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Morphological Variability of *Liza abu* (Heckel, 1843) from Northwestern Part of the Persian Gulf

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Abstract: Morphological Variability of *Liza abu* (Heckel, 1843) were studied in traditional morphometric measurements in 23 morphological characters from 97 specimens in three fishery areas in Karoon River (KR) (32 specimens), Arvand Kenar estuary (AK) (31 specimens) and Mousa Creek (MC) (34 specimens) from northwestern part of the Persian Gulf. Univariate analysis of variance showed significant differences among the means of the three groups for 18 out of 23 standardized morphometric measurements. Principal Component Analysis results (PCA) for morphometric data indicated that samples of KR and AK with high degree of overlap between two locations with respect on morphometric characters and these two regions were high different from MC. In discriminant function analysis (DFA), the proportion of individuals correctly classified into their original groups was 100%. The dendrogram derived from cluster analysis showed that two samples of *L. abu* from the KR and AK had same clade while both were obviously distinct from MC.

Key words: Morphological differentiation · Phenotype plasticity · Distance effect · Environmental effect · Mugilidae

INTRODUCTION

Liza abu is a mugilid species found in rivers, streams, channels, canals and drains, lakes, reservoirs ponds, on fish farms and occasionally entering estuaries. This mullet usually occurs in schools and inhabits Asia: Iraq, Syria, Turkey, Pakistan and Iran [1-7]. Also it is reported in rivers draining to the Persian Gulf such as Arvand (Shatt al-Arab), Dez, Zohreh River, Karkheh and Karoon rivers [6, 8, 9]. It is the most abundant species in autumn in the Karoon River, Iran, comprising 44.2% of the catch [10]. The species remains in fresh waters [3, 11], but Nasir and Naama [12] reported it from the Khawraz Zubayr in a marine environment, probably a consequence of human-induced environmental changes [6]. It is an important food fish in Iran and in southern Iraq which appears in stores as a regular food [6]. There are numerous studies on the biological aspects, reproductive biology, feeding, growth, morphometric characters, behavior and survival aspects [13-18] of *L. abu* from southern Iraq. Also There are several studies on reproductive biology, abundance, disease, parasites and feeding aspects [9, 10,19-22] of *L. abu* from southwest of Iran (northwestern drainage of the Persian Gulf). Also it was studied meristic comparison of *L. abu* from Basrah of Iraq with *L. abu* from Karkheh of Iran [23]. However, there is no study showing the present morphometric status of *L. abu* stocks in the Karoon River (freshwater), Arvand Kenar (brackish water) and Mousa Creek (saline water). *L. abu* is the most morphologic variable species in the family Mugilidae [24] and Mullets are very important marine species successful on all accessible foods [25]. A sufficient degree of isolation may result in notable morphological, meristic and genetic differentiation among stocks within a species, which may be recognizable as a basis for the management of distinct stocks [25]. Study of fishes in aquatic ecosystem is important from point of evolution, ecology, behavior, conservation, water resource management and stock assessment [27]. Morphometric measurements and statistical relationships of fishes are imperative for both fishery biology and taxonomy studies [28-30]. 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 [31,

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32]. The aim of the present study was to examine the morphological variation of *L. abu* from northwestern part of the Persian Gulf basin to evaluate the differences between abu mullet communities of fresh water Karoon River (KR (1)), Brackish Water Arvand Kenar (AK (2)) and Marine water Mousa Creek (MC (3)).

MATHERIALS AND METHODS

Sampling: A total of 97 adult individuals of the *Liza abu* were collected from three southwestern points of Iran in May 2014, that comprising 32 individuals from Karoon River in Khorramshahr (KR (1)) (30°26'N, 48°11'E), 31 individuals from Arvand Kenar estuary (AK (2)) (29°55'N, 48°37'E) and 34 individuals from Mousa creek (MC (3)) (30°25'N, 49°11'E) (Fig. 1). The specimens caught by gill net [33] and preserved in 4% formalin and sent to the marine biology laboratory of Khorramshahr University of Marine Science and Technology.

Laboratory Work: 23 traditional morphometric characters were measured in centimeter using a digital caliper to the nearest 0.01 mm (Fig 2); measurements follow [34-37]. 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. Gender 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 *L. abu*.

Data Analysis: As variation should be attributable to body shape differences and not related to the relative size of the fish, an allometric method [38] 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 [38]. 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 [39] and

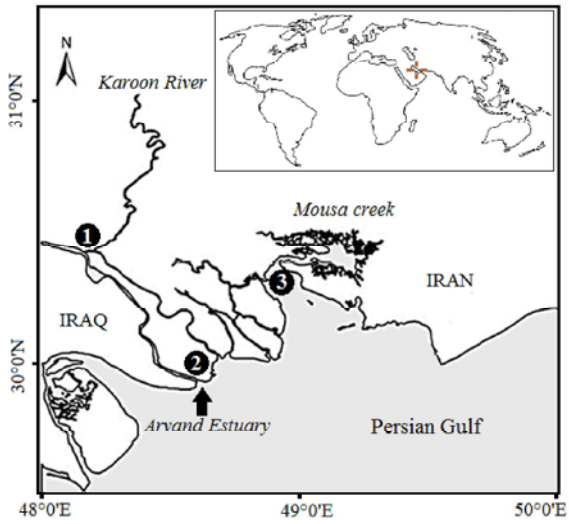

Fig. 1: The map of northwestern Persian Gulf showing the location of fishing regions (1- Karoon River, 2- Arvand Kenar estuary and 3- Mousa Creek) for *Liza abu* (Heckel, 1843)

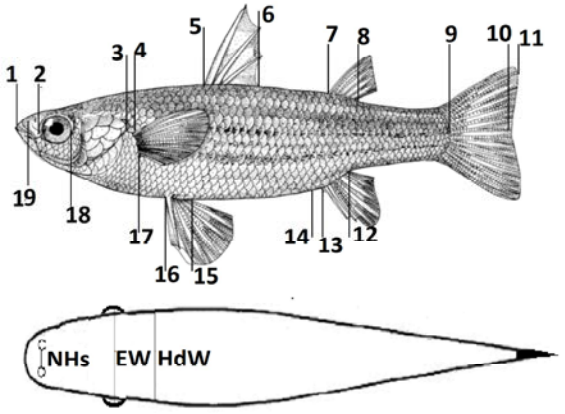

Fig. 2: The codes of morphological characters investigated in *Liza abu* (Heckel, 1843) from northwestern part of the Persian Gulf

the morphometric characters that were significant were used for principal component analysis (PCA) and function analyses (DFA). As a complement to discriminant analysis, morphometric distances between the individuals of three groups were inferred to Cluster analysis (CA) [40]. Statistical analyses were performed using the SPSS version 21 software package and Excel 2007.

RESULT

Morphological characters abbreviations and the results of ANOVA for morphological characteristics between two sexes of *Liza abu* (Heckel, 1843) from

Table 1: Morphological characters abbreviations and description and the results of ANOVA for morphological characteristics between two sexes of *Liza abu* (Heckel, 1843) from the northwestern part of the Persian Gulf

Abbreviations	description	code	F value	P value
TL	Total Length	1-11	.000	.983
FL	Fork Length	1-10	.960	.330
SL	Standard Length	1-9	.055	.814
BH	Body Height	5-15	.184	.669
PrD1	First PreDorsal distance	1-5	.001	.970
PrD2	Second PreDorsal distance	1-7	.008	.930
DFL1	First Dorsal Fin Length	5-6	.370	.544
DFL2	Second Dorsal Fin Length	7-8	.021	.885
CFL	Caudal Fin Length	9-11	.002	.961
PrP	PrePectoral distance	1-4	.001	.982
PrV	PreVentral distance	1-16	.000	.991
PrA	PreAnal distance	1-13	.000	.988
PFL	Pelvic Fin Length	4-17	.004	.948
VFL	Ventral Fin Length	15-16	.001	.980
AFL	Anal Fin Length	12-13	.002	.962
ED	Eye Diameter	2-18	.002	.961
SNH	Snout to Nose Hole	1-19	.122	.728
AAF	Anus to Anal Fin	13-14	.138	.712
PrOC	PreOperculum distance	1-3	.061	.805
SA	Snout to Anus	1-14	.001	.976
NHs	Nose Holes		.031	.860
HdW	Head Wide		.032	.859
EW	Eye Wide		.026	.871

Table 2: The results of ANOVA for morphological characters of *Liza abu* (Heckel, 1843) from the northwestern part of the Persian Gulf

	KR(1)	AK(2)	MC(3)		
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Abbreviations	Mean ± S.D.	Mean ± S.D.	Mean ± S.D.	F value	P value
TL	19.1 ± 1.8	20.1± 2.1	20.5± 1.9	3.585	.032
FL	18.2 ± 1.6	18.9 ± 1.8	19.8.3± 1.9	1.188	.310
SL	17.8 ± 1.7	17.9± 1.6	18.1 ± 1.7	.824	.442
BH	2.6 ±. 55	3.4 ±. 32	3.8 ±. 6	46.894	.000
PrD1	7.9 ± 1.1	7.6 ± 1.5	7.7± 1.5	.384	.683
PrD2	11.6 ± 1.1	12.1± 1.1	12.9 ± 1.6	7.132	.001
DFL1	1.42±. 27	1.43±. 29	1.42±. 21	0.011	.875
DFL2	1.42±. 21	1.47±. 26	1.48±. 31	0.097	.779
CFL	2.6±. 53	3.1±. 42	4.1 ±. 7	58.000	.000
PrP	3.7±. 4	4.4±. 5	5.5 ±. 6	104.950	.000
PrV	5.9 ±. 4	6.8 ±. 6	7.9±. 5	145.659	.000
PrA	12.3 ±. 4	13.1±. 4	14.9 ±. 1	9244.453	.000
PFL	.89±. 09	.91±. 09	1.08±. 19	18.935	.000
VFL	.98±. 19	.1.32±. 17	1.6±. 39	381.176	.000
AFL	1.7±. 15	1.9±. 15	1.01±. 08	423.673	.000
ED	1.01±. 07	1.11±. 08	1.58 ±. 07	332.961	.000
SNH	.51±. 08	.55±. 08	.58±. 07	7.599	.001
AAF	.5±. 07	.58±. 05	.59±. 07	12.043	.000
PrOC	3.9±. 3	4.5±. 3	5.14±. 5	76.779	.000
SA	11.1 ±. 3	12.2 ±. 6	12.1 ±. 4	41.166	.000
NHs	1.1 ±. 07	1.1±. 08	1.2 ±. 08	8.475	.000
HdW	2.4±. 17	2.7±. 14	3.1±. 16	103.460	.000
EW	1.9±.12	2.1±. 1	2.2±.17	16.590	.000

Table 3: Eigen values, percentage of variance and percentage of cumulative variance for the principal components in case of morphometric variables for *Liza abu* (Heckel, 1843) from the northwestern part of the Persian Gulf

Factor	Eigen values	Percentage of Variance	Percentage of Cumulative variance
PC1	10.523	58.460	58.460
PC2	2.563	14.238	72.697
PC3	1.209	6.715	79.412

Table 4: Factor loadings for the principal components and correlations between the measured morphometric variables and the discriminant functions for *Liza abu* (Heckel, 1843) from the northwestern part of the Persian Gulf

Abbreviations	PC1	PC2	PC3
TL	.918		
PrD2	.916		
SA	.853		
PrOC	.808		
CFL	.789		
PrP	.760		
BH	.755		
PrV			
HdW			
EW			
AFL		-.907	
PrA		-.903	
ED		-.895	
VFL		.818	
PFL			
SNH			
NHs			.828
AAF			

the northwestern part of 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 *L. abu* of the KR(1), AK(2) and MC(3) was observed for 18 out of 23 of the morphometric characters (Table 2). The traits that were significant were used for PCA, DFA and CA. Being KMO coefficients approximately more than 0.6 indicate that PCA method will suitable for our data (41). In this study the KMO coefficient were obtained 0.865 and for morphological characteristics that is explaining of appropriation of this test at good and medial level. In this analysis the characteristics with an eigen values of 1 were included and others discarded (Table 3). Principal component analysis of 18 morphometric characters showed that PC I accounts for 58.460% of the variation, PC II for14.238% and PC III for 6.715% (Table 3) and that the most significant weightings on PC I were from TL, PrD2, SA, PrOC, CFL, PrP and BH, on PC II were from AFL, PrA, ED and VFL and on PC III were from NHs (Table 4). The rotated (Varimax) component loadings for

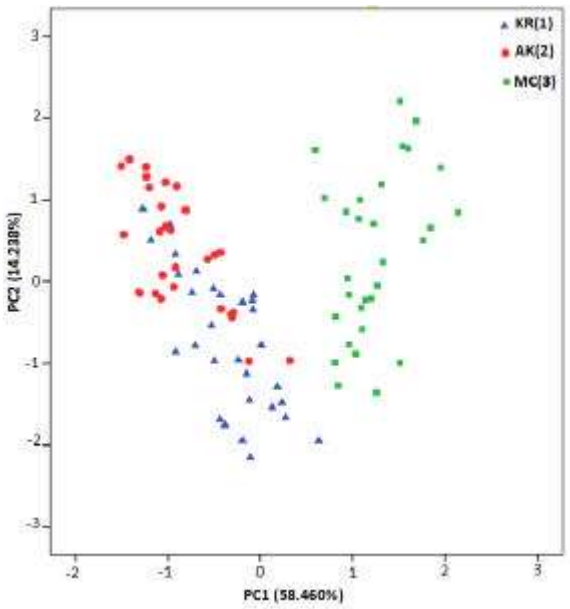

Fig. 3: Plot of the factor scores for PC1 and PC2 of 18 morphometrics characters for *Liza abu* (Heckel, 1843) from northwestern part of the Persian Gulf

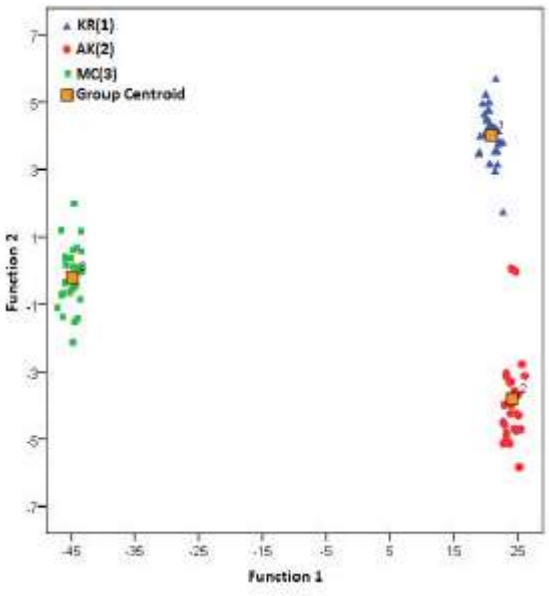

Fig. 4: Coordinate plot of *Liza abu* (Heckel, 1843) from northwestern part of the Persian Gulf according to the first two discriminant functions from morphometric data analysis

Table 5: Percentage of specimens classified in each group and after cross validation for morphometric characters for *Liza abu* (Heckel, 1843) from the northwestern part of the Persian Gulf

	KR(1)	AK(2)	MC(3)
Original			
KR(1)	100	0	0
AK(2)	0	100	0
MC(3)	0	0	100
Cross Validated			
KR(1)	100	0	0
AK(2)	3.3	96.7	0
MC(3)	0	0	100

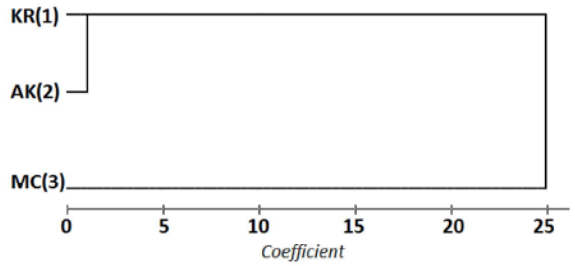

Fig. 5: Dendrogram derived from cluster analyses of 18 morphometric variables for *Liza abu* (Heckel, 1843) from Karoon River (KR(1)), Arvand Kenar (AK(2)) and Mousa Creek (MC(3)) in northwestern part of the Persian Gulf

the three components (factors) are presented in Table 4. Visual examination of plotted PC I and PC II scores for samples (Fig. 3) revealed that there were a relatively high degree of overlap between two samples of *L. abu* from the KR(1) and AK(2) on northwestern part of Persian Gulf while both study area (KR(1) and AK(2)) were distinct from in MC(3) these regions (Fig. 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 KR(1) (100%), AK(2) (96.7%) and MC(3) (100%) stocks indicating a high correct classification of individuals into their original populations with respect to morphometric characters (Table 5; Fig. 4).The dendogram derived from cluster analysis showed that two samples of *L. abu* from the KR(1) and AK(2) on northwestern part of Persian Gulf had same clade with great homogeneity while both study area (KR(1) and AK(2)) were obviously distinct from MC(3) that confirming the results obtained from PCA and DFA (Fig. 5).

DISCUSSION

In the present study, highly significant morphological variation was detected among *L. abu* stocks comprising the fresh water Karoon River (KR(1)), Brackish Water Arvand Kenar (AK(2)) and Saline water Mousa Creek (MC(3)). Discriminant Function Analysis could be a useful method to distinguish different stocks of a same species, concern to stock management programs [42]. The results of DFA obtained in this study, demonstrated a high differentiation among the populations of *L. abu* in the study areas. Also results obtained from ANOVA analysis showed that 18 out of 23 transformed morphometric data were significantly different in three groups of abu mullets living in the northwestern Persian Gulf basin that demonstrates a high phenotypic variation among these three populations. The allometry among sexes would not be a cause of variability in this case, since there were no different variables among to sexes in *L. abu* 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 [43]. The phenotypic plasticity of fish allows them to respond adaptively to environmental change by modifications in their physiology and behavior, which lead to changes in their morphology, reproduction or survival that mitigate the effects of environmental change [44]. Therefore, the distinctive environmental conditions of the Karoon River, Arvand Kenar and Mousa Creek, may underlie the morphological differentiation between these three locations. Based on our study, there are at least three distinct communities of *Liza abu* 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 Karoon River and Arvand kenar with high degree of overlap between two locations with respect on morphometric characters and these two region were high different and distinct from Mousa Creek. The overlapping distribution of these samples may be attributable to extensive migration between Karoon River and Arvand Kenar which are near and connected, in contrast with geographical separation with Mousa Creek. Gonzalez-Castro [45] 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, as morphology is especially dependent on environmental conditions during early life history stages [46]. The environmental characteristics prevailing during the early development stages, when individuals are more phenotipically influenced by the environment, are of particular importance [47, 48]. So different spawning places and occurring of early development stages in different locations with different salinity and conditions maybe effects on early hatched individuals and influenced them phenotipically [48]. Three stations has a great distance from each other, so the balance between gene flow and the forces responsible for population differentiation, such as genetic drift or differential selection, may result in clines, whereby genetic differentiation increases with geographic distance [48, 49]. But, it's noticeable that the phenotypic variability may not necessarily reflect population differentiation at the molecular level [47]. 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 [50] and phenotypic adaptations may not result in genetic changes in the stock [51]. For example, Turan [26] investigated allozyme electrophoresis for genetic comparison and the truss network system for morphometric comparison *L. 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 [52] 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 [53]. 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 [54-56], which might reflect different feeding environment, prey types, food availability or other features. So, various environmental factors may determine the phenotypic differentiation in the abu mullet. This research has provided scientific data for regulation of wild caught fisheries to protect natural populations and will be useful to evaluate possible long term stock enhancement programs of this important fisheries resource in future (57).

CONCLUSION

The present study provided basic information about Morphological Variability of *Liza abu* (Heckel, 1843) populations from northwestern part of the Persian Gulf and it suggests that there are at least three separated groups living in the mentioned area. However, there were a relatively high degree of overlap between two communities of *L. abu* from the Karoon River and Arvand Kenar estuary on northwestern part of Persian Gulf while both study area were distinct from in Mousa creek, therefore morphological variations observed in abu 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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