

# Biometric Relation between Asteriscus Otolith Size and Fish Total Length of Seven Cyprinid Fish Species from Inland Waters of Turkey

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## Abstract

The relationships between asteriscus otolith morphology (OL, OW, OR and OM) and fish total length were described with a non-linear function (power model) for seven Cyprinid fish species: *Capoeta angorae*, *C. antalyensis*, *C. caelestis*, *C. erhani*, *C. pestai*, *Pseudophoxinus antalyae* and *P. fahrettini*. These species are endemic to Turkey and have limited distributions. The regression models are quite well fitted with all asteriscus otolith measurements. We were also conducted the regression models for genus level. There was no significant difference between the size of the left and right otoliths (paired t-test) in any of the seven species. This is the first study that examines the relationships between asteriscus otolith morphology and fish total length for four Cyprinid species. These results showed that the equations generated to obtain the fish size using otolith morphology data can be used in dietary studies.

## Introduction

Otoliths have a characteristic shape which is highly species specific and also differs widely between species (Maisey, 1987). The size of fish prey and their importance in the diet can partly be estimated from the otoliths (Nielsen, Methven & Kristensen, 2010). By applying a relationship between the otolith morphology and fish length, it is possible to predict the fish size (Echeverria, 1987; Gamboa, 1991). Recently, researchers have shown an increased interest in the use of otoliths for calculating the fish sizes (Altin & Ayyildiz, 2018; Ayyildiz, Emre, Ozen & Yagci, 2014; Ayyildiz, Ozen & Altin, 2014a; Ayyildiz, Ozen & Altin, 2014b; Ayyildiz, Ozen & Altin, 2015; Echeverria, 1987; Emre *et al.*, 2016; Emre, Ayyildiz, Ozen & Yağci, 2014; Kumar, Nikki, Oxona, Hashim & Sudhakar, 2017; Templeman & Squires, 1956). Otoliths may also assist to identify fossil fish species for paleontological studies (Nolf, 1995).

Asteriscus otoliths are the most preferred otoliths because they are the largest of the three pairs of otoliths in bony fishes which members of the Cypriniformes (Hecht, 1977). The age and growth of these species have been studied from Menzelet Reservoir (Ayyildiz, Emre, Ozen & Yagci, 2014), Fırnız Stream (Emre, Ayyildiz, Ozen & Yağci, 2014) and a small river entering the Eğirdir Lake (Emre *et al.*, 2016) by using asteriscus otoliths.

The main purpose of this study is to determine the relationships between asteriscus otolith morphology (length, width, radius and mass) and fish total length based on allometric power equation for 7 Cyprinid fish species from inland waters of Turkey. This paper also investigates the usefulness of relationships between otolith morphology and total length for every genus. Part of the aim of this paper is to provide first biometric data for the future studies on food habits for 7 Cyprinid fish species.

## Materials and Methods

Samplings were performed seasonally in the Beyşehir Lake (Konya), Eğirdir Lake (Isparta), Aksu River (Kahramanmaraş), Alara River (Antalya), Göksu River (Mersin) and Menzelet Reservoir (Kahramanmaraş) from August 2011 through May 2013. Fish samples were collected by using gill nets and electrofishing devices. In the laboratory, 1233 specimens of each species were measured to the nearest 1 mm for total length (TL) and with a digital balance with precision to 0.01 g for total weight. Then asteriscus otoliths were extracted and placed in eppendorf tube. After a while, the length (OL), width (OW), radius (OR) and mass (OM) of the asteriscus otoliths were measured by using QCapture Pro2 imaging software (vers. 5.1; QImaging, Surrey, Canada) with an accuracy of 0.001 mm.

The distance between the anterior and posterior otolith edge was defined as OL, and the distance from the dorsal to the ventral edge of the asteriscus otolith was defined as OW. OR is the longest axis between the core and posterior edge. OM were measured with an analytical balance with precision to 0.0001 g. asteriscus otolith sizes (OL, OW, OR, and OM) between right and left otoliths were compared with a paired t-test.

The relationships between fish total length (TL) and asteriscus otolith sizes (OL, OW, OR and OM) are adjusted through described by (Huxley, 1924; Huxley, 1932). An alternative method was performed, for the possibility of erosion of the otolith in the stomach of the piscivorous, by using the allometric power equation at genus level.

## Results

For each species, the size of the sample, minimum and maximum lengths and the mean values of TL, OL, OW, OR and OM were recorded and summarized in Table 1. There were no significant differences between the morphometric measurements of the right and left asteriscus otoliths (paired t-test,  $N = 30$ ,  $P > 0.05$ ). Therefore, only one otolith was randomly selected for further analysis. Biometric relationships between OL, OW, OR and OM with fish total length are summarized in Table 2. Regression analyses showed that otolith sizes (OL, OW, OR and OM) and fish total length were highly correlated.

The coefficients of determination ( $R^2$ ) ranged from 0.760 to 0.979 in all cases. The lowest correlation coefficient was found in relations between TL-OM ( $R^2=0.760$ ) for *C. angorae* and TL-OR ( $R^2=0.790$ ) for *P. fahrettini*, while the highest correlation coefficient was calculated for the relations between TL-OW ( $R^2=0.979$ ) for *C. pestai*. Regression coefficients of asteriscus otolith sizes to fish total length were larger than 0.9 in 19 cases and between 0.8 and 0.9 in 7 cases (Table 2).

Our study provides the first relationships between OL, OW, OR and OM with fish total length for *C.*

*antalyensis*, *C. caelestis*, *P. antalyae* and *P. fahrettini*. We also have described the regression within a genus level (Table 3). The lowest correlation coefficient was found in relations between TL-OM ( $R^2=0.703$ ), while the highest correlation coefficient was calculated for the relations between TL-OL ( $R^2=0.979$ ) for *Capoeta* genus. The best fit for the all relationships were recorded for *Capoeta* ( $R^2=0.934$ ,  $R^2=0.931$  and  $R^2=0.891$ , respectively), except TL-OM relations ( $R^2=0.703$ ) compared to the *Pseudophoxinus* genus.

## Discussion

Little information is available on the otolith morphology of Cyprinid fishes from Turkish inland waters. In this study the relationships between OL, OW, OR and OM with fish total length for *C. antalyensis*, *C. caelestis*, *P. antalyae* and *P. fahrettini* were examined for the first time (Table 1). These results provide a baseline reference for trophic studies for identification of prey and the estimation of its size.

Somatic growth rates of fishes have significant effects on the otolith growth (Munk, 2012). One of the most useful methods for predicting fish size in the stomachs of predators is the relationships between otolith size and fish size. With these relationships, it is possible to identify fish species and to determine their sizes. In the present study, our results showed a percentage of explained deviance higher than 75% for all regressions. Otolith morphometric measurements with the genus regressions were used successfully by Giménez, Manjabacas, Tuset & Lombarte (2016) when species identification is not possible. The findings of the current study are consistent with Giménez, Manjabacas, Tuset & Lombarte (2016) and the estimation of the regression within a genus level provided variances above 70%.

Previous studies focused mainly on the relationship between otolith dimensions OL and OW and fish size (Harvey *et al.*, 2000; Battaglia *et al.*, 2010; Jawad *et al.*, 2011; Ja-wad and Al-Mamry, 2012). This study provides additional information by considering four otolith measurements (OL, OW, LR, and SR). In many cases the tip or the dorsal or ventral edges of an otolith might be damaged, making it difficult to measure OL or OW accurately (Battaglia *et al.*, 2010; Jawad *et al.*, 2011); this could influence the reliability of subsequent calculations. Presenting the four models (L-OL, L-OW, L-LR, and L-SR) for each species helps mitigate this potential problem. Previous studies focused mainly on the relationship between otolith dimensions OL and OW and fish size (Harvey *et al.*, 2000; Battaglia *et al.*, 2010; Jawad *et al.*, 2011; Ja-wad and Al-Mamry, 2012). This study provides additional information by considering four otolith measurements (OL, OW, LR, and SR). In many cases the tip or the dorsal or ventral edges of an otolith might be damaged, making it difficult to measure OL or OW accurately (Battaglia *et al.*, 2010;

**Table 1.** Size ranges in 7 Cyprinid species from inland waters of Turkey. N; Sample size, OL; otolith length, OW; width, OR; radius, and OM; mass.

Species	N	TOTAL LENGTH				OL				OW				OR				OM			
		Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD
<i>Capoeta angorae</i>	178	7.5	37.8	18.07	4.14	1.402	4.170	2.602	0.415	1.249	3.570	2.182	0.326	0.365	2.834	1.287	0.397	0.001	0.009	0.002	0.001
<i>Capoeta antalyensis</i> *	112	7.1	34	12.56	3.54	1.311	3.950	1.996	0.650	0.996	3.568	1.656	0.635	0.646	2.142	1.036	0.368	0.000	0.004	0.001	0.001
<i>Capoeta caelestis</i> *	159	4.4	28.3	14.83	6.3	0.881	3.557	1.841	0.927	0.798	2.787	1.530	0.684	0.447	1.891	0.960	0.501	0.000	0.006	0.003	0.001
<i>Capoeta erhani</i>	135	15	47	23.15	5.66	2.310	4.590	3.590	0.485	1.900	3.590	2.759	0.342	1.010	2.307	1.541	0.238	0.001	0.009	0.002	0.001
<i>Capoeta pestai</i>	154	6.2	26.8	15.08	4.37	1.253	3.876	2.625	0.664	1.074	2.986	2.091	0.481	0.579	1.898	1.263	0.344	0.000	0.010	0.002	0.002
<i>Pseudophoxinus antalyae</i> *	344	2.8	16.8	7.717	3.22	0.563	2.824	1.891	0.494	0.491	2.304	1.562	0.395	0.277	1.403	0.917	0.247	0.000	0.005	0.002	0.001
<i>Pseudophoxinus fahrettini</i> *	151	5.3	19.6	12.23	2.46	0.913	3.074	2.049	0.365	0.779	2.945	1.978	0.368	0.589	1.481	1.031	0.174	0.000	0.006	0.002	0.001

\* No previous data for the relationships between OL, OW, OR and OM with fish length.

**Table 2.** Regression parameters of the relationships between otolith dimensions and fish total length for 7 Cyprinid species from inland waters of Turkey. Sample size (N) and coefficients of determination ( $R^2$ ) given along with power equations

Species	N	TL-OL		TL-OW		TL-OR		TL-OM	
		Equation	$R^2$	Equation	$R^2$	Equation	$R^2$	Equation	$R^2$
<i>Capoeta angorae</i>	178	OL = 0.3411TL <sup>0.6975</sup>	0.858	OW = 0.3477TL <sup>0.6308</sup>	0.858	OR = 0.039TL <sup>1.1899</sup>	0.951	OM = 1E-05TL <sup>1.8248</sup>	0.760
<i>Capoeta antalyensis</i> *	112	OL = 0.3107TL <sup>0.7106</sup>	0.947	OW = 0.1895TL <sup>0.8253</sup>	0.961	OR = 0.1366TL <sup>0.7725</sup>	0.937	OM = 1E-05TL <sup>1.6617</sup>	0.930
<i>Capoeta caelestis</i> *	159	OL = 0.2902TL <sup>0.7497</sup>	0.968	OW = 0.2946TL <sup>0.6722</sup>	0.953	OR = 0.1417TL <sup>0.7751</sup>	0.938	OM = 6E-06TL <sup>1.9572</sup>	0.919
<i>Capoeta erhani</i>	135	OL = 0.5167TL <sup>0.5865</sup>	0.908	OW = 0.4341TL <sup>0.5593</sup>	0.922	OR = 0.1467TL <sup>0.7164</sup>	0.968	OM = 6E-06TL <sup>2.0748</sup>	0.851
<i>Capoeta pestai</i>	154	OL = 0.3069TL <sup>0.7712</sup>	0.965	OW = 0.3TL <sup>0.6988</sup>	0.979	OR = 0.132TL <sup>0.8106</sup>	0.958	OM = 2E-06TL <sup>2.55</sup>	0.905
<i>Pseudophoxinus antalyae</i> *	344	OL = 0.2231TL <sup>0.8997</sup>	0.957	OW = 0.2036TL <sup>0.8558</sup>	0.956	OR = 0.109TL <sup>0.9056</sup>	0.948	OM = 6E-06TL <sup>2.3595</sup>	0.870
<i>Pseudophoxinus fahrettini</i> *	151	OL = 0.2441TL <sup>0.8265</sup>	0.825	OW = 0.1731TL <sup>0.9461</sup>	0.892	OR = 0.1494TL <sup>0.7506</sup>	0.790	OM = 1E-05TL <sup>2.0025</sup>	0.883

\*No previous data for the relationships between otolith morphometrics and fish length

**Table 3.** Regression parameters of the relationships between otolith dimensions and fish total length for 2 genus from inland waters of Turkey. Sample size (N) and coefficients of determination ( $R^2$ ) given along with power equations.

Genus	N	TL-OL		TL-OW		TL-OR		TL-OM	
		Equation	$R^2$	Equation	$R^2$	Equation	$R^2$	Equation	$R^2$
<i>Capoeta</i>	738	OL = 0.3019TL <sup>0.7426</sup>	0.934	OW = 0.2757TL <sup>0.7076</sup>	0.931	OR = 0.1283TL <sup>0.7864</sup>	0.891	OM = 5E-05TL <sup>1.3011</sup>	0.703
<i>Pseudophoxinus</i>	495	OL = 0.261TL <sup>0.8121</sup>	0.882	OW = 0.1771TL <sup>0.9302</sup>	0.929	OR = 0.1348TL <sup>0.7983</sup>	0.881	OM = 1E-05TL <sup>2.0025</sup>	0.883

Jawad *et al.*, 2011); this could influence the reliability of subsequent calculations. Presenting the four models (L-OL, L-OW, L-LR, and L-SR) for each species helps mitigate this potential problem.

Previous studies focused mostly on the relationship between otolith length and width with fish length (Ayyildiz & Altin, 2018; Battaglia, Malara, Romeo & Andaloro, 2010; Harvey, Loughlin, Perez & Oxman, 2000; Jawad, Al-Mamry & Al-Busaidi, 2011). The present study provides additional information by considering four otolith measurements (OL, OW, OR, and OM). It is more reliable to calculate more than one equation. In many cases otolith might be damaged, and it might be difficult to determine fish size from the otolith size (Battaglia, Malara, Romeo & Andaloro, 2010; Jawad, Al-Mamry & Al-Busaidi, 2011; Jawad, Park, Kwak & Ligas, 2017). Presenting the four equations (TL-OL, TL-OW, TL-OR, and TL-OM) for each species provides some support for the solution of this potential problem.

In conclusion, the present study makes several contributions to the biometric relationships between asteriscus otolith morphometric measurements and fish total length for Cyprinid fishes caught on the Turkish inland waters. This research will contribute towards future dietary studies as well as for paleontological studies and population dynamics in the region.

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