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Quantification of morphological variations among populations of *Channa gachua* (Hamilton, 1822) from different geographical locations in India

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ABSTRACT

Morphological variations among distinctly distributed populations of *Channa gachua* (Hamilton, 1822) from three different geographical locations in India, viz., Gangetic Plains (GP), Western Hills and Plateau (WHP) and Eastern Himalaya (EH), were studied based on 200 specimens collected from these regions. The average total length of *C. gachua* was recorded as 128.5±4.0 mm, 126.3±5.5 mm and 123.1±6.9 mm from GP, WHP and EH, respectively. The analysis revealed variations in sixteen morphometric variables out of twenty measured variables among the GP and other two populations ($p < 0.05$), except eye diameter, head width, anal fin base length and caudal fin length. However, WHP and EH populations did not show any significant difference among the measured characters. Principal component analysis (PCA) indicated that first three PCs explained 90.12% of the total variance. Linear discriminant analysis (LDA) revealed that 108 out of 200 fish samples (54.0%) were correctly classified to the actual sampling locations whereas remaining samples (46.0%) showed overlapping spatial distribution. The corrected classification rate of each population ranged from 24 to 67%. It is concluded that despite morphometric variability in head and jaws, features among GP and other two populations studied, the three must still be considered to be of the same species. The study indicates the existence of two distinct stocks of *C. gachua*; one in the Gangetic Plains and another in Western Hills and Plateau and Eastern Himalayan regions.

Keywords: *Channa gachua*, Eastern Himalaya, Gangetic Plains, Morphometrics, Western Hills and Plateau

The fishes of the family Channidae, commonly known as 'snakeheads' or 'murrels', are freshwater predatory fishes occurring mainly in Asian countries (Haniffa *et al.*, 2003; Benziger *et al.*, 2011; Ali *et al.*, 2013; Singh *et al.*, 2013; Conte-Grand *et al.*, 2017). Only two genera, *Channa* and *Parachanna* are known under the family Channidae comprising of 41 (38 *Channa* spp. and 3 *Parachanna* spp.) valid species worldwide, of which, 16 species have been reported from India (Froese and Pauly, 2019). *Channa* spp. are important food fish and also find use in pharmaceutical industries and as ornamental species (Wee, 1982; Sampath and Pandian, 1984; Williams, 2004; Courtenay and Gam *et al.*, 2006; Qin and Fast, 2007; Benziger *et al.*, 2011; Zhu *et al.*, 2013; Conte-Grand *et al.*, 2017).

The 'dwarf snakehead' or 'walking snakehead' *Channa gachua* (Hamilton, 1822) inhabits wetlands and riverine ecosystems (Vishwanath and Geetakumari, 2009). This species can live in poorly oxygenated, turbid and even very foul stagnant water bodies (Kumar *et al.*, 2013). Adaptation to local climatic conditions plays a key role in survival, growth, reproductive success, distribution and evolution of a species (Atkins and Travis, 2010; Bocedi

et al., 2013; Peterson *et al.*, 2014; Conte-Grand *et al.*, 2017). Sometimes, it can lead to phenotypic variability among populations of a species which is influenced by ecological factors including physicochemical parameters of water, habitat types, food availability, competition and predation (Sajina *et al.*, 2011; Drinan *et al.*, 2012; Scharnweber *et al.*, 2013; Lostrom *et al.*, 2015; Prado *et al.*, 2016; Bernatchez, 2016; Seebacher *et al.*, 2017). Several synonyms and morphological variations have posed difficulties in the segregation of this species and its congeners like *C. orientalis* and *C. harcourtbutleri* (Deraniyagala, 1929; Ng and Lim, 1990; Pethiyagoda, 1991; Ng *et al.*, 1999; Mishra *et al.*, 2013). Studies based on molecular biology could not resolve the ambiguities in *C. gachua* species complex (Conte-Grand *et al.*, 2017). As a result, taxonomists have suggested further investigations on this species complex (Deraniyagala, 1929; Pethiyagoda, 1991; Ng *et al.*, 1999; Vishwanath and Geetakumari, 2009; Kumar *et al.*, 2013). Since species and stock identification play a vital role in understanding diversity of life (Conte-Grand *et al.*, 2017; Maurya *et al.*, 2018), the current research work was planned to investigate possible morphological variations among the populations of *C. gachua* from three different geographical locations in

India *i.e.* Gangetic Plains (GP), Western Hills and Plateau (WHP) and Eastern Himalaya (EH).

A total of 200 specimens of *C. gachua* were collected during 2015-16, from Gangetic Plains (n=100) (Uttar Pradesh, Bihar and West Bengal), Western Hills and Plateau (n=50) (Maharashtra) and Eastern Himalaya (n=50) (Assam and Manipur). The collected specimens were kept in ice or preserved in 8% formalin solution to transport them to the laboratory. Thereafter, specimens were stored at -20°C until further examination. The specimens were identified based on morphological characters following standard published literature (Ng and Lim, 1990; Courtney and Williams, 2003; Vishwanath and Geethakumari, 2009; Jayaram, 2010). Twenty morphometric traits were measured using a digital vernier caliper to the nearest 0.01 mm; all the measurements were conducted on the left side of each fish. The measured morphometric traits were total length, standard length, snout length, head length, head width, inter-orbital space, dorsal fin base length, upper jaw length, lower jaw length, anal fin base length, pelvic fin length, pectoral fin length, pre-dorsal fin length, pre-anal fin length, pre-pelvic fin length, pre-pectoral fin length, eye diameter, gap between dorsal and caudal fin, gap between anal and caudal fin and caudal fin length. Meristic traits like dorsal fin rays, pectoral fin rays, pelvic fin rays, anal fin rays, caudal fin rays, lateral line scales on both the right and left side of the body, pre-dorsal scales, scale row above the lateral line and scales row below the lateral line were counted.

Descriptive analysis was done using SPSS software (SPSS, 2007). The data was transformed following log transformation function using PAST (PAleontological STatistical Software Package) version 3.21 (Hammer, *et al.*, 2001) to remove size-dependent variation from the raw data that may lead to misinterpretation of body shape variations. The transformed data were subjected to test for significance of correlation between each of the 20 transformed variables and the standard length (SL) measurement using Pearson's correlation coefficient at $p < 0.05$ (Poulet, *et al.*, 2004; Jerranaiprepame, 2017). The log-transformed data was analysed using one-way ANOVA *post hoc* multiple comparisons test of Scheffe (Scheffe, 1959) provided in SPSS software. A significance level of 95% was used throughout the analysis. Principal component analysis (PCA) was performed using PAST software version 3.21 (Hammer *et al.*, 2001). The PCA was conducted to examine the patterns of morphometric variations among three distinctly located populations of *C. gachua* by reducing the redundancy in morphometric variables and extracting fewer independent variables as principal components (PCs) for differentiation of the populations (Samaee and Patzner, 2011; Mir, *et al.*,

2013; Jerranaiprepame, 2017). Discriminant analysis was performed to investigate the integrity of pre-defined groups using linear discriminant analysis (LDA) function (Fisher, 1936; Hammer, *et al.*, 2001). The accuracy of classification was evaluated using jackknife cross validation (Cheng *et al.*, 2005; Jerranaiprepame, 2017).

The total length of *C. gachua* (Hamilton, 1822) ranged from 68.5 mm to 195.5 mm. The average total length recorded from GP, WHP and EH were 128.5 ± 4.0 mm 126.3 ± 5.5 mm and 123.1 ± 6.9 mm, respectively indicating that *C. gachua* is a small sized species. The statistical analysis of meristic traits did not indicate statistically significant differences among the populations of *C. gachua* collected from three distinct locations ($p > 0.05$) (Table 1). Since *C. gachua* does not exhibit sexual dimorphism on morphometric traits, the effect of sex on measured variables was not studied (Lim and Ng, 1990; Courtenay and Williams 2003; Ward-Campbell and Beamish 2005; Jerranaiprepame, 2017).

One-way analysis of variance indicated significant difference among the sixteen morphometric traits out of twenty morphometric variables ($p < 0.05$) among GP and WHP and EH population, except eye diameter, head width, anal fin base length and caudal fin length (Table 2). The findings revealed variations in total length, standard length, head length, jaw length and fins between GP and other two populations of *C. gachua*. Generally, morphological variations among the populations of fish are often more than that of other vertebrates and these variations can be the results of effects of the local environment rather than the influence of genetics alone or the interaction between genetics and environmental factors (Jerranaiprepame, 2017). Interestingly, it was found that the WHP and EH populations did not show any statistically significant difference in the measured morphometric characters except in length of lower jaw (Table 2).

Principal component analysis showed that first three principal components (PCs) were accountable for 90.12% of the total variance, which was 68.01% in PC1, 15.86% in PC2 and 7.25% in PC3. The scree plots also indicated three significant principal components (Fig. 1). The PC1 comprised of six strongly positive correlated variables *viz.*, snout length, upper jaw length, lower jaw length, dorsal fin base length, pelvic fin length and gap between dorsal and caudal fin, responsible for variation in the studied populations (Table 3). However, such variations may be affected by differential habitat use, especially the use of different ecological niches with food availability in the ecosystem, feeding regimes and physicochemical parameters of the water (Hegrenes, 2001; Khan, *et al.*, 2013). The larger size of head, snout and jaws in the population of GP may be results of fast flowing water and

Table 1. Meristic traits of *C. gachua*

Meristic traits\Location (Nos.)	GP			WHP			EH		
	Min.	Max.	Mode	Min.	Max.	Mode	Min.	Max.	Mode
Dorsal fin rays	33	37	33	33	37	35	33	37	35
Pectoral fin rays	12	15	15	12	15	15	12	15	15
Pelvic fin rays	6	6	6	6	6	6	6	6	6
Anal fin rays	22	24	23	22	24	23	22	24	22
Caudal fin rays	12	15	14	12	15	15	12	15	15
Lateral line scales on right side	41	46	42	41	46	43	41	46	43
Lateral line scales on left side	42	46	42	42	46	43	42	46	43
Pre-dorsal scales	12	13	12	12	13	12	12	13	12
Scales above lateral line	3.5	4.5	4.5	3.5	4.5	4.5	3.5	4.5	4.5
Scales below lateral line	7.5	9.5	8.5	7.5	9.5	8.5	7.5	9.5	8.5

Table 2. Morphometric traits of *C. gachua*

Morphometric variables (mm)	GP	WHP	EH
	Mean±SD	Mean±SD	Mean±SD
Total length	128.5±4.0 ^a	126.3±5.5 ^b	123.1±6.9 ^b
Standard length	105.2±3.4 ^a	103.9±3.9 ^b	101.6±5.1 ^b
Head length	31.5±2.1 ^a	31.2±2.2 ^b	30.1±2.4 ^b
Head width	19.0±1.4 ^a	19.0±1.5 ^a	18.6±1.5 ^a
Eye diameter	05.5±0.1 ^a	05.5±0.2 ^a	05.6±0.3 ^a
Inter-orbital space	09.8±0.8 ^a	09.5±1.3 ^b	08.8±1.6 ^b
Snout length	04.7±0.3 ^a	04.5±0.3 ^b	04.4±0.3 ^b
Upper jaw length	12.2±1.2 ^a	11.9±1.6 ^{a,c}	11.5±1.3 ^c
Lower jaw length	12.4±1.0 ^a	12.3±1.3 ^{a,b}	11.8±1.2 ^c
Dorsal fin base length	61.9±2.3 ^a	61.0±2.6 ^b	59.5±3.6 ^b
Anal fin base length	37.6±2.2 ^a	37.0±2.0 ^a	36.9±2.4 ^a
Pelvic fin length	09.9±0.6 ^a	09.5±0.8 ^{a,c}	09.1±1.1 ^c
Pectoral fin length	21.0±0.7 ^a	20.3±1.3 ^b	19.8±1.7 ^b
Pre-dorsal fin length	37.1±1.9 ^a	36.4±2.0 ^b	35.4±2.0 ^b
Pre-anal fin length	58.5±2.5 ^a	57.6±2.6 ^b	55.8±3.5 ^b
Pre-pelvic fin length	38.2±1.9 ^a	37.6±1.4 ^b	37.0±1.5 ^b
Pre-pectoral fin length	34.8±1.4 ^a	34.5±2.1 ^b	33.1±2.6 ^b
Gap between dorsal and caudal fin	07.5±0.6 ^a	07.2±0.7 ^b	06.9±0.9 ^b
Gap between anal and caudal fin	09.6±1.3 ^a	08.9±1.0 ^b	08.9±1.2 ^b
Caudal fin length	23.2±1.8 ^a	22.2±1.9 ^b	21.4±2.2 ^b

The mean values with same superscripts are not significantly different ($p>0.05$); GP - Gangetic Plains, WHP - Western Hill and Plateau, EH - Eastern Himalaya

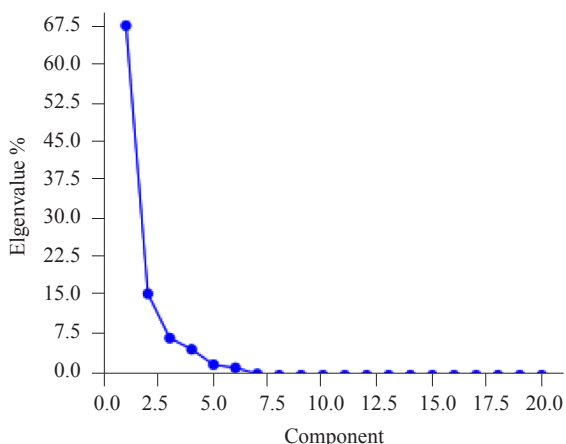


Fig. 1. Scree plot depicting number of PCs

big prey feeding behaviour which reasonably correlated to the abundance of bigger preys in fast moving waters (Deepa, *et al.*, 2009; Chandran, *et al.*, 2019) as most of the specimens were collected from the Ganga River. In PC2, the positively correlated variables were snout length, the gap between dorsal fin and caudal fin and gap between anal fin and caudal fin, which showed variations in the caudal peduncle region, while negatively correlated variable was dorsal fin base length. Moreover, PC3 was composed of four positively and two negatively correlated variables, associated with inter-orbital space, anal fin base length, pre-pelvic fin length and gap between anal fin and caudal fin and upper jaw length and the gap between dorsal fin and caudal fin, respectively.

Table 3. Factor loadings of each measured variable on first three PCs

Morphometric traits	PC1	PC2	PC3
Total length	0.1468	-0.0304	0.1725
Standard length	0.1175	-0.0912	0.2008
Head length	0.2159	0.0366	-0.2340
Head width	0.1797	-0.1803	-0.0277
Interorbital space	0.1195	-0.1325	0.2830
Snout length	0.2520	0.2517	0.0732
Upper jaw length	0.2907	-0.2339	-0.3124
Lower jaw length	0.2699	-0.2233	-0.1970
Dorsal fin base length	0.4830	-0.3154	0.2030
Anal fin base length	0.0551	-0.1887	0.4050
Pelvic fin length	0.3011	0.1213	-0.1546
Pectoral fin length	0.2041	-0.0496	0.0985
Pre-dorsal fin length	0.1763	0.0707	0.0092
Pre-anal fin length	0.1602	-0.0525	0.1728
Pre-pelvic fin length	0.1021	0.0033	0.2863
Pre-pectoral fin length	0.2007	-0.0931	-0.0039
Eye diameter	-0.0570	0.0979	0.0953
Gap between dorsal fin and caudal fin	0.2743	0.3110	-0.4252
Gap between anal fin and caudal fin	0.2264	0.6653	0.3341
Caudal fin length	0.2290	0.2311	0.0042
Variation (%)	68.01	15.86	7.25

Linear discriminant analysis (LDA) revealed that 108 out of 200 samples (54%) of *C. gachua*, collected from three distinct locations, were correctly classified to the actual sampling locations whereas rest of the samples showed overlapping spatial distributions. The corrected classification rate of each population ranged from 24 to 67%. This probably explains the manifestation of more similarity than variability among the three distinctly located populations of *C. gachua*.

Results of the present study indicate that morphometric variability exists, particularly in head and jaw features, among the three distinctly located populations of dwarf snakehead in India. The GP population of *C. gachua* was found to be quite different from the other two (WHP and EH) populations, but WHP and EH populations did not show distinct variation in their morphology. However, morphological similarity between WHP and EH populations may be the results of exchange of genetic materials. Hence, it is advisable to consider the populations to be of the same species. The study indicates the existence of two distinct stocks of *C. gachua*; one in Gangetic Plains and another in Western Hills and Plateau and Eastern Himalayan regions. To derive a better understanding of intra-specific variation in *C. gachua* populations from different locations, it is essential to take into account the influence of ecological diversification along with morphological and molecular approaches. The results of the current study provides baseline information

to follow further studies on these lines, which will be helpful for the management and conservation of this species.

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