PCO (*Pethia conchonius*), showing quotients of the TL and other body parameters; HL and other body parameters

1.73, 2.33, 5.60, 2.88 and 4.73; whereas the values obtained in the present study were 1.82, 2.51, 5.08, 3.66 and 5.34 respectively (Table 1). In case of *P. sophore* the quotient values were 1.71, 2.60, 6.42, 3.10 and 5.84 respectively (Choudhury and Dutta, 2013), whereas in the present research the values obtained were 1.77, 2.48, 4.75, 4.23 and 4.98 respectively. The quotient values for *P. ticto* obtained by Choudhury and Dutta (2013) were 1.79, 2.31, 3.15, 3.17 and 5.72 respectively, whereas the findings of the present study showed them to be 1.77, 2.55, 4.72, 3.52 and 4.98 respectively (Table 1).

The meristic counts of the present study were observed to vary within a particular range (Table 2), which coincided with the meristic analysis of *P. sophore*, *P. conchonius*, *P. ticto* from central India (Saroniya et al., 2013) and Tripura (Kumar et al., 2019).

The coefficient of correlation (r) for all the species by taking TL as independent variable for 16 body parameters and HL as independent variables for four (04) head parameters it was recorded that, for *P. sophore,* the values of correlation coefficient showed to be of high value indicating highly positive and significant correlation except for SL, BD, AFL,

Table 2. Meristic count of five barb species collected from study sites

Parameters	*P. sophore*	*P. dorsalis*	*P. amphibious*	*P. ticto*	*P. conchonius*
LLS	25-26	26-27	24-26	24-25	23-24
ALLS	5 ½	5 ½	4 ½	4 ½	4 ½
BLLS	3 ½	3 ½	3 ½	3 ½	3 ½
PRDS	08-Sep	9	8	9	8
POAS	05-Jun	05-Jun	7	5	7
CPED	10-Dec	10-Dec	10	10	10
CFER	16-18	16-18	16	16	16
DFR	i-ii 7-8	i 8	i 8	i-ii 8	i 8
CFR	ii 18	iv-vi 16-19	iv 19	iv 18	iv-vi 16-17
AFR	i 5	i 5-6	i 6	iii 5	i 6
PLFR	i-ii 7-8	i-ii 6-8	i 7	ii-iii 7-8	ii 7
PFR	ii 10	iv 9-11	v-vi 8	iii 8-10	iii-iv 8
NOB	NIL	2 (1 pair)	2 (1 pair)	NIL	NIL

CPDL, HCPD, ED, PrOL, PsOL, out of which BD was observed to be insignificantly correlated ($p>0.05$). (Table 3). For *P. dorsalis,* all the morphometric parameters were positive and significantly correlated ($p<0.05$) except for CPDL which showed a negative but significant correlation with TL and ED exhibited a positive but insignificant correlation with HL. For *P. amphibius* and *P. conchonius* all the parameters were observed to be positively and significantly correlated showing high correlation of the parameters with TL and HL. In the case of *P. ticto,* the low value of the correlation coefficient between ED and HL showed a significant but very low correlation among them, while CPDL and TL showed negative correlation among them (Table 3). The results of the present study were found to be similar to the findings of Choudhury and Dutta (2013) i.e. all the morphometric characters were highly significantly correlated except for TL and PrOL for six species of barbs; with the findings of Alam *et al.* (2012) and Saroniya et al. (2013) who recorded most of the morphometric parameters to be highly correlated with TL for *P. conchonius*, *P. sophore* and *P. ticto* except for SL and ED in *P. conchonius* and *P. ticto*.

For all the species, the value of b in the regression equation ($y=bx+a$) was observed to be less than 3 ($b<3$) for all the parameters thereby showing negative allometric growth (Habib et al., 2019) i.e. all the body and head parameters were observed to show very slow growth rate in relation to TL and HL respectively (Table 3).

All the morphometric parameters (n=21) generated were transformed to ratios with respect to total length (n=16) and head length (n=4) and were subjected to one-way ANOVA to test for the significant difference of the parameters among the species and all the parameters were found to vary significantly ($p<0.05$) at 5 % level of significance (Table 4). Thereby all the parameters were selected for LDA to examine the sufficiency of attributes for discrimination of species.

Based on transformed morphometric parameters, four axes had been created in LDA among which axis 1 showed the maximum variance of 67.6% with Eigen value 1.117. Based on scores of axis 1, it was recorded that *P. ticto, P. conchonius* and *P. amphibius* were relatively closely placed than that of *P. sophore and P. dorsalis* (Fig 4), which was observed to be similar to the findings of Kumar et al. (2019), who recorded maximum proximity of the *P. conchonius* and *P. ticto* based on Discriminant Function Analysis. Based on LDA plot the main parameters which contributed highly towards the discriminant analysis were observed to be: HCPD, MBW, PsOL, HL, AFL, PDL, POPL, PAL, SL, DFL, PPL, PODL, CFL, PrOL, POAL and BD (Fig 4, Table 5). The confusion matrix showed that all the specimens for each species had been completely separated i.e. 100% (Table 6). Similar work was conducted by Choudhury and Dutta (2013), which reflected that based on Principal Component Analysis, *P. chola* and *P. conchonius* to be one group, *P. ticto ticto*, *P. sarana sarana* and *P. gelius* forming another group, while *P. sophore* was completely different indicating it to be a unique species among the *Puntius* genus (Mirza, 1975). This variation in morphology leading to closeness or grouping of the species (Roesma and Chronelia, 2014) may owe to the integral role of the physical environment of the habitat, resulting

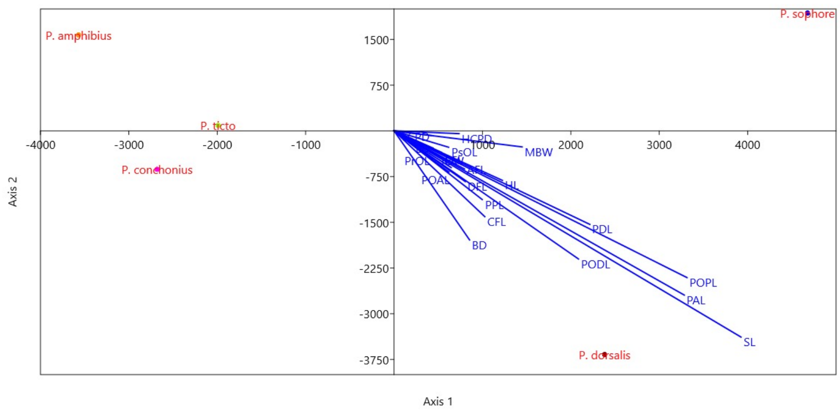

Fig. 4. LDA analysis for Interspecific variation of sampled five barb species of Koraput, Odisha

Table 3. Regression Equation, Correlation coefficient (r) and significance (p) value of morphometric parameters of the sampled Puntius species (Total Length vs. other characters and Head Length vs. other characters)

Standardized Parameters (mm)		*P. sophore*			*P. dorsalis*			*P. amphibious*			*P. ticto*			*P. conchonius*		
		y=bx+a	r	p	y=bx+a	r	p	y=bx+a	r	p	y=bx+a	r	p	y=bx+a	r	p
SL	TL	y=1.900x-2.232	0.426	0.005	y=1.105x-0.478	0.989	4.23E-25	y=1.038x-0.369	0.985	2.75E-23	y=0.997x-0.262	0.96	6.67E-20	y=0.952x-0.170	0.967	1.16E-20
MBW	TL	y=1.916x-3.848	0.643	4.31E-06	y=1.205x-2.412	0.847	3.55E-09	y=1.111x-2.323	0.907	4.51E-12	y=2.748x-5.447	0.798	9.06E-09	y=0.780x-1.830	0.495	0.002
BD	TL	y=0.435x-0.323	0.242	0.122	y=1.312x-2.019	0.896	2.07E-11	y=1.115x-1.703	0.923	3.74E-13	y=1.492x-2.218	0.95	2.46E-18	y=1.147x-1.573	0.933	8.84E-16
HL	TL	y=0.725x-1.054	0.66	1.98E-06	y=1.174x-1.991	0.933	5.21E-14	y=1.083x-1.807	0.955	2.43E-16	y=0.885x-1.379	0.884	1.93E-12	y=1.062x-1.791	0.876	1.15E-11
PDL	TL	y=0.986x-0.881	0.945	4.57E-21	y=1.014x-0.974	0.958	8.00E-17	y=1.104x-0.296	0.914	1.61E-12	y=1.245x-1.416	0.966	4.78E-21	y=0.855x-0.652	0.939	1.95E-16
PODL	TL	y=0.867x-0.620	0.908	9.71E-17	y=0.969x-0.826	0.966	4.65E-18	y=1.062x-1.057	0.971	4.81E-19	y=1.115x-1.112	0.961	4.17E-20	y=0.955x-0.771	0.921	1.12E-14
DFL	TL	y=0.570x-0.906	0.659	2.01E-06	y=1.296x-2.479	0.92	5.87E-13	y=1.067x-2.088	0.796	1.40E-07	y=1.142x-2.155	0.888	1.11E-12	y=0.572x-1.118	0.507	0.0021
PAL	TL	y=1.039x-0.650	0.967	1.76E-25	y=1.112x-0.795	0.955	1.96E-16	y=1.237x-1.122	0.915	1.33E-12	y=1.098x-0.760	0.961	5.01E-20	y=0.980x-0.564	0.808	7.16E-09
POAL	TL	y=0.858x-1.236	0.527	0	y=1.007x-1.631	0.81	5.67E-08	y=0.802x-1.090	0.816	3.66E-08	y=0.870x-1.293	0.766	8.16E-08	y=1.243x-1.869	0.556	0.0006
AFL	TL	y=0.753x-1.701	0.38	0.013	y=1.478x-3.182	0.936	3.04E-14	y=1.215x-2.635	0.873	2.92E-10	y=0.899x-2.083	0.572	0.0003	y=0.466x-1.222	0.161	0.361
PPL	TL	y=0.856x-1.251	0.848	1.29E-12	y=1.006x-1.554	0.891	3.95E-11	y=1.137x-1.842	0.864	7.67E-10	y=0.803x-1.165	0.881	2.73E-12	y=1.018x-1.604	0.422	0.012
POPL	TL	y=1.224x-1.008	0.947	2.01E-21	y=1.000x-0.543	0.946	3.11E-15	y=0.986x-0.607	0.925	2.43E-13	y=1.170x-0.899	0.974	6.15E-23	y=0.977x-0.490	0.906	1.53E-13
PFL	TL	y=0.771x-1.494	0.673	1.02E-06	y=0.986x-1.928	0.893	3.23E-11	y=1.100x-2.243	0.937	2.31E-14	y=1.061x-2.055	0.888	1.03E-12	y=1.247x-2.454	0.802	1.17E-08
CFL	TL	y=0.592x-0.699	0.574	7.05E-05	y=0.933x-1.337	0.921	5.37E-13	y=1.064x-1.702	0.965	7.63E-18	y=1.532x-2.622	0.42	0.011	y=0.982x-1.440	0.885	3.45E-12
CPDL	TL	y=0.320x-0.180	0.133	0.397	y=-0.712x+2.114	-0.571	0.0009	y=-1.194x-1.842	0.917	9.85E-13	y=-0.947x+2.197	-0.582	0.0002	y=-1.046x-1.449	0.5	0.002
HCPD	TL	y=0.521x-1.055	0.401	0.008	y=0.332x-0.657	0.723	6.19E-06	y=1.201x-2.519	0.874	2.64E-10	y=1.988x-4.130	0.923	2.89E-15	y=0.515x-1.140	0.613	0.0001
ED	HL	y=0.453x-0.899	0.451	0.003	y=0.214x-0.773	0.314	0.090703	y=1.396x-1.618	0.878	1.82E-10	y=0.420x-0.962	0.378	0.025046	y=0.565x-1.054	0.522	0.001
PrOL	HL	y=0.473x-0.914	0.413	0.006	y=1.327x-1.332	0.877	1.99E-10	y=1.532x-1.624	0.898	1.60E-11	y=1.121x-1.121	0.646	2.71E-05	y=1.329x-1.192	0.737	6.49E-07
PsOL	HL	y=0.631x-0.602	0.47	0.001	y=0.961x-0.779	0.867	5.91E-10	y=1.001x-0.828	0.778	4.16E-07	y=1.103x-0.865	0.825	1.04E-09	y=0.422x-0.738	0.493	0.0029
IOW	HL	y=0.443x-0.555	0.566	9.11E-05	y=0.682x-0.654	0.739	3.05E-06	y=0.655x-0.775	0.774	5.02E-07	y=0.837x-0.811	0.695	3.58E-06	y=0.250x-0.699	0.546	0

Table 4. Summary of One-way ANOVA analysis of sampled barb fishes

Parameters	**p value**
SL	2.02E-17
MBW	7.90E-17
BD	2.15E-18
HL	4.84E-25
PDL	1.08E-19
PODL	1.61E-18
DFL	1.55E-32
PAL	1.32E-21
POAL	1.18E-09
AFL	2.58E-25
PPL	4.09E-22
POPL	1.48E-19
PFL	3.41E-24
CFL	4.89E-24
CPDL	2.76E-09
HCPD	2.60E-23
ED	1.00E-49
PrOL	8.95E-26
PsOL	4.94E-30
IOW	1.49E-40

Table 5. Summary of LDA of five sampled barb species from Koraput, Odisha

Variable	Axis 1	Axis 2	Axis 3	Axis 4
SL	-14117	-1565.8	2152.7	6159.6
MBW	-2912.1	1530.1	9504.1	-5938.2
BD	-9823.8	1476.5	3393.6	-3236.8
HL	20685	14799	10875	4657.5
PDL	3623.1	4812.2	-3440.2	25946
PODL	652.55	-13642	-15058	-4127.7
DFL	1808.7	-163.83	756.9	-2071.1
PAL	565.85	4415.9	-11012	-9075.8
POAL	-8985.5	15565	319.91	-7054.8
AFL	3718.9	-444.23	1830.1	-6494.9
PPL	-4428.9	-6847.5	22095	-8073.6
POPL	16981	-1835.6	-1.52	-7663.6
PFL	2207.6	4570.9	-281.95	1683.4
CFL	4301.8	-16783	10657	9556.9
LCPD	-290.14	784.81	1961.5	-1435
HCPD	-3893.6	7504.1	1139.2	-4289.9
ED	16.43	-13.71	-35.19	17.48
PrOL	2.47	-17.24	-11.15	20.48
PsOL	-47.47	71.86	76.55	-65.89
IOW	59.25	-84.33	-84.42	70.96
Proportions				
Eigenvalue	1.11	3.91	1.42	14362
Variance%	67.6	23.66	8.65	0.08
Scores				
Variables	Axis 1	Axis 2	Axis 3	Axis 4
P. sophore	4677.24	1932.38	-281.4	-13.53
P. dorsalis	2381.92	-3670.1	901.45	-24.41
P. amphibius	-3568.66	1574.43	1752.07	-95.95
P. ticto	-1991.32	90.25	-135.84	221.04
P. conchonius	-2680.73	-630.85	-1853.89	-104.62

Table 6. Confusion matrix of LDA Analysis for the sampled species

Species	*P. sophore*	*P. dorsalis*	*P. amphibius*	*P. ticto*	*P. conchonius*	Total
P. sophore	42	0	0	0	0	42
P. dorsalis	0	0	0	0	30	30
P. amphibius	0	0	0	30	0	30
P. ticto	0	35	0	0	0	35
P. conchonius	0	0	34	0	0	34
Total	42	35	34	30	30	171

Table 7. Summary of Bray Curtis Similarity Index of five sampled barb species from Koraput, Odisha

	P. sophore	*P. dorsalis*	*P. amphibius*	*P. ticto*	*P. conchonius*
P. sophore	1	0.95	0.91	0.92	0.87
P. dorsalis	0.95	1	0.86	0.88	0.82
P. amphibius	0.91	0.86	1	0.97	0.96
P. ticto	0. 92	0. 88	0.97	1	0.93
P. conchonius	0. 87	0. 82	0.96	0.94	1

in adaptation (Horyono, 2001) and thereby variation in phenotype as a consequence of genetic responses caused by physical alterations of environment (Thompson, 1991) as evident in the findings of De Silva and Liyanage (2006) which highlighted the impact of altitude on morphological variations in Sri Lanka.

Based on results of the multivariate cluster analysis of standardised morphometric characters (Table 7) *P. sophore* showed maximum similarity with *P. dorsalis* (0.95), *P. amphibius* showed maximum similarity with *P. ticto* (0.97*)* and *P. conchonius* with *P. amphibius* (0.96). Based on the similarity matrix, a single link Bray- Curtis dendrogram (Fig. 5) was constructed in order to understand the closeness among the studied species. The maximum proximity was shown by *P. ticto*, *P. amphibius* and *P. conchonius* forming one group while *P. sophore* and *P. dorsalis* forming another group (Fig. 5). The results were observed to be similar with the findings of Choudhury et al. (2011), which indicated *Puntius sarana sarana* and *P. gelius* to be the most closely related species followed by *P. ticto ticto*, *P. chola* and *P. conchonius,* however, Kumar et al. (2019) recorded proximity between *P. conchonicus* and *P. ticto* while Talwar and Jhingram (1991) observed morphological closeness of characters between *P. conchonius* and *P. chola*.

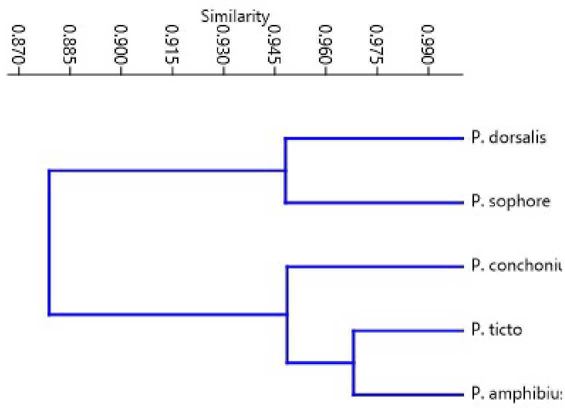

Fig. 5. Bray Curtis Cluster dendrogram of sampled barb species of Koraput, Odisha

4. Conclusion

The present study is the first report on the morphological variation of five selected barbs sampled from both lotic and lentic water bodies in Koraput, Odisha from the Eastern Ghats of India. The findings indicate that though there is similarity mostly in meristic characters and in some morphometric characters, there is a clearcut variation in good numbers of morphometric characters of species within a genus and among the two genera studied. The body shape being the most important and integrative aspect of an organism's morphology, the variation in body shape within the species and among the species is due to their adaptation to a variety of environmental factors and niche requirements. World over, most of the freshwater bodies are threatened and required conservation attention. For the conservation and management of freshwater bodies, the present morphometric study will provide a source of taxonomic information for the studied barbs and other small indigenous species of India.

Acknowledgement

We are thankful to UGC for providing Non- NET fellowship to the first author to carry out the study as well as to the local fishermen for providing the samples and from fish catch.

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