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Sagittal Otolith Morphology of Sharpsnout Seabream *Diplodus puntazzo* (Walbaum, 1792) in the Aegean Sea

Morfología de los Otolitos Sagitales del Sargo Picudo *Diplodus puntazzo* (Walbaum, 1792) en el Mar Egeo

Derya Bostanci[*]; Mahmut Yilmaz[**]; Serdar Yedier[*]; Gülsah Kurucu[*]; Seda Kontas[*]; Muammer Darçin[*] & Nazmi Polat[***]

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SUMMARY: The morphology, biometry and shape indices of the left and right sagittal otoliths were studied for sharpsnout seabream, *Diplodus puntazzo* species from Aegean Sea. The shape, sulcus acusticus shape, proximal and distal surfaces, anterior and posterior regions of left and right sagittal otoliths for a total of 52 *D. puntazzo* were analyzed. The morphometric measurements such as weight, length, width, area and perimeter were recorded for each pair of sagittal otoliths of the sharpsnout seabream. The shape indices such as form factor, roundness, aspect ratio, circularity, rectangularity, and ellipticity were calculated for left and right sagittal otoliths of *D. puntazzo*. The otolith width and ellipticity were significantly different ($P < 0.05$) for left and right sagittal otolith measurements and shape indices, respectively in *D. puntazzo* inhabiting the Aegean Sea. Morphological characteristics of fish otoliths were highly variable in species and populations; there was limited information on the sagittal otolith morphology and shape indices. The present study provided sufficient information of the sharpsnout seabream left and right otolith morphologies, biometry, and shape indices in the Aegean Sea, they may provide a useful tool for marine and freshwater species discrimination and identification in further investigations.

KEY WORDS: Morphology; Biometry; Shape indices; *Diplodus puntazzo*.

INTRODUCTION

The term otolith refers to calcareous structures in the inner ear of teleost fish. They are three pairs such as *sagittae*, *lapilli*, and *asterisci*. Their shapes and morphologies are species specific (Lombarte & Castellón, 1991). Due to the combined effects of genetics and environment, fish with different life histories often show variation in otolith morphology and shape. Therefore, the characteristics have been considered crucial criteria in fisheries (Bostanci *et al*., 2015). Their species specific properties have been extensively used to identification, discrimination, and ageing (Cardinale *et al*., 2004) in freshwater and marine species. Studies of otolith morphology, contour shape have recently increased more and more in importance with the development of digital techniques, image analysis systems and shape analysis methods (Zhuang *et al*., 2014; Bostanci *et al*.). The otoliths and the techniques-methods have proven to be a powerful time- and cost-efficient in the identification of various freshwater and marine species (Sadighzadeh *et al*., 2012; Tuset *et al*., 2013; Bostanci *et al*.).

Sharpsnout seabream, *Diplodus puntazzo* (Walbaum, 1792) is a demersal marine, brackish, benthopelagic, and oceanodromous fish species in Sparidae (Riede, 2004). The sharpsnout seabream was found in groups over rocky and sandy bottoms and down to depths of about 150 m. This species is widespread in the Aegean Sea, the Mediterranean and the Black Sea. *D. puntazzo* is commercial important fish species in all the coastal areas of Turkey, especially in the Aegean Sea for fisheries and fishery management (Altin *et al*., 2015).

The otoliths are used in various studies such as age determination, fish growth and population dynamics all over the world (Bostanci *et al*.); however, the otolith morphology and shape indices for *D. puntazzo* with other variables remains largely unknown or is limited in Turkey. The aims of the current paper were to describe the morphology and shape indices of left and right sagittal otoliths of the *D. puntazzo* in the Aegean Sea.

[*] Department of Biology, Ordu University, Ordu, Turkey.
[**] Department of Biology, Ahi Evran University, Kırsehir, Turkey.
[***] Department of Biology, 19 Mayıs University, Samsun, Turkey.

MATERIAL AND METHOD

Diplodus puntazzo specimens were sampled in the Aegean Sea (Fig. 1). Each *D. puntazzo* was cleaned from external materials and weighted to the nearest 0.01 g. Their standard length (SL), fork length (FL) and total length (TL) were measured to the nearest 0.1 cm by digital caliper.

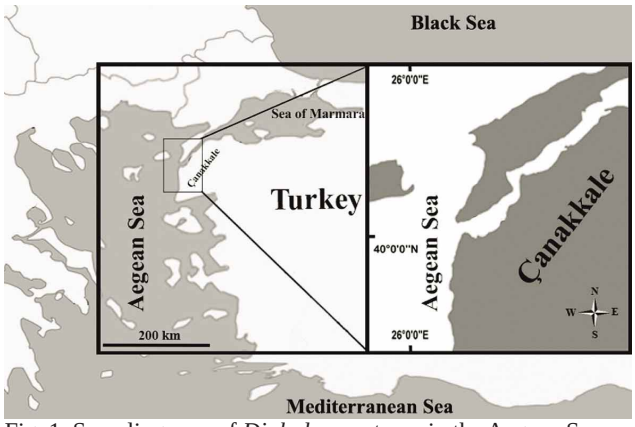


Fig. 1. Sampling area of *Diplodus puntazzo* in the Aegean Sea.

The sharpsnout seabream sagittal otolith pairs were removed and cleaned. The otolith pairs were weighed to the nearest 0.0001 g. Each otolith pairs were photographed on distal and proximal surface by using Leica S8APO microscope and computer-connected camera system. The otolith length (OL, mm), otolith width (OW, mm), otolith area (A, mm^2) and otolith perimeter (P, mm) were measured using the photographs by Leica Application Suite software. While sagittal otolith length was measured from anterior to posterior axis, the otolith width was from dorsal to ventral edge through the otolith focus.

The paired t-test was applied in order to determine the differences between right and left otoliths. All calculations were performed with MINITAB 17.0 statistical analysis software program. *D. puntazzo* sagittal otolith shape indices were calculated using the following formulas (Tuset *et al*., 2003; Ponton, 2006):

· Form factor: 4π x Otolith Area x Otolith Perimeter^{-2}
· Roundness: 4 x Otolith Area x (π x Otolith Length^2)$^{-1}$
· Aspect ratio: Otolith Length x Otolith Width^{-1}
· Circularity: Otolith Perimeter^2 x Otolith Area^{-1}
· Rectangularity: Otolith Area x (Otolith Length x Otolith Width)$^{-1}$
· Ellipticity: (Otolith Length - Otolith Width) x (Otolith Length + Otolith Width)$^{-1}$

The values of form factor (FF), roundness (RD), aspect ratio (AR), circularity (C), rectangularity (R) and ellipticity (E) were calculated for *D. puntazzo* left and right sagittal otoliths in the Aegean Sea. Sagittal otolith morphological characters such as otolith shape, sulcus acusticus shape, proximal and distal surfaces, anterior region, and posterior region were investigated for the left and right sagittal otolith of the sharpsnout seabream in the Aegean Sea.

RESULTS

A total of 52 *D. puntazzo* were examined and their standard length, fork length, total length and weight distributions were determinate such as 11.2–24.5 cm, 12.6–26.8 cm, 14.2–29.0 cm, and 54.3–454.4 g respectively in the Aegean Sea. Left and right sagittal otolith distal (a) and proximal (b) surfaces photographs were presented with otolith length, otolith width, and otolith area for the sharpsnout seabream in the Aegean Sea (Fig. 2). All sagittal otolith measurements were determinate for each sharpsnout seabream and the summary of descriptive statistics such as mean, standard deviation (SD), standard error (SE), minimum, and maximum for left and right sagittal otoliths and paired-t test results were shown in Table I.

While the left otolith length and otolith perimeter were bigger than the right otolith values, the other right otolith measurements such as otolith weight, otolith width, and otolith area were bigger than left otolith of the sharpsnout seabream in the Aegean Sea (Tab. I). According to paired t-test results, the width of left and right otolith were estimated as 3.561 mm and 3.608 mm, respectively and the differences between left and right otolith width values were statistically important ($P < 0.05$); however, other measurements values were not significant ($P > 0.05$) for between left and right otolith values of the species (Tab. I).

The otolith shape indices such as form factor (FF), roundness (RD), aspect ratio (AR), circularity (C), rectangularity (R) and ellipticity (E) were calculated using the left and right otolith sagittal measurements values for the sharpsnout seabream in the Aegean Sea (Tab. II). The mean values of FF, RD, AR, E, C, and R were calculated as 0.72061, 0.53226, 1.7325, 0.26735, 17.507, and 0.72199, respectively for *D. puntazzo* left sagittal otolith and 0.72912, 0.53825, 1.7092, 0.26074, 17.295, and 0.71954, respectively right sagittal otolith of the shape indices in the Aegean Sea (Table II). The difference between right and left otoliths shape indices were not important statistically ($P > 0.05$), except ellipticity of the species in the Aegean Sea (Table II).

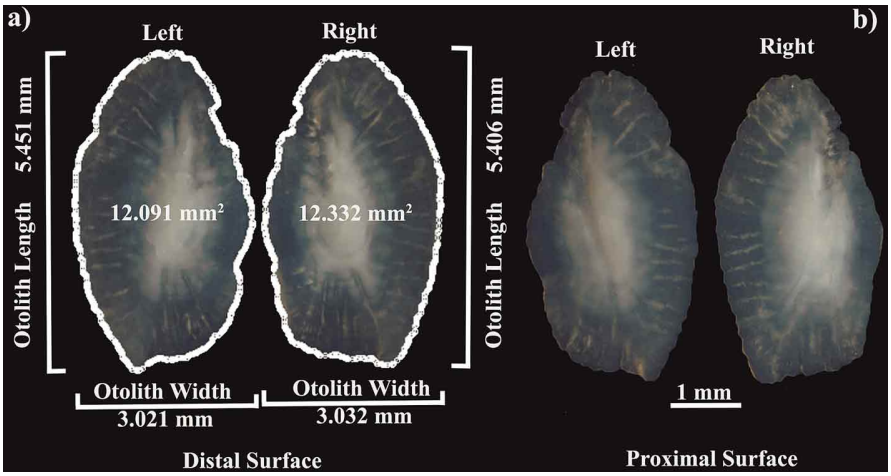


Fig. 2. Left and right sagittal otolith distal (a) and proximal (b) surfaces from *Diplodus puntazzo* in the Aegean Sea.

Table I. Summary of descriptive statistics and paired t-test results for left and right sagittal otoliths measurements of *Diplodus puntazzo* in the Aegean Sea.

Otolith Measurements		Mean	SE	SD	Min	Max	Sig.	
Otolith Weight	Left	0.02173	0.00105	0.00688	0.0112	0.0389	P >0.05	0.377
	Right	0.02201	0.00093	0.00661	0.0117	0.0406		
Otolith Length	Left	6.171	0.105	0.691	5.169	7.965	P >0.05	0.935
	Right	6.164	0.091	0.642	5.116	7.602		
Otolith Width	Left	3.561	0.053	0.345	3.021	4.406	**P <0.05**	**0.006**
	Right	3.608	0.045	0.321	2.960	4.549		
Otolith Area	Left	16.010	0.508	3.331	11.389	25.671	P >0.05	0.148
	Right	16.101	0.413	2.923	11.766	24.200		
Otolith Perimeter	Left	16.671	0.305	2.001	14.199	22.017	P >0.05	0.913
	Right	16.632	0.253	1.789	14.166	20.910		

Abbreviations: SE=Standard error; SD=Standard deviation; Min=Minimum; Max=Maximum; Sig=Significant differences.

Table II. Summary of descriptive statistics of shape indices for left and right sagittal otoliths of *Diplodus puntazzo* in the Aegean Sea.

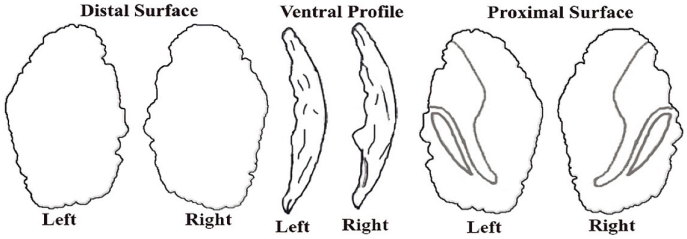
Otolith Shape indices		Mean	SE	SD	Min	Max	Sig.	
Form factor	Left	0.72061	0.00727	0.04767	0.62247	0.79891	P >0.05	0.249
	Right	0.72912	0.00631	0.04462	0.61863	0.80157		
Roundness	Left	0.53226	0.00467	0.03064	0.46837	0.59197	P >0.05	0.196
	Right	0.53825	0.00502	0.03549	0.44049	0.62333		
Aspect ratio	Left	1.7325	0.0134	0.0880	1.6092	1.9853	P >0.05	0.057
	Right	1.7092	0.0148	0.1049	1.4999	2.0299		
Ellipticity	Left	0.26735	0.00353	0.02318	0.23349	0.33005	**P <0.05**	**0.035**
	Right	0.26074	0.00393	0.02780	0.19995	0.33991		
Circularity	Left	17.507	0.183	1.200	15.722	20.178	P >0.05	0.328
	Right	17.295	0.161	1.142	15.669	20.303		
Rectangularity	Left	0.72199	0.00241	0.01578	0.68590	0.75611	P >0.05	0.118
	Right	0.71954	0.00242	0.01714	0.68336	0.76061		

Abbreviations: SE=Standard error; SD=Standard deviation; Min=Minimum; Max=Maximum; Sig=Significant differences.

Some important otolith morphology features such as otolith and sulcus acusticus shapes, proximal and distal surfaces, anterior and posterior regions were determinate for left and right sagittal otoliths of the sharpsnout seabream and their general morphology were shown (Table III).

Table III. Left and right sagittal otolith morphology features of *Diplodus puntazzo* in the Aegean Sea.

	Otolith Morphology Features					
Diplodus puntazzo	**Otolith Shape**	**Sulcus acusticus Shape**	**Proximal Surface**	**Distal Surface**	**Anterior Region**	**Posterior Region**
Left Otolith	Pentagonal	Heterosulcoid	Concave	Convex	Round	Oblique
Right Otolith	Pentagonal	Heterosulcoid	Concave	Convex	Round	Oblique



DISCUSSION

The current study is the first to compare left and right sagittal otolith biometry, shape indices and morphology of *D. puntazzo* in the Aegean Sea. Otolith morphology was indicated species and genus diagnostic in marine and freshwater species (Bostanci *et al*.; Tuset *et al*., 2015). Small differences in left and right sagittal otolith shape and shape indices were determine in *D. puntazzo* inhabiting the Aegean Sea (Tables II and III). Moreover, the left and right otolith sides are denticulated for the sharpsnout seabream in the Aegean Sea (Table III). Lombarte & Cruz (2007) indicated that individuals of the same species with their phylogenetic patterns can be reflected in their otolith morphology and patterns as it's seen in the current study.

All studied sagittal otolith (left-right) irregular pentagonal shapes were characterized by the sharpsnout seabream inhabiting the Aegean Sea (Table III). However, the sharpsnout seabream sagittal otolith shapes were determinate as elliptic in western Mediterranean, north and central eastern Atlantic (Tuset *et al*., 2008). According to the present study, min-max circularity and rectangularity were calculated as 15.6–20.3, 0.6–0.7, respectively of *D. puntazzo* in the Aegean Sea; however, they were calculated as 15.6–16.7, 0.2–0.3, respectively of *D. puntazzo* in western Mediterranean, north and central eastern Atlantic by Tuset *et al*. (2008). Environmental and ecological factors especially habitat type inducing differences in food quality and quantity affect otolith morphology (Vignon *et al*., 2008); therefore these types of differences in *D. puntazzo* may be a primary factor in the development of differences in otolith morphometry in the different habitats such as Aegean Sea and western Mediterranean, north and central eastern Atlantic.

In that study, left and right otolith pairs were not compared for *D. puntazzo*. In the current study, left and right otolith pairs were compared and their sulcus acusticus shape is determinate heterosulcoid and their sulcus acusticus is deep and well-defined for sagittal otolith of sharpsnout seabream in the Aegean Sea (Table III). The left and right otolith were concave in the proximal surface and convex in the distal surface for *D. puntazzo* (Table III). While anterior region is round for left and right sagittal otolith in the sharpsnout seabream, posterior region is oblique for left and right sagittal otolith in the same species in the Aegean Sea (Table III).

It is the first time, the difference of otolith shape indices were investigated left and right pairs of the shape indices a member of Sparidae in the Aegean Sea. The ellipticity was statistically important between right and left otoliths of the sharpsnout seabream in the Aegean Sea ($P < 0.05$). The morphologic diversity of the sagittal otoliths are still very poorly known and limited information, the using *D. puntazzo* left and right otolith morphologies may be a useful tools for marine and freshwater species identification, taxonomic, and phylogenetic information in further investigations. However, for powerful identification and determination, the further investigation is needed, including a comparative study with otolith morphometry, biometry, shape indices, and genetic methods in male-female individuals and their left-right otolith pairs of various marine and freshwater fish species.

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RESUMEN: Los índices morfológicos, biometría y la forma de los otolitos sagitales izquierdo y derecho se estudiaron para la especie sargo picudo, *Diplodus puntazzo* del mar Egeo. Se analizaron en 52 *D. puntazzo* la forma del surco acústico, las superfi-

cies proximal y distal y las regiones posteriores de los otolitos sagitales izquierdo y derecho. Además, se registraron para cada par de otolitos sagitales las mediciones morfométricas de peso, longitud, ancho y perímetro. Se calcularon en ambos otolitos sagitales los índices de forma, factor de forma, relación de aspecto, circularidad, ortogonalidad y elipticidad. En el *D. puntazzo* que habita en el mar Egeo, el ancho y elipticidad de los otolitos fueron significativamente diferentes (P <0,05), para las mediciones de otolitos sagitales izquierdo y derecho, respectivamente. Existen gran variabilidad en las características morfológicas de los otolitos de diferentes especies y poblaciones de peces, asimismo es limitada la información de los índices morfológicos y la forma de los otolitos sagitales. El presente estudio proporciono información suficiente sobre la morfología y biometría de los otolitos izquierdo y derecho del sargo picudo en el Mar Egeo, lo que puede proporcionar una herramienta útil para la discriminación e identificación de especies marinas de agua dulce y para nuevas investigaciones.

PALABRAS CLAVE: Morfología; Índices de biometría; Índices de forma; *Diplodus puntazzo*.

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Correspondence to:
Derya Bostancı
Department of Biology
Ordu University
Ordu
TURKEY

Email:deryabostanci@gmail.com

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