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Landmark-Based Morphometric and Meristic Variations in Populations of Mullet, (*Rhinomugil corsula*) (Hamilton, 1822) in Bangladesh

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Abstract: The landmark-based morphometric and meristic variations of three different stocks (the Meghna, Padma and Ichamoti) of Mullet (*Rhinomugil corsula*) were examined from a phenotypical point of view to evaluate the population structure and to assess shape variation. A total of 125 of Mullet (*Rhinomugil corsula)* were collected from three different water bodies: the Meghna, the Padma and the Ichamoti of Bangladesh during January to August 2013. Thirteen morphometric and seven meristic characters were analyzed along with twenty five truss network measurements. Eight (fork length, head length, pre-orbital length, post orbital length, highest body depth, lowest body depth, pelvic fin length and mouth gap) of 13 morphometric measurements, one (pectoral fin rays) of 7 meristic measurements and fourteen (1 to 2, 1 to 11, 1 to 12, 2 to 3, 2 to 12, 2 to 11, 2 to 9, 3 to 4, 3 to 11, 4 to 5, 4 to 7, 5 to 7, 7 to 8, 8 to 9) of 25 truss network measurements were significantly different ($p<0.05$ or $p<0.01$ or $p<0.001$) among three different populations of *Rhinomugil corsula* samples. For morphometric and landmark measurements, the first discriminant functions (DF) accounted for 89.8% and 83.3% and the second DF accounted for 10.2% and 16.7%, respectively of among group variability, explaining 100% of total among groups variability. For the morphometric and truss network measurements, plotting discriminant functions did not show the well separated clusters of the stocks. The dendrogram based on morphometric and landmark distances data showed two major clusters: the Meghna and the Padma stocks in one cluster and the Ichamoti stock in another cluster. High degree of variation was observed in morphological characteristics among three different stocks (the Meghna, Padma and Ichamoti) of *Rhinomugil corsula* due to their environmental variation and separate geographical location. These results of this study are very useful for proper conservation and successful aquaculture management of *Rhinomugil corsula*.

Key words: *Rhinomugil corsula* · Landmark Measurements · Morphometrics · Meristics · Population Structure · Fish Stock

INTRODUCTION

In Bangladesh, there are 475 species of marine fishes and 260 species of freshwater fishes [1]. Among them the mullets are a large group of freshwater and estuarine fishes and serving as an important source of food in Bangladesh as well as all over the world. The fish *Rhinomugil corsula* [2] belongs to the order Mugilliformes and the family Mugillidae commonly known as Corsula mullet and locally called "Khorsula" or "Khalla" which are widely distributed in the rivers and estuaries waters throughout Bangladesh. It is also distributed in India, Nepal, Bangladesh and Myanmar [3]. It is one of the most popular and commercially important fish due to its taste, high nutritive and market value. Because of their popularity, they are harvested

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commercially almost throughout the year including the offseason of the other commercial fisheries without considering its stock, size and maturity. The catch of this species has been declined in recent years because of over fishing. This species is suitable for aquaculture due to high quality of its flesh, its extreme tolerance of a wide range of temperature and salinity, which is important for culture in intertidal ponds and cultured in many developing countries commercially [4]. In contrast, no breeding protocol has been developed for artificial breeding of this species in Bangladesh due to the lack of technical knowledge. Collection of the naturally produced fry of Corsula is difficult and not so popular and as a result there is limited seed available and farmers are not so interested to develop this type mullet farming in coastal areas. So, to meet up the demand of this fish it is necessary to conserve the biodiversity of this species and also large scale culture is needed. For developing proper management and conservation strategies, it is needed to know the biology, structure and present status of various populations including short-term and environmentally induced variations of this species across the country [5].

Morphometric differences among stocks of a species are recognized as important for evaluating the population structure and as a basis for identifying different fish races and/or populations [6-11]. Morphometric and meristic characters of fish are the measurable and countable characters, respectively common to all fishes. But nowadays, Truss measurements along with the measurement of morphometric and meristic characters are powerful tools for stock identification, revealing similarity and dissimilarity among populations or races which are constructed with the help of landmark points. Landmarks refer to some arbitrarily selected points on a fish's body and with the help of these points, the individual fish body shape can be analyzed and that matches between and within populations [12, 13]. The measurements may be more applicable for studying short-term, environmentally induced differences and the findings can be effectively used for improved fisheries management [6, 7, 14-17]. In the present study, landmark-based morphometric and meristic analysis of *Rhinomugil corsula* populations was carried out to determine the variation of population structure and develop breeding program for sustainable production and conservation.

MATERIALS AND METHODS

Collection of Samples: During January to August 2013, A total number of 125 of Mullet (*Rhinomugil corsula)* were collected from three different water bodies: the Meghna, the Padma and the Ichamoti in Bangladesh and immediately preserved in ice box. The samples were then brought to the laboratory of Department of Fisheries and Marine Science of Noakhali Science and Technology University in Bangladesh for morphometric, meristic and landmark studies. The sample size, total length and date of collection are presented in Table 1.

Measurement of Morphometric Characteristics: Fourteen morphometric characters of each sample fish were measured to an accuracy of 0.05 mm with vernier calipers and metallic ruler, following the methods described by Hubbs and Lagler [18] (Table 2).

Measurement of Meristic Characteristics

In Total, 7 Meristic Characters: first Dorsal Fin Rays (fDFR), Second Dorsal Fin Rays (sDFR), Pectoral Fin Rays(PcFR), Pelvic Fin Rays (PvFR), Anal Fin Rays (AFR), Caudal Fin Rays (CFR) and Branchiostegal Rays (BR) of each sample were analyzed.

Measurement of Landmark Distances of the Species: The truss network system described for fish body morphometric [19] was used to construct a network on fish body for measurement of landmark distances of the species. Twelve landmarks delineating 25 distances were measured on the body (Figure 1). Data points were arranged in "trusses" around the fish which layout maximize the number of measurements and increases the sensitivity of the analysis [20]. Each landmark was obtained by placing a fish on graph paper and then the landmarks were detected with colored pointers for enabling accurate and consistent measurements. Finally, the distances on the graph paper were measured using Vernier calipers.

Statistical Analysis: For morphometric data, a multivariate discriminant analysis [21, 22] was used to identify the combination of variables that separate *Rhinomugil corsula* species best. Prior to the analysis, size effects from the data set were eliminated. Variations were attributed to body shape differences and not to the relative size of the fish. In the present study, there were significant linear correlations among all measured characters and the total length of the fish. Therefore, it was necessary to remove size-dependent variation for all the characters. An allometric formula given by Elliott *et al.* [23] with slight modification was used to remove the size effect from the data set.

Table 1: Sources, sample size, total length and date of collection of *Rhinomugil corsula*

Source of fish samples	Collection site (District)	Sample size	Total length (Mean ± S.D.)	Date of collection
The Meghna	Ramgoti (Laximpur)	50	15.75±1.64	06.01.2013
The Padma	Shibaloy (Manikgonj)	50	18.72±0.64	21.04.2013
The Ichamoti	Kaligonj (Satkhira)	51	15.54±1.05	10.05.2013

Table 2: Morphometric characteristics of *Rhinomugil corsula*

SL. NO.	Characteristics	Description
01	Total Length (TL)	Distance from the tip of the snout to the longest caudal fin ray
02	Fork Length (FL)	Distance from the tip of the snout to the middle part of the fork of the tail
03	Standard Length (SL)	Distance from the tip of the snout to the end of the vertebral column
04	Head Length (HL)	Distance from the tip of the snout to the posterior margin of the opercula
05	Eye Length (EL)	Diameter of the eye
06	Pre-Orbital Length (PrOL)	Distance from tip of snout to anterior margin of eye
07	Post-Orbital Length (PoOL)	Distance from posterior margin of eye to end of operculum
08	Highest Body Depth (HBD)	The vertical distance from the anterior part of the first dorsal fin and ventral part of the body
09	Lowest Body Depth (LBD)	The vertical distance at the end of the vertebrae
10	First Dorsal Fin Length (FDFL)	Length of the base of the first dorsal fin
11	Pectoral Fin Length (PcFL)	Length of the base of the pectoral fin
12	Pelvic Fin Length (PvFL)	Length of the base of the pelvic fin
13	Anal Fin Length (AFL)	Length of the base of the anal fin
14	Mouth Gap (MG)	Distance between upper and lower jaw

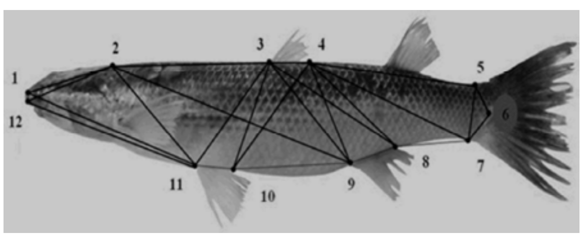

Fig. 1: Locations of 12 landmark points used for the shape analysis of *Rhinomugil corsula*.

Legend of Figure 1: Landmarks refer to some randomly selected points on a fish's body which is used for measurement of fish body morphometric. These 12 landmark points refer to: (1) anterior tip of snout at upper jaw, (2) most posterior aspect of neurocranium (beginning of scaled nape), (3) origin of dorsal fin, (4) ending of dorsal fin, (5) dorsal origin of caudal fin, (6) posterior end of vertebrae column, (7) ventral origin of caudal fin, (8) ending of anal fin, (9) origin of anal fin, (10) ending of pelvic fin, (11) origin of pelvic fin and (12) corner of the jaws. Twelve landmark points outlining 25 distances on the body which were measured for analyzing fish body morphometric.

$$M_{adj} = M (L_s/L_o)^b$$

where M: Original measurement, M_{adj}: Size adjusted measurement, L_o: Total length of fish and L_s: Overall mean of total length for all fish from all samples. Parameter b was estimated for each character from the observed data as the slope of the regression of log M on log L_o, using all fish in all groups. The efficiency of the size adjustment transformations was assessed by testing the significance of the correlation between a transformed variable and the TL. Univariate analysis of variance (ANOVA) was carried out to test the significance of morphological differences. Non parametric Kruskal-Wallis test was used to test the significance of meristic characters.

In addition, size-adjusted data were standardized and submitted to a discriminant function (DF) analysis. A dendrogram of the populations based on the morphometric and landmark distance data was drawn using the Squared Euclidean Dissimilarity Distance Method [24]. All statistical analyses were done using SPSS software package version 16.0 (SPSS, Chicago, IL, USA).

RESULTS

Meristic Counts: Meristic counts of all samples were fixed on 4 (median, $m_e = 4$) for first dorsal fin rays, 7-9 ($m_e = 7$) for second dorsal fin rays, 15-17 ($m_e = 15$) for pectoral fin rays, 5($m_e = 5$) for pelvic fin rays, 9 ($m_e = 9$) for anal fin rays, 15 ($m_e = 15$) for caudal fin rays and 3 (me = 3) branchiostegal rays. The mean number of first dorsal, second dorsal, pelvic, anal and caudal fin rays and branchiostegal rays were not different (Kruskal-Wallis test, $p>0.05$) among fishes of three different stocks (the Meghna, Padma and Ichamoti) and difference were only occurred in pectoral fin rays (df = 2, pectoral fin rays: H = 6.75, $p<0.05$).

Table 3: Univariate statistics (ANOVA) testing differences among samples from 13 morphometric measurements

Characters	Wilks' Lambda	F	df1	df2	Significance
FL	.879	8.390	2	122	0.000***
SL	.987	.796	2	122	0.453
HL	.944	3.603	2	122	0.030*
ED	.950	3.210	2	122	0.044
PrOL	.890	7.533	2	122	0.001**
PoOL	.868	9.298	2	122	0.000***
HBD	.662	31.120	2	122	0.000***
LBD	.872	8.958	2	122	0.000***
FDFL	.975	1.570	2	122	0.212
PcFL	.985	.950	2	122	0.390
PvFL	.947	3.412	2	122	0.036*
AFL	.967	2.094	2	122	0.128
MG	.888	7.730	2	122	0.001**

Among 13 morphometric measurements, 8 were significantly different in varying degrees (*p<0.05, ** p<0.01, *** p<0.001). Abbreviations of characters are defined in Table 2.

Table 4: Univariate statistics (ANOVA) testing differences among samples from twenty five truss measurements

Landmark distance	Wilks' Lambda	F	df1	df2	Significance
1 to 2	.846	11.064	2	122	0.000***
1 to 11	.822	13.206	2	122	0.000***
1 to 12	.853	10.478	2	122	0.000***
2 to 3	.826	12.892	2	122	0.000***
2 to 12	.781	17.064	2	122	0.000***
2 to 11	.866	9.477	2	122	0.000***
2 to 9	.702	25.837	2	122	0.000***
3 to 4	.868	9.273	2	122	0.000***
3 to 11	.753	20.000	2	122	0.000***
3 to 10	.965	2.227	2	122	0.112
3 to 9	.958	2.665	2	122	0.074
3 to 8	.965	2.189	2	122	0.116
4 to 5	.874	8.785	2	122	0.000***
4 to 10	.983	1.039	2	122	0.357
4 to 9	.975	1.584	2	122	0.209
4 to 8	.931	4.544	2	122	0.012
4 to 7	.872	8.982	2	122	0.000***
5 to 6	.935	4.241	2	122	0.017
5 to 7	.884	7.996	2	122	0.001**
6 to 7	.968	1.988	2	122	0.141
7 to 8	.927	4.769	2	122	0.01*
8 to 9	.947	3.386	2	122	0.037*
9 to 10	.990	.590	2	122	0.556
10 to 11	.983	1.031	2	122	0.360
11 to 12	.974	1.652	2	122	0.196

Among 25 truss measurements, 14 were significantly different in varying degrees (*p<0.05, ** p<0.01, *** p<0.001)

Morphometric and Landmark Distance: The efficiency of the allometric formula in removing the size effect from the data was justified by using correlations between the total length and adjusted characters. Among the 13 transformed morphometric and 25 truss measurements, none of them showed a significant correlation with total length. Therefore, all the values were used for further calculation. Univariate statistics (ANOVA) showed that 8 (fork length-FL, head length-HL, pre-orbital length-PrOL, post orbital length PoOL, highest body depth-HBD, lowest body depth-LBD, pelvic fin length-PvFL and mouth gap-MG) of 13 morphometric and 14 (1 to 2, 1 to 11, 1 to 12, 2 to 3, 2 to 12, 2 to 11, 2 to 9, 3 to 4, 3 to 11, 4 to 5, 4 to 7, 5 to 7, 7 to 8 and 8 to 9) of 25 truss measurements were significantly different among samples in varying degrees (p<0.05 or p<0.01 or p<0.001) (Table 3 and Table 4).

Discriminant function analysis produced two discriminant functions (DF1 and DF2) for both morphometric and landmark measurements. For morphometric and landmark measurements the first DF accounted for 89.8% and 83.3% and the second DF accounted for 10.2% and 16.7%, respectively of among group variability, explaining 100% of the total among groups variability. In case of both morphometric and truss measurements, the stocks were not clearly separated from each other in the discriminant space (Figure 2 and Figure 3) with virtually overlapping in varying degrees. This finding suggested that there was intermingling among populations and the populations were not fully separated. On the basis of morphometric measurements, 77.5%, 76.5% & 88.2% of original grouped cases correctly classified in case of Meghna, Padma and Ichamoti samples respectively and a total of 81.6% of original grouped cases correctly classified for all the three samples (Table 5). With truss network system 80.0%, 79.4%, 76.5% of original grouped cases correctly classified in case of Meghna, Padma and Ichamoti samples respectively and a total of 78.4% original grouped cases correctly classified for all the three samples (Table 6).

Pooled within-groups correlations between discriminant variables and DFs shown that among the thirteen morphometric measurements, 4 measurements of highest body depth (HBD), post-orbital length (PoOL), lowest body depth (LBD) and eye diameter (ED) dominantly contributed to first DF and the rest 9 characters -mouth gap (GP), pre-orbital length (PrOL), head length (HL), fork length (FL), pelvic fin length (PvFL), first dorsal fin length (fDFL), pectoral fin length (PcFL), anal fin length (AFL) and standard length (SL) contributed to the second DF (Table 7). In case of truss measurements, among the twenty five measurements twelve measurements - 2 to 9, 3 to 11, 2 to 12, 1 to 11, 2 to 3, 1 to 2, 2 to 11, 3 to 4, 5 to 7, 5 to 6, 6 to 7 and 10 to 11 dominantly contributed to first DF and the rest 13 contributed to the second DF (Table 8).

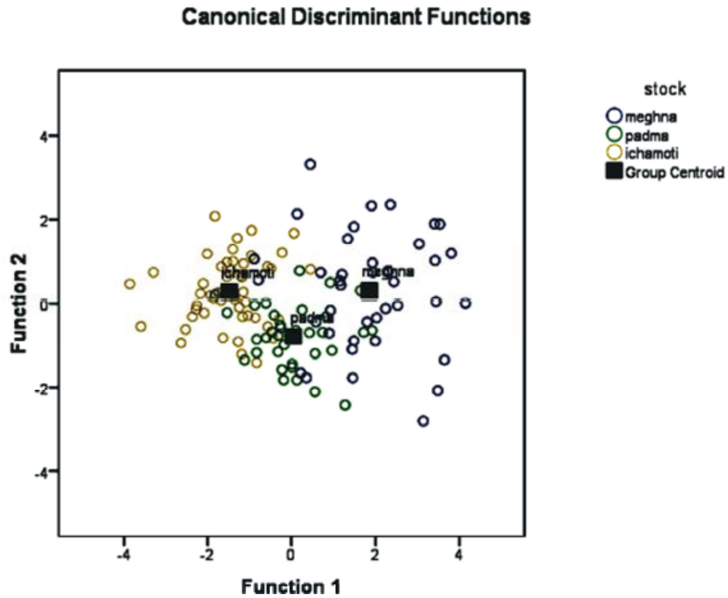

Fig. 2: Sample centroids of discriminant function scores based on morphometric measurements

Legend of Figure 2: Samples referred to: the Meghna River, the Padma River and the Ichamoti River. The sample stocks were not clearly separated from each other in the discriminant space based on morphometric measurements. Discriminant function analysis suggested that there was intermingling among three different populations (the Meghna, Padma and Ichamoti) of Rhinomugil corsula.

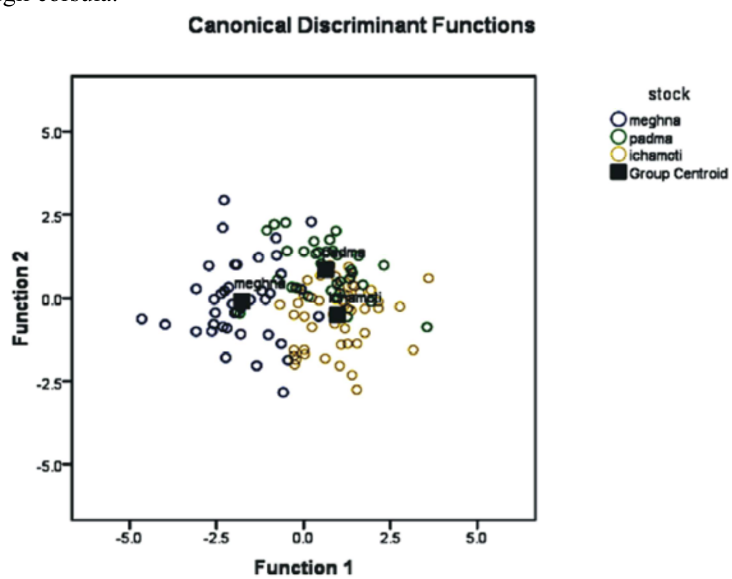

Fig. 3: Sample centroids of discriminant function scores based on truss measurements

Legend of Figure 3: Samples referred to: the Meghna River, the Padma River and the Ichamoti River. Based on truss measurements, the sample stocks were not well separated from each other in the discriminant space. Discriminant function analysis suggested that there was intermingling among three different populations (the Meghna, Padma and Ichamoti) of Rhinomugil corsula.

A dendrogram based on morphometric and land-mark distances data was drawn for the population of the Meghna, the Padma and the Ichamoti. Two main clusters were formed among three populations. The Meghna and the Padma populations (9.518) formed one cluster. On the other hand Ichamoti population formed separated cluster based on the distance of squared Euclidean dissimilarity (Figure 4).

Table 5: Showing classification results of canonical discriminant function based on morphometric measurement Classification Results

			Predicted Group Membership			
		Stock	Meghna	Padma	Ichamoti	Total
Original	Count	Meghna	31	6	3	40
		Padma	4	26	4	34
		Ichamoti	1	5	45	51
	%	Meghna	77.5	15.0	7.5	100.0
		Padma	11.8	76.5	11.8	100.0
		Ichamoti	2.0	9.8	88.2	100.0

a. 81.6% of original grouped cases correctly classified

Table 6: Showing classification results of canonical discriminant function based on all truss measurements Classification Results

			Predicted Group Membership			
		Stock	Meghna	Padma	Ichamoti	Total
Original	Count	Meghna	32	5	3	40
		Padma	2	27	5	34
		Ichamoti	1	11	39	51
	%	Meghna	80.0	12.5	7.5	100.0
		Padma	5.9	79.4	14.7	100.0
		Ichamoti	2.0	21.6	76.5	100.0

a.78.4% of original grouped cases correctly classified

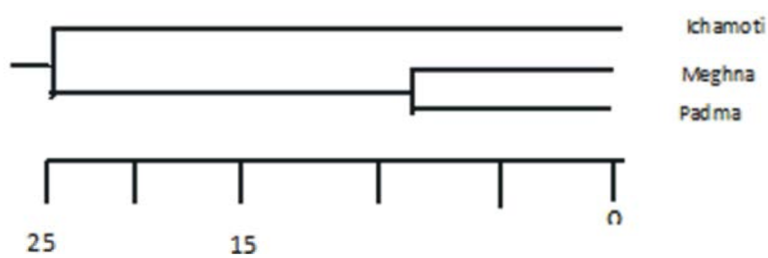

Fig. 4: Dendrogram based on morphometric and landmark distances of the Meghna, the Padma and the Ichamoti River samples

Legend of Figure 4: The dendrogram based on morphometric and land-mark distances data of Rhinomugil corsula collected from three different stocks (the Meghna, Padma and the Ichamoti River) showed 2 clusters: the Meghna and Padma stocks in one cluster and the Ichamoti stock in another.

Table 7: Pooled within-groups correlations between discriminating variables and discriminant functions in case of general morphometric characteristics

	Discriminant Function	
Characters	1	2
Highest body depth (HBD)	-.494*	.222
Post orbital length (PoOL)	.273*	.010
Lowest body depth (LBD)	-.268*	.006
Eye diameter(ED)	-.160*	-.047
Mouth gap (MG)	.127	.635*
Head length (HL)	-.122	-.351*
Pre-orbital length (PrOL)	.226	-.285*
Fork length (FL)	-.244	-.264*
Pelvic fin length (PvFL)	.145	.239*
First dorsal fin length (fDFL)	.098	-.165*
Pectoral fin length (PcFL)	-.068	.162*
Anal fin length (AFL)	.118	-.157*
Standard length (SL)	.074	-.090*

Variables ordered by absolute size of correlation within function. The largest correlation between each discriminating variable and standardized canonical discriminant functions is indicated by *.

Table 8: Pooled within-groups correlations between discriminating variables and discriminant functions in case of landmark distances

	Discriminant Function	
Landmark distance	1	2
2 to 9	-.522*	-.070
3 to 11	.425*	-.397
2 to 12	.418*	.171
1 to 11	-.374*	.001
2 to 3	-.370*	-.006
1 to 2	.342*	.046
2 to 11	-.317*	-.038
3 to 4	-.309*	-.114
5 to 7	.291*	.038
5 to 6	.212*	-.010
6 to 7	.139*	.095
10 to 11	.097*	.089
1to12	-.230	-.540*
4 to7	.253	.396*
4 to 5	.271	.312*
4 to 9	.034	-.280*
3 to 8	-.089	.276*
11to 12	-.067	.255*
4 to 8	.189	.249*
3 to 10	.110	-.241*
8 to 9	.157	.237*
7 to 8	.199	.236*
4 to10	-.003	-.235*
3 to 9	-.144	-.195*
9 to10	.004	-.177*

Variables ordered by absolute size of correlation within function. The largest correlation between each discriminating variable and standardized canonical discriminant functions is indicated by *.

DISCUSSION

In the present study, Meristic counts of all samples ranged from 4 rays for first dorsal fin, 7-9 rays for second dorsal fin, 15-17 rays for pectoral fin, 5 rays for pelvic fin, 9 rays for anal fin, 15 rays for caudal fin and 3 for branchiostegal rays. Among the samples of 3 wild sources (the Meghna, the Padma and the Ichamoti), the fairly constant fin rays showed similarity with the findings of Reed *et al.* [25] and Holden & Reed [26]. Among the 3 stocks, only the mean number of pectoral fin rays were significantly differ ($p<0.05$). The differences are also found in meristic counts in Japanese charr (*Salvelinus leucomaenis*) among the river systems (Naka and Tone rivers, central Japan) and among the tributaries of the Naka River (Ashinagasawa, Akasawa, Ushirosawa and Moto-Okashirasawa streams) [27]. In the present study, highly significant morphometric differences were found among the Meghna, Padma and Ichamoti corsula mullet populations. Among the 13 morphometric measurements, 8 (fork length, head length, pre-orbital length, post orbital length, highest body depth, lowest body depth, pelvic fin length and mouth gap) were significantly different ($p<0.05$ or <0.01 or <0.001) (Table 3). These phenotypic differences among these 3 stocks (the Meghna, the Padma and the Ichamoti) may be occurred due to their separate geographical location, existing environmental variation of their three habitats or may be originated from different ancestors. Fish are very sensitive to environmental changes and quickly change their essential morphometrics for adapting themselves with new environmental conditions. Morphological characters can show high plasticity in response to changes in environmental conditions, such as food abundance and temperature [28-30]. Generally, fish show greater variances in morphological characters both within and between populations than any other vertebrates and are more vulnerable to environmentally induced morphological variations [30, 31].

The rates of environmental changes from place to place are probably very low in a small country like Bangladesh. Each of the rivers (the Meghna, the Padma and the Ichamoti) of this research work possesses a different environmental condition from each other. Due to the phenotypic plasticity of fish is very high, they modify their physiology and behavior to adapt quickly to environmental changes which modifications ultimately change their morphology [20]. However, it might be impossible to detect small morphological differences in fish which are create due to small environmental differences by analyzing only gross morphometric and meristic characters.

For this reason, Truss network measurement method was implied in this research. Truss network systems are a powerful tool for identifying different stocks of fish species [7]. In truss network, 14 (1 to 2, 1to 11, 1to 12, 2 to 3, 2 to 12, 2 to 11, 2 to 9, 3 to 4, 3 to 11, 4 to 5, 4 to 7, 5 to 7, 7 to 8 and 8 to 9) of 25 distance were significantly different ($p<0.05$ or <0.01 or <0.001) (Table 4). Hossain *et al*. [19] observed significant differences ($p<0.05$ or <0.001) in 4 (maximum body height (MBH), pre-orbital length (PrOL), peduncle length (PL) and maxillary barbel length (MxBL)) of 9 morphometric and four of 22 truss network measurements in kalibaus (*Labeo calbasu)* populations collected from the Jamuna, the Halda and a hatchery in Bangladesh. The significant differences ($p<0.05$) were also found in 16 of 25 truss measurements in Anchovy (*Engraulisen crasicolus* L.) in Black, Aegean and Northeastern Mediterranean sea [7]. Parvej *et al*. [32] found significant differences ($p<0.001$) in 4 of 17 morphometric traits and only 1 of 22 truss network measurements in *Eutropiichthys vacha* populations from Kaptai Lake, Meghna River &Tanguar Haor in Bangladesh.

Plotting DFs (Figure 2 and Figure 3) revealed high isolation in morphometrics among the three stocks. In the Figure 2, the Ichamoti stock displayed intermediate characteristics between the Padma and the Meghna stocks of *Rhinomugil corsula* and the Padma and Meghna stocks partially overlapped. In the Figure 3, the Padma and Ichamoti stocks broadly overlapped. In this experiment, DF analysis determined the dissimilarity among the stocks and significant correlations were observed between size and truss measurement characteristics among three stocks of *Rhinomugil corsula*. In the Table 5, the 1st DF accounted for much more (81.6%) of the among group variability than did the 2nd DF (18.4%). In the Table 6, the 1st DF accounted for much more (78.4%) of the among group variability than did the 2nd DF (21.6%). From both Table 5 and Table 6, it was obvious that the 2nd DF explained much less of the variance than did the 1st DF. Therefore, the 2nd DF was much less informative in explaining differences among the stocks.

In the dendrogram, two main clusters were formed among three populations. The Padma and the Meghna rivers stocks in one cluster and Ichamoti stock in another (Figure 4). These differences among the three stocks of *Rhinomugil corsula* (the Padma, Meghna and Ichamoti rivers) might be happened due to environmental as well as genetic variations. A dendrogram based on data of the meristic and morphometric characters shown that the population of Japanese charr, *Salvelinus leucomaenis* of the Tone River was included within the variation detected among the tributary populations of the Naka River reported by Nakamura [27]. Meristic and morphometric characters of Japanese charr, *Salvelinus leucomaenis* varied not only between river systems but also among tributaries within a river system were possibly due to environmental condition, separate habitat as well as genetic variations. In their study, DFs showed isolation in morphology among the stocks of different sources.

CONCLUSION

Fish and fisheries are integral parts of the culture and heritage of Bangladesh. But day by day this sector is facing an increasing threat due to over fishing, habitat degradation, pollution in the rivers and the indiscriminate use of agrochemicals, introduction of exotic species, lack of suitable habitat, decreased fecundity and so on. *Rhinomugil corsula* is highly demanded across the country for its taste and nutritional values. So, we have to conserve this species from being threatened or extinct. For proper conservation and management of any population, it is needed to know about their biology and population structure. It is also essential to select genetically superior stocks along with better features for both successful aquaculture and open-water management. Anyone can found all of this information from the findings of this research work which used as the store house of information about *Rhinomugil corsula* that can be used for the further studies. More research specially based on genetics studies and investigations of the causes of environmental factor is needed for conservation of such demandable species, *Rhinomugil corsula* in Bangladesh.

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