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Morphological variations of *Alburnus mossulensis* Heckel, 1843 populations in the Tigris tributaries of the Persian Gulf basin in Iran (Teleostei: Cyprinidae)

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Abstract: The genus *Alburnus* (Cyprinidae) is distributed in Europe and northern southwest Asia with about 38 species among which seven species are present in Iran. In this study 229 specimens of *Alburnus mossulensis* were collected from eight rivers of Tigris sub basin which drain into the Persian Gulf, and were fixed in %10 formalin for further investigation. Eighteen morphometric and 12 meristic characters of the each specimen and their weight were measured. Morphometric characters in ratio method and meristic characters in classification method were used for population comparison. Analysis of variance (ANOVA) showed significant differences ($P<0.05$) in all population in all morphometric characters, except interorbital depth/head width. Classification of meristic characters showed most specimens of all populations has eight soft rays in dorsal fin, 10 soft rays in anal fin, 19 soft rays in caudal fin, 15 soft rays in pectoral fin, nine soft rays in pelvic fin, 2.4.5-5.4.2 formula in Pharyngeal teeth type, and 42 vertebrae. ANOVA showed significant differences ($P<0.05$) in means of all meristic characters among the populations. DFA analysis showed a low degree of separation among four populations of Abdanan, Leileh, Little Zab and Shoisheh from each other, but high separation from other population and high separation among the other populations of *A. mossulensis*.

Keywords: Meristics, Morphometrics, Mossul bleak, Phenotypic variation, Taxonomy.

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Introduction

In biodiversity conservation and fisheries management, the basic factor is species identification (Ibañez et al. 2007). Many biological features of fish such as feeding efficiency, locomotion performance, vulnerability to predators and reproductive success can be considered using body shape analysis (Guill et al. 2003). Fishes to enhance their survival can adopt to the environment conditions in various ways such as morphological changes (Maltagliati et al. 2003; Peres-Neto et al. 2004; Nacua et al. 2010; Yavno et al. 2013; Gholami et al. 2015a). Morphological changes induced by environmental factors can help to better understanding of the phenotypic plasticity process as a result of induced factors (Peres-Neto et al. 2004; Mohadasi et al. 2013; Gholami et al. 2015b).

Hence, measuring phenotypic differences in species may help to understand its natural history across a species geographic range, which have implications for both theoretical and applied works in ecological and fishery science (Nasri et al. 2013). It

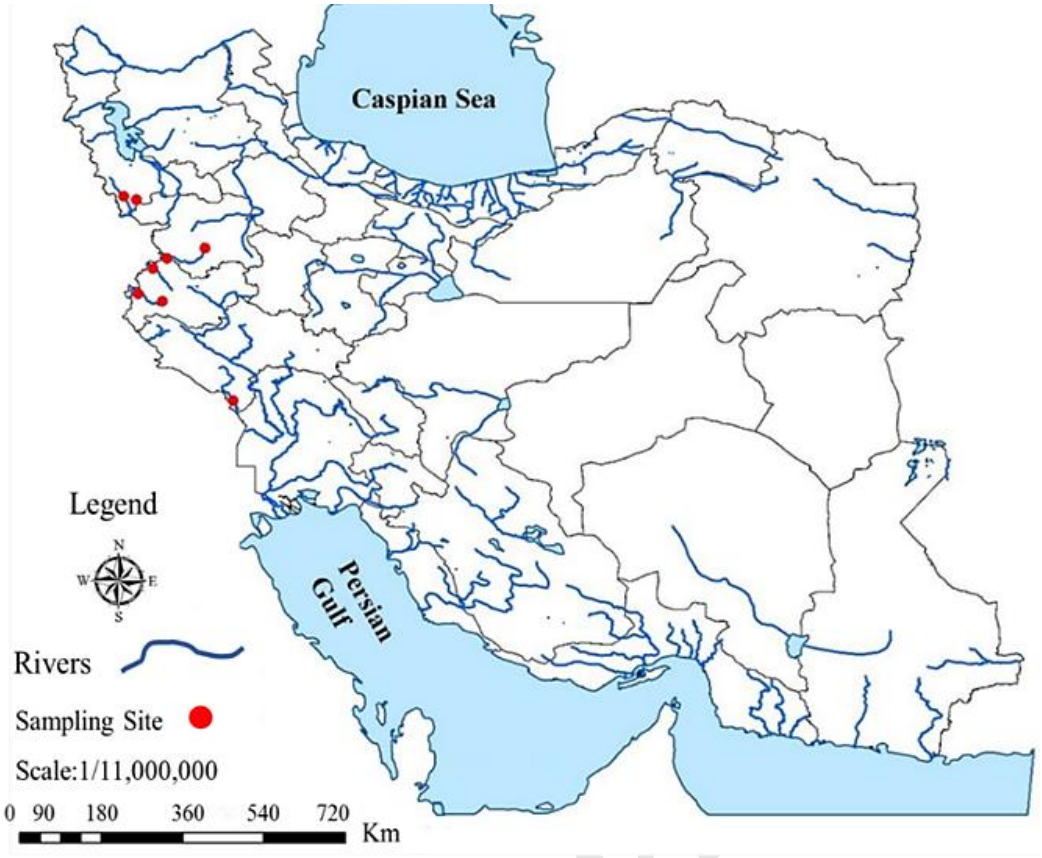

Fig.1. Collection points of *A. mossulensis* in the Tigris tributaries in Iran.

is understood that the investigation of phenotypic variation in morphometric or meristic characters is the method most generally used to define stocks of fish (Creech 1992; Mamuris et al. 1998; Bronte et al. 1999; Hockaday et al. 2000; Mohadasi et al. 2013). Despite the advent of techniques which directly examines biochemical or molecular genetic variation, these traditional methods continues to have an important role in stock identification even to now (Swain & Foote 1999). The body shape differences of populations is considered as essential steps in process of speciation (Balon 1993) and morphometric and meristic methods remain the simplest and most direct way among methods of species identification (Samaradivakara et al. 2012). Body shape differences not only reflect genetic characteristics of populations but also environmental parameters (Guill et al. 2003).

The cyprinid genus, *Alburnus* Rafinesque, 1820 comprises seven confirmed species from Iranian waters, among which three species including *A. caeruleus* Heckel, 1843, *A. mossulensis* Heckel, 1843 and *A. zagrosensis* Coad, 2009 are present in the Tigris-Euphrates basin which drains into the Persian Gulf. *Alburnus mossulensis* is widely distributed in the Tigris-Euphrates and adjacent basins such as Persis (Helleh and Mond) Karun, Kor and upper reaches of Hormuz basins (Esmaeili et al. 2010, 2015; Keivany et al. 2016). *Alburnus mossulensis* is not considered as a trade fish; however, it is used for consumption in some areas (Coad 2016). The aim of this study is to survey the meristic and morphometric variations of *A. mossulensis* in different rivers and tributaries of Tigris in western Iran.

Material and Methods

In total, 229 specimens of *A. mossulensis* were collected from eight rivers of Tigris (border rivers connecting to Tigris tributaries in Iraq) (Fig. 1)

Table 1. Eighteen morphometric characters and 12 meristic characters measured in *A. mossulensis*.

No.	Abbreviation	Morphometric characters	No.	Meristic characters
1	T.L	Total length	1	Dorsal soft rays
2	F.L	Fork length	2	Anal soft rays
3	S.L	Standard length	3	Caudal rays
4	B.D	Body depth	4	Pectoral fin rays
5	H.L	Head length	5	Pelvic fin rays
6	H.W	Head width	6	Scales between the origin of anal fin and the lateral line
7	Sn.L	Snout length		
8	O.D	Orbital diameter	7	LL scales
9	I.D	Interorbital distance	8	Scales between the origin of dorsal fin and the lateral line
10	C.L	Caudal peduncle length		
11	C.D	Caudal peduncle depth	9	Predorsal scales
12	Pr.D.L	Predorsal Length	10	Circumpeduncle scales
13	Po.D.L	Postdorsal length	11	Gill raker
14	Pr.A.L	Preanal length	12	Vertebrae
15	D.B	Dorsal fin base length		
16	D.H	Dorsal fin height		
17	V.L	Ventral fin length		
18	P.L	Pectoral fin length		

Table 2. Number, mean total length and weight and result of ANOVA of *A. mossulensis* from different Tigris tributaries in Iran.

Tributaries	Coordinate	Number	Total Length (Mean±SD) (cm)	Weight (Mean±SD) (g)
Abdanan	33º00'07"N, 47º25'38"E	11	8.71±2.20^{cd}	7.18±5.59^{c}
Haran	33º53'50"N, 45º42'10"E	40	7.95±0.82^{bc}	4.08±1.45^{ab}
Kangir	33º53'53"N, 45º42'13"E	25	7.10±1.01^{b}	2.53±0.99^{a}
Leileh	34º50'28"N, 46º21'15"E	17	9.95±3.30^{d}	12.56±7.35^{d}
Little Zab	36°34'05"N, 45°12'46"E	16	9.36±1.90^{cd}	7.79±3.80^{c}
Rabat	36°14'23"N, 45°33'47"E	86	5.58±3.00^{a}	2.68±4.09^{a}
Shoisheh	35º19'17"N, 46º36'32"E	10	8.67±0.68^{cd}	5.83±1.27^{bc}
Sirvan	35º07'05"N, 46º15'25"E	24	9.00±1.37^{cd}	6.29±3.22^{bc}
Total		229	7.39±2.74	4.73±4.68

Specimens were caught in summer 2010 by a seine net (5mm mesh sized), anesthetized in 1% clove oil solution, fixed in buffered 10% formalin at the sampling site and transferred to the laboratory for further examination. Eighteen morphometric characters and 12 meristic characters were studied (Table 1). Counts and measurements were done under a stereomicroscope using a digital caliper to the nearest 0.01mm. For analysis, ratios of morphometric characters were also used (Table 3). The one way ANOVA and Duncan grouping was used for parametric data. These analyses were carried out using Excel 2010 and SPSS 19 for Windows at 95% confidence limit. Also, discriminant functions analysis (DFA) was performed in MorphJ to separate the populations.

Results

Morphometric and ratios: The highest mean total length and weight was in specimens from Leileh River (9.95cm and 12.56g) (Table 2). The mean total length was 7.38±2.74 (Mean±SD) for all specimens. Also, the minimum total length was 5.58±3.00cm for Rabat population (Table 2). The result of ANOVA showed that the populations were different in total length and weight (Table 2). Some 16 common ratios

Table 3. The calculated ratios (Mean±SD) for *A. mossulensis* from different Tigris tributaries in Iran.

Ratio	Abdanan	Haran	Kangir	Leileh	Little Zab	Rabat	Shoisheh	Sirvan	All
S.L/F.L	0.90±0.01bc	0.90±0.01cd	0.89±0.01a	0.91±0.02d	0.91±0.01cd	0.89±0.02ab	0.90±0.01cd	0.91±0.01cd	0.90±0.02
S.L/T.L	0.84±0.02c	0.82±0.01b	0.80±0.01a	0.84±0.02c	0.84±0.01c	0.81±0.02a	0.83±0.01bc	0.83±0.02bc	0.82±0.02
B.D/T.L	0.18±0.01c	0.18±0.01c	0.16±0.00a	0.19±0.02d	0.18±0.01c	0.16±0.01a	0.18±0.01c	0.17±0.01b	0.17±0.02
H.L/S.L	0.26±0.01c	0.26±0.01c	0.26±0.00a	0.24±0.01d	0.24±0.01c	0.25±0.02a	0.25±0.01c	0.24±0.01b	0.25±0.02
Pr.D.L/SL	0.52±0.02b	0.51±0.01b	0.51±0.02b	0.50±0.02a	0.52±0.01b	0.52±0.02b	0.51±0.01b	0.51±0.01 b	0.52±0.02
C.L/S.L	0.25±0.01bc	0.24±0.01a	0.24±0.01ab	0.25±0.01c	0.25±0.01cd	0.26±0.01d	0.24±0.01abc	0.25±0.01cd	0.25±0.01
C.D/S.L	0.10±0.01c	0.10±0.01bc	0.09±0.00b	0.09±0.01b	0.09±0.00b	0.09±0.01a	0.10±0.00bc	0.09±0.00b	0.09±0.01
Pr.A.L/S.L	0.65±0.01bc	0.67±0.01d	0.66±0.02c	0.64±0.01a	0.64±0.01ab	0.65±0.02bc	0.64±0.01ab	0.65±0.02bc	0.65±0.02
D.B/S.L	0.11±0.00b	0.12±0.01b	0.11±0.01b	0.10±0.01a	0.11±0.01b	0.11±0.01b	0.12±0.00b	0.10±0.00a	0.11±0.01
D.H/S.L	0.19±0.01a	0.20±0.01cd	0.21±0.01e	0.19±0.01a	0.19±0.01ab	0.21±0.01de	0.20±0.01bc	0.19±0.01a	0.20±0.02
V.L/S.L	0.15±0.01cde	0.16±0.01de	0.16±0.01e	0.14±0.01a	0.14±0.01ab	0.15±0.01ab	0.15±0.01cd	0.15±0.01bc	0.15±0.01
P.L/S.L	0.19±0.01bc	0.20±0.01d	0.21±0.01e	0.18±0.00a	0.18±0.01a	0.19±0.01bcd	0.19±0.01b	0.19±0.01cd	0.19±0.01
Sn.L/H.L	0.25±0.01b	0.25±0.02b	0.24±0.02b	0.25±0.01b	0.26±0.01b	0.23±0.03a	0.26±0.01b	0.24±0.02b	0.24±0.02
O.D/H.L	0.26±0.01b	0.28±0.02c	0.29±0.02c	0.24±0.02a	0.24±0.01ab	0.27±0.03c	0.25±0.01ab	0.25±0.02ab	0.27±0.03
I.D/H.W (ns)	0.61±0.02	0.63±0.21	0.62±0.02	0.62±0.03	0.62±0.03	0.61±0.05	0.63±0.02	0.61±0.03	0.62±0.09
Pr.D.L/Pr.A.L	0.79±0.03b	0.76±0.02a	0.78±0.03b	0.78±0.02b	0.81±0.01c	0.80±0.02bc	0.79±0.02bc	0.79±0.03b	0.79±0.03

Table 4. Eigenvalues, percentage of variance, percentage of cumulative variance and Canonical Correlation for the Canonical Discriminant Functions in case of morphometric characters of *A. mossulensis* from different Tigris tributaries in Iran.

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	2.475	50.3	50.3	0.844
2	1.399	28.4	78.8	0.764
3	0.458	9.3	88.1	0.560
4	0.340	6.9	95.0	0.504
5	0.171	3.5	98.5	0.382
6	0.067	1.4	99.8	0.251
7	0.008	0.2	100.0	0.091

Table 5. Result of Wilks' lambda test for verifying difference among five populations of *A. mossulensis* from different Tigris tributaries in Iran, when morphological measurements are separately compared using discriminant function analysis.

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1 through 7	0.049	655.797	98	0.000
2 through 7	0.169	385.502	78	0.000
3 through 7	0.406	195.581	60	0.000
4 through 7	0.592	113.752	44	0.000
5 through 7	0.793	50.230	30	0.012
6 through 7	0.929	15.976	18	0.594
7	0.992	1.816	8	0.986

were calculated for the species from different rivers. (Table 3). Significant differences ($P<0.05$) for 15 out of 16 ratios were observed among five populations of *A. mossulensis* studied in the Tigris tributaries.

The Wilks' lambda test of discriminant analysis indicated significant differences in morphometric characters of five populations. In this test, all functions were highly significant ($P\leq0.01$) (Tables 4, 5). For the discriminant analysis, the averages of percentage of correctly classified specimens (PCC) were 76.4 % in original grouping and 69.0 % in cross-validated grouping for morphometric characters. High classification success rates were obtained for Abdanan (63.6%), Haran (85.0%), Kangir (84.0%), Leileh (70.6%), Little Zab (81.3%), Rabat (69.8%), Shoisheh (80.0%) and Sirvan (83.3%) stocks, indicating a high correct classification of individuals into their original populations with respect to morphometric characters (Table 6).

Figure 2 indicates the coordinates of the eight populations in the two first axes of DFA. In this analysis there was a low degree of separation among

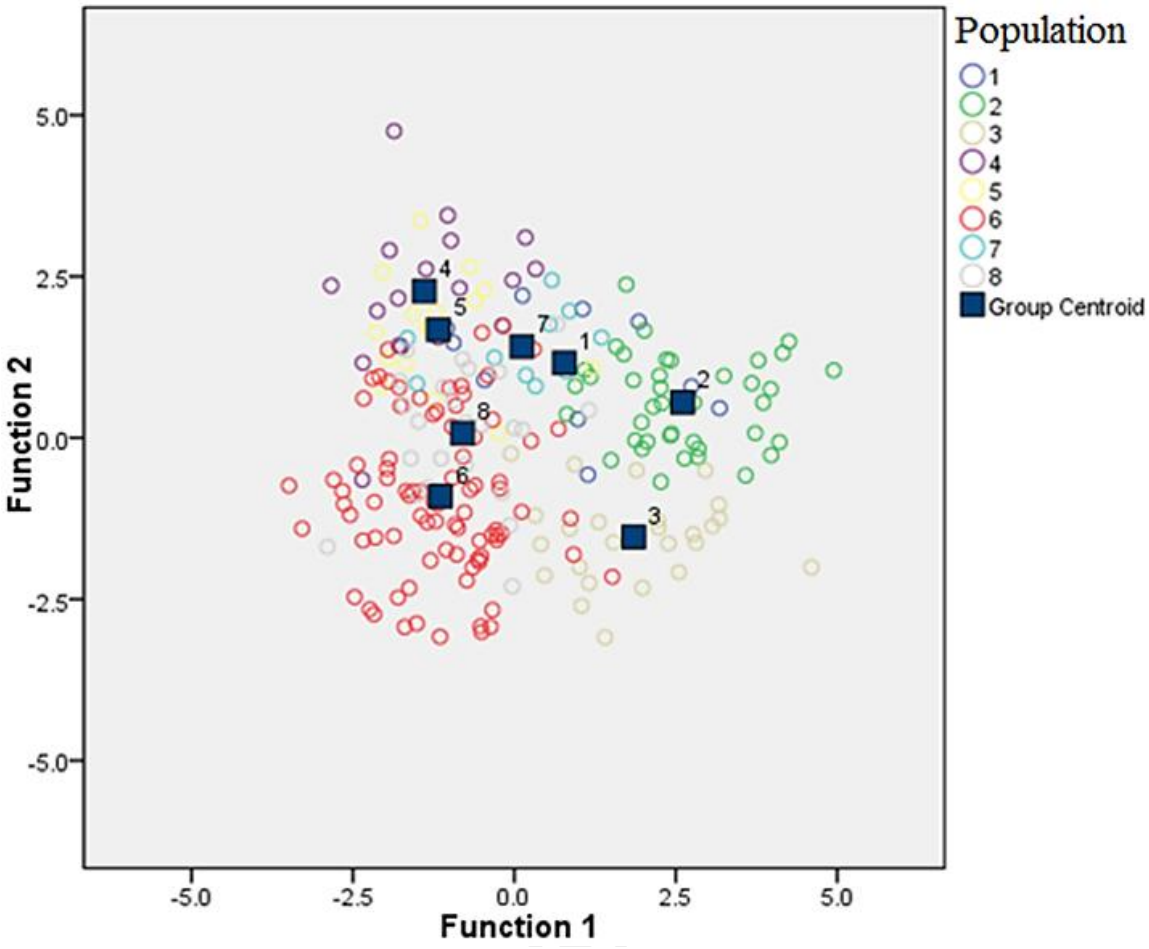

Fig.2. Coordinate plot of *A. mossulensis* from the eight rivers of Tigris basin according to the first two discriminant functions from morphometric data analysis (1: Abdanan, 2: Haran. 3: Kangir, 4: Leileh, 5: Little Zab, 6: Rabat, 7: Shoisheh, 8: Sirvan).

four populations of Abdanan, Leileh, Little and Shoisheh from each other, but high separation from other population and high separation among other populations of *A. mossulensis*.

Meristic characters: The minimum-maximum, Mean±SD, frequency of each count (%) and result of ANOVA of meristic characters is shown in Tables 7-Table 11. There were 2-3 spiny rays in dorsal fin in all specimens from different rivers. The dorsal soft rays ranged between 7-9 and most specimens (> %78) had eight soft rays in their dorsal fin. There were significant differences among some of the populations (P<0.05) (Table 7). There were 2-3 anal fin spiny rays in all specimens from different tributaries. The anal fin soft rays ranged between 7-12, although, frequency of seven and nine count of anal fin soft rays was very low. There were significant differences among some of the tributaries (P<0.05) (Table 7). The principal caudal fin rays ranged between 17-20, although, frequency of 17 and 20 count of principal caudal fin rays was very low. There were no significant differences among the tributaries for the caudal rays (P>0.05) (Table 8). The pectoral fin rays ranged between 12-18 and the pelvic fin rays ranged between 7-10 in all populations, although, frequency of 12 and 18 count of pectoral fin rays and 7 and 10 count of pelvic fin rays was very low. The result of ANOVA showed differences among the tributaries for the count of pectoral and pelvic fins rays (P<0.05) (Table 9).

The number of scales below the lateral line, on the lateral line, above the lateral line, predorsal and circumcaudal peduncle ranged between 3-7, 48-84, 11-16, 24-42 and 17-25 in all specimen in all rivers

Table 6. Percentage of specimens classified in each group and after cross validation for morphometric characters for *A. mossulensis* from different Tigris tributaries in Iran.

Population	Abdanan	Haran	Kangir	Leileh	Little Zab	Rabat	Shoisheh	Sirvan
Original %								
Abdanan	63.6		9.1		9.1		18.2	
Haran	7.5	85.0	7.5					
Kangir		8.0	84.0			4.0	4.0	
Leileh				70.6	11.8	5.9	11.8	
Little Zab	6.3				81.3		6.3	6.3
Rabat	2.3		1.2	2.3	2.3	69.8	3.5	18.6
Shoisheh					20.0		80.0	
Sirvan				4.2	8.3		4.2	83.3
Cross-validated %								
Abdanan	36.4		18.2		27.3		18.2	
Haran	7.5	82.5	7.5			2.5		
Kangir	4.0	8.0	76.0			8.0	4.0	
Leileh	5.9			64.7	17.6	5.9	5.9	
Little Zab	12.5				75.0		6.3	6.3
Rabat	2.3	1.2	2.3	2.3	3.5	65.1	3.5	19.8
Shoisheh	20.0				30.0		50.0	
Sirvan				4.2	8.3	4.2	8.3	75.0

Table 7. Minimum-maximum, Mean±SD and frequency of each count (%) for the dorsal and anal fin rays of *A. mossulensis* from different Tigris tributaries in Iran.

	Dorsal soft rays		Frequency of each count (%)			Anal soft rays		Frequency of each count (%)					
Tributaries	Min-Max	Mean±SD	7	8	9	Min-Max	Mean±Sd	7	8	9	10	11	12
Abdanan	7-8	7.82±0.40ab	19	81	0	9-11	10.55±0.52a	0	0	45	55	0	0
Haran	9-7	7.93±0.35ab	10	88	2	9-12	11.30±0.69c	0	0	8	65	25	2
Kangir	7-8	8.00±0.00ab	12	88	0	9-12	11.00±1.00bc	0	0	12	68	20	0
Leileh	7-8	8.00±0.00ab	18	82	0	9-12	11.00±1.00bc	0	0	18	64	18	0
Little Zab	8-9	8.00±0.00b	0	94	6	8-12	11.00±1.00bc	0	6	18	39	31	6
Rabat	7-9	8.00±1.00a	37	62	1	7-12	11.00±1.00ab	1	0	31	56	12	0
Shoisheh	7-8	8.00±0.00ab	9	81	0	9-12	11.00±1.00abc	0	0	18	73	9	0
Sirvan	7-8	7.92±0.28ab	8	92	0	9-12	11.08±0.77bc	0	0	25	42	33	0
Total	7-9	7.81±0.42	21	78	1	7-12	10.97±0.73	4	4	23	55	20	1

ns: Non significant among the population. a, b, c and d are results of Duncan grouping analysis.

(Table 10). The result of ANOVA showed differences among the tributaries for the meristic characters ($P<0.05$).

The gill rakers ranged 11-15 in all populations. There were significant differences among populations in the Tigris Basin ($P<0.05$) (Table 11). The vertebrae ranged from 40-45 in all tributaries. There were significant differences among the tributaries ($P<0.05$) (Table 11). The pharyngeal teeth were in three rows, but in two forms; A: 2.3.5-5.3.2; B: 2.4.5-5.4.2. Form B was the most frequent in all tributaries. There were no significant differences in pharyngeal teeth among the tributaries ($p>0.05$) (Table 11).

The Wilks' lambda test of discriminant analysis indicated significant differences in morphometric characters of the five populations from basins. In this test, all functions were highly significant ($P\leq0.01$) (Tables 12-13). For the discriminant analysis, the averages of percentage of correctly classified (PCC) were 55.5 % in original grouping and 50.5% in cross-validated grouping for morphometric characters. High classification success rates were obtained for Abdanan (45.5%), Haran (80.0%), Kangir (44.0%),

Leileh (35.3%), Little Zab (18.8%), Rabat (61.6%), Shoisheh (20.0%) and Sirvan (62.5%) stocks, four populations of Abdanan, Kangir, Little and Shoisheh from each other, but high separation from

Table 8. Minimum-maximum, Mean±SD and frequency of each count (%) of the caudal fin rays of *A. mossulensis* from different Tigris tributaries in Iran (P>0.05).

	Caudal rays		Frequency of each count (%)			
Tributaries	Min-Max	Mean±SD (ns)	17	18	19	20
Abdanan	18-19	18.91±0.30	0	9	91	0
Haran	18-20	19.03±0.28	0	2	93	5
Kangir	18-19	18.96±0.20	0	4	96	0
Leileh	18-19	18.82±0.39	0	18	82	0
Little Zab	18-19	18.94±0.25	0	6	94	0
Rabat	18-19	18.85±0.36	0	12	88	0
Shoisheh	19	19.00±0.00	0	0	100	0
Sirvan	17-20	18.79±0.59	4	17	75	4
Total	17-20	18.90±0.35	1	10	88	1

Table 9. Minimum-maximum, Mean±SD and frequency of each count (%) of the pectoral and pelvic fin rays of *A. mossulensis* from different Tigris tributaries in Iran.

	Pectoral fin rays	Frequency of each count (%)								Pelvic fin rays		Frequency of each count (%)			
Tributaries	Min-Max	Mean±SD	12	13	14	15	16	17	18	Min-Max	Mean±SD	7	8	9	10
Abdanan	14-15	14.73±0.47bc	0	0	27	73	0	0	0	8-9	8.91±0.31bc	0	9	81	0
Haran	15-18	17.25±0.90e	0	0	0	5	15	30	50	8-10	8.98±0.28c	0	2	96	2
Kangir	13-18	15.84±1.31d	0	8	4	20	44	12	12	8-9	8.80±0.41bc	0	20	80	0
Leileh	12-14	13.47±0.71a	12	29	59	0	0	0	0	7-10	8.29±0.85a	18	41	35	6
Little Zab	13-16	14.38±0.86b	0	19	31	44	6	0	0	8-9	8.63±0.50b	0	37	63	0
Rabat	13-16	14.49±0.85b	0	13	35	23	9	0	0	7-9	8.22±0.44a	1	74	25	0
Shoisheh	14-17	15.30±0.95cd	0	0	20	40	30	10	0	8-9	8.80±0.42bc	0	20	80	0
Sirvan	13-15	13.56±0.73a	0	37	50	13	0	0	0	8-9	8.79±0.41bc	0	19	82	0
Total	12-18	15.00±1.48	0	13	18	20	13	7	10	7-9	8.61±0.88	1.7	40.6	56.8	0

Table 10. Minimum-maximum and Mean±SD of the scales in *A. mossulensis* from different Tigris tributaries in Iran.

	Scales below LL		LL sclaes		Scales above LL		Predorsal sclaes		Circumpeduncle scales	
Tributaries	Min-Max	Mean±Sd	Min-Max	Mean±Sd	Min-Max	Mean±Sd	Min-Max	Mean±Sd	Min-Max	Mean±Sd
Abdanan	5-6	5.09±0.30^{b}	59-72	66.45±3.56^{a}	13-15	13.82±0.60^{a}	31-34	32.45±1.21^{bc}	20-23	21.27±0.90^{a}
Haran	5-7	5.18±0.50^{bc}	65-76	69.80±3.28^{ab}	12-16	14.25±0.84^{ab}	25-40	31.73±2.99^{ab}	19-25	21.18±1.30^{a}
Kangir	3-5	4.72±0.54^{a}	48-76	68.20±6.45^{ab}	11-15	14.12±1.01a^{b}	24-34	30.44±2.43^{a}	17-22	20.72±1.10^{a}
Leileh	5-6	5.60±0.51^{d}	66-80	73.27±4.68^{c}	14-16	15.33±0.62^{c}	35-39	37.00±1.25^{f}	21-23	22.07±0.80^{b}
Little Zab	5-6	5.06±0.25^{b}	65-77	70.38±3.20^{bc}	13-15	13.87±0.83^{a}	32-39	34.67±2.38^{de}	20-23	20.93±0.88^{a}
Rabat	5-6	5.04±0.20^{b}	61-82	69.76±5.70^{ab}	13-16	14.64±0.81^{b}	32-38	35.08±1.32^{d}	20-23	21.36±1.76^{ab}
Shoisheh	4-5	4.70±0.48^{a}	61-73	68.90±3.63^{ab}	14-15	14.70±0.48^{b}	31-36	33.40±1.71^{cd}	20-22	21.50±0.71^{ab}
Sirvan	5-6	5.46±0.51^{cd}	65-84	71.71±4.48^{bc}	13-15	14.13±0.61^{ab}	33-40	36.00±2.06^{ef}	20-23	21.50±0.88^{ab}
Total	3-7	5.12±0.51	48-84	70.33±4.72	11-16	14.33±0.87	24-40	33.57±3.07	17-25	21.26±1.05

indicating a high correct classification of individuals into their original populations except Leileh, Little Zab and Shoisheh populations with respect to meristic characters (Table 14).

Figure 3 indicates the coordinates of the eight populations in the two first axes of DFA. In this analysis there was a low degree of separation among other population and high separation among other populations of *A. mossulensis*.

Discussion and Conclusions

The meristic characters such as scales, fin rays, gill rakers and pharyngeal teeth are genetically controlled, instead, body shape characters such as

Table 11. Minimum-maximum and Mean±SD of gill rakers, vertebrae and various pharyngeal teeth types in *A. mossulensis* from different Tigris tributaries in Iran.

	Gill raker		Pharyngeal teeth type frequency (%)		Vertebrae		Frequency of each count (%)					
Tributaries	Min-Max	Mean±Sd	A	B	Min-Max	Mean±Sd	40	41	42	43	44	45
Abdanan	11-13	12.18±0.60^{ab}	-	100	40-44	42.50±1.43^{d}	10	10	40	-	40	-
Haran	11-15	12.50±1.01^{b}	33	67	40-43	40.69±0.84^{a}	50	35	12	3	-	-
Kangir	11-15	13.36±1.11^{c}	30	70	40-43	40.88±0.99^{a}	41	41	7	11	-	-
Leileh	11-13	12.07±0.80^{ab}	29	71	40-43	41.21±1.12^{ab}	36	21	29	14	-	-
Little Zab	11-14	12.38±0.89^{ab}	25	75	40-45	42.36±1.28^{cd}	8	15	31	31	8	7
Rabat	11-15	12.50±1.01^{bc}	12.5	87.5	40-45	40.69±0.84^{bc}	8	17	38	29	4	4
Shoisheh	11-15	12.50±1.01^{a}	100	0	40-43	40.69±0.84^{abc}	20	30	40	10	-	-
Sirvan	11-15	12.50±1.01^{bc}	28.6	71.4	40-43	40.69±0.84^{d}	10	0	43	16	21	10
Total	11-15	12.61±1.12	30.2	69.8	40-45	41.68±1.35	15	22	28	15	8	3

Table 12. Eigenvalues, percentage of variance, percentage of cumulative variance and Canonical Correlation for the Canonical Discriminant Functions in case of morphometric characters of *A. mossulensis* from different Tigris tributaries in Iran.

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	1.920	79.0	79.0	0.811
2	.393	16.2	95.2	0.531
3	.081	3.3	98.5	0.273
4	.022	.9	99.4	0.147
5	.014	0.6	100.0	0.118
6	.001	0.0	100.0	0.029

Table 13. Result of Wilks' lambda test for verifying difference among five populations of *A. mossulensis* from different Tigris tributaries in Iran. When morphological measurements are separately compared using discriminant function analysis.

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1 through 6	0.219	335.308	42	0.000
2 through 6	0.640	98.478	30	0.000
3 through 6	0.892	25.227	20	0.193
4 through 6	0.964	8.100	12	0.777
5 through 6	0.985	3.272	6	0.774
6	0.999	0.186	2	0.911

length factors and their ratios are affected by environment and they are sensitive to environmental changes and quickly adapt themselves to new conditions (Brraich & Akhter 2015).

In the present study, the average minimum total length was 5.58±3.00cm (Mean±SD) in Rabat population and the maximum was 9.95±3.30cm in Leileh River. The average of this parameter in Tigris basin was 7.39±2.74cm; however, the standard length and weight of *A. mossulensis* in Persian Gulf basin were ranged between 7.0-15.5cm (11.7±1.2) and 6.3-54.6g (20.6±6.4), respectively (Mousavi-Sabet et al. 2013). The standard length of *A. mossulensis* in Razarvar, Godarkhosh, Dehno, Maran and Ghamasiab rivers in western Iran was 74±24.6, 73.4±17.5, 94.3±22 and 111.9±21.5cm and body weight was 10.5±9.6, 8.1±7.1, 16.8±11.3 and 15.4±7.1g, respectively (Yousefian et al. 2013).

Mousavi-Sabet et al. (2014) reported the total length and body weight for seven species of *Alburnus* between 75.45-97.44 (84.93±5.44)mm and 3.68-8.49 (5.88±1.31)g for *A. atropatenae*, 66.10-82.12 (72.60±6.49)mm and 2.83-5.40 (3.71±1.08)g for *A. caeruleus*, 124.60-184.74 (154.28±11.76)mm and

Table 14. Percentage of specimens classified in each group and after cross validation for morphometric characters for *A. mossulensis* from different Tigris tributaries in Iran.

population	Abdanan	Haran	Kangir	Leileh	Little Zab	Rabat	Shoisheh	Sirvan
Original %								
Abdanan	45.5					9.1	27.3	18.2
Haran		80.0	12.5				7.5	
Kangir	4.0	24.0	44.0	8.0		4.0	16.0	
Leileh	5.9			35.3		23.5		35.3
Little Zab	6.3		6.3	6.3	18.8	12.5	18.8	31.3
Rabat	3.5		10.5	12.8	1.2	61.6	7.0	3.5
Shoisheh	20.0	10.0	30.0		10.0	10.0	20.0	
Sirvan	4.2			12.5	8.3	8.3	4.2	62.5
Cross-validated %								
Abdanan	36.4					9.1	27.3	27.3
Haran		80.0	12.5				7.5	
Kangir	4.0	24.0	44.0	8.0		4.0	16.0	
Leileh								
Little Z								
Rabat								
Shoish								
Sirvan								

14.88-41.70 (30.45±5.82)g for *A. chalcoides*, 78.50-107.79 (95.80±7.48)mm and 3.65-9.02 (6.82±1.67)g for *A. filippii*, 48.88-65.41 (56.56±5.05)mm and 1.35-3.22 (2.14±0.56)g for *A. hohenackeri*, 100.94-156.88 (127.66±14.30)mm and 8.00-28.23 (17.77±5.74)g for *A. mossulensis* and 53.27-129.72 (84.81±31.43)mm and 1.40-23.04 (8.56±8.33)g for

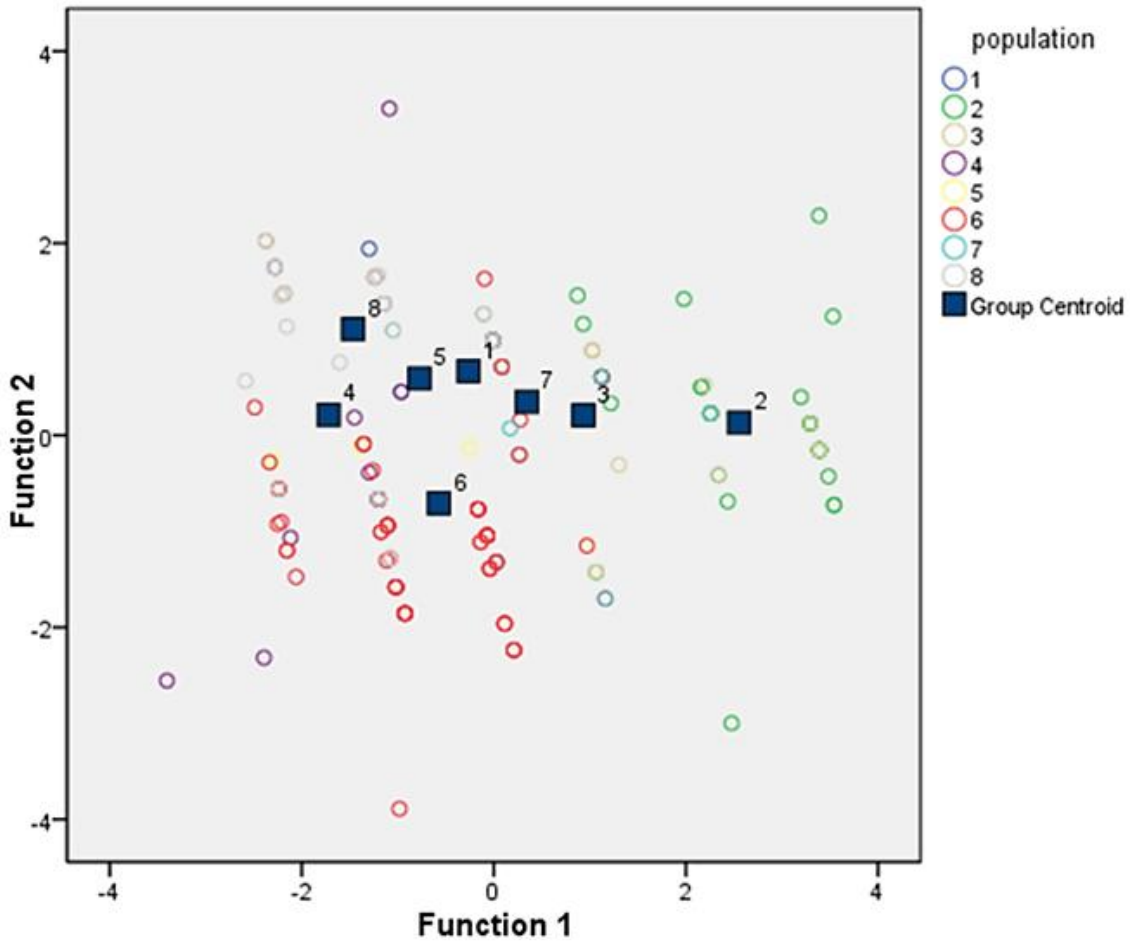

Fig.3. Coordinate plot of *A. mossulensis* from the eight rivers of Tigris basin according to the first two discriminant functions from meristic data analysis (1: Abdanan, 2: Haran. 3: Kangir, 4: Leileh, 5: Little Zab, 6: Rabat, 7: Shoisheh, 8: Sirvan).

A. zagrosensis, respectively.

Most specimens had 8 rays in their dorsal and 10 rays in their anal fin. Caudal fin rays ranged from 17 to 20 (18.91±0.30) in all specimens and most samples (about 88%) had 19 caudal fin rays. However, the dorsal fin spines, soft dorsal fin rays and anal fin spines for *A. mossulensis* were III, 7.6±0.4 and III in Razavar River, III, 7.5±0.5 and III in Godarkhosh River, III, 8.5±0.5 and 3.3±0.4 in Dehno River and III, 8±0.1 and III in Maran River, respectively (Yousefian et al. 2013); while Elp et al. (2015) reported 7-8 rays in dorsal fin and Mousavi-Sabet et al. (2015) 10.5–13.5 branched rays in anal fin, usually 11.5–12.5 in *A. mossulensis* inhabiting Tigris tributaries. Investigation on paired fins in *A. mossulensis* in Tigris tributaries in this study showed pectoral fins having 12-18 (15.00±1.48) rays and most samples (30%) had 15 rays and pelvic fins had 7-9 (8.61±0.88) rays and most specimens (56.8%) had nine rays.

The number of scales below the lateral line in all specimens of Tigris tributaries ranged 3-7 (5.12±0.51), on the lateral line 58-84 (70.33±4.72) and above the lateral line 11-16 (14.33±0.87). Predorsal scales ranged 24-40 (33.57±3.07) and circumpeduncle scales ranged 17-25 (21.26±1.05); However, Yousefian et al. (2013) reported these in four river branches of Gamasiab River in western Iran, as follows: scale on, above and below the lateral line and cicumpeduncle as 88.1±1.7, 89.5±2.4, 92.1±2.4 and 36±1.4 in Razavar River, 85.5±0.6, 87.8±0.7, 92.2±0.7 and 43.7±1.8 in Godarkhosh River, 85.5±11.6, 94.1±2, 95.3±1.8 and 35.1±1.8 in Dehno River and 87.7±0.9, 88.6±2.2, 91.8±1.4 and 43.4±2.8 in Maran River, respectively.

It is well-known that morphological characters can show high phenotypic plasticity in response to differences in environmental conditions, such as food abundance and temperature, presence or absence of predator, competitors and habitat size, (Allendorf et al. 1987; Swain et al. 1991; Wimberger 1992; Maltagliati et al. 2003; Peres-Neto et al., 2004; Yavno et al. 2013; Gholami et al., 2015b; Keivany et al. 2015). Fishes adapt quickly by altering their physiology and behavior to environmental changes. These alterations ultimately change their morphology. In general, fish demonstrate greater variances in morphological characters both within and between populations than any other vertebrates and are more susceptible to environmentally induced morphological variations (Stearns 1983; Allendorf et al. 1987; Wimberger 1992). Therefore, Analysis of morphometric and meristic characteristics can provide important information at multiple taxonomic levels which are important in the study of divergence between populations and in the recognition of intraspecific variation.

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تنوع ریختی جمعیت‌های شاه‌کولی جنوبی *Alburnus mossulensis* Heckel, 1843 در سرشاخه‌های تیگریس در ایران

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گروه شیلات، دانشکده منابع طبیعی، دانشگاه صنعتی اصفهان، اصفهان، ۸۳۱۱۱-۸۴۱۵۶، ایران.

چکیده: جنس شاه‌کولی *Alburnus* (از خانواده Cyprinidae) با ۳۸ گونه، در آب‌های اروپا و جنوب غرب آسیا پراکنش دارند که هشت گونه از آنها در آب‌های ایران حضور دارند. برای انجام این مطالعه، ۲۲۹ قطعه ماهی شاه کولی جنوبی (*Alburnus mossulensis*) از هشت رودخانه از حوضه تیگریس جمع‌آوری شده و بعد از تثبیت در فرمالین ۱۰٪ برای مطالعات بیشتر به آزمایشگاه منتقل شدند. تعداد ۱۸ صفت اندازشی و ۱۲ صفت شمارشی و وزن بدن نمونه‌ها اندازه‌گیری شد. برای مقایسه جمعیت‌ها از روش نسبت برای صفات اندازشی و روش طبقه‌بندی برای صفات شمارشی استفاده گردید. آنالیز واریانس (ANOVA) تفاوت‌های معنی‌داری را در بین جمعیت‌های شاه‌کولی جنوبی در کلیه صفات اندازشی، به جز صفت نسبت قطر حدقه چشم به عرض سر نشان دادند. طبقه‌بندی صفات شمارشی نیز نشان داد که اکثریت نمونه‌ها در کلیه جمعیت‌ها دارای هشت شعاع نرم در باله پشتی، ده شعاع نرم در باله مخرجی، ۱۹ شعاع نرم در باله دمی، ۱۵ شعاع نرم در باله سینه‌ای، نه شعاع نرم در باله شکمی، دندان حلقی با فرمول ۲۰۴۰۵-۵۰۴۰۲ و نیز ۴۲ مهره در ستون فقرات هستند. همچنین، آنالیز واریانس نیز تفاوت‌های معنی‌داری را در بین جمعیت‌ها بر اساس صفات شمارشی نشان داد. آنالیز DFA نشان داد که جدایی کمی در بین چهار جمعیت آبدانان، لیله، زاب کوچک و شویشه وجود دارد، اما جدایی زیادی با دیگر جمعیت ها دارند و جدایی زیادی در بین چهار جمعیت دیگر وجود دارد.

کلمات‌کلیدی: آرایه‌شناسی، شاه‌کولی جنوبی، ویژگی‌های اندازشی، ویژگی‌های شمارشی، تنوع فنوتیپیکی.