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RESEARCH ARTICLE

Meristic character variability among populations of *Silurus triostegus* Heckel, 1843 from the Euphrates, Tigris, and Shatt al-Arab Rivers, Iraq

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Abstract. Variation in the numbers of pectoral fin spines and rays, pelvic fin rays, gill rakers on the first gill arch, anal fin rays, and the number of vertebrae of *Silurus triostegus* Heckel were examined in specimens from 16 localities that span its entire distribution range in the Tigris, Euphrates, and Shatt al-Arab rivers in Iraq. The mean number of the six meristic traits increases toward high latitudes with maximum and minimum values in the north and south of Iraq. Based on cluster analysis and PCA, the Mesopotamian river samples were clearly separated into three distinct groups. The upper Tigris populations were isolated from those of the middle and southern populations of this river and from those of the Euphrates River. Possible reasons for such differentiation among populations are discussed, and the integration of research on this species among the countries neighboring Iraq is required.

Keywords: Siluridae, Mesopotamia, population, morphology

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Introduction

A fish population or stock is considered among the fundamental concepts in fisheries management (Begg and Waldman 1999). It is defined as a group of fish that is quite large, it is essentially self-reproducing, and it shares similar life history traits (Hilborn and Walters 1992). In fisheries, the effective management of fish stocks begins when the stock or population structure of a species is fully understood, as are the distribution of fishing effort and mortality (Grimes et al. 1987). The understanding of stock structure is fundamental to planning suitable management guidelines in fisheries (Ricker 1981).

Meristic characters and morphological structures are countable (e.g., fin rays, gill rakers, scales in rows, vertebrae), and have historically been a vital way of identifying fish stocks. Count data are discrete, thus enabling statistical analysis. Both genetic and environmental factors control meristic characters in fishes in unknown proportions (Barlow 1961, Swain and Foote 1999, Liasko et al. 2012). These characters are set early in ontogeny and remain stable throughout the life of the fish, which means that they reflect environmental effects over the relatively short time of larval development. because of these criteria, significant statistical differences can occur within a stock among year classes or geographic subgroups subjected to varying environmental conditions (Silva 2003). However, consistent environmental influences have the potential to provide stock discrimination where there is weak genetic divergence among actual stocks (Begg and Waldman 1999, Ünlü et al. 2012, Coad, 2014).

S. triostegus was described by Heckel in 1843 in the Tigris River at the city of Mosul, 352 km north of the capital Baghdad (Coad 2014). Usually, there are four mandibular barbels, but Haig (1952) and Al-Daham and Al-Seyab (2001) suggest that this species has six pairs of barbels when young and that one pair is reabsorbed later in development. The maxillary barbels are longer than the head. There is a strongly serrated pectoral fin spine with serration directed toward the inner surface. There are two patches of vomerine teeth. The lower jaw is longer than the upper with recurved teeth in both jaws. This species differs from *Silurus glanis* L. in that it has longer, robust teeth, lower jaw teeth that are exposed when the mouth is closed, a coarsely serrated pectoral fin spine, a lighter color, and maxillary barbels that are equal to head length, while in *S. glanis* they are much longer and the eye is larger. The body is speckled a pale yellow-brown and black on the upper part with a white abdomen spotted with black.

The distribution of *S. triostegus* is confined to Iraq, Iran, Turkey, and Syria within the Tigris-Euphrates basin (Najafpour 1997, Abdoli 2000, Esmaeili et al. 2010). In Iraq, it prefers open vegetated lakes, marshes, and rivers (van den Eelaart 1954) and it is abundant in the southern marshes of Iraq (Hussain and Ali 2006). Recent environmental changes in the marsh areas of southern Iraq have caused an increase in the biomass of this predatory fish as a consequence of decreases in the number of otters and aquatic birds (Hussain et al. 2008). In other parts of Iraq, several factors such as dam construction that has altered the hydrological regime, increased salinity, and pollution could have contributed to changes in the distribution and the status of populations of *S. triostegus* (Hashemi et al. 2012).

In Basrah, Iraq, this species can reach 7 years of age (Al-Abood 1989, Al-Hassan and Al-Sayab 1994), while in Atatürk Dam Lake, Turkey, it can reach up to 11 years (Oymak et al. 2001). Males and females reach maturity at age 3 at 326 mm total length and 4 years at 332 mm total length (Coad 2014). Spawning takes place in March-May in Iraq (van den Eelaart 1954, Al-Hassan et al. 1990, Al-Daham and Al-Seyab 2001) and in May-June in Turkey (Oymak et al. 2001) with eggs of up to 4.2 mm in diameter deposited on unguarded vegetation (Al-Rudainy 2008). Dawn is the best time for this species to spawn; the male, and sometimes two males, dash toward the female, chasing her, and rotating around her so their bodies came into contact and then a strong jerk is produced from the female. Later, the males and females move to deeper water (Coad 2014).

This species feeds mainly during the night with short peak in the late afternoon (Al-Daham and Al-Seyab 2001). The main food items for this species are fishes including *Liza abu* (Heckel), *Acanthobrama marmid* Heckel, *Leuciscus vorax* (Heckel), and *Mesopotamichthys sharpeyi* (Günther) (Al-Shamma'a and Jasim 1993, Ünlü and Bozkurt 1996, Dawood 1997, Coad 2014); while occasionally it eats aquatic insects, frogs, shrimps, and crabs. Detritus and aquatic plants were also found in the gut contents (Al-Daham and Al-Seyab 2001).

Economically, this species is an important commodity and represents 8.5% of total fisheries production in Iraq (Das et al. 1978), but it is not a popular food. It is not eaten by the major Shi'a Muslim sector in Iraq because of the absence of scales on its body. Therefore, large quantities are exported to neighboring countries (Andersskog 1970). The meat of *S. triostegus* is an excellent source of protein (Jasim et al. 1988, 2006, Al-Badri et al. 1993, Al-Habbib et al. 1993, Mahdi et al. 2005), and it is a desirable human food item (Cengiz et al. 2012).

There is currently no knowledge about the *S. triostegus* stock structure in Iraq. This study aims to investigate the morphologic population structure of *S. triostegus* taken from 16 different areas along the Euphrates and Tigris rivers in Iraq based on meristic characters, and to determine whether these constitute one demographic unit or independent management groups.

Material and methods

The Tigris is one of the two longest rivers in Mesopotamia at 1,850 km. Its source is in the Taurus Mountains in eastern Turkey. After flowing through Turkish territory, the river enters Iraqi lands from the north. Several tributaries join this river in the north, middle, and south of Iraq (Isaev and Mikhailova 2009). The Shatt al-Arab River originates at the city of Qurnah, north of Basrah at the confluence of the Tigris and Euphrates rivers. It is 200 km long. It varies in width from 230 meters at Basrah to 800 meters at its mouth in the Persian Gulf (Country-data.com, 2015). The sixteen localities selected for this study cover the distribution of this species in the northern, mid, southern, and western regions of Iraq (Fig. 1, Table 1). Fish samples were obtained from fishers operating in the areas. Gillnets (200 m × 1.30 m, 25, 40 and 50 mm mesh) and cast nets (6 m diameter, 20 mm mesh) were used by the fishers. Fish samples were collected from August 2003 to January 2004. The depth at which the samples were caught ranged from 0.5 to 2.4 m. The sample size and mean lengths (± standard deviation) of the specimens collected at the 16 locations are presented in Table 1. Specimens (2,981 individuals) were examined shortly after landing while still fresh. A total of six meristic characters (the number of pectoral fin spines, the number of pectoral fin rays, the number of pelvic fin rays, the number of gill rankers on the first gill arch, the number of anal fin rays, and the number of vertebrae) were used for the present study (Table 2) following the widely accepted method by Hubbs and Lagler (1958). All counts were taken from the left side of the fish. The gill rakers of the first gill arch were counted under a dissecting microscope after the anterior gill arch had been removed from the fish. Meristic characters are fixed early in ontogeny and remain stable throughout life (Barlow 1961), so no size correlation was applied. Sex was determined macroscopically and age was determined by reading the growth rings on vertebrae. Sex was determined macroscopically and sexual variation was analyzed first using one-way ANOVA tests.

Hierarchical cluster analysis and Principal Component Analysis (PCA) were used with the aim of identifying internally homogenous groups according to the specific set of variables collected during the field work activities at the 16 sampling sites. Hierarchical cluster analysis allows identifying groups of sites on the basis of similarity (Sneath and Sokal 1973). In order to accomplish this

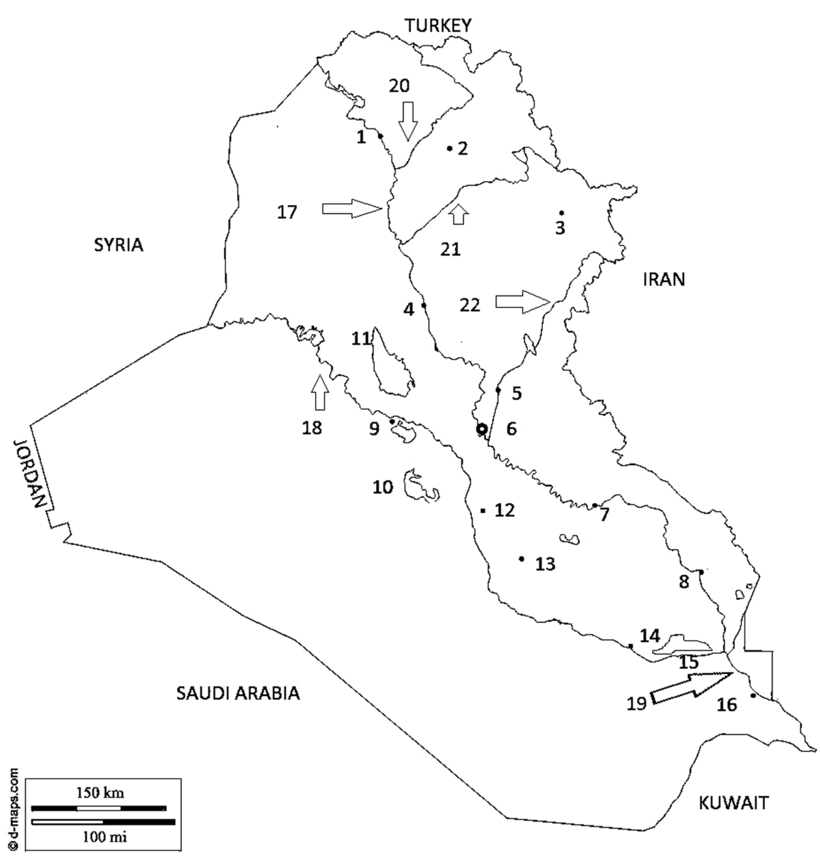

Figure 1. Map showing capture points of *S. triostegus* in the Tigris, Euphrates, and Shatt al-Arab Rivers, Iraq. 1 – Mosul; 2 – Arbil; 3 – Sulaimania; 4 – Tikrit; 5 – Diyala; 6 – Baghdad; 7 – Wasit; 8 – Maisan; 9 – Al-Anbar; 10 – Al- Razaza Lake; 11 – Al-Tharthar Lake; 12 – Babil; 13 – Al-Muthana; 14 – Thiqar; 15 – Al-Hammar Marsh; 16 – Basrah; 17 – Tigris River; 18 – Euphrates River; 19 – Shatt al-Arab River; 20 – Upper Zab River; 21 – Lowe Zab River; 22 – Diyala River.

Table 1
Sampling locations with coordinates, sample size, and range and mean total length of fish. SD – standard deviation

Locality	Sample size	Total length (mm) range	Mean total length (mm) ± SD	Cordinate	Rivers
Tigris River Basin					
Mosul	181	200 - 500	357.3 ± 3.6	36.34°N 43.13°E	Tigris
Arbil	193	210 - 496	359.2 ± 3.3	36°11'28''N 44°0'33''E	Great Zab
Sulaimania	178	210 - 495	350.0 ± 2.9	35°31'N 45°19'E	Little Zab
Tikrit	178	195 - 490	345.2 ± 1.9	34°36'36''N 43°40'48''E	Tigris
Diyala	188	195 - 485	348.4 ± 1.4	33°53'N 45°4'E	Diyala
Baghdad	218	195 - 480	335.5 ± 2.3	33°20'N 44°26'E	Tigris
Wasit	218	189 - 478	332.5 ± 1.1	32°14'N 14°N 46°18'E	Tigris
Mysan	218	185 - 475	331.4 ± 2.0	31°54'N 47°2'E	Majar Al-Kabir
Euphrates River Basin					
Al-Anbar	168	195 - 472	333.6 ± 1.3	32°54'N 41°36'E	Euphrates
Al- Razaza Lake	148	194 - 471	331.4 ± 1.1	32°45'N 43°38'E	Euphrates
Al- Tharthar Lake	148	193 - 470	330.5 ± 1.3	33°58'N 43°11'E	Euphrates
Babil	168	192 - 469	329.7 ± 1.2	32°37'N 44°33'E	Euphrates
Al-Muthana	128	190 - 465	328.6 ± 1.0	31°19'N 45°17'E	Euphrates
Thiqar	223	185 - 460	323.5 ± 1.5	31°03'N 46°16'E	Euphrates
Al-Hammar Marsh	258	185 - 455	321.4 ± 1.3	30°50'40''N 46°53'20''E	Euphrates
Shatt al-Arab River locality					
Basrah	178	180 - 450	316.4 ± 1.4	30°30'N 47°49'E	Shatt al-Arab

objective, a dissimilarity matrix using Euclidean distance was calculated (Clifford and Stephenson 1975). The analyses were performed using R3.1.2 (R Core Team 2015). In particular, the package *cluster* (available in R) was used to perform the hierarchical cluster analysis.

Results

Univariate statistics (ANOVA) revealed no statistical differences between males and females with regard to meristic variables (P>0.05), so the sexes were pooled for further analysis. The range and means of the meristic counts of the *S. triostegus* populations are presented in Table 2. All six of the meristic traits studied showed variability among populations of *S. triostegus*. The number of spines in the pectoral fin ranged from two to four, and the number of rays ranged from 10 to 14. The pelvic fin ray count ranged from seven to 13. The number of gill rakers on the upper limb of the first gill arch ranged from 11 to 17. The anal fin ray count ranged from 76 to 90. The number of vertebrae ranged from 67 to 70.

The dissimilarity matrix computed using Euclidean distance for the morphometric parameters of the 2,981 specimens collected at the 16 sampling sites is presented in Table 3.

The dendrogram obtained through hierarchical cluster analysis carried out on the dissimilarity matrix with Euclidean distance is shown in Figure 2. Three separate groups or clusters can be observed on the dendrogram. Group I includes sites located in the northern and northeastern parts of the Tigris River

Table 2
Mean, range, and standard deviation (SD) of meristic characters of populations of *S. triostegus* from the Euphrates, Tigris, and Shatt al-Arab rivers, Iraq

	Pectoral fin spine count		Pectoral fin ray count		Pelvic fin ray count		Gill raker count on 1st gill arch		Anal fin ray count		Number of vertebrae	
Localities	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD
Mosul	3-4	3.0 ± 0.4	13-14	13.9 ± 0.1	12-13	12.7 ± 0.2	16-17	16.9 ± 0.3	89-90	89.9 ± 0.4	69-70	69.9 ± 0.3
Erbil	3-4	3.0 ± 0.2	13-14	13.9 ± 0.3	12-13	12.8 ± 0.6	16-17	16.9 ± 3.1	93-94	93.7 ± 0.2	69-70	69.7 ± 0.2
Sulaimania	3-4	3.9 ± 0.5	13-14	13.5 ± 0.3	12-13	12.9 ± 0.4	16-17	16.8 ± 0.1	92-93	92.8 ± 0.1	69-70	69.9 ± 0.5
Tikrit	3-4	3.7 ± 0.4	12-13	12.9 ± 0.2	11-12	11.8 ± 0.5	15-16	15.9 ± 0.4	87-88	87.7 ± 0.5	69-70	69.8 ± 0.5
Diyala	3-4	3.8 ± 0.4	12-13	12.8 ± 0.2	11-12	11.9 ± 0.4	15-16	15.7 ± 0.6	86-87	86.8 ± 0.6	69-70	69.7 ± 0.3
Baghdad	3-4	3.6 ± 0.6	12-13	12.7 ± 0.6	10-11	10.5 ± 0.7	14-15	14.9 ± 0.7	84-85	84.9 ± 0.2	69-70	69.9 ± 0.1
Wasit	3-4	3.9 ± 0.6	12-13	12.9 ± 0.4	9-10	9.9 ± 0.7	14-15	14.6 ± 0.6	82-83	82.8 ± 0.1	69-70	69.7 ± 0.2
Mysan	3-4	3.7 ± 0.3	12-13	12.8 ± 0.3	9-10	9.6 ± 0.8	14-15	14.9 ± 0.5	79-80	79.9 ± 0.3	69-70	69.9 ± 0.4
Al-Anbar	2-3	2.9 ± 0.5	10-11	10.6 ± 0.1	8-9	8.9 ± 0.4	13-14	13.9 ± 0.3	76-77	76.9 ± 0.6	67-68	67.8 ± 0.2
Lake Razazah	2-3	2.8 ± 0.3	10-11	10.8 ± 0.3	8-9	8.8 ± 0.1	13-14	13.8 ± 0.1	76-77	76.7 ± 0.2	67-68	67.9 ± 0.1
Lake Tharthar	2-3	2.6 ± 0.7	10-11	10.9 ± 0.4	8-9	8.7 ± 0.1	13-14	13.9 ± 0.2	76-77	76.9 ± 0.2	67-68	67.7 ± 0.2
Babil	2-3	2.9 ± 0.7	11-12	11.8 ± 0.7	7-8	7.9 ± 0.5	12-13	12.1 ± 0.4	77-78	77.9 ± 0.1	67-68	67.9 ± 0.2
Al-Muthana	2-3	2.7 ± 0.5	11-12	11.7 ± 0.8	7-8	7.8 ± 0.5	11-12	11.9 ± 0.2	77-78	77.8 ± 0.8	67-68	67.8 ± 0.5
Thiqar	2-3	2.9 ± 0.3	11-12	11.9 ± 0.8	7-8	7.9 ± 0.2	11-12	11.5 ± 0.4	78-79	78.9 ± 0.7	67-68	67.9 ± 0.2
Al-Hammar Marsh	2-3	2.8 ± 0.2	11-12	11.6 ± 0.5	7-8	7.6 ± 0.2	11-12	11.4 ± 0.5	78-79	78.9 ± 0.1	67-68	67.7 ± 0.2
Basrah	2-3	2.5 ± 0.2	11-12	11.9 ± 0.5	7-8	7.9 ± 0.4	11-12	11.9 ± 0.1	78-79	78.7 ± 0.3	67-68	67.9 ± 0.4

Table 3
Dissimilarity matrix using Euclidean distance

	Al-Hammar	Arbil	Babel	Baghdad	Basrah	Diyala	Maisan	Mosul	Muthena	Ramadi	Razazah	Sulaimania	Tharthar	Thiqar	Tikrit
Al-Hammar	-														
Arbil	18.2	-													
Babel	1.5	18.9	-												
Baghdad	8.4	10.3	9.0	-											
Basrah	0.1	18.2	1.5	8.4	-										
Diyala	10.9	7.9	11.5	2.6	10.9	-									
Maisan	4.9	15.7	4.6	5.5	4.8	7.9	-								
Mosul	14.5	4.3	15.0	6.4	14.4	3.9	11.6	-							
Muthena	1.1	19.2	1.1	9.3	1.1	11.9	5.3	15.4	-						
Ramadi	3.4	19.6	2.2	9.6	3.4	11.9	4.8	15.6	2.9	-					
Razazah	3.4	19.6	2.2	9.6	3.4	12.0	4.9	15.6	2.9	0.0	-				
Sulaimania	17.3	1.5	18.0	9.2	17.2	6.8	14.6	3.4	18.3	18.6	18.6	-			
Tharthar	3.4	19.6	2.2	9.6	3.4	12.0	4.9	15.6	2.9	0.0	0.0	18.6	-		
Thiqar	0.0	18.2	1.5	8.4	0.1	10.9	4.9	14.5	1.1	3.4	3.4	17.3	3.4	-	
Tikrit	11.8	6.8	12.4	3.6	11.8	1.1	9.0	3.0	12.8	13.0	13.0	5.7	13.0	11.8	-
Wasit	6.4	12.6	6.8	2.4	6.4	4.9	3.2	8.6	7.3	7.4	7.4	11.5	7.5	6.4	5.9

Table 4
Summary of the PC axes and associated variance (in %) from PCA carried out on *S. triostegus* samples collected in 16 locations in Iraq

	PC Axes					
	1	2	3	4	5	6
Standard deviation	6.28	1.13	0.65	0.35	0.25	0.20
% of variance	95.3	3.1	1.0	0.4	0.1	0.1
Cumulative % of variance	95.3	98.4	99.4	99.8	99.9	100.0
Eigenvalue	39.4	1.28	0.43	0.12	0.06	0.04
Loadings						
Vertebrae	-0.14	-0.33	0.61			0.70
Pectoral fin spines		-0.21	0.47	-0.68	-0.17	-0.49
Pectoral fin rays	-0.14		0.53	0.69		-0.47
Pelvic fin rays	-0.29	-0.43	-0.21		0.80	-0.19
Gill rakers	-0.26	-0.71	-0.29	0.21	-0.55	
Anal fin rays	-0.89	0.39		-0.12	-0.12	

(Arbil, Sulaimania, Mosul, Diyala, and Tikrit); Group II is represented by sites located in the southern part of the Tigris River (Baghdad, Wasit, and Maisan). Group III includes sites located in the hydrographic basin of the Euphrates River: Ramadi, Razazah, Tharthar, Babel, Al-Muthna, Thiqar, Al-Hammar Marsh, and the Shatt al-Arab River: Basrah.

Principal Component Analysis (PCA) confirms the insights obtained through hierarchical cluster analysis. The summary of the PC axes and their importance is presented in Table 4. The first row of the table describes the standard deviation associated with each PC axis. The second row shows the proportion of the variance in the data explained by each component, while the third row describes the cumulative proportion of the explained variance. The first two PC axes account for almost 99% of the variance in the data set. Figure 3 shows the PCA distance biplot. Three separate groups are identified, as was demonstrated previously by hierarchical cluster analysis. The separation is mainly on the first PC axis (PC1), which is the one that explains most of the variance (95.9%).

Within the upper Tigris River cluster, the Arbil and Sulaimania populations cluster together, while the Tikrit and Diyala populations are also clustered, and the Mosul population is linked strictly to this cluster. The cluster that contains the populations of the lower Tigris River, the Euphrates River, and the Shatt al-Arab River have sub-groups such as that of the Baghdad-Wasit-Maisan, the Babil-Al-Muthana, and the Thiqar-Al-Hammar Marsh-Basrah populations. Lakes Al-Anbar-Tharthar and Razazah are attached as a sister group to the two sub-groups of the Babil-Al-Muthana and the Thiqar-Al-Hammar Marsh-Basrah subgroups. The cluster analysis results (Fig. 2) were supported by the results obtained from PCA (Fig. 3).

Discussion

In fish, meristic characters such as the fin ray count and the number of vertebrae are determined early during larval development. These characters are influenced by environmental factors, especially temperature (Tåning 1952). It has been shown that the lower the temperature is in early life stages, the larger the number of vertebrae (Templeman and Pitt 1961). Therefore, differences in meristic characters among

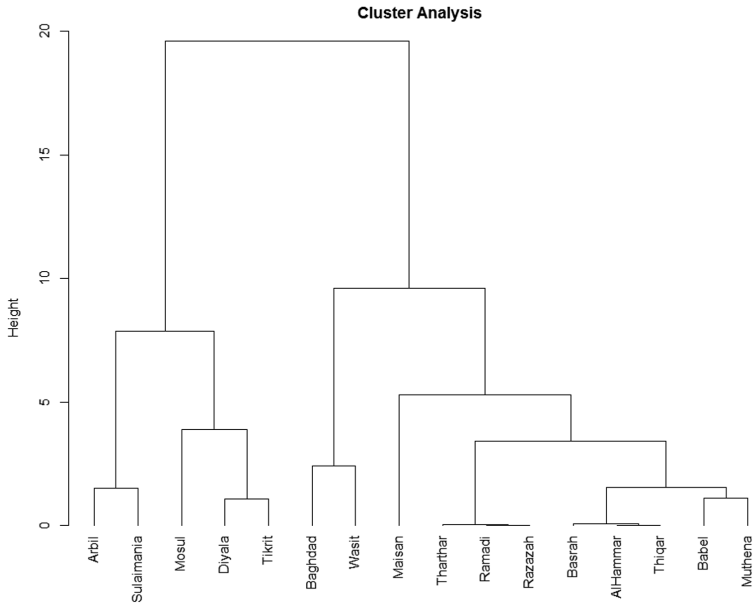

Figure 2. Dendrogram obtained through hierarchical cluster analysis showing population groupings of *S. triostegus* in the Tigris, Euphrates, and Shatt Al-Arab rivers.

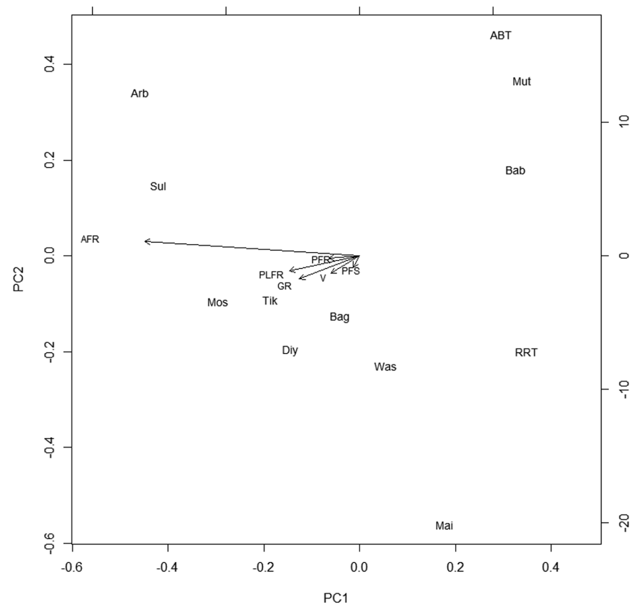

Figure 3. Principle Component Analysis distance biplot of morphological characters of *S. triostegus*. ABT: Al-Hammar-Basrah-Thiqar; ARB – Arbil; BAB – Babil; BAG – Baghdad; BAS – Basrah; DIY – Diyala; MOS – Mosul; MUT – Al-Muthana; RRT: Ramadi-Razazah-Tharthar; SUL – Sulaimania; TIK – Tikrit; WAS – Wasit.

areas show that larvae were exposed to different environmental conditions, and this can be interpreted as evidence of the existence of geographically separated spawning populations.

Variations in meristic counts were observed among the 16 populations of *S. triostegus* distributed in the Tigris, Euphrates, and Shatt al-Arab rivers in Iraq. These variations could have resulted from environmental or genetic factors, or both. Although the causative agents cannot be identified in the present work, it is apparent that different populations of *S. triostegus* can be identified based on meristic characters. This finding should be considered during the planning of conservation programs for this species.

The high differentiation in meristic characters that was detected could indicate reproductive isolation among the *S. triostegus* populations. Cluster analysis and PCA showed that the 16 populations of this species studied were divided into two main groups. Group I includes the upper Tigris River populations (Mosul, Erbil, Sulaimania, Tikrit, and Diyala). These populations are characterized as having the highest meristic counts for all six characters examined. Group II is composed of the lower Tigris River populations and populations of both the Euphrates and Shatt al-Arab rivers. There is a general increasing trend in the values of the six meristic characters studied from south to north and east to west. This trend coincides with the decreases in water temperature from south to north and from east to west.

Warm water temperatures result in shorter incubation periods and lower meristic counts, i.e., the number of fin rays and vertebrae (Kwain 1975). In the north of Iraq, where our samples were collected from Mosul, Arbil, and Sulaimania, water temperatures are lower in spring when *S. triostegus* eggs are spawned, than they are in locations in the middle, south, and west of Iraq. The increased values of meristic characters noted in the present study also correspond to latitude. This agreement suggests that Jordan's rule is persistent in the distribution of the species in Iraq. Similar results were obtained for two species of Menidia collected from the east and west coasts of Florida, U.S.A. by Yamahira et al. (2006).

Variation in the number of gill rakers seems to be related to the food and feeding habits of fish (Quilang et al. 2007). Fewer rakers are noted in fish that feed on benthos, which is the case for populations from the south of Iraq such as those from Al-Muthana, Thiqar, Al-Hammar Marsh, and Basrah. High gill raker counts are noted in populations from the upper Tigris River such as those from Mosul, Arbil, and Sulaimania, where feeding habits differ from those in mid and southern Iraq.

It has been known for decades that fish that consume large food items have small numbers of gill rakers, while those that feed on small prey items have numerous gill rakers (Nikolsky 1963, Labropoulou and Eleftheriou 1997, Amundsen et al. 2004, Kahilainen et al. 2011). The main food item of the *S. tristegus* populations from southern Iraq is large prey such as fish (Al-Shamma'a 2005). This explains the differences in the number of gill rakers among individuals from the populations of mid and southern Iraq, which have fewer gill rakers than do the fish inhabiting the upper Tigris River such as those from Mosul, Arbil, and Sulaimania, which have higher numbers of gill rakers. In the upper reaches of the Iraqi Tigris River and its tributaries, large prey such as fish are not abundant and they are less available there than they are in mid and southern Iraq (Al-Habbib et al. 1993, Jawad 2003). Fish inhabiting these areas feed instead on small-sized prey, which include mainly different species of crustaceans and detritus (Mohamed and Salem, personal communication).

In the upper Tigris River group, there are three components–the Mosul population, the Arbil-Sulaimania populations, and the Tikrit and Diyala populations. The similarities between the Arbil and Sulaimania populations could stem from the fact that the Arbil population is from the Great Zab River, while the Sulaimania population is from the Little Zab River. The sources of both the Little and Great Zab rivers are close to Iran, which means that it is highly likely that the populations of *S. triostegus* are mixed together, and, hence, they are from the same gene pool. The proximity of the Tikrit and Diyala populations means it is possible for the individuals of these two populations to have a common gene pool. No natural barriers occur in the area separating them that could prevent the movement of fish between the two locations. The population of *S. triostegus* from Mosul stands by itself as a sister clade to the other two clades in the upper Tigris River group. Although the Mosul population clades with the other populations from the north, it is geographically separated from the remaining populations in the upper Tigris River group.

In the second group that contains populations from the lower Tigris River, the Euphrates, and the

Shatt al-Arab rivers, it is clear that the populations of *S. triostegus* from the lower Tigris River, e.g., Baghdad, Wasit, and Maisan, are clustered together. The similarities among these populations stem from the geographical proximity of these populations to each other, which means that there is similarity in environmental factors. The Maisan population seems to be slightly different and appears to be a sister group of the Baghdad-Wasit cluster.

The population of *S. triostegus* from Al-Anbar, Lake Al-Tharthar, and Lake Al-Razazah represents the most western distribution of this species and the upper Euphrates River section. These populations form a separate cluster in the second group. The populations of the lower reaches of the Euphrates River, e.g., Babil, Al-Muthana, Thiqar, and Al-Hammar Marsh, cluster with the population of this species from Basrah on the Shatt al-Arab River. There are great similarities in the physicochemical properties of the waters of the lower reaches of the Euphrates River and the Shatt al-Arab River, which, in turn, have similar effects on the meristic characters studied.

We have shown the efficiency of using hierarchical cluster and principle component analyses in studying the population structure of the catfish *S. triostegus* from locations in the Tigris, Euphrates, and Shatt al-Arab rivers in Iraq. However, further studies are needed to better understand the relationships between the observed meristic variability and differences in habitat, especially environmental factors that can influence embryonic and larval stages. Further morphological and molecular studies of other populations of *S. triostegus* in Iraq and neighboring countries are required in order to explain the continuous variation in the meristic characters observed in this study.

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