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Research Article

Morphological diversity of *Cyprinion* Heckel, 1843 species (Teleostei: Cyprinidae) in Iran

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Abstract: This work aimed to study some meristic and morphometric variations among *Cyprinion* of Iran to find new morphological differences and phenotype plasticity among them. Specimens of six reported species were collected from five Iranian inland water basins. 10 meristics were counted, 12 morphometric were measured and 17 ratios were calculated. The multivariate analysis of variance/canonical variate analysis was used for group comparisons. The meristic and morphometric characters of *C. microphthalmum* and *C. watsoni* were widely overlapping and could not distinguish the species. In case of *C. kais,* it is distinguished from others by having the least head depth, the largest body depth at dorsal fin origin, the most dorsal fin base length/SL, the most pectoral fin length/SL and the most dorsal fin height/SL ratios. *Cyprinion milesi* is a very distinct species from other congeners based on having the largest head height/body depth, the least body depth/SL, the least dorsal fin base length/SL, the least pectoral fin length/SL and the least dorsal fin height/SL ratios.

Keywords: Biodiversity, Cyprinidae, Ichthyology, Inlandwater fishes, Morphology.

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Introduction

Iran harbors high biodiversity in freshwater fish and is an important biogeographical exchange region in south-west Asia as it situated between African, Oriental and Palearctic biogeographical regions (Coad 1996, 2018). The fish fauna of Iran contains 288 species in 107 genera, 28 families, 18 orders and 3 classes distributed in 19 basins. The Cyprinidae are the most diverse family distributing in all basins of Iran (Esmaeili et al. 2010; Esmaeili et al. 2017; Coad 2018). One of the most phylogeographically interesting cyprinid genus is *Cyprinion* that distributed in southern, southwestern and northwestern Asia (Bilici et al. 2016; Coad 2018; Froese & Pauly 2018).

The meaning of the genus name, *Cyprinion*, is being the diminutive of *Cyprinus* (common carp) possibly referring to the similarity of *C. macrostomum* to that of juvenile *Cyprinus carpio* (Scharpf & Lazara 2014). The members of this genus are consumed as food in western Iran, Iraq, Syria and Pakistan (Nasri 2008; Ullah et al. 2015). In Iran, this genus is distributed in western, southern and south-eastern exoreic drainages, including Tigris, Persis, Hormuz, Makran, Mashkid and also endorheic basins of Maharlu, Sistan, Jazmurian, Kerman and Lut

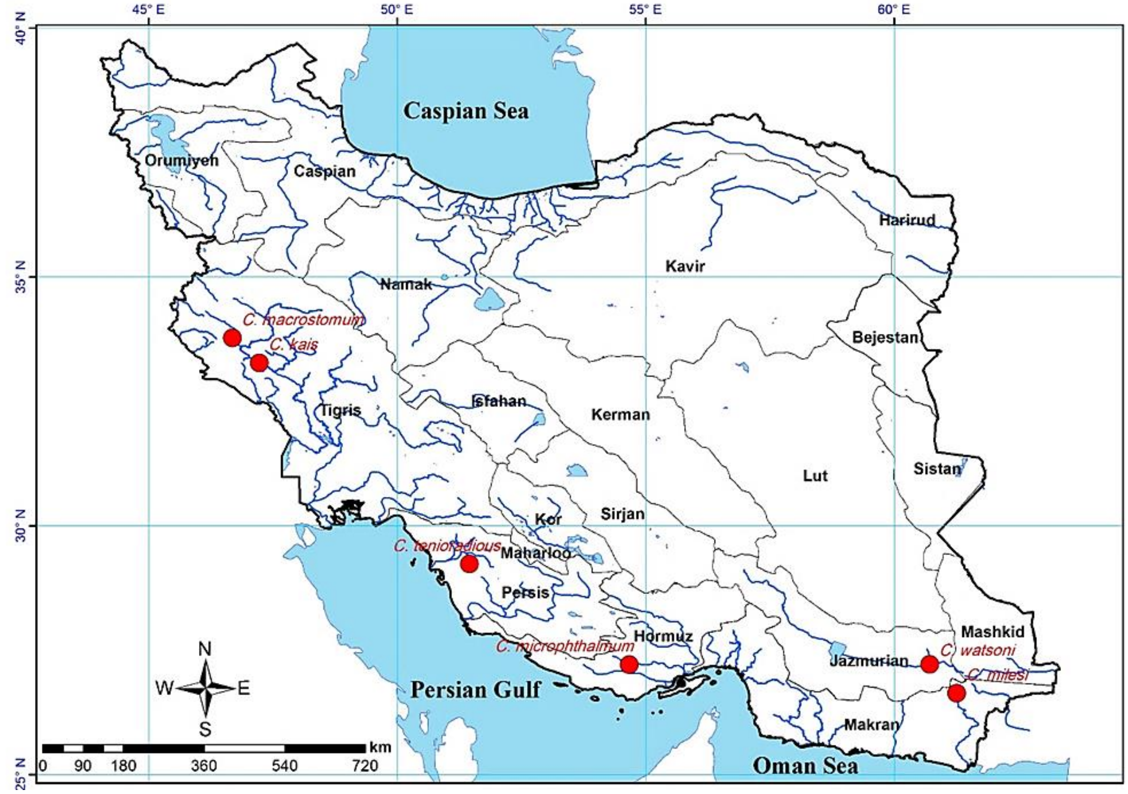

Fig.1. Map of Iran and sampling sites of *Cyprinion* species.

(Esmaeili et al. 2010; Teimori et al. 2010; Jouladeh-Roudbar et al. 2015; Keivany et al. 2016; Coad 2018).

Despite wide distribution of the genus *Cyprinion*, there is a little interspecific morphological comparison among them. Kafuku (1969) compared morphology of *C. macrostomum* and *C. kais* in Iraq based on traditional characters. The taxonomic study of *C. macrostomum* and *C. kais* revealed some morphological differences (Nasri 2008). A morphological study showed that the three species of *C. macrostomum*, *C. kais* and *C. tenuiradius* can be distinguished based on dorsal-fin rays, mouth form and lateral line scales (Banarescu & Herzig-Straschil 1995). There are some ecological (Ünlü 2006; Tutar et al. 2013; Çelik et al. 2014), biochemical (Akpinar 1999; Deúerlü & Akpinar 2002) and molecular studies that provided some basic information about this genus focused on Tigris-Euphrates and Southern Iran basins (Esmaeili & Gholamifard 2012). There is also little works on Eastern species of the genus *Cyprinion* in Pakistan (Khattak & Hafeez 1996; Shah 2002), and the studies' situation of southern species of this genus in the Arabian Peninsula is the same (Alkahem et al. 1990).

Recently some valuable osteological (Aydin et al. 2008; Nasri et al. 2013) and molecular studies (Daştan et al. 2012) on the members of this genus have been published, but still there many works need to be done about various aspects of the *Cyprinion* biology. Also some new techniques such as molecular or geometrics methods are developed in ichthyology but yet, the classical morphology is the base of many ichthyological studies (Ihssen et al. 1981; Swain & Foote 1999; Cadrin 2000). The genus *Cyprinion* as a very adoptable fish could tolerate various environmental an ecological conditions and distributed in a wide region in south and southwestern Asia (Coad 2018; Froese & Pauly 2018). *Cyprinion* fishes were named as sector mouth as they possess a broad, ventral mouths with certified keratinized edge (Howes 1982). In this group, the situation of *C. kais* and *C. milesi* is so different because there is no keratinized edge in their lower

Table 1. The sampling locations of *Cyprinion* species.

Species	Number	Coordinates	Basin	Province	River
C. kais	40	47°13'32"E 33°16'31"N	Tigris	Ilam	Seimareh (Talkhab)
C. macrostomum	313	46°40'54"E 33°46'26"N	Tigris	Ilam	Homeil
C. tenuiradius	142	51°27'19"E 29°13'57"N	Persis	Bushehr	Faryab
C. watsoni	67	60°43'02"E 27°12'48"N	Jazmurian	Sistan and Balochestan	Sarzeh Aqueduct
C. milesi	32	61°15'35"E 26°37'53"N	Makran	Sistan and Balochestan	Sarbaz
C. microphthalmum	143	54°40'09"E 27°12'28"N	Hormuz	Hormuzgan	Eelood

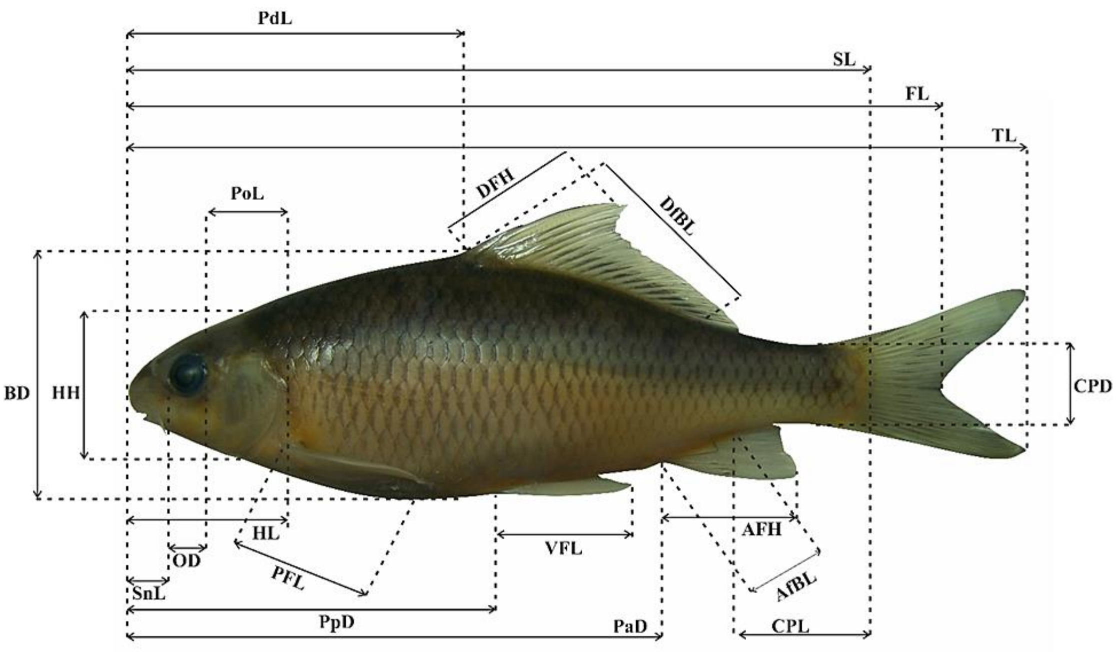

Fig.2. Diagram of morphometric measurements on *Cyprinion* fishes. (AfBL- anal fin base length; AFH- anal fin height; BD- body depth at dorsal fin origin; CPD- caudal peduncle depth; CPL- caudal peduncle length; DfBL- dorsal fin base length; DFH- dorsal fin height; FL- fork length; HH- head depth at nape; HL- head length; OD- orbital diameter; PaD- preanal distance; PdL- predorsal length; PFL- Pectoral fin length PoL- postorbital length; PpD- prepelvic distance; SL- standard length; SnL- snout length; TL- total length; VFL- ventral fin length).

jaw. Therefore, this work aimed to study some meristic and morphometric variations among *Cyprinion* fishes of Iran to find new morphological differences and phenotype plasticity among them.

Materials and Methods

A total of 737 specimens from six species of the genus *Cyprinion* were collected from five inland water basins of Iran by electrofishing device during September 2013-September 2015 (Fig. 1). Samples ranged from 32 to 313 individuals per sampling location (Table 1). Fish identification were done using Keivany et al. (2016) and Coad (2018). The fish were preserved in 4% buffered formalin after anesthetizing in 1% clove oil solution. Since *Cyprinion* does not show sexual dimorphism, sex determination was not carried out. Ten meristic characters, including branched and unbranched dorsal fin rays, branched and unbranched anal fin rays, branched pectoral fin ray, branched ventral fin ray, lateral line scales, scales above lateral line, scales below lateral line and total vertebrae were counted.

Table 2. Confusion matrix of *Cyprinion* fishes based on meristic characters.

	Species	1	2	3	4	5	6	Total
1	*C. kais*	40						40
2	*C. macrostomum*	19	225	20			1	265
3	*C. tenuiradius*	5	5	132				142
4	*C. watsoni*				63		4	67
5	*C. microphthalmum*				22		121	143
6	*C. milesi*						32	32

Twenty morphometric characters including anal fin base length; anal fin height; body depth at dorsal fin origin; caudal peduncle depth; caudal peduncle length; dorsal fin base length; dorsal fin height; fork length; head height; head length; orbital diameter; preanal length; predorsal length ; postorbital length; prepelvic distance; standard length; snout length; total length; ventral fin length; pectoral fin length were measured to the nearest 0.1mm (Fig. 2) and seventeen morphometric ratios, including head height to body depth, head length to standard length, eye diameter to head length, post orbital length to head length, snout length to head length, predorsal length to standard length, preventral length to standard length, pre anal length to standard length, body depth to standard length, pectoral fin length to standard length, pelvic fin length to standard length, dorsal fin high to standard length, dorsal fin base length to standard length, anal fin length to standard length, caudal peduncle length to standard length, caudal peduncle depth to body depth and caudal peduncle depth to standard length were calculated.

The specimens were photographed from left side at 6 megapixel resolution. linear measurements were made using ImageJ software (Abramoff et al. 2004) after calibration. Meristic counts were done using a 10X stereomicroscope. The morphometric traits and meristic counts were performed mainly as described by Coad (2018). The allometric growth effect was removed from morphometric measurements based on Elliott et al. (1995). Since meristic characters are independent of fish size (Strauss 1985; Murta 2000), the raw meristic data were used in analyses. The multivariate analysis of variance/canonical variate analysis (MANOVA/CVA) was used to investigate power of distinction among groups. All statistical analyzes were done using PAST software (Hammer 2012) at the 95% confidence limit.

Results

Meristic traits: Since the unbranched dorsal-fin ray and unbranched ana- fin ray counts were fixed in all specimens (4 and 2, respectively), the statistical analysis was not performed on them. The MANOVA/CVA showed that there were a significant differences between the studied species (Pillai trace=2.398, F=78.33, P<0.001). The pairwise Hotelling's test of the groups showed significant differences between all pairs (P<0.001). The CVA grouped all the specimens in its group at 100% succession. The confusion matrix compared the given group and their belonging to the predicted groups (Table 2). The scatterplot based on CVA (Fig. 3) showed three distinct cluster, including *C. kais*, *C. macrostomum* and *C. tenuiradius* (A), *C. watsoni* and *C. microphthalmum* (B) and *C. milesi* (C). According to CVA loading, the most important factors clustering the fishes were BrD, BrA and PfR in CV1 and LL in CV2 (Fig. 3). Among meristic characters, the branched dorsal-fin ray number well-separated group (A) from all others by having more than 11 branched fin rays in dorsal-fin versus less than 12, but others showed wide overlaps (Table 4). In the two other groups, *C. milesi* can be distinguished from *C. watsoni* and *C. microphthalmum* based on the lowest number of BrD (9.41±0.49 vs. >10), BrA (6.3±0.47, vs. ≥6.5), VfR (6.4±0.5, vs. ≥6.87) and upper numbers of PfR

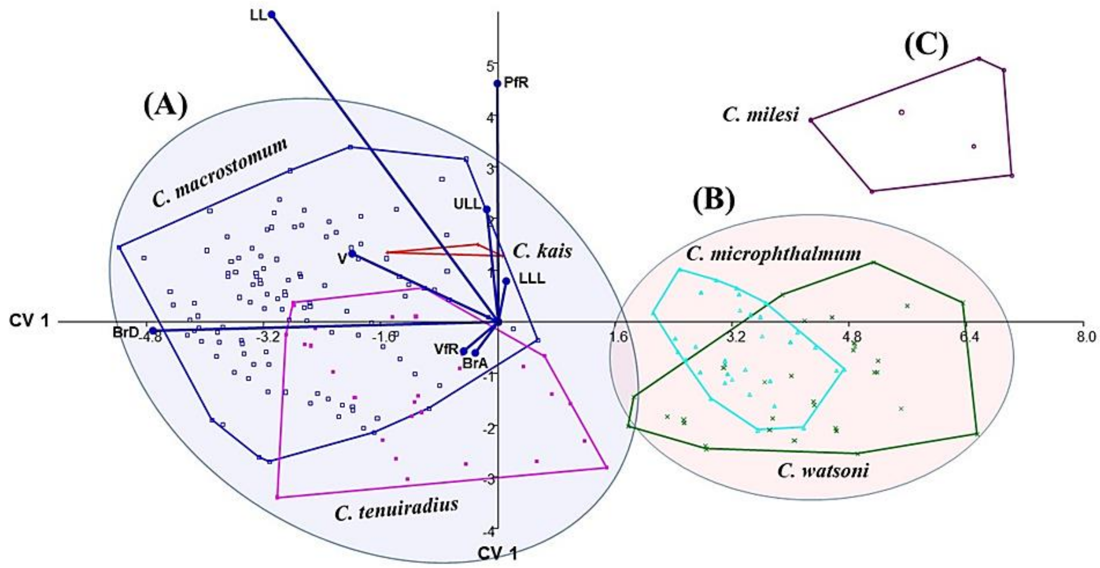

Fig.3. Canonical Variates Analysis Biplot (scatter plot and loading plot) of the meristic characters. (**BrD-** branched dorsal fin ray, **BrA-** branched anal fin ray, **PfR-** pectoral fin ray, **VfR-** ventral fin ray, **LL-** lateral lime scales, **ULL-** scale above lateral line, **LLL-** scale below lateral line, **V-** total vertebra).

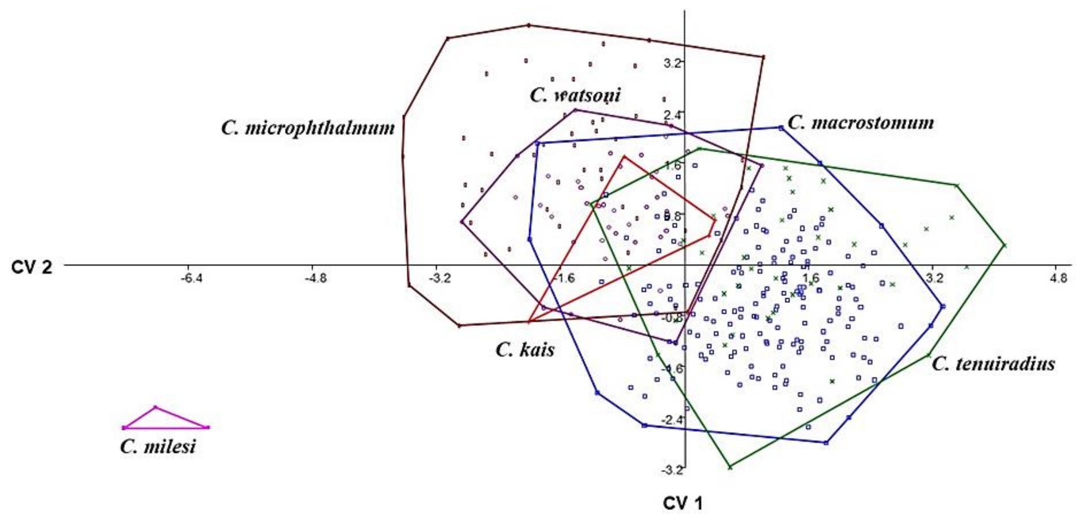

Fig.4. Scatter plot of standardized morphological measurements based on Canonical Variates Analysis.

(13.44±0.5, vs. ≤10.3) and 5 LLL (Table 3).

Morphometric traits: The regressions for canonical variates 1 and 2 of discriminate analysis against standard length were not significant at $P<0.001$ ($r^2=0.009$, df=735 and $r^2=0$, df=735, respectively) indicating that size effects had been removed from morphometric measurements successfully. The MANOVA/CVA of standardized morphological measurements showed significant differences between species (Pillai trace=2.384, F=35.33, $P<0.001$). The pairwise Hotelling's test of the species showed significant differences between all pairs ($P<0.001$). The scatter plot depicted based on the first two CVs clustered *Cyprinion* species into three distinct groups (Fig. 4). All species except *C. milesi*, showed a large overlapping. According to the CVA loadings, the morphological measurements that showed the most variances between groups were OD, SnL, HH and DfBL in CV1 and OD, PdL and PpD in CV2. *Cyprinion milesi* was placed distantly

Table 3. Morphometry of *Cyprinion* populations of Iran. The size effects were removed based on Elliott et al. (1995).

Species	*C. kais*	*C. macrostomum*	*C. tenuiradius*	*C. watsoni*	*C. microphthalmum*	*C. milesi*
BD	27.8±0.5 27.22-28.52	26.8±2 21.20-31.77	26.4±2.4 20.20-30.92	24.9±2.1 19.81-29.81	24.6±1.8 21.43-22.34	21.8±0.4 21.45-28.05
HL	20.4±1.5 17.92-21.60	20±2 14.48-25.03	20.0±1.8 15.42-23.12	20±1.7 17.19-24.83	19.7±2.2 22.51-23.14	22.8±0.2 15.34-25.59
SnL	5.5±0.5 4.73-5.83	6±1.3 3.48-9.07	5.8±0.9 3.59-7.49	6.4±0.9 5.09-9.10	5.9±1.3 5.50-5.77	5.7±0.1 3.52-8.50
PoL	10.7±0.6 10.07-11.7	10.3±1.4 7.34-15.58	10.2±0.8 7.75-11.94	10.4±1.2 8.50-13.90	10.2±1.4 11.93-12.64	12.3±0.3 7.55-13.67
OD	3.8±0.2 3.63-4.08	4.3±0.6 2.76-5.83	4.0±0.6 2.46-5.23	3.7±0.5 2.90-4.85	3.9±0.6 5.16-5.48	5.4±0.1 2.64-5.14
PdL	47.5±1.6 45.71-49.74	44.5±1.7 39.86-50.10	44.8±0.4 40.75-48.31	45.3±1.3 42.32-48.82	46.3±1.3 45.19-45.82	45.5±0.3 44.13-49.15
PpD	48.7±2.1 45.71-49.94	45.9±1.6 40.49-50.44	46.1±1.8 42.68-49.92	46.2±2.1 40.89-51.06	45.5±2 50.75-50.13	51.5±0.6 40.96-52.01
PaD	68.9±2 66.79-71.18	66.1±1.9 60.33-72.83	65.6±1.9 61.73-68.95	65.9±1.7 62.18-69.27	65.9±2.1 68.51-68.93	68.8±0.2 61.63-71.51
DFH	17.7±0.9 16.50-18.96	17.1±1.8 12.27-20.68	16.9±1.7 13.59-19.70	14.6±1.6 10.83-18.93	14.6±1.3 13.83-14.07	13.9±0.1 11.13-17.31
DfBL	25.6±2 22.79-28.72	24.4±2.9 17.82-32.82	24.6±1.8 20.18-29.22	22.2±1.5 16.49-26.47	21.1±2.2 14.73-15.20	15±0.2 16.51-26.25
AFH	14.6±1 13.22-15.91	15.2±1.7 10.87-20.25	15.8±2.4 10.36-20.19	14.1±2.1 9.41-18.78	16.2±1.5 12.36-12.76	12.5±0.2 12.31-18.26
AfBL	9.3±0.6 8.68-10.34	8.5±1.4 5.68-12.45	9.2±2.1 3.84-13.06	9.7±1.3 7.42-13.50	9.5±1 8.30-9.02	8.6±0.3 7.73-12.27
VFL	14.3±0.3 13.94-14.75	15.3±1.4 10.89-18.67	15.8±1.3 10.22-17.55	13.9±1.6 10.72-19.02	13.8±1.4 11.67-13.65	12.4±0.8 10.39-17.91
PFL	18.6±0.4 17.94-19.03	17.7±1.5 13.96-21.04	17.8±1.9 12.33-21.57	16.1±1.8 12.35-20.18	15.6±2.8 17.05-17.53	17.3±0.2 10.11-20.84
CPL	13.5±1 12.59-15.11	16.6±4.6 8.92-29.18	16.8±1.8 11.78-20.45	16.1±1 13.34-18.46	15.5±1.7 13.33-14.51	13.8±0.5 12.04-18.55
CPD	9.3±0.3 8.89-9.64	10.6±2.7 7.15-18.84	10.1±0.8 8.17-11.92	9.6±0.7 8.32-10.59	9.3±0.7 8.29-8.41	8.3±0.1 8.15-10.43
HH	16.2±0.7 15.41-17.10	16.9±1 11.96-19.35	16.9±0.9 14.68-18.93	15.2±0.9 12.67-17.37	15.6±1.7 15.97-16.55	16.3±0.2 12.96-18.20

AfBL- Anal fin base length; **AFH-** Anal fin height; **BD-** Body depth; **CPD-** Caudal peduncle depth; **CPL-** Caudal peduncle length; **DfBL-** Dorsal fin base length; **DFH-** Dorsal fin height; **HH-** Head height; **HL-** Head length; **OD-** Orbital diameter; **PFL-** Pectoral fin length; **PoL-** Postorbital length; **PAD-** Preanal distance; **PdL-** Predorsal distance; **PpD-** prepelvic distance; **SnL-** Snout length; **SL-** Standard length; **VFL-** Ventral fin length.

from all other species having the least VFL, DfBL, BD, DFH and biggest POL, OD, PpD and HL. According to the standardized morphological measurements, there were a wide overlap between the five other species, but there was an apparent pattern to distinguish them. According to the Figure 4 and Table 4, *C. macrostomum*, *C. kais* and *C. tenuiradius* can be distinguished from *C. watsoni*

Table 4. Frequency of meristic features of *Cyprinion* populations of Iran.

Species	Branched dorsal fin rays								Branched anal fin rays				
	Range	Mean±Sd	Frequency %						Range	Mean±Sd	Frequency %		
			9	10	11	12	13	14			6	7	8
C. kais	13	13					100		7	7		100	
C. macrostomum	12-14	13.52±0.67				10	28	62	6-8	6.76±0.49	27	70	3
C. tenuiradius	12-14	13.2±0.7				17	48	35	6-8	6.9±0.4	10	82	8
C. watsoni	9-11	10±0.63	16	60	24				6-7	6.54±0.5	46	54	
C. microphthalmum	10-11	10.7±0.43		25	75				6-8	6.7±0.46	24	74	2
C. milesi	9-10	9.41±0.499	59	41					6-7	6.31±0.471	69	31	

Species	Pectoral fin rays							Ventral fin rays				
	Range	Mean±Sd	Frequency %					Range	Mean±Sd	Frequency %		
			10	11	12	13	14			6	7	8
C. kais	12-13	12.75±0.439			25	75		7-8	7.75±0.439		25	75
C. macrostomum	10-13	11.63±0.77	5	41	41	13		6-8	7.5±0.57	3	43	54
C. tenuiradius	10-13	11.3±0.81	19	36	42	3		6-8	7.4±0.59	6	48	46
C. watsoni	10-12	10.3±0.53	70	27	3			6-8	6.87±0.38	15	84	1
C. microphthalmum	10-12	11.3±0.73	17	40	43			7-8	7.7±0.47		33	67
C. milesi	13-14	13.44±0.504				56	44	6-7	6.44±0.504	56	44	

Species	**Lateral line Scales**									**Scales below lateral line**			
	Range	Mean±Sd	Frequency %							Range	Mean±Sd	Frequency%	
			35	36	37	38	39	40	41			4	5
C. kais	39	39					100			4	4	100	
C. macrostomum	37-41	39.8±1.1			3	11	17	36	33	4-5	4.3±0.44	74	26
C. tenuiradius	36-39	37.3±1		32	18	39	11			4-5	4.4±0.5	61	32
C. watsoni	35-38	35.9±1	43	27	21	9				4	4	100	
C. microphthalmum	37-39	37.8±0.82			46	28	26			4-5	4.3±0.48	62	38
C. milesi	37-38	37.72±0.457			28	72				5	5		100

Species	**Scales above lateral line**					**Total Vertebrae**						
	Range	Mean±Sd	Frequency %			Range	Mean±Sd	Frequency %				
			6	7	8			36	37	38	39	40
C. kais	7	7		100		37-39	38.3±0.698		23	52	25	
C. macrostomum	6-8	7.2±0.6	11	60	29	37-40	38.5±0.94		12	43	26	19
C. tenuiradius	6-7	6.6±0.5	37	63		38-40	38.3±0.57			79	15	6
C. watsoni	6-7	6.7±0.44	27	73		36-40	37.16±1.6	63	3	8	9	18
C. microphthalmum	6-8	6.9±0.42	15	81	4	36-40	36.9±1.2	55	11	24	3	7
C. milesi	7-8	7.72±0.457		28	72	37-39	37.69±0.693		44	44	12	

and *C. microphthalmum* by having greater BD, DFH, DfBL and VFL. Beside these general pattern, there are some unique characters for the species. *Cyprinion kais* can be distinguished from all others species by having greater BD, DFH, DfBL, PFL and shorter CPL, *C. tenuiradius* by the largest VFL, *C. microphthalmum* due to the least PpD, and *C. watsoni* by the largest VFL.

Morphological ratios: MANOVA/CVA of morphological ratios showed significant differences between all pairs based on the pairwise Hotelling's test (Pillai trace=1.916, F=24.52, $P<0.001$). The biplot depicted based on CV1 and CV2 clustered *Cyprinion* species into three distinct groups (Fig. 5). There was apparent overlap between all *Cyprinion* species but *C. milesi* (group C) that was well-separated from all others. Other species were divided into two groups; *C. macrostomum*, *C. tenuiradius* and *C. kais* (group A) and *C. watsoni* and *C. microphthalmum* (group B). According to CVA loadings (Fig. 5), the most important characters for this discrimination were Z13, Z1, Z9, Z6, Z10 and Z12, respectively. *Cyprinion milesi* can be distinguished from other species based on having the

Table 5. Mean and standard deviations of the 17 morphological ratios of *Cyprinion* populations of Iran (Z1- Head height to body depth, Z2- head length to standard length, Z3- eye diameter to head length, Z4- post orbital length to head length, Z5- snout length to head length, Z6- predorsal length to standard length, Z7- preventral length to standard length, Z8- pre anal length to standard length, Z9- body depth to standard length, Z10- pectoral fin length to standard length, Z11- pelvic fin length to standard length, Z12- dorsal fin height to standard length, Z13- dorsal fin base length to standard length, Z14- anal fin length to standard length, Z15- caudal peduncle length to standard length, Z16- caudal peduncle depth to body depth and Z17- caudal peduncle depth to standard length).

Species	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8
C. kais	54.7±1.2	22.2±1.6	17.3±2.2	51.3±3.9	28.6±1.1	52.1±1.6	53.4±2.3	77.3±2.3
C. macrostomum	62.1±6	22.3±2.3	20.9±3.9	50.8±4.7	30.3±5.2	49.7±2.1	51.3±2.5	74.4±2.3
C. tenuiradius	67.4±6.3	23.4±2.4	21.8±4	52.5±4	27.7±3.9	51.8±1.9	53.4±2.6	74.4±2.3
C. watsoni	64.6±5.7	23.4±1.9	19.9±2.5	53.2±3.7	30.3±3.1	52.3±1.5	53.6±2.9	74.7±2
C. microphthalmum	66.7±7.5	22.9±2.5	21.7±4.8	52.9±3.7	28.5±4.6	53.4±1.4	52.5±2.4	74.7±2.4
C. milesi	73.9±0.5	25.5±0.4	23±0.4	53.7±1.5	25.2±0.3	51±0.2	57.7±0.5	77.5±0.2

Species	Z9	Z10	Z11	Z12	Z13	Z14	Z15	Z16	Z17
C. kais	32.6±0.7	21.6±0.5	16.8±0.3	20±1	29.7±2.4	10.5±0.7	16.2±1.1	34.4±1.3	11.2±0.3
C. macrostomum	30.7±2	20.1±1.3	17.6±1.6	19.3±2	27.8±3.1	9.6±1.6	19.3±5.9	40.3±12	12.2±3.4
C. tenuiradius	28.9±2.6	19.6±2	17.2±1.5	19±2	27.2±2.2	10.3±2.4	17.9±1.8	37.5±3.7	10.7±0.7
C. watsoni	27.3±2.1	17.8±2	15.1±1.8	16.4±1.8	24.3±1.5	10.9±1.4	17.2±1.2	37.7±2.3	10.3±0.5
C. microphthalmum	27±2.1	17.3±3	15.1±1.5	16.5±1.4	23.3±2.4	10.7±1.2	16.6±1.7	37.2±3.2	10±0.6
C. milesi	24.8±0.4	19.6±0.2	14.2±0.9	15.8±0.1	17.1±0.2	9.8±0.4	15.8±0.5	38.6±0.4	9.6±0.1

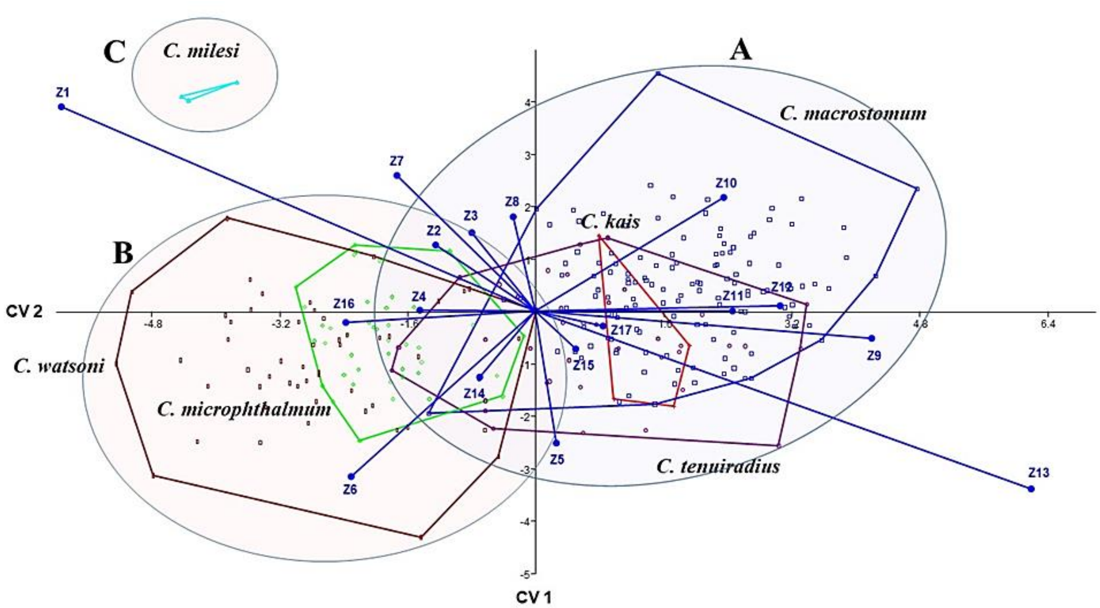

Fig.5. Biplot (scatter plot and loading plot) of morphological ratios based on Canonical Variates Analysis.

biggest head high/body depth and the lowest dorsal fin base length/SL, body depth/SL, dorsal fin high/SL (Table 3). *Cyprinion kais* among group (A) can be recognized based on having the least head high/body depth and the biggest dorsal fin base length/SL, body depth/SL, pectoral fin length/SL and dorsal fin high/SL. The two groups A and B of *Cyprinion* can be separated based on Ratios Z13, Z9, Z10 and Z12 that in all cases group A has higher amounts and there are wide overlap between them in all other ratios (Table 3).

The results can be summarized as; *C. macrostomum* group distinguished from the other two groups by having more than 11 simple dorsal fin rays (vs. less than 12), dorsa-fin base length/SL greater than 27 (vs. less than 24.3), body depth/SL more than 28.9 (vs. less than 27.3), pectoral fin length/SL more than 19.6 (vs. less than 19.6), dorsal fin high/SL more than 19 (vs. less than 16.5). *Cyprinion kais* in group *C. macrostomum* can be distinguished by having the least head height/body depth (54.7) and the most dorsal fin base length/SL (29.7), the most body depth/SL (32.6), the most pectoral fin length/SL (21.6) and the most dorsal fin height/SL (20). *Cyprinion milesi* can be distinguished from all other congeners by having the most head height/body depth (73.9) and the least dorsal fin base length/SL (17.1), body depth/SL (24.8) and dorsal fin height/SL (15.8). All other characters are not distinctive among species.

Discussion

Morphometric and meristic characters are practical aspects of fish morphology definition of new species (Strauss & Bond 1990) and species identification (Nelson et al. 2016). In addition, fish morphology can affect their reproductive activities, swimming performance, nutrition and camouflage activities etc. (Sfakiotakis et al. 1998). Due to allometry, morphological measurements change through ontogeny (Elliott et al. 1995), but meristic characters do not related to size (Helfman et al. 2009), therefore it is important to remove size effects from morphometric measurements before their analysis.

Banarescu & Herzig-Straschil (1995) reviewed five members of the *Cyprinion* genus based on four morphological characters and divided them into two distinct groups (*C. macrostomum* and *C. microphthalmum-watsoni*). In this study, *C. milesi* was well-separated from the others as a distinct group. Morphological variation is common even within populations of a single species (Elliott et al. 1995) that can be controlled by both genetic and environment factors (Helfman et al. 2009). Phenotype plasticity help organisms adopting to their ecosystem to survive and well exploiting their environment (Whitman & Agrawal 2009). Most of eastern and south-eastern rivers of Iran (e.g., Sarbaz and Nahang rivers in this study) are low-water and temporary. They would be dried in parts of the route. Fishes inhabitants of these rivers are always faced to environmental selective pressures. Beside of direct effects, environmental pressures can affect the abundance and diversity of food items e.g. invertebrates and plant organisms. Therefore, fish have to adapt changing environment. Food availability is one of the important factors that can affect fish morphology particularly feeding related characters (Nicieza 1995). These adaptations may be morphological, behavioral, physiological etc. Some intra-specific morphological studies revealed the great ability of genus *Cyprinion* for adaptation responses to various environmental conditions (Al-Habbib & Al-Habbib 1979; Nasri et al. 2014). Such an ability was confirmed about some other fishes *Alburnoides eichwaldii* (Eagderi et al. 2013) and *Aphanius sophiae* (Eagderi & Kamal 2013). On the other side, western and south-western rivers of Iran are usually permanent. Most of these rivers are rich and have a high biodiversity (Coad 2018).

Shape of organisms can be affected by environmental factors via natural selection (Chan 2001). *Cyprinion macrostomum* group that live in Tigris-Euphrates basins have more dorsal-fin branched rays, a deeper body, a longer dorsal fin base, longer pectoral fin, higher dorsal fin and longer dorsal fin base than *C. watsoni-microphthalmum* group. One of the best models for phenotypic plasticity are stickleback fishes. They are originally marine fishes that colonized separately in freshwater and marine ecosystems. The freshwater populations are morphologically diverse showing their ability to adapt local selection pressures, but marine populations are uniform globally that reflects the stability of marine environments (Robinson & Wilson 1994). In case of the two sympatric species

C. macrostomum and *C. kais*, it seems that the most powerful selective factor is food competition, since all other environmental factors are the same (Robinson & Wilson 1994). The mouth form, as a trophic characters in *C. kais* (Coad 2018) can be considered as a developmental plasticity as well as some related morphological adaptations to feed on benthic invertebrates (the least head height and the deeper body, longer pectoral-fin, dorsa-fin height and dorsal fin base length). Some authors believed that these species are synonym (Berg 1949) but new molecular, osteological and morphological data rejected their synonymy (Banarescu & Herzig-Straschil 1995; Daştan et al. 2012; Nasri et al. 2013; Coad 2018). The present study emphasizes on *C. kais* validity based on five morphological characters.

According to this study, the two species *C. macrostomum* and *C. tenuiradius* cannot be distinguished based on meristic or morphometric characters and the only character that can distinguish *C. tenuiradius* is having slightly ossified last unbranched dorsal fin ray vs. strongly ossified and serrated in *C. macrostomum* (Coad 2018; Froese & Pauly 2018). Dorsal fin resistance against water current during swimming and maneuvering is supported by stoutness of the last unbranched dorsal-fin ray. It seems that in *C. tenuiradius* living in low current rivers in southern Iran, this character is not needed. The common ancestor of *Cyprinion* appeared from East of Iran (Nasri 2015), thus it can be concluded that increasing the number of dorsal-fin rays is an synapomorphy for *C. macrostomum* group in response to increasing water current and appearing an stout dorsal unbranched ray is an synapomorphy for *C. kais* and *C. macrostomum*.

In case of southern and south-eastern species, there are some common distinctive characters like lower number of dorsal fin rays, lower body depth, lower pectoral fin length, lower dorsal fin height and lower dorsal fin base length. *Cyprinion milesi* can be distinguished from other congeners based on its unique oblique mouth form (Coad 2018; Froese & Pauly 2018). As the etymology of *C. microphthalmum* implies, the eye diameter in this fish is the least (Scharpf & Lazara 2014), but in this study there is no distinctive character distinguishing *C. microphthalmum* from *C. watsoni*.

The osteological structures relating to feeding can be responses to selective pressures (Gregory 1933) as *C. milesi* mainly relays on aquatic invertebrates for food (Authors' unpublished data). The greater head height/SL in *C. milesi* can be related to its adaptation to predatory behavior. Other characters like the least body depth can simplify maneuvering near bottom and the shortest pectoral fin, shortest dorsal fin height and the shortest dorsal-fin base length all supporting the predatory activities (Robinson & Wilson 1994).
The meristic and morphological characters of *C. microphthalmum* and *C. watsoni* are widely overlapping and they cannot be distinguished using a unique character. In case of *C. kais*, there are some morphometric ratios that can well distinguish *C. kais* from the others, i.e. the least head height/body depth, the biggest body depth/SL, the most dorsal fin base length/SL, the most pectoral fin length/SL and the most dorsal fin height/SL. Finally, it was revealed that *C. milesi* is a very distinct species from other congeners based on having the biggest head height/body depth and the least body depth/SL, the least dorsal fin base length/SL, the least pectoral fin length/SL and the least dorsal fin height/SL.

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مقاله پژوهشی

تنوع ریختی ماهیان جنس *Cyprinion* **Heckel, 1843** (کپورماهیان) در ایران

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چکیده: این مطالعه با هدف بررسی تغییرات صفات شمارشی و اندازشی بین گونه های جنس *Cyprinion* در ایران به‌منظور یافتن تفاوت‌های ریختی جدید و انعطاف‌پذیری ریختی بین آن‌ها به اجرا درآمد. نمونه‌های شش گونه متعلق به این جنس از پنج حوضه آبریز ایران به‌منظور تعیین تفاوت‌های ریختی بالقوه مورد بررسی قرار گرفت. تعداد ۱۰ صفت شمارشی، ۱۲ صفت اندازشی و ۱۷ صفت نسبی مورد تجزیه‌وتحلیل قرار گرفت. به‌منظور مقایسه بین گروه‌های مورد مطالعه، از روش آنالیز واریانس چندمتغیره تجزیه‌وتحلیل تغییرات متعارف (MANOVA/CVA) استفاده شد. در این مطالعه صفات شمارشی و اندازشی گونه‌های *C. microphthalmum* و *C. watsoni* هم‌پوشانی بالایی را نشان داده و غیرقابل تفکیک بودند. گونه *C. kais* بر اساس داشتن کمترین نسبت ارتفاع سر به ارتفاع بدن، بیشترین نسبت ارتفاع بدن به طول استاندارد، بیشترین نسبت طول قاعده باله پشتی به طول استاندارد، بیشترین نسبت طول باله سینه‌ای به طول استاندارد و بیشترین نسبت ارتفاع باله پشتی به طول استاندارد قابل تمایز بود. گونه *C. milesi* بر اساس داشتن بیشترین نسبت ارتفاع سر به ارتفاع بدن، کمترین نسبت ارتفاع بدن به طول استاندارد کمترین نسبت طول قاعده باله‌ی پشتی به طول استاندارد، کمترین نسبت طول باله سینه‌ای به طول استاندارد و کمترین نسبت ارتفاع باله پشتی به طول استاندارد، از سایر گونه‌های جنس *Cyprinion* قابل تمایز است.

کلمات‌کلیدی: تنوع زیستی، کپورماهیان، ماهی‌شناسی، آب‌های داخلی، ریخت‌شناسی.