

Taxonomic Diversity of Paradise Threadfin *Polynemus paradiseus* (Linnaeus, 1758) Inhabiting Southern Coastal Rivers in Bangladesh

(Kepelbagaian Taksonomi *Polynemus paradiseus* (Linnaeus, 1758)

Mendiami Selatan Pesisir Sungai di Bangladesh

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ABSTRACT

The study was aimed to determine the variation in taxonomic diversity of Polynemus paradiseus based on morphometric and meristic analyses of samples collected from three coastal rivers of Bangladesh (Payra, Tentulia and Kirtonkhola). A total of 105 individuals ranging at 10-20 cm in total length (TL) and 7.91-60.64 g in body weight (BW) were sampled using Been nets and Kachal and Veshal nets. Significant differences were observed in 24 out of 25 morphometric measurements and 6 out of 10 meristic counts among the populations. In morphometric measurements, the first discriminant function (DF1) was accounted for 78.6% and the second discriminant function (DF2) was accounted for 21.4% of among groups variability, explaining 100% of total among group variability. A dendrogram based on morphometric data showed that the Tentulia and Kirtankhola populations showed high degree of overlapping and these two populations were highly different from Payra river population. The canonical graph also showed that the populations of Tentulia and Kirtankhola rivers were more closely related comparing with Payra river population for isometric condition. These findings may provide useful information for the conservation and sustainable management of this important fish.

Keywords: Coastal river; meristic; morphometric; Polynemus paradiseus; taxonomic diversity

ABSTRAK

Kajian ini bertujuan untuk menentukan perubahan dalam kepelbagaian taksonomi Polynemus paradiseus berdasarkan morfometrik dan analisis meristik untuk sampel yang diambil dari tiga pesisir Sungai di Bangladesh (Payra, Tentulia dan Kirtonkhola). Sejumlah 105 individu berjangka antara 10-20 cm jumlah panjang (TL) dan 7.91-60.64 g berat badan (BW) disampel menggunakan net Been serta net Kachal dan Veshal. Terdapat perbezaan ketara dalam 24 daripada 25 ukuran morfometrik dan 6 daripada 10 bilangan meristik diperhatikan antara populasi. Dalam pengukuran morfometrik, fungsi diskriminan pertama (DF1) telah menyumbang sebanyak 78.6% dan fungsi diskriminan kedua (DF2) 21.4% daripada kalangan kebolehubahan kumpulan, menjelaskan 100% jumlah keseluruhan kebolehubahan kumpulan. Dendrogram berdasarkan data morfometrik menunjukkan bahawa populasi Tentulia dan Kirtankhola mempunyai tahap bertindih tertinggi dan sangat berbeza daripada populasi Sungai Payra. Graf berkanon juga menunjukkan bahawa populasi Sungai Tentulia dan Kirtankhola lebih berkait berbanding dengan populasi Sungai Payra dalam keadaan isometrik. Penemuan ini boleh memberikan maklumat yang berguna untuk pemuliharaan dan pengurusan mapan untuk ikan penting ini.

Kata kunci: Kepelbagaian taksonomi; meristik; morfometrik; pesisir sungai; Polynemus paradiseus

INTRODUCTION

The southern coastal rivers and estuaries of Bangladesh are characterized by high levels of commercial fish catch contributing a huge currency (USD 456 million per year) to the national economy of Bangladesh (Alam & Thomson 2001; Belton et al. 2014; Islam 2003). Despite its vast potential, the coastal rivers are facing a continuous increase by over exploitation, apparent deterioration of the habitat, recreational activities, demographic increase and even global change consequences (Ahamed et al. 2012; Murshed-e-Jahan et al. 2014; Siddik et al. 2013). Environmental and man-made hazards (overexploitation, pesticide and aquatic pollution, spread of disease, uncontrolled introduction of exotic fishes and habitat modification due to industrialization, river-valley projects,

excessive water abstraction and siltation due to clearing occurring in aquatic ecosystem) may be responsible for the alteration of taxonomic characters of fish and water parameters. These factors can cause alterations in taxonomic diversity and structure of marine communities that disrupt the production of important commercial fishery (Ahmed et al. 2013; Diego et al. 2014; Sajina et al. 2011). To ensure the sustainable capture from these resources, it is very crucial to facilitate the development of management strategies, the design of biological sampling programs and strategies for conserving the species state and biodiversity. On the contrary, poor understanding of the fish and fishery management can lead to dramatic changes in the biological attributes and productivity of a species (Ahmed et al. 2013; Sajina et al. 2011).

Morphometrics and meristics variations have been most frequently used to differentiate stocks of a variety of fish species, despite the advent of biochemical and molecular genetics (Salini et al. 2004; Sedaghat et al. 2012; Swain & Foote 1999; Turan et al. 2006). These studies are fundamental for stock identification as well as to show stable differences in shape between groups of fish that demonstrate different growth, mortality or reproductive rates relevant for the definition of stocks (Cadrin 2000; Haniffa et al. 2014; Mohaddasi et al. 2013; Swain & Foote 1999). As we believe, the morphological study of *Polynemus paradiseus* within these impacted coastal ecosystems will provide insight for other fish species as well.

Paradise threadfin fish *Polynemus paradiseus* is widely distributed throughout the Indian subcontinent including Bangladesh, India, Pakistan, Sri Lanka and also found in Indo-Pacific Ocean confluence of the Bay of Bengal (Afroz & Alam 2013; Hossain 2001; Hossain et al. 2006; Hoq 2007; Nahar et al. 2014). This species has an increasingly commercial importance in southern coastal regions of Bangladesh because of its nutritional value and considered as important food item next to importance in hilsa fishery. Thus, a basic knowledge on its biology, including information on population structure could be a privilege. Few studies have been carried out in different

aspects as biology and genetic variation of this species (Motomura et al. 2002; Nahar et al. 2014) but knowledge on taxonomic diversity of the *P. paradiseus* is totally unavailable. Therefore, the present study has been carried out to investigate the morphometric and meristic variation within three river populations of *P. paradiseus* inhabiting in the southern coastal regions of Bangladesh.

MATERIALS AND METHODS

SAMPLING

The threadfin fish *P. paradiseus* samples were collected from three rivers in the southern coastal region of Bangladesh. A total number of 105 threadfin fish ranging at 10-20 cm in total length (TL) and 7.91-60.64 g in body weight (BW) were sampled using Been nets and Kachal and Veshal nets (<3 mm) for examination. The sampling was conducted during monsoon because the water quality parameters and physiological condition of fish remain in sound condition. Once collected, the samples were preserved in 10% formaldehyde solution. The details of the collection sites, number of specimens and date of collection are presented in Table 1 and Figure 1. Water quality parameter were collected at one week intervals from different predetermined sites (Table 2).

TABLE 1. Sources, number of specimens and date of collection of *P. paradiseus* population

Sample No.	Population	Collection site (District)	No. of fish	Date of collection
1	Payra river	Lebukhali (Patuakhali)	35	June 10, 2014
2	Tentulia river	Patarhut (Bhola)	35	July 05, 2014
3	Kirtankhola river	Gajalia (Barisal)	35	July 21, 2014

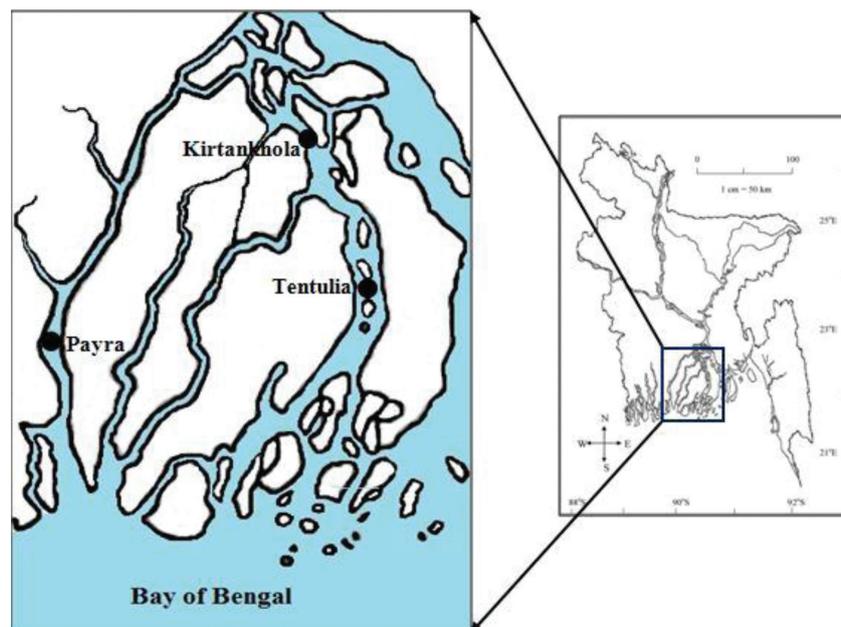


FIGURE 1. Sampling locations of *P. paradiseus* in three rivers, the Payra, Tentulia and Kirtankhola, located in Southern Coastal region of Bangladesh

TABLE 2. State of aquatic environmental parameters (mean±SE) during the study period

Sources	Temperature	DO	Transparency	pH	Alkalinity (mg/L)
Payra River	28.58±1.34 ^a	8.69±.40 ^a	25.83±.55 ^a	7.83±.16 ^a	116.08±2.77 ^a
Tentulia River	30.08±1.15 ^a	5.38±.57 ^b	18.06±.96 ^b	6.87±.07 ^b	86.54±6.83 ^b
Kirtankhola River	28.99±1.54 ^a	5.25±.26 ^b	16.82±2.04 ^b	6.99±.13 ^b	80.24±4.36 ^b

Values are mean±standard error. Mean values in each row bearing different superscripts are significantly different ($p<0.05$)

LABORATORY WORK

The fish were measured for 25 morphometric characters and 10 meristic counts (Figure 2). The total length of each fish was measured with digital slide calipers up to the nearest 0.1 cm and weighed with a digital balance up to the nearest 0.1 g. A stereomicroscope was used for the counting of meristic features. Identification of fishes was done following Konan et al. (2014).

STATISTICAL ANALYSIS

Size effects were eliminated from the dataset prior to analysis. Variations were attributed to body shape differences and not to the relative sizes of the fish. In the present study, there were significant linear correlations among all measured characters and the TL of the fish. Therefore, it was necessary to remove size-dependent variations from all of the characters. An allometric formula given by Elliott et al. (1995) with slight modification was used to remove the size effect from the dataset:

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

where M is the original measurement; M_{adj} is the size-adjusted measurement; L_o is the TL of the fish; and L_s is the overall mean of the TL 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 results derived from the allometric method were confirmed by testing the significance of the correlation between transformed variables and standard length. To identify whether there were any statistically significant differences ($p<0.05$) between the populations for each character, a one-way analysis of variance (ANOVA) was performed. The morphometric characters that significant were used for discriminant function analyses (DFA). As a complement to discriminant analysis, morphometric distances between the individuals of the three groups were inferred based on cluster analysis (Veasey et al. 2001). All statistical analyses were performed using SPSS v12 and SYSTAT v10.

RESULTS

WATER QUALITY PARAMETERS

The values of water quality parameters (water temperature, dissolved oxygen, transparency, pH and alkalinity) in different rivers are shown in Table 2. The mean values of water temperature in different river were 28.58±1.34, 30.08±1.15 and 28.99±1.54, respectively (Table 2), indicating no significant variation one to another. The DO, transparency, pH and alkalinity of Payra river showed significant variation ($p<0.05$) compare to Tentulia and Kirtankhola rivers.

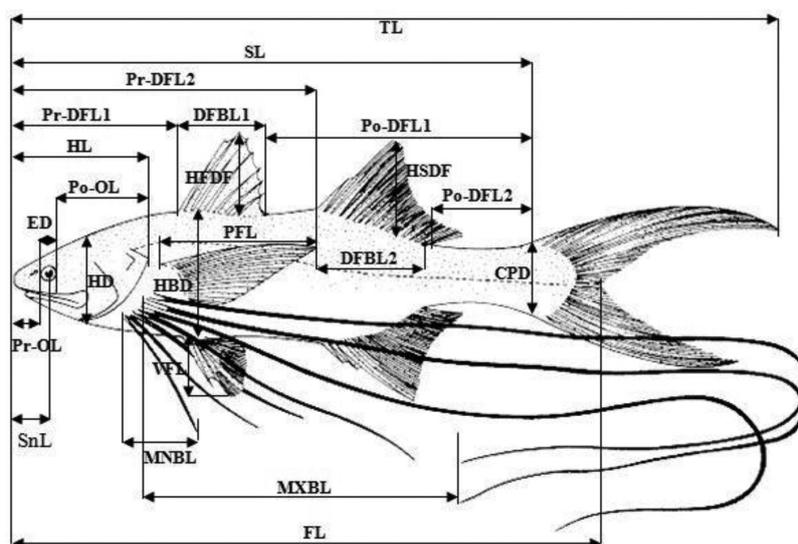


FIGURE 2. Morphometric measurement of paradise threadfin, *P. paradiseus*

MORPHOMETRIC CHARACTERS

Twenty five morphometric characters were recorded for *P. paradiseus* samples from the three populations (Table 3). All the morphometric characters for Payra population demonstrated significantly higher average values than the other two populations (Tentulia and Kirtankhola) and Tentulia population showed lower average value than other two populations (Payra and Kirtankhola). Among the 25 morphometric characters, eye diameter (ED) for all the populations showed no significant difference from each other. The TL, FL, SL, BD, Pr-DFL1, Pr-DFL2, PFL, VFL, DFBL1 and CPD showed significant variation among all the populations. The HL, HW, Po-DFL2 and MNBL of Tentulia river populations were significantly higher than those of the Payra and Kirtankhola populations. Pr-OL, Po-OL and SnL of Kirtankhola population showed significant variation compared to the Payra and Tentulia populations.

A dendrogram based on morphometric data was drawn for the three river populations (Figure 3). The Tentulia and Kirtankhola populations were closer to each other according to the distance of Squared Euclidean Dissimilarity. The distance between Payra and Tentulia/Kirtankhola populations was high.

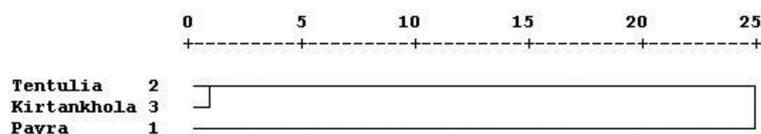
MERISTIC COUNTS

Ten meristic counts of *P. paradiseus* recorded from the three river populations are shown in Table 4. Among them, four characters (DFR1, PFR, VFR and NB) in all the populations showed no significant difference one to another. The BSR of Tentulia populations was significantly higher than that of the Payra and Kirtankhola populations. Payra population showed significantly higher compared with Tentulia and Kirtankhola populations. But the CFR, STLL and SBLL of Tentulia and Kirtankhola populations showed significant

TABLE 3. Morphometric characters of *P. paradiseus* observed in three river populations

Character	Abbreviation	Population		
		Payra	Tentulia	Kirtankhola
Total length	TL	17.46 ± 0.26 ^a	14.96 ± 0.02 ^c	16.23 ± 0.21 ^b
Fork length	FL	13.61 ± 0.23 ^a	11.53 ± 0.26 ^c	12.49 ± 0.17 ^b
Standard length	SL	12.21 ± 0.19 ^a	10.19 ± 0.15 ^c	11.11 ± 0.17 ^b
Head length	HL	2.67 ± 0.05 ^a	2.33 ± 0.04 ^b	2.62 ± 0.05 ^a
Head wide	HW	2.16 ± 0.04 ^a	1.94 ± 0.21 ^b	2.17 ± 0.05 ^a
Body depth	BD	3.22 ± 0.06 ^a	2.52 ± 0.05 ^c	2.73 ± 0.06 ^b
Pre-Orbital length	Pr-OL	0.62 ± 0.03 ^b	0.61 ± 0.02 ^b	0.69 ± 0.02 ^a
Post-Orbital length	Po-OL	0.79 ± 0.02 ^b	0.81 ± 0.02 ^b	0.88 ± 0.02 ^a
Eye diameter	ED	0.19 ± 0.06 ^a	0.19 ± 0.04 ^a	0.1974 ± 0.03 ^a
Snout length	SnL	0.72 ± 0.02 ^b	0.72 ± 0.02 ^b	0.786 ± 0.015 ^a
1st Pre-dorsal fin length	Pr-DFL1	3.8 ± 0.08 ^a	3.09 ± 0.06 ^c	3.43 ± 0.06 ^b
2nd Pre-dorsal fin length	Pr-DFL2	6.89 ± 0.10 ^a	5.53 ± 0.08 ^c	6.06 ± 0.10 ^b
1st Post-dorsal fin length	Po-DFL1	6.03 ± 0.11 ^a	5.57 ± 0.09 ^b	5.797 ± 0.09 ^{ab}
2nd Post-dorsal fin length	Po-DFL2	2.8 ± 0.07 ^a	2.49 ± 0.04 ^b	2.85 ± 0.08 ^a
Height of first dorsal fin	HFDF	2.19 ± 0.04 ^a	1.84 ± 0.03 ^b	1.81 ± 0.03 ^b
Height of second dorsal fin	HSDF	2.5 ± 0.04 ^a	2.08 ± 0.03 ^b	2.09 ± 0.04 ^b
Pectoral fin length	PFL	3.91 ± 0.11 ^a	3.24 ± 0.05 ^c	3.52 ± 0.06 ^b
Ventral fin length	VFL	1.9 ± 0.04 ^a	1.66 ± 0.03 ^c	1.79 ± 0.03 ^b
Height of anal fin	HAF	2.25 ± 0.04 ^a	1.88 ± 0.03 ^b	1.83 ± 0.03 ^b
1st dorsal fin base length	DFBL1	2.21 ± 0.11 ^a	1.59 ± 0.05 ^c	1.79 ± 0.04 ^b
2nd dorsal fin base length	DFBL2	2.52 ± 0.06 ^a	2.15 ± .04 ^b	2.23 ± 0.03 ^b
Length of anal base	LAB	2.19 ± 0.07 ^a	1.85 ± .03 ^b	1.88 ± 0.02 ^b
Caudal peduncle depth	CPD	1.65 ± 1.65 ^a	1.33 ± 0.03 ^c	1.53 ± 0.04 ^b
Maximum barbell length	MXBL	24.76 ± 0.94 ^a	18.64 ± 0.54 ^b	20.15 ± 0.50 ^b
Minimum barbell length	MNBL	2.99 ± 0.11 ^a	2.49 ± 0.056 ^b	2.83 ± 0.075 ^a

Values are mean±standard error. Mean values in each row bearing different superscripts are significantly different ($p < 0.05$)

FIGURE 3. Dendrogram based on morphometric characters of *P. paradiseus*

variation than that of the Payra population. The SALL of Kirtankhola population was significantly higher compared to Tentulia population, but not with Payra population.

Discriminant function analysis produced two discriminant functions (DF1 and DF2) for morphometric measurements. The DF1 was accounted for 78.6% and the DF2 was 21.4% among group variability, explaining 100% of total among group variability. All the samples were slightly different from one another in the discriminant space and virtually with some overlapping (Figure 4). This suggests that there was some intermingling among populations and the populations were not separated. The diagram showed that the Kirtankhola population was more dispersed in their morphological parameters than the Payra and Tentulia populations. The Payra population was more or less uniformly patterned in their morphological parameters. The Tentulia population contained somewhat compact in form.

The canonical graph of three river populations was sequentially distributed in cluster form around

their centroid value. This suggests that morphological growth trend of them more or less similar. The Tentulia and Kirtankhola populations are more closely related comparing to the Payra population for isometric condition.

DISCUSSION

In the present study highly significant morphological variations has been observed among the Payra, Tentulia and Kirtankhola populations. The mean value for all attributes of Payra population was higher compared to Tentulia and Kirtankhola populations, indicating the condition of Payra river was better than other two rivers. Almost all the morphometric characters (TL, FL, STL, HL, HW, BD, Pr-OL, Po-OL, SnL, Pr-DFL1, Pr-DFL2, Po-DFL1, Po-DFL2, HFDF, HSDF, PFL, VFL, HAF, DFBL1, DFBL2, LAB, CPD, MXBL and MNBL) showed significant variation whereas only ED was not significant among each other (Table 3). These significant variations might be related to the geography, ecology, human activities and genetic

TABLE 4. Meristic counts of *P. paradiseus* observed in three river populations

Sample	Abbrevia-tions	Payra Mean±SE	Tentulia Mean±SE	Kritonkhola Mean±SE
No.branchiostegal ray	BSR	7.00±0.00 ^a	6.86±0.083 ^b	7.00±0.00 ^a
1st dorsal fin ray	DFR1	6.97±0.03 ^a	7.03±0.029 ^a	7.00±0.00 ^a
2nd dorsal fin ray	DFR2	15.20±0.20 ^b	15.80±0.099 ^a	15.80±0.02 ^a
Pectoral fin ray	PFR	15.83±0.14 ^a	15.91±0.048 ^a	15.91±0.06 ^a
Ventral fin ray	VFR	5.06±0.06 ^a	5.00±0.000 ^a	5.00±0.00 ^a
Caudal fin ray	CFR	18.80±0.15 ^a	18.29±0.088 ^b	18.00±0.04 ^b
Scale through the lateral line	STLL	66.49±0.34 ^a	64.43±0.379 ^b	64.37±0.21 ^b
Scale above the lateral line	SALL	7.71±0.14 ^{ab}	7.43±0.094 ^b	7.86±0.06 ^a
Scale below the lateral line	SBLL	15.97±0.21 ^a	13.89±0.224 ^b	13.86±0.15 ^b
No. barbell	NB	7.00±0.00 ^a	7.00±0.000 ^a	7.00±0.00 ^a

Values are mean±standard error. Mean values in each row bearing different superscripts are significantly different ($p<0.05$)

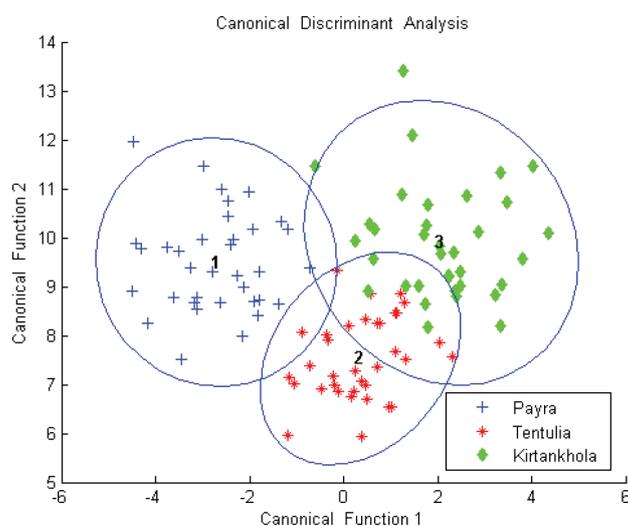


FIGURE 4. Coordinate plot of two discriminant functions based on morphometric measurement of *P. paradiseus* from three river populations. 1: Payra population, 2: Tentulia population and 3: Kirtankhola population

diversity of the populations. A similar study was performed on endangered carp *Labeo calbasu* from two stocks of isolated rivers and a hatchery population where significant variation was observed in all the morphometric characters (Hossain et al. 2010). Several studies has also reported on morphometric measurements and meristic counts on different fishes and variations due to geography, ecology and human activities were observed (Cabral et al. 2003; Khayyami et al. 2014; Pinheiro et al. 2005). Morphometric differences are expected among stocks collected from separated locations as they might have originated from different ancestors (Hossain et al. 2010) and might be due to their adaptation capacity. Fish are very sensitive to environmental changes (such as food abundance and temperature) and they have ability to adapt themselves by changing necessary morphometric (Allendorf & Phelps 1988; Mir et al. 2013; Swain et al. 1991; Wimberger 1992). In general, fish demonstrate greater variances in morphological traits both within and between populations than any other vertebrates and they are more susceptible to environmentally induced morphological variations (Coad 1980; Scheimer 1993; Wimberger 1992).

Water quality parameters were in good condition in Payra River compared to the other two rivers, while the water parameters were homogenous in Tentulia and Kirtankhola Rivers. Observed morphometric and meristic differences in this investigation were probably influenced by environmental parameters. The present findings agree with those of Schreck and Moyle (1990) and Kurata (1975) who reported that the meristic counts of fishes were affected by environmental factors (such as water temperature, pH) in fresh water.

The dendrogram contained two clusters - the Tentulia and Kirtankhola stocks in one cluster and the Payra stock in another (Figure 3). The difference between the Payra stock and the other two stocks might have been due to environmental as well as genetic variations. The Tentulia and Kirtankhola stocks are more or less similar and this might be consequence of migratory behavior of the fish from Tentulia to Kirtankhola Rivers and vice-versa. Paradise threadfin fish inhabits in the estuaries and Bengal Bay, Bangladesh (Rahman 2005) and enters freshwater during spawning time (Talwar & Jhingran 1991). Since the Tentulia River is located in the estuarine region and has direct connection with the Kirtankhola River (Figure 1), it may contribute to the similarity in taxonomic characters. A relationship was found among the three stocks according to the two discriminant functions (DF1 and DF2) from the morphometric measurement of three populations of *P. paradiseus*. In DF1, the Tentulia and Kirtankhola populations displayed some similar characteristics. The Tentulia and Kirtankhola populations were broadly overlapped, while the Payra population clearly differed the former two based on DF2.

The meristic counts of the three populations varied from 6 to 8 for branchiostegal rays, 5 to 8 for dorsal fin rays, 14 to 18 for pectoral fin rays, 4 to 6 for ventral

fin rays and 17 to 20 for caudal fin rays. The number of barbels for all the samples was 7. This result was adapted with the taxonomic formula (Rahman 2005; Talwar & Jhingran 1991). The mean number of BSR, DFR2, CFR, STLL, SALL and SBLL were significantly different among all the populations but no significant correlations were observed between meristic counts of *P. paradiseus* on DFR1, PFR, VFR and NB. A similar result was observed in the study of endangered carp *Labeo calbasu* where difference in meristic counts was recorded for *L. calbasu* from two stocks of isolated rivers and a hatchery (Hossain et al. 2010).

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CONCLUSION

The output of this study will provide useful baseline information of *P. paradiseus* populations for further studies. In both aquaculture and open-water management, it is essential to know the population structure, the habitats in which they inhabit and the impacts of external factors on their well-being. The morphometric and meristic diversities observed in this study will help in monitoring the species status in the southern coastal regions of Bangladesh as a bid to take appropriate management measures for the populations in future.

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