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Research Article

Morpho-meristic analysis of the great snakehead (*Channa marulius*) collected from the Lowland ecosystem in Bangladesh and its future implications

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Abstract

The genus Channa has many species including several cryptic species like the great snakehead (*Channa marulius*), locally known as “Gajar”, distributed across its natural distribution range of Southern and Southeast Asian countries including Bangladesh. This fish needs to be conserved but there is no information regarding the morphological variations in Bangladesh. This study reveals the morphometric traits and meristic counts of *C. marulius* collected from the lowland ecosystem in Bangladesh. A total of 67 samples were collected from 7 locations in Bangladesh to record morphological observations. This investigation was done on 6 meristic traits and 17 morphometric features. The fin formulae of *C. marulius* were dorsal 55-45, pectoral 19-14, pelvic 2-6, anal 37-28, and caudal C. 17-12. The lateral line is present which continued with 68-61 scales in a single line. All relationships (coefficient of determination, r^2) of the morphological measurements were found significant statistically ($p \leq 0.05$) by analysis of variance. The r^2 value shows the length-length relationships by total length (TL) vs. standard length (SL) (TL=a+b×SL) as the best-fitted model among seventeen equations. The fifteen morphometric measurements were used for the classification of populations by discriminant function analysis and could separate the populations at $p<0.001$ at a highly significant level. The principal component analysis showed that SL, TL, and LDFB (length of dorsal fin base) of the morphometric measurements were important for the phenotypic variation in *C. marulius* fish populations. Thus, three key characteristics can be used to know the populational variations of *C. marulius* in Bangladesh and these findings can be useful for making any comparisons with its related species.

Introduction

The genus *Channa* is a group of percoid fishes having wide natural distribution in various parts of Southeast Asian countries. The great snakehead (*C. marulius*) is a freshwater fish that belongs to the family Channidae of the order Anabantiformes (Nelson *et al.*, 2016). The members of Channidae commonly known as snakeheads, comprise a vast proportion of the total fish caught in Bangladesh (Ahmed *et al.,* 2018). There are four major species of snakeheads, viz. *Channa striata*, *C. marulius*, *C. gachua,* and *C. punctata* found in Bangladesh are also distributed in other Asian countries like India, Pakistan, Thailand, Vietnam, Malaysia, Laos, and China (Roy *et al.,* 2020). *C. marulius* locally known as *Gajar* in Bangladesh is highly regarded for its flavor, high nutritional values, curative, and medicinal properties, and it is occasionally suggested as a diet during recovery from illness in humans (Rakhi *et al.,* 2023). At least 40 species belong to the genus *Channa*, mainly occurring in southern Asia (Froese and Pauly, 2022). It is also reported to be the largest in size of the family Channidae, reaching a length of 120-122 cm (Talwar and Jhingran, 1991). *Channa* populations in Southeast Asia are now regarded as separate species (Adamson and Britz, 2018; Adamson *et al*., 2019). According to the list of the international union conservation of nature (IUCN, 2015), *C. marulius* fish species was listed as endangered in Bangladesh due to loss of habitats, various anthropogenic factors, indiscriminate fishing, aquatic pollution, and killing to save cultured fish. However, *C. marulius* and *C. maruiloides* are unlikely to be mistaken in the wild (Courtenay and Williams, 2004). And the species *C. maruiloides*, is known to have a big ocellus at the base of the upper lobe of the caudal fin, and the species is distributed in Thailand, Malaysia, and Indonesia. Both species' juveniles may have a series of dark spots down the sides, but in *C. marulius*, these spots are bordered on the back and front by white scales. However, late juveniles and adults of *C. marulioides* typically display black, white-margined blotches (Lee and Ng, 1991).

Morphometry is one of the multidisciplinary methods used to identify stocks (Ihssen *et al.,* 1981). According to Kováč *et al*. (1999), one of the key factors in influencing the growth variability, systematics, and ontogenetic trajectories of fishes is their morphological traits. In the opinion of some researchers, phenotypic variation is a dynamic and flexible concept that has an immediate impact on population structure since it is modified by external factors (Tudela, 1999). Morphometry is a technique used for narrating body form by assessing the length or distance between physical characteristics and landmarks (Muchlisin, 2013). Studies on morphometric and meristic features can be constructive tools for the exact identification of any species and its classification (Bagenal and Tesch, 1978; Jayaram, 1999; Hossen *et al.*, 2016).

Additionally, morphological traits have been successfully applied to identify fish stocks, describe their spatial distributions, and determine the morphological differences between the populations of a species (Mustać and Sinovčić, 2010; Ivanković *et al.,* 2011). Furthermore, morphological features are crucial for life cycle assessment in fisheries research, as well as for assessing an individual's health and evaluating the morphological features of various populations (King, 2007; Hossain, 2010; Hossain *et al.*, 2013). Fish morphological qualities, primarily morphometric properties, can differ between populations as a result of the interactions between genetics, environmental variables, and developmental stages (Yen *et al.,* 2019). Although several studies have been done in the past, systematic studies on snakeheads are very rare. Taxonomic studies on *Channa* species in northeastern India were undertaken by Vishwanath and Geetakumari (2009) and they grouped *Channa* species under the *Marulius* and *Gachua* with clear anatomical distinctions. There is no detailed record of the population description using morphometric and meristic traits of this fish yet. While some researchers have conducted morphometric studies on other species of *Channa*, such as Song *et al*. (2013) and Nguyen and Duong (2016), who reported on the morphological characterization of *C. striata* in Vietnam and Malaysia, Paunikar and Panwar (2021) examined the morphological features of *C. gachua* in India along with four other freshwater fish species, and studies with *C. punctata* (Islam *et al.,* 2020), *C. orientalis* (Chowdhury *et al.,* 2021), and *C. striata* (Jannat *et al.,* 2022) have been reported from Bangladesh. From this aspect, the present study was undertaken to document morphometric and meristic characteristics of *C. marulius* inhabiting the natural ecosystem of Bangladesh using multi-linear dimensions and to provide taxonomic implications for the conservation and management of the endangered *C. marulius*.

Materials and methods

Sample collection

Native great snakeheads (*C. marulius*) were collected from the natural habitats of Bangladesh. Generally, in winter season when the low land ecosystem in Bangladesh becomes dried these great snakehead fishes along with other fishes were captured and sold near the bank of the beel, haor, and river by the local fishermen or in the nearby fish market. Thus the samples were collected through close monitoring during that time and a total of 67 samples were collected from natural sources of 7 divisions of Bangladesh viz. Barishal, Chattogram, Dhaka, Khulna, Mymensingh, Rajshahi, and Sylhet represent all-natural sources in Bangladesh (Fig. 1).

Morphometric analysis

Data on the 17 morphometric measurements of individuals were analyzed using univariate and multivariate techniques (Jannat *et al.*, 2022). Regression equations and coefficient of determination of morphometric characters of *C. marulius* with total length were calculated with ANOVA analysis in Originpro software (version. 2022). Principal Component Analysis (PCA) and Discriminant Function Analysis (CDFA) were performed in evaluating the data. PCA analysis was performed by statistical package R, and CDFA was performed by Originpro software (version. 2022) and a 5% level of significance threshold was considered for all tests (Fig. 2).

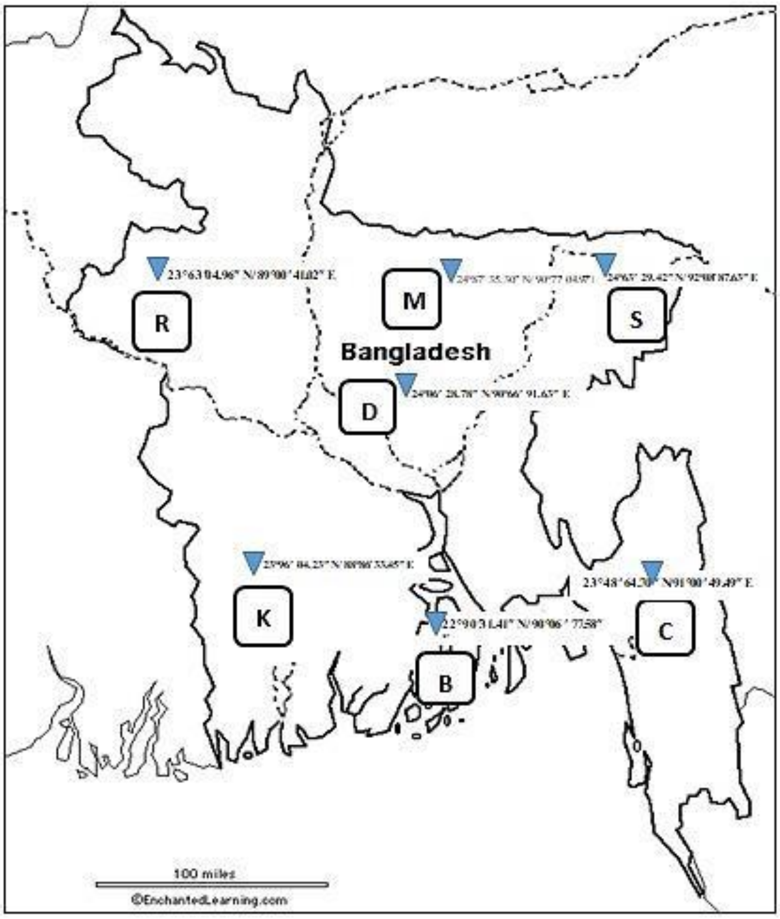

Figure 1: Map shows the sampling location used in the present study. D= Dhaka (S.N=15); C=Chattogram (S.N=10); M=Mymensingh (S.N=13); S= Sylhet (S.N=8); R= Rajshahi (S.N=9); B= Barishal (S.N=7); K= Khulna (S.N=5). *S.N= Sample number

Results

The great snakehead (*C. marulius*) has a nearly cylindrical anterior shape and a compressed posterior lateral shape (BDFish Feature). A large mouth with villiform teeth on the jaws. Large plate-like scales were present on the head. There were 61-68 scales on the lateral line. Four to five large black blotches were present along the sides of the body. A conspicuous black, light-edged ocellus was visible at the upper base of the caudal fin. The body color was white to pale yellow on the ventral side and dark grey to black on the dorsal side.

The descriptive statistics of morphometric data are given in Table 1, and the meristic characteristics analyzed by studying lateral line count, scale count, and fin count (6 counts) are given in Table 2. The TL was diverse from 26.31-37.46 cm (mean±SD= 31.05±4.44) (Table 2) and the fin formula was: dorsal fin, D. 55-45; pectoral fin, P1.19-14; pelvic fin, P2. 6; anal, A. 37-28; and caudal fin, C. 17-12 (Table 1).

Table 1: Descriptive statistics of the morphometric characters of *Channa marulius* populations.

Morphometric Characteristics (cm)	Localities							
	Khulna (Mean±SD)	Barishal (Mean±SD)	Dhaka (Mean±SD)	Mymensingh (Mean±SD)	Rajshahi (Mean±SD)	Chattogram (Mean±SD)	Sylhet (Mean±SD)	(Mean±SD)
SL	29.36± 3.20	22.71±3.75	24.9±4.61	25.12±2.92	29.83±2.63	24.86±2.43	33.24±2.22	27.15±3.72
TL	34.64 ±2.86	26.48±3.76	28.8±4.93	26.31±2.64	34.544±2.66	29.10±2.86	37.46±1.31	31.05±4.44
PVFL	3.20±0.46	2.24±0.42	2.45±0.49	2.65±0.28	3.01±0.41	2.41±0.36	3.27±0.21	2.75±0.40
PCFL	4.67±0.79	3.62±0.52	3.83±0.74	3.51±0.42	4.37±0.69	3.81±0.43	5.20±0.27	4.14±0.62
CFL	5.02±0.45	4.2±0.43	3.87±0.49	3.96±0.33	4.71±0.61	4.54±0.89	4.38±0.77	4.38±0.41
PDL	9.04±0.61	7.29±1.25	7.73±1.12	8.22±0.82	10.86±2.81	7.62±0.71	9.93±0.47	8.67±1.33
PAL	14.83±1.07	12.22±1.62	13.17±2.32	12.87±2.05	15.09±1.83	13.03±1.38	16.63±0.92	13.98±1.57
PPCL	8.68±0.81	6.85±1.28	7.23±1.09	7.54±0.68	8.21±1.57	7.39±0.75	9.20±0.52	7.88±0.85
PPVL	9.19±1.00	7.58±0.96	7.9±1.44	8.1±0.72	8.55±1.46	7.95±0.88	9.93±0.67	8.46±0.83
LDFB	19.71±1.86	14.62±2.39	16.3±3.35	15.8±1.96	16.93±1.3	15.95±1.73	21.81±1.22	17.30±2.53
LAFB	12.50±1.46	9.36±1.45	10.14±2.24	10.55±0.85	13.44±2.39	10.03±0.97	13.84±0.69	11.38±1.77
MG	2.94±0.52	2.61±0.54	2.52±0.29	2.65±0.16	2.56±0.08	2.36±0.37	3.14±0.38	2.68±0.27
BW	4.92±0.75	3.3±0.58	3.33±1.01	3.04±0.31	4.14±1.15	3.53±0.43	4.57±0.69	3.83±0.71
ED	1.11±0.13	1.12±0.19	1.01±0.09	1.05±0.09	1.12±0.13	1.01±0	1.07±0.11	1.07±0.04
HDL	8.58±0.33	6.13±1.12	7.38±1.17	7.46±0.52	8.382±0.64	7.59±0.93	9.11±0.34	7.80±0.98
Pre OL	1.27±0	1.05±0.22	1.007±0.19	1.07±0.11	1.27±0.25	1.21±0.26	1.39±0.23	1.18±0.14
Post OL	6.14±0.18	4.17±0.93	5.42±0.91	5.33±0.41	6.09±0.49	5.51±0.81	6.57±0.39	5.58±0.78

Table 2: Meristic characteristics of *Channa marulius.*

Meristic Characteristics	Dhaka	Mymensingh	Sylhet	Khulna	Barishal	Rajshahi	Chattogram	Range (Present study)	Reference (Rahman, 2005)
DFR	51-54	51-54	51-53	48-52	45-52	51-55	48-54	45-55	49-55
AFR	28-33	31-35	31-34	30-33	28-37	30-33	28-34	28-37	28-35
CFR	13-17	14-17	13-16	13-14	12-16	14-17	13-16	12-17	Absent
PVFR	6	6	6	6	6	6	6	6	6
PCFR	14-17	15-17	15-17	15-18	14-18	15-19	14-17	14-19	17-19
LLS	62-65	62-65	65-67	64-68	62-66	61-65	61-64	61-68	54-65

*DFR = Dorsal fin ray, AFR = Anal fin ray, CFR= Caudal fin ray, PVFR = Pelvic fin ray, PCFR = Pectoral fin ray, LLS = Lateral line scale

Length-length relationships (LLR) were estimated by using the linear regression equation y=a+b*x, where y=TL (dependent variable) and x=other sixteen morphometric parameters (independent variable). Among seventeen equations TL vs. SL, TL vs. PCFL, TL vs. PAL, TL vs. LDFB, and TL vs. LAFB relationships were highly correlated with r^2 values ≥ 0.75. Based on the maximum r^2 value, LLR by TL vs. SL was the best-fitted model among all equations (Table 3).

In the case of PCA analysis, the morphometric measurements used to cluster the populations showed that there was a high admixture of clusters which were presented with a 95% confidence ellipse (Fig. 3). According to the morphological characters used in this study, phenotypic variations could not be seen clearly in *C. marulius* populations. The first principal component (PC1) accounted for 95% of the variation where the most significant loadings on PC1 were SL, TL, PDL, PAL, LDFB, and LAFB, the second (PC2) and third (PC3) for 3% and 2%, respectively (Table 4).

According to DFA, fifteen morphometric measurements (SL, TL, PVFL, PCFL, CFL, PDL, PAL, PPCL, PPVL, LDFB, LAFB, BW, HDL, Pre OL, and Post OL) were found to be highly significant for separating the populations at p<0.001.

Table 3: The estimated parameters of the length-length relationships (LLR), (y = a+b*x) of *Channa marulius.*

Equation	Regression Parameters a	Regression Parameters b	95% CL of a	95% CL of b	r^2
TL= a+b*SL	4.172	0.994	1.57 to 6.77	0.90 to 1.09	0.87
TL= a+b*PVFL	9.45	7.89	5.84 to 13.04	6.58 to 9.20	0.69
TL= a+b*PCFL	8.76	5.43	5.68 to 11.88	4.67 to 6.14	0.76
TL= a+b*CFL	13.53	3.54	8.85 to 22.21	2.00 to 5.08	0.24
TL= a+b*PDL	12.38	2.14	8.60 to 16.15	1.71 to 2.57	0.6
TL= a+b*PAL	4.17	1.93	0.52 to 7.81	1.66 to 2.19	0.76
TL= a+b*PPCL	5.33	3.27	0.86 to 9.78	2.70 to 3.80	0.67
TL= a+b*PPVL	4.4	3.15	-0.11 to 8.9	2.61 to 3.69	0.68
TL= a+b*LDFB	7.1	1.39	3.69 to 10.50	1.19 to 1.58	0.75
TL= a+b*LAFB	8.88	1.96	6.06 to 11.69	1.71 to 2.21	0.79
TL= a+b*MG	10.78	7.54	4.38 to 17.17	7.54 to 10.78	0.38
TL= a+b*BW	16.03	3.99	13.08 to 18.99	3.21 to 4.77	0.62
TL= a+b*ED	11.18	18.34	1.52 to 20.84	9.33 to 27.35	0.2
TL= a+b*HDL	3.19	3.56	-1.27 to 7.65	2.99 to 4.13	0.7
TL= a+b*Pre OL	15.69	12.98	11.05 to 20.33	9.05 to 16.90	0.4
TL= a+b*Post OL	8.14	4.05	3.41 to 12.86	3.21 to 4.89	0.59

*a=intercept, b=slope, CL=confidence intervals, r^2=coefficient of determination.

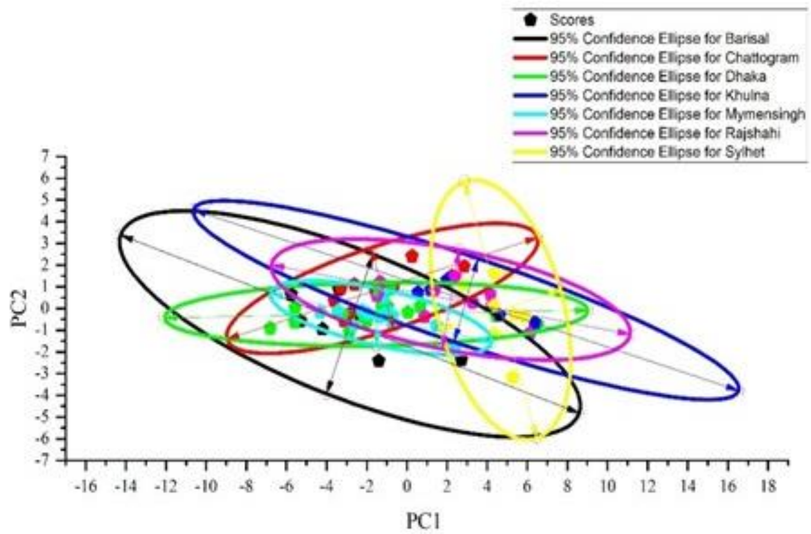

Figure 3: Principle Component Analysis (PCA) based on morphometric measurements of the seven populations.

The DF1 vs. DF2 plot explained 100% of the total variance among the samples and showed clear separation among the populations, however, slight inter-mingling was observed between them as Dhaka and Chattogram populations were found to be very close with each other and from the predicted group of populations, it is also clear that Dhaka and Chattogram population is formed by a mixture of almost same populations except for the presence of 13.33% from Sylhet in Dhaka group and 20.00% from Mymensingh in Chattogram group.

Table 4: Explained variation of principal components (PC) associated with loadings.

Characteristics	PC1	PC2	PC3
SL	0.53	-0.06	0.46
TL	0.63	-0.16	-0.68
PVFL	0.05	-0.00	0.00
PCFL	0.09	0.07	0.07
CFL	0.03	-0.06	-0.08
PDL	0.16	-0.53	0.24
PAL	0.22	-0.02	0.11
PPCL	0.12	0.07	0.10
PPVL	0.11	0.17	0.11
LDFB	0.34	0.75	0.10
LAFB	0.25	-0.26	0.24
MG	0.02	0.09	0.05
BW	0.09	0.05	-0.24
ED	0.00	-0.02	-0.01
HDL	0.13	0.02	0.14
Pre OL	0.08	-0.00	-0.01
Post OL	0.10	-0.01	0.13
Proportion of Variance	0.95	0.03	0.02

Among seven populations, the Rajshahi population is found almost in separate clusters from others (Fig. 4) hence from the group prediction it is found that the Rajshahi group is formed by a mixture of 77.78% of Rajshahi and 22.22% of Chattogram (Table 5). Discriminant function analysis showed 80.25% correct classification of individuals into their original populations.

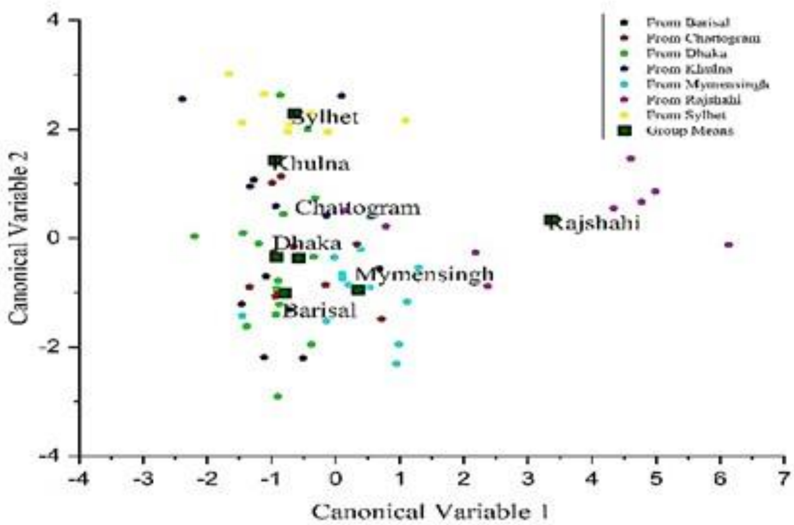

Figure 4: Graphical representation of discriminant function analysis (DFA) for the classification of *Channa marulius* populations according to morphometric characteristics.

Table 5: The predicted group from the percentage of species classified in each group by morphometric measurements for *Channa marulius.*

	Barishal	Chattogram	Dhaka	Khulna	Mymensingh	Rajshahi	Sylhet	Total
Barishal	71.43%	0.00%	0.00%	14.29%	14.29%	0.00%	0.00%	100.00%
Chattogram	20.00%	30.00%	10.00%	20.00%	20.00%	0.00%	0.00%	100.00%
Dhaka	46.67%	6.67%	26.67%	6.67%	0.00%	0.00%	13.33%	100.00%
Khulna	0.00%	20.00%	0.00%	60.00%	0.00%	0.00%	20.00%	100.00%
Mymensingh	7.69%	15.38%	0.00%	0.00%	76.92%	0.00%	0.00%	100.00%
Rajshahi	0.00%	22.22%	0.00%	0.00%	0.00%	77.78%	0.00%	100.00%
Sylhet	0.00%	0.00%	0.00%	25.00%	0.00%	0.00%	75.00%	100.00%

Discussion

There is a substantial lack of knowledge regarding the morphometric and meristic characteristics of *C. marulius* in Bangladesh. Great snakehead is one of the endangered fish species in Bangladesh (IUCN, 2015), resulting large number of samples could not be collected during the experimental period. Nonetheless, the sample size can be considered as fair enough for the morphometric and meristic analysis.

During this study, the maximum length was 31.05 cm TL, which is quite similar to the previous study from Sunamganj, Bangladesh (33.4 cm TL) (Ahmed *et al.*, 2018). Maximum length is beneficial to calculate the growth parameters (i.e., asymptotic length, growth coefficient), thereby essential for resource management for fisheries (Hossain *et al.*, 2017). Based on the analysis of regression and correlation it was observed that most of the characters (except for CFL, MG, ED, and Pre OL) followed a linear relationship and showed a generous degree of correlation coefficient indicating that maximum morphometric characters increase as with the increase in the proportion of total length. The values of the coefficient of correlation were most significant at $p \leq 0.05$ for the maximum morphometric characters (TL vs. SL, TL vs. PCFL, TL vs. PAL, TL vs. LDFB, and TL vs. LAFB). Compared to *C. marulius*, *C. marulioides* contains 55–58 lateral line scales, 13–15 predorsal scales, and 5-7 preopercular scales (Lee and Ng, 1991). The present investigation reveals that *C. marulius* displays a decline between the 16th and 18th scales and contains 61-68 lateral line scales whereas, *C. marulioides* exhibits a steady fall in lateral line between the 17th and 20th scales as per the report of Lee and Ng (1991).

Interestingly, the pelvic fins of the bowfin (*Amia calva*), which may be separated from *C. marulius* by having both a long dorsal fin and a short, rounded anal fin, and by having their pelvic fins inserted more posteriorly on the body, may also be confused with *C. marulius*. The caudal peduncle of bowfin has a large and dark eyespot with a golden halo but no parietal scales. Another distinguishing feature of the bowfin that no snakehead species shares is a large, gular plate (Lee and Ng, 1991). The findings of the present study also support this statement as *C. marulius* does not have any gular plate between the lower jaws in the ventral region.

However, the study integrating morphological and molecular data to resolve the taxonomic status of fishes related to *C. marulius* in India has discovered two species in Indian Rivers. Consequently, *C. pseudomarulius* is restored as a separate species and removed from the synonymy of *C. marulius*. *Channa pseudomarulius* can be distinguished from the more common *C. marulius* by having fewer lateral-line scales, fewer dorsal- and anal-fin rays, fewer vertebrae, and a difference of about 8% in the mitochondrial cytochrome c oxidase subunit 1 gene sequences (Britz *et al.*, 2017). The observed fin formula in this investigation was D. 55-45; P1.19-14; P2. 6; A. 37-28; and C. 17-12, which was consistent with previous research (Rahman, 2005; Plamoottil, 2017; Ahmed *et al.*, 2018).

The higher correlation coefficient of determination “r^2” indicated a positive correlation in the case of various morphometric characters with the total length for *C. marulius*, the maximum being between total length and standard length (0.87). The morphometric parameters showed a proportional positive increase with the increase in the length of fish. The positive growth was recorded in morphometric parameters with an increase in fish length (Ujjania *et al.*, 2012; Kamboj and Kamboj, 2019; Paunikar and Panwar, 2021).

Principal component analysis (PCA) helps in morphometric data reduction by decreasing the redundancy among the variables and extracting several variables for population differentiation (Verma and Serajuddin, 2016), and DFA is used to separate taxa and estimate their differences. Multivariate analysis (PCA and DFA) was used to distinguish populations from each other and to determine which morphometric characters better reflect these distinctions. Mir *et al.* (2014a), Özpiçak and Polat (2019), Jannat *et al*. (2022), and Mahfuj *et al*. (2022) used a multivariant approach for distinguishing populations of *Schizothorax curvifrons, Barbus tauricus, C. striata,* and *Botia dario* from different sites, respectively. The SL and TL had the maximum character loadings in PC1, LDFB had the maximum loadings in PC2, and SL had in PC3. All populations were highly intermingled in the bi-plot result of PCA analysis (Fig. 3). Therefore, PCA is considered a valuable tool for finding the morphological characteristics of several species that are regarded as significant sources of variation among populations (Arechavala-Lopez *et al.*, 2012).

According to DFA analysis, classification success among seven *Channa* species from seven locations in this study was 80.25%. Several studies found classification success from DFA as 83.4% (Mir *et al.*, 2014b), 97.5% (Motamedi *et al.*, 2014), and 92.3% (Özpiçak and Polat, 2019). In the present study by observing the DFA graph it can be seen that the Dhaka and Chattogram populations are found very close and the Rajshahi population is distantly related to all populations. As a result of phenotypic plasticity in response to unusual hydrological conditions including variations in alkalinity, water current pattern, temperatures, turbidity, and land-use patterns among various places, the variation among the stocks of the seven populations may be a result. According to environmental conditions, morphometric traits are known to have a very high degree of elasticity (Wimberger, 1994). The same ecological characteristics and environmental impacts between stocks could explain their close association (Mir *et al.*, 2013). Additionally, the environment, genetics, and interactions among them all influence the morphological traits of fish (Poulet *et al.*, 2004; Tzeng, 2004; Motamedi *et al.*, 2014; Kashyap *et al.*, 2016). Thus, there is the possibility that the observed morphological variations in the present study might be due to genetic differences among the populations. This research revealed essential differences in the morphological characteristics of native *C. marulius*.

Morphometric and meristic traits have long been recognized as key tools for determining the distinctive characteristics of a species (Musikasinthorn, 2000). Morphometric differences among stocks of a species are recognized as necessary for evaluating the population structure and as a basis for identifying stocks (Cadrin and Friedland, 1999; Turan, 2004). Morphometric adds a quantitative element allowing more rigorous comparisons of trait variations. Morphometric data is considered a powerful tool for displaying differences in shape and size as well as identifying stocks of species with unique morphological characteristics (Mojekwu and Anumudu, 2015). These analyses provide a solid basis for the identification, rational management, breeding, and conservation of fish genetic resources (Gonzalez-Martinez *et al.*, 2021). Despite the recent descriptions of a few new *Channa* species, many of the earlier scientific names of the species in this genus are still thought to be synonyms of other readily accessible species. As a result, the taxonomy and phylogeny of the Channid fishes are still a challenging and unsolved issue. The present study provides morphological characters of *C marulius* across seven natural stocks with the enumeration of stock variations. The information can be well applied in undertaking future breeding schemes, for the conservation of genetic resources and protection from being critically endangered or extinct. Taxonomic identification has implications for species recovery and abundance plans, habitat protection, and restoration. The present work might help to restore natural availability and increase genetic variability through pragmatic breeding programs. For example, diallel cross schemes and rotational line breeding in captivity for all those seven stocks and additional stocks of *C. marulius* since the conservation of species requires consolidated effort from taxonomists, legislators, and conservation biologists, that needs to be undertaken to save this valuable species from further threats.

The present study provides baseline information for *C. marulius* and asserts that physical characteristics may vary among populations. The present study revealed that morphometric and meristic counts of freshwater fish from different regions of Bangladesh showed a proportional growth rate of fish species increasing with an increase in fish length and showing a higher positive correlation with the total length. Meristic counts were found to be constant. Although PCA analysis showed a high admixture but identified the most important morphometric traits (SL, TL, and LDFB) to be used in the morphological research. The morphological traits of *C. marulius* populations from Bangladesh were examined for the first time in this study which would be helpful if any confusion arises with other closely identical congener cryptic species in the future. Additionally, it would benefit the protection and restoration of this species in the wetland's ecosystem.

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