Morphometric comparisons of African catfish, *Clarias gariepinus*, populations in Turkey

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Abstract. The pattern of morphometric differentiation among six populations of *Clarias gariepinus* sited in the Asi, Seyhan, Ceyhan, Göksu, Aksu, and Sakarya river systems in Turkey was examined. Univariate analysis of variance revealed significant differences between means of the six samples for 18 out of 20 standardized morphometric measurements. The first canonical function accounted for 39 % and the second for 29 % of between–group variability. In principal component analysis, the first component accounted for 20 % and the second for 12 % of the shape variations among the samples. Plotting the first and second principal components showed that the observed differences were mainly from measurements taken from the head of fish, indicating this region to be important in the description of population characteristics. Visual examination of the samples along the canonical functions revealed a clear between-sample differentiation. All the samples except the Seyhan and Aksu samples were clearly distinct from each other. Sakarya and Göksu samples were mostly isolated from each other and from all other samples. The overall random assignment of individuals into their original groups was high (78%). The proportion of correctly classified individuals into their original group was highest in the Sakarya sample (93%) and high in the Göksu (88 %) and the Ceyhan (86 %) samples, indicating that these samples are highly divergent from each other.

Key words: *Clarias gariepinus*, stock identification, morphometric structuring, Turkey

Introduction

The family Clariidae at present consists of 14 genera, which comprise 92 species distributed in Africa and South-East Asia (Teugels 1986). Only one species, *Clarias gariepinus* (Burchell, 1822), of this family is found in Turkey (Teugels 1986, Geldiay & Balik 1996). *C. gariepinus* has increasing commercial importance in fisheries and aquaculture. Scientifically sound management of fish resources relies on basic knowledge on the biology of the species, including information on population structure. Such information influences the development of management strategies and strategies for conserving biodiversity. Morphological characters such as morphometrics and meristics have been commonly used to identify stocks of fish (Teugels 1982, Turan et al. 2004, Turan 2004). Virtually nothing is known about the morphological population structure of *C. gariepinus* in river systems of Turkey. It is vitally important to obtain detailed knowledge on the population structure in commercially exploited *C. gariepinus* and to apply such knowledge to the management of the fisheries (Teugels 1986, Carvalho & Hauser 1992). *C. gariepinus* occurs naturally in the rivers Asi, Seyhan, Ceyhan, Goksu and Aksu in Turkey.

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A population of *C. gariepinus* was recently introduced to the Sakarya River in the north part of the Turkey. Although a large number of studies on the taxonomic status of *C. gariepinus* have been conducted on a large scale comprising several countries, there has been no any study on the population structure of *C. gariepinus* in Turkish rivers. Therefore, this study aims to preliminary investigate population structure of *C. gariepinus* using morphometric characters throughout its distributional range in the rivers of Turkey.

Material and Methods

Specimens were collected from six locations throughout the species distribution comprising the rivers Asi (AS), Ceyhan (CE), Seyhan (SE), Göksu (GS), Aksu (AK) and Sakarya (SA) (Fig. 1). From each population, 30–32 specimens were collected by cast net for morphometric measurements and other sampling details of *C. gariepinus* are given in Table 1. Morphometric measurements (mm) were taken from each specimen according to T e u g e l s (1982) (Fig. 2).

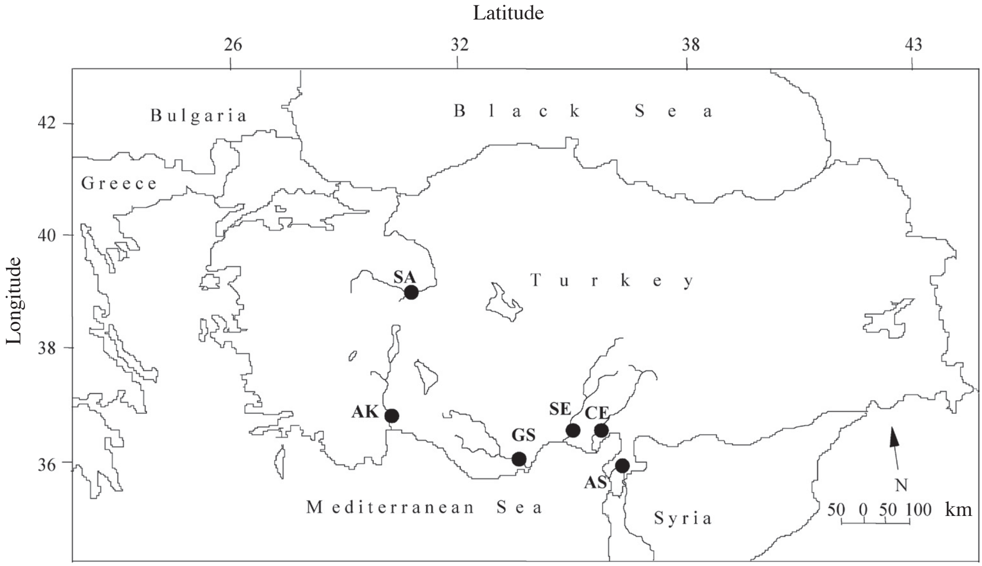


Fig. 1. The map of the sampling. •; indicate sampling locations. The samples referred to in the text were Asi (AS), Ceyhan (CE), Seyhan (SE), Göksu (GS), Aksu (AK) and Sakarya (SA) Rivers.

In the present study, there were significant linear correlations between all morphometric characters and standard length of fish. In order to eliminate any size effect in the data set, an allometric formula by E l l i o t t et al. (1995) was used to remove length effects in the samples;

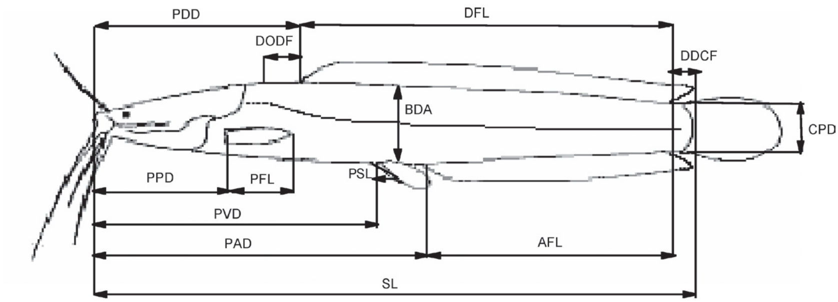
$$M_{adj} = M\,(L_s / L_o)^b$$

where M: original measurement, M_{adj}: size adjusted measurement, L_o: standard length of fish, L_s: overall mean of standard length for all fish from all samples in each analysis. Parameter b was estimated for each character from the observed data as the slope of the regression of log M on log L_o, using all fish in all groups. The efficiency of size adjustment transformations was assessed by testing the significance of correlations between transformed variables and standard length.

Table 1. Sampling details of *C. gariepinus* used in this study (SD = standard deviation, n **=** number of specimens).

Locality	Code	n	Date of capture	Location of samples	Mean standard length (cm) ± SD
Asi	AS	32	July 1999	36° 10' N 36° 05' E	38.73 ± 2.93
Ceyhan	CE	30	October 1999	37° 05' N 35° 15' E	36.87 ± 3.38
Seyhan	SE	30	October 1999	37° 05' N 35° 43' E	25.38 ± 2.52
Göksu	GS	32	April 1999	36° 25' N 33° 55' E	36.34 ± 2.64
Aksu	AK	30	November 1999	36° 53' N 30° 53' E	26.63 ± 6.04
Sakarya	SA	30	October 1999	39° 24' N 31° 17' E	36.95 ± 2.31

Both univariate and multivariate analysis of variance were carried out to test the significance of morphometric differences among populations. In addition, size-adjusted data were standardized and submitted to a principal component analysis (PCA) and a canonical variate analysis (CVA) using SPSSv9.0, and graphs were generated using SYSTATv5.0. Population centroids with 95% confidence ellipses derived from the CVA were used to visualize relationships among populations. Individuals were assigned to the samples using the canonical functions, and the percentage of correctly assigned fish was an additional measure of differentiation among samples. This output shows the number of cases correctly



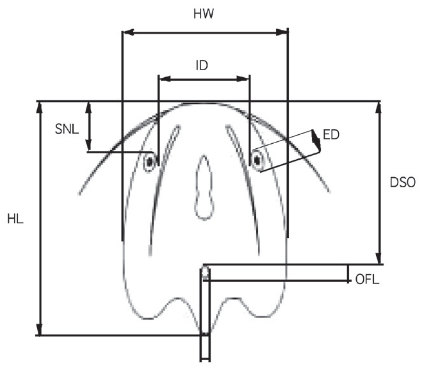


Fig. 2. Location of measurements on *C. gariepinus* from T e u g e l s 1986. SL, Standard length; PDD, Predorsal distance; PAD, Preanal distance; PVD, Preventral distance; PPD, Prepectoral distance; DFL, Dorsal fin length; AFL, Anal fin length; PFL, Pectoral fin length; PSL, Pectoral spine length; DDCF, Distance between dorsal and caudal fin; DODF, Distance between occipital process and dorsal fin; CPD, Caudal peduncle depth; BDA, Body depth at anus; HL, Head length; HW, Head width; SNL, Snout length; ID, Interorbital distance; ED, Eye diameter; OFL, Length of occipital fontanelle; OFW, Width of occipital fontanelle; DSO, Distance between snout and occipital processes.

and incorrectly assigned to each of group based of discriminant analysis. The percentage of correctly classified individuals gives a measure of the morphological distinctness of the samples. The number of misclassified individuals indicates the degree of intermingling between the populations. Mean of Ratios of the original measurements of the samples were calculated according to M a y r (1969) to compare the degree of differentiation of each character for each sample.

Results

Testing the interaction between variables and sexes from 147 sex-recorded fish revealed that 19 out of 20 morphometric measurements did not differ significantly, demonstrating a negligible effect of sex on observed variation. Only PAD measurement showed significant differences between sexes ($P<0.05$). Therefore the data were standardized and analysed without distinguishing the sexes. After the allometric transformation, there was no significant correlation between standard length and the morphometric measurements, which indicate that size effect was removed effectively from the data with the allometric transformation.

Univariate analysis of variance (ANOVA) revealed significant differences with varying degrees between means of the six river samples for 18 out of 20 standardized morphometric measurements (only AFL and DDCF were not significantly different, $P>0.05$).

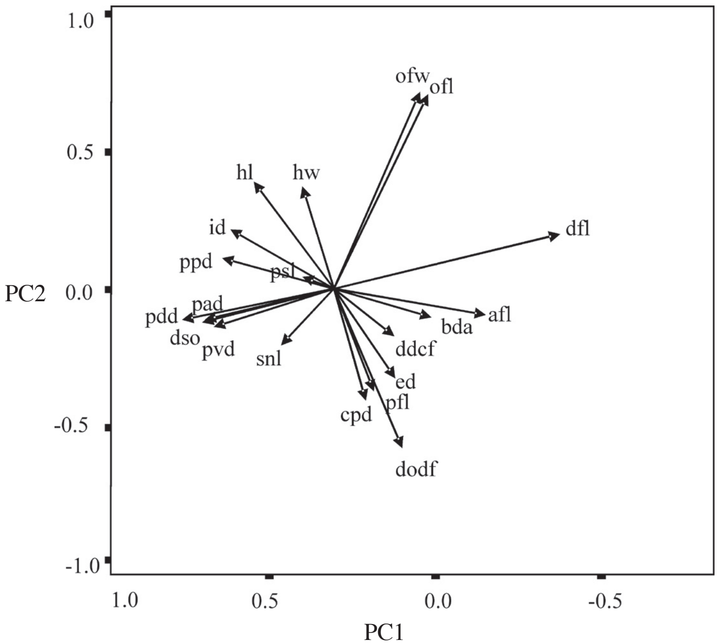


Fig. 3. Contribution of morphometric variables to the canonical functions. Vectors indicate the loadings of the scores for each variable on the first two discriminant functions.

The first canonical function accounted for the largest amount of between–group variability (39 %), the second, third, forth and fifth accounted for 29 %, 17 %, 13 % and 2 % respectively. In order to illustrate which morphometric characters differentiate populations, the contribution of variables to the principal components (PC) were examined. The first principal component (PC) accounted for 20% and second PC accounted for 12 % of the shape variations among the samples (Fig. 3). Examination of the distance of the variables from the origin revealed that the observed differences were mainly from head measurements, OFW, OFL, DFL, HW, HL, PPD, DODF, indicating this region to be important in the description of population characteristics. In addition examination of ratios of these head measurements among samples (Table 2) revealed that OFW was lowest in the Sakarya sample and highest in the Seyhan and Aksu samples. OFL was lowest in the Sakarya sample and highest in the Seyhan sample.

Table 2. The ratio of morphometric characters of *C. gariepinus*. Morphometric characters are as defined in Fig. 2.

	Measurement									
Samples	PDD	PAD	PVD	PPD	DFL	AFL	PFL	PSL	DDCF	DODF
GS	0.343	0.548	0.445	0.214	0.633	0.426	0.119	0.089	0.036	0.075
AS	0.324	0.534	0.431	0.183	0.657	0.442	0.114	0.078	0.032	0.070
SE	0.335	0.536	0.443	0.194	0.644	0.477	0.121	0.085	0.029	0.074
CE	0.341	0.543	0.447	0.197	0.642	0.435	0.113	0.089	0.033	0.066
AK	0.333	0.535	0.444	0.199	0.637	0.431	0.123	0.093	0.037	0.059
SA	0.336	0.535	0.442	0.184	0.643	0.459	0.127	0.084	0.034	0.081
	CPD	BDA	HL	HW	SNL	ID	ED	OFL	OFW	DSO
GS	0.082	0.134	0.270	0.189	0.063	0.125	0.020	0.023	0.013	0.201
AS	0.081	0.153	0.260	0.183	0.053	0.115	0.019	0.024	0.013	0.189
SE	0.083	0.153	0.270	0.185	0.056	0.127	0.023	0.034	0.016	0.199
CE	0.083	0.157	0.277	0.187	0.054	0.125	0.021	0.026	0.014	0.205
AK	0.082	0.154	0.267	0.183	0.052	0.120	0.025	0.030	0.016	0.197
SA	0.085	0.154	0.253	0.167	0.057	0.115	0.021	0.020	0.011	0.200

The canonical function 1 (CF1) and canonical function 2 (CF2) were plotted to allow visual examination of the distribution of each sample along the CF axis that showed a clear between-sample differentiation (Fig. 4). In the discriminant space, all the samples except the Seyhan (SE) and Aksu (AK) samples were clearly distinct from each other. Remarkably, the Sakarya and Göksu samples were mostly isolated from each other and from all other samples.

The overall random assignment of individuals into their original group was high (78%) (Table 3). The proportion of individuals correctly classified into their original group was highest in the Sakarya sample (93%) and high in the Göksu (88 %) and Ceyhan (86 %) samples, indicating that these samples are highly divergent from each other.

Discussion

The present morphometric analysis of the *C. gariepinus* in Turkish rivers revealed five considerably distinct populations with varying degrees, though not necessarily with any clear geographic pattern.

The Sakarya river sample was the most divergent from the others (Fig. 4). *C. gariepinus* was introduced in the Sakarya river from the Göksu river in 1974 (E r g ü v e n 1978).

Table 3. Direct and percentage of grouped cases correctly classified into their original population. Samples are as defined in Table 1.

Samples	GS	AS	SE	CE	AK	SA	Total
GS	28	0	2	1	1	0	32
%	88	0	6	3	3	0	100
AS	0	24	2	2	4	0	32
%	0	75	6	6	13	0	100
SE	3	5	15	4	1	2	30
%	10	17	50	13	3	7	100
CE	0	0	2	25	2	0	29
%	0	0	7	86	7	0	100
AK	0	3	0	2	22	3	30
%	0	10	0	7	73	10	100
SA	0	0	2	0	0	28	30
%	0	0	7	0	0	93	100

C. gariepinus was sampled from the Middle Anatolian part of the Sakarya river; this is a cold region of Turkey and is incongruous with its usual distributional habitat (south part of Turkey). It is well known that morphometric characters can show high plasticity in response to differences in environmental conditions, such as food abundance and temperature (Allendorf 1988, Swain et al. 1991, Wimberger 1992). Therefore, the distinct environmental structure of the Sakarya river from the others may cause the detected high

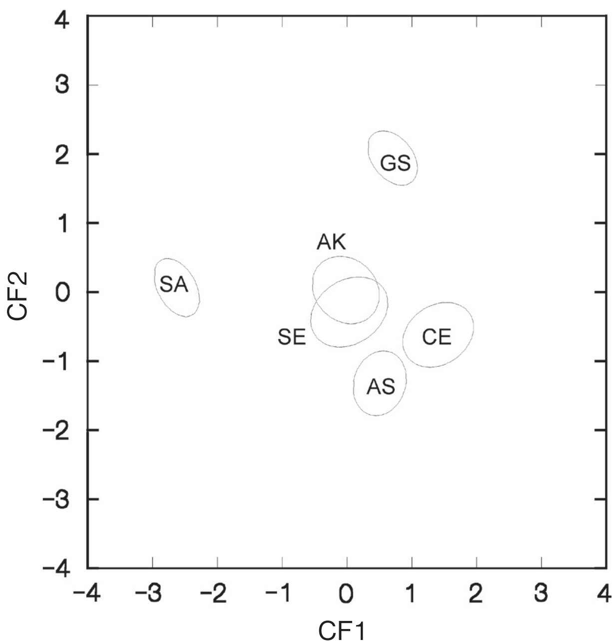


Fig. 4. 95% confidence ellipses of CFA scores of morphometric characters. The first canonical function (CF1) accounts for 96%, and second (CF2) accounts for 4% of the between group variability.

morphometric variation of *C. gariepinus* though it is a widely tolerant fish to extreme environmental conditions.

The Göksu sample also highly deviated from the other samples (Fig. 4). This high deviation might be related to the geographic isolation of the Göksu from the adjacent rivers (the Seyhan, Ceyhan and Asi) (Fig. 1), which may have resulted in restricted intermingling and subsequent morphological differentiation.

The overlapping of the Aksu and Seyhan river samples in discriminant space may suggest a sufficient degree of intermingling between these rivers to homogenize populations. Moreover, *C. gariepinus* may have been introduced to the Aksu river from the Seyhan river, and there has been not enough time to generate phenotypic differentiation among populations since these rivers have similar environmental conditions. This finding leads us to use a genetic technique such as mtDNA analysis to reveal introduced populations and the history of movement among populations. The potential of mtDNA as a tool for population genetic analysis has been provided by A v i s e (1994).

PCA revealed that morphometric differentiation between samples was largely located in the head of *C. gariepinus*. In the Asi population, the dorsal and ventral fins were placed more anteriorly, pectoral spine and head length were both shorter, and the eyes were closer to each other than that in the other samples. Such differences between the populations maybe related to different habitat characteristics, such as temperature, turbidity, food availability, water depth and flow. For example, eye diameter was greater in the Aksu and Ceyhan populations, which may be due to differences in turbidity among rivers (M a t t h e w s 1988). Position of eyes in the head was related to vertical habitat preference (A l e e v 1969). Lateral placement was assumed to indicate pelagic habitat, and dorsally increased displacement was assumed to reflect a more sedentary mode of life (A l e e v 1969). Moreover, short head length was correlated with small prey size in stream fishes (G a t z 1979). In the Sakarya sample, the dorsal fin and posterior fontanelle were placed posteriorly, and the head was smaller in comparision to the other samples (Table 2). In the Göksu population, pectoral fins (PPD) were placed posteriorly, and the body depth at the anus was shorter than in the other populations (Table 2). Moreover, the dorsal fin was placed more anteriorly in the Aksu population, and more posteriorly in the Göksu population than in the others. The location of the dorsal fin is related to the vertical position in the water column, with posteriorly-placed dorsal fins representing adaptations to surface habitats in non-flowing waters (M a t t h e w s 1988). K e s s l e r et al. (1995) considered that a benthic sculpin and four benthic darter species had differences in habitat use in streams at high flow that corresponded to differences in morphology, with two species having robust bodies and large pectoral fins, which allowed them to withstand currents on smaller, smoother substrata. On the other hand, in order to support the given hypotheses above, more detailed data on the environmental conditions from each location (river) sampled were needed.

Consequently the present analysis suggests high morphologic differentiation among *C. gariepinus* populations. The detected differentiation may be related to differential environmental conditions such as temperature, turbidity, food availability, and water depth. On the other hand the detected high phenotypic differences between the rivers lead us to think and investigate that the divergent populations may belong to other taxa. However, it should be emphasized that application of genetic techniques (C a r v a l h o & H a u s e r 1992, T u r a n et al. 1998, S h a w et al. 1999, H a u s e r et al. 2001) would be very beneficial to confirm the detected phenotypic differentiation.

A c k n o w l e d g e m e n t s

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