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Research Article

MORPHOLOGICAL VARIABILITY OF *MUGIL CEPHALUS* (LINNAEUS, 1758) FROM BANDAR ABBAS PORT AND QESHM ISLAND IN NORTHEASTERN PERSIAN GULF

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ABSTRACT

Morphological Variability of *Mugil cephalus* (Linnaeus, 1758) were studied in traditional morphometric measurements in 25 morphological characters from 71 specimens in two fishery areas in Bandar Abbas Port (37 specimens) and Qeshm Island (34 specimens) in northeastern Persian Gulf . Univariate analysis of variance showed significant differences between the means of the two groups for 17 out of 25 standardized morphometric measurements. Principal Component Analysis results (PCA) for morphometric data indicated that samples of Bandar Abbas Port and Qeshm Island with high degree of distinction between two locations with respect on morphometric characters. In discriminant function analysis (DFA), the proportion of individuals correctly classified into their original groups was 100%.

Keywords: Morphological differentiation, Phenotype plasticity, Distance effect, Environmental effect, Mugilidae.

INTRODUCTION

The grey mullet *Mugil cephalus* (Linnaeus, 1758) is a cosmopolitan species that is distributed in tropical and temperate zones at latitudes 42°N–42°S (Thomson, 1963). This species is rare in Iranian freshwaters (Coad, 1979), wherever Akbari (2002) records this species from creeks and coastal waters of Hormozgan. In Hormozgan coastal area, it is caught by cast net and stake-net and it is an important fish as food item (Coad, 2008). Ghelichi and Jorjani (2004) state that this species is expected to play an important future role in fish culture in Iran. Study of fishes in aquatic ecosystem is important from point of evolution, ecology, behaviour, conservation, water resource management and stock assessment (Anvarifar *et al.*, 2011). To rational and effective fisheries management, determination of exploitive fish stock is too important, because each stock needs separate management to aim of optimal harvest (Erguden and Turan, 2005; Salini *et al.*, 2004). The study of morphological characters with the aim of defining or characterizing fish stock units has for some time been a strong interest in ichthyology (Tudela, 1999). Although grey mullet is reported from Bandar Abbas Port formerly (Akbari, 2002) , however, there are no studies showing the present morphometric status of *M. cephalus* stocks in the Bandar Abbas Port (BAP) and Qeshm Island (QMI). The aim of the present study was to examine the morphological variation of *M. cephalus* from northeastern Persian Gulf to evaluate the differences between the grey mullet communities of Bandar Abbas Port (BAP) and Qeshm Island (QMI).

MATERIAL AND METHOD

A total of 71 adult individuals of the *Mugil cephalus* (Linnaeus, 1758) were collected from Bandar Abbas Port (27°18'N, 56°26'E) (BAP) (37 specimens) and Qeshm Island (26°69'N, 55°61'E) (QMI) (34 specimens) in northeastern Persian Gulf, Iran in June 2014 (Figure 1). The

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specimens were caught by stake-net and were preserved in 4% formalin and sent to the marine biology laboratory of Khorramshahr University of Marine Science and Technology. A total of 25 traditional morphometric characters were measured in centimeter using a digital caliper to the nearest 0.01 cm (Figure 2) measurements follow (Ibanez- Aguirre 2006; Kastelis et *al.*, 2006; Rezaei et al., 2012; Konan *et al.*, 2014). To avoid human error all morphological measurement were performed by the same person. After measuring, fish were dissected to identify the sex by macroscopic examination of the gonads. Gener was used as the class variable in ANOVA to test for the significant differences in the morphometric characters if any, between males and females of *M. cephalus.* As variation should be attributable to body shape differences, and not related to the relative size of the fish, an allometric method (Elliott *et al.*, 1995) was used to remove size-dependent variation in morphological characters:

$$Madj = M\ (Ls / L0)^{b}$$

where M is original measurement, Madj is the size adjusted measurement, L0 is the standard length of the fish, Ls the overall mean of standard length for all fish from all samples in each analysis and b was estimated for each character from the observed data as the slope of the regression of log M on log L0 using all fish in any group. The results derived from the allometric method were confirmed by testing significance of the correlation between transformed variables and standard length. Univariate Analysis of Variance (ANOVA) was performed for each morphometric character to evaluate the significant difference between the three locations (Zar, 1999) and the morphometric characters that were significant were used for principal component analysis (PCA) and function analyses (DFA) (Veasey *et al.*, 2001). Statistical analyses were performed using the SPSS version 21 software package and Excel 2007.

RESULTS

Morphological characters abbreviations and the results of ANOVA for morphological characteristics between two sexes of *M. cephalus* (Linnaeus, 1758) from the northeastern Persian Gulf are shown in Table 1. Interaction between morphometric characteristics used in this study and sex were not significant ($p>0.05$), demonstrating a negligible effect of sex on observed variations (Table 1). Descriptive data for mean length and standard deviation (S.D.) of sampled specimens is shown in Table 2. Differences ($p<0.05$) between *M. cephalus* of the BAP and QMI was observed for 17 out of 25 of the morphometric characters (Table 2). The traits that were significant were used for PCA. Being KMO coefficients approximately more than 0.6 indicate that PCA method will suitable for our data (Kasier, 1974). In this study the KMO coefficient were obtained 0.925 and for morphological characteristics that is explaining of appropriation of this test at good and medial level. In this analysis the characteristics with an eigenvalues more than 1 were included and others discarded (Table 3). Principal component analysis of 17 morphometric characters showed that PC I accounts for 77.071% of the variation, PC II for 9.957% and PC III for 4.694% (Table 3) and that the most significant weightings on PC I were from BH, PrD2 and CFL and on PC II were from DFL1, DFL2, PrP, VFH, PFL, VFL, AFL and HdW and on PC III were from PrOC (Table 4). The rotated (Varimax) component loadings for the three components (factors) are presented in Table 4. Visual examination of plotted PC I and PC II scores for samples revealed that there were a relatively high degree of distinction between two samples of *M. cephalus* from the BAP and QMI on northeastern Persian Gulf (Figure 3). For the discriminant analysis, the averages of percentage of correctly classified (PCC) were 100% for morphometric characters. High classification success rates were obtained for the BAP (100%) and QMI (100%) stocks indicating a high correct classification of individuals into their original populations with respect to morphometric characters (Table 5).

Table 1. Morphological characters abbreviations and description and the results of ANOVA for morphological characteristics between two sexes of *M. cephalus* from Northeastern Persian Gulf. Persian Gulf.

Abbreviations	Description	Code	F value	P value
TL	Total Length	1-15	.032	.859
FL	Fork Length	1-14	.078	.781
SL	Standard Length	1-13	.093	.761
BH	Body Height	9-20	.008	.931
PrD1	First PreDorsal distance	1-9	.000	.984
PrD2	Second PreDorsal distance	1-11	.032	.859
DFL1	First Dorsal Fin Length	9-10	.006	.938
DFL2	Second Dorsal Fin Length	11-12	.000	.986
CFL	Caudal Fin Length	13-15	.012	.911
PrP	PrePectoral distance	1-6	.014	.906
PrV	PreVentral distance	1-21	.008	.930
PrA	PreAnal distance	1-17	.065	.800
PFH	Pelvic Fin Height	6-8	.082	.776
VFH	Ventral Fin Height	19-21	.005	.942
PFL	Pelvic Fin Length	6-7	.004	.948
VFL	Ventral Fin Length	20-21	.075	.785
AFL	Anal Fin Length	16-17	.028	.868
ED	Eye Diameter	3-4	.554	.459
SNH	Snout to Nose Hole	1-2	.090	.765
AAF	Anus to Anal Fin	17-18	.447	.506
PrOC	PreOperculum distance	1-5	.000	1.000
SA	Snout to Anus	1-18	.003	.958
NHs	Nose Holes	-	.026	.872
HdW	Head Wide	-	.017	.898
EW	Eye Wide	-	.019	.891

Table 2. The results of ANOVA for morphological characters of *M. cephalus* (Linnaeus, 1758) from Bandar Abbas Port (BAP) and Qeshm Island (QMI) in Northeastern Persian Gulf.

Abbreviations	BAP	QMI	F value	P value
	Mean ± S.D.	Mean ± S.D.		
TL	23.6 ± 3.87	24.6 ± 4.25	1.20	.276
FL	22.6 ± 3.76	23.8 ± 4.19	1.49	.225
SL	19.6 ± 3.65	20.8 ± 4.1	1.75	.190
BH	3.7 ± .72	4.3 ± .73	11.40	.001
PrD1	9.6 ± 1.01	10.9 ± 1.1	23.72	.000
PrD2	15.1 ± 2.31	16.5 ± 2.4	6.55	.013
DFL1	.92 ± .16	1.31 ± .15	106.80	.000
DFL2	1.1 ± .11	1.4 ± .12	217.73	.000
CFL	3.1 ± .78	3.8 ± .790	14.69	.000
PrP	4.5 ± .36	5.4 ± .38	115.6	.000
PrV	7.1 ± 1.11	8.1 ± 1.2	14.98	.000
PrA	15.6 ± 1.63	17.1 ± 1.7	12.06	.001
PFH	4.1 ± .52	4.5 ± .58	15.3	.000
VFH	2.6 ± .177	3.4 ± .19	350.1	.000
PFL	.93 ± .15	1.3 ± .24	64.2	.000
VFL	1.1 ± .11	1.4 ± .093	161.9	.000
AFL	1.7 ± .59	2.1 ± .16	51.1	.000
ED	1.11 ± .38	1.1 ± .11	.325	.570
SNH	.93 ± .123	.94 ± .14	.025	.876
AAF	.81 ± .103	.83 ± .11	.002	.964
PrOC	4.6 ± .489	5.2 ± .45	23.01	.000
SA	12.5 ± 2.82	13.7 ± 3.22	2.9	.093
SA	12.5 ± 2.82	13.7 ± 3.22	2.9	.093
NHs	1.7 ± .37	1.91 ± .33	3.6	.062
HdW	3.6 ± .65	4.1 ± .645	7.1	.010
EW	2.8 ± .62	3.3 ± .658	8.6	.004

Table 3. Eigen values, percentage of variance and percentage of cumulative variance for the principal components in case of morphometric variables for *M. cephalus* from Northeastern Persian Gulf.

Factor	Eigen values	Percentage of Variance	Percentage of Cumulative variance
PC1	19.268	77.071	77.071
PC2	2.489	9.957	87.028
PC3	1.173	4.694	91.721

Table 4. Factor loadings for the principal components and correlations between the measured morphometric variables and the discriminant functions for *Mugil cephalus* (Linnaeus, 1758) from northeastern Persian Gulf.

Abbreviations	PC1	PC2	PC3
BH	0.829	-	-
PrD1	-	-	-
PrD2	0.889	-	-
DFL1	-	0.865	-
DFL2	-	0.936	-
CFL	0.801	-	-
PrP	-	0.868	-
PrV	-	-	-
PrA	-	-	-
PFH	-	-	-
VFH	-	0.965	-
PFL	-	0.805	-
VFL	-	0.908	-
AFL	-	0.758	-
PrOC	-	-	0.949
HdW	-	0.821	-
EW	-	-	-

Table 5. Percentage of specimens classified in each group and after cross validation for morphometric characters for *Mugil cephalus* (Linnaeus, 1758) from Bandar Abbas Port (BAP) and Qeshm Island (QMI) in northeastern Persian Gulf.

	BAP	QMI
Original		
BAP	100	0
QMI	0	100
Cross Validated		
BAP	100	0
QMI	0	100

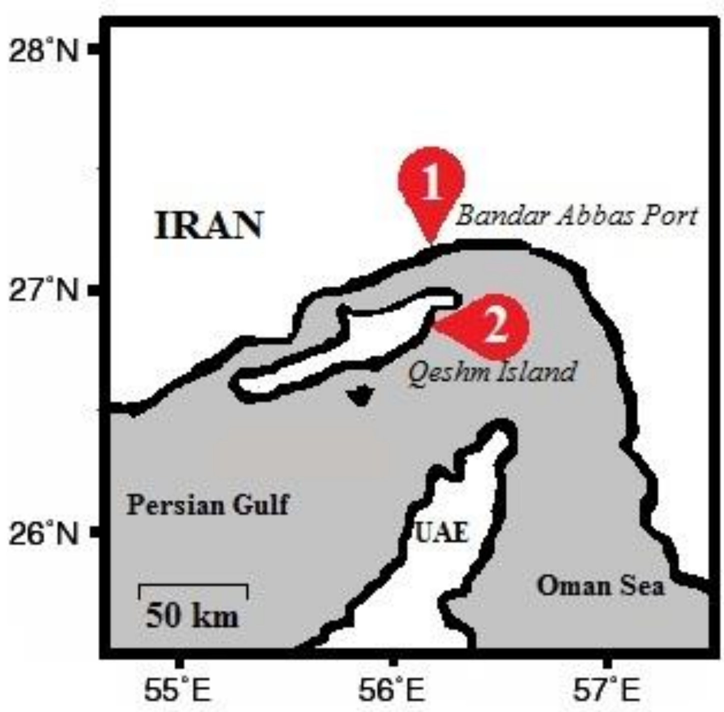

Figure 1. The map of northeastern Persian Gulf showing the location of fishing regions (1- Bandar Abbas Port and 2- Qeshm Island) for *Mugil cephalus* (Linnaeus, 1758).

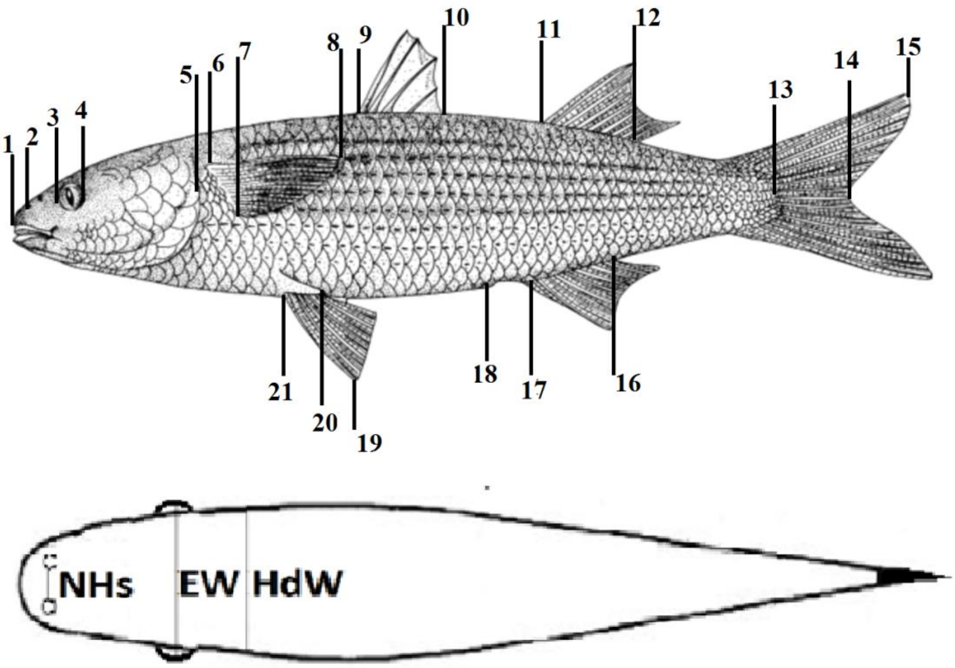

Figure 2. The codes of morphological characters investigated in *Mugil cephalus* (Linnaeus, 1758) from northeastern Persian Gulf.

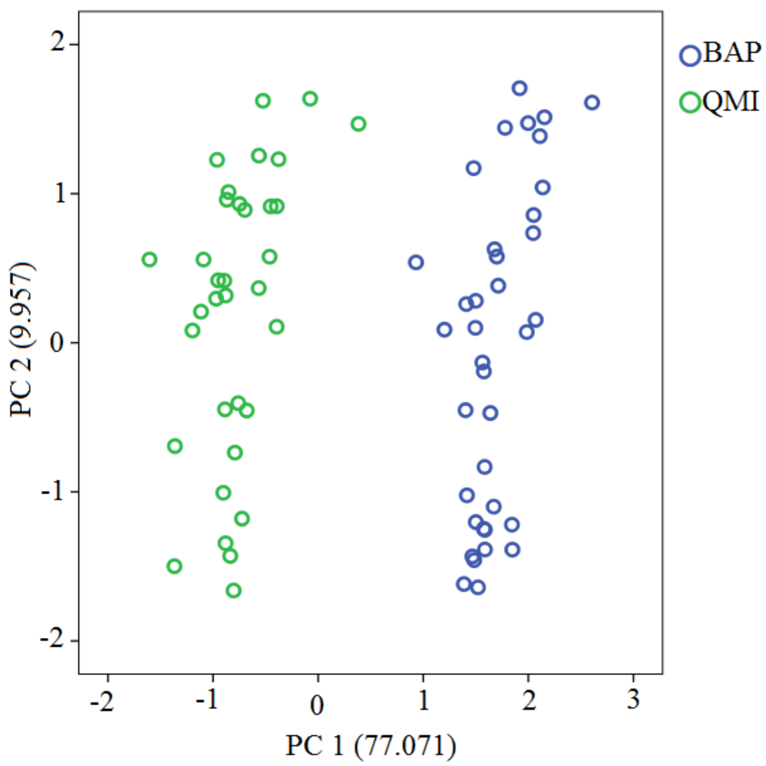

Figure 3. Plot of the factor scores for PC1 and PC2 of 17 morphometrics characters for *Mugil cephalus* (Linnaeus, 1758) from Bandar Abbas Port (BAP) and Qeshm Island (QMI) in northeastern Persian Gulf.

DISCUSSION

In the present study, results obtained from ANOVA analysis showed that 17 out of 25 transformed morphometric data were significantly different in *Mugil cephalus* living in the Bandar Abbas Port (BAP) and Qeshm Island (QMI) in northeastern Persian Gulf that demonstrates a high phenotypic variation among these two populations. The allometry among sexes would not be a cause of variability in this case, since there were no different variables among two sexes in grey mullets in northwestern Persian Gulf. The detected pattern of phenotypic discreteness also suggests a direct relationship between the extent of phenotypic divergence and geographic separation, indicating that geographic separation is a limiting factor to migration among stocks. It is well known that morphological characteristics can show high plasticity in response to differences in environmental conditions. This raises the possibility that phenotypic plasticity may itself be adaptive, allowing stocks to shift their appearance to match their ecological circumstances. (Swain and Foote, 1999). The phenotypic plasticity of fish allows them to respond adaptively to environmental change by modifications in their physiology and behaviour, which lead to changes in their morphology, reproduction or survival, which mitigate the effects of environmental change (Stearns, 1983). Therefore, perhaps the distinctive environmental conditions of the BAP and QMI may underlie the morphological differentiation between these two locations. Based on our study, there are at least two distinct communities of *M. cephalus* living in study area confirming by geographical separation in mentioned areas. This segregation was confirmed by another multivariate analysis, PCA, where the visual examination of plotted PC I and PC II scores for each sample revealed that samples of BAP and QMI with high degree of distinction between two locations with respect on morphometric characters and these two region were high different and distinct from each other. Morphology is especially dependent on environmental conditions during early life history stages (Lindsey, 1988). The environmental characteristics prevailing during the early development stages, when individuals are more phenotipically influenced by the environment, are of particular importance (Tudela, 1999; Pinheiro *et al.*, 2005). So different spawning places and occurring of early development stages in different locations with different conditions maybe effects on early hatched individuals and influenced them phenotipically (Pinheiro *et al.*, 2005). Gonzalez-Castro *et al.*, (2012) explained non-contact populations Mugilidae species, reflected broad shape differentiation. It has been suggested that the morphological characteristics of fish are determined by an interaction between genetic and environmental factors. Although, it's noticeable that the phenotypic variability may not necessarily reflect population differentiation at the molecular level (Tudela, 1999). The major limitation of morphological characters at the intra-specific level is that phenotypic variation is not directly under genetic control but is subjected to environmental modification (Clayton, 1986) and phenotypic adaptations may not result in genetic changes in the stock (Ihssen *et al.*, 1981). For example, Turan *et al.*, (2004) investigated allozyme electrophoresis for genetic comparison and the truss network system for morphometric comparison *Liza abu* stocks from the rivers Orontes, Euphrates and Tigris and they results showed phenotypic discreteness also suggests a direct relationship between the extent of phenotypic divergence and geographic separation, however, the pronounced phenotypic differentiation was not supported by genetic data or Swain *et al.*, (1991) used the truss system in the identification of hatchery and wild populations of Coho salmon (*Oncorhynchus kisutch*). They found significant morphometric variation, which was attributed to an effect of the rearing environment rather than genetic differences between the hatchery or wild stocks. The morphological differences may be solely related to body shape variation and not to size effects which were successfully accounted for by allometric transformation. In the other hand, factor of size play a predominant role in morphometric analysis and make result in erroneous status if it cannot be removed in statistical analyses of data (Tzeng, 2004). In present study, the size effect had been removed successfully by the allometric transformation, so any significant differences represented the body shape variation when it tested using ANOVA and multivariate analysis. In general, fishes demonstrate greater variance in morphological traits both within and between populations than other vertebrates, and are more susceptible to environmentally induced morphological variation (Thompson, 1991; Wimberger, 1992; Turan *et al.*, 2006), which might reflect different feeding environment, prey types, food availability or other features (Rezaei *et al.*, 2012). So, various environmental factors may determine the phenotypic differentiation in the grey mullet.

CONCLUSION

The present study provided basic information about morphological variability of *M. cephalus* populations from Northeastern Persian Gulf and it suggests that there are at least two separated groups living in the mentioned area, therefore morphological variations observed in grey mullet should be considered in fisheries management and commercial exploitation of this species. These were analyzed using multivariate methods to establish the value of conducting deeper and more detailed morphological and molecular analyses in the future.

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