Length-Weight Relationship, Condition Factor and Otolith Morphometric of *Serranus cabrilla* from the East Libya Mediterranean Sea Coast

Eman Salem Alfergani*, Mohammad El-Mabrok, Sokaina Muloud Mostafa and Rasha Momen Ahmed

ABSTRACT

This study investigated the length-weight relationship, condition factor, and otolith morphometrics of *Serranus cabrilla* specimens captured near the Benghazi coast, Libya, during spring 2021. Total body length (TL), total weight (TW), and otolith dimensions were measured. The mean TL and TW were 15.06±0.12 cm and 41.87±1.13 g, respectively. The regression coefficient (2.72) for the length-weight relationship was not significantly different from 3 according to the t-test ($b = 3$, $p \geq 0.05$), indicating that growth is isometric. Fulton's condition factor (K_f) ranged from 0.77 to 1.81 (mean = 1.20±0.01), and the relative condition factor (K_n) ranged from 0.65 to 1.48 (mean = 1.02±0.01). *S. cabrilla* otoliths exhibited a fusiform shape with a heterosulcoid sulcus, characterized by a funnel-shaped ostium and a tubular cauda. No significant differences ($p \geq 0.05$) were observed between left and right otoliths, so the left otolith was used for subsequent analyses. The otolith length constituted 3.51% of TL, and the height-to-length ratio averaged 42.71±0.39%. Based on relative size (0.36±0.00), the otoliths were classified as medium-sized. Ellipticity, rectangularity, and roundness values were 0.40±0.03, 0.67±0.00, and 0.37±0.00, respectively. The strongest correlation was observed between body length and otolith length.

Keywords: Benghazi-Libya, Length-weight relationship, Otoliths, *Serranus cabrilla*

INTRODUCTION

The Serranidae family consists of 200 species found in the temperate and tropical seas, of which 14 are Mediterranean species, 13 in the eastern basin, and two originating from the Red Sea: *Epinephelus coioides* and *Epinephelus malabaricus* under the subfamily Epinephelinae. In the subfamily Serraninae, the genus *Serranus* includes three species: *S. cabrilla, S. scriba*, and *S. hepatus*. The comb, *S. cabrilla* (Linnaeus, 1758), is characterized by longitudinal yellow-orange stripes on the body. Its distribution range is wide, extending in the Atlantic Ocean from the English Channel to South Africa, where it reaches Natal, and it is also found in the Mediterranean Sea and the Red Sea (Golani *et al*., 2006). Its habitat is mainly on sandy and rocky bottoms in areas covered by seagrass meadows at depths up to 500 m (Louizy, 2005). *S. cabrilla* is a carnivorous predator that preferentially feeds on benthic prey, consuming crustaceans (48.53%) and teleosts (29.14%) (Buzaid, 2018; Rachedi *et al*., 2018). *S. cabrilla* is a hermaphroditic fish, possessing both testicular and ovarian functions, with a breeding season in the spring and summer (Golani *et al*., 2006).

The length-weight relationship is one of the basic tools in fisheries, expressed in a mathematical formula through which the average weight can be

Department of Marine Science, Faculty of Science, Omar Al-Mukhtar University, Albayda, Libya
*Corresponding author. E-mail address: eman.salem@omu.edu.ly
Received 17 January 2024 / Accepted 31 October 2024

determined using length, providing data about the growth pattern of the fish (Beyer, 1987). It is a widely used tool for generating information that supports fish stocks assessments worldwide, as well as for comparisons across regions and life histories of fish (Stergiou and Moutopoulos, 2001; Lima *et al*., 2020; Zuchi *et al*., 2020). The length-weight relationship varies greatly between species, depending on inherited body form and physiological factors (Schneider *et al*., 2000). On the other hand, the condition factor, or plumpness index, is another important metric in fisheries studies and is often used to determine the health of a fish population. High condition factor values indicate adequate food availability, supporting both physical development and gonadal maturation (Moyle and Cech, 2004). It is also useful for estimating growth rates, life span, and environmental quality (Navarro *et al*., 2010; Olopade and Tarawallie, 2014).

Otoliths are calcium carbonate structures found in the inner ear of teleost fish (Popper *et al*., 2005). Otoliths are used in numerous studies, including those on age, growth (Paladin *et al*., 2023), and migration (Secor *et al*., 1995). Morphometrics is also used as a classification tool for distinguishing between fish species (Echreshavi *et al*., 2021; Morales *et al*., 2023), The relationship between body size and otolith dimension is highly useful for fisheries management and studies on feeding habits, where the identity and size of prey can be determined through otoliths isolated from fish-eating organisms, as well as for stock assessment, environmental change, and resource conservation (Osman *et al*., 2021; Singh *et al*., 2023).

There is considerable literature on *S. cabillar* addressing the length-weight relationship (Moutopoulos and Stergiou, 2002; Çakir *et al*., 2008; Bök, 2011; Cengiz, 2013; Özvarol, 2014; Rachedi and Dahel, 2019), condition factors (Torcu-Koc *et al*., 2004; Rachedi and Dahel, 2019; Ragheb, 2023), and otolith morphology and its relationship to body size (Smale *et al*., 1995; Tuset *et al*., 2003b; 2008; Jaramillo *et al*., 2014; Bilge and Filiz, 2018). However, such studies are limited on the Libyan coast. The aims of this study were to quantify the length-weight relationship of *S. cabrilla* in the Benghazi region and assess the body condition of this species. Additionally, the study investigates the morphology of the fish's otoliths. Lastly, it seeks to evaluate the correlation between body size and otolith dimensions in *S. cabrilla*. By achieving these objectives, the study comprehensively elucidates the morphometric characteristics, growth patterns, and health status of this fish population.

MATERIALS AND METHODS

Sample collection

One hundred and seven *Serranus cabrilla* fish were collected during the spring of 2021. These samples were obtained from local fishermen at Benghazi Sea Port (32° 36’ N, 20° 03' E), located on the eastern coast and representing the second-largest port in Libya. Upon arrival at the laboratory, the samples were stored at -20 °C. In the laboratory, total weight (TW) and total length (TL) were measured to the nearest 0.01 g and 0.1 cm, respectively. The otoliths were extracted through the gill opening by making a cut in front of the first gill arch into the otic capsule. After extraction, the otoliths were thoroughly cleaned of blood and tissue residues using distilled water, dried, and stored in numbered plastic boxes. The otoliths were weighed with a sensitive balance (Ohaus Adventurer SL, model Adventurer Pro AS214) to the nearest 0.0001 g (otolith weight: OW). The specimens were examined and photographed using a stereoscopic microscope (OPTECH, model SZ) equipped with a camera (Olympus, model NO.C-7070). Otolith length (OL), otolith height (OH), and otolith area (OA) were measured to the nearest 0.1 mm using image processing software (Digimizer software, version 4) (Figure 1).

Data analysis

The length-weight relationship was estimated according to Ricker (1975): $TW = aTL^b$, which was converted to its logarithmic form as $\log_{10} TW = \log_{10} a + b \log_{10} TL$, where a is the intercept of the regression line on the y-axis, and b is the slope or regression coefficient. The length-weight relationship parameters were then estimated by linear regression using log-transformed values from this equation. The 95% confidence interval (CI) for the value of b was determined using the equation:

CI = b±(1.96×S_b), where b is the slope and S_b is the standard error of *b*. A Student's t test was used to determine whether the b value significantly deviated from isometric growth (b = 3) using the following formula: t_s = (b-3)/S_b, where b is the slope or regression coefficient of the length-weight relationship and S_b is the standard error of b (Sokal and Rohlf, 1987).

The condition factor of the fish was calculated through two different parameters: (1) Fulton's condition factor (Fulton, 1904), which assumed that both weight and length increase isometrically, calculated as: K_f= 100×TW/TL^3, and (2) the relative condition factor of Le Cren (1951), which assumes that fish growth is standard and not necessarily isometric, calculated as: K_n = TW/aTL^b, where a is the intercept, and b is theslope obtained from the Length-weight relationship estimation.

Differences between the mean length, weight, height and area of left and right otoliths were tested for significance using a paired t-test at the 0.05 significance level. The percentage of otolith length relative to total fish length (OL/TL %), and the percentages of otolith height relative to otolith length (OH/OL %) were calculated. Three otolith shape indices were computed as follows: Rectangularity (R = OA/(OL×OH)), Roundness (RD = 4OA/3.14×OL^2), and Ellipticity (E = (OL-OH)/(OL+OH)). The relative size of the otoliths was determined using the equation O_R = 1,000×OA×TL^{-2} according to Lombarte and Cruz (2007). The relationship between body size (TL and TW) and otolith dimensions, as well as between otolith length and other measurements (OH and OA), were determined using the power regression model. All statistical analyses for this study were computed in Microsoft Excel and SPSS software (version 21).

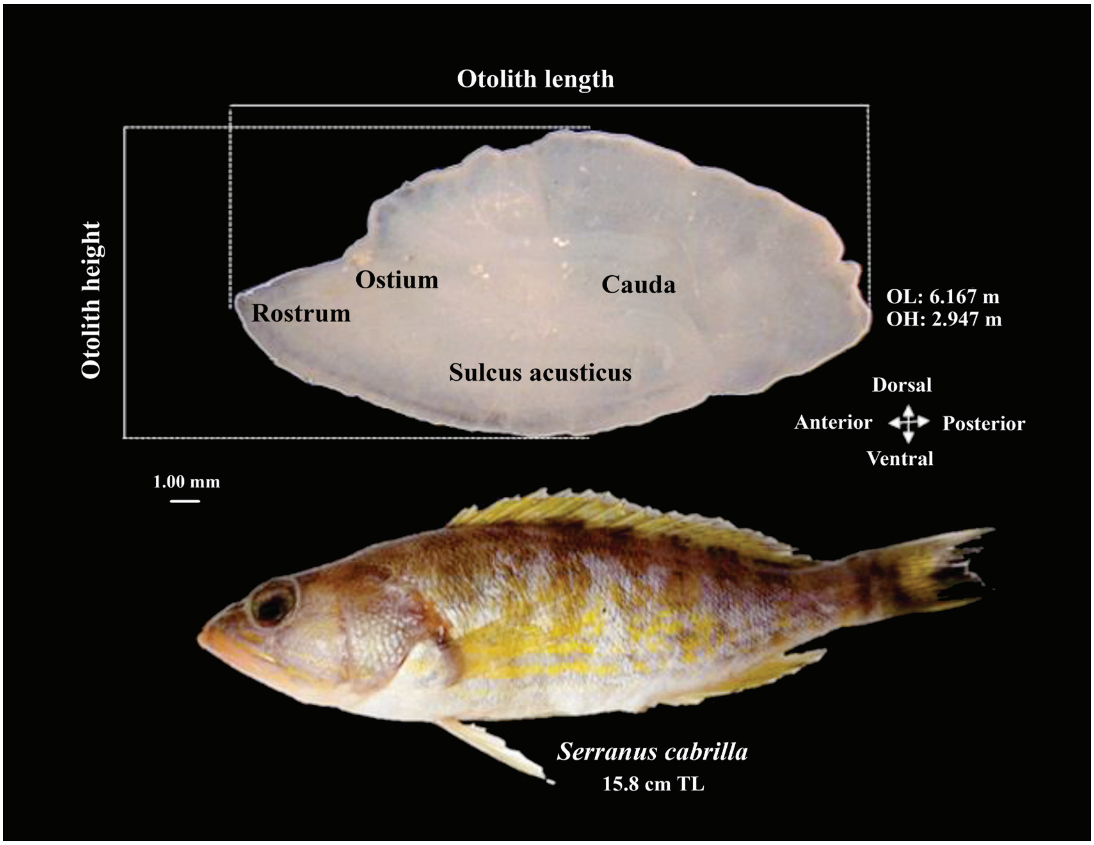

Figure 1. *Serranus cabrilla* and its measured morphometric parameters of the otolith.

RESULTS AND DISCUSSION

Length-weight relationship

The length-weight relationship in fish is a crucial tool for assessing growth rates, stock status, and age structures, as well as for comparing life histories of species across regions and studying other aspects of fish population dynamics (Binohlan and Pauly, 2000; King, 2007). In this study, *Serranus cabrilla* specimens had a total length ranging from 12.01 to 19.30 cm (mean = 15.06± 0.12 cm) and a total weight from 20.00 to 88.00 g (mean = 41.87±1.13 g) (Table 1). The length-weight relationship for *S. cabrilla* was statistically significant ($p<0.05$) and is described by the equation: TW = 0.025TL2.72, $r^2 = 0.68$. The b value was 2.72 (SE = 0.18), with a 95% confidence of 2.35–3.08. A t-test showed that the b value was not significantly different from 3 ($p \geq 0.05$), indicating an isometric growth pattern (Figure 2, Table 1).

In similar studies, Özvarol (2014) recorded a b value of 3.04, while Cengiz (2013) and Sangun *et al*. (2007) reported values of 3.08 for fish collected from the northeastern Mediterranean, all indicating an isometric growth pattern. In the western Mediterranean, specifically from the Gulf of Annaba, Rachedi and Dahel (2019) reported a b value of 3.06, contrasting with a value of b = 3.18 estimated by Bök (2011) in samples from the Sea of Marmara, which indicated positive allometric growth. In the Aegean Sea, Moutopoulos and Stergiou (2002) recorded a b value of 2.60, and Çakir *et al*. (2008)

Table 1. Descriptive statistics of morphometric parameter and estimated parameters of the length-weight relationship of *Serranus cabrilla*.

Total weight (g)		Total length		Length–weight parameters			SE(b)	CI 95% of b
Mean±SE	Min–max	Mean±SE	Min–max	a	b	r^2		
41.87±1.13	20.00–88.00	15.06±0.12	12.01–19.30	0.025	2.72	0.68	0.18	2.35–3.08

Note: r^2 = coefficient of determination

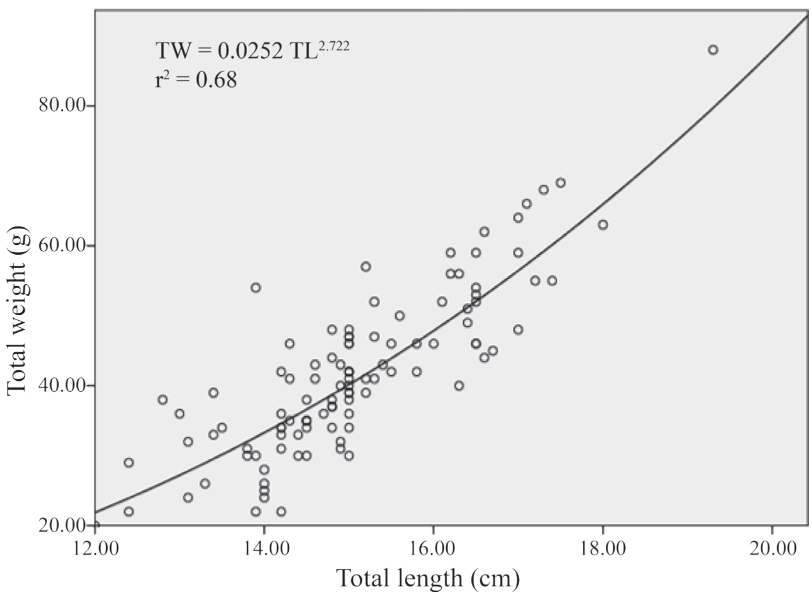

Figure 2. Length–weight relationship of *Serranus cabrilla*.

reported 2.62, both indicating negative allometric growth. The variation in the b values can be attributed to several factors, including environmental conditions, sampling time, fish sizes, sampling methods, age, stage of maturity, and stomach condition (Anene, 2005; Ama-Abasi, 2007; Yem *et al*., 2007; Adeyemi *et al*., 2009; Miller *et al*., 2015).

Condition factor

The condition factor is a commonly used indicator of fish body condition and reflects the nutritional and physiological status of species, such as the gonads index and liver index (Labocha *et al*., 2014; Peig and Green, 2010; Jacobs *et al*., 2012). In this study, we used two indicators: Fulton's condition factor, which is a standard tool for assessing fish health, especially when b does not equal 3 (Ragheb, 2023), and the relative condition factor, proposed by Le Cren (1951), which compares the observed mass of an individual fish to its expected mass based on the length-weight relationship. As shown in Table 2, the values of Fulton's condition factor (K_f) ranged from 0.77 to 1.81, with an average of 1.20± 0.01. The relative condition factor (K_n) ranged from 0.65 to 1.48 with an average of 1.02±0.01. The average values of K_f and K_n being approximately 1 suggest that the fish in this region are growing under favorable conditions. In contrast, previous studies reported lower K_f values, such as 0.84 in the Gulf of Annaba, indicating poor growth, possibly due to nematode infections (Rachedi and Dahel, 2019). For *S. cabrilla* from the coast of Alexandria, Ragheb, (2023) reported K_F and K_n values of 1.16± 0.05 and 0.988±0.041, respectively. Torcu-Koc *et al*. (2004) found a higher K_f value of 1.28±0.22 in *S. cabrilla* from the Gulf of Edremit in the northern Aegean Sea. According to Jisr *et al*. (2018), K_n values greater than or equal to 1 indicate that fish are obtaining sufficient food for growth. Angelescu *et al*. (1958) observed that the highest condition factor values in some species occur during gonad maturity. On the other hand, K_n values above one suggest an abundance of prey, while values below 1 indicate low prey availability (Muchlisin *et al*., 2010; Anderson and Newman, 1996). Finally, several factors influence condition factor, including sexual cycle, age, food availability, and environmental conditions (De Giosa *et al*., 2014; Adeyemi *et al*., 2009; Narsimham, 1970).

Otolith morphometrics and its relationships with fish size

The otolith of *S. cabrilla* is fusiform in shape, with anteriorly beaked and posteriorly rounded and irregular (Figure 1). The morphological characteristics observed in this study align with previous descriptions in the literature (Smale *et al*., 1995; Tuset *et al*., 2008). The otolith is of medium thickness and slightly convex, with a heterosulcoid sulcus that opens in the ostial, positioned centrally, and divided into a funnel-shaped ostium and a tubular cauda.

A t-test revealed no significant differences between the right and left otoliths in terms of length, height, weight, and area ($p \geq 0.05$) (Table 3). Therefore, only the left otolith was used for the remaining measurements. The otolith length was 3.50±0.03% (OL/TL) of the total length. The elongation ratio, represented by the OH/OL%, was 42.71±0.38 (Table 4).

According to Jaramillo *et al*. (2014), the values of the OL/TL% and OH/OL% were 4.160 and 42.31%, respectively. Similarly, data from Tuset *et al*. (2008) showed that OL/TL% and OH/OL% values ranged between 4.3–4.2% and 39.9–47.1%, respectively, which are consistent with the findings of this study.

Table 2. Fulton's condition factor and the relative condition factor of the *Serranus cabrilla*.

Condition factor	Min–max	Mean±SE	95% Confidence interval
Fulton factor's	0.77–1.81	1.20±0.01	1.16–1.23
Relative condition factor	0.65–1.48	1.02±0.01	0.99–1.05

Table 3. The descriptive statistics of otolith parameters of *Serranus cabrilla*.

Parameters	Side	Mean	SD	SE
OL (mm)	R	5.41	0.52	0.06
	L	5.40	0.52	0.06
OH (mm)	R	2.26	0.24	0.03
	L	2.33	0.24	0.03
OW (g)	R	0.01	0.00	0.00
	L	0.01	0.00	0.00
OA (mm^2)	R	8.28	1.64	0.19
	L	8.51	1.59	0.19

Note: R = Right otolith; L = Left otolith; OL = Otolith length; OH = Otolith height; OW = Otolith weight; OA = Otolith area

Table 4. Descriptive statistics of percentage index (OH/OL%, OL/TL %), shape index (ellipticity, rectangularity, and roundness), and otolith relative size of *Serranus cabrilla*.

Indices	Min–max	Mean±SE
OH/OL%	27.94–54.57	42.71±0.39
OL/TL%	2.57–4.25	3.51±0.03
Ellipticity	0.29–0.56	0.40±0.00
Rectangularity	0.47–0.88	0.67±0.00
Roundness	0.26–0.59	0.37±0.00
Otolith relative size	0.21–0.63	0.36±0.00

Three shape indicators were calculated, as shown in the Table 3. The highest values were for rectangularity > ellipticity > roundness, with values of 0.67±0.00, 0.40±0.00, and 0.37±0.00, respectively. These results are consistent with those found by Tuset *et al*. (2003a) in their comparative studies of the otoliths of the genus *Serranus* from the Canary Islands, where significant differences in ellipticity were observed across different length groups. Based on the four categories proposed by Lombarte and Cruz (2007), the otolith of *S.cabrilla* is considered medium in size. The relative size value of the otolith was 0.36±0.00, which falls within the middle category (0.33–0.65).

The relationship between body size and otolith dimensions (length, height, and area), as well as between otolith length and other otolith measurements (OH and OA) in *S. cabrilla*, was calculated using a power regression modal (Table 5, Figures 3–5). The regression results were positive, indicating that as body size increased, the otolith dimensions also increased. The highest coefficient of determination was observed between otolith length and otolith area, with $r^2 = 0.91$. However, the r^2 values for the relationships between otolith dimensions and body size were moderate ($r^2 = 0.40$–0.66), suggesting that these parameters (OL, OH, and OA) are not strong predictors of body length and weight in our fish population. Our findings contrast with the majority of previous studies, which have reported higher r^2 these relationships. For instance, Bilge and Felez (2018) found a strong relationship between body size and otolith dimensions in *S. cabrilla* from the southern Aegean Sea, with coefficient of determination ranging from $r^2 = 0.82$ (OW–TW) to $r^2 = 0.93$ (OL–TL) using linear and exponential regression models.

Table 5. Relationships between otolith dimension (OL, OH and OA) and fish size (TL and TW), and the relationship between otolith length and other measurements of the otolith (OH and OA) of *Serranus cabrilla*.

Traits	Regression equation	r^2
OL–TL	$OL = 0.50TL^{0.86}$	0.66
OH–TL	$OH = 0.19TL^{0.89}$	0.47
OA–TL	$OA = 0.12TL^{1.52}$	0.57
OL–TW	$OL = 0.57TW^{0.58}$	0.57
OH–TW	$OH = 0.35TW^{0.48}$	0.40
OA – TW	$OA = 0.95TW^{0.53}$	0.65
OH–OL	$OH = 0.47OL^{0.93}$	0.84
OA–OL	$OA = 0.66OL^{1.50}$	0.91

Note: TL = Total length; TW = Total weight; OL = Otolith length; OH = Otolith height; OA = Otolith area; r^2 = coefficient of determination

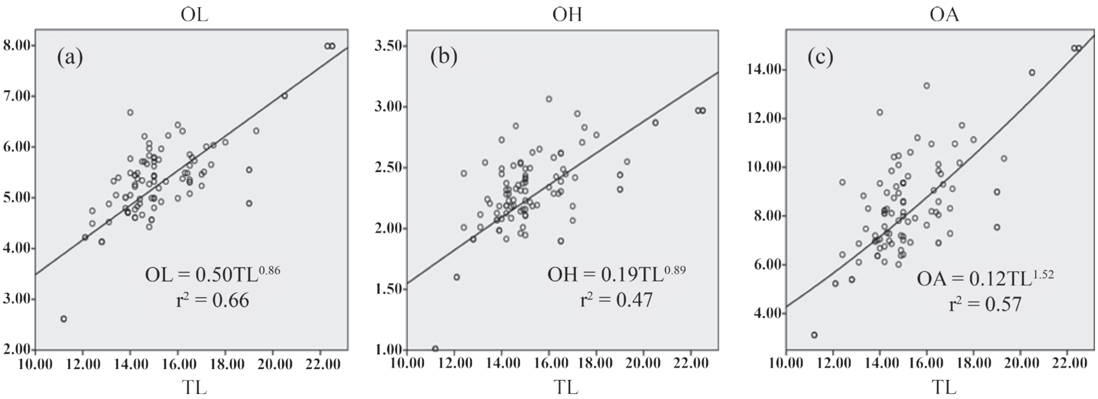

Figure 3. Relationship between total length and otolith parameters (OL, OH, OA) of *Serranus cabrilla*, (a: Total length with otolith length, b: Total length with otolith height, and c: Total length with otolith area).

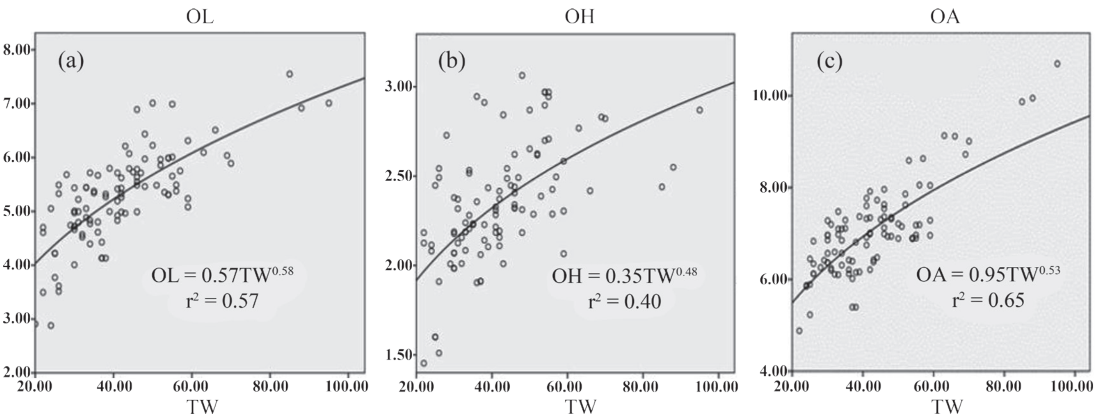

Figure 4. Relationship between total weight and otolith parameters (OL, OH, OA) of *Serranus cabrilla*, (a: Total weight with otolith length, b: Total weight with otolith height, and c: Total weight with otolith area).

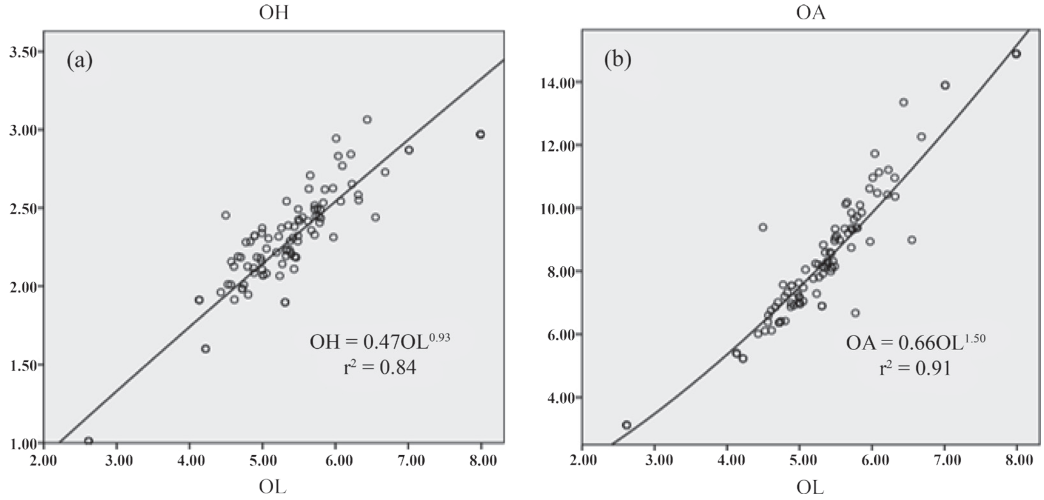

Figure 5. Relationship between otolith length and otolith parameters (OH and OA) of *Serranus cabrilla*, (a: Otolith length with otolith height and b: Otolith length with otolith area).

In ldir Bay, Uyan *et al*. (2016) reported the relationship between standard length and otolith length as $r^2 = 0.90$, and between standard length and otolith height as $r^2 = 0.75$, both of which are higher than our estimations. Variations in these results may be attributed to differences in habitat characteristics and ecosystem features (Bal *et al*., 2018).

CONCLUSIONS

This study provides essential baseline information on *Serranus cabrilla*, demonstrating an isometric growth pattern and overall good condition. Moreover, it is the first to offer data on the morphological characteristics of otoliths and their relationship to body size in *S. cabrilla* from Libya, contributing valuable insights for biological and taxonomic studies of fish in the region.

ACKNOWLEDGEMENTS

The authors would like to express their thanks to staff members of the Marine Science department at Omar Al-Mukhtar University for their support.

LITERATURE CITED

Adeyemi, S.O., N.O. Bankole, I.A. Adikwu and P.M. Akombo. 2009. Age, growth and mortality of some commercially important fish species in Gbadikere Lake, kogi state, Nigeria. **International Journal of Lakes and Rivers** 2(1): 63–69.

Ama-Abasi, D. 2007. **A review of length-weight relationship and its parameters in Aquatic species.** Proceedings of the 22nd Annual Conference of the Fisheries Society of Nigeria, Kebbi, Kebbi State, Nigeria 2007: 240–244.

Anderson, R.O. and R.M. Neumann. 1996. **Length, weight, and associated structural indices.** In: Fisheries Techniques, 2nd ed. (eds. B.R. Murphy and D.W. Willis), pp. 447–482. MD: American Fisheries Society, Bethesda, Maryland, USA.

Anene, A. 2005. Condition factors of four cichlid species of a man-made lake in Imo state, Southwest, Nigeria. **Turkish Journal of Fisheries and Aquatic Sciences** 5: 43–47.

Angelescu, V., F.S. Gneri and A. Nani. 1958. T**he Hake from the Argentine Sea (Biology and Taxonomy).** Naval Hydrographic Service, Secretary of the Navy, Buenos Aires, Argentina. 240 pp. (in Spanish)

Bal, H., D. Türker and K. Zengin. 2018. Morphological characteristics of otolith for four fish species in the Edremit Gulf, Aegean Sea, Turkey. **Iranian Journal of Ichthyology** 5(4): 303–311. DOI: 10.22034/iji.v5i4.312.

Beyer, J.E. 1987. On length-weight relationship. part1: Computing the mean weight of the fish of a given length class. **Fishbyte** 5(1): 11–13.

Bilge, G. and H. Filiz. 2018. Determination of sagittal otolith biometry and body size of *Serranus cabrilla* (Linnaeus, 1758) Distributed in Southern Aegean Sea. **Aquatic Research** 1(2): 50–54. DOI: 10.3153/AR18006.

Binohlan, C. and D. Pauly. 2000. **The length-weight table.** In: FishBase: Concepts, Design and Data Sources (eds. R. Froese and D. Pauly), pp. 131–134. ICLARM, Los Baños, Philippines.

Bök, D.T., D. Göktürk, A. Kahraman, T. Alıçlı, T. Acun and C. Ateş. 2011. Length-weight relationships of 34 fish species from the Sea of Marmara, Turkey. **Journal of Animal and Veterinary Advances** 10(23): 3037–3042.

Buzaid, E.M.K. 2018. Study of the feeding habits, liver and reproduction of some Spp. Serranus fish Coasts of Benghazi, winter 2018. **Journal of Marine Sciences and Environmental Technologies** 4(1): 37–52. (in Arabic)

Çakır, D.T., H.T. Koç, A. Başusta and N. Başusta. 2008. Length–weight relationships of 24 fish species from Edremit Bay, Aegean Sea. **E-journal of New World Sciences Academy** 3: 47–51

Cengiz, Ö. 2013. Length–weight relationships of 22 fish species from the Gallipoli Peninsula and Dardanelles (northeastern Mediterranean, Turkey). **Turkish Journal of Zoology** 37: 419–422.

De Giosa, M., P. Czerniejewski and A. Rybczyk. 2014. Seasonal changes in condition factor and weight-length relationship of invasive *Carassius gibelio* (Bloch, 1782) from Leszczynskie Lakeland, Poland. **Advances in Zoology** 2014: 678763. DOI: 10.1155/2014/ 678763.

Echreshavi, S., H.R. Esmaeili, A. Teimori and M. Safaie. 2021. Otolith morphology: A hidden tool in the taxonomic study of goatfishes (Teleostei: Perciformes: Mullidae). **Zoological Studies** 7: 60–36. DOI: 10.6620/ZS.2021.60-36.

Fulton, T.W. 1904. **The Rate of Growth of Fishes.** Fisheries Board of Scotland, Edinburgh, Scotland. 241 pp.

Golani, D., B. Ozturk and N. Basusta. 2006. **Fishes of the Eastern Mediterranean.** Turkish Marine Research Foundation, Istanbul, Turkey. 259 pp.

Jacobs, S.R., K. Elliott, M.F. Guigueno, A.J. Gaston, P. Redman, J.R. Speakman and J. Weber. 2012. Determining seabird body condition using nonlethal measures. **Physiological and Biochemical Zoology** 85(1): 85–95. DOI: 10.1086/663832.

Jaramillo, A.M., A.D. Tombari, V. Benedito Durá, M.E. Rodrigo Santamalia and A.V. Volpedo. 2014. Otolith eco-morphological patterns of benthic fishes from the coast of Valencia (Spain). **Thalassas: An International Journal of Marine Sciences** 30(1): 57–66.

Jisr, N., G. Younes, C. Sukhn, H. Mohammad and M.H. El-Dakdouki. 2018. Length-weight relationships and relative condition factor of fish inhabiting the marine area of the Eastern Mediterranean city, Tripoli-Lebanon. **Egyptian Journal of Aquatic Research** 44: 299–305.

King, M.G. 2007. **Fisheries Biology, Assessment, and Management,** 2nd ed. Blackwell Publishing, Oxford, UK. 382 pp.

Labocha, M.K., H. Schutz and J.P. Hayes. 2014. Which body condition index is best? **Oikos** 123(1): 111–119. DOI: 10.1111/j.1600-0706.2013.00755.x.

Le Cren, E.D. 1951. The length-weight relationships and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*) **Journal of Animal Ecology** 20: 201–219. DOI: 10.2307/1540.

Lima, J.S, I.D. da Costa and I.R. Zalmon. 2020. Length-weight relationship of fish species captured around an artificial offshore reef (northern Rio de Janeiro, Brazil) **Journal Applied Ichthyology** 37: 337–341.

Lombarte, A. and A. Cruz. 2007. Otolith size trends in marine com-munities from different depth strata. **Journal of Fish Biology** 71(1): 53–76. DOI: 10.1111/j.1095-8649.2007.01465.x.

Louizy, P. 2005. **Marine Fish Identification Guide: Western Europe and the Mediterranean,** 2nd ed. Eugen Ulmer, Paris, France. 430 pp. (in French)

Miller, S.J., D.T. Van Genechten and C.E. Cichra. 2015. Length–weight relationships and an evaluation of fish–size and seasonal effects on relative condition (K_n) of fishes from the Wekiva River, Florida. **Florida Scientist** 78(1): 1–19.

Morales, C.J.C., K.D.E. Barnuevo, E.S. Jr. Delloro, R.A. Cabebe-Barnuevo, J.K.S. Calizo, S.D.P Lumayno and R.P. Babaran. 2023. Otolith morphometric and shape distinction of three red fin species under the genus *Decapterus* (Teleostei: Carangidae) from Sulu Sea, Philippines. **Fishes** 8(2): 95. DOI: 10.3390/fishes8020095.

Moutopoulos, D.K. and K.I. Stergiou. 2002. Length-weight and length length relationships of fish species from the Aegean Sea (Greece). **Journal of Applied Ichthyology**18: 200–203.

Moyle, P.B. and J.J. Cech. 2004. **Fishes: An Introduction to Ichthyology,** 5th ed. Pearson Prentice Hall, New Jersey, USA. 132 pp.

Muchlisin, Z.A., M. Musman and M.N. Siti-Azizah. 2010. Length-weight relationships and condition factors of two threatened fishes, *Rasbora tawarensis* and *Poropuntius tawarensis*, endemic to Lake Laut Tawar, Aceh Province, Indonesia. **Journal of Applied Ichthyology** 26: 949–953.

Narsimham, K.A. 1970. On the length-weight relation and relative condition in *Trichiurus lepturus*. **Indian Journal of Fishery** 17(182): 91–96.

Navarro, J.T., F. Zetina-Rejon and N.E. Arreguin-Sanchez. 2010. Length-weight relationships of demersal fish from the Eastern coast of the mouth of the Gulf of California. **Journal of Fisheries and Aquatic Science** 5(6): 494–502.

Olopade, J.O. and S. Tarawallie. 2014. The length-weight relationship, condition factor and reproductive biology of *Pseudotholithus senegalensis* (Valenciennes, 1833) in Tombo Western Rural District of Sierra Leone. **African Journal of Food, Agriculture, Nutrition and Development** 14(6): 2176–2188.

Osman, Y.A.A., K. Mahé, S.M. El-Mahdy, A. Mohammad and S.F. Mehanna. 2021. Relationship between body and otolith morphological characteristics of Sabre squirrelfish (*Sargocentron spiniferum*) from the Southern Red Sea: Difference between right and left otoliths. **Oceans** 2(3): 624–633. DOI: 10.3390/oceans2030035.

Özvarol, Y. 2014. Length–weight relationships of 14 fish species from the Gulf of Antalya (northeastern Mediterranean Sea, Turkey) **Turkish Journal of Zoology** 38: 342–346. DOI: 10.3906/zoo-1308–44.

Paladin, A., N. Ugrin, S. Matić-Skoko, B. Dragičević and J. Dulčić. 2023. Age, growth, and validation of otolith morphometrics as predictors of age in the blackspot seabream, *Pagellus bogaraveo*, (Brunnich, 1768) from the Eastern Adriatic Sea. **Fishes** 8(6): 301. DOI: 10.3390/fishes8060301.

Peig, J. and A.J. Green. 2010. The paradigm of body condition: A critical reappraisal of current methods based on mass and length. **Functional Ecology** 24(6): 1323–1332. DOI:10.1111/ j.1365-2435.2010.01751.x.

Popper, A.N., J. Ramcharitar and S.E. Campana. 2005. Why otoliths? Insights from inner ear physiology and fisheries biology. **Marine and Freshwater Research** 56(5): 497–504.

Rachedi, M., F. Derbal and M.H. Kara. 2018. Feeding habits of the comber *Serranus cabrilla* (Linnaeus, 1758) (Teleostei, Serranidae) from the gulf of Annaba (Eastern coast of Algeria), **Cahiers de Biologie Marine** 59: 149–158. DOI: 10.21411/CBM.A.7B25A05C.

Rachedi, M. and A.T. Dahel. 2019. Population dynamic parameters of the comber *Serranus cabrilla* (Teleostei, Serranidae) in Western Mediterranean (Eastern Coast of Algeria). **Egyptian Journal of Aquatic Biology and Fisheries** 23(5): 31–42.

Ragheb, E. 2023. Length-weight relationship and well-being factors of 33 fish species caught by gillnets from the Egyptian Mediterranean waters off Alexandria, **Egyptian Journal of Aquatic Research** 49(3): 361–367. DOI: 10.1016/j.ejar.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. **Bulletin of the Fisheries Research Board of Canada** 191: 1–382.

Sangun, L., E. Akamca and M. Akar. 2007. Weight-length relationships for 39 fish species from the north-eastern Mediterranean coast of Turkey. **Turkish Journal of Fisheries and Aquatic Sciences** 7: 37–40.

Schneider, J.C., P.W. Laarman and H. Gowing. 2000. **Length-weight relationships, Chapter 17.** In: Manual of Fisheries Survey Methods II: With Periodic Updates (ed. J.C. Schneider), pp. 1–18. Michigan Department of Natural Resources, Fisheries Special Report 25, Ann Arbor, Michigan, USA.

Secor, D.H., A. Henderson-Arzapalo and P.M. Piccoli. 1995. Can otolith microchemistry chart patterns of migration and habitat utilization in anadromous fishes. **Journal of Experimental Marine Biology and Ecology** 192: 15–33. DOI: 10.1016/0022-0981(95)00054-U.

Singh, J., S.K. Ahirwal, T. Kumar, V. Bharti, P. Gogoi and K. Sarma. 2023. Relationship between fish body and sagittal otolith morphometrics in the pool barb *Puntius sophore* (Hamilton, 1822) from the Ganga and Punpun rivers of Bihar, India. **Indian Journal of Fisheries** 70(2): 86–94.

Smale, M.J., G. Watson and T. Hecht. 1995. **Otolith Atlas of Southern African Marine Fishes.** Ichthyological Monographs of the J.L.B. Smith Institute of Ichthyology, Grahamstown, South Africa. 253 pp.

Sokal, R.R. and F.J. Rohlf. 1987. **Introduction to Biostatistics.** W.H. Freeman, New York, USA. 374 pp.

Stergiou, K.I. and D.K. Moutopoulos. 2001. A review of length-weight relationships of fishes from Greek marine waters fisheries section of the Network of Tropical Aquaculture and Fisheries Professionals (NTAFP) **Fishbyte** 24: 23–39.

Torcu-Koc, H., D. Türker-Çakir and J. Dul. 2004. Age, growth and mortality of the comber, *Serranus cabrilla* (Serranidae) in the Edremit Bay (Nw Aegean Sea, Turkey). **Cybium** 28(1): 19–25.

Tuset, V.M., A. Lombarte, J.A. González, J.F. Pertusa and M. Lorente. 2003a. Comparative morphology of the sagittal otolith in *Serranus* spp. **Journal of Fish Biology** 63(6): 1491–1504. DOI:10.1111/j.1095-8649.2003.00262.x.

Tuset, V.M., I.J. Lozano, J.A. González, J.F. Pertusa and M. García-Díaz. 2003b. Shape indices to identify regional differences in otolith morphology of comber, *Serranus cabrilla* (L., 1758). **Journal of Applied Ichthyology** 19: 88–93. DOI: 10.1046/j.1439-0426.2003.00344.x.

Tuset, V.M., A. Lombarte and C.A. Assis. 2008. Otolith atlas for the western Mediterranean north and central eastern Atlantic. **Scientia Marina** 72(S1): 7–198. DOI: 10.3989/scimar.2008.72s17.

Uyan, U., M. Çelik, R. Tezel and C. Ateş. 2016. Otolith biometry and fish length relation of *Serranus cabrilla* (Linnaeus, 1758) caught from Ildir Bay. **Natural and Engineering Sciences** 1(3): 57. DOI: 10.13140/RG.2.2.17657.26723.

Yem, I.Y., O.A. Sani, M.B. Mshelia and H.U. Onimisi. 2007. **The length-weight relationship and condition factor of the banded jewel fish (*Hemichromis mfasciatus* Peters) from Kainji Lake, Nigeria.** Proceedings of the 22nd Annual Conference of the Fisheries Society of Nigeria (FISON) 2007: 15–23.

Zuchi, N., C. Ropke, A. Shibuya, T. Farago, M. Carmona, J. Zuanon and S. Amadio. 2020. Length weight relationship of fish species from Central Amazon floodplain. **Journal Applied Ichthyology** 36: 837–841.