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Age and growth of common pandora, Pagellus erythrinus (Perciformes; Sparidae) from the Gökçeada Island, North Aegean Sea

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Abstract

The aim of this study was to describe age, growth and the relationships between otolith morphometrics and fish length, weight and age of the common pandora, *Pagellus erythrinus*. This study was carried out from the shores of Gizli liman to Kefalos Cape in the north of Gökçeada Island, between April-June 2018. The samples were collected at the depths of 40-120m by long lines. The 90 individuals obtained from *P. erythrinus* ranging in total length (TL) from 18.5 to 34.5 cm. The calculated length–weight relationships was calculated as $W= 0.022TL^{2.7767}$ (R^2 = 0.92). Individual ages were macroscopically determined by counting the annuli of sagittal otoliths. Estimated ages ranged from 2 – 14 years old. The von Bertalanffy growth curve was fitted to the age/total length data as follows: L_∞= 51.13 cm, K= 0.061 and t_0= -4.96. The common pandora sagittal otolith length, width and mass were measured between 7.67-12.95mm, 5.38–8.65mm and 0.0810-0.2706g, respectively. No significant differences in otolith morphometrics were found between left and right otoliths. This study provides valuable data for the stock assessment of common pandora in fishing grounds Gökçeada Island located in the North Aegean Sea.

Keywords: Age structure; Otolith morphometry; *Pagellus erythrinus*; Gökçeada.

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1. Introduction

Age structure of a fish species plays a major role to better-understand the biology of fish and about their population dynamics (Megalofonou, 2006; Cassoff *et al*., 2007). Age and growth data provide important information about both individuals and populations (Quist *et al*., 2012). Thus, determination of age and growth rates of a fish species has great importance (Jackson, 2007). Otoliths are the most preferred structures because they provide the most accurate estimates of age (Campana and Thorrold, 2001). Otoliths are a calcium carbonate structure in the saccule or utricle of the inner ear, which contribute to hearing and balance (Campana, 1999). These structures continue to grow throughout the life of a fish, and this occurs by the accumulation of protein and calcium secreted by the macular cells surrounding the surface of the otolith (Campana and Neilson, 1982). These are natural data loggers that record information about growth and environment at different temporal scales into their microstructures and chemistry (Kalish, 1989; Campana, 1999).

Otoliths are species–specific and have a characteristic shape with great differences between species (Maisey, 1987). It is possible to identify the fossils by otolith morphology and to determine the species and size of food resources in the stomach of a predatory fish (Echeverria, 1987; Gamboa, 1991; Nielsen *et al*., 2010). In addition, a considerable number of researchers have reported that the age of the fish can be determined by otolith morphology (Shakman *et al*., 2008; Skeljo and Ferri, 2012; Emre *et al*., 2014; Pattoura *et al*., 2015; de Santana *et al*., 2018).

The common pandora, *Pagellus erythrinus* (Linneaus, 1758), which belongs to the Sparidae family (https://www.fishbase.in/summary/893), is a commercially important seabream for coastal fisheries in the Turkish waters. It is a demersal fish species, distributed throughout the Mediterranean, along the Atlantic coast of Europe and Africa, from Angola to Norway (Bauchot and Hureau, 1986). They usually live in rocky, gravel, sandy and muddy places with depths of 0 –200 m in the Mediterranean Sea or 0 – 300 m in the Atlantic (Bauchot and Hureau, 1990). This species is a protogynic hermaphrodite female that becomes male in their third year (Bauchot and Hureau, 1990). There is a large volume

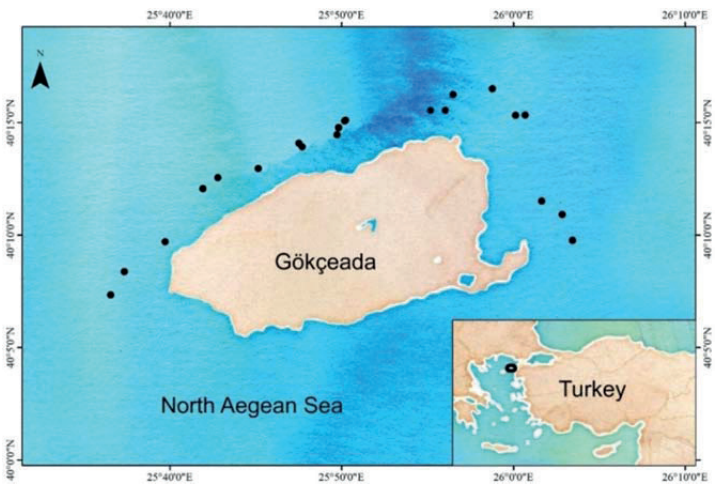

Figure 1. Sampling stations where common pandora, *Pagellus erythrinus* were collected with long lines from the island of Gökçeada, Turkey, March – June 2018

of published studies describing the age and growth characteristics of this species due to its high economic value (Pajuelo and Lorenzo, 1998; Somarakis and Machias, 2002; Abecasis *et al*., 2008; Fassatoui *et al*., 2012; Ayyildiz and Altin, 2018).

The aim of this study is to determine the age and growth rates of the common pandora from Gökçeada, Turkey. In addition, the relationships between otolith morphometry and fish length and age were investigated.

2. Material and methods

This study was carried out from the shores of Gizli liman to Kefalos Cape in the north of Gökçeada Island, Turkey (Figure 1). The samples were collected using long lines, from 40–120m depths between March–June 2018.

2.1. Length–weight relationships

The common pandora were measured for total length (TL) and total weight (W). Sexes were determined by morphological examination in the laboratory. The Mann–Whitney U test was applied to examine the differences between sexes according to the total length. The relation between the total length and the weight was calculated for each sex separately using a power function:

$W = aTL^b$

where, b is the regression coefficient and a is the regression constant. The regression parameters a, b and the coefficient of determination (R^2) were estimated for all individuals and for each sex. The allometric index value (b) was compared to the theoretical value of 3 by a t-test (Zar, 1984).

2.2. Age and Growth

Sagittal otoliths of common pandora were extracted and stored in eppendorf tubes. Randomly selected otoliths were immersed in plastic vial with glycerin solution for one hour. Sagittal otolith annual rings were counted from the core to the outer edge under

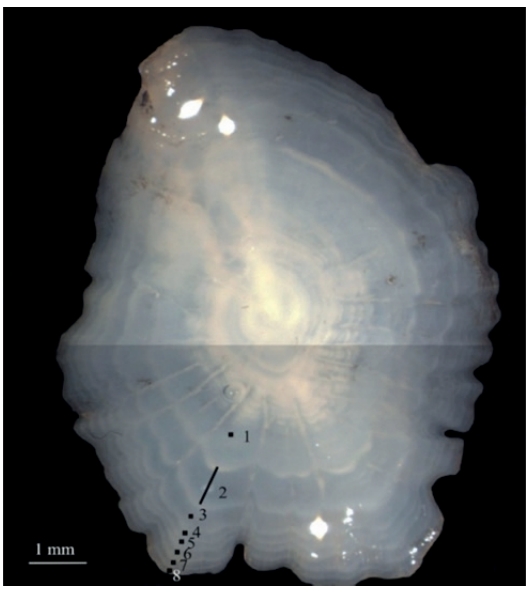

Figure 2. Image of the annual rings seen in a sagittal otolith of common pandora, *Pagellus erythrinus* collected from Gökçeada, Turkey. This fish was aged at 8 years and had a total length of 26 cm female. Line corresponds to an annual growth ring.

a light microscope (Figure 2). Two readers independently counted the annual rings without prior knowledge of fish length. Estimates of the precision of growth ring counts between readers were determined by using the average percentage error (APE) of (Beamish and Fournier, 1981) and coefficient of variation (CV) (Chang, 1982).

The von Bertalanffy growth curve was fitted to the length at age data using non-linear least squares parameter estimation (Von Bertalanffy, 1938);

$TL = L_{\infty} [1\text{-}e^{(-K (t-t_0))}]$

where, TL is the fish length at age t, L_{∞} the theoretical asymptotic length, K the growth rate coefficient, and t_0 the theoretical age when fish length is zero.

2.3. Otolith morphometry

Otolith length (OL) and width (OW) were measured to the nearest 0.01 mm using Q Capture Imaging Software and weighed (OM) to the nearest 0.00001g using a Shimadzu electronic balance. OL was defined as the longest axis between the anterior and posterior otolith edge and OW as a distance from the dorsal to the ventral edge. Differences between

Table 1. Summary of the total lengths in centimeters of *Pagellus erythrinus* collected from Gökçeada. The number of specimens (n) and range, mean, and standard deviation of the mean (SD) for total length are provided

	Female					Male					Undetermined				
Capture Date	n	Min.	Max.	Mean	SD	n	Min.	Max.	Mean	SD	n	Min.	Max.	Mean	SD
March 18	7	21.5	27.4	24.2	1.82	6	22.2	31.0	27.7	3.21		…	…	…	…
April 18	43	18.5	28.5	24.4	2.48	26	21.4	34.5	27.4	3.21	1	20.6	20.6	20.6	…
May 18	3	22.5	25.0	24.0	1.32	1	30.5	30.5	30.5	…	1	24.5	24.5	24.5	…
June 18	…	…	…	…	…	2	18.5	21.4	19.9	2.05		…	…	…	…

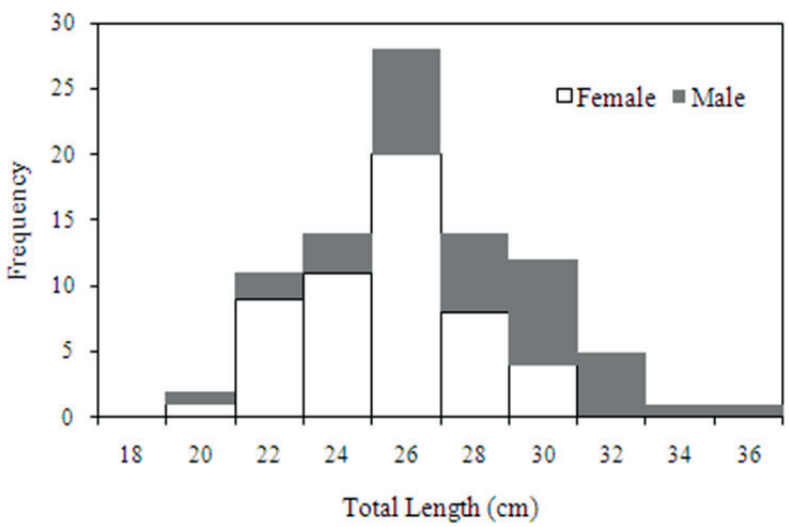

Figure 3. Length–frequency distribution of males and females of common pandora collected from Gökçeada, Turkey

left and right otoliths were tested by paired t-test. Furthermore, the relationships between the fish length and the otolith morphometry were investigated. Moreover, the relations between age and otolith weight were calculated using the exponential model.

3. Results

A total number of 90 *Pagellus erythrinus* were sampled from Gökçeada, Turkey. The common pandora individuals ranged in size from 18.5 to 34.5 cm total length (Table 1). Female and male total lengths ranged from 18.5 to 28.5 cm and from 18.5 to 34.5 cm, respectively (Figure 3). The Mann–Whitney test revealed significant differences between sexes, regarding TL ($U = 472$, $Z = –3.881$; $P < 0.05$). The overall male: female ratio (M: F = 1:1.51) was biased in favor of females.

3.1. Length-weight relationships

The parameters of the length–weight relationships are provided for each sex and all individuals in Table 2. Our data suggested that common pandora from Gökçeada showed negative allometric growth. The parameter b of length–weight relationships was significantly different from 3 ($P < 0.05$). The allometric exponent b of females was greater than males.

3.2. Age and Growth

Ages were determined successfully from 90 otoliths of common pandora that ranged in size

Table 2. Parameters of the length–weight relationships for males, females, and all individuals of common pandora from Gökçeada, Turkey

	n	a	b	R^2	P
Female	53	0.0136	2.9513	0.9082	<0.01
Male	35	0.0406	2.6207	0.9239	<0.01
All	90	0.0223	2.776	0.9285	<0.01

Table 3. Age–length key for common pandora from Gökçeada, Turkey.

Total Length (cm)	Age												
	2	3	4	5	6	7	8	9	10	12	13	14	N
18-19.9	1	1											2
20-21.9		7	4	1									12
22-23.9		1	3	3		1							8
24-25.9			1	10	18	2							31
26-27.9						10	5	2					17
28-29.9						1	5	6	1				13
30-31.9								2	2	1			5
32-33.9											1		1
34-35.9												1	1
N	1	9	8	14	18	14	10	10	3	1	1	1	90

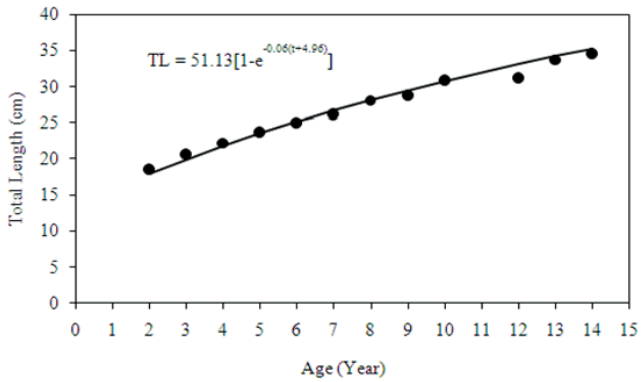

Figure 4. The von Bertalanffy growth curves for *Pagellus erythrinus* from Gökçeada, Turkey

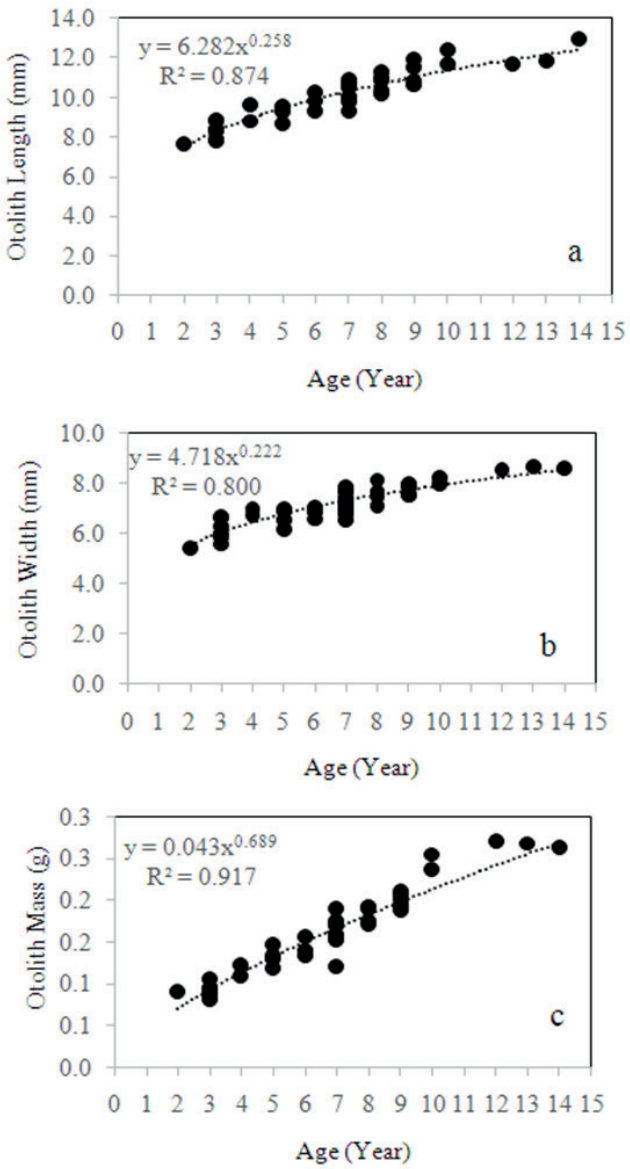

Figure 5. The relationships between otolith morphometry and age for *Pagellus erythrinus* from Gökçeada, Turkey; Otolith length (a), Otolith width (b), Otolith mass (c)

from 18.5 to 34.5 cm TL. Based on the annual growth ring counts of common pandora otoliths, the maximum observed age was 14 years and the minimum observed age was 2 years old (Table 3). Most of the fish, accounting for 73.3% of the total sample, were between 5 and 9 years old. The APE and CV were calculated as 5.6% and 4.0%, respectively. Only males represented age classes of older than 9 years. The von Bertalanffy (1957) model was used to describe common pandora growth (Figure 4). The estimated parameters of the equation were; L_{∞}= 51.13; W_{∞}= 1332.96; K= 0.061 and t_0= -4.96.

3.3. Otolith morphometry

Otolith length, width and mass were ranged between 7.67–12.95 mm, 5.38–8.65 mm and 0.0810–0.2706 mm, respectively (Table 4). No significant differences in otolith morphometrics were found between left and right otoliths (paired t-test, P>0.05). OL and OW showed significant linear relations with the TL while OM represented by power model (Table 5). The relationships between otolith morphometry and age were described in Figure 5. An exponential model explained between 80% and 91% of the variation in age. No significant differences were found between ages estimated from otoliths and ages predicted from OL, OW, and OM (Mann-Whitney U test; P>0.05).

4. Discussion and Conclusion

The maximum length and weight reported in this study (TL = 34.5 cm for W = 456.1 g) are the second biggest reported values from Turkey. Akyol *et al*. (2007), Metin *et al*. (2011), Çiçek *et al*. (2012), and Ozvarol (2014) in their studies from Turkey reported that the larger individuals were 41.0, 27.8, 21.5, and 15.8 cm in total length, respectively. The biggest individual of common pandora was observed in the French Catalan coast and reported as 58 cm. The observed difference between our study and the study from Catalan coast may possible due to the growth of common pandora in the East Mediterranean is faster than West Mediterranean, or it may only be due to the sampling procedure (Crec'hriou *et al*., 2012).

Table 4. Otolith length (OL), width (OW) and mass (OM) measurements according to the age of *Pagellus erythrinus* from Gökçeada, Turkey

Age	Left												Right											
	OL				OW				OM				OL				OW				OM			
	Min.	Max.	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.	Mean	SD
2	7.67	7.67	7.67	---	5.38	5.38	5.38	---	0.09	0.09	0.09	---	7.84	7.84	7.84	---	5.83	5.83	5.83	---	0.09	0.09	0.09	---
3	7.85	8.90	8.39	0.42	5.54	6.65	6.14	0.45	0.08	0.11	0.09	0.01	7.73	8.78	8.27	0.40	5.83	6.64	6.18	0.28	0.08	0.11	0.09	0.01
4	8.83	9.66	9.25	0.59	6.71	6.95	6.83	0.17	0.11	0.12	0.12	0.01	8.86	9.76	9.31	0.64	6.81	6.96	6.89	0.11	0.11	0.12	0.11	0.01
5	8.69	9.60	9.28	0.41	6.15	6.93	6.61	0.36	0.12	0.15	0.13	0.01	8.71	9.82	9.35	0.50	6.07	6.95	6.62	0.38	0.12	0.14	0.13	0.01
6	9.36	10.33	9.85	0.49	6.54	7.01	6.79	0.24	0.13	0.16	0.14	0.01	9.56	10.48	10.01	0.46	6.57	7.18	6.79	0.34	0.13	0.16	0.14	0.01
7	9.37	10.91	10.33	0.53	6.50	7.83	7.14	0.42	0.12	0.19	0.16	0.02	9.47	11.09	10.39	0.47	6.37	7.69	7.13	0.39	0.13	0.19	0.16	0.02
8	10.24	11.30	10.76	0.44	7.05	8.10	7.56	0.38	0.17	0.19	0.18	0.01	9.94	11.28	10.78	0.58	7.12	7.94	7.61	0.32	0.17	0.20	0.18	0.01
9	10.70	11.92	11.14	0.55	7.48	7.96	7.75	0.20	0.19	0.21	0.20	0.01	10.81	12.48	11.42	0.60	7.44	8.15	7.79	0.29	0.19	0.21	0.20	0.01
10	11.65	12.35	12.00	0.49	7.93	8.20	8.07	0.19	0.24	0.25	0.25	0.01	11.56	12.53	12.05	0.69	8.04	8.30	8.17	0.18	0.25	0.25	0.25	0.00
12	11.70	11.70	11.70	---	8.52	8.52	8.52	---	0.27	0.27	0.27	---	12.88	12.88	12.88	---	8.62	8.62	8.62	---	0.26	0.26	0.26	---
13	11.80	11.80	11.80	---	8.63	8.63	8.63	---	0.27	0.27	0.27	---	11.64	11.64	11.64	---	8.60	8.60	8.60	---	0.26	0.26	0.26	---
14	12.93	12.93	12.93	---	8.55	8.55	8.55	---	0.26	0.26	0.26	---	12.95	12.95	12.95	---	8.65	8.65	8.65	---	0.26	0.26	0.26	---

Table 5. Parameters of the relationships between the otolith morphometry and the fish total length and weight for *Pagellus erythrinus* from Gökçeada, Turkey. n = number of specimens, a = slope of the regression line, b = y-intercept, r^2 = coefficient of determination; TL = fish total length, OL = otolith length, OW = otolith width, OM = otolith mass.

Otolith–fish relationships	Model	n	a	b	r^2	P
TL - OL	Linear	90	1.980	1.110	0.916	<0.05
TL - OW	Linear	90	2.234	1.245	0.850	<0.05
TL - OM	Exponential	90	55.39	0.406	0.884	<0.05
W - OL	Exponential	90	0.108	3.248	0.901	<0.05
W - OW	Exponential	90	0.131	3.743	0.855	<0.05
W - OM	Exponential	90	1774.8	1.156	0.892	<0.05

During the present study, negative allometric growth was determined for the males, females and whole sample separately from Gökçeada, Turkey. For the same species, Metin *et al*. (2011) reported similar type of growth from Gulf of Izmir, and Çiçek *et al*. (2012) from İskenderun Bay and by Ercan (2008) from Saros Bay. In addition, the findings of the current study are consistent with those of other studies conducted from Mediterranean Sea (Giacalone *et al*., 2010; Crec'hriou *et al*., 2012; Moutopoulos *et al*., 2013). Although, there are many factors affecting the b value throughout the fish life (Le Cren, 1951), most of the previous studies have shown that common pandora showed negative allometric growth.

The results of this study indicate that the estimated ages of the common pandora was between 2 and 14 years. For males, the oldest specimen determined as 14 years old, while the oldest female was 9 years old. We have observed some false rings before the first growth ring of the sagittal otoliths of common pandora (Figure 2). These false rings can be formed during the pelagic phase and/or during the transition from pelagic to benthopelagic life (Carbonara and Follesa, 2019). As mentioned by Carbonara and Follesa (2019) the increment between consecutive growth rings should decrease with age for the true growth rings of common pandora. Similar study was done by Coelho *et al*. (2010), based on otolith readings, reported the oldest fish for this species, a 21-year-old, measuring 40 cm of total length. In this study, we found that the oldest fish was 14 years old and 34.5 cm of total length.

The calculated asymptotic length for the common pandora of Gökçeada population shows similarity with other researches especially for the population in the Southern Portuguese region and Southern Tyrrhenian Sea (Coelho *et al*., 2010; Busalacchi *et al*., 2014). Lower asymptotic lengths were presented for the populations in the Saros Bay, Gulf of Izmir and Iskenderun (Ercan, 2008; Metin *et al*., 2011; Çiçek *et al*., 2012). The calculated asymptotic length values by some authors (Metin *et al*., 2011; Çiçek *et al*., 2012) are smaller than the older individual obtained from our study. These differences may be due to the size range of sampled fish (Mouine *et al*., 2010; Agius Darmanin *et al*., 2019). The findings observed in this study mirror those

of the previous studies (Coelho *et al*., 2010; Busalacchi *et al*., 2014) that found a lower k values indicating a slower growth rate.

Otolith morphology has proven to be a powerful tool in various taxonomic studies (Rani *et al*., 2019). This paper investigates the relationship of fish TL and age with otolith morphometrics (OL and OW) by a linear regression model and OM by power model. The results of this study indicate that OL and the OW were linearly while the OM was exponentially correlated to the fish TL. The OL was found to be a better parameter than the others (OW and OM) in estimating fish length and weight. These results are consistent with those of other studies and suggest that fish size and weight could be estimated by using the otolith morphometrics (Ayyildiz *et al*., 2014; Yilmaz *et al*., 2015; Ayyildiz and Altin, 2018; Rani *et al*., 2019). However, the best model for predicting the fish age of common pandora was found for OM. In recent years, researchers have reported that otolith morphometric characteristics could be effectively used instead of age readings (Megalofonou, 2006; Skeljo and Ferri, 2012; Ayyildiz and Altin, 2018).

In conclusion, the findings of present study showed that total length and weight could be estimated from its otolith morphometrics or vice versa. Information about the otolith morphometrics is considered as an important marker for the identification of fish species and determines the prey size that obtained from the stomach contents of piscivorous predators. The results provide essential information needed for stock assessment and management of common pandora in the Mediterranean Sea.

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