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ORIGINAL ARTICLE

Inter-species study of three species of Gobiidae on the Makran coast of Iran by both geometric and traditional morphometric methods

Nassim HOSSEINI, Fatemeh TABATABAEI YAZDI*

Department of Environment, Faculty of Natural Resources and Environment, Ferdowsi University of Mashhad, Mashhad, Iran.

Correspondence
f.tabatabaei@um.ac.ir

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Abstract
The Gobiidae is one of the largest families of fish in the world. This study deals with the morphometric characteristics as well as the geometric morphology of the specimens belong to three species from Gobiidae family, i.e. *Acentrogobius dayi* Koumans, 1941, *Bathygobius meggitti* (Hora and Mukerji, 1936) and *Istigobius ornatus* (Rüppell, 1830) from Makran coast, South-East of Iran. A total of 56 specimens were captured from the three stations Tis, Lipar and Darya-Bozorg, from spring to summer 2018. 36 morphological variables were analysed (including univariate and multivariate), using SPSS and PAST software. Also, to test the morphological plasticity of the specimens, the dorsal, lateral (left side) and ventral sides of the specimens were photographed. 12 Landmarks from the dorsal side, 20 Landmarks from the latral side and 19 Landmarks from the ventral side of the specimens were digitized using tpsDig software. The shape data, based on landmarks coordinates, data were investigated using multivariate analyses. Body shape of each population was visualized based on the average total shape. The results revealed a significant difference in body shape between the studied species. Based on a cluster analysis, *A.dayi* and *I.ornatus* species were more similar and most difference was observed between *B.meggitti* and other species. The observed morphological differences could be relevant to the environmental conditions and feeding habits of the studied species. To what degree this continuous data can now be translated into discrete and diagnostic features, useful for taxonomic purposes, remains to be studied.

Keywords: Gobiidae, Makran coast, Morphometric characteristics, Geometric morphometric, Phenotypic plasticity.

INTRODUCTION

The primary goal of comparative biology is to investigate the evolutionary rate of morphological differences. Phenotypic diversification may be related to factors such as morphological plasticity and adaptation to new habitats, habitat complexity, niche specialization, and / or competition (Yoder et al. 2010) and has also been evaluated in a phylogenetic context in many fish groups (Sidlauskas 2007, 2008; Collar et al. 2009; Cooper & Westneat 2009; Price et al. 2011; Aguilar-Medrano et al. 2011). Morphological diversification is often assessed by quantifying changes in body shapes that could be linked to feeding habits or movement patterns (Thacker 2014).

Geometric morphometric is a powerful tool in shape analysis (Bookstein 1996 a,b; 1997). Its application in the study of fish shape has been reported extensively in recent literatures (Loy et al. 1995, 1999; Cataudella et al. 1995, 1996; Mohadasi et al. 2013; Jalili et al. 2015; Mouludi-Saleh et al. 2019, 2020, 2021, Secer et al. 2022; Eagderi et al. 2021). This method relies on detecting homologous landmarks that explicitly retain information on spatial covariation among landmarks (Zelditch et al. 2004).

This technique is also applicable for investigating the link between body shape and ecological traits i.e. to test eco-evo-morphology or adaptive divergence (Linde et al. 2004; Tabatabaei Yazdi & Adriaens 2011; Tabatabaei Yazdi 2011, 2014).

Gobiidae family is a significant component of nearshore marine, estuarine, and freshwater fish faunas in tropical and temperate habitats (Eagderi et al. 2019, 2022). They are remarkable for their adaptation and diversification of a wide range of environmental conditions (Thacker 2014). The most

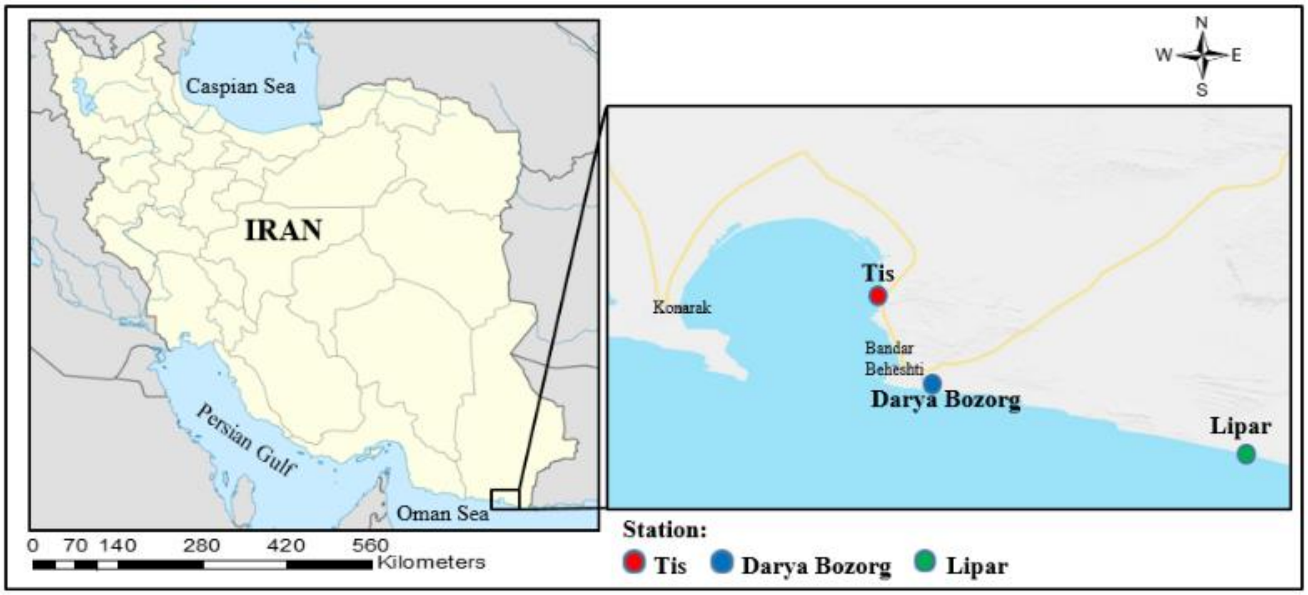

Fig.1. Geographical location of three stations Tis, Lipar and Darya-Bozorg on the coast of Makran, South Eastern Iran.

Table 1. Specifications of sampling areas and the number of specimens.

Station	Bed type	Species			Latitude	Height (m)
		A. dayi	*I. ornatus*	*B. meggitti*		
Tis	Muddy	16	5	9	25°21'25.08"N 60°36'20.46"E	9
Darya-Bozorg	Rocky	7	4	-	25°16'39.19"N 60°39'47.05"E	6
Lipar	Pebbled	12	3	-	25°15'3.29"N 60°49'53.79"E	57
Total		35	12	9		

highly diverse gobioids are often considered exceptional vertebrate species diversity (Birdsong et al. 1988; Nelson 2006; Thacker 2009). Their elevated diversification was confirmed in the broad analysis of teleost diversification (Near et al. 2013; Thacker 2014). Here, we tried to investigate the morphometric characteristics of the three species of the Gobiidae family, viz. *Acentrogobius dayi* Koumans, 1941, *Bathygobius meggitti* (Hora and Mukerji, 1936) and *Istigobius ornatus* (Rüppell, 1830) collected from Makran coast, South-East of Iran using geometric and traditional morphometric methods.

MATERIAL AND METHODS

A total of 56 specimens were collected during the spring and summer of 2018 along the shores of the Gulf of Oman in Iran from three muddy, Rocky and Pebbled coastal stations, namely Tis (A), Darya-Bozorg (B) and Lipar (C) (Fig. 1) using a hand net. Data on the various characteristics of the pool are given in Table 1. The samples were fixed into 10% buffered formalin and then transferred to 96% alcohol after 48 hours. They transferred to the Natural Resources and Environment Laboratory, Ferdowsi University, Iran. The samples were identified based on proper identification keys (Springer & Gomon 1975; Goren 1979; Smith & Heemstra 1986; Springer & Williams 1994; Randall 1995; Carpenter et al. 1997; Eagderi et al. 2019). The specimens included 35 *A. dayi*, 9 *B. meggitti*, and 12 *I. ornatus* (Table 1).

For the traditional morphometric study, 36 morphological traits were measured using a digital caliper with an accuracy of 0.01 and recorded. To collect geometric morphometric data, the specimens' left, dorsal and ventral sides were photographed using a Nikon D5500 digital reflex camera with a Sigma

Fig.2. Landmarking on the three dorsal, lateral and ventral sides of the specimens.

105mm macro lens at 5 megapixels resolution. Then, the lateral, dorsal and ventral sides were digitized using TPSDIG 2.31 (Rohlf 2015) by applying 20, 12 and 19 landmark points on 2D pictures, respectively (Fig. 2). A scale was included in the images to allow the acquisition of a scaling factor for calculating centroid sizes (CS) (mm unit).

Shape analysis in geometric method: In the landmark-based method, the alignment of the specimens was performed using the Generalized (Procrustes) Least Squares (GLS = GPA) method (Rohlf & Slice 1990). The Transformation network was used to display graphs for shape changes relative to the reference shape (Bookestein 1989, 1991).

For each PCA (Principal Components Analysis) and CVA (Canonical Variate Analysis) analyses, the deformation grid for the beginning and end of each PC and CV was determined and matched to the Principal Component Analysis chart and Canonical Variate Analysis to interpret the directional change between the operational taxonomic units (OTUs). Analysis of the main components PCA was performed to show the distribution of individuals in the space obtained from all variables and to examine the variations among the specimens. To study the maximum separation between the OTUs, CVA was implicated. To show morphological differences between OTUs, Discriminant Function Analysis was performed in Morpho J software. Calculation of the central size was done in PAST software. The consensus form and deformation grids were visualized using MorphoJ software (Klingenberg 2011).

To evaluate the general pattern of geometric morphometric similarity among the OTUs, the analysis of UPGMA (Unweighted Pair Group Method with Arithmatic Mean) was performed on the matrix of Euclidean distances between the mean of the samples. PAST (Hammer et al. 2001) software was used to perform this analysis and the resulting tree pulp was estimated at 10,000 random bootstraps.

Complete evaluation of interspecific differences in tree-side fusion data was performed with NPMANOVA with Bonferroni p-values corrected and 10,000 random replications for pairwise Euclidean distance comparisons between species and groups using the Monte Carlo random method (Tabatabaei Yazdi & Adriaens 2011).

Size analysis: A central size (Centroid Size) was calculated in PAST software (Darvish 2015). The Box-Plot diagram was also plotted in SPSS software to compare the size between species and show differences between groups. Duncan's test was done in SPSS software to test significant morphological differences between OTUs based on traditional morphometric. To test the significant differences between the OTUs, because of software limitations (Tabatabaei Yazdi & Adriaens 2011).

RESULTS

Analysis of GLM and Duncan test showed that out of 36 characters, 10 characters (Table 2) were significantly different between the three studied species (P<0.05).

The relative distance of spatial and numerical characteristics between species: Due to the effect of

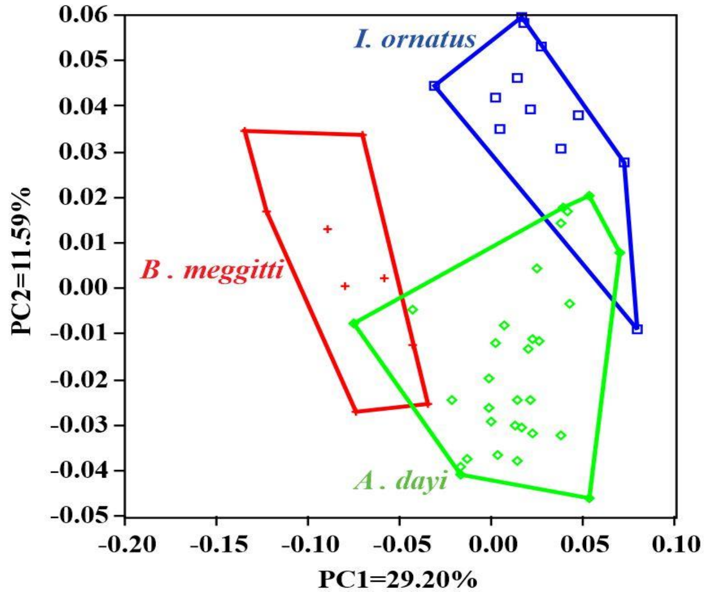

Fig.3. Scatter plot of PC1 vs. PC2 for three studied Gobiidae species occurring in Makran coast by traditional morphometric methods.

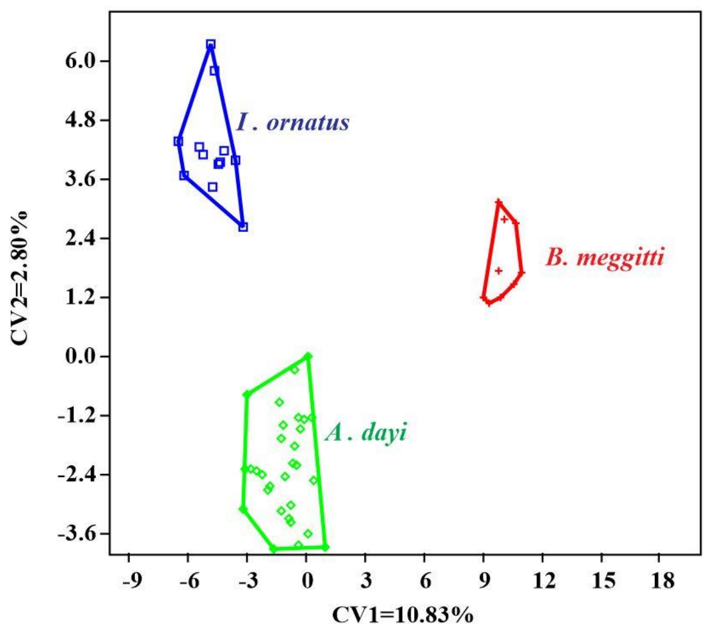

Fig.4. Scatter plot of CV1 vs. CV2 on the shape date of three studied Gobiidae species occurring in Makran coast by traditional morphometric methods.

the body size, variables that had significant differences were also calculated relatively. The results GLM and Duncan showed that all the variables that were significantly different between species in measurements were relatively significant (P<0.05) for all three species, as well.

Multivariate statistics analysis results: Analysis of the principal components (PCA) showed that the first two components explain more than 35% (PC1=27.24%, PC2=11.35%) of variation (Fig. 3).

Multivariate analysis of variance: Results of the canonical variable analysis (CVA) showed a significant difference among the three species (P<0.05). Based on a comparison of the Hotelling P-values pair, Bonferroni corrected, the values of CV1 and CV2 were 10.83% and 2.80%, respectively

Table 2. Mean and standard deviation calculated for three species of *A. dayi*, *B. meggitti* and *I. ornatus*, collected from Tis, Lipar and the Darya-Bozorg (Makran Beach, Persian Gulf).

character	Mean ± SD			P-Value F
	I. ornatus	*B. meggitti* N=9	*A. dayi* N=35	
Distance from the snout to the mouth	4.10±1.04[a]	4.46±1.01[ab]	5.01±0.77[b]	P=0.008 F=5.309
Distance between the mouth and the front of the gills	8.16±2.20[a]	11.51±2.01[b]	9.24±1.87[a]	P=0.001 F=7.720
Distance between the snout and the front of the gills	12.04±3.70[a]	14.62±2.29[b]	13.20±2.15[ab]	P=0.083 F=2.604
Diameter of the head	7.42±2.67[a]	9.25±2.60[b]	7.33±1.57[a]	P=0.044 F=3.312
Distance between the back of the eye and the front of the gills	7.40±2.83[a]	9.32±2.13[b]	1.63±1.63[ab]	P=0.101 F=2.393
Distance between the backs ventral eye and fin	10.28±3.59[a]	12.93±1.99[b]	10.1±1.96[a]	P=0.009 F=5.143
Distance between the pharynx and the front of the dorsal fin	12.15±2.96[a]	14.76±2.07[b]	13.08±2.32[ab]	P=0.059 F=2.996
Distance between the pharynx and the front of the abdominal fin	6.55±2.58[a]	9.81±2.36[b]	5.93±1.39[a]	P=0.769 F=0.264
Distance between the front of the snout and the front of the pectoral fin	13.48±4.2[a]	15.86±2.31[b]	14.08±2.17[ab]	P=0.133 F=2.093
Distance between the front of the snout and the back of the pectoral fin	14.29±4.15[a]	17.18±2.57[b]	15.27±2.32[ab]	P=0.078 F=2.677

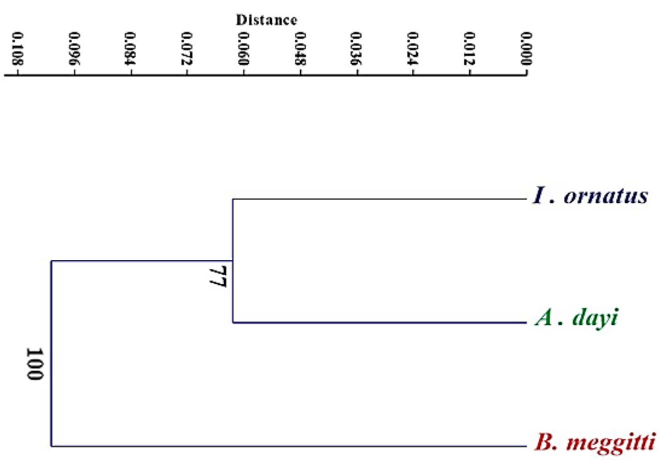

Fig.5. UPGMA (Unweighted Pair-Group Moving Average) dendrogram on the traditional morphometric traits of three species of Gaumahian family on the Makran coast based on the square factor of Euclidean distance.

(wilks lambda=0.003157, F=6.533) (Fig. 4). Cluster analysis based on Euclidean distance with 10,000 repetitions for three species showed that *B. meggitti* species did not cluster with other species (Fig. 5).

Geometric morphometric multivariate analysis

Shape analysis: The results of principal component analysis on the data sets of three sides, dorsal, lateral, and ventral, confirmed that the species are significantly different from each other. The deformation grids along the main axes for the dorsal side showed that the three species are mainly different in the head and caudal peduncle (Fig. 6a). For the lateral side, the differences are mainly in the head, mouth part, and as well as the tail (Fig. 6b). For the ventral side, the differences are mainly in the snout and tail (Fig. 6c). The PC graphs show that two species of *A. dayi* and *B. meggitti* reveals no overlap in morphospace, based on the dorsal and ventral morphological data, but they show partly overlap in morphospace, based on the lateral side (Fig. 6a-c).

Multivariate analysis of variance (NP-MANOVA, CVA and UPGMA): Based on the geometric morphometric shape data, on the dorsal side, the differences were significant ($P<0.05$) between the three species (F = 9.681 and Wilks-lambda= 0.013). The differences were mainly related to head and tail diameter (Fig. 7a). At the lateral side, the species were significantly different ($P<0.05$) in the head and tail (F = 5.247 and wilks lambda = 0.00391) (Fig. 7b). At the ventral side, the main differences ($P<0.05$) were observed in the head area (F = 7.648 and Wilks-lambda = 0.002723) (Fig. 7c). These results were consistent with the results of principal component analysis. Cluster analysis based on Euclidean distances with 10,000 repetitions for three species of

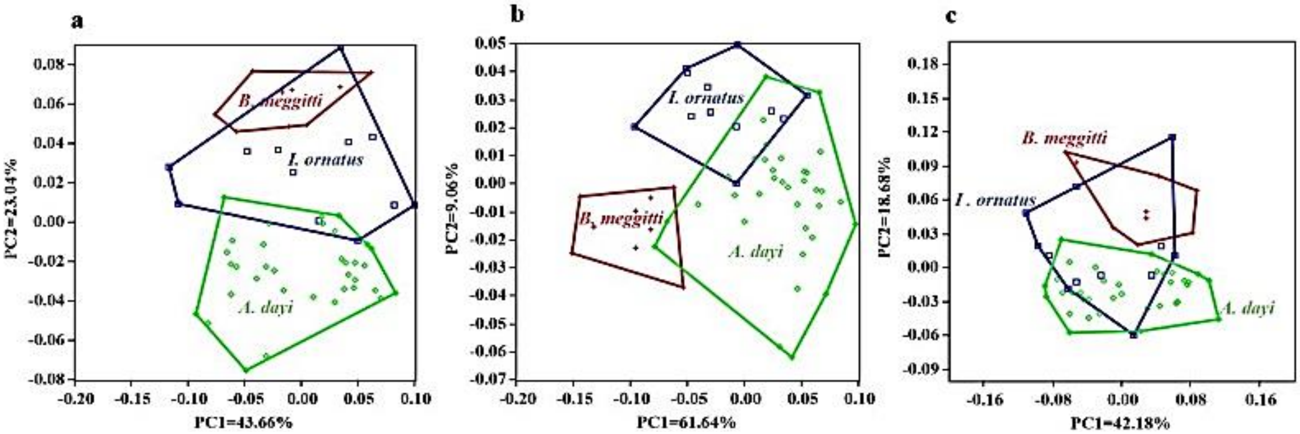

Fig.6. Between-group principal component analyses (PCA) scatter plot (PC1 versus PC2) of the three studied Gobiidae species occurring in Makran coast (data based on sides dorsal (a), lateral sides (b), and vertical sides (c).

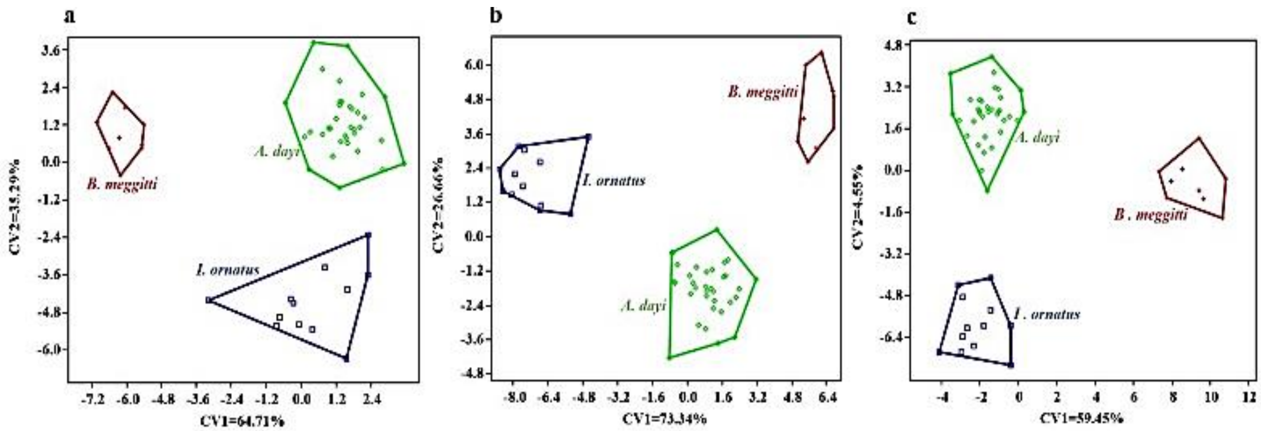

Fig.7. CVA graphs and deformation grids along the main axes (CV1 vs. CV2) on three species of gobiidae for dorsal (a), lateral (b), and ventral (c) sides.

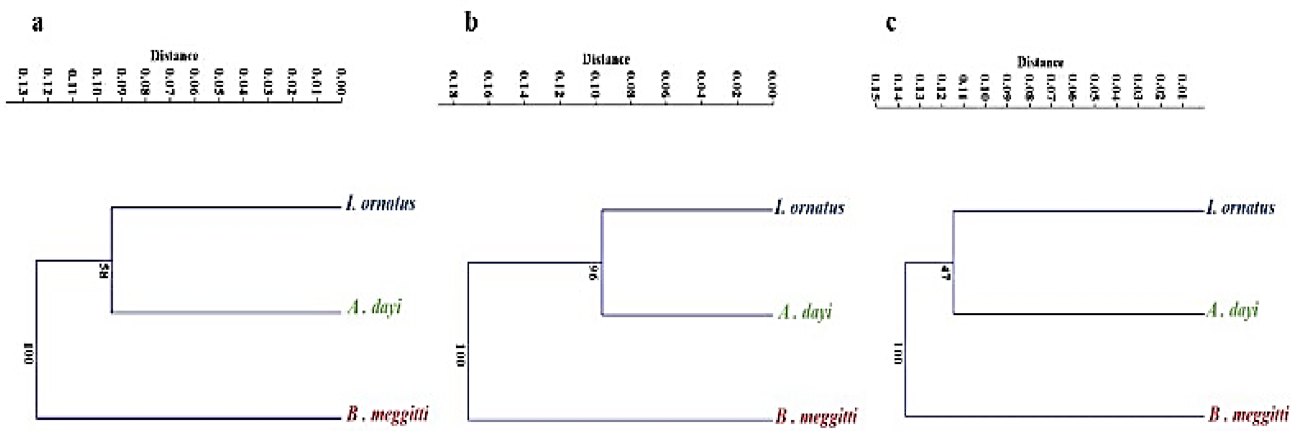

Fig.8. UPGMA dendogram based on the Euclidean distances of the geometric morphometric shape variables with 10,000 repetitions for dorsal (a), lateral (b), and ventral (c) sides.

Gobiidae showed that for all the dorsal, lateral and ventral sides, *B. meggitti* is different from other species, and the two species *A. dayi* and *I.ornatus* are more similar to each other, based on the shape data (Fig. 8a-c). The results of the Monte Carlo Randomization test with 10000 replications show that the difference in shape between species is significant (Table 3).

Size analysis: Analysis of GLM and Duncan tests from 22 indicators, 16 characters (Table 4) showed a significant difference between the three species on the dorsal sides ($P<0.05$). These analyses show that 5 out of 28 characters revealed a significant interspecies

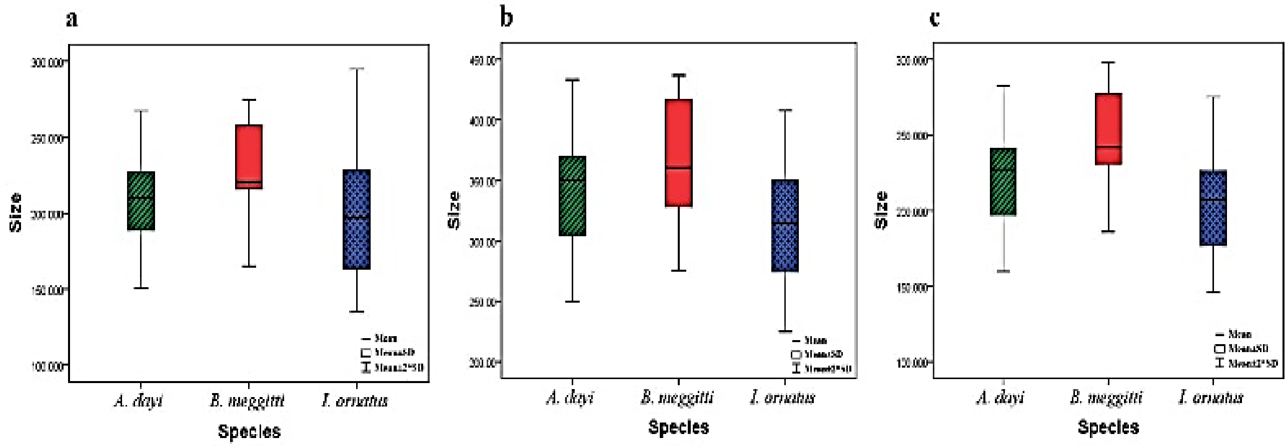

Fig.9. Box charts for comparing three species of gobiidae based on dorsal sides (a), lateral sides (b), ventral sides (c) by geometric morphometric.

Table 3. Shape distances (based upon Euclidean distances) between the three species is significant mean.

Pairwise grouping	Dorsal	Latral	Ventral
B.meggitti-L.ornatus	Mean=0.071 P=0.0042	Mean=0.094 P=0.0005	Mean=0.090 P=0.0001
B.meggitti-A.dayi	Mean=0.092 P=0.0001	Mean=0.129 P=0.0001	Mean=0.082 P=0.0003
I.ornatus-A.dayi	Mean=0.059 P=0.0018	Mean=0.059 P=0.0042	Mean=0.070 P=0.0004

Table 4. Mean and standard deviation calculated for three species *A. dayi*, *B. meggitti*, *I. ornatus*, captured from Tis, Lipar and the Darya-Bozorg stations (Makran Beach, Persian Gulf).

Side	character	Mean ± SD			P-Value F
		I. ornatus N=12	*B. meggitti* N=9	*A. dayi* N=35	
	Head of the diameter	19.22±4.11^{a}	23.86±4.57^{b}	22.89±4.80^{b}	p=0.039 F=3.459
	Distance between the back of the eye and the ventral fins	29.57±6.53^{a}	41.57±7.34^{b}	29.19±5.23^{a}	P=0.0 F=16.529
	istance between the throat and the start of the dorsal fin	33.57±8.50^{a}	41.25±7.42^{b}	37.26±6.86^{ab}	p=0.528 F=0.646
	Distance between the throat and the beginning of the ventral fin	14.00±4.97^{b}	23.23±4.80^{c}	10.54±2.36^{a}	p=0.0 F=47.662
	Distance between the front of the dorsal fin and the ventral fin	36.10±9.52^{a}	47.71±8.86^{b}	38.29± 6.54 ^{a}	p=0.002 F=6.844
	Distance between front and back of dorsal fin I	12.24±5.53 ^{a}	22.68±5.68 ^{b}	10.16±2.18 ^{a}	p=0.375 F=0.999
	Distance between the back of the dorsal fin I and the ventral fin	32.70±10.31 ^{a}	40.44±6.41^{b}	35.81±6.43 ^{ab}	p=0.068 F=2. 822
Dorsal	Distance between the back of the dorsal fin I and the anterior fin	43.44±15.47 ^{a}	54.98±7.62 ^{b}	48.95±8.80 ^{ab}	p=0.049 F=3.190
	The distance between the two dorsal fins	38.17±12.22^{a}	41.57±5.77 ^{ab}	46.73±7.66 ^{b}	p=0.011 F=4.891
	Distance between the front of the dorsal fin II and the anterior fin	6.70±4.87 ^{a}	14.23±3.12 ^{c}	9.61±2.86 ^{b}	p=0.0 F=12.484
	Length of the anterior fin	23.51±7.25 ^{a}	34.02±5.24^{b}	29.59±5.82 ^{b}	p=0.001 F=8.152
	Distance between the front of the anterior fin and the back of the dorsal fin II	28.76±9.69 ^{a}	42.82±7.26 ^{b}	37.91±6.72 ^{b}	p=0.0 F=10.146
	Distance between the front of the dorsal fin II and the back of the anterior fin	18.52±4.84 ^{a}	24.26±3.75 ^{b}	21.09±3.99^{ab}	p=0.011 F=4.919
	Length of dorsal fin II	25.12±9.09^{a}	36.91±6.73^{c}	30.38±4.82^{b}	p=0.0 F=9.199

Table 4. Continued.

Side	character	Mean ± SD			P-Value F
		I. ornatus N=12	*B. meggitti* N=9	*A. dayi* N=35	
Dorsal	Distance between the back of the anterior fin and the back of the dorsal fin II	8.10±6.00[a]	15.55±4.23[b]	10.05±2.50[a]	p=0.0 F=10.358
	Distance between the back of the anterior fin and the front of the tail fin	21.92±7.93[a]	29.96±4.44[b]	21.72±3.72[a]	p=0.0 F=10.178
Lateral	Head of the diameter	54.86±12.31[a]	63.62±9.63[b]	62.93±10.14[ab]	p=0.065 F=2.875
	Distance between the back of the dorsal fin I and the ventral fin	45.21±11.82 [b]	41.97±7.10 [ab]	37.31±7.41 [a]	p=0.019 F=4.25
	Diameter of the tail	17.67[a]±69.04	12.22[b]±83.89	13.43[ab]±73.41	p=0.019 F=4.25
	Distance between the front of the snout and the front of the eye	67.32±21.90[a]	81.70±13.34[b]	67.49±10.20[a]	p=0.025 F=3.971
	Distance between the front of the snout and the back of the dorsal fin II	59.96±17.21[a]	71.89±11.25[b]	64.24±10.99[ab]	p=0.106 F=2.344
Ventral	Distance between the snout and the front of the gills	49.71±12.78[a]	59.39±9.37 [b]	59.91±11.85 [b]	p=0.037 F=3.507
	Diameter of the head	41.93±11.13[a]	52.26±9.72[b]	52.68±11.58[b]	p=0.019 F=4.260
	Distance between the back of the eye and the front of the gills	44.66±11.95[a]	54.71±10.35[b]	54.18±11.61[b]	p=0.044 F=3.310
	Distance between the back of the eye and the abdominal fins	44.75±11.44[a]	54.65±10.09[b]	54.12±11.66[b]	p=0.046 F=3.276
	Distance between the front of the dorsal fin and the ventral fin	1.79[ab]±6.86	8.29±1.95[b]	6.23±2.05[a]	p=0.026 F=3.894
	Distance between the front of the dorsal fin II and the anterior fin	15.69±3.19 [a]	18.16±2.60[ab]	19.49±4.63 [b]	p=0.028 F=3.837
	Distance between the back of the anterior fin and the back of the dorsal fin II	15.82±3.72[a]	20.33±5.26 [b]	19.92±4.35 [b]	p=0.018 F=4.336
	Diameter of the tail	43.44±11.72[a]	56.15±8.57[b]	51.81±9.86[b]	p=0.014 F=4.627

differences at lateral level ($P<0.05$) and 8 out of 28 character (Table 4) at the ventral side, were significantly different at inter specific level ($P<0.05$). Based on the size data of the dorsal, lateral, and ventral sides by geometric morphometric, the *I.ornatus* species has the smallest size, and the *B. meggitti* species has the largest size (Fig. 9).

DISCUSSION

Sadeghi & Esmaeili (2018) investigated the length-weight relationships of three gobiid species along the coasts of the Persian Gulf and the Makran Sea. Length-weight ratios (LWRs) were estimated for three species of *Bathygobius meggitti*, *Acentrogobius dayi* and *Cryptocentroides arabicus*, which were collected from 13 localities of the Iranian intertidal coast of the Persian Gulf and Makran Sea. Iranmanesh et al. (2020) investigated the diversity of shape and structural-functional adaptation that is relevant to the feeding system in Gobiidae. In this study, using a geometric morphometric analysis, the shape changes of urohyal bone in seven species of gobiidae from the tidal environment between the Persian Gulf and the Gulf of Oman were studied. The results showed that the shape of the urohyal bone is distinct in any species, which is almost consistent with their phylogenetic relationships. Ghanbarifardi & Lagzian (2019) investigated the molecular phylogeny of Gobiidae from Iranian waters. The population structure of *I. ornatus* in the Persian Gulf and the Sea of Oman was studied by them. Emamian et al. (2021), in their report on morphological of sagittal otolith using geometric morphometrics in two species of gobiidae *B. meggitti* and *I. ornatus* on Makran coast, noticed a significant intra-species and intra-population difference that highest difference was observed in Tis population for both species. Also, morphological differences were obtained between two populations of Tis and Big Sea for *B. meggitti* species and for *I. ornatus* species in Tis and Big Seda; their results showed significant Intra- and inter-species difference was obtained in the size of the otolith growth zone.

Morphological body variation of *I. ornatus*, *B. meggitti*, *Scartelaos tenuis*, *Boleophthalmus dussumieri* and *Periophthalmus waltoni* was investigated by Iranmanesh et al. (2021), from the Intertidal Zone of the Persian Gulf and Gulf of Oman, according to their results, whole morphological traits except the only two characters total length and preanal distance showed a significant difference and among these species.

Single-variables and multivariate interspecies analyses: The traditional morphometric variability in the present study showed the significance variables, which were mainly highlighted in the head part. The results of multivariate analyses showed that *B. meggitti* had the maximum morphological distance from two species of *A. dayi* and has been *I. ornatus*. The species *B. maggitti,* with the largest body size, was found only at Tis station. This limited distribution can be attributed to the habitat's specificity and narrow ecological niche.

Analyzing the size of the inter-species dorsal sides showed that the three species have significant differences in most of the examined parameters. Size analysis at the inter-species lateral level showed that the studied species had significant differences in head diameter, body length and width, and tail diameter. Analysis of the size of the inter-species ventral sides showed that the three species differed significantly in head diameter, body width, and tail diameter.

Using geometric morphometry, the distinction between the studied species became clear that this morphological difference could depend on the adaptation to their habitat characteristics, interspecies competition and morphological plasticity (Robinson & Wilson 1994; Wimberger 1994; Robinson & Wilson 1995; Smith & Skulason 1996; Ruzzante et al. 1998; Mittelbach et al. 1999; Holtmeier 2001; Langerhans et al. 2010).

In general, in this study, two traits of head diameter and distance between the back of the eye and the ventral fins were identified as distinguishable variables at the interspecies level and could be considered in the identification keys to the Gobiidae family. On the ventral side, the distance between the back of the eye and the ventral fins were confirmed by traditional morphometric analysis, and from the dorsal and ventral sides, geometric morphometric analysis were confirmed as key traits. To better understand of biodiversity in the studied region, the genetic and ecological aspects of these species are needed to be investigated.

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مقاله کامل

مطالعه بین گونه‌ای سه گونه از گاوماهیان در سواحل مکران ایران با استفاده از دو روش ریخت‌سنجی هندسی و سنتی

نسیم حسینی، فاطمه طباطبایی یزدی*

گروه محیط زیست، دانشکده منابع طبیعی و محیط زیست، دانشگاه فردوسی، مشهد، ایران.

چکیده: گاو ماهیان (Gobiidae) یکی از بزرگترین خانواده‌های ماهی در جهان است. این مطالعه به بررسی خصوصیات ریخت‌سنجی سنتی و همچنین ریخت‌سنجی هندسی نمونه‌های متعلق به سه گونه از خانواده Gobiidae شامل؛ *Acentrogobius dayi* Koumans, 1941 ، *Bathygobius meggitti* (Hora and Mukerji, 1936)، و *Istigobius ornatus* (R83üellran) ، از سواحل جنوب شرق ایران می‌پردازد. در مجموع ۵۶ نمونه از سه ایستگاه تیس، لیپار و دریا بزرگ از بهار تا تابستان ۱۳۹۷ جمع‌آوری شد. ۳۶ متغیر ریخت‌شناختی (شامل تک متغیره و چند متغیره) با استفاده از نرم‌افزار SPSS و PAST مورد تجزیه و تحلیل قرار گرفت. همچنین برای آنالیز ریخت‌شناسی نمونه‌ها از سه سطح پشتی، جانبی (سمت چپ) و شکمی نمونه‌ها عکسبرداری شد. ۱۲ لندمارک از سمت پشتی، ۲۰ لندمارک از سمت جانبی و ۱۹ نشانه از سمت شکمی نمونه‌ها با استفاده از نرم‌افزار tpsDig رقومی‌سازی شدند. داده‌های شکل، بر اساس داده‌های مختصات نشانگر، با استفاده از تجزیه و تحلیل چند متغیره بررسی شد. شکل بدن هر جمعیت نسبت به شکل میانگین کلی مصورسازی گردید. نتایج نشان داد که بین گونه‌های مورد مطالعه تفاوت معنی‌داری در شکل بدن وجود دارد. بر اساس تجزیه و تحلیل خوشه‌ای، گونه‌های *A.dayi* و *I.ornatus* شباهت بیشتری داشتند و بیشترین تفاوت بین گونه‌های *B.meggitti* و سایر گونه‌ها مشاهده شد. تفاوت‌های ریختی مشاهده شده می‌تواند با شرایط محیطی و عادات تغذیه گونه‌های مورد مطالعه مرتبط باشد. اینکه تا چه حد این داده‌های پیوسته می‌توانند به ویژگی‌های گسسته و تشخیصی که برای اهداف طبقه‌بندی مفید هستند تفسیر شوند، هنوز مورد مطالعه قرار دارد.

کلمات‌کلیدی: گاو ماهیان، سواحل مکران، خصوصیات ریخت‌سنجی، ریخت‌سنجی هندسی، انعطاف‌پذیری ریختی.