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Morphological Variations of the Trouts (*Salmo trutta* and *Salmo platycephalus*) in the Rivers of Ceyhan, Seyhan and Euphrates, Turkey

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Abstract

In this study, morphometric and meristic characters of trouts (*Salmo trutta* and *Salmo platycephalus*) were investigated in the upper basin of Seyhan, Ceyhan and Euphrates rivers. According to Principal Component Analysis (PCA) has been determined that morphological variations were determined among the populations. *Salmo platycephalus* population in Seyhan River formed different cluster from *S. trutta* on the graphic. *S. platycephalus* living in Seyhan basin differ from *S. trutta* living in Ceyhan and Euphrates basin by the number of pyloric caeca, gill rakers, head depth and predorsal on outer side of first gill arch.

Keywords: *Salmo trutta, Salmo platycephalus,* morphometric properties.

Ceyhan, Seyhan ve Fırat Nehirlerindeki Alabalıklarda (*Salmo trutta* ve *Salmo platycephalus*) Morfolojik Farklılıklar

Özet

Bu çalışmada, Seyhan, Ceyhan ve Fırat nehir havzalarındaki alabalıkların (*Salmo trutta* ve *Salmo platycephalus*) morfometrik ve meristik özellikleri incelendi. Principal Companent Analizine (PCA) göre; Seyhan, Ceyhan ve Fırat havzalarındaki alabalıklarda (*Salmo trutta* ve *Salmo platycephalus*) morfometrik ve meristik farklılıkların olduğu tespit edildi. Birinci ve ikinci varyasyonlar grafik üzerinde kümeleştirildiğinde, Seyhan havzası gruplarının, Ceyhan ve Fırat havzası gruplarından ayrı kümeler oluşturduğu tespit edildi. Seyhan havzasında yaşayan *S. platycephalus* bireyleri baş yüksekliği, predorsal uzunluğu, plorik çeka ve birinci solungaç kemeri üzerindeki solungaç diken sayıları bakımından diğerlerinden farklılık göstermiştir.

Anahtar Kelimeler: *Salmo trutta, Salmo platycephalus*, morfometrik özellikler.

Introduction

The water systems of Turkey are inhabited by three different forms of trout: sea-run trout (*Salmo trutta labrax*), lake-run brown trout (*Salmo trutta abanticus*) and resident brown trout (*Salmo trutta macrostigma* and *Salmo platycephalus*) (Behnke, 1968; Geldiay and Balık, 1988). These forms were originated from two different sources: North originated (from Black Sea, Hazar and Aral Lake) and west originated (South Europe and Mediterranean populations). *Salmo trutta macrostigma* which is west originated, firstly occured in Mediterranean Sea and then scattered into Anatolia in the geologiacal area of glacial. Also it may be expected new and endemic forms such as *S. abanticus* because of isolation and various ecological factors.

The studies on *S. t. macrostigma* in Turkey are related to the taxonomy (Tortonese, 1954; Kuru, 1975; Aras, 1976; Ekingen, 1976; Balık, 1984; Balık, 1988; Geldiay and Balık, 1988; Bardakçı *et al*., 1994; Çetinkaya, 1996), population structure (Geldiay, 1968; Aras *et al*., 1986; Çetinkaya, 1996; Yüksel and Kocaman, 1998; Alp *et al*., 2003; Alp and Kara, 2004; Arslan and Aras, 2007; Gülle *et al*., 2007), reproduction traits (Karataş, 1997, 1999; Alp *et al*., 2003) and feeding habits (Kara and Alp, 2005). *Salmo trutta labrax* was firstly described by Berg (1932) in the Black sea region of Turkey (Geldiay and Balık, 1988). *Salmo trutta labrax* in Turkey was also investigated by Koswig-Battalgil (1942), Slastenenko (1939), Slastanenko (1955-1956), Tortonese (1955), Ladiges (1964), FAO (1971), Kuru (1971), Aras (1974), Kuru (1975), Bardakçı *et al*. (1994) and

Tabak *et al*. (2001). According to these studies *S. t. labrax* inhabits rivers in the north and northeast region of Anatolia, Mt. Olympus and Black Sea. Recently, Turan *et al*. (2009) discussed the identity of the trouts from the rivers of northern Anatolia draining to the Black Sea. They showed that in the Coruh River and adjacent drainages the sympatric resident and migratory trouts are two species, distinguished by morphological and molecular characters, *S. rizeensis* and *S. coruhensis*. The other studies are related to *S. platycephalus*, *S. abanticus* and *S. caspius* (Behnke, 1968; Geldiay and Balık, 1988; Turan *et al*., 2009). *Salmo platycephalus* was also reported in Örenşehir-Uzunyayla (Alp and Kara, 2004), Soğuksu and Karagöz (Behnke, 1968) in the upper Seyhan Basin. *Salmo platycephalus* has a very restricted distribution in Zamantı stream system. In recent years, weight and condition factors (Alp and Kara, 2004), philogenetic traits (Sušnik *et al*., 2004; Bardakçı *et al*., 2006) and conservation status (Tarkan *et al*., 2008) of *S. platycephalus* were investigated.

Different populations of the same fish species are often different in phenotypic characters (Pakkasmaa and Piironen, 2001; Sandlund *et al*., 1992; Schluter and McPhail, 1992; Eliot, 1994). Morphological differentiations can be principle result from two causes; genetic differences or environmental factors, or their interactions. Genetic differences and reproductive isolation between populations can lead to local adaptation, which is reflected in morphology, behaviour, physiology and life history traits (Pakkasmaa and Piironen, 2001; Taylor, 1991). Environmental factors, on the other hand, can produce phenotypic plasticity, which is the capacity of a genotype to produce different phenotypes in different environmental conditions (Scheiner, 1993; Stearns, 1989). Recent molecular data, including both variation in the mitochondrial and nuclear genome, tend to divide Eurasian trout into five geographic groups (Bernatchez *et al*., 1992, Garcia-Marin *et al*., 1999). The mediterranean-Adriatic region contains the richest source of endemic *Salmon* species as well as the greatest differentiation within the species *S. trutta* (Behnke, 1968). The latter specimens were recognized as Adriatic whereas the former one as the Dunabien phylogegraphic lineage of *Salmo trutta* (Bernatchez, 2001). According to mitocondrial DNA analysis Turkish brown trout populations orginated from the Adriatic and Dunabian phlogeographic lineages (Bernatchez, 2001).

In this study, it was aimed to determine morphological variations among the trout populations in the rivers of Ceyhan, Seyhan and Euphrates.

Materials and Methods

The fish specimens were collected form the streams of Aksu, Törbüzek, Kömür and Hurman of the river Ceyhan, stream Zamantı of Seyhan which run into the eastern Mediterranean Sea, and in the stream Göksu of the river Euphrates which runs into the Persian Gulf (Figure 1). Geographic positions of the studied stations were given in Table 1.

A total of 84 individuals of the brown trout (*S. trutta*) and flathead trout (*S. platycephalus*) was caught monthly at three selected sampling sites, 50 m apart from each other in each stream, between May 2000 and April 2006 by electrofishing. However, due

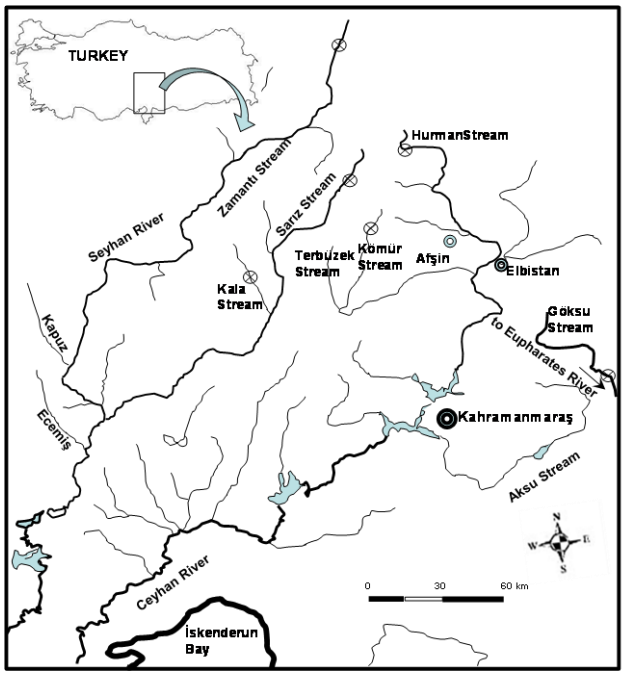

Figure 1. The distribution map of *S. platycephalus* which upper branches Seyhan and *S. trutta* which upper branches Ceyhan and Euphrates basin.

to few number specimens weren't consider captured from Sarız and Kala Stream samples and it is to save as museum material. All the captured fish specimens were immediately preserved in a plastic barrel containing 4% formaldehyde solution. Measurements were taken with digital callippers on the left side of the specimens and rounded to the nearest 0.1 mm in the Figure 2.

These characters included the following: standart length (SL), from the tip of the snout to the end of the caudal peduncle; pre-dorsal distance (PD), from the tip of the snout to the origin of the dorsal fin; head length (HL), from the tip of the snout to the most posterior point of the opercula on the ventral side; head depth (HD), head depth at posterior to margin of eye; dorsal fin length (DFL), from the origin of the dorsal fin to the end of the dorsal fin; snout length (NL), from the tip of the snout to anterior margin of eye; eye diameter (ED), horizontal diameter of the eye; body depth (BD), at level of origin of dorsal fin; caudal peduncle depth (CPD) (Figure 2). Meristic characteristics were counted from the number of dorsal, anal, pectoral and ventral fin rays. Standard lengths are given as original values of avarage, while other morphometric characters are given as a percent of standard length.

The data for morphometric characters were in transformed and then subjected to principal component analysis (PCA) in SYSTAT v 10.0. Data reduction was carried out by PCA to reduce the initial morphometric variation to uncorrelated principal components. Therefore, morphometric characters were used in the analysis. Three components were produced in PCA. In the morphometric data set, the first principal component (PC1) represents size, whereas the second and third principal components (PC2 and PC3) most often lack correlation to size and they are the most informative (Delling *et al*., 2000) and therefore, highest character loadings in PC2 and PC3 should be taken into consideration to indicate the differences.

Results

Distribution

S. platycephalus individuals in the upper branches of Zamantı stream were collected from Örenşehir-Uzunyayla, Sarız stream and Kala stream. Two specimens of *S. platycephalus* were caught form from Sarız stream and one from Kala stream. However, *S. platycephalus* was not present in the samples of Karagöz of Zamantı stream. *S. trutta* individuals was commonly determined in Aksu,

Table 1. Geographic locations of the streams and the number of the fish during the study area

Stream	River system	Number of fish	Altitude (m)	Latitude (N)	Longitude (E)	Trout zone (km)	Flow (L/sn)
Zamantı	Seyhan	15	1768	38°38'	36°17'	45	1260
Kala Suyu	Seyhan	1	1512	38°14'	36°13'	5	-
Sarız suyu	Seyhan	2	1778	38°38'	36°26'	-	-
Göksu	Euphrates	12	1280	37°52'	37°18'	55	1750
Hurman	Ceyhan	17	1258	38°26'	36°54'	50	4737
Kömür	Ceyhan	10	1417	38°08'	36°33'	20	1035
Terbüzek	Ceyhan	19	1390	38°04'	36°27'	15	2300
Aksu	Ceyhan	9	1125	37°46'	37°21'	45	3698

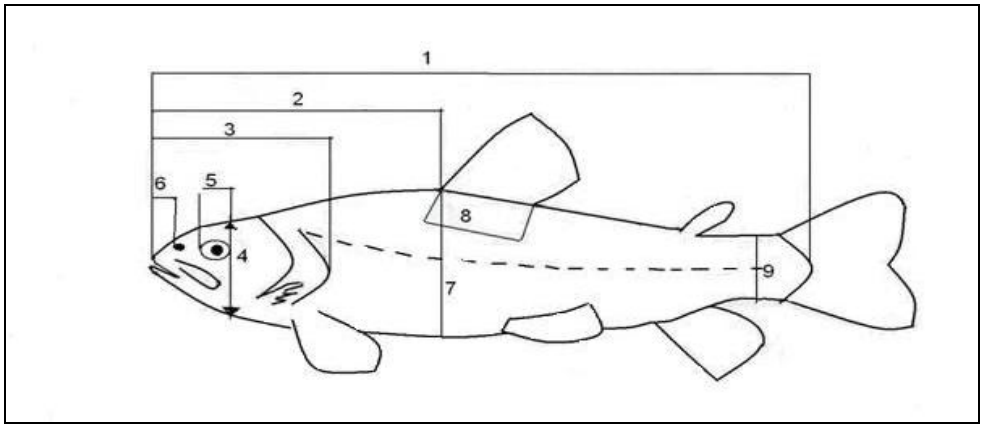

Figure 2. Morphometric meassurements of *S. trutta* specimens.1. standart length (SL); 2. pre-dorsal (PD); 3. head length (HL); 4. head depth (HD); 5.Eye diameter (ED); 6. nasal length (NL); 7. body depth (BD); 8. dorsal fin length (DFL); 9. caudal peduncle depth (CPD).

Törbüzek, Kömür and Hurman streams in the upper branches of Ceyhan river and in the stream of Göksu (Yılanovası) in Euphrates River (Table 1).

Colaration

General body collor of trouts in Ceyhan and Euphrates basins is greyish to brownish in life. Their back has clear brown, green of olive and also, toward line lateral has more clear. Their abdomen part has yellowish white and its fin has grey-brown orange. Adipose fins of individuals in Ceyhan system has reddish while adipose fins of individuals in Euphrates system has one or two red spot. Individuals in Ceyhan and Euphrates have red and black spots on their dorsal fins, however trouts in Seyhan River system have not red and black spots on the dorsal fins. Body surface of trouts in Ceyhan and Euphrates system have been dispersed as unsystematic both bottom and on the line lateral. They have 20-30 red spots surrounded by clear coloured ring. Flathead trout in Seyhan River has not red spots in larger specimens than 70 mm SL. There is no black spots in specimens than about 170 mm SL (Figure 3, 4, 5).

Meristic

Meristic characteristics such as gill raker, line lateralis scales and fin rays of the trouts in the rivers of Ceyhan, Seyhan and Euphrates were given in Table 2. The number of gill rakers and pyloric caeca of flathed trout in Seyhan River differed form brown tourts in Ceyhan and Euphrates. Meristic data were reduced to 3 Principal Components (Table 3). Pyloric caeca and gill rakers had the highest component loadings.

Morphometric

Standard lengths (SL) and other morphometric traits were given as percent of SL in Table 4. Standard lengths (SL) of trouts in Zamantı stream were highest than brown trouts in Ceyhan and Euphrates. This situation may be arised from fishing pressure on trout populations in Ceyhan and Euphrates. However, body depth (BD), head length (HL), nasal length (NL), dorsal fin length (DFL) and caudal peduncle depth (CPD) were generally similar in three populations. Predorsal (PD) and head depth (HD) of flathead trout

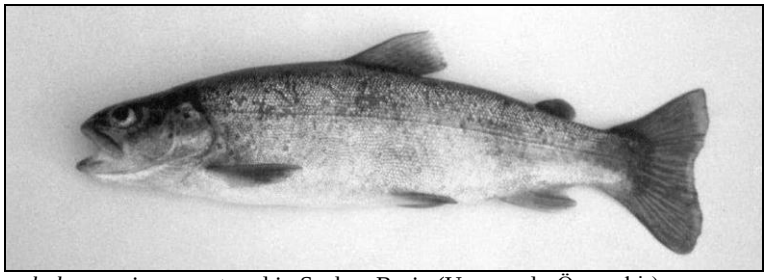

Figure 3. The *S. platycephalus* specimen captured in Seyhan Basin (Uzunyayla-Örenşehir).

Figure 4. The *S. trutta* specimen captured in Ceyhan Basin (from Törbüzek stream).

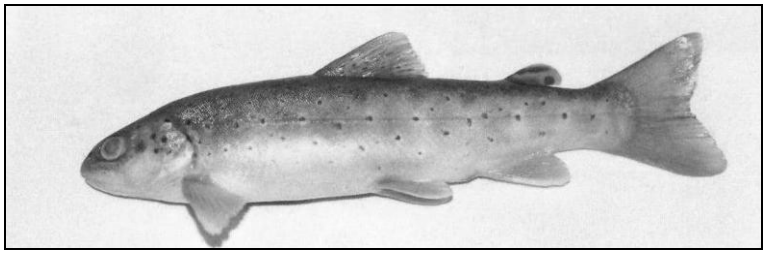

Figure 5. The *S. trutta* specimen captured in Euphrates Basin (from Yılanovası, Nurhak, Kahramanmaraş).

Table 2. Meristic characteristics of the trouts in the upper branches of Ceyhan, Seyhan and Euphrates

	Systems	Zamantı	Göksu	Törbüzek	Kömür	Aksu	Hurman
Scales lateral line	N	17	12	19	10	9	17
	103		1				
	104		1				
	105						
	106						
	107						
	108		3				
	109		3				
	110		2				
	111		1				
	112	2	1	2		2	1
	113	2		2	1	1	1
	114	4		4	3	4	2
	115	4		5	2	2	4
	116	3		5	1		4
	117			1	1		2
	118	2			2		3
	X	115	108	115	115	114	116
Gill rakers	N	17	12	19	10	9	17
	17		1	1	1	1	
	18		1	2	2	2	2
	19		10	14	7	6	15
	20			1			
	21	2					
	22	5					
	23	7					
	24	3					
	X	23	19	19	19	19	
Unbranched dorsal fin rays	N	17	12	19	10	9	17
	2		1	1	1		4
	3	17	11	18	9	9	13
	X	3	3	3	3	3	3
Branched dorsal fin rays	9	1	1	2	2		3
	10	16	15	17	7	8	14
	11		1			1	
	X	10	10	10	10	10	10
Unbranched anal fin rays	N	17	12	19	10	9	17
	2		1	1	1	1	2
	3	17	11	18	9	8	15
	X	3	3	3	3	3	3
Branched anal fin rays	7			2	1	8	1
	8	10	10	16	8	1	13
	9	7	2	1	1		3
	X	8	8	8	8	8	8
Caudal fin rays	22						
	23	1	1				
	24	16	11	19	10	9	17
	X	24	24	24	24	24	24
Vertebrae	N	17	12	19	10	9	17
	54				2	1	2
	55		2	1	2		2
	56	12	8	8	10	7	10
	57	2	2	3		3	
	58	1	3	3	1	3	1
	59	2					
	X	56	56	56	56	56	56
Pyloric caeca	N	17	12	19	10	9	17
	22		3	3			
	23		3	1			
	24	3	6	1			
	25	1					
	26	6		2	1	2	1
	27			1			1
	28	4	1	6	2	2	4
	29	1		1		1	
	30	1		1	1	2	3
	31				1		1
	32	1		5	5	1	3
	33						
	34				1	1	1
	35						1

Table 3. Meristic traits' loadings on Principal Component Analysis result

	Principal Component loads		
	PC1	PC2	PC3
Unbranched dorsal fin ray	0.227	0.054	0.723
Unbranched anal fin rays	0.306	0.682	0.248
Branched dorsal fin rays	0.183	0.240	0.662
Branched anal fin rays	0.105	0.851	0.083
Caudal fin rays	0.632	0.460	0.011
Pyloric ceaca	0.910	0.049	0.041
Gill rakers	0.909	0.035	0.047
Vertebrae	0.742	0.222	0.178
Scales of line lateral	0.764	0.100	0.132
Variance	37.552	16.925	12.021

Table 4. Morphometric characters of *Salmo trutta*, measurements, except SL are percentage of SL

	Zamantı X (Min-Max)	Göksu X (Min-Max)	Törbüzek X (Min-Max)	Kömür X (Min-Max)	Aksu X (Min-Max)	Hurman X (Min-Max)
SL (mm)	229.83 (85.9-407.11)	156.12 (119.22-197.84)	164.74 (130.61-238.46)	150.67 (89.97-178.16)	186.63 (156.9-245.3)	150.93 (120.02-224.82)
PD(%SL)	47.14 (42.75-72.00)	44.96 (42.69-47.47)	46.15 (41.63-49.00)	47.63 (45.18-54.26)	44.57 (42.55-48.01)	47.02 44.83-50.59
BD(%SL)	25.10 (22.65-28.58)	25.43 (22.48-26.82)	24.48 (21.23-26.96)	26.56 (24.62-30.13)	26.08 (24.93-28.97)	24.47 (21.94-26.85)
HL(%SL)	24.54 (22.48-27.79)	25.72 (24.45-27.56)	25.20 (23.72-26.55)	26.18 (24.10-27.40)	26.05 (24.21-28.75)	24.94 (23.45-26.37)
HD(%SL)	15.64 (14.73-16.81)	16.72 (15.13-17.23)	16.34 (15.04-17.98)	16.77 (15.19-18.37)	17.51 (16.29-18.28)	16.11 (15.00-19.07)
ED(%SL)	4.19 (3.59-5.08)	5.71 (4.89-6.84)	5.33 (4.28-6.23)	5.36 (4.57-5.91)	4.95 (4.53-5.88)	5.84 (5.21-6.40)
NL(%SL)	7.04 (6.03-7.88)	7.11 (6.71-7.90)	7.17 (6.32-7.84)	6.30 (5.19-7.48)	7.45 (6.94-8.09)	6.20 (5.56-7.11)
DFL(%SL)	13.13 (11.85-14.44)	13.79 (11.83-14.87)	13.34 (11.07-14.97)	13.89 (13.02-14.86)	13.81 (13.17-14.34)	12.90 (11.75-14.67)
CPD(%SL)	10.59 (9.68-11.49)	11.39 (10.70-12.10)	11.90 (10.34-13.56)	11.24 (10.62-11.99)	11.62 (11.09-12.38)	10.76 (9.77-11.64)

(X: Mean value, Min and max: minimum and maximum, SL: Standart length, PD: Predorsal, BD: Body depth, HL: Head length, HD: Head depth, ED: Eye diameter, NL: Nasal length, DFL: Dorsal fin length, CPD: Caudal peduncle depth).

individuals in Zamantı stream were different from *S. trutta* in Ceyhan and Euphrates basin (Table 4). According to Principal Component analysis the highest load were determined for head depth (HD) and predorsal (Table 5). According to plot graphic using by PC1 and PC2, flathead trout population was different form the brown trouts in Ceyhan and Euphrates (Figure 6) and these arised from pectoral fin rays, pyloric caeca, gill rakers, head depth and predorsal characteristics.

Discussions

In this study, it was determined *S. trutta* in Aksu, Hurman, Törbüzek and Kömür streams belonging to Ceyhan streams upper branches. Besides, it has been existed as widespread in Göksu (Yılanovası) which one branch of Euphrates river. Flathead trout individuals living in Seyhan river has a much limited distribution. So far, it is to state that existing of flathead trout individuals living in Soğuksu, Sarız water, Karagöz and Uzunyayla which upper branches of Zamantı stream (Behnke, 1968; Susnik *et al*., 2004; Alp and Kara, 2004). *S. platycephalus* individuals living in Seyhan river are the most numerous existing in Uzunyayla district of Zamantı stream (Figure 1).

It was mentioned by Aras *et al*. (1997) that countable morphological traits of *S. trutta* individuals generally variable. It was also reported that species of *Salmo trutta* had dorsal fin ray with III-IV simple and 9-12 branched rays, anal fin with III-IV simple, 7-9 branched rays, 11-18 gill rakers on outer side of first gill arch, 98-137 line lateral scales and 21-41 pyloric caeca (Tortonese, 1954). The morphological caharacters of *S. trutta* reported by Kuru (1975), Aras (1976), Ekingen (1976), Balık (1984), Balık (1988), Geldiay and Balık (1988), Çetinkaya (1996) and Aras *et al*. (1997) are consistent with our results. It was reported by Bhenke (1968) that *S. platycephalus* in Zamantı stream, a branch of Seyhan river, had 15-16

Table 5. Morphometric traits' loadings on Principal Component Analysis result

	Principal Component loads		
	PC1	PC2	PC3
Body depth	0.347	0.004	0.000
Head length	0.300	0.005	0.004
Head depth	0.291	0.097	0.001
Eye diameter	0.170	0.018	0.072
Nasal length	0.377	0.020	0.027
Dorsal fin length	0.268	0.013	0.020
Caudal peduncle depth	0.326	0.004	0.003
Predorsal	0.323	0.059	0.049
Variance	95.062	1.733	1.125

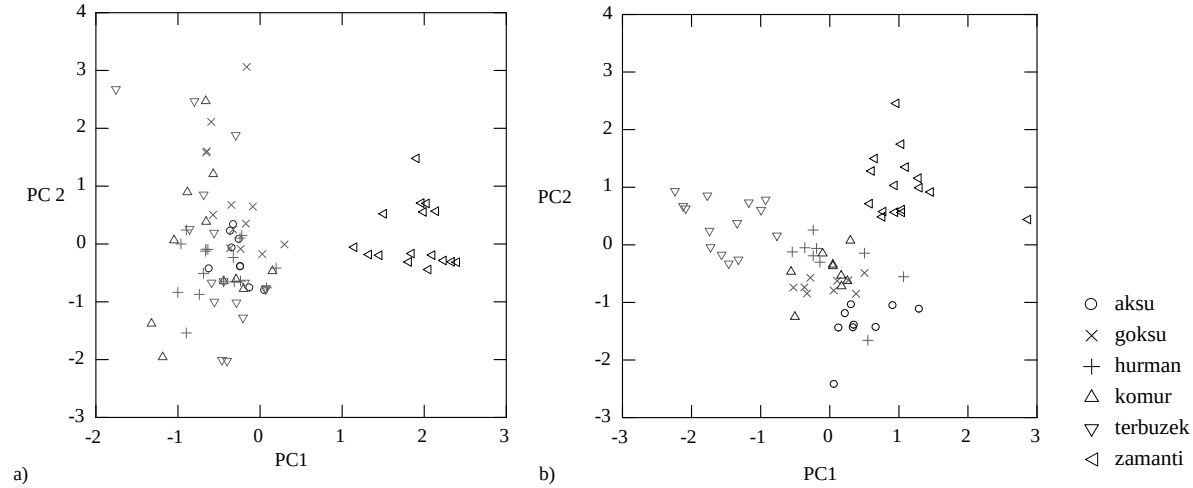

Figure 6. Plotting PC1 against PC2, illustrating morphometric differences among the *Salmo* species(a. Meristic, b. Metric).

pyloric caeca and 23-24 gill rakers on outer side of first gill arch. Sušnik *et al*. (2004) were declared that *S. platycephalus* had 22-25 pyloric caeca and 20-24 gill rakers on outer side of first gill arch. In this study, also gill raker number of flathead trouts living Seyhan basin have been determined as different from trouts living in Ceyhan and Euphrates basin. Once more, also pyloric caeca number of flathead trouts living in Seyhan basin are very variable and it is between 24-32 (Table 2). Also, this situation has showed quite difference from results of Behnke (1968). According to Principal Component Analysis (PCA) results, pyloric caeca, gill rakers, head depth and predorsal of *S. platycephalus* individuals living in Zamantı stream are difference from *S. trutta* individuals living in Ceyhan and Euphrates basin.

It is to statement that it can be extreme variations as generally to ecological traits of habitat colour and basing on to individuals ages patterns of trouts, their colour are rather dim, spots are unclear, besides it has been declared that it will be occuring of important changes at pyloric caeca number and flat and wide of head of specimens captured from different habitats (Balık, 1988; Dorofeeva *et al*., 1986; Aras *et al*., 1997). It has been declared by Sušnik *et al*. (2004) that differences on morphometric traits determined pertaning to *S. platycephalus* including its special morphology and special adaptation has necessitate as related to some environmental traits (water have dense aquatic plants, physico-chemical feature of water, flow, aquatic fauna etc.) which special for its habitats.

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