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Original Article

Comparison of meristic traits in Transcaucasian chub (*Squalius turcicus* De Filippi, 1865) from Caspian Sea basin

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Abstract: For comparison of meristic characters of *Squalius turcicus*, in 12 rivers of Caspian Sea basin, 535 specimens were captured. Some 14 meristic characters were counted. Classification of meristic characters showed that most specimens of all populations have 8 soft dorsal rays, 9 soft anal rays, 19 branched caudal fin rays, 15 soft pectoral rays, 9 soft pelvic rays, 41-47 lateral line scales, 7-9 scales above LL, 3-5 scales below LL, 18-21 predorsal scales and 14-16 circumpeduncle scales. The results showed significant differences (P<0.05) in means of all meristic characters except dorsal, pelvic and pectoral fin spins between the populations. The PCA and CVA showed overlapping among the populations, although some populations were separated from the others. Also, cluster analysis divided Divandareh River population in a separate group and it was distinct from other populations. Generally, the results of meristic characters cannot well-separate the populations of this species from each other.

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Introduction

Transcaucasian chub, *Squalius turcicus* formerly known as *S. cephalus* in the Iranian inland waters is a cyprinid species distributed in the Caspian Sea and Urmia Lake basins (Keivany et al., 2016a; Esmaeili et al., 2017). This species lives in the middle and upper parts of rivers with relatively cool water and cobblestone bottoms. Turan et al. (2007) studied the morphological variation in *S. cephalus*, across Turkish inland waters. Mouludi-Saleh et al. (2016b, c, 2017a) studied the morphology of *S. namak* populations in rivers of the Namak Lake basin. Poria et al. (2014) studied morphometric and meristic characteristics of *S. cephalus* in the Shohaday-e-Songhor Dam Lake. Gorjian Arabi et al. (2011) surveyed morphological diversity of *S. cephalus* in the Talar River, Mazandaran Province. Babazadeh and Vatandoost (2013) surveyed morphometric and meristic characteristics of *S. cephalus* in Tajan River, Mazandaran Province. Alizadeh et al. (2015) studied morphological variation of *S. orientalis* in the southern Caspian Sea basin. Despite its wide distribution, there is no comprehensive work on the species.

Recently, Özuluğ and Freyhof (2011) suggested that *S. turcicus* De Filippi, 1865 might be a valid species occurring in the southern Caspian Sea basin and Turan et al. (2013) supported this view and provided some morphological data distinguishing this species from *S. orientalis*. Khaefi et al. (2016) suggest that *S. orientalis* and *S. turcicus* are very closely related and might represent just one species. *Squalius turcicus* might be more widespread and *Squalius* populations of the Urmia Lake and Caspian Sea basins might belong to this species (Esmaeili et al., 2017). Herein, we followed Esmaeili et al. (2017) and consider the southern Caspian Sea species as *S. turcicus*. The aim of this study was to evaluate the diversity of meristic characters in populations of *S. turcicus* in the Caspian Sea basin for possibility of finding distinct populations.

Materials and Methods

During 2010-2011 from 16 rivers of the Caspian Sea basin, including Babol, Palangab, Tajan, Talvar, Chalak, Divandareh, Zarin, Zalkie, Sefid, Shafa Ghezel-Ozan, Kasma, Tonekabon, Neka, Noor and

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Figure 1. Collection points of *Squalius turcicus* in the Caspian Sea basin.

Table 1. Minimum-maximum, mean±SD and frequency of each count (%) of the dorsal and anal fin rays of *Squalius turcicus* from different Caspian Sea basin tributaries in Iran, collected during summer 2010-2011.

	Dorsal soft rays		Frequency of each count (%)				Anal soft rays		Frequency of each count (%)		
rivers	min-max	mean±SD	7	8	9	10	min-max	mean±SD	25	52	10
Babol	8-10	9.31±0.71	0	16	37	47	8-10	8.97±0.70	18	32	23
Palangab	8-10	9.14±0.59	0	10	64	26	8-10	9.32±0.77	22	56	50
Tajan	8-10	8.83±0.71	0	34	48	18	8-10	9.00±0.67	7	79	22
Talvar	8-9	8.50 ±0.52	0	50	50	0	8-10	9.07±0.47	0	56	14
Tonekabon	8-10	8.81±0.75	0	38	44	18	9-10	9.44±0.51	0	88	44
Chalak	8-9	8.11±0.32	0	88	12	0	9-10	8.11±0.32	25	65	12
Divandareh	8-10	8.40±0.68	0	70	20	10	8-10	8.85±0.59	54	46	10
Zarin	8	7.00±0.00	0	100	0	0	8	8.33±0.49	92	4	0
Zalkie	8-9	8.11±0.32	0	11	89	0	8-10	8.12±0.44	67	33	4
Sefied	7-9	7.89±0.47	17	78	5	0	8-9	8.33±0.49	62	38	0
Shafa	8-9	8.23±0.44	0	38	62	0	8-9	8.23±0.44	43	67	0
Gheze-Ozan	8-9	8.63±0.49	0	37	63	0	8-9	8.57±0.50	54	46	0
Kasma	8-9	8.03±0.19	0	3	97	0	8-9	8.47±0.51	59	31	0
Neka	8	8.00±0.00	0	100	0	0	8-9	8.41±0.50	71	29	0
Noor	8	8.00±0.00	0	100	0	0	8-9	8.29±0.46	59	31	0
Haraz	8-9	8.00±0.00	0	97	3	0	8-9	8.23±0.44	42	46	0
Total	7-10	8.47±0.69	1	61	30	8	8-10	8.69±0.66	25	52	12

Haraz rivers (Fig. 1), 535 specimens were collected by a seine net. After anesthetizing with 1% clove oil solution and fixing in 10% neutralized formalin, specimens were transferred to the Isfahan University of Technology Ichthyology Museum (IUT-IM) for further studies. Some 14 meristic characters were counted under a stereomicroscope (Tables 1, 2, 3). The data were analysed for normality using Kolmogorov-Smirnov test and non-normal data were analyzed by Kruskal-Wallis test. These analyses were carried out using Excel 2013 and SPSS 19 for Windows at 95% confidence limit. Significantly different data were used for Principal Component Analysis (PCA), Canonical variate analysis (CVA) and Cluster analyses (CA) in PAST software.

Results

According to the results, all data were not normal. Except dorsal, pelvic and pectoral fin spins, all other 11 examined characters were significantly different among the populations. The significant characters were used for PCA, CVA and cluster analyses. Dorsal spins were 2-3 in all specimens from different rivers and their soft rays ranged 7-10. There were significant differences between some populations (P<0.05) (Table 1). Anal spins were 2-3 in all specimens from different basins and their soft rays ranged 8-10. There were significant differences between some populations (P<0.05) (Table 1). The principal caudal rays ranged 18-21 and a significant differences found between basins (P<0.05) (Table 2).

Table 2. Minimum-maximum, mean±SD and frequency of each count (%) of the caudal fin rays of *Squalius cephalus* from different Caspian Sea basin tributaries in Iran, collected during summer 2010-2011.

	Caudal rays	Frequency of each count (%)				
rivers	min-max	min-max	18	19	20	21
Babol	18-21	18-21	2	51	35	13
Palangab	18-20	18-20	7	79	14	0
Tajan	18-20	18-20	10	78	12	0
Talvar	18-20	18-20	14	64	22	0
Tonekabon	18-20	18-20	6	82	12	0
Chalak	19-20	19-20	0	74	26	0
Divandareh	18-20	18-20	10	85	5	0
Zarin	18-19	18-19	20	80	0	0
Zalkie	18-19	18-19	12	88	0	0
Sefied	18-20	18-20	6	88	6	0
Shafa	18-20	18-20	7	61	32	0
Ghezel-Ozan	18-20	18-20	4	93	3	0
Kasma	19-21	19-21	0	86	7	7
Neka	18-19	18-19	2	98	0	0
Noor	18-19	18-19	2	98	0	0
Haraz	18-20	18-20	3	3	14	80
Total	18-21	18-21	5	80	12	3

Table 3. Minimum-maximum and mean±SD of the scales in *Squalius turcicus* from Caspian Sea basin during 2010-2011.

	Scales below LL		LL sclaes		Scales above LL		Predorsal sclaes		Circumpeduncle	
rivers	min-max	mean±SD	min-max	mean±SD	min-max	mean±SD	min-max	mean±SD	min-max	mean±SD
Babol	3-4	3.79±0.58	41-45	43.29±0.6	7-8	7.97±0.16	18-20	18.79±0.66	14-15	14.01±0.12
Palangab	3-4	3.68±0.48	43-46	43.96±0.9	8-9	8.22±0.15	18-19	18.32±0.48	14-16	14.21±0.63
Tajan	4-5	4.43±0.50	42-46	43.33±1.0	7-8	7.97±0.18	18-20	18.24±0.50	14	14.00±0.00
Talvar	3-4	3.43±0.51	43-47	44.14±1.1	7-8	7.36±0.50	18-20	19.07±0.92	14-15	14.14±0.53
Tonekabon	3-4	3.19±0.40	43-46	43.88±1.0	8-9	8.38±0.25	18-20	18.50±0.52	14-16	14.75±1.00
Chalak	3-4	3.06±0.24	42-47	43.79±1.2	7-8	7.97±0.17	18-20	18.57±0.70	14-16	14.74±0.98
Divandareh	3-4	3.35±0.75	43-45	43.90±0.9	7-8	7.30±0.47	18-21	19.05±0.94	14-15	14.05±0.60
Zarin	4-5	4.13±0.35	43-46	43.80±0.7	7-8	7.60±0.51	18-19	18.53±0.52	14-16	14.53±0.92
Zalkie	3-4	3.80±0.82	42-46	43.80±1.0	7-8	7.20±0.41	18-21	18.88±0.83	14-16	14.48±0.77
Sefied	4-5	4.89±0.32	43-46	43.67±0.9	7-8	7.17±0.38	18-20	18.50±0.62	14-16	15.00±0.97
Shafa	4-5	3.77±0.60	43-46	43.77±1.1	7-8	7.23±0.44	18-20	18.77±0.73	14	14.00±0.00
Ghezel-Ozan	4-5	4.69±0.47	43-45	44.02±0.8	7-8	7.55±0.85	18-20	18.76±0.52	14-16	15.10±1.01
Kasma	3-4	3.97±0.18	44-47	45.87±0.9	7-8	7.27±0.45	18-21	18.90±0.76	14-16	15.20±1.00
Neka	3-4	3.69±0.47	44-47	44.59±0.7	7-8	7.18±0.39	18-20	18.88±0.56	14-16	14.18±0.57
Noor	4-5	4.29±0.51	43-47	44.81±0.8	7-8	7.02±0.14	18-20	18.69±0.55	14-15	14.73±0.74
Haraz	3-4	3.07±0.26	44-46	44.59±0.5	7-8	7.14±0.35	18-19	18.31±0.47	14	14.00±0.00
Total	3-5	3.60±0.71	41-47	44.03±1.1	7-9	7.55±0.59	18-21	18.65±0.66	14-16	14.42±0.78

The pectoral spiny rays were 0-1 in the examined specimens and their branched rays ranged 14-17. The pelvic spiny rays were 1-2 in the examined specimens and their rays ranged 7-9 in all populations. A significant differences was found between some of the rivers for the pectoral rays (P<0.05) (Table 4). The scales below the lateral line ranged 3-5, on the lateral line 41-47, above the lateral line 7-9, predorsal 18-21 and circumpeduncle 12-16 in the examined specimens. There was a significant differences between some of the rivers (P<0.05) (Table 4).

According to PCA, 52.83% of the variance were accounted for first two components positioned above the Jolliffe line and circumpeduncle scales along the two main axes of PC1 and PC2 had the highest variation (Fig. 2). According to the classification of the populations (Fig. 3), the studied populations partially overlap and do not fully differentiate from each other. Although some populations (Ghezel-Ozan, Kasma, Sefid and Talvar) are separated. The results of

Table 4. Minimum-maximum, mean±SD and frequency of each count (%) of the pectoral and pelvic fin rays of *Squalius turcicus* from different Caspian Sea basin tributaries in Iran, collected during summer 2010-2011.

	Pectoral fin rays		Frequency of each count (%)				Pelvic fin rays		Frequency of each count (%)		
rivers	min-max	mean±SD	14	15	16	17	min-max	mean±SD	7	8	9
Babol	14-16	15.12±0.77	24	40	36	0	9	9.00±0.00	0	0	100
Plangab	14-16	15.07±0.90	32	32	36	0	9	9.00±0.00	0	0	100
Tajan	14-17	15.25±0.97	26	35	28	11	8-9	8.65±0.48	0	39	61
Talvar	14-16	15.29±0.61	7	57	36	0	9	9.00±0.00	0	0	100
Tonekabon	14-15	14.69±0.48	5	95	0	0	8-9	8.56±0.51	0	43	67
Chalak	14-16	14.49±0.61	57	37	6	0	8-9	8.37±0.49	0	66	34
Divandareh	15-16	15.55±0.51	0	45	55	0	8-9	8.80±0.41	-	20	80
Zarin	14-15	14.33±0.49	67	33	0	0	8	8.00±0.00	0	100	0
Zalki	14-16	14.84±0.75	36	44	20	0	8-9	8.88±0.33	0	8	92
Sefied	14-15	14.33±0.49	67	33	0	0	8-9	8.28±0.46	0	72	28
Shafa	14-16	15.00±0.82	31	38	31	0	8-9	8.62±0.51	0	38	62
Gheze-Ozan	14-16	15.00±0.61	18	63	19	0	8-9	8.49±0.51	0	50	50
Kasma	14-16	15.17±0.53	6	70	24	0	8-9	8.87±0.35	0	13	87
Neka	14-15	14.51±0.51	49	51	0	0	8-9	8.43±0.50	0	57	43
Noor	14-16	14.65±0.53	37	61	2	0	8-9	8.40±0.49	0	65	35
Haraz	14-15	14.62±0.49	38	62	0	0	8-9	8.86±0.35	0	10	90
Total	14-17	14.89±0.74	32	42	18	8	8-9	8.64±0.47	0	35	65

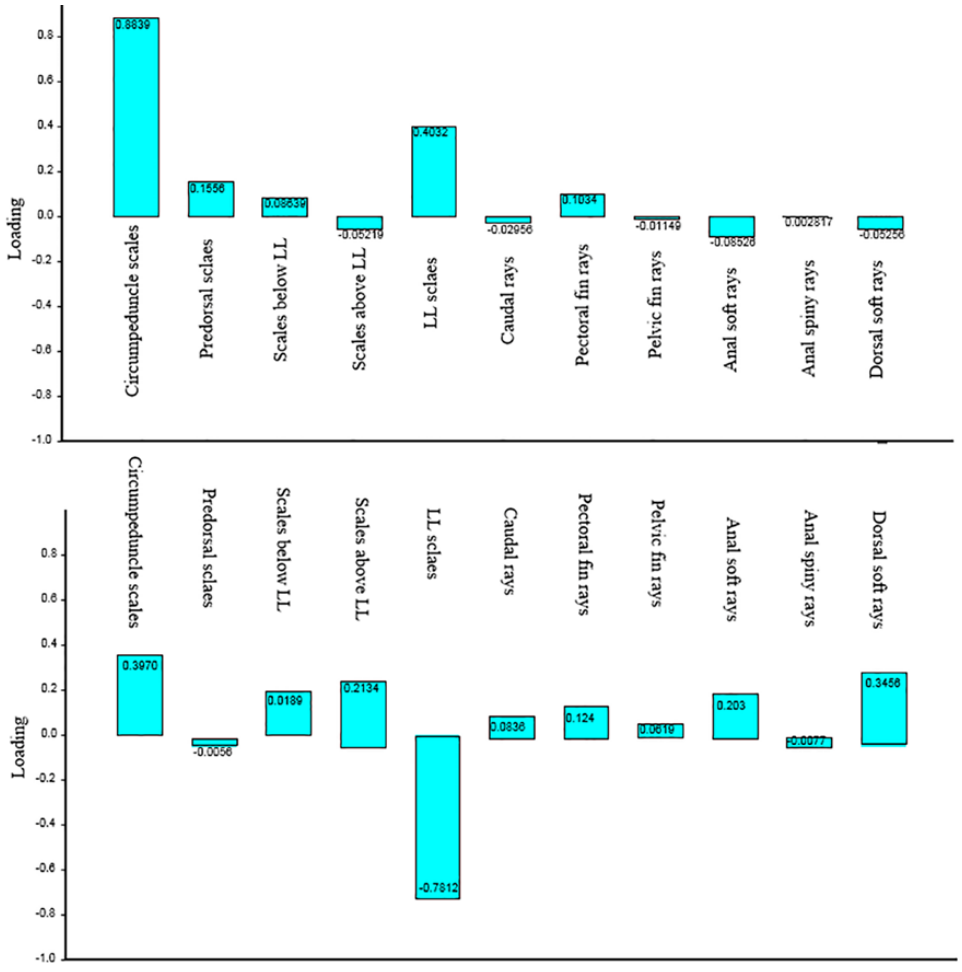

Figure 2. The role of the first character along the two axes.

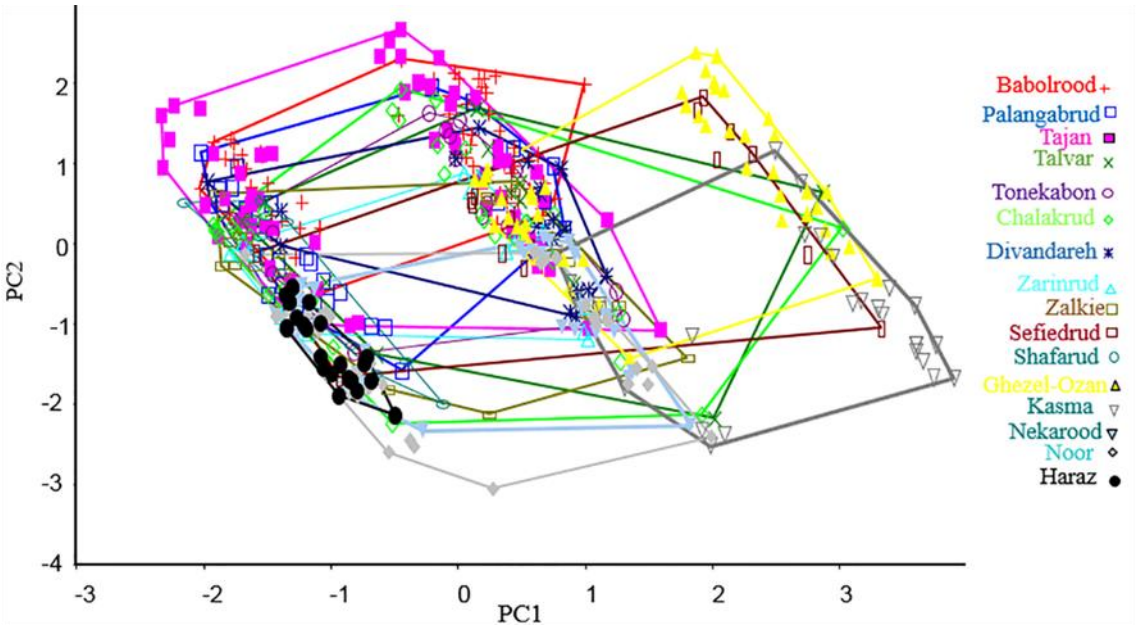

Figure 3. The result of PCA of meristic characters of the studied populations in the Caspian Sea basin.

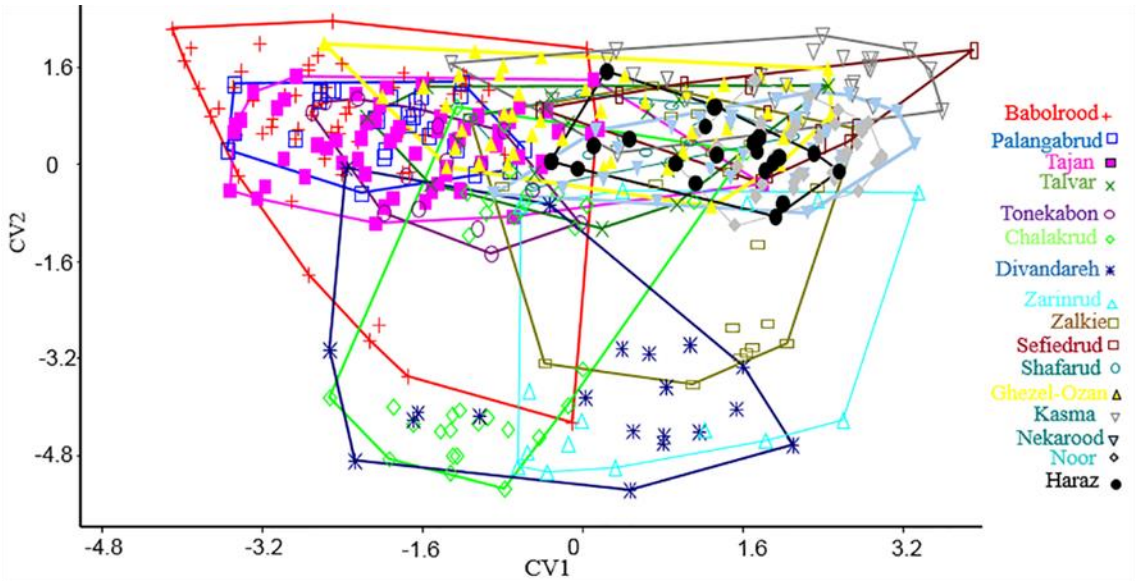

Figure 4. The results of CVA of meristic characters of the studied populations in Caspian Sea basin.

CVA showed significant differences amongst the populations and little overlap can be observed. Although some populations (Palangab, Talvar, Zari and Zalkie) are well-separated from each other by great distances (Fig. 4). In the cluster analysis, six major clusters were recognized (Fig. 5). Kasma population was the most distinct population, and other groups were Tajan+Palangab+Babol+Tonekabon, Divandareh+Talvar, Shafa+Haraz+Noor+Neka+ Zalkie, Chalak+Zari, and Sefid+ Ghezel-Ozan.

Discussion

The meristic characters of fishes such as scales, fin rays, gill rakers and pharyngeal teeth are genetically controlled, while, morphometric characters such as lengths and their ratios are highly affected by environmental factors (Keivany et al., 2016b). The final number of meristic characters on fish depends on prevailing environmental conditions during early development of the individuals. Fish populations in habitats with different environmental conditions, will

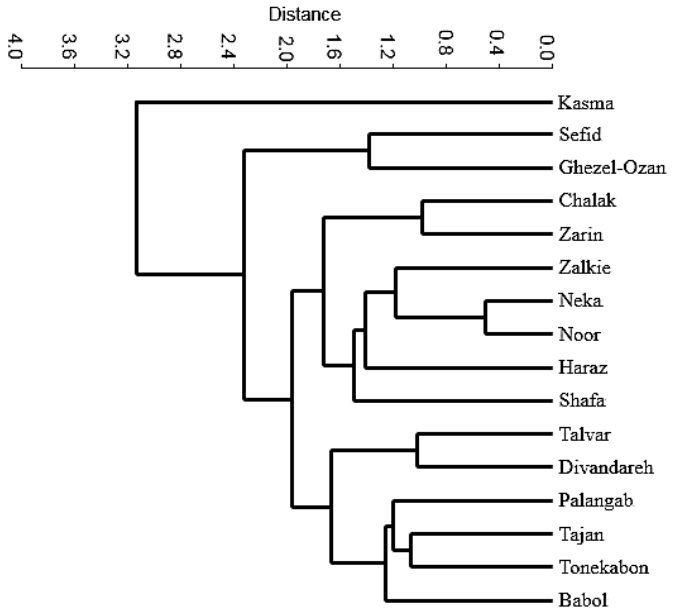

Figure 4. Cluster analysis of the studied populations of *Squalius turcicus* in the Caspian Sea basin.

show a high morphological diversity (Keivany et al., 2016c). Although there are significant differences in mean values of most meristic characters, but they are highly overlapping. It seems that genetic differentiations among the studied populations are not sufficient to fully separate the populations from each other (Keivany et al., 2012). Besides, these characters are affected by size and environmental conditions (Khara et al., 2006; Daneshvar et al., 2013). The results separated some studied populations (Such as Ghezel-Ozan, Kasma, Sefid and Talvar) based on meristic data using PCA that this method used in other studies as well (Keivany et al., 1997, 2015; Patimar et al., 2010). Also, in CVA, there were overlaps, however, some populations were separated. In cluster analysis, Divandareh River population was clustered in one group and was separated from other populations and had the highest distinction.

In the current study the dorsal spiny and soft rays were 2-3, 7-10, anal spiny and soft rays 3, 8-10, caudal fin rays 18-21, pelvic soft rays 8-9, pectoral soft rays 14-17, circumpeduncle scales 12-16, predorsal scales, 18-21, lateral line sclaes41-47, scales above LL 7-9 and scales below LL 3-5. In other studies conducted in Iran, the dorsal spines and soft rays of this species were 2-3, 7-9, anal spines anal soft rays 2-3, 7-10, caudal fin rays as 18-21, pelvic 6-9, pectoral soft rays 13-19, circumpeduncle scales 12-16, predorsal scales 18-21, lateral line scales 38-48, scales above LL 5-7 and scales below LL 7-8 (Abdoli and Naderi, 2009; Dadashpour Ahangari et al., 2011; Alizadeh et al., 2015). For *S. cephalus* in Europe, dorsal spines and soft rays were reported as 3, 8, anal soft rays 7-9, pectoral spine and soft rays 1, 14-17, pelvic spine and soft rays 2, 8, lateral line scales 42-48, scales above LL 7-9, scales below LL 3-5, (Steindachner, 1895; Karaman, 1924; Drensky, 1951; Libosvarsky, 1956; Banarescu, 1964; Dimovski and Grupce, 1972; Ivanovi, 1973; Economidis, 1974; Georgieve, 2000).

In general, the figures in this study are consistent with previous studies for this species and for *S. cephalus* complex in other regions (e.g., Mouludi-Saleh et al., 2017b). Thus, the meristic characters do not well-defined characters in *S. cephalus senso lato* populations (in Iran *S. turcicus*, *S. orientalis* and *S. berak*) due to their low variation and overlapping.

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چکیده فارسی

مقایسه ویژگی‌های شمارشی ماهی سفید رودخانه‌ای (*Squalius turcicus* De Filippi, 1865) در حوضه خزر

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چکیده:

برای مقایسه ویژگی‌های شمارشی ماهی سفید رودخانه‌ای *Squalius turcicus* در ۱۲ رودخانه حوضه خزر، ۵۳۵ نمونه صید گردید. حدود ۱۴ ویژگی شمارشی شمارش گردید. طبقه‌بندی صفات شمارشی نشان داد که اغلب نمونه‌های جمعیت‌ها دارای ۸ شعاع نرم پشتی، ۹ شعاع نرم مخرجی، ۱۹ شعاع منشعب دمی، ۱۵ شعاع نرم سینه‌ای، ۹ شعاع شکمی، ۴۷-۴۱ فلس خط جانبی، ۷-۹ فلس بالای خط جانبی، ۵-۳ فلس زیر خط جانبی، ۲۱-۱۸ فلس جلوی باله پشتی و ۱۶-۱۴ فلس دور ساقه دمی هستند. نتایج تفاوت‌های معنی‌داری ($P<0/05$) در بین همه ویژگی‌های شمارشی به جز خارهای باله پشتی، مخرجی و سینه‌ای نشان داد. آنالیز مؤلفه‌های اصلی و متغیرهای کانونی بین جمعیت‌ها همپوشانی نشان داد، گرچه برخی از جمعیت‌ها از هم جدا بودند. همچنین، آنالیز خوشه‌ای جمعیت رودخانه دیواندره را در یک خوشه جداگانه و جدای از سایر جمعیت‌ها قرار داد. در مجموع، نتایج صفات شمارشی نمی‌تواند جمعیت‌های این گونه را به خوبی از هم جدا نماید.

کلمات کلیدی: آنالیز خوشه‌ای، آزمون کولموگروف-اسمیرنو، ویژگی‌های شمارشی، ریخت‌شناسی.