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Morphometric Traits of the Sagittae of Common Sole (*Solea solea* (Linnaeus, 1758)) Captured from East Libya Mediterranean Sea Coast

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ABSTRACT

This paper aimed to establish traits of morphometric parameters of *Solea solea* sagittae and to determine the relationship of these parameters to fish size. A total of 74 fish collected from Al-Tamimi shore, eastern Libya, during winter 2020 were used in the study. Total weight (TW), total length (TL), standard length (StL), head length (HL), and body depth (BD) were measured for individual fish. Mean TL and TW were 23.33cm and 106.76gm; the length-weight relationship (TL-TW) indicated negative allometric growth (b=2.64, R^2=0.84). Sagittae weight (SWt), length (SL) and width (SW), sulcus acoustic length (SAL), cauda length (CL), cauda width (CW), and ostium length (OSL) were measured. Because differences between parameters of sagittae on the eyed side and the blind side were statistically insignificant, only values of the eyed side were used to calculate sagittae area and perimeter, and the shape parameters. The anterior region of the sagittae was rounded, the posterior end was flattened and the proximal was slightly convex, whereas the distal surface was concave. SAL and CL were 1.57 and 0.572 mm, and CW and OSL were 0.367 and 0.958mm in order. The sagittae was bullet shaped with smooth surface, and sulucus acusticus was slightly deepened. The ostium and the cauda were distinguishable. The Ostium was tubular and longer than the cauda which is elliptical. Percentages of SH/OL%, CL/SAL%, and OSL/SAL% were calculated. Regressions of the measured sagittae parameters with fish TL, BD and SL, and regressions of the shape parameters with SL, were established.

Keywords: sagittae, Mediterranean Sea, *Solea solea*, morphometric.

الملخص

هدفت هذه الدراسة إلى تحديد سمات المعلمات الشكلية لـــحجر الاذن (sagittae) لسمكة موسى *Solea solea* ولتحديد علاقة هذه المعلمات بحجم السمكة. استخدمت 74 سمكة في الدراسة تم جمعها من شاطئ التميمي بشرق ليبيا خلال شتاء 2020. تم قياس الوزن الإجمالي (TW) والطول الإجمالي (TL) والطول القياســي (StL) وطول الرأس (HL) وعمق الجسم (BD) لكل سمكه على حده، كانت متوسطات الطول والوزن 23.33 سم و106.76 جرام. أشارت علاقة طول السمكة بوزنها (TL-TW) إلى نمو قياســي سـلبي اذ بلغ ثابت معادلة انحدار القوة "ب" 2.64، ومعامل التحديد (R^2) 0.84. بالنسبة لحجر الاذن فقد تم قياس وزنه (SWt) وطوله (SL) وعرضـه (SW) وطول اخدوده الصـوتي (SAL) وطول (CL) وعرض ذنبه (CW) وطول فوهته (OSL)؛ نظرًا لأن الفروق بين معلمات حجر جانب الســمكة الأعمى وحجر جانب العينين كانت غير ذات دلالة إحصـائية، فقد تم اسـتخدام قيم حجر جانب العينين فقط لحسـاب مسـاحة الحجر ومحيطه ومعلمات شـكله. منطقة الحجر الأمامية مقوســه الشـكل بينما المنطقة الخلفية مسـطحه. الجانب القريب للحجر

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محدبً قليلاً بينما الســـطح البعيد مقعر. بلغ طول SAL وCL 1.57 و0.527 ملم على التوالي، وCW وOSL 0.367 و0.958 ملم. كان حجر الاذن على شكل رصاصة بسطح أملس وكان الاخدود الصوتي عميقًا قليلاً. كانت الفوهة والذنب واضـــحتان، الفوهة كانت أنبوبيَّة وأطول من الذنب البيضـــاوي الشـــكل. تم في الدراســـة حســـاب النســـب SH/OL٪ وCL/SAL٪ وOSL/SAL٪، كما تم حساب انحدارات معلمات الحجر المقاسة مع طول السمكة الكلى والقياسي وعمق الجسم، وأيضا حساب انحدارات معلمات شكل حجر الآذن مع طول الحجر.

الكلمات المفتاحية: حجر الآذن، البحر الأبيض المتوسط، سمكة موسى، الصفات الشكلية

1. INTRODUCTION

All teleost fish have otoliths, which are three hard calcified structures in the inner ear. Sagittae, asteriscus, and lapillus are the three pairs of otoliths (Das, 1994). These organs participate in hearing and perform vestibular functions (Baxendale and Whitfield, 2014). Sagittae is used in a variety of research projects, including age determination, fish growth, and population dynamics. Changes in fish sagittae are caused by environmental variables and geographic separation of populations (Lombarte 1992; Sadighzadeh *et al*. 2014; Torres *et al*. 2000; Vignon and Morat 2010). In addition, in fisheries biology, otolith morphometry is a helpful taxonomic tool enabling species and population comparisons (Campana, 2004; Campana and Casselman, 1993; King, 1995; Lombarte *et al*., 2006; Tuset *et al*., 2006).

Solea solea (Linnaeus, 1758) is commonly known as common sole, and dover sole. Their bodies are oval and compressiform, and their eyes are located on the right side. *S. solea* belongs to the order Pleuronectiformes and the family Soleidae (Golani *et al*., 2006). In Libya, there are very few published studies on common soles, e.g. on their food habits (El-Mor, 2008) and morphological characteristics (Belhassan *et al*., 2021). This paper aims to provide information on length-weight relationship and morphometry of *Solea solea*, morphometric traits of its Sagittae, and the relationships between these traits and fish size.

2. MATERIALS AND METHODS

Seventy-four samples of *Solea solea* collected from the artisanal catch of Al-Tamimi area, east Libya Mediterranean Sea (32° 19` N - 23° 06` E) (Fig. 1), during 2020, were used in the present work. The total weight (TW), total length (TL), standard length (StL), body depth (BD), and head length (HL) were measured for individual fish to the nearest 0.1g and 0.1cm.

Figure 1: Map of the study area.

Figure 2: Sagittae extraction via cutting into the otic capsule of *S. solea.* ESS: Eyed Side Sagittae, BSS: Blind Side Sagittae

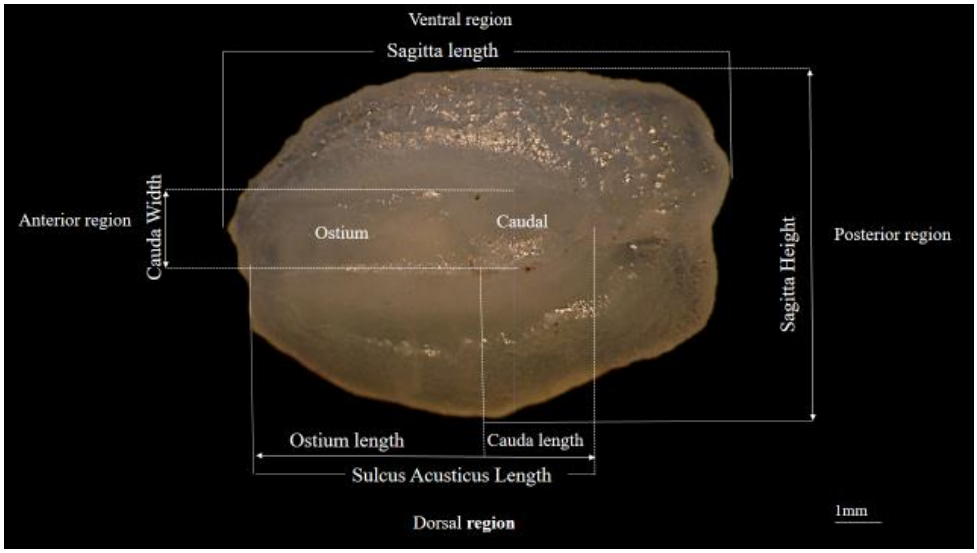

Figure 3: Morphometric measurements taken on the sagittae.

Then, the head region of each fish was dissected, eyed (right) and blindside (left) sagittae were removed from their capsules (fig.2), cleaned, dried and weighed to the nearest 0.0001g (sagittae weight: SWt). Sagittae length (SL), height (SH), perimeter (SP) and area (SA in mm^2), sulcus acusticus length (SAL), ostium length (OSL), and cauda length (CL) and width (CW) were measured to the nearest 0.1mm using image processing (Digimizer software, version 4), (Fig. 3). Percentage of sagittae height from sagittae length (SH/TL%), and percentages of cauda length and ostium length from sulcus length (CL/SAL% and OSL/SAL%) were calculated. Sagittae shape indices were calculated as: circularity (SP^2/SA), rectangularity (SA/(SL*SH)), form-factor ($(4\pi SA)/P^2$), roundness ($(4SA)/(\pi SL^2)$), ellipticity (SL-SH)/(SL+SH). The power equation ($(SL=a+(x)^b$) was used to describe the relationship between the other sagittae parameters (x) and sagittae length (SL). Differences between mean length, weight and height of sagittae on the eyed side and sagittae on the blind side of the fish were tested for significance by independent t-test. All calculations and statistics were performed with Excel and SPSS (Version 21.0).

3. RESULTS AND DISCUSSION

Descriptive statistics of *S. solea* morphometric parameters is presented in Table (1). The fish length-weight relationship of $TW= 0.0428*TL^{**2.460}$, $R^2= 0.84$, N=74 (Fig. 4) indicates negative allometric growth; length increases at faster rate than weight (b = 2.460, less than 3, the theoretical value for isometric growth at $P<0.05$). This b value is less than that obtained for the same fish by Bayhan *et* al. (2008), Mehanna *et al* (2015), and Desouky (2016). Length-weight relationships of fish are known to be affected by a combination of factors such as season, habitat, gonadal stage, sex, diet, stomach fullness and preservation techniques (Bagenal and Tesch, 1978; Froese, 2006).

Tab (1). Descriptive statistics of morphometric parameters of *Solea solea*.

Parameter	Descriptive Statistics		
	Minimum -Maximum	**Mean**	**Std. Error**
Total length (cm)	15.40 -36.60	23.3316	0.49850
Total weight (gm)	28.80 -286.60	106.7658	5.62765
Standard length (cm)	2.90 -188.50	21.9380	2.19291
Body depth (cm)	4.60 -12.50	7.4709	0.19635
Head length (cm)	2.30 - 6.70	4.1658	0.09958

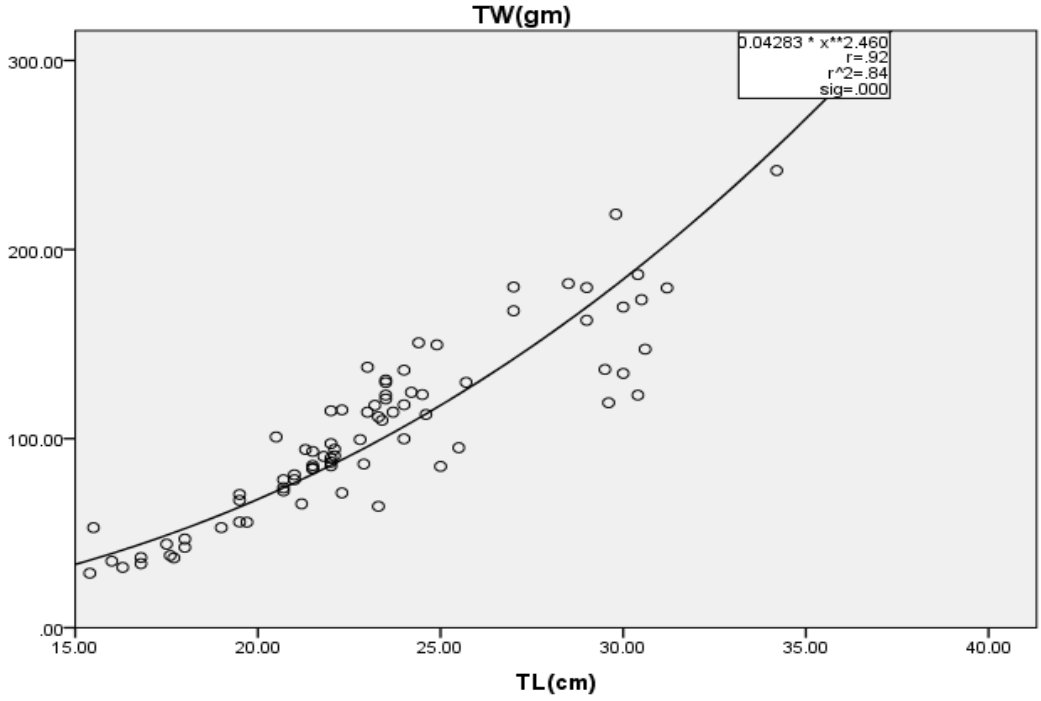

Figure 4: The power length-weight relationship of *Solea solea* of the present study.

The difference between values of length, weight and height of sagittae on the eyed and the blind sides were not significant (Tab. 2, Fig.5), however, differences were observed on individual bases (Fig. 6). Absence of differences between sagittae of the two sides is in agreement with Basuusta *et al*. (2020) for *Solea solea* of the northeastern Mediterranean Sea. Therefore, in the present study only eyed side sagittae was used for establishing Sagittae morphometrics (Tab. 3). The Sagittae was bullet-shaped with smooth surface, and Sulcus Acusticus was slightly deepened, its mean length was 1.570±0.405mm. The ostium and the cauda were distinguishable. The Ostium (0.958±0.265 mm) was tubular and longer than the cauda (0.572±0.152 mm long, and 0.367±0.023mm wide), the cauda was elliptical. The posterior end of the sagittae was flattened, the anterior region was rounded but the proximal region was slightly convex, whereas the distal surface was concave.

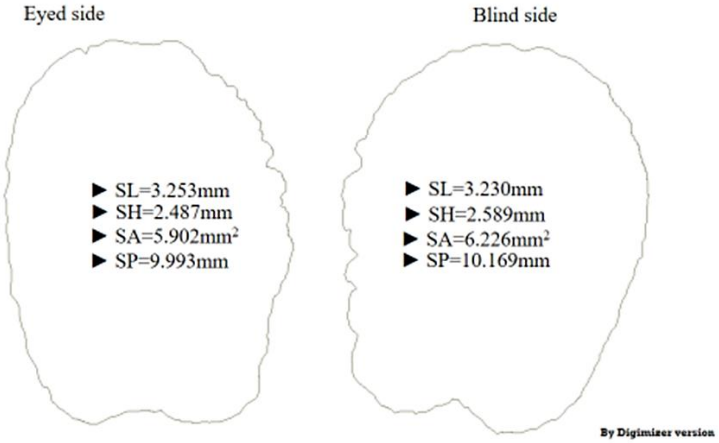

Figure 5: Sagittae of eyed and blind sides of *Solea solea* of the present study.

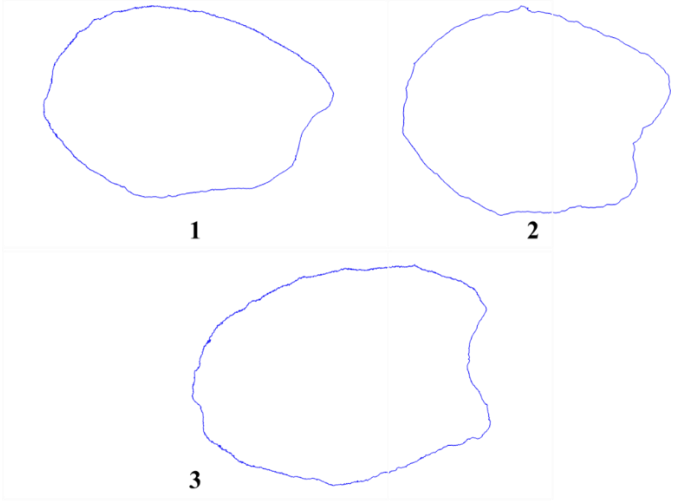

Figure 6: eyed side sagittae on individual *Solea solea*

Table 2: length (SL), height (SH) and width (SW) of sagittae of *Solea solea* eyed and blind sides in mm; all differences were not significant ($p > 0.05$).

Group Statistics					
Morphometric parameters	**Side**	**Mean**	**Std. Deviation**	**Std. Error**	***P* value**
SL	eyed side	3.733	.75014	.12169	.669
	blind side	3.660	.7202	.11841	
SH	eyed side	2.835	.5435	.0881	.781
	blind side	2.800	.5435	.0881	
SW	eyed side	.0162	.01253	.00246	.895
	blind side	.0158	.01032	.00202	

The ratios of sagittae height to sagittae length (SH / SL %), cauda length to sulcus length (CL / SAL %), and ostium length to sulcus length (OSL / SAL %) were 79.358±1.319, 36.42±3.075, and 61.89±6.850 respectively.

In the present study, mean CL/SAL% was 36.42±3.075. Jawad *et al* (2017) described morphological and ontogenetic changes in sagittae of *Ceratocopelus maderensis*, *Vinciguerria attenuate* and *V.poweriae*: the CL/SAL% were 43.15±6.81, 66.43±13.49, and 51.90±9.26 respectively which were higher than the one obtained in the present study.

In the present study, sagittae shape indices were calculated from values of the measured parameters of the eyed side (Tab. 3), mean values of circularity, rectangularity, form-factor, roundness, and ellipticity were 30.803±1.429, 0.722±0.006, 0.440±0.018, 0.720±0.006, and 0.123± 0.005 respectively. The highest value recorded was for the circularity, while the lowest value was for the ellipticity.

Table 3. Mean and standard error of the morphological indices of *Solea solea*.

Morphological characters	Mean	Std. Error
Sulcus Acusticus Length, SAL	1.570	0.405
Cauda Length, CL	0.572	0.152
Cauda Width, CW	0.367	0.023
Ostium Length, OSL	0.958	0.265
Perimeter, P	15.616	0.585
Area, A	8.423	0.511
SH/SL%	79.358	1.319
CL/SAL %	36.42	3.075
OSL/SAL %	61.89	6.850
Circularity	30.803	1.429
Rectangularity	0.722	0.006
Form-factor	0.440	0.018
Roundness	0.720	0.006
Ellipticity	0.1233	0.005

Several studies have focused on the regressions between fish size and corresponding sagittae dimensions because they can be used to infer the length of prey-fish isolated from guts of carnivores such as fish, seabird, and marine mammals (Bal *et al*., 2018; Treacy and Crawford, 1981; Trippel and Beamish, 1987; Souza *et al*., 2019). In the present study, regressions relating sagittae dimensions to fish dimensions (Table 4) had moderate to weak R^2, for example BD-SL (R^2=0. 65), BD-SH (R^2=0.64), BD-SWt (R^2=0.63), TL-SWt (R^2=0.21) and SL-TL (R^2=0.17); these equations can also be used as functional tools to estimate the size of fish from corresponding sagittal dimensions in future studies. According to Başusta *et al*., (2020), the SL-TL regression of females *S. solea* was stronger (R^2=0.50) than the same regression performed for mixed male/female sexes (R^2=0.48) or males alone (R^2=0.20). In the present study, regressions of sagittae length SL with the other measured sagittae morphometric parameters (Table 4) showed that growth of these parameters was positive, the coefficient of determination (R^2) was highest in sagittae length with the area (SL-SA, R^2= 0.98), and sagittae length with sagittae height (SL-SH, R^2=0.84) and lowest at cauda length with sagittae length (R^2=0.38), in general, b value ranged from 0.58 to 1.90. Jawad *et al*., (2018) reported that among binary correlations of otolith length with the other otolith indices

of *C. sordidus* and *H. harid*, the strongest correlations (r = 0.87 and r = 0.86) were observed for OL/SS and OL/OP respectively.

Table 4: Regressions of fish length TL, fish body depth BD, and sagittae length SL, with different sagittae parameters.

Regression equations	R^2
$\mathbf{TL} = 1.278\mathbf{SL}^{0.345}$	0.16
$\mathbf{TL} = 1.090\mathbf{SH}^{0.316}$	0.12
$\mathbf{TL} = 0.000\mathbf{SWt}^{1.05}$	0.21
$\mathbf{BD} = 1.165\mathbf{SL}^{0.604}$	0.65
$\mathbf{BD} = 0.843\mathbf{SH}^{0.602}$	0.64
$\mathbf{BD} = 0.007\mathbf{SWt}^{1.54}$	0.63
$\mathbf{SL} = 0.855\mathbf{SH}^{0.932}$	0.84
$\mathbf{SL} = 0.000\mathbf{SWt}^{2.57}$	0.64
$\mathbf{SL} = 0.636\mathbf{SA}^{1.90}$	0.98
$\mathbf{SL} = 4.496\mathbf{SP}^{0.927}$	0.67
$\mathbf{SL} = 0.840\mathbf{SAL}^{0.66}$	0.59
$\mathbf{SL} = 0.483\mathbf{OSL}^{0.72}$	0.61
$\mathbf{SL} = 0.325\mathbf{CUL}^{0.588}$	0.38

This study documented the link between fish size (length and body depth) and Sagittae dimensions and morphological indices of the *S. solea* for the first time in the Eastern coast of Libya in the Mediterranean Sea and provides a reliable tool for stomach contents research and fish size in paleobiological investigations.

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