Morphometrics studies of Mahisefid (*Rutilus frisii kutum,* Kamensky, 1901) from selected rivers in the southern Caspian Sea

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Abstract

Mahisefid, *Rutilus frisii kutum*, is a cyprinid fish which is distributed from Turkmenistan to Azerbaijan along the Caspian Sea. It is one of the economically important fish in the region. As part of the Iranian Fisheries Company's policy to improve the stocks of this species, every year, fingerling of Mahisefid are released into the southern basin of the Caspian Sea. The main objective of this study was to determine populations in different of rivers. In total, 387 fish were collected from four rivers, including Lemir, Sefidrood, Shirrood and Tajan, where this fish migrates for spawning, in spring 2005. Thirteen conventional morphometric factors, 13 ratio and 12 Truss morphometrics were measured and calculated in this study. Conventional and Truss morphometric data were analyzed using two-way ANOVA Principal Component Analysis and discriminant. Average of coefficient of variation (CV%) of morphometric in males was 14.95, 10.28, 17.47 and 16.56 and in females was 21.35, 19.74, 18.25, and 19.74 in Lemir, Sefidrood, Shirrood and Tajan River, respectively, showing that all morphometric characters were significantly different (P<0.05) among four sampling sites (populations). The first component of morphometrics 44.32% in males and 68.94% in females were positive, indicating that the conventional morphometric was good descriptor of the body shape variation among the populations, especially in females. The total cumulative variances were 76.6% and 87.8% in males and females, respectively, suggesting that this can be considered as a useful discriminator. The total cumulative variances were 64.27% and 64.21% in males and females, respectively. The first component of truss was 87.7% and 81.3% of the total variance, in males and females, respectively. The results of the present study suggest that each sampling site represents independent population in each river.

Keywords: Conventional Morphometric, Truss Morphometric, *Rutilus frisii kutum*, Principal Component Analysis (PCA), Mahisefid, Caspian Sea

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Introduction

Mahisefid (*Rutilus frisii kutum*) is a cyprinid fish, distributing along the Caspian Sea, from Atrak River (Turkmenistan) to Kura River (Azerbaijan) (Kazancheev, 1981). This fish is one of the commercially important fishes in the south of the Caspian Sea (Ebrahimi, 2001; Salehi, 2002). Iranian fish hatcheries release more than 200 million fingerlings every year to improve the stocks (Abdolhay, 1997; Abdolhay & Tahori, 2006). The total catch of Mahisefid in Iran ranges from 10,000 to 18,000 ton per year (Razavi Sayad, 1995,1999; Abdolmaleki, 2006).

Mahisefid broodstocks migrate to several rivers for spawning, where broodstocks are caught and induced for spawning, then eggs are stripped, fertilized and transferred to the hatcheries to develop to fingerling larvae. Fingerlings (approximately (1g, 5cm) are released into the rivers (Abdolhay & Tahori, 2006). Several rivers flowing to the Caspian Sea are very important for fish migration. Thus, this long coastline is expected to have numerous subdivisions of populations of Mahisefid.

There are some evidences of morphological differences among geographically different populations. Conventional and Truss morphometrics are normally used to describe morphological variations among different populations of a species. Truss morphometry has been widely used especially for stock differentiation (Gary & Richard, 1987; Corti *et al*., 1988; Li *et al*., 1993; Cardin *et al*., 1999; Dynes *et al*., 1999; Bouton *et al*., 2002; Silva, 2003; Cramon-Taubadel *et al*., 2005; Heras *et al*., 2006; Keeley *et al*., 2006; Turan *et al*., 2006; Tzeng *et al*., 2007). Daud *et al.* (2005) used 15 conventional morphometric and 28 Truss morphometrics to cluster Malaysian Oxudercine goby (*Boleophthalmus boddari*) into five populations. Two populations of bream (*Abramis brama*) in the Caspian Sea and Aras Dam were clustered based on 40 morphometric characters (Khara *et al*., 2007) also Akbarzadeh (2006) reported that there were different populations of pikeperch in the south of the Caspian Sea (Anzali Lagoon, west and east Guilan population) and Aras Dam based on 16 conventional and 5 Truss morphometrics. The objective of the present study was to investigate morphometric variations among different river populations of Mahisefid in the south of the Caspian Sea.

Materials and methods

In spring 2005, a total of 387 random samples of Mahisefid (males and females) were collected from four different rivers, including Lemir, Sefidrood, Shirrood and Tajan (Fig. 1), where the fish migrate for spawning with the distance of 155, 120 and 167km between Lemir to Sefidrood, Sefidrood to Shirrood and Shirrood to Tajan, respectively (a total distance of 992km). The body measurements were taken using vernier calipers to the nearest 0.01cm for each individual during the spawning season. Males were identified based on the presence of the epithelial tubercles on the body and head. Fourteen selected conventional morphometric data were taken for each sample (Fig. 2) TL = Total length (distance from premaxillary to hind of caudal fin), FL = Fork length (distance from premaxillary to caudal fin), BW = Body weight, HL = Head length, HD = Head depth, HDE = Head depth at center of eyes, SNL = Snout length, PDL = The distance from spinous of pectoral fin to origin of dorsal fin, DNS = Distance from nostril to snout, DTE = Distance between two eyes (dorsal), DES = Distance from eye to snout, CPL = Caudal peduncle length (distance from upper to lower caudal fin), PL = Predorsal length (distance from spinous of pectoral fin to spinous of dorsal fin), MW = Mouth width (across the mouth). To minimize errors, all morphometric data were transformed into ratio to TL or FL.

For Truss morphometric, 12 landmarks were selected based on the methods described by Strauss and Bookstein (1982). All measurements were taken on the left side of the fish (Fig. 3).

Conventional, Truss morphometric data and ratio were analyzed by Two-way ANOVA to determine the differences between males and females among population from four rivers. Principal Component Analysis (PCA) and discriminate were carried out on conventional, Truss morphometric data and ratio using SPSS version 15 (Corti *et al.,* 1988). To reduce the allometric effect and make the results more comparable, each measurement was expressed as ratio to fork length.

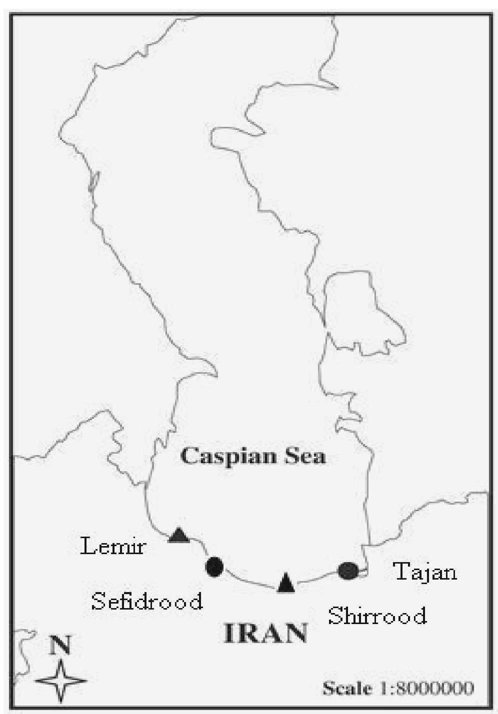
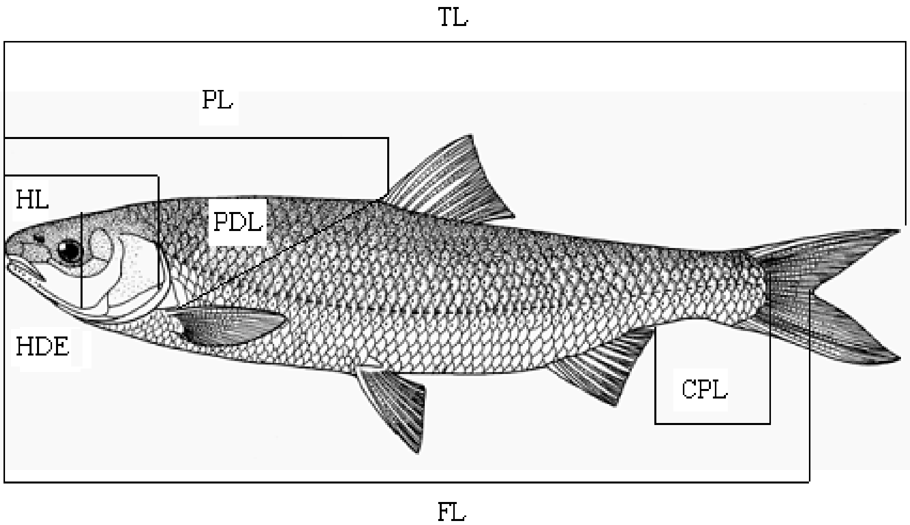


Figure 1: Sampling stations of Mahisefid in the south of Caspian Sea



TL = Total length (distance from premaxillary to hind of caudal fin)
SL = Standard length (distance from premaxillary to base of caudal fin)
FL = Fork length (distance from premaxillary to caudal fin)
BW = Body weight
HL = Head length (distance from premaxillary to end of caudal fin)
HD = Head depth
HDE = Head depth at center of eyes
SNL = Snout length
PDL = the distance from spinous of pectoral fin to origin of dorsal fin
DNS = Distance from nostril to snout
DTE = Distance between two eyes (dorsal)
DES = Distance from eye to snout
CPL = Caudal peduncle Length (distance from upper to lower caudal fin)
PL = Predorsal length (distance from spinous of pectoral fin to spinous of dorsal fin)
MW = Mouth width (across the mouth)

Figure 2: Morphometric characters used for Mahisefid

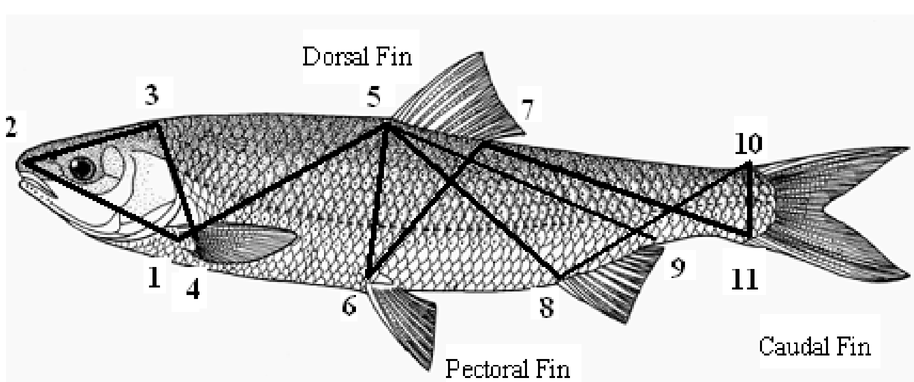


Figure 3: The body landmarks used for the Truss morphometric characters in the present study

Results

The total length of all samples ranged from 30 to 66cm with a mean of 42.45±7.2cm, the standard length ranged from 29.2 to 52.5cm with a mean 43.13± 6.7cm and the fork length ranged from 27 to 60cm with a mean of 38.66cm (Table 1). In males, the Lemir River populations consisted smaller individuals (mean 35.9±3.7cm in TL) than those in other rivers while samples from Shirrood had the biggest individuals (mean 41.30±6.34cm in TL). However, in females, the Sefidrood River population had smaller individuals (mean 43.54±6.8cm in TL), and similarly Shirrood River were the biggest (mean 47.59±7.9cm in TL). The weight of female was significantly higher than that in males ($P<0.05$; Table 1).

Average of coefficient of variation (CV %) of morphometric in males was 14.95, 10.28, 17.47 and 16.56, in Lemir, Sefidrood, Shirrood and Tajan, respectively. Average of coefficient of variation (CV%) of ratio in males was 12.04, 7.60, 5.88 and 16.06 in Lemir, Sefidrood, Shirrood and Tajan, respectively. Average of coefficient of variation (CV%) of Truss morphometric in males was 16.68, 8.66, 17.37 and 12.67 in Lemir, Sefidrood, Shirrood and Tajan, respectively.

Average of coefficient of variation (CV%) morphometric in females was 21.35, 19.74, 18.25 and 19.74 in Lemir, Sefidrood, Shirrood and Tajan, respectively. Average of coefficient of variation (CV%) of ratio in females was 11.83, 9.24, 6.68 and 15.67 in Lemir, Sefidrood, Shirrood and Tajan, respectively. Average of coefficient of variation (CV%) of Truss morphometric in females was 10.22, 13.19, 18.36 and 12.4 in Lemir, Sefidrood, Shirrood and Tajan, respectively.

The data was tested with KMO (Kaiser-Meyer-Olkin) which was more than 0.70%, showing that correlation of data is good for PCA. The ANOVA showed that the all characters had highly significant difference except for weight (Table 2).

Based on the Principal Component Analysis (PCA) on the 13 morphometric characters four principal components were calculated. The values of the four principal components performed on the 13 morphometric data and weight of Mahisefid were shown in Table 3. The positive and negative values indicated the shape of variation. The first component of 44.32% in males and 68.942% in females were positive, indicating that the conventional morphometric is a useful descriptor of the body shape variation among the populations especially for females.

The total cumulative variances were 76.6% in males and 87.8% in females which are considered good discriminates. For the first component TL variable had the highest factor loading. In second component DTE variable had the highest loading and in third component CPL variable had highest loading. Therefore, these four variables can be selected as the main components.

Table 1: Range and mean ± standard deviation (SD) of morphometric characters of males and females of Mahisefid in four rivers in the south of the Caspian Sea

Males

MC	Gilan province				Mazandaran province			
	Lamir River (N = 38)		Sefidrood River (N = 78)		Shirrood River (N = 34)		Tajan River (N = 29)	
	Range (cm)	Mean± SD	Range (cm)	Mean±SD	Range (cm)	Mean±SD	Range (cm)	Mean± SD
TL	30.0-47.5	35.9 ± 3.7	31.0-47.0	38.86 ±3.44	33.10-53.0	41.30±6.38	34.20-42.10	38.31±2.58
FL	27.0-43.2	32.64±3.33	28.0-42.5	35.21±2.79	30.3-48.6	37.74±6.0	31.0-39.60	34.71±2.8
BW (g)	220-850	432.37±137.8	270-1010	526.64±120.25	270 - 910	591± 180	300-900	534.5±137
HL	5.10-8.10	6.48±0.73	5.0-8.0	6.55±0.62	5.70-9.70	7.42±1.2	5.5-8.30	6.61±0.86
HD	4.20-8.20	5.12±0.82	4.5-7.0	5.42±0.46	4.5-8.10	5.86 ± 0.96	4.10-6.20	4.99±0.51
HDE	2.30-4.70	3.55±0.5	3.0-5.50	4.17±0.4	3.40-6.0	4.5±0.73	3.40-5.20	3.87±0.37
SNL	1.60-3.20	2.53±0.28	1.5-3.0	2.27±0.34	2.0-4.30	2.87±0.59	1.4-3.10	2.57±0.44
PDL	6.0-13.5	9.21±1.34	6.0-11.0	8.61±0.94	8.9-15.10	11.59±2.0	9.10-11.20	10.06±0.68
DNS	1.10-1.90	1.45±0.17	1.0-2.0	1.57±0.22	1.10-2.5	1.74±0.36	1.0-2.60	1.30 ±0.42
DTE	2.30-3.80	2.74±0.3	2.5-4.0	3.03±0.24	2.40-4.40	3.19±0.57	2.5-3.5	3.09±0.22
DES	1.0-3.60	1.79±0.74	2.0-3.0	2.47±0.28	1.7-3.60	2.54±0.5	1.0-2.30	1.27±0.4
CPL	7.40-13.20	9.0±1.27	3.5-6.50	4.76±0.59	5.70-9.50	7.47±1.11	5.5-17.10	8.47±3.79
PL	14.5-31.5	19.13±2.78	13.5-20.0	16.98±1.26	14.0-23.5	18.18±2.83	13.10-19.0	15.36±2.04
MW	1.40-2.70	2.03±0.26	2.0-2.5	2.10±0.24	1.60-3.30	2.27±0.44	1.40-2.50	1.98±0.23

Females

MC	Gilan province				Mazandaran province			
	Lamir River (N = 54)		Sefidrood River (N = 75)		Shirrood River (N = 48)		Tajan River (N=31)	
	Range (cm)	Mean± SD	Range (cm)	Mean± SD	Range (cm)	Mean± SD	Range (cm)	Mean± SD
TL	32.0-66.0	46.76± 8.96	31.5-60.0	43.54± 6.83	34.5-61.5	47.59±7.9	38.40-57.10	46.42±5.82
FL	28.0-60.0	42.68±8.27	28.5-55.0	39.54±6.35	31.0-56.60	43.58±7.38	34.5-54.10	42.73±5.7
BW (g)	300-2100	957.96±518	280-2350	816.53±456	400-2200	1067 ± 182	500-2100	1018.39±345
HL	5.20-11.0	8.16±1.5	5.0-12.0	7.17±1.3	5.50-10.70	8.33±1.4	5.90-10.50	7.58±1
HD	4.50-8.80	6.75±1.4	4.0-9.0	6.0±1.0	4.40-9.30	6.61±1.17	5.10-8.10	6.43±0.74
HDE	2.40-6.60	4.5±0.96	3.0-7.0	4.44±0.81	3.0-7.90	5.03±0.1	3.50-6.20	4.6±0.63
SNL	2.30-4.80	3.25±0.58	1.5-4.50	2.48±0.6	2.10-4.70	3.19±0.62	1.80-4.10	2.84±0.69
PDL	7.80-18.20	12.06±2.5	7.0-15.0	10.18±2.0	9.60-17.20	13.52±2.28	9.60-19.0	12.96±1.94
DNS	1.0-2.50	1.74±0.33	1.0-3.0	1.79±0.43	1.1-2.50	1.9±0.37	0.9-2.20	1.39±0.34
DTE	2.30-4.90	3.42±0.65	2.0-6.0	3.23±0.66	2.20-4.90	3.55±0.69	1.0-4.70	3.55±0.72
DES	1.0-4.0	2.44±0.1	2.0-4.0	2.7±0.48	1.70-3.80	2.85±0.53	1.0-3.10	1.49±0.56
CPL	7.40-16.90	11.19±2.39	3.0-9.0	5.19±1.2	5.50-11.0	8.43±1.37	6.80-20.40	10.19±4.24
PL	17.00-33.30	24.10±4.29	13.5-29.5	20.15±3.57	14.0-35.80	21.29±4.17	15.0-27.20	18.72±2.52
MW	1.20-3.60	2.48±0.51	1.50-4.0	2.42±0.54	1.80-3.30	2.53±0.45	1.80-3.0	2.23±0.32

Abbreviations: MC = Morphometric character, TL = total length, FL=fork length, BW =body weight, HL = Head length, HD = head depth, HDE= head depth at center of eyes, SNL=Snout length, PDL =The distance from pectoral to dorsal fin, DTE = the distance between two eyes, DES = Distance from eye to snout the distance from nostril to snout, CPL = Caudal peduncle length, PL= Predorsal length, MW=mouth width. All measurement scale is centimeter.

Table 2: Summary of Two-way ANOVA for each morphometric character in *R. frisii kutum* for males and females in four different rivers

Row	Character	Sex		River		Sex & River	
		F value	P	F value	P	F value	P
1	Total Length	125.67	0.00*	5.32	0.001*	4.89	0.003*
2	Fork Length	127.51	0.00*	6.22	0.00*	5.05	0.002*
3	Weight	98.49	0.00*	2.22	0.11^{ns}	3.96	0.02*
4	Head Length	70.27	0.00*	13.96	0.00	4.07	0.007*
5	Head Depth	114.21	0.00*	5.28	0.001*	6.37	0.00*
6	Depth head at center of eyes	66.16	0.00*	13.68	0.00*	5.52	0.001*
7	Snout Length	42.17	0.00*	33.21	0.00*	4.48	0.004*
8	Distance of pectoral fin to dorsal fin	135.6	0.00*	57.13	0.00*	3.29	0.021*
9	Distance of nostril to snout	29.06	0.00*	25.41	0.00*	0.71	0.547^{ns}
10	Distance of two eyes	50.47	0.00*	5.81	0.001*	3.62	0.013*
11	Distance of eye to snout	29.53	0.00*	74.00	0.00*	2.77	0.42^{ns}
12	Caudal peduncle length	35.89	0.00*	144.27	0.00*	3.96	0.008*
13	Predorsal Length	115.45	0.00*	29.95	0.00*	1.85	0.138^{ns}
14	Mouth width	48.87	0.00*	6.15	0.00*	1.15	0.328^{ns}

Ns = not significant at (P>0.05); * significant at (P< 0.05).

Table 3: Values of the first four components obtained through a PCA performed on raw morphometric data of males and females of Mahisefid

Row	Characters	Male				Female			
		Component				Component			
		1	2	3	4	1	2	3	4
1	TL	0.946	0.006	-0.089	-0.148	.959	-.047	.009	.021
2	FL	0.923	-0.003	-0.087	-0.141	.959	-.085	-.027	.033
3	BW(g)	0.897	0.025	-0.142	-0.179	.890	.025	.102	-.096
4	HL	0.791	0.220	0.112	-0.190	.927	-.042	.092	.010
5	HD	0.674	-0.238	0.055	0.125	.902	-.082	-.054	-.101
6	HDE	0.723	-0.346	-0.235	-0.283	.916	.048	-.135	-.184
7	SNL	0.351	0.598	-0.300	0.488	.856	-.160	-.114	.310
8	PDL	0.597	0.644	-0.007	0.088	.861	-.353	-.051	-.080
9	DNS	0.552	-0.404	0.507	-0.002	.671	.533	.030	-.396
10	DTE	0.748	-0.008	-0.410	0.032	.847	-.069	-.393	.080
11	DES	0.291	-0.739	0.219	0.131	.363	.791	.361	.225
12	CPL	0.083	0.701	0.455	-0.286	.543	-.510	.611	-.024
13	PL	0.551	0.222	0.649	0.224	.891	.062	.189	.102
14	MW	0.557	-0.216	0.025	0.567	.806	.310	-.203	.158
15	Eigen value	6.204	2.294	1.299	.923	9.652	1.446	.792	.407
16	Variance explained (%)	44.311	16.383	9.276	6.593	68.942	10.331	5.654	2.908
17	Cumulative variance (%)	44.311	60.694	69.970	76.563	68.942	79.274	84.928	87.836

Based on Principal Component Analysis (PCA) on conventional morphometric data, the Mahisefid populations were clustered into 4 groups, where in Shirrood and Tajan were closer, while Lemir and Sefidrood populations were completely separate groups. The grouping was similar in males and females of Mahisefid in the southern part of the Caspian Sea.

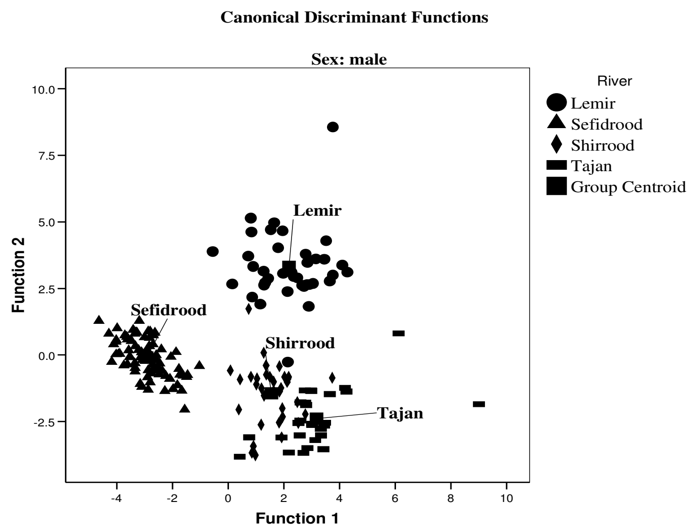
The ratios of head length (HL) and head width (HW) to TL as well as the ratios of snout width (SNL), the distance from nostril to snout (DNS), distance of two eyes (DTE), and mouth width (MW) to fork length (FL) were significantly different (P<0.05) between males and females. No significant difference were observed in head depth (HD), the distance from eyes to snout (DES), caudal peduncle length (CPL), distance of snout to dorsal fin (PDL) to FL, (P<0.05) between males and females (Table 4). The ratio of characters to fork length and total length had significantly difference except for FL/TL (Table 4).

The data used to study the discriminant function for morhometric characters showed that in males 98.3% and in females 97.6% of original grouped cases were correctly classified (Figs. 4a & b).

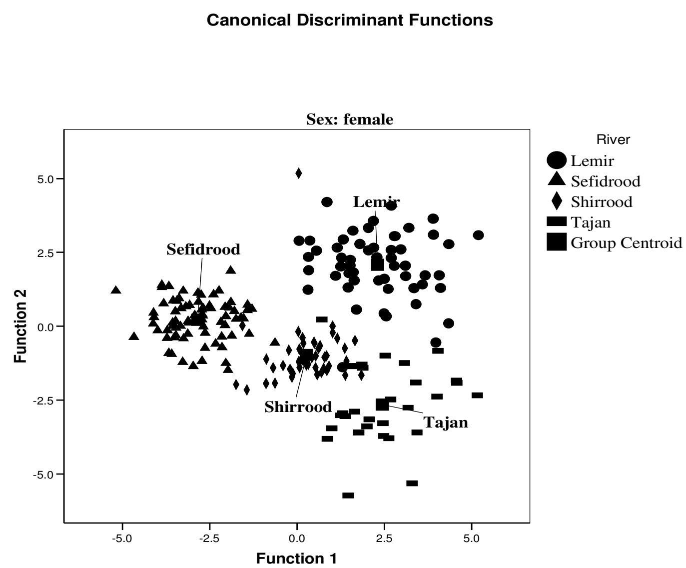
Table 4: The ratios of morphometric data to total or fork length in males and females of Mahisefids in four different rivers in southern part of the Caspian Sea

Row	Ratio	Male			Female			P value
		Range	Mean±SD	CV%	Range	Mean±SD	CV%	
1	FL/TL	0.78 – 0.97	0.91±0.02	2.25	0.82–1.12	0.91±0.03	3.07	0.026*
2	HL/TL	0.14 –0.22	0.17 ± 0.01	6.49	0.11–0.26	0.17±0.01	7.46	0.000*
3	HW/TL	0.50 – 1.24	0.81±0.09	8.90	0.56–1.27	0.83±0.09	8.16	0.000*
4	HD/FL	0.1 0– 0.24	0.15± 0.01	11.21	0.13–0.24	0.15±0.01	9.39	0.490ns
5	HDE/FL	0.08–0.14	0.12 ± 0.01	7.73	0.08–0.19	0.11±0.01	9.47	0.001*
6	SNL/FL	0.04–0.09	0.07 ± 0.01	13.06	0.04–0.1	0.07±0.01	12.44	0.000*
7	PDL/FL	0.19–0.36	0.27 ± 0.03	7.06	0.22–0.38	0.28±0.03	8.18	0.001*
8	DNS/FL	0.03–0.07	0.04 ± 0.01	16.17	0.02–0.07	0.04±0.01	15.66	0.000*
9	DTE/FL	0.07–0.11	0.09 ± 0.01	6.76	0.02–0.11	0.08±0.01	9.65	0.000*
10	DES/FL	0.03–0.12	0.06 ± 0.02	22.83	0.02–0.09	0.06±0.02	23.09	0.600ns
11	CPL/FL	0.11–0.53	0.19 ± 0.07	16.05	0.09–0.46	0.20±0.07	16.97	0.183ns
12	PL/FL	0.40–0.83	0.50 ± 0.06	6.39	0.32–0.68	0.51±0.05	6.22	0.425ns
13	MW/FL	0.04–0.08	0.06±0.01	10.25	0.03–0.08	0.06±0.01	11.35	0.000*
Average				10.40	Average		10.85	

*** Significant at (P<0 .05), ns= not significant at (P> 0.05).**



(a)



(b)

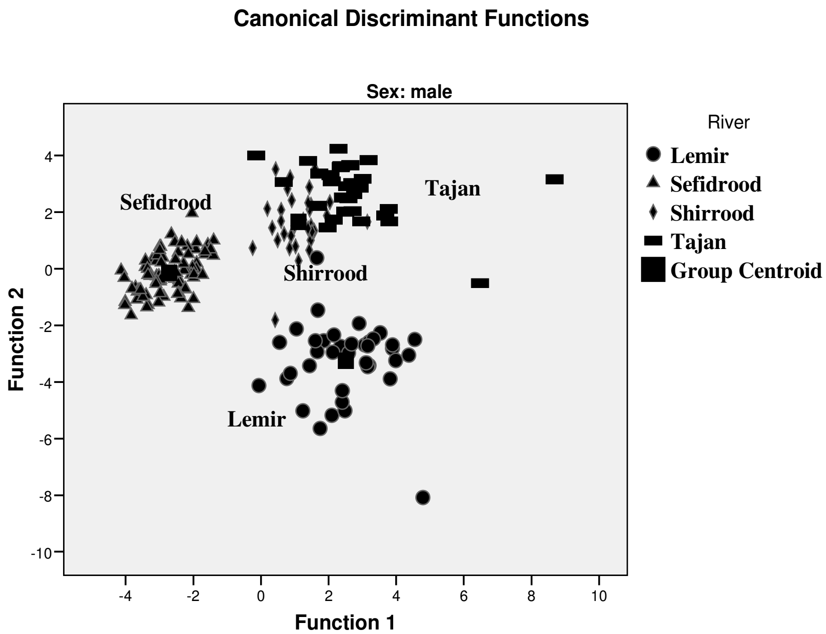
Figure 4: Plots of the coordinate of individual males (a) and females (b) of Mahisefid according to the first two discriminant functions obtained from the conventional morphometric data.

Based on the Principal Component Analysis (PCA) on the 13 ratio characters, four principal components were calculated. The values of the four principal components performed on the 13 ratio of morphometric data to TL or FL of Mahisefid were presented in Table 5. The first components were 22.56% in males and 20.61% in females. These values were lower than the raw conventional morphometric data especially in females. The total cumulative variances were 64.27% in males and 64.21% in females, indicating that morphology of males and females are almost similar. For the first component HW/TL variable had the highest factor loading. In second component variable SNL/FL had the highest loading and in third component DNS/FL variable had the highest loading in males and in females. MW/FL had highest loading in first component, HL/TL had highest loading in second component, HW/TL had highest loading in third component and PL/FL had highest loading in fourth component.

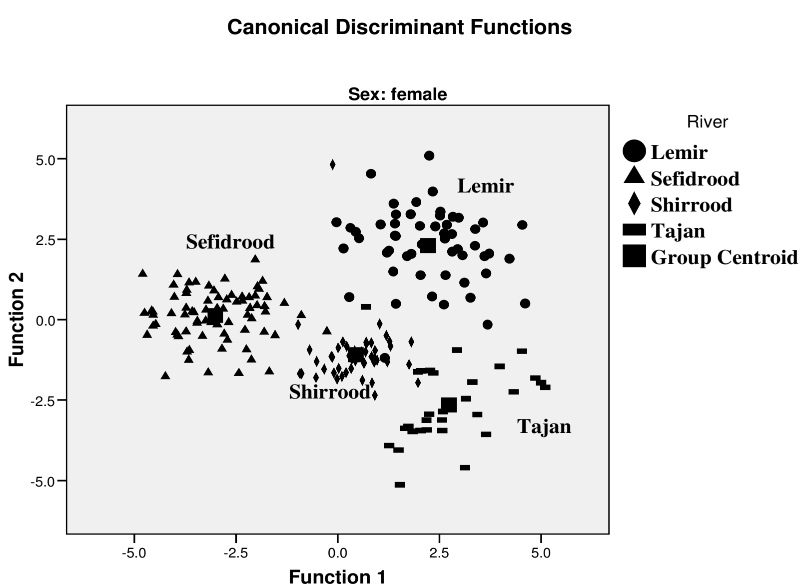
The data used to study the discriminant function for morhometric ratio showed that in males 98.3% and in females 96.2% of original grouped cases were correctly classified (Figs. 5a & b).

Table 5: Values of the four components obtained a PCA on ratio data in males and females of Mahisefid in the present study

Row	Ratio	Male				Female			
		Component				Component			
		1	2	3	4	1	2	3	4
1	FL/TL	-0.368	-0.355	0.242	-0.246	-.284	.318	.038	-.393
2	HL/TL	-0.457	0.414	0.425	0.451	.159	.815	-.278	-.047
3	HW/TL	0.814	-0.03	-0.211	-0.482	.291	-.513	.729	.147
4	HD/FL	0.762	0.361	-0.001	-0.203	.585	.007	.636	.274
5	HDE/FL	0.515	-0.115	-0.105	0.597	.560	.012	.189	-.316
6	SNL/FL	-0.078	0.726	-0.32	0.095	.265	.710	.209	-.009
7	PDL/FL	-0.198	0.712	-0.209	-0.068	-.185	.606	.371	-.117
8	DNS/FL	0.442	0.209	0.662	0.246	.729	.045	-.344	-.020
9	DTE/FL	0.461	0.305	-0.508	0.33	.366	.213	.371	-.556
10	DES/FL	0.591	-0.172	0.483	0.028	.521	-.111	-.627	.105
11	CPL/FL	-0.339	0.659	0.017	-0.209	-.258	.414	.268	.616
12	PL/FL	0.049	0.578	0.516	-0.329	.437	.299	-.135	.618
13	MW/FL	0.401	0.319	0.199	0.043	.730	-.074	-.071	-.132
14	Eigenvalue	2.933	2.513	1.677	1.233	2.679	2.225	1.975	1.467
15	Variance explained (%)	22.565	19.327	12.898	9.481	20.610	17.119	15.194	11.287
16	Cumulative variance (%)	22.565	41.892	54.790	64.271	20.610	37.729	52.923	64.210



(a)



(b)

Figure 5: Plots of the coordinate of individual males (a) and females (b) of Mahisefid according to the first two discriminant functions obtained from the ratio data.

Truss morphometric

Of 12 Truss morphometric characters with exception of the distance between posterior of dorsal fin and ventral part of the caudal base (7-11), all landmarks were significantly different (P<0.05) between males and females of Mahisefids in the present study (Table 6). Four components were extracted from 12 Truss morphometric data (Table 7). The first component accounted for 87.7% for males and 81.3% for females of the total variance. The total cumulative variances were 96.17% in males and 93.60% in females, indicating that morphology of males and females are almost similar. The component loadings were also higher for both males and females than those of morphometric characters and ratio. For the first component TL variable had the highest factor loading in males and females. The Truss landmarks indicated that it is much better than row morphometric and ratio to cluster Mahisefid.

Table 6: Summary of two-way ANOVA for each Truss character in males and females of Mahisefid from selected rivers in the southern part of Caspian Sea, in the present study.

Row	Character	Sex		River		Sex & River	
		F value	P value	F value	P value	F value	P value
1	Total Length	61.48	0.00*	39.43	0.00*	0.75	0.473 ns
2	Weight	55.59	0.00*	18.81	0.00*	1.42	0.238 ns
3	1-2	28.13	0.00*	23.22	0.00*	1.06	0.369 ns
4	2-3	47.80	0.00*	20.66	0.00*	2.77	0.043 ns
5	3-4	47.80	0.00*	20.66	0.00*	2.77	0.043 ns
6	4-5	60.21	0.00*	18.19	0.00*	0.43	0.73 ns
7	5-6	129.29	0.00*	71.90	0.00*	0.79	0.5 ns
8	6-7	104.00	0.00*	40.70	0.00*	0.16	0.921 ns
9	7-8	69.56	0.00*	67.69	0.00*	0.53	0.662 ns
10	7-9	53.56	0.00*	47.97	0.00*	0.65	0.584 ns
11	7-11	0.91	0.342 ns	77.62	0.00*	27.50	0.00*
12	8-10	33.18	0.00*	15.61	0.00*	1.80	0.149 ns
13	10-11	33.18	0.00*	15.61	0.00*	1.80	0.149 ns

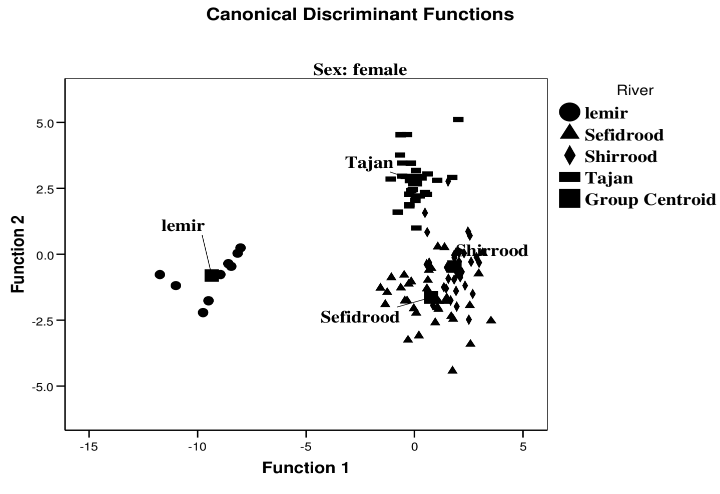
*** Significant at P< 0.05; ns= not significant at P>0.05.**

Table 7: Values of the first four components obtained through a PCA performed on raw truss data of males and females

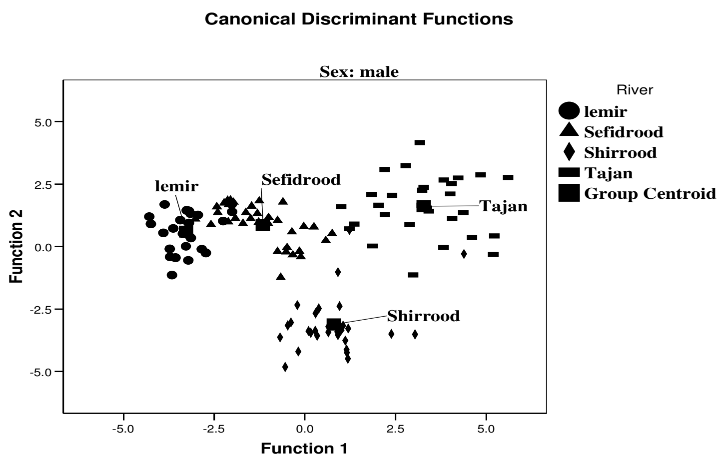
Row	Truss Landmark (cm)	Male				Female			
		Component				Component			
		1	2	3	4	1	2	3	4
1	Total Length	.971	.055	-.135	.017	.967	.090	-.108	-.059
2	Weight	.955	.021	-.195	.124	.958	-.107	.027	.045
3	1-2	.637	.756	.096	.049	.622	.706	.092	.286
4	2-3	.936	.022	.009	-.297	.895	.286	-.176	-.085
5	3-4	.949	.078	.219	-.066	.925	-.082	.104	.183
6	4-5	.964	.012	-.047	.116	.833	.172	.286	-.409
7	5-6	.954	-.234	.092	.053	.908	-.352	.077	.067
8	6-7	.974	-.123	.064	.040	.945	-.170	.122	.045
9	7-8	.954	-.221	.102	.002	.935	-.249	.062	.095
10	7-9	.968	-.157	.031	.018	.951	-.155	.000	.035
11	7-11	.968	-.079	-.056	-.046	.868	-.070	-.424	-.055
12	8-10	.933	.121	-.220	-.117	.928	.175	-.053	-.152
13	10-11	.960	.010	.070	.112	.931	.013	.021	.051
14	Eigenvalue	11.403	.746	.196	.157	10.570	.910	.352	.341
15	Variance explained (%)	87.717	5.737	1.508	1.209	81.308	7.002	2.710	2.620
16	Cumulative variance (%)	87.717	93.454	94.962	96.170	81.308	88.310	91.020	93.640

The data used to study the discriminant function for morhometric ratio showed that in males 98.3% and in females 97.6% of original grouped cases were correctly classified (Figs. 6a & b). Based on Truss morphometric data, populations of *Rutilus frisii kutum* were classified into 4 distinct groups (Figs. 6a & b), although the population of Shirrood River and Tajan River were closely related compare to populations in Sefidrood and Lemir Rivers.

There was a correlation between weight and length based on the figure 7. Weight and length were distributed evenly around the tread line. R^2 coefficient also showed correlation between these two variables. The tread lines between these row factors were a power form model.



(a)



(b)

Figure 6: Plots of coordinates of individuals of male (a) and female (b) according to the first two discriminant functions obtained from Truss morphometric data.

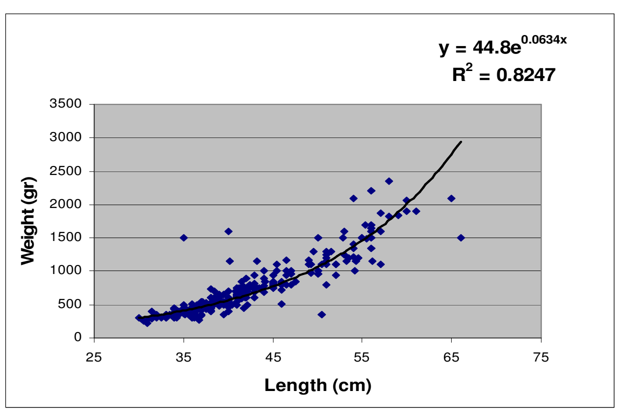


Figure 7: length- weight relationships among samples in the present study

Discussion

Conventional Truss morphometric data and ratio from samples in four regions (Lemir, Sefidrood, Shirrood and Tajan) were analyzed using two-way ANOVA and Principal Component Analysis (PCA). Thirteen morphometric, 12 truss landmarks data and ratio were analyzed to examine the degree of similarity among the four regions of males and females. All morphometric characters were significantly different ($P<0.05$) in males and females in the present study suggesting that *Rutilus frisii kutum* can be classified into four populations, including Lemir and Sefidrood in Gilan province and Shirrood and Tajan in Mazandaran province. The first component coefficient of morphometric data had positive values indicating morphologic variation (cumulative variance 44.31% in males and 68.94% in females). Some conventional morphometric data for *Rutilus frisii kutum* from different rivers have been recorded and analyzed previously by Razavi Sayad (1993) for stock assessment of this fish. According to Razavi Sayad (1993), there were no significant difference ($P>0.05$) among *Rutilus frisii kutum* in different regions.

Akbarzadeh (2006) studied different group of pikeperch in south of Caspian Sea (Anzali Lagoon, west and east Gilan province) and Aras Dam and he found significant difference in 16 morphometric and 5 Truss data between Anzali Lagoon, Aras dam, east and west of Gilan province. Based on the truss morphometric data the grouping was same.

Based on discriminant function data, the populations of males (98.3%) and females (96.7%) of Mahisefid were classified into four groups using both conventional (Fig. 4) and Truss morphometric data although the clustering patterns were slightly different (Fig. 6). According to the present study, 95.1% females could be classified to four groups, including Lemir (100%), Sefidrood (91.4%), Shirrood (93.5%) and Tajan (100%). Also, 95.8% males could be classified to four groups, including Lemir (100%), Sefidrood (91.4%), Shirrood (93.3%) and Tajan (100%). These differences could be based on physical characteristics of each habitat, such as water temperature, environment because the climate of rivers has differences. Comparison of average coefficient of variation (CV%) of raw data, Truss morphometric and ratio in females was higher than those in males. In conclusion, it seems that there are various populations in different rivers, suggesting that in releasing fingerling, the broodstock and larvae from different populations should be kept separately and fingerling of each river should be released to the same river where the broodstock are caught. Further study on genetic differentiation of individuals from different localities is necessary to confirm findings of the present study.

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مطالعه مورفومتریك ماهي سفید *Rutilus frisii kutum* (Kamenski 1901) در چهار رودخانه حوزه جنوبي درياي خزر

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تاريخ دريافت: آذر ۱۳۸۷ تاريخ پذيرش: خرداد ۱۳۸۸

چكيده

ماهی سفید متعلق به خانواده کپور ماهیان و در محدودۀ ترکمنستان تا آذربایجان در دریای خزر زندگی می‌کند. این ماهی از نظر اقتصادی یکی از گونه‌های مهم این منطقه می‌باشد. به منظور حفظ ذخایر این ماهی در منطقه، شیلات ایران هرساله به رهاسازی بچه ماهی سفید در جنوب دریای خزر اقدام می‌نماید. هدف از این مطالعه بررسی جمعیت‌های مختلف این ماهی در برخی از رودخانه‌های حوزه جنوبی دریای خزر بود. ۳۸۷ نمونه ماهی سفید نر و ماده در بهار سال ۱۳۸۴ از چهار رودخانه لمیر، سفیدرود، شیرود و تجن از مهمترین رودخانه‌هایی می‌باشند که ماهی سفید برای تخم‌ریزی به آنجا مهاجرت می‌کند، جمع‌آوری گردید. ۱۴ شاخص مورفومتریک، ۱۳ شاخص نسبی و ۱۲ لندمارک برای مطالعه انتخاب شدند و داده‌های ثبت شده با نرم‌افزار SPSS15 و براساس روش آزمونهای دو عاملی و مؤلفه‌های اصلی و تجزیه تابع تشخیص آنالیز شدند. میانگین ضریب تغییرات در شاخصهای مورفومتریک ماهیان نر در رودخانه لمیر ۱۴/۹۵، سفیدرود ۱۰/۲۸، شیررود ۱۷/۴۷ و تجن ۱۶/۵۶ بود. میانگین ضریب تغییرات در شاخصهای مورفومتریک ماهیان ماده در رودخانه لمیر ۲۱/۳۵، سفیدرود ۱۹/۷۴، شیررود ۱۸/۲۵ و تجن ۱۹/۷۴ بود. نتایج نشان داد که با شاخصهای مورفومتریک، نسبی و تراس در رابطه با جنس و رودخانه دارای اختلاف معنی‌دار بودند ($P<0.05$). واریانس اولین مؤلفه شاخصه‌ای مورفومتریک در ماهی نر ۴۴/۳۲ درصد، در ماهی ماده ۶۸/۹۴ درصد و مثبت بود. جمع واریانس چهار مؤلفه در ماهی نر ۷۶/۶ درصد و در ماهی ماده ۸۷/۸ درصد بود که نشاندهندۀ آن است که شاخصهای مورفومتریک برای آنالیز تغییرات شکل بدن مناسب هستند. جمع واریانس چهار مؤلفه در ماهی نر ۶۴/۲۷ درصد و در ماهی ماده ۶۴/۲۱ درصد بود. واریانس اولین مؤلفه شاخصهای تراس در ماهی نر ۸۷/۷ درصد و در ماهی ماده ۸۱/۳ درصد بود. نتایج مطالعه حاضر نشان می‌دهد که محلهای نمونه‌برداری جمعیتهای غیروابسته در هر رودخانه دارد. از دلایل این اختلاف می‌توان به خصوصیات فیزیکی محیط، درجه حرارت و شرایط محیطی رودخانه‌ها و مناطق جنوبی دریای خزر اشاره نمود.

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