AGE, GROWTH AND OTOLITH BIOMETRY-BODY LENGTH RELATIONSHIPS OF RED BANDFISH (Cepola macrophthalmal L., 1758) IN THE SEA OF MARMARA, TURKEY

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Abstract: The age, growth, and the otolith biometry-total length relationships of Cepola macrophthalmal (Linnaeus, 1758) were investigated. The individuals were caught with beam trawl in the Sea of Marmara from March 2012 to June 2014. The individual with 51.5 cm total length sampled in this study was recorded as the new maximum size of C. macrophthalmal in the Marmara Sea. The length-weight relationship showed negative allometric growth with a 1.36 b value. Otolith length-otolith weight, otolith width-otolith weight, otolith length-total length, otolith width-total length, otolith length-otolith width and total length-otolith weight relationships were found as \( OW=0.0002*OL^{2.6377} \) \( (R^2=0.91) \), \( OW=0.001*OW^{2.6215} \) \( (R^2=0.94) \), \( O=0.057*TL+3.2087 \) \( (R^2=0.57) \), \( OW=0.0316*TL+1.8511 \) \( (R^2=0.55) \), \( OW=0.527*OL+0.2015 \) \( (R^2=0.86) \), \( OW=0.0004*TL+0.0029 \) \( (R^2=0.58) \), respectively. Ages were estimated from 80 otolith readings and the minimum and maximum ages observed were 1 and 5 years, respectively. The growth parameters of the von Bertalanffy equation were calculated as \( L_{\infty}=61.95 \) cm, \( K=0.19 \) year\(^{-1} \), \( t_0 = -0.05 \) years. A great majority of the stock (77%) consisted of younger individuals (1-2 age groups). Cepola macrothalmal stock consisted of mainly younger individuals which may indicate that an effective fishing pressure is effective on the stock.

Özet: Cepola macrothalmal (Linnaeus, 1758)’in yaş, büyüme ve otolit biyometri-total boy ilişkileri araştırılmıştır. Bireyler Mart 2012-Haziran 2014 tarihleri arasında Marmara Denizi’nde algılara ile yakalanmıştır. Bu çalışmada ölçülen 51.5 cm ilelik C. macrothalmal bireylerin boyu, Marmara Denizi’nde bu tür için maksimum olarak kaydedilmiştir. Boy-otolit ilişkisi denklemine göre boyumı tipi negatif allometrik olarak belirlenmiştir \( (b=1.36) \). Otolit boyu-otolit ağırlığı, otolit genişliği-otolit ağırlığı, otolit boyu-total boy, otolit genişliği-total boy, otolit boyu-otolit genişliği, toplu otolit ağırlığı-otolit genişliği ilişkileri OW=0,0002*OL\(^{2.6777}\) \( (R^2=0.91) \), OW=0,001*OW\(^{2.6215}\) \( (R^2=0.94) \), O=0.057*TL+3.2087 \( (R^2=0.57) \), OW=0,0316*TL+1.8511 \( (R^2=0.55) \), OW=0,527*OL+0,2015 \( (R^2=0.86) \), OW=0,0004*TL+0,0029 \( (R^2=0.58) \) olarak hesaplanmıştır.Yaşalar 80 adet otolit okumalandan hesaplanmıştır; gözlemlenen en küçük ve en büyük yaşlar sırasıyla 1 ve 5'tir. von Bertalanffy denklemine göre hesaplanan büyüme parametreleri değerleri \( L_x=61.95 \) cm, \( K=0.19 \) yıl\(^{-1} \), \( t_0 = -0.05 \) yıl olarak belirlenmiştir. Stoğun büyük çoğunluğu (%77) genç bireylerden (1-2 yaş grubu) oluşmaktadır. Marmara Denizi’nde C. macrothalmal stoğunun daha çok genç bireylerden oluşması stokların av baskısı altında olduğu düşünülmektedir.

Introduction

The red bandfish, Cepola macrophthalmal (Linnaeus, 1758) is a marine demersal fish species that inhabit soft and muddy bottoms at depths ranging from 15 to 400 m (Sanches 1991). It usually lives in vertical burrows and distributes singly or in groups. There is little information about early life stages of the species except that the eggs are pelagic. The main food source of the species are small crustaceans and chaetognaths (Whitehead et al. 1986). The maximum size of the species has been recorded as 80 cm TL in the Biscay Bay (Sanchez et al. 1995) but the mean length is at about 40 cm in Guiné-Bissau costs in the Atlantic Ocean (Sanches 1991). The details of ecology and life history of C. macrothalmal is poorly known. Although it is known as an eastern Atlantic origin species,
it has an extensive geographical distribution from the Strait of Gibraltar to northern Senegal; northward extending into the Canary Islands, the Mediterranean and north Atlantic up to Scotland and the Orkney Islands (Smith-Vaniz 2015).

In the Mediterranean, C. macrophthalma is present in the Catalan Sea (Coll et al. 2006), the Gulf of Lions (Gaertner et al. 1998), the Ligurian Sea (Molinari & Tunesi 2003), the Tyrrenian Sea (Colloca et al. 2004, Carpentieri et al. 2005), the Cretan Sea (Kallianiotis et al. 2000), the Aegean Sea (Stergiou 1999, Lamprakis et al. 2003, Machias et al. 2004, Labropoulou & Papaconstantinou 2005, Gokce & Metin 2007, Özaydın et al. 2007) and the Sea of Marmara (Bok et al. 2011). It also is present in the Levantine Sea and along the North African coast. It does not occur in the Black Sea (Smith-Vaniz 2015). Due to the minor commercial interest and threats, C. macrophthalma is listed as Least Concern in the IUCN Red List of Threatened Species (IUCN 2015, Smith-Vaniz 2015).

The majority of the literature on the biology and ecology of the species is about its feeding, age, growth, reproduction, and length weight relationships (LWRs) (Stergiou et al. 1992, Kaya et al. 2001, Vallisneri et al. 2006, Dulčić et al. 2008, Özaydın et al. 2007, Bok et al. 2011). Some studies investigated the age, growth, and length-weight relationship parameters in Turkey seas (Kaya et al. 2001, Özaydın et al. 2007, Leblebici 2007, Bok et al. 2011) of which one study reported data on length-weight relationship parameters in the Sea of Marmara (Bok et al. 2011).

The aim of this study is to estimate the relationship between otolith size and fish size, age and growth parameters of C. macrophthalma in the Sea of Marmara. We reported the first results on the age and growth of C. macrophthalma in the Sea of Marmara and the first results about otolith and fish morphometric relationships in general.

**Materials and Methods**

A total of 105 C. macrophthalma specimens were sampled in the Sea of Marmara with monthly samplings between March 2012 and June 2014 from (Fig. 1). The samplings were carried out using a commercial beam trawl net. Total length (TL) and weight (W) values of the samples were determined to the nearest 1 mm and 0.01 g, respectively. The length-weight relationship was determined according to the formula of Le Cren (1951): $W=aL^b$, where $W$ is the total body weight (g), $L$ is the total length (cm) while $a$ and $b$ are constants. To check whether fish growth is statistically different from isometric growth ($b=3$) Student’s t-test was used by the equation according to Sokal & Rohlf (1987): $t=\frac{(b-3)}{SE(b)}$, where $ts$ is the t-test value, $b$ is the slope and $SE(b)$ is the standard error of the $b$ value.

The ages of 80 specimens were determined using the sagittal otoliths, while the rest 25 otoliths were not evaluated as they were broken to a degree which made it impossible to determine their age. The otolith is the most commonly used material for age estimation (Holden & Raitt 1974) and was commonly used for age determination of C. macrophthalma (Kaya et al. 2001, Leblebici 2007). The otolith of this species is easily readable. The nucleus is totally opaque, first translucent band starts after the opaque zone. Estimation of age was based almost exclusively on the interpretation of otolith structures for the presence of translucent and opaque zones which are assumed to represent winter and summer growth periods and the date of birth is assumed 1 January. Sagittal otoliths from each fish were removed and cleaned. The size of the otoliths was measured with Q-Capture Digital Imaging Software attached on an Olympus SZX-7 stereomicroscope with a camera sensitivity to 0.01 mm and weighed with the precision of 0.0001 g by scales (Fig. 2). Annual rings on the whole otoliths were counted in glycerin under a stereomicroscope. The translucent and opaque zones were counted for age determination. The otoliths were read by three different observers and age was determined when minimum two of the readings agreed.

**Fig. 1.** Sampling stations in the Sea of Marmara, Turkey (İşmen et al. 2018). Each open dot represent a different station.

**Fig. 2.** Distal view and measurement axes of the sagittal otolith of C. macrophthalma in the Sea of Marmara (TL: 31.8 cm, W: 18.56 g, Age: 3).
Otolith length (OL), otolith width (OWi) and otolith weight (OW) were measured in all otoliths as shape parameters. For the analysis of relationships between OL-OW, OWi-OW, OL-TL, OWi-L, OL-OWi and TL-W, the equation \( y=ax+b \) was used where \( y \) is OW, OWi or OL, \( x \) is TL or OL, and equation \( y=ax^b \) where \( y \) is OW, \( x \) is OL or OWi, and \( a \) and \( b \) are constant coefficients. The chosen regression model was decided based on the magnitude of the R\(^2\) value.

Growth parameters were determined using the von Bertalanffy equation (Beverton & Holt 1957): \( L_t=L_\infty (1-e^{-K(t-t_0)}) \), where \( L_\infty \) is the asymptotic total length, \( L_t \) the total length at age \( t \), \( K \) the growth curvature parameter and \( t_0 \) is the theoretical age when fish would have been at zero total length. Growth parameters were estimated using the “Analyze of length at age data” method in FAO-ICLARM Stok Assessment Tools (FISAT II) software. For the sake of comparison, the index of overall growth performance \( \Phi \) proposed by Pauly & Munro (1984) was calculated. This test indicated the reliability of age estimates since it had been suggested that phi-prime test values were similar for the same species and genera. The test was based on \( \Phi = \log K+2\log L_\infty \) (Pineiro & Sainza 2003).

All statistics were analyzed using the MINITAB 16 program. The normality assumptions were checked with Kolmogorov-Smirnov test. Student’s t-test was used for analyzing the fish growth type. Paired t-test was used to test whether there is a difference between right and left otoliths. The regression models were used to explain relationships between fish and otolith morphometry.

**Results**

A total of 105 specimens ranged from 8.5 to 51.5 cm in TL and from 1.65 to 24.54 g in weight. A pair of 80 sagittal otoliths were measured. Otolith length, weight and width measurements are given in Table 1. There was no significant difference between right and left otoliths (paired t-test, \( P=0.63 \)), therefore, only right otoliths (n=80) were used for further analysis.

**Table 1.** Morphometric measurements of sampled *C. macrophthalma* and their and otolith length, weight and width.

| Age | N | Total length (cm) |
|-----|---|------------------|
|     |   | Min-Max | Mean |
| 1   | 23 | 14.0-19.9 | 17.7±1.6 |
| 2   | 37 | 18.0-26.9 | 22.0±1.9 |
| 3   | 12 | 25.1-34.2 | 29.4±2.7 |
| 4   | 6  | 30.0-39.2 | 35.5±3.9 |
| 5   | 2  | 50.2-51.5 | 50.9±0.9 |

TL: total length, W: weight, OL: otolith length, OWi: otolith width, OW: otolith weight, R: right, L: left

**Length-weight relationship** was calculated as \( W=0.126^*TL^{1.36} \) (\( R^2=0.74 \)) and showed a negative allometric growth pattern (Fig. 3). Otolith length-otolith weight, otolith width-otolith weight, otolith length-total length, otolith width-total length, otolith length-otolith width and total length-otolith weight relationships were found as \( OW=0.0002^*OL^{2.6377} \) (\( R^2=0.91, p<0.001 \)), \( OW=0.001^*OWi^{2.6215} \) (\( R^2=0.94, p<0.001 \)), \( OL=0.057^*TL+3.2087 \) (\( R^2=0.57, p<0.001 \)), \( OW=0.0316^*TL+1.8511 \) (\( R^2=0.55, p<0.001 \)), \( OW=0.527^*OL+0.2015 \) (\( R^2=0.86, p<0.001 \)), \( OW=0.0004^*TL+0.0029 \) (\( R^2=0.58, p<0.001 \)), respectively (Fig. 4).

The von Bertalanffy growth parameters for *C. macrophthalma* were estimated as \( L_\infty=61.95 \) cm, \( K=0.19 \) year\(^{-1} \), \( t_0 = -0.5 \) year and growth performance index was calculated as \( \Phi=2.86 \) (Fig. 5).

The age interval ranged between 1 and 5. The highest represented age group was 2 (46%) and the age group 1 (30%) and age group 3 were considerably well represented (Table 2).
Fig. 4. OL-OW (a), OW-OWi (b), TL-OL (c), TL-OW (d), OL-OWi (e) and TL-OW (f) relationships of *C. macrophthalma* in the Sea of Marmara.

Fig. 5. The von Bertalanffy growth curve of *C. macrophthalma* in the Sea of Marmara.

Discussion

The life span of the *C. macrophthalma* is shorter than many demersal fish species (Dulčić *et al.* 2008). According to our results, the oldest individual was 5 years old. A great number of limiting factors may have contributed to the occurrence of a shorter life span, as high fishing pressure, nutritional inadequacy, morphological characteristics of the species, etc. The same results were observed in studies conducted in the eastern Adriatic (Dulčić *et al.* 2008), Adriatic (Vallisneri *et al.* 2006), Izmir Bay (Kaya *et al.* 2001) and Euboikos Gulf, western Aegean Sea (Stergiou & Papaconstantinou 1993). In contrast, relatively long life spans were determined in studies conducted in the British Isles (Atkinson 1976) and in Pagassitikos Gulf, western Aegean Sea (Stergiou & Papaconstantinou 1993). This may be a result of lower fishing pressure and availability of more sheltering areas for *C. macrophthalma* in these areas. Its elongated, laterally compressed body shape [horizontal dimension 16 times the vertical one, Stergiou & Papaconstantinou 1993].
(1993)] may be advantageous for escaping from the mesh of fishing nets. Barely squeeze in the trawl and beam trawl bag prevents occurring of this advantage. It’s slow, wavy mode of swimming (Wilson 1953) may make the species an open target for fishing vessels. The observed short life span in a great majority of studies caused us to focus on fishing pressure. Trawl fishing is the main reason for fishing pressure on demersal species. Demersal trawling is prohibited in the Sea of Marmara. Conversely, beam trawl fishery is legally allowed and extensively applied. The relatively lower growth rate and shorter life span may have resulted from the high fishing pressure of beam trawl fishery in the Marmara Sea. The age-frequency distribution also supports this finding. A majority of individuals were of age groups 1 and 2.

The b value shows negative allometry (Student t-test). Negative allometry is mandatory due to the physical nature of the species. The exponent b usually varies between 2.5-3.5 for other fish species. Merely, the lifestyle of C. macrophthalma may cause unproportional length increases according to growth in weight, and this may induce lower b values (Froese 2006). However, the calculated b value (1.358) in this study reveals the lowest value compared with the others (Table 3). Poor food availability and competition for food resources in the Sea of Marmara may have caused this situation. In a single study conducted in the Sea of Marmara on C. macrophthalma, Bok et al. (2011) calculated the b value as 1.510.

Due to the absence of studies on the age and growth parameters of C. macrophthalma in the Sea of Marmara, growth parameters were compared with other studies conducted in adjacent waters. In almost all studies, the calculated L∞ and K values are greater than the ones in this study. The estimated L∞ and K values in our study are in agreement with the findings of Stergiou et al. (1992). Also, the same K value was obtained in the findings of Kaya et al. (2001), whereas our calculated L∞ value is lower. We think this may be due to the high number of smaller individuals in our data set (Table 4).

Table 3. Total length-total weight relationships of C. macrophthalma obtained by different researchers.

| Researcher(s)       | Region                | N  | Sex       | a     | b     | R²  | Length   |
|---------------------|-----------------------|----|-----------|-------|-------|-----|----------|
| Stergiou 1991       | Euboikos and Pagassitikos Gulfs | 515 | Female    | 0.0491 | 1.667 | 0.75 | 11.8-51.3  |
|                     |                       | 452 | Male      | 0.0401 | 1.716 | 0.75 | 11.6-54.3  |
|                     |                       | 967 | Mixed     | 0.0456 | 1.683 | 0.75 | 11.7-52.3  |
| Pereda & Villamor 1991 | Cantabrica           | 103 | Mixed     | 0.0128 | 2.169 | 0.98 | 11-65     |
| Stergiou et al. 1992 | Aegean Sea            | 3351 | Mixed    | 0.0166 | 2.03  | 0.93 | 10.4-58.7  |
| Kaya et al. 2001     | Aegean Sea            | 131 | Female    | 0.3288 | 1.270 | 0.79 | 11.5-45.6  |
|                     |                       | 144 | Male      | 0.2154 | 1.384 | 0.81 | 19.8-47.1  |
| Lamprakis et al. 2003 | North Aegean Sea     | 1021 | Mixed    | 0.0863 | 1.543 | 0.80 | 10.3-53.2  |
| Özaydın & Taşkavak 2006 | İzmir Bay          | 254 | Mixed     | 0.0203 | 1.97  | 0.98 | 16.2-50.9  |
| Özaydın et al. 2007 | İzmir Bay            | 881 | Mixed     | 0.0741 | 1.669 | 0.95 | 16.2-50.9  |
| Leblebici 2007      | İzmir Bay            | 340 | Female    | 0.0189 | 2.063 | 0.91 | 17.4-39.6  |
|                     |                       | 1450 | Male     | 0.0405 | 1.823 | 0.94 | 16.3-54.0  |
| Türker Çakır et al. 2007 | Edremit Bay        | 356 | Mixed     | 0.1379 | 1.442 | 0.88 | 12.3-43.7  |
| İşmen et al. 2007   | Saros Bay            | 136 | Mixed     | 0.03461 | 1.853 | 0.92 | 19.1-49.6  |
| Ilkyaz et al. 2008  | Aegean Sea           | 635 | Mixed     | 0.0716 | 1.65  | 0.97 | 16.4-51.6  |
| Bok et al. 2011     | Northern Sea of Marmara | 17  | Mixed    | 0.0093 | 1.510 | 0.84 | 20.8-46.7  |
| Torres et al. 2012  | Gulf of Cadiz        | 447 | Mixed     | 0.0270 | 2.090 | 0.95 | 6.8-98.2   |
| Bilge et al. 2014   | Aegean Sea           | 988 | Mixed     | 0.0126 | 1.442 | 0.88 | 7.5-51     |
| This study          | Sea of Marmara       | 105 | Mixed     | 0.126  | 1.358 | 0.74 | 8.5-51.5   |

Table 4. Parameters of von Bertalanffy growth equation (K, L∞, t₀, φ) obtained by different researchers.

| Researcher(s)       | Region                | N  | Sex       | L∞   | K     | t₀   | φ    |
|---------------------|-----------------------|----|-----------|------|-------|------|------|
| Stergiou et al. 1992 | South Evvoikos Gulf  | 42.5 | 0.379 | -0.1 | 2.84  |
| Stergiou et al. 1992 | North Evvoikos and Pagassitikos Gulfs | 67.6 | 0.214 | 0    | 2.99  |
| Kaya et al. 2001     | İzmir Bay            | Female | 78.5 | 0.17  | 0.1  | 3.02 |
|                     |                       | Male  | 83.2  | 0.16  | 0.09 | 3.04 |
| Leblebici 2007      | İzmir Bay            | Female | 48.78 | 0.354 | -0.39 |
|                     |                       | Male  | 56.82 | 0.393 | -0.45 |
| This study          | Sea of Marmara       | 80   | Mixed   | 61.95 | 0.19  | -0.50 | 2.86 |
Since otolith biometry (shape, size, etc.) varies according to to size of the fish species, the relationship between otolith biometry and fish length can be useful for species identification and prey length from the otoliths found in stomach content (Campana & Thorrold 2001). Besides, it can be used by archaeologists to reveal the mystery from excavation (Hajkova et al. 2003). Otolith biometry fish length relationship has been carried out for many species (Appelbaum & Hechte 1978, Hare & Cowen 1995, Hoşsucu et al. 1999, Bostancı 2009, Park et al. 2018). This study reveals the first results for otolith biometry-total length relationship approach of C. macrophthalmalma. The morphological difference was not found between the left and right otoliths (paired t-test, p=0.63). Therefore the researchers studying on C. macrophthalmalma can use both otoliths in their calculations.

Because of its minor commercial interest, C. macrophthalmalma is listed as Least Concern in the IUCN Red List of Threatened Species (IUCN 2015). According to IUCN, the species has been assessed lastly in 2013 and its population trend is identified as unknown. In addition, the stocks of mature individuals are stated to show a decline trend. Cepola macrophthalmalma is occasionally fished for utilizing fresh, fish soup, fish oil or fishmeal (Whitehead et al. 1986) especially around Spain, Portugal and along the West African coasts. Although it has no commercial value, it is known to have a high discard rate in trawling fishery in the Aegean and the Mediterranean Sea and the Sea of Marmara in Turkey. Knowledge of specific conservation measures for C. macrophthalmalma is unknown, and there exists not enough scientific work to take protective measures in the Sea of Marmara. More detailed further studies should be advised especially on the biology and population dynamics.

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