Morphometric and meristic variations of *Photopectoralis bindus* (Valenciennes, 1835) in the waters Iraq: implications for stock identification and management

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Abstract

Morphometric and meristic analyses of the ponyfish Photopectoralis bindus *were used to discriminate stocks throughout the freshwater, estuarine and marine habitats of the lower reaches of Mesopotamia, Iraq. The analyses of these characters showed a different pattern of differentiation between* P. bindus *stocks and the meristic characters revealed a clear discreteness of two groups, freshwater populations and the estuarine-marine populations. Discriminant analysis based on morphometric characters failed to separate the marine environment populations as one entity and this could be due to the biological factors rather than environmental issues. On the contrary, the dendrogram based on meristic characters separated clearly the marine inhabitants' populations from those of the freshwater, which might due to the environmental factors such as water temperature. The total length range of individuals inhabiting Al-Hammar Marsh showed to have a new maximum size ever recorded for this species (136-140 mm TL). The importance of alterations in body shape have important consequences for hydrodynamics and swimming performance, and variation in meristic counts vertebral number variation in* P. bindus *also holds implications for both individual and population fitness. These two issues were discussed from the stock management point of view.*

Key words: *variations, characters, stock identification, population structure, Al-Hammar Marsh, body shape.*

Introduction

Information about the stock structure of exploited species with a wide distribution is important for management of fish stock, and two or more stocks must be managed separately to enhance their produce (Grimes *et al.*, 1987; Bolles and Begg, 2000; Devries *et al.*, 2002). Demarcating the population elements is essential when managing multi-stock commercial fisheries because different stocks may react differently to exploitation and rebuilding. The term "stock" or "group" is reliable with the notion of population and includes some concept of genetic integrity (Begg and Waldman, 1999).

Stock status estimations regarding management reference points were more robust to the doubts in stock discreetness (a single-stock hypothesis) and indicate that the species is currently under stress from heavy overfishing (Vasconcellos and Haimovici 2006). A stock can be described as an intraspecific group of randomly matting individuals with temporal or spatial integrity (Ihssen *et al.*, 1981). Misused fish stocks commonly derived from several spawning components (Begg *et al.*, 1999), and the input of each element to the harvested stocks differs with their obtainability to the fishery.

The two morphological traits, body proportions meristics are characters that have been most regularly used to outline stocks of a variety of exploited fish species (Murta, 2000; Silva, 2003; O'Reilly and Horn, 2004; Turan, 2004). Morphometric characters are continuous characters depicting features of body shape. Meristic characters are the number of discrete, serially repeated, countable structures that are secured in embryos or larvae. Investigations of morphologic variation between populations remain to have a vital role to play in stock identification while stable differences in shape between groups of fish may reveal different growth, mortality or reproductive rates that are relevant for the definition of stocks (Swain and Foote, 1999; Cadrin, 2000).

The Orangefin ponyfish *Photopectoralis bindus* (Valenciennes, 1835) is a tropical and brackish water species inhabits demersal environment (Riede, 2004) and lives at depth range 2-160 m (Woodland *et al.*, 2001). Its distribution is confined to the Indo-West Pacific region, where it reported from the Red Sea, Arabian Gulf to Japan and Australia (Russell and Houston, 1989). It reaches maximum total length of 110 mm, with common total length of 80 mm (James, 1984).

Along their geographical distribution, members of the family Leiognathidae form fairly significant fisheries. Although there is no commercial market for these species in Iraq due to the small size, but there is a huge potential for fisheries investment and export due to the presence of a large population in the Iraqi waters. As in other countries such as Malaysia or Thailand, these small sized species can be used for purposes other than human consumption such as manure, fish meal and protein source (Pauly, 2018). Therefore, the fisheries importance of the leiognathid species to Iraq is still there and the fishery management of their populations is an important task to add to the national revenue of the country.

However, the question of whether there is a single stock or multiple stocks of *P. bindus* in the Iraqi waters (freshwater, estuarine and marine) remains unanswered, since the ichthyological surveys in Iraq show a continuous distribution of the resource with a clear pattern of juveniles and adults distribution, as stated above (Jawad *et al.*, 2016).

The present study is the first attempt to analyze stock structure of orangefin ponyfish *P. bindus* with linear morphometrics and meristic characters and using samples from fresh, estuarine and coastal regions where the fishery of this species is exploited for several purposes. Morphometric variations between stocks form an indirect basis for stock structure analysis and elucidate the occurrence of "phenotypic stocks". An important challenge in morphometric studies is to generate consensus on biologically meaningful interpretations (Cadrin, 2000).

The objective of the present study is to investigate the morphologic population structure of *P. bindus* based on the morphometric and meristic traits of specimens collected from three freshwater localities of Iraq (marsh area, north and middle parts of Shatt al-Arab River), one estuarine area (estuary of Shatt al-Arab River) and 3 marine habitats (Khor al-Zubair, Umm Qasar, Khor al-Ummia areas) in order to highlight any possible morphologically differentiated groups of this leiognathid species.

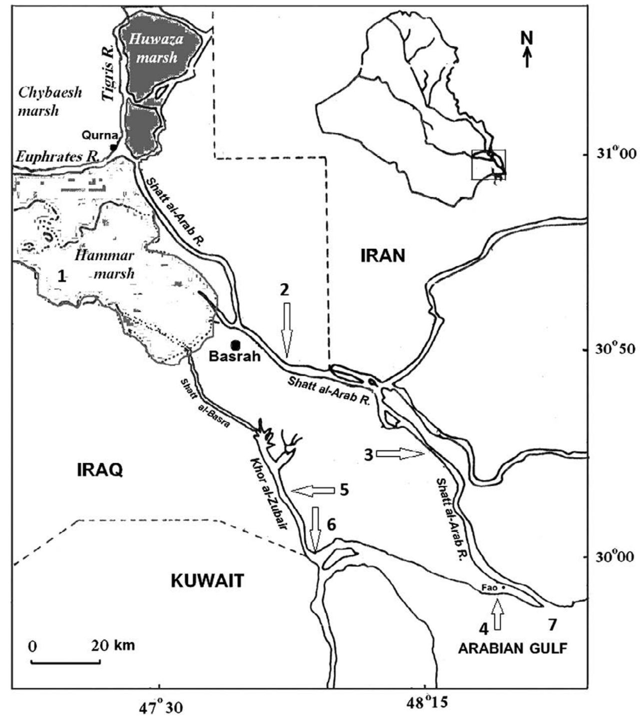

Fig. 1 – Map showing collection localities. **1**. Al-Hammar Marsh (AHM); **2**. north of Shatt al-Arab River (NSHR); 3. middle part of Shatt al-Arab River (MSHR); 4. Shatt al-Arab estuary (SHRE); **5**. Khor al-Zubair area (KHZ); **6**. Umm Qasar area (UQA); 7. Khor al-Ummia area (KHM)

Materials and methods

Sampling

The Orangefin ponyfish specimens were collected from seven localities in June-September 2016 extending from the freshwater environment of Al-Hammar marsh (AHM) (n=128), north of Shatt al-Arab River (NSHR) (n=178), middle part of Shatt al-Arab River (MSHR) (n=198), through the estuarine habitat estuary of Shatt al-Arab River (SHRE) (n=238), and marine waters of Khor al-Zubair (KHZ) (n=218), Umm Qasar (UQA) (n=218) and Khor al-Ummia (KHM) areas (n=268) located in south of Iraq (Figure 1). All samples were collected by gill nets except for those from Khor al-Ummia, where they collected by small commercial trawler. Following to capture, the sam-

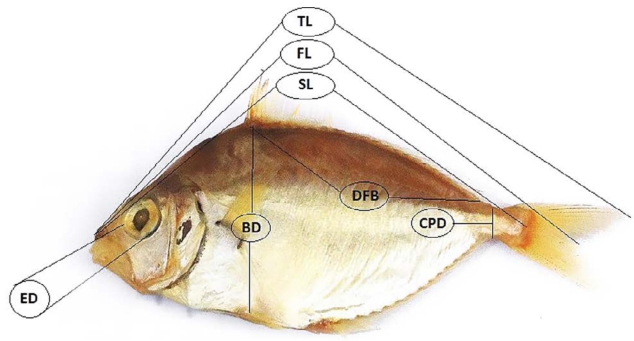

Fig. 2 – Morphometric measurements taken to *Photopectoralis bindus* (95 mm TL).

TL	Total length
SL	Standard length
FL	Fork length
ED	Eye diameter
BD	Body depth
CPD	Caudal peduncle depth
DFB	Dorsal fin base length

ples were located individually into plastic bags were kept deep-frozen (-20°C) until further analysis. The identification of the species was based on Fischer and Bianchi (1984). The specimens were dissected to decide the sex of the individual and this was built on the shape and appearance of gonads (Abraham *et al.*, 2011). All the specimens collected were with well-developed gonads and the data collected are from mature individuals of the parent stock. There was no problem in the determination of the sex of the specimens.

Morphological analysis

Morphological analyses were based on 1446 individuals of orangefin ponyfish *P. bindus*. A total of 7 morphometric were taken to the nearest millimeter using digital calliper and 5 meristic characteristics (Figure 2) were analyzed according to the method of Hubbs and Lagler (1947). The morphometric distances are: total length (TL), from tip of mouth to tip of longest caudal fin; standard length (SL), from tip of mouth to caudal base (hypural bone junction); fork length (FL); from tip of mouth to the fork of caudal fin; eye diameter (ED), the horizontal distance between the anterior and posterior edges of the eye; body depth (BD), distance between dorsal and ventral surface at the deepest point; caudal peduncle depth (CPD), the vertical distance at the base of the caudal fin; dorsal fin base length, the horizontal distance between the anterior and posterior edges of the base of the dorsal fin (DFB); number of dorsal fin rays (DFR); number of pectoral fin rays (PFR); total number of vertebrae (TNV); total number of gill rakers (TNGR); total number of pored scales on the lateral line. The meristic variables were reviewed through box plot diagrams and One-Way Anova to determine whether there are statistically significant differences between the means of meristic variables between locations and ambient. The morphometric characters were organized by ambient and location with five columns (one for each variable: ED, BD, CPD, DFB and TL) and 1446 number of rows or specimens. Standard length and fork length were not used since they are highly correlated with Standard length, therefore just one length were utilized. The data were transformed according to the normalization of individuals of each group recommended by Lleonart *et al.* (2000) in order to remove the size effects, using the Lleonart Sizestd programme. The resultant matrix was submitted to canonical discriminant analysis to compute generalized Mahalanobis distances to discriminate functions and to assess the efficacy in their classification. Cross-validated discriminant analysis was used to assess and compare the efficacy of fish shape in classification by ambient and location. All statistical tests were carried out by SPSS version 23. Phenetic relationships were investigated through cluster analysis of the mean values of filtered morphometric data and for meristic characteristics. Cluster analyses were performed based on quadratic Euclidean distance using Ward's method. A strict consensus tree was computed based on these methods.

Results

Mean standard deviation and range (minimum–maximum) of the morphological and meristic characters of seven locations for *Photopectoralis bindus* are shown in Table 1. As can be seen similar values are shared basically by ambient, this behavior is also clear in Figure 3. It is possible to see the wide differences among the meristic ($P<0.05$) and morphometric characters ($P<0.05$). These differences could be due to size which is significant different among freshwater and estuarine and marine ambient as is depicted in Figure 4. In estuarine and marine ambient size is lower than the ones from freshwater and meristic variables vary for the three ambient.

	Al-Hammar Marsh		North of Shatt al-Arab River		Shatt al-Arab River		Estuary of Shatt al-Arab River		Khor al-Zubair area		Umm Qasar area		Khor al-Umia area	
	MEAN ± STD	MIN-MAX	MEAN ± STD	MIN-MAX	MEAN ± STD	MIN-MAX	MEAN ± STD	MIN-MAX	MEAN ± STD	MIN-MAX	MEAN ± STD	MIN-MAX	MEAN ± STD	MIN-MAX
Morpho														
TL	137.9±1.2	136.0-140	125.1±3.4	121.7-133.0	126.0±4.3	120.4-134.0	87.7±12.4	75.5-116.0	87.8±12.8	71.6-110.0	91.9±13.3	72.6-113.0	92.3±12.1	71.9-114.0
SL	117.1±1.5	115.3-120.0	102.6±4.7	96.7-109.0	102.0±4.9	95.6-110.0	80.2±13.2	56.6-92.0	75.5±12.2	55.6-91.0	73.6±10.6	52.6-83.0	70.1±10.3	53.7-84.0
FL	132.6±1.7	130.5-135.0	121.5±0.8	120.3-123.0	121.1±2.0	118.7-125.0	87.7±17.2	65.7-110.0	79.0±10.3	60.5-89.0	76.6±8.5	61.7-90.0	81.2±10.7	60.2-91.0
ED	6.3±0.1	6.1-6.5	6.7±0.0	6.7-6.9	7.1±0.1	7.0.7.2	7.3±0.0	7.3-7.4	5.5±0.3	5.1-5.8	5.5±0.7	7.7-9.5	8.6±0.7	7.6-9.6
BD	56.5±0.6	55.6-57.0	52.8±0.5	51.3-53.0	49.6±0.6	48.2-50.0	44.0±0.8	42.5-45.0	10.7±0.2	10.5-11.0	10.8±0.1	10.6-10.9	10.8±0.1	10.7-11.0
CPD	19.7±0.3	19.2-20.0	18.1±0.1	17.9-18.3	15.0±0.3	14.3-15.2	8.2±0.5	7.2-8.6	5.3±0.1	5.0-5.4	5.6±0.3	5.2-5.9	5.6±0.7	4.1-6.2
DFB	68.7±0.8	67.7-70.0	64.5±0.5	63.4-65.0	60.9±0.2	60.3-61.0	56.4±1.9	53.4-58.0	49.2±2.4	44.6-51.0	41.5±0.6	40.1-42.0	35.7±1.7	32.5-37.0
Meristic														
TGR	23±1	23-24	23±0	23-24	24±0	23-24	20±0	20-21	20±0	19-20	19±1	19-20	18±0	18-19
NV	25±1	24-25	22±0	22-23	23±0	22-23	22±0	22-22	20±0	20-21	20±0	20-21	19±0	18-19
PSLL	48±0	48-49	48±0	48-49	48±0	48-49	46±0	46-47	45±0	45-45	45±0	45-45	45±0	45-45
DFR	19±0	19-20	17±0	17-18	17±0	17-18	16±0	16-16	15±0	15-16	15±0	15-16	16±0	15-16
PFR	20±1	20-21	21±0	20-21	21±0	20-21	17±0	17-18	16±0	16-17	16±0	16-17	16±1	16-17

TL Total length
SL Standard length
FL Fork length
ED Eye diameter
BD Body depth
CPD Caudal peduncle depth
DFB Dorsal fin base

The meristic characters were:
TGR Total number of gill rakers
NV Total number of vertebrae
PSLL Number of pored scales on lateral line
DFR Number of dorsal fin rays
PFR Number of pectoral fin rays

Table 1 – Mean and standard deviation and range (minimum–maximum) of the morphological characters of seven locations for Photopectoralis bindus. Locations: Al-Hammar Marsh, North of Shatt al-Arab River, Shatt al-Arab River, Estuary of Shatt al-Arab River at Fao City, Khor al-Zubair area, Umm Qasar area and Khor al-Umia area

Ambient	Predicted Group Membership			Total
	Freshwater	Estuarine	Marine	
Freshwater	88.3	0	11.7	100.0
Estuarine	0	100.0	0	100.0
Marine	27.6	0	72.4	100.0

82.5% of cross-validated grouped cases correctly classified

Table 2 – Classification results (%) for total cross-validated predicted specimen's membership using the morphological characters of fish from the different ambient. Discriminant analysis used filter data

Fish shape data accounted by the filtered morphometric measurements since length was widely different (P<0.01) showed significant differences for the seven locations (Wilks' lambda = 0.001; P<0.001). The cross-validated discriminant analysis using filtered variables from all 1446 specimens correctly classified 99.9% by locations. All classification between locations was of 100% with exception of Umm Qasar area (UQA) that varied with 99.5%. Seven locations were defined in the plot of the first two discriminant functions; the more separated populations were SHRE and KHZ from the rest (Figure 5).

Fish shape data (also accounted by the filtered morphometric measurements) showed significant differences for the three ambient (Wilks' lambda = 0.112; P<0.001). The cross-validated discriminant analysis using filtered variables from all 1446 specimens correctly classified 82.5% by ambient. Only the specimens from the Estuarine ambient were classified with 100%, while the misclassification occurred between freshwater and marine zones (Table 2).

The consensus dendrogram of mean shape (Figure 6a) showed the distinctions among three clusters: NSHR, MSHR and AHM, the freshwater ambient form one group joined with the marine samples (UQA, KHM and KHZ) and SHRE is separated from the rest of the locations. The consensus dendrogram of mean meristic characteristics (Figure 6b) showed the distinctions between two clusters: the marine samples (UQA, KHM and KHZ) with the estuarine location (SHRE) and the freshwater ambient (NSHR, MSHR and AHM) form the other group.

Discussion

Fishes normally display an elevated degree of dissimilarity within and among the population than other vertebrate and besides, the local habitats are affect the morphological variation (Wimberger, 1992). A high degree of isolation may as a consequence to produce a remarkable differentiation in the phenotypic and genetic within a population, as a source for separation and management of distinct population (Turan, 2004; Sen *et al*., 2011). This departure happens through reproduction between stocks and hindrance of migration between areas. Inability to know or record the stock complexity leads to failure of spawning components results damage of genetic diversity. The presence of physical obstacles among fish populations is not always clear (Joyeux *et al*., 2001). Nevertheless, geographic subdivisions allow the formation of population's traits signifying appropriate models for biogeographic, ecological and genetic studies. In such cases, biometric analyses can produce valuable information about the phenotypic plasticity of the species and any possible effects of genetic changes on their morphological variation (Hauser *et al*., 1995).

There are no previous studies on the biology, dynamics or stock structure of the orangefin ponyfish *P. bindus* in the Iraqi waters. Samples from seven locations from the fresh, estuarine and marine waters of Iraq showed that the fishery of this species in the Iraqi waters are supported by three main populations inhabiting freshwater, estuarine and marine areas (Figure 3).

Morphometric analysis can be a powerful means for stock identification, although problems with understanding phenotypic characters. Waldman *et al*. (1997) concluded that the morphometric methods achieved best among phenotypic methods, and future mixed-stock analyses should be depend on morphometrics or mitochondrial DNA.

The maximum total length reported for the orangefin ponyfish *P. bindus* is 110 mm by James (1984). The results obtained in the present study showed that the total length range of this species has extended over the maximum total length reported. The smallest individuals of 71 mm were obtained from the marine waters localities, while the large specimens of total length ranges 136-146 mm were obtained from the freshwater habitats at Al-Hammar marsh area. With this finding, the size of 146 mm TL is considered the highest ever reported so far for this species. This large size could be related to the water

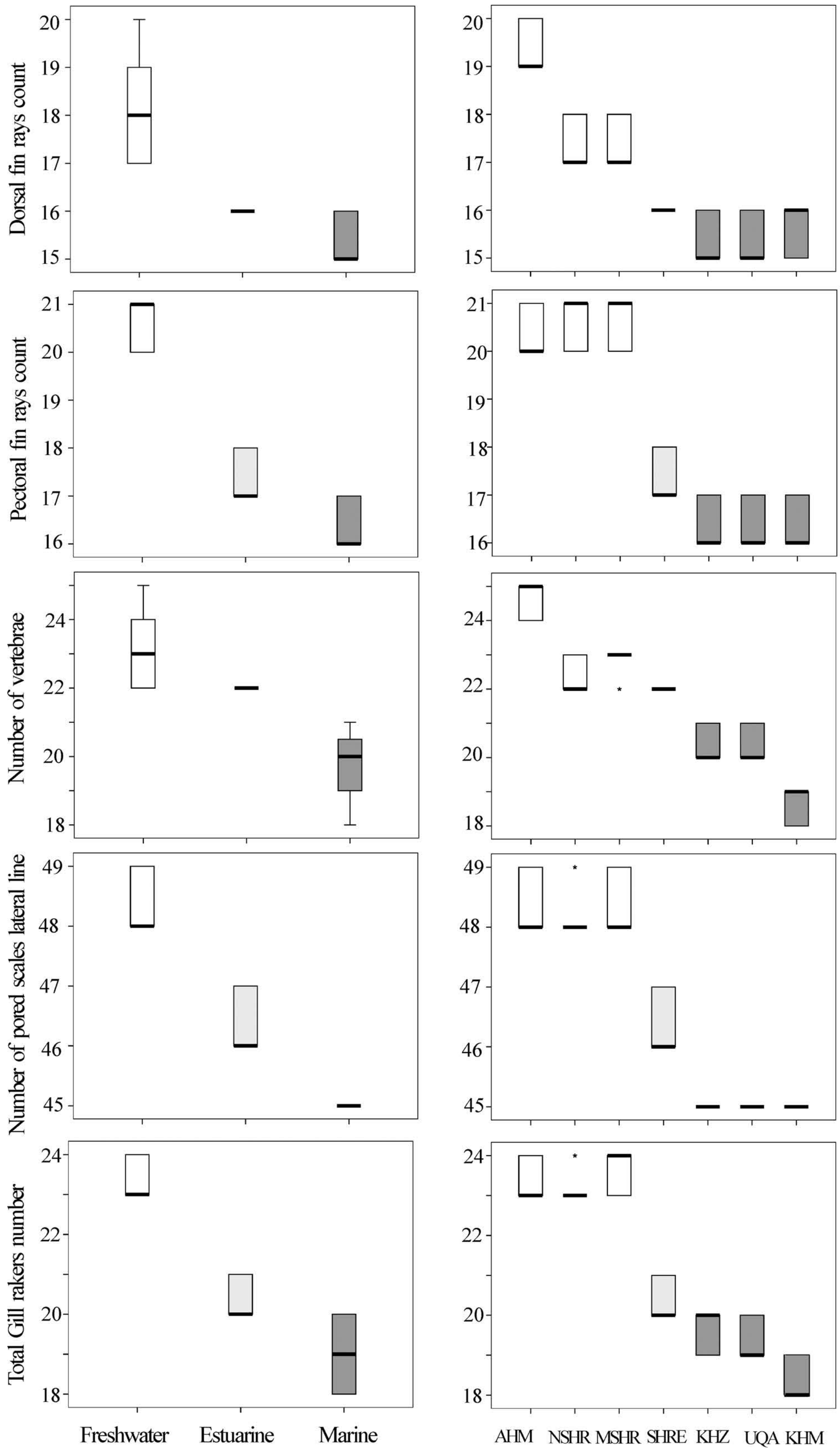

Fig. 3 – Boxplot depicting the meristic characters: Total number of gill rakers TGR, Total number of vertebrae NV, Number of pored scales on lateral line PSLL, Number of dorsal fin rays DFR and Number of pectoral fin rays PFR for the three ambient (Freshwater, Estuarine and Marine) and from the seven locations: Al-Hammar Marsh (AHM), North of Shatt al-Arab River (NSHR) and the middle part of Shatt al-Arab River (MSHR); Estuary of Shatt al-Arab River at Fao City (SHRE); Khor al-Zubair area (KHZ), Umm Qasar area (UQA) and Khor al-Umia area (KHM)

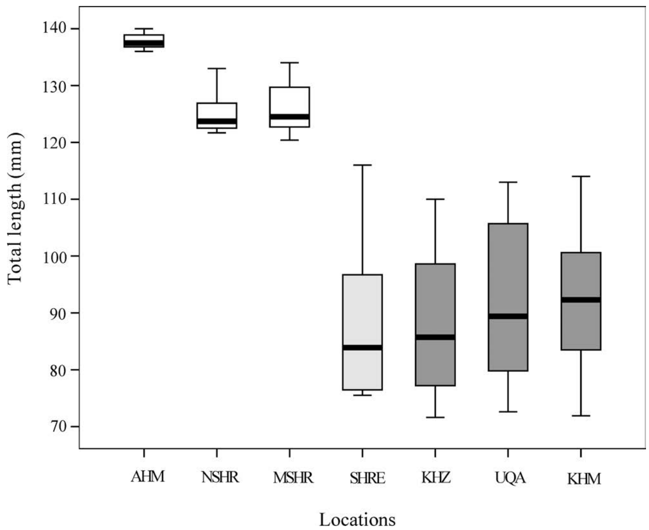

Fig. 4 – Boxplot depicting Total length (TL) from the seven locations: Al-Hammar Marsh (AHM), North of Shatt al-Arab River (NSHR) and the middle part of Shatt al-Arab River (MSHR); Estuary of Shatt al-Arab River at Fao City (SHRE); Khor al-Zubair area (KHZ), Umm Qasar area (UQA) and Khor al-Umia area (KHM)

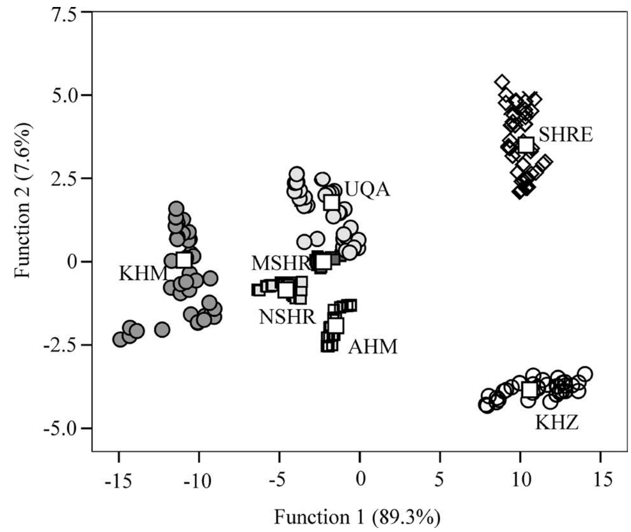

Fig. 5 – Scatter plot of the discriminant functions scores from the morphometric analysis of locations. The proportion of total variance explained by the first and second canonical discriminant functions is shown

temperature in the marsh area. During late spring and early summer (March-June), water temperature drops to around 25°C (Taher, 2007). This drop in water temperature could have effect on the development of the fish individuals so the growth rate will be slower than anywhere else in the adjacent Iraqi waters, so large size is reached. Such a correlation between fish growth and water temperature at development has been described by Tåning (1952).

The morphometric study of *P. bindus* obviously described the variation of fishes from the seven localities studied in the present, though in small magnitude, but completely enough to be considered as subpopulations which can be considered as separate management units. There is an obvious morphological dissimilarity between specific characters in the populations studied. It is often interesting to elucidate the causes of morphological variations between populations (Cadrin, 2000). These deviations may be genetically related differences or they might be related with phenotypic plasticity in reaction to different environmental factors in each area (Murta, 2000). Thus, morphological variation can obvious genetic differences between stock and/or environmental changes between localities.

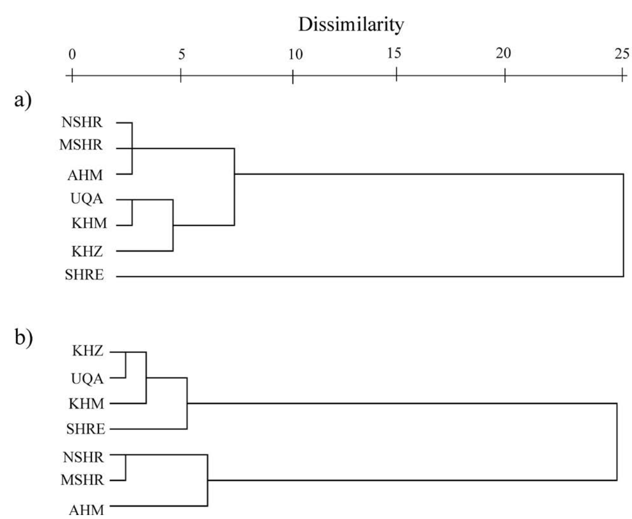

Fig. 6 – Cluster analysis performed on the matrix of morphometric (a) and meristic (b) characters using Ward's method for the seven locations. Al-Hammar Marsh (AHM), North of Shatt al-Arab River (NSHR) and the middle part of Shatt al-Arab River (MSHR); Estuary of Shatt al-Arab River at Fao City (SHRE); Khor al-Zubair area (KHZ), Umm Qasar area (UQA) and Khor al-Umia area (KHM)

Significant differences between the seven populations were found using 7 and 5 morphometric and meristic characters respectively. Morphological and genetic methods have been used to characterize different populations of fishes (Agnese *et al*., 1997). Consequently, the probability occurs that the noticed morphological disparities in the present study might be have a genetic bases. In the present study, the genetic basis of morphometric differences is not explored. However, the use of molecular markers would be a very beneficial method (Agnese *et al*., 1997; Delling *et al*., 2000; Poulet *et al*., 2004) for supporting the apparent phenotypic fluctuations among different localities and for enabling the development of management strategies and future exploitation of this species.

Water temperature can cause inconsistency in the morphometric traits (Georgakopoulou *et al*., 2007; Sfakianakis *et al*., 2011), which may interrupt fish metabolism through differences in dissolved oxygen (Wimberger, 1992). The results achieved in the present study have shown that individuals of the population of *P. bindus* at the freshwater water localities (Al-Hammar Marsh, north and middle parts of Shatt al-Arab River localities) have larger eye diameter, deeper caudal peduncle area and body, and larger dorsal fin base than the individuals of the populations at the estuarine and marine environments studied. In the latter area, water temperature at Shatt al-Arab estuary and the coastal water areas in the southern part of Iraq is higher than those of Al-Hammar Marsh, north and middle parts of Shatt al-Arab River localities. In the marine waters of Iraq (Khor al-Zubair, Umm Qasar, Khor al-Ummia areas), water temperature reaches 37°C, which is far more higher than that found in freshwater localities further north (Al-Hassan and Muhsin 1986). Related effects were attained by Atkinson (1994), Haddon and Willis (1995), Emmrich *et al*. (2014) and Pazhayamadom *et al*. (2017). Water viscosity and density will increase with low water temperature increases and, consequently, disparities of body shape will be valuable to reducing drag (Wimberger, 1992). Thus, physicochemical features of aquatic ecosystems alter with water temperature and, hence, fish will react with new differences in body shape (Sfakianakis *et al*., 2011).

The eye diameter is greater for specimens collected from the marsh and the north and middle parts of Shatt al-Arab River areas and this is possible due to the effect of light intensity at the relevant environments because fishes may decrease or bestow more resources to eye if they grow in environments with low visibility (Pankhurst, 1987; 1989; Kotrschal *et al*., 1998; Remington, 2008). Studies show that the turbidity of the Shatt al-Arab estuary, Khor al-Zubair and the marine water areas (9.4 m Secchi Disc depth) is relatively higher when compared to the other three freshwater localities (Al-Yamani, 2008; Al-Imarah *et al*., 2010). The small eye size of the individuals of *P. bindus* from marine habitats studied is probably due to the reduction in light intensity and therefore hindering the vision of fish individuals. Studies show that the allometry of eye diameter (positive or negative) generally rest on the behaviour and biology of the fish in the new environment (Remington, 2008; Dugas and Franssen, 2012). For example, the eyes may decrease or degenerate if they are no more useful for survival of the population (Jeffery, 2005). Width of the transmission spectrum explains the largest part of the eye length in the three freshwater areas. When the transmission spectrum is broader (i.e. in clear water) the eyes are larger and the dorsal oral length (snout length) is shorter. This may be inferred as an architectonic interaction: eye size is influenced by the width of the transmission spectrum and eyes get larger at the expense of dorsal oral length (Bouton *et al*., 2002). Thus, the cause of the growth in the eye diameter requires more insight into the behaviour of *P. bindus*, how they acclimatize in a turbid environment of the marine waters an mainly in the Shatt al-Arab estuary and Khor al-Zubair are for growth, feeding and reproductive purposes so their life cycle can be completed.

The individuals of the marsh and Shatt al-Arab River populations of *P. bindus* are characterized by a deeper body and caudal peduncle area which is more functioning through flow swimming (Webb, 1984) and may be linked with higher swimming efforts but also with a higher ability to gather energy reserves (Boily and Magnan 2002). Hence, their deep body appears to be more suitable for a resident life model and should also assume sustained competition and more aggressive behavior (Holtby *et al*., 1993). The Marsh and Shatt al-Arab River areas have a distinct eco-hydrological features dissimilar from that of the estuarine and coastal area due to their nearly continuous discharge throughout the year. Possibly due to this fact, the marsh and the river can endure a very rich and plentiful invertebrate community. Such a constant environment with heavily distributed and rich food sources must certainly necessitate the resident life model with strong territorial behavior and can elucidate the morphological outline of the populations of both the marsh and Shatt al-Arab River areas.

Populations of *P. bindus* inhabiting the three freshwater localities, Al-Hammar Marsh, north and middle parts of Shatt al-Arab River, are characterised from the remaining populations studied in having large dorsal fin base. Such variations can be explained in conjunction with the current velocity (Beacham *et al.*, 1989; Brinsmead and Fox 2002). Beachman *et al.* (1989) showed that Chinook salmon *Oncorhynchus tshawytscha* populations living in slow running rivers having smaller dorsal fin base in comparison with those inhabiting fast flowing areas. Also, Brinsmead and Fox (2002 have confirmed that fish individuals living in flowing water will have larger dorsal fin area. This verification comes to support the results of Webb (1984) that suggest that the fishes adapted to prolonged steady swimming should have a larger fin area relative to body size. Larger fins should displace a larger volume of water and could diminish energy outlays from additional fin beats. Moreover, larger fins may be used by stream fishes in conjunction with steady swimming, a propulsive mechanism observed for stream fishes in the field (McLaughlin and Noakes, 1998). The hydrological status of Al-Hammar Marsh and the two localities in Shatt al-Arab River (North and Middle parts) showed that fast currents are present in these area (Abdullah *et al.*, 2015; Isaev and Mikhailova, 2009; Abdullah, 2013), which in turn influence the development of the dorsal fin of the individuals of *P. bindus*.

Meristic counts are often controlled during a moderately short length of time during early development and the features that are last to appear during ontogeny are the most labile (Barlow, 1961). According to Tåning (1952), the represented cline appears to be linked to temperature since there is a worthy association between cooler environmental temperatures and higher meristic numbers. Seemingly the number of meristic components is established by developmental rate, with larger developmental periods frequently making higher counts in meristic structures (Barlow, 1961). This therefore is the means of action of lower temperatures since developmental rate differs directly with temperature (Tåning 1952). Since during reproduction and early development of *P. bindus* (late spring and early summer) the water temperature reaches much higher values in estuarine and coastal water environments than in the freshwater areas (Yaseen *et al.*, 2016).

The notable variation in meristic characters obtained between the populations studied might represent reproductive isolation among the freshwater, estuarine and coastal populations of *P. bindus* examined. Statistical analysis showed that the freshwater localities, Al-Hammar Mars, north and middle parts of Shatt al-Arab River populations are marked in having the highest meristic counts for all five characters examined. There is a decreasing trend in the values of the five meristic characters examined from north to south (marsh area to the coastal area). This trend coincides with the increasing in water temperature and salinity from north to the south (Hameed *et al.*, 2013; Moyel, 2014; Abdullah *et al.*, 2016).

Dissimilarities in the mean number of gill rakers may be related to the food and feeding habits of fish (Quilang *et al.*, 2007). Fewer rakers are noted in fish that lives in the estuarine and coastal waters and higher counts are represented in individuals from the marsh and Shatt al-Arab River areas. In the freshwater, estuarine and coastal habitats studied, the feeding habit of the individuals of *P. bindus* living in is differ according to the food contents. Results of previous studies have shown that fish species feed on large food particles frequently need small numbers of gill rakers, while those feed on small food items require large gill rakers (Amundsen *et al.*, 2004; Kahilainen *et al.*, 2011). Individuals of The orangefin ponyfish *Photopectoralis bindus* are zooplankton and carnivorous (Qasim, 1972; Abdurahiman *et al.*, 2010). The populations of the coastal water are usually feed on larger sized food items such as crustacean zooplankton and small fish larvae, thus they have less number of gill rakers (Mohamed and Hussain, 1993). On the other hand, those individuals inhabiting the marsh and Shatt al-Arab River areas feed on smaller items such small aquatic insects and larvae of other aquatic invertebrates (Hussain and Ali, 2006), therefore, they larger number of gill rakers.

This study of the morphometrics and meristic of the species shows that the *P. bindus* populations in the lower reaches of Mesopotamia and its coastal area are distinct from each other. The dendrogram based on the morphometric characters (Figure 6a) showed three main clades, freshwater habitat, which includes populations from Al-Hammar Marsh, north and middle part of Shatt al-Arab River, estuarine environment contains Shatt al Arab estuary at Fao City, and the coastal territories, which comprise Khor al-Zubair, Umm Qasar and Khor al-Ummia areas. The two habitats, freshwater and marine environments are sister groups, while estuarine population clades separately from the two groups. This indicates how distinct is the environment of Shatt al-Arab estuary from the freshwater and marine habitats studied. Such differences can be in the biological activities more than the environmental factors that lead to disparity in morphometric characters.

Estuarine and coastal regions are exceptionally productive since they obtain inputs from several primary production sources and detrital food webs (Roessig *et al.*, 2004). Nevertheless, these structures present the biota with a severe environment, driving organisms to evolve physiological or behavioral alterations to survive with wide ranging physical and chemical variables (Horn *et al.*, 1999). Due to water circulation and marine changes, estuarine system are expected to suffer a loss of marsh and intertidal habitat, a greater marine intrusion or freshwater plumes, and increased eutrophication, hypoxia, and anoxia (Officer *et al.*, 1984; Kennedy, 1990; Ray *et al.*, 1992; Schwartz, 1998). The chief physical drivers in terms of the biological or ichthyological functioning of estuaries can be found under geographical and hydrographical classes (Whitfield and Elliott, 2002). These factors generate the circumstances accessible to the fishes but, subject on their environmental and physiological acceptances, this group of organisms becomes influenced by other biological factors such as predator-prey interactions and inter- and intra-specific competition (Elliott and Hemingway, 2002).

In the clade of freshwater-marine habitats (Figure 6a), the three freshwater localities were clade together. This indicates the similarity in the effect of both the biological and environmental factors on individuals of the three freshwater population of *P. bindus* studied. On the other hand, the marine habitat clade showed that Khor al-Zubair population found in separate branch, which indicate clearly the nature of this area as a shallow, arid and muddy bottom area that completely different from that of the deep areas of Umm Qasar and Khor al-Ummia.

The cladogram (Figure 6b) is based on analysis of meristic characters. Here, the seven localities were grouped into two main clades, freshwater and estuarine-marine habitats. In this cladogram, the distribution of the seven populations of *P. bindus* in the clades is probably affected by water temperature and other environmental factors rather than biological activities of the fish. The freshwater habitat clade clearly showed the distinction of the population of *P. bindus* that inhabits Al-Hammar Marsh from those populations of north and middle parts of the Shatt al-Arab River. Hydrological variables of the marsh areas in general are different from those of rivers (Jones *et al.*, 2008), which in turn can induce physiological changes that lead to morphological variations. For the marine environment clade, here the estuarine population of *P. bindus* nested within the clade of the marine habitat populations. This signifies the similarities in water temperatures and other environmental factors and the same time indicates the marine environment effect on the estuary of Shatt al-Arab River more than the freshwater nature.

The cross-validated discriminant analysis (Figure 5) showed grouping of the seven populations of *P. bindus* different from that shown by the cladogram (Figure 6). Here, four groups are present, i.e., Khor al-Ummia, freshwater habitats-Umm Qasar, Khor al-Zubair and the estuarine locality. In this analysis, the freshwater localities remain grouped together, but the marine habitats has shown the departure of its three elements and form a separate entities. Clearly, such distribution of the seven populations of *P. bindus* examined is not based on the similarities in the environmental factors as there is no way for purely marine population of *P. bindus* inhabiting Umm Qasar can experience the same environmental factors present in both the marsh and Shatt al-Arab Areas. On the other hand, the clear separation of the marine habitats studied could well be due to the different in the biological factors such as predator-prey interactions and inter- and intra-specific competition (Elliott and Hemingway 2002) that can have greater pressure on the physiology and morphology of the individuals than the environmental factors.

To summarise the results obtained by the discriminant analysis (Figure 5) and the cladogram (Figure 6), the meristic characters have clearly separate the seven populations of *P. bindus* into two distinct self-contained stocks. Such separation could be based on the environmental factors such as water temperature and salinity rather than the biological activities. On contrary, the morphometric characters although they were shown to be different in individuals of the seven populations, they fail to separate the marine localities into one entity as shown in Figure 3. Based on the result of differences in body morphometrics occur between *P. bindus* caught in the Iraqi waters, the biological significance of these distinctions, and their possible implications for management of the orange roughy fishery, are not immediately clear. Such differences suggest that in some way the fish in the two areas are members of two different communities or entities (Figure 3). Whether this means that the fish in the two areas should be managed as separate stocks rests questionable. On the other hand, the detected high meristic differentiation may indicate reproductive isolation the marine-estuarine and the freshwater populations of *P. bindus*, which would verify the genetic basis of observed differentiation between the samples.

As meristic traits are especially dependent on environmental conditions during early life-history stages (Ryman *et al.*, 1984; Lindsey, 1988; Cheverud, 1988), phenotypic differentiation may indicate that the majority of fish spend their entire lives in separate regions. Such conclusions are vital for fisheries management since absence of visible genetic heterogeneity does not necessarily prevent the existence of populations that are effectively self-recruiting and demographically distinct (Carvalho and Hauser, 1994; Hauser and Ward, 1998).

Further studies are required to show if the growth and mortality rates of two populations of *P. bindus* (marine and freshwater) are sufficiently different, then it would be practical to manage them separately, as the optimal collecting policy may be different for each population. Nevertheless, if these rates cannot be resolute easily, then other ways of determining stock separation are mandatory. The idea of a "stock" of fish has gathered many different uses, but Smith *et al.* (1990) carefully condensed these uses to two categories. The first could be termed the "pragmatic" use, whereby a fish stock is taken to be the group of fish which is subjugated in a particular geographical area or by a particular fishing method. The second use could be termed the "biological" or "population" use, whereby fish stocks are identified as natural breeding units that are mostly reproductively isolated from other similar intraspecific populations. As the first category of use is only a way of identifying or labelling a particular fishery, it implies no more information than is contained in the name. The main point about biological fish stocks is that they create a population which is primarily accountable for any recruitment to itself, and this is why they are genetically homogeneous and also what leads to their continuity through time. This view lends to the idea of biological fish stocks a degree of isolation and therefore taxonomic identity, at least at the level of geographical diversity. Such future investigations will improve the administration of the fish stocks and their assessment especially if the aspects driving the stock separation are known and fully assumed.

Acknowledgements

The authors are grateful to the assistant and help of the late Mustafa Al-Mukhtar of the Department of Fisheries and Marine Resources, College of Agriculture, University of Basrah, Basrah, Iraq for his valuable assistant and help during the fish sample collection.

Funding
No fund was received to perform this study.

Conflict of interest
Authors of this study declare no conflict of interest.

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