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Morphological Differences Among the Mesopotamian Spiny Eel, *Mastacembelus mastacembelus* (Banks & Solander 1794), Populations

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Abstract

Morphological status of the Mesopotamian spiny eel, *Mastacembelus mastacembelus*, populations from Karakay Reservoir, Tohma Stream and Tigris River were investigated using morphometric and meristic traits.

Significant morphometric differences were detected among the populations, while meristic traits did not differ in three populations. Lower jaw length (LJL) was significantly smaller in Atatürk Reservoir population than the river populations of Tohma and Dicle. Stepwise discriminant analysis was applied for transformed morphometric and meristic data. In discriminant function analysis, morphometric differentiation was determined among the populations. The percentage of correctly classified individuals into their original groups was 71% for Tigris and Tohma and 97% for Karakaya populations. River populations had two more dorsal fin rays than reservoir. However, in the discriminant function analysis the populations were not clearly separated from each other in terms of meristic traits. The classification rates of meristic traits analysis were 86% for Karakaya and Tohma and 71% for Tigris populations.

Keywords: Mesopotamian spiny eel, *Mastacembelus mastacembelus*, morphology.

Dikenli Yılan Balığı, *Mastacembelus mastacembelus* (Banks & Solander, 1794) Populasyonları Arasındaki Morfolojik Farklılıklar

Özet

Bu çalışmada morfometrik ve meristik özellikler kullanılarak Karakaya Baraj Gölü, Tohma Çayı ve Dicle Nehrindeki dikenli yılan balığı (*Mastacembelus mastacembelus*) populasyonlarının morfolojik özellikleri incelenmiştir.

Meristik özellikler bakımından üç populasyon birbirinden farksız bulunurken, morfometrik özellikler bakımından populasyonlar arasındaki fark istatistiksel açıdan önemli bulunmuştur. Karakaya Baraj Gölü populasyonunda alt çene uzunluğu (LJL) Tohma Çayı ve Dicle Nehrindeki akarsu populasyonlarından önemli oranda daha küçük bulunmuştur. Trasformasyona tabii tutulmuş morfometrik ve meristik verilere stpwise discriminant analizi uygulanmıştır. Söz konusu discirminant analizine göre, populasyonlar arasında mofometrik farklılıklar önemli olmuştur. Discirminanat analizi Dicle ve Tohma örneklerinin %71'ini kendi grubu içerisinde doğru şekilde sınıflarken Karakaya Baraj Gölü populasyonunda %97'ini doğru olarak sınıflamıştır. Dorsal yüzgeç ışın sayısı nehir populasyonlarında, baraj gölü pupulasyonuna göre iki ışın fazla bulunmuştur. Ancak Discirminant analizinde populasyonlar meristik açıdan farklı bulunmamışlardır. Meristik özellikler bakımından sınıflama oranları Karakaya ve Tohma populasyonları için %86 ve Dicle populasyonu için ise %71 olarak hesaplanmıştır.

Anahtar Kelimeler: dikenli yılan balığı, *Mastacembelus mastacembelus*, morfoloji.

Introduction

The family Mastacembelidae (78 valid species) known as spiny eels belongs to the order Synbranchioformes together with the family of Synbranchidae (20 valid species) and Chaudhuriidae (9 valid species) (Froese and Pauly, 2008). The members of the Mastacembelidae are found principally in freshwaters and distributed in tropical and subtropical Africa, the Middle East and South-East Asia, north of China. Mastacembelidae family includes 3 genera - *Mastacembelus* (61 valid species), *Macrognathus* (16 valid species) and *Sinobdella* (1 valid species) (Froese and Pauly, 2008). Nine species of *Mastacembelus* inhabit Asian inland waters while 52 species occur in African inland waters and all the members of the *Macrognathus* inhabit Asian inland waters (Froese and Pauly, 2008). More than 70 species of spiny eels are important as food fishes (Britz, 2007). Mastacembelids can attain a maximum length of about 1 m. They are eel-like fishes and have a long series of well-separated dorsal spines and a short series of anal spines. They have also no pelvic girdle and fins (Vreven, 2005a; 2005b).

Mastacembelus mastacembelus occurs in the Euphrates and Tigris River basin in the Middle East, Turkey, Syria, Iraq and Iran, and it is known as Mesopotamian spiny eel due to its inhabiting area (Coad, 1996; Coad, 2006; Oymak *et al*., 2009). This species is also sole representative of the order Synbranchioformes in Turkish freshwaters and it was reported as *M. simack* (Geldiay and Balık, 1988). However, *M. mastacembelus* is accepted as valid species instead of *M. simack*, *M. halepensis* and *Ophidium simack*, because these are the synonyms. *M. mastacembelus* is a typical species of the Mastacembelidae and contains all characteristics of the family. It is an important species in the commercial fisheries in the region.

Mastacembelidae has been classified based on morphological characters (Travers, 1984; Britz, 1996; Vreven, 2005a; 2005b; Britz, 2007). Although, majority of the Mastacembelids were described morphologically, no detailed meristic and morphometric study is present on Mesopotamian spiny eel, *M. mastacembelus*. The original habitats of this species are lotic ecosystems. On the other hand, in recent years, many reservoirs have been constructed on the basins of Euphrates and Tigris Rivers, which are the main habitats of *M. mastacembelus.* However, its morphological differences between river and lacustrine populations have not been described so far. It is well known that different habitats present different ecological parameters and populations are expected to show variation in the morphological characters.

In order to determine the morphological differentiation of the fish populations, truss network or geometric methods have been used in recent years (Janhunen *et al*., 2009; Tzeng *et al*., 2007; Turan *et al*., 2005; Ergüden and Turan, 2005; Tzeng, 2004; Turan *et al*., 2004; Parsons *et al*., 2003; Delling, 2003; Delling, 2002; Fitzgerald *et al*., 2002; Delling *et al*., 2000; Bookstein, 1982). Parsons *et al.* (2003) compared traditional methods (truss network) and geometric morphometrics and they reported that geometric morphometrics could be a more effective way to analyze and interpret body form, but also that traditional methods (truss network) could be relied upon to provide statistical evidence of shape differences and it could be used for distinguished two species.

The aim of this study is to identify meristic and morphometric characters of the Mesopotamian spiny eel, *M. mastacembelus*, using by truss network method and determine the differences between river and reservoir populations morphologically. These may be used to identify stocks of Mesopotamian spiny eels in the fisheries management and will also contribute to the taxonomic studies of this species.

Materials and Methods

The samples of the Mesopotamian spiny eels were obtained from Karakaya Reservoir, Tohma Stream in Euphrates in Malatya-Elazığ and Tigris River in Diyarbakır. A total of 57 specimens were collected by gill nets in reservoir and electro-fishing in streams. The samples were transferred to the laboratory into 70% ethanol.

The truss network method was applied to construct a network on *M. mastacembelus* specimens (Schaefer, 1991; Bookstein, 1982). Eight landmarks determining 15 distances were chosen and measured on the body (Figure 1a). The fish were placed on their right side on acetate sheets, and the body posture and fins were conditioned into a natural position. Each landmark was taken by piercing the acetate sheet with

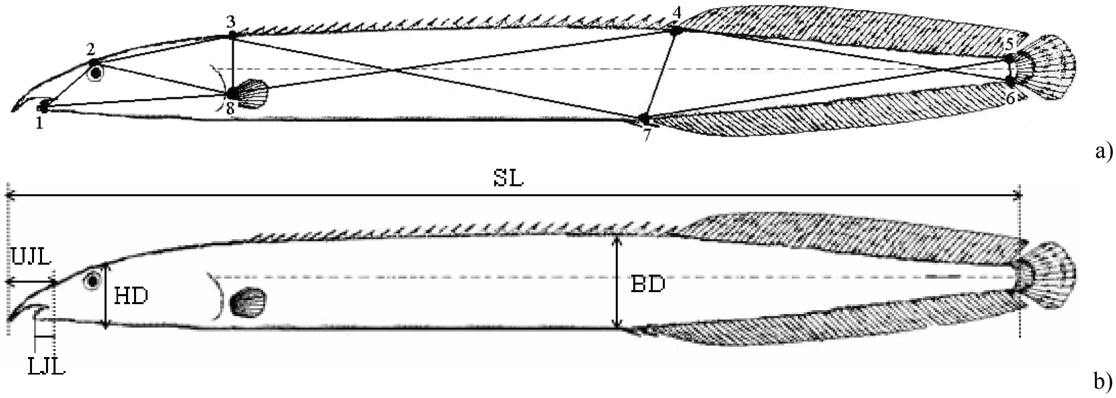

Figure 1. Morphometric measurements of *M. mastacembelus*. a) Constructing of the truss network, b) Ordinary morphometric traits.

a dissecting needle. In addition, upper jaw length (UJL), lower jaw length (LJL), head depth (HD), body depth (BD) and standard length (SL) were measured with digital callipers (Figure 1b). Dorsal spines (DS), anal spines (AS), dorsal fin rays (D), anal fin rays (A), caudal fin rays (C) and pectoral fin rays (P) were counted with a stereomicroscope. The number of the total vertebrae (TV), abdominal vertebrae (AV) and caudal vertebrae (CV) were also counted from the radiographs.

Morphometric measurements were submitted as the percentage of the standard length (SL) and the differences among the populations were tested by ANCOVA. Morphometric measurements and meristic counts were subjected to stepwise discriminant function analysis (DFA). The DFA was performed for allometrically transformed measurements and square-rooted counts. In order to remove the size effects on the morphometric traits, an allometric formula was applied prior to DFA (Pinheiro *et al*., 2005; Turan *et al*., 2004);

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

Where M is the original measurement, M_{adj} is the size-adjusted measurement, L_o is the SL, and L_s is the mean SL of all fish. 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 traits reduced the data to two orthogonal axes or discriminant functions (DF 1 and DF 2) and then plotting the individual scores of DF 1 and DF 2, the populations were visualised on the graphs. Differences of individual scores of DF1 and DF 2 among the populations were tested by ANOVA and Tukey tests. Hierarchical cluster analysis was also applied to clustering *Mastacembelus* species in terms of vertebrae. Statistic analyses were performed using SYSTAT v10.0 and SPSS v13.0.

Results

Mesopotamian spiny ell specimens were significantly smaller in the Karakaya Reservoir than two rivers (Tohma and Dicle) (Table 1). There were further significant differences among the populations once SL had been controlled for using ANCOVA. The length of the lower jaw length (LJL) was significantly smaller in reservoir population. However, the length of the upper jaw length (UJL) and head depth (HD) did not differ among the populations while body depth (BD) was smaller in Tigris River population. All the measurements of the truss network significantly differed among the populations except from 3-8, 4-7, 4-8 and 7-8.

The overall degree of differences among the populations was visualized by stepwise discriminant function analysis. The variables used in the model were 3-7, 4-5, 4-7 and 5-7 in the truss network and body depth (BD). This reduced data to two significant orthogonal axes or "discriminant functions" (DF 1 and DF 2: Wilks Lambda, d.f.=42 and 68, P=0.0001). In plotting the individual scores of DF 1 against DF 2, the populations clearly separated: the Karakaya Reservoir population on the basis of DF 1 and the two river populations on the basis of DF 2 (Figure 2a). Individual scores for each function were highly significant in the first discriminant function (ANOVA, DF 1, d.f.=2 and 54, $P<0.0001$). However, it was not significant in the second discriminant function (DF 2, d.f.=2 and 54, $P>0.005$). Tukey tests revealed that for DF 1 three populations were significantly different from the each other. The analysis correctly classified, 88% of the individuals on average. The classifications was 71% for Tigris, 97% for Karakaya and 71% for Tohma populations.

For the meristic traits (Table 2), dorsal (D) and pectoral (P) fin rays significantly differed in the populations. However, the other meristic traits were not significant among the populations. All the meristic traits were subjected to the discriminant function analysis and discriminant functions (DF 1 and DF 2) were not significant in the populations. In plotting the individual scores of DF 1 against DF 2, the populations have not separated clearly (Figure 2b). Discriminant function analysis for meristic traits correctly classified, 82% of the individuals on average. The classification rates were 86% for Karakaya and Tohma and 71% for Tigris populations.

Discussion

The present results demonstrated significant differences in morphometric traits among the populations of *M. mastacembelus*. This morphometric differentiation, however, was not supported by meristic traits.

In both Tigris River and Tohma Stream, the fish were of a similar and significantly larger body size than in the Karakaya Reservoir. Further to the basal differences in body size, the populations showed significant differences in a number of morphometrics. Upper jaw length (UJL), head depth (HD), body depth (BD) and the truss network measurements of 3-8, 4-7, 4-8 and 7-8 did not differ in the populations. Other morphometric traits, however, showed significant differences in three populations. Some traits are interpretable from an adaptive perspective, e.g., the thicker and longer caudal peduncle of the river populations may enhance swimming ability in fast-flowing water (Neat *et al*., 2003). In the present study, caudal peduncle measurements (4-5, 5-6 and 6-7 in truss model) of Tigris River and Tohma Stream *M. mastacembelus* were higher than Karakaya Reservoir. The similar findings were reported for lake and river populations of pumpkinseeds *Lepomis gibbosus*, rock bass *Ambloplites rupestris* (Brinsmead and Fox, 2002) and *Salaria fluviatilis* (Neat *et al*., 2003). The *M.*

Table 1. Morphometry of *M. mastacembelus* as percent of Standard length (SL)

	Karakaya (n=36)		Tohma (n=7)		Dicle (n=14)			
	X±SD	Range	X±SD	Range	X±SD	Range	F	Sig.
SL	301.5±94.1	93-461	617.9±103.4	472-734	601.0±83.1	425-720	71.93	0.000
LJL	1.28±0.25	0.7-1.9	1.51±0.14	1.3-1.7	1.51±0.17	1.3-1.9	6.835	0.000
UJL	1.85±0.32	1.3-3.2	1.74±0.14	1.6-1.9	1.73±0.14	1.5-2.0	1.143	0.327
HD	4.33±0.59	3.3-6.1	4.34±0.19	4.1-4.7	3.94±0.40	3.1-4.5	3.035	0.056
BD	8.40±0.99	6.9-11.2	8.33±0.70	7.4-9.2	7.58±0.58	6.7-8.6	4.490	0.016
1-2	5.81±0.85	4.7-8.2	4.80±0.72	4.1-6.1	4.57±0.24	4.2-5.2	16.678	0.000
1-8	15.95±1.39	12.1-19.4	14.31±1.40	12.6-15.9	13.87±0.84	12.5-16.0	15.245	0.000
2-3	14.24±0.96	12.6-17.1	13.54±0.69	12.4-14.2	13.45±0.62	12.5-14.7	5.162	0.009
2-8	11.74±1.14	7.9-15.3	10.70±1.11	9.3-12.3	10.44±0.57	9.4-11.3	9.394	0.000
3-4	46.08±1.69	43.8-51.0	43.35±1.74	40.6-45.9	44.92±2.64	42.4-53.3	6.312	0.003
3-7	43.47±1.71	40.7-50.0	40.65±2.03	38.0-43.9	42.13±1.06	40.6-43.9	10.526	0.000
3-8	5.72±0.63	4.4-7.0	5.69±0.89	4.1-6.9	5.57±0.65	4.56-6.93	0.258	0.773
4-5	36.94±2.52	32.9-48.9	40.55±1.07	38.7-42.2	39.85±1.67	35.1-41.7	13.505	0.000
4-6	36.68±1.75	32.3-39.8	40.49±0.94	39.5-41.8	39.99±1.59	36.0-41.8	30.138	0.000
4-7	9.26±1.13	6.6-12.2	9.25±0.48	8.6-9.9	8.60±0.58	7.7-9.9	2.470	0.094
4-8	48.73±2.27	40.8-53.1	47.68±1.33	46.0-49.6	48.04±1.35	45.8-50.3	1.179	0.316
5-6	2.94±0.46	1.8-3.8	3.52±0.40	3.0-4.3	3.52±0.28	3.0-4.2	13.115	0.000
5-7	40.43±1.96	37.3-46.6	43.87±1.93	41.7-47.3	42.55±1.46	39.6-45.4	13.959	0.000
6-7	39.91±1.44	36.9-43.9	43.24±1.59	41.7-46.3	41.47±2.50	34.7-44.8	12.080	0.000
7-8	45.22±2.05	36.1-48.2	43.70±2.24	40.2-46.7	45.20±1.30	43.1-47.6	1.909	0.158

LJL: Lower jaw length, UJL: Upper jaw length, HD: Head depth and BD: Body depth

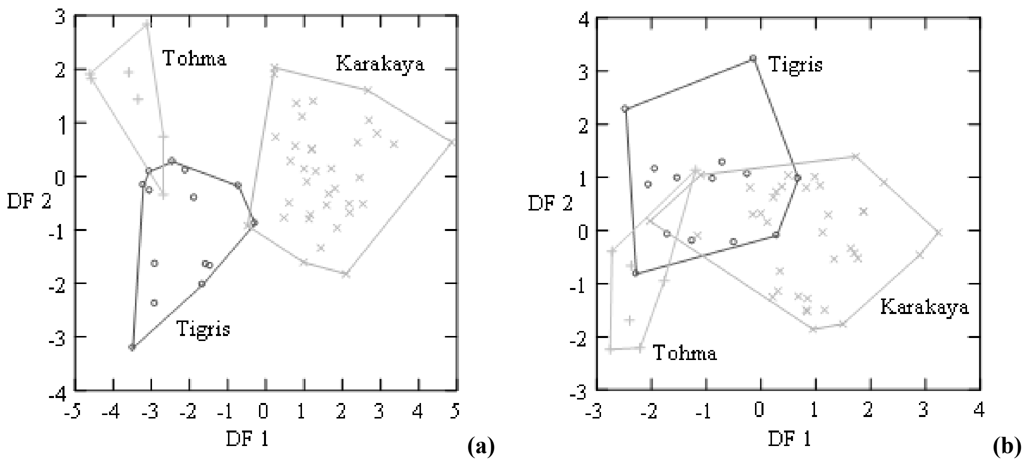

Figure 2. Morphological differences illustrated through discriminant analysis by plotting DF 1 against DF 2. a) The scores of morphometric measurements b) The scores of meristic counts.

Table 2. Meristic data of *M. mastacembelus*

	Karakaya (n=36)		Tohma (n=7)		Dicle (n=14)			
	X±SD	Range	X±SD	Range	X±SD	Range	F	Sig.
DS	34.12±0.6	33-35	33.7±0.4	33-34	33.9±0.7	33-35	0.318	0.276
AS	3.0	3-3	3.0	3-3	3.0	3-3	-	-
D	73.3±1.7	70-78	75.5±1.2	74-77	74.8±1.6	72-78	7.342	0.002
A	74.6±2.1	70-78	75.8±1.7	73-78	73.6±2.3	70-77	2.562	0.086
C	18.4±0.6	17-19	17.7±0.7	17-19	18.7±1.1	16-21	4.211	0.020
P	20.3±0.8	18-21	19.1±0.6	18-20	19.5±1.0	18-21	10.564	0.000
AV	36.7±0.4	36-37	36.8±0.4	36-37	37.0	37-37	1.031	0.363
CV	49.7±0.5	49-51	50.1±0.4	50-51	49.8±0.3	49-50	3.144	0.051
TV	86.5±0.7	85-88	87.0±0.6	86-88	86.8±0.3	86-87	2.143	0.127
CV-AV	13.0±0.6	12-14	13.3±0.5	13-14	12.8±0.3	12-13	1.875	0.163

DS: Dorsal spine, AS: Anal spine, D: Dorsal fin ray, A: Anal fisn ray, C: Caudal fin ray, P: Pectoral fin ray, AV: Abdominal vertebrae, CV: Caudal vertebrae and TV: Total vertebrae *mastacembelus* from both rivers had significantly longer lower jaws than fish from the Karakaya Reservoir. The similar situation was reported for lake and river populations of *S. fluviatilis* (Neat *et al*., 2003). This could related to feeding adaptations. Body height and width characterize the overall body build, and robustness of the fish, which are of considerable importance for the swimming performance, while head morphology reflects the feeding habits of the species (Pakkasmaa, 2001).

The discriminant function analysis for morphometric traits clearly separated three *M. mastacembelus* populations. The first axis (DF1) approximated to an overall measure of body size (strongly correlated to standard length) and the second (DF2) represented a non-specific dimension of overall morphometric variance. Although, the size effects on the morphometric traits were removed by an allometric transformation, Karakaya Reservoir population located on the basis of DF 1 and other populations, however, located on the basis of DF 2.

The *M. mastacembelus* populations showed no significant differentiation in terms of meristic traits. However, both Tigris and Tohma populations had two more dorsal fin rays and one more pectoral fin ray than Karakaya Reservoir. The other meristic traits did not show any differences in three populations. Caudal fin rays varied from 16-21 in the present study and this was consistent with the results reported by Vreven (2005a). The numbers of the vertebrae were also consistent with the result of the previous study (Vreven, 2005b). The total vertebrae number of Mastacembelus varied from 63 to 104. According to hierarchical cluster analysis for the vertebrae numbers (AV, CV, TV and CV-AV) from the modified data of Vreven (2005b), the nearest species to *M. mastacembelus* were *M. armatus* and *M. marmoratus* (Figure 3).

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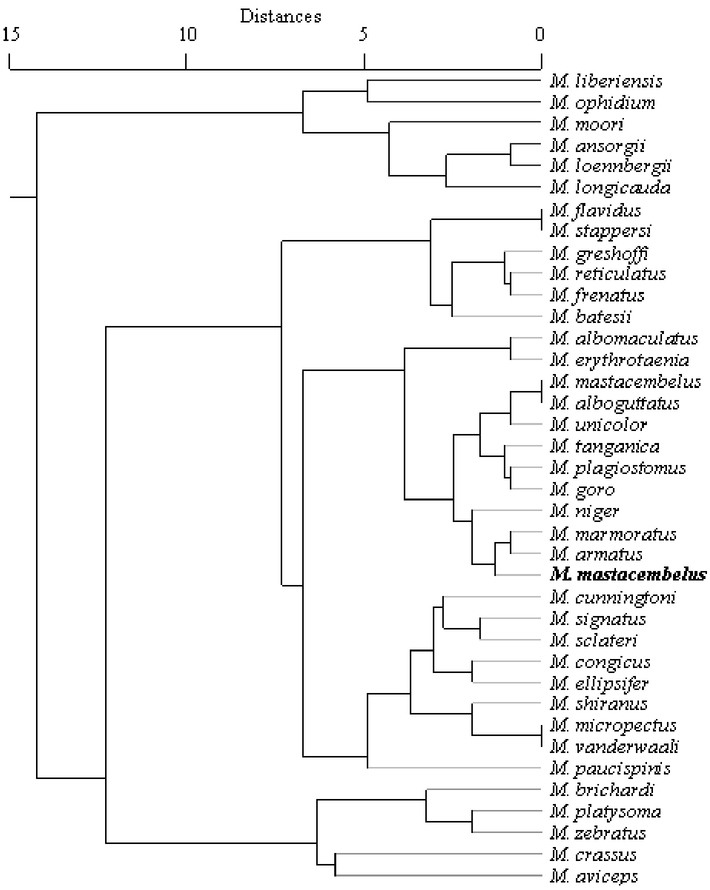

Figure 3. Dendrogram of hierarchical cluster analysis for the vertebrae numbers (AV, CV, TV and CV-AV) of *Mastacembelus* species. Bold letters indicate the present study and the other were modified from Vreven (2005a).

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