

**CONDITION AND LENGTH-WEIGHT RELATIONSHIP OF THE HORSE MACKEREL
(*TRACHURUS TRACHURUS* L.) AND THE MEDITERRANEAN HORSE MACKEREL
(*TRACHURUS MEDITERRANEUS* L.) FROM THE EASTERN ADRIATIC SEA**

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Abstract - The length-weight relationship and variation of condition factor in relation to the total length (TL) of *Trachurus trachurus* (Linnaeus, 1758) and *Trachurus mediterraneus* (Steindachner, 1868) were studied. Samples were collected in the eastern Adriatic Sea using bottom-trawl during 2008 and 2009. The *b* values for males, females and total sample showed that the growth of *T. trachurus* was isometric, i.e. equal in length and weight. The growth of the males and females of *T. mediterraneus* was positively allometric while the total sample (males, female and immature) showed isometric growth. The condition factor was calculated indicating the smallest values in immature specimens. The highest values of condition factor for males and females of both species were observed in the range of TL from 16 to 19 cm and 31 to 33 cm, respectively.

Key words: Adriatic Sea, *Trachurus trachurus*, *Trachurus mediterraneus*, length-weight, condition

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INTRODUCTION

The condition of fish and their related length-weight relationship are widely used parameters which enhance the understanding of their general state, growth, survival, maturity and reproduction (Richter et al., 2000). These parameters are also broadly used in the estimation of weight from the length, conversion of growth in length equations to growth in weight equations in stock assessment models, estimation of biomass from the length, indication of sex and differences between regions, and for comparison of the individuals of the same species (Anderson and Gutreuter, 1983; Gonçalves et al., 1997).

Horse mackerel (*Trachurus trachurus* Linnaeus, 1758) and Mediterranean horse mackerel (*Trachurus mediterraneus* Steindachner, 1868) are very common in the Adriatic Sea, especially off-shore near the continental shelf above muddy and sandy bottoms

(Jardas, 1996). In the Adriatic Sea, both species are of commercial value and very abundant, whereas many other economically important species are considered as being over-fished (Jardas et al., 2008). In the Adriatic Sea, bottom trawlers actively exploit these species. There are no reliable statistics on *T. trachurus* and *T. mediterraneus* landings in the eastern Adriatic, but rough estimates of the annual catch for each species are around 400 tons (FAO, 2009). Despite their abundance, little is known about the biology and ecology of *T. trachurus* and *T. mediterraneus* in the Adriatic waters. For instance, only a few studies have provided some biological information of the horse mackerel in the Adriatic Sea (Alegria-Hernandez, 1984, 1994; Šantić et al., 2002). Alegria-Hernandez (1984, 1994) analyzed the reproductive aspects and documented length-weight relationships (LWR) for a limited area in the central Adriatic. Šantić et al. (2002) noted the age, growth and mortality. In the Adriatic Sea, the biology of the Mediterranean horse mackerel was de-

scribed by Viette et al. (1997) and Šantić et al. (2003). Viette et al. (1997) presented data on the reproductive biology of the Mediterranean horse mackerel while Šantić et al. (2003) analyzed the feeding habits of this species. However, the condition factors of both species in relation to ontogenetic development have not yet been analyzed.

The aim of this study was to determine the length-weight relationship and variation of condition factor in relation to the total length (TL) of *T. trachurus* and *T. mediterraneus*.

MATERIALS AND METHODS

Samples of *T. trachurus* and *T. mediterraneus* were collected from five localities in the eastern Adriatic Sea along the continental shelf, mostly at depths from 90 to 120 m (Fig. 1). The fish were sampled during 2008 and 2009 with commercial bottom-trawls (stretched cod-end mesh size of 22-24 mm). The total length (TL) of all specimens was measured to the nearest 0.1 cm, and the body weight to the nearest 0.1 g. The fish were grouped into 1.0 cm size classes. The sex was assigned macroscopically. The relationship between weight and total length, $W = aL^b$, was converted into its logarithmic expression: $\log W = \log a + b \log L$. Parameter b is the exponent of the arithmetic form of LWRs and the slope of the regression line in the logarithmic form (Froese, 2006). When $b = 3$, TL and W are growing at the same rate (isometry); when $b > 3$, W is increasing faster than TL (positive allometry); when $b < 3$, W is increasing slower than TL (negative allometry) (Froese, 2006). Statistical methods used for data analysis included the usual calculations of means and standard deviations. The significant difference of b values from 3, which represent isometric growth, was tested with the \hat{t} -test (Pauly, 1983). To test for possible significant differences between the sexes, we used analysis of covariance (ANCOVA). The t-test was used to compare the b values between this study and some previously reported in the Adriatic and Mediterranean Sea.

Changes in condition were measured by indices of weight-length data. Condition factor (K) was es-

timated according to the Fulton equation: $K = (W/L^3) \times 100$.

All results obtained in these analyses of *T. trachurus* and *T. mediterraneus* are carried out for male, female and total samples (both sex and immature specimens).

RESULTS

Horse mackerel (T. trachurus)

From the total of 1384 specimens of *T. trachurus* collected during the study period, 565 were males, 604 were females and 215 were immature specimens. The total length of all samples (males, females and immature) ranged from 9.1 to 37.8 cm and the weight from 7.0 to 430.3 g. Total lengths of males ranged from 15.3 to 37.8 cm, and weight from 21.8 to 422.1 g. Total lengths of females ranged from 15.1 to 37.7 cm, and weight from 21.0 to 430.3 g. The length-weight relationship for males, females and total population sampled were determined as $W = 0.0090 TL^{2.9841}$, $W = 0.0081 TL^{3.0380}$, $W = 0.0081 TL^{3.0012}$, respectively. The growth of males, females and total population sampled did not significantly differ from 3.

Variations of the condition factor (K) for males, females and total population of horse mackerel in relation to the total length (TL) are shown in Figs. 2a and 2b. The condition factor of the total sample ranged from 0.064 to 0.089. The condition factor of males ranged from 0.077 to 0.090 while that of females ranged from 0.078 to 0.091.

Mediterranean horse mackerel (T. mediterraneus)

From the total of 1411 specimens of *T. mediterraneus* collected during the study period, 571 were males, 633 were females and 207 were immature specimens.

The total length of all samples (males, females and immature) ranged from 9.2 to 37.9 cm and weight from 7.9 to 466.9 g. Total lengths of males ranged from 15.5 to 37.2 cm, and weight from 21.9

Fig. 1.

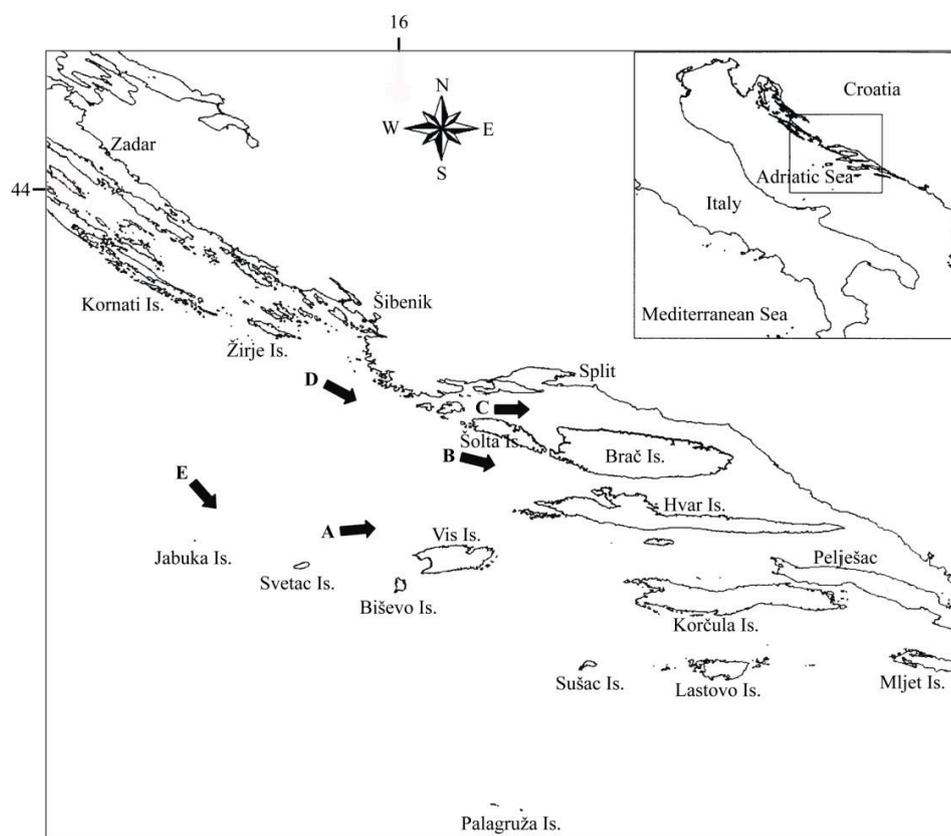


Fig. 1. – Study area and sampling localities of *T. trachurus* and *T. mediterraneus* in the eastern Adriatic: A - near islands Vis and Svetac, B - south off Maslenica, C - Split Channel, D - Blitvenica fishing area, E - Islands of Jabuka.

to 430.2 g. Total lengths of females ranged from 15.0 to 37.9 cm, and weight from 22.7 to 466.9 g. The length-weight relationship for males, females and total population sampled were determined as $W = 0.0090 TL^{3.1397}$, $W = 0.0081 TL^{3.1568}$, $W = 0.0081 TL^{2.9992}$, respectively. The growth of males and females showed significant differences from 3. On the other hand, values of b for the total sample did not significantly differ from 3.

Variations of the condition factor (K) for males, females and the total population of the Mediterranean horse mackerel in relation to the total length (TL)

are shown in Figs. 3a and 3b. The condition factor of the total sample ranged from 0.060 to 0.090. The condition factor of males ranged from 0.075 to 0.091 while that of females ranged from 0.074 to 0.092.

DISCUSSION

The b values for males, females and the total sample showed that growth of *T. trachurus* was isometric, i.e. equal in the length and weight. The isometric growth of the horse mackerel was also recorded in the central Adriatic (Alegria-Hernandez, 1984) and Mediterranean Sea (Karlou-Riga and Sinis, 1997) (Table 1). On

Fig. 2 a

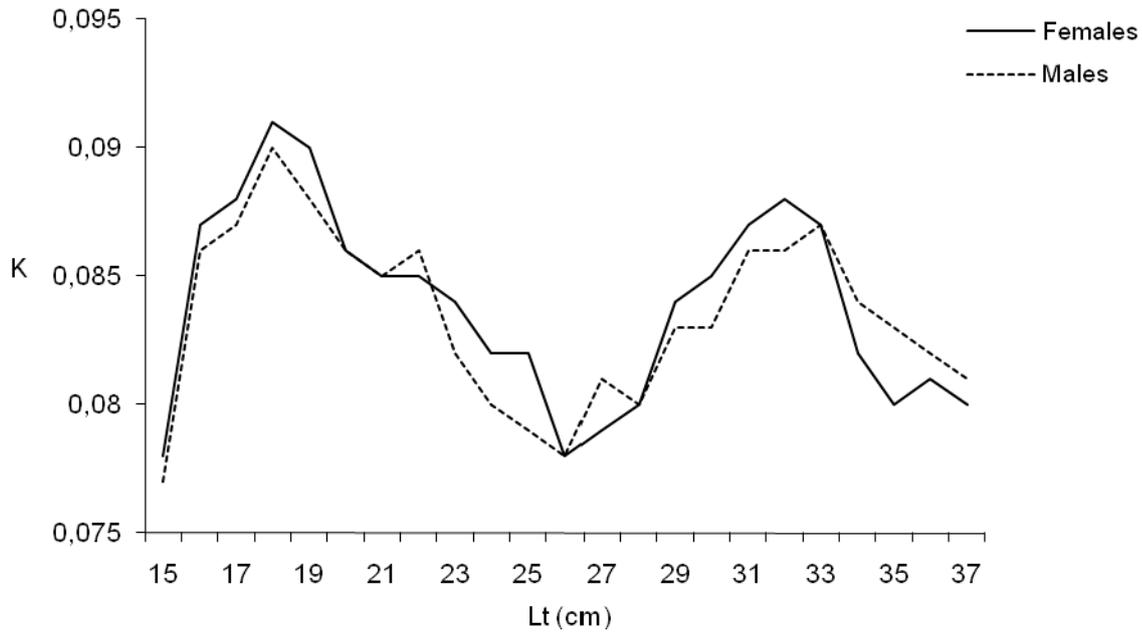


Fig. 2 b

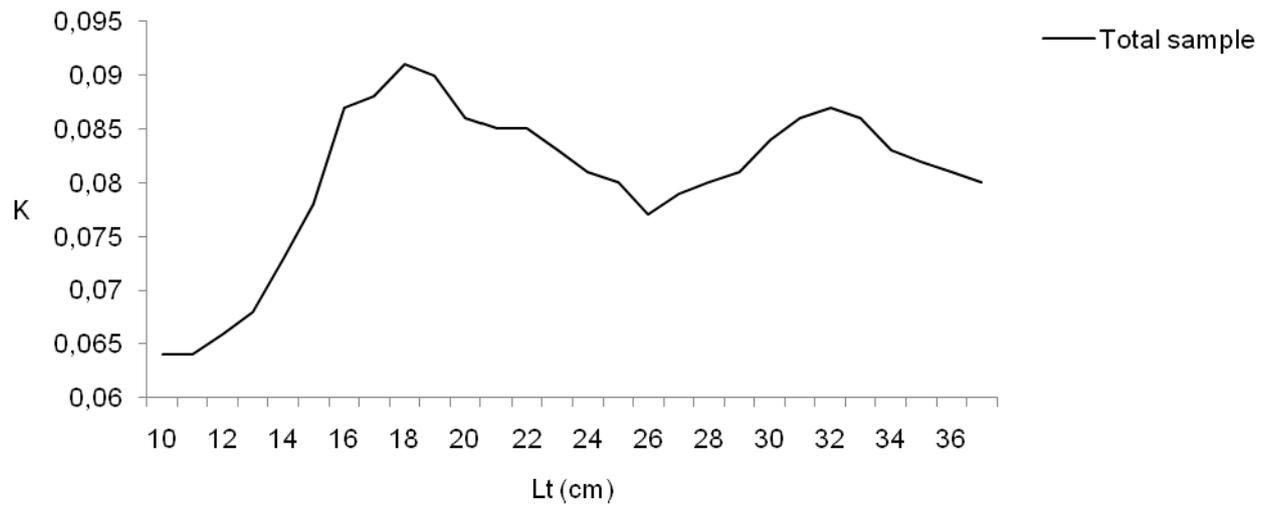


Fig. 2. – *Trachurus trachurus*. Variation of condition factor for a) males and females, b) total sample population (immature, males and females).

Fig. 3a

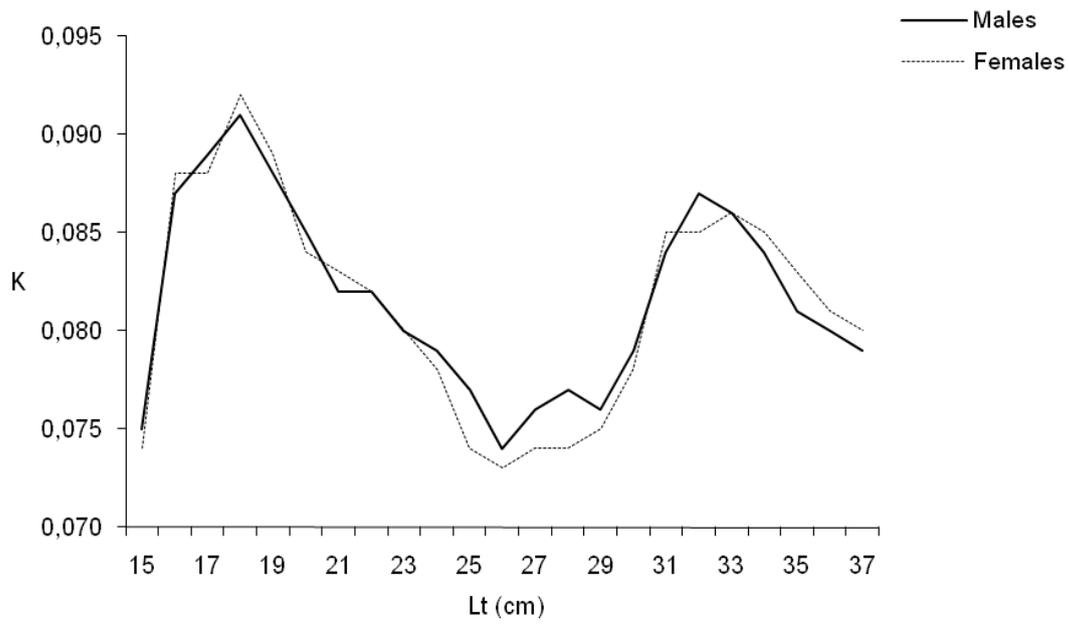


Fig. 3 b

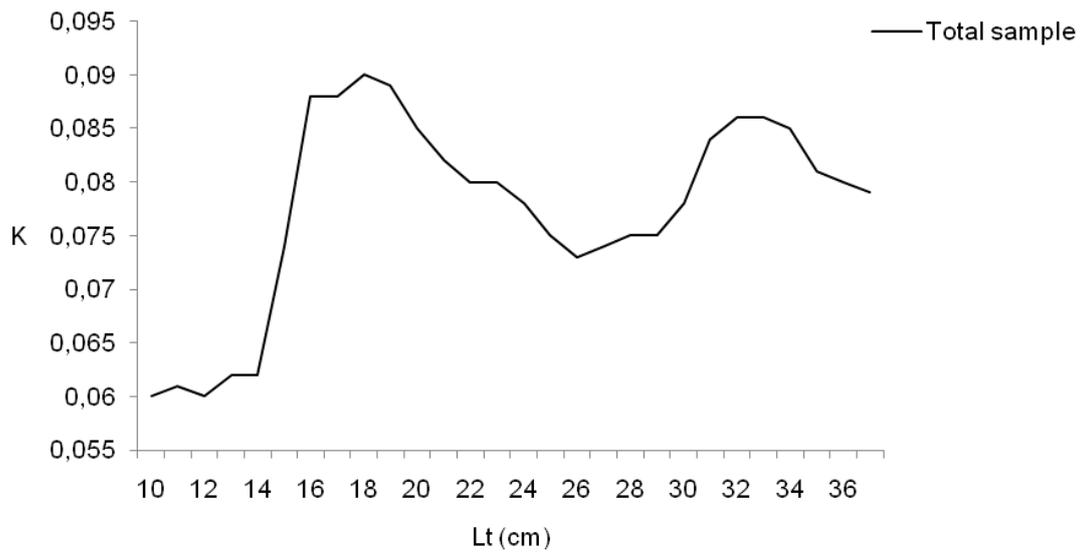


Fig. 3. – *Trachurus mediterraneus*. Variation of condition factor for a) males and females, b) total sample population (immature, males and females).

other hand, in the northeast Atlantic the values of b decreases more or less steadily from approximately 20° N to 41° N, where negative allometric growth appears (Farina-Perez, 1983; Arruda, 1984). From 41° N to higher latitudes an opposite trend appears, indicating positive allometric growth (Kerstan, 1985; Coull et al., 1989) (Table 1). The reason for this might be the availability of food (Margalef, 1974). Along most of the eastern Atlantic coast upwelling is a typical phenomenon during the spring-summer season (Santos et al., 2001). The intensity of upwelling is also related to the production of zooplankton, which is the main food for horse mackerel (Olaso, et al., 1999; Cabral and Murta, 2002). However, the northern European waters are characterized by the presence of extensive shelves with areas of high productivity, which support rich benthic communities (Ware, 2001). These conditions could be related to the increased values of b observed in northern areas compared to the respective values of b at 41° N. In the present study, the allometric parameters of the b values showed no differences between males and females. Similarly, Lucio and Martin (1989) and Karlou-Riga and Sinis (1997) reported no differences in the LWRs between the

sexes of horse mackerel in northeastern Atlantic (Bay of Biscay) and Mediterranean Sea (Greek waters).

The b values for males and females showed that the growth of *T. mediterraneus* was slightly positively allometric, i.e. slightly faster in weight than in length. On the other hand, the growth of the total sample of the Mediterranean horse mackerel (males, females and immature specimens together) was isometric, i.e. equal in the length and weight.

In the available literature, results of LWRs parameters have been presented for a total sample including both sexes and immature specimens together. A comparison of b values between this study and those of previous reports (Table 2) indicate that the LWRs for the Mediterranean horse mackerel in Greek waters and surrounding the Balearic Islands differed significantly from our results. This regional variation in the b exponents could be attributed to differences in sampling, sample size or length ranges. In addition, growth increment, differences in age and stage of maturity, food, and environmental conditions, such as temperature, salinity and seasonality,

Table 1. Previously reported length-weight relationships for *Trachurus trachurus* from the Adriatic, Mediterranean Sea and NE Atlantic. Number of specimens (N), length range (TL or FL), a and b values. Values of * b significantly different from 3.

Authors	Areas	N	Length range (cm)	a	b
Farina-Perez (1983)	NW Spain	1238	TL 7.4-51.0	0.0129	2.854*
Alegria-Hernandez (1984)	Adriatic Sea	1726	TL 14.0-35.0	0.0002	2.918
Arruda (1984)	Portugese coast	1519	TL 17.2-25.5	0.0199	2.885*
Kerstan (1985)	Ireland and UK	1281	TL 5.5-45.5	0.0043	3.125*
Coull et al. (1989)	North Sea	283	TL 16.0-41.0	0.0034	3.294*
Karlou-Riga and Sims (1997)	Greek waters	1139	TL 6.5-33.9	0.0061	3.070
Our study	Adriatic Sea	1384	TL 8.9-38.4	0.0084	3.001

Table 2. Previously reported length-weight relationships for *Trachurus mediterraneus* from the Adriatic and Mediterranean Sea. Number of specimens (N), length range (TL or FL), a and b values. Values of * b significantly different from result in our study.

Authors	Areas	N	Length range (cm)	a	b
Petrakis and Stergiou (1995)	Greek waters	81	FL 13.2-26.1	0.0319	2.804*
Mere Ila et al. (1997)	Balearic islands	232	TL 3.9-24.4	0.0138	2.760*
Moutopolous and Stergiou (2002)	Greek waters	191	TL 17.3-34.1	0.0144	2.824*
Koutrakis and Tsikliras (2003)	Greek waters	21	TL 11.7-25.7	0.0122	2.870*
Our study	Adriatic Sea	1411	TL 9.2-39.0	0.0030	2.999

can also affect the value of b (Shepherd and Grimes, 1983; Weatherley and Gill, 1987).

Fulton's condition factor showed various oscillations throughout ontogenetic development (Fig. 2 and Fig. 3). Certain trends can be observed when comparing the values of condition factor of both species. The smallest values of condition factor were recorded in immature specimens (lengths between 10 and 14 cm) (Figs. 2b and 3b). The highest values of condition factor in males and females of both species were recorded in the lengths between 16 and 19 cm and 31 and 33 cm, respectively (Fig. 2a and 3a). The range of TL from 16 to 19 cm coincides with the start of sexual maturation and gonad development in both species. For these fish it is size that corresponds to the transition from the first to second year of life (Šantić, 1999). After this period in life, the condition factor decreases. The decrease of condition is probably related to the process of gonad enlargement in males and females. Possibly, *T. trachurus* and *T. mediterraneus*, while transitioning from first to second year, invests the available energy into the length-weight relationship, and less into gonad maturation. Also, Alegria-Hernandez (1994) reported that changes in the condition of the fish are related to the development and maturation of the gonads when, due to the significant energy expenditure for these processes, the condition of the fish declines. Šantić (1999) noted a spawning peak of both species during the third and fourth year of age (lengths between 24 to 29 cm, respectively), which afterwards decreases. Consequently, across the length range of 24 to 29 cm, the condition factor exhibited low values. Reaching the length of 31 to 33 cm (corresponding to the age of six to seven-year-old specimens), the condition values increase. Probably throughout this age period the ability to reproduce slowly diminishes, which possibly increases the condition of the fish. Naidenova (1977) has observed that during intensive gonad development, the protein content in the organs of these fish is changed. An increase in the protein content of the gonads and decrease in the muscles and blood probably confirms the fact that these changes are directly related to the reproduction process (Naidenova, 1977).

In conclusion, in the eastern Adriatic *T. trachurus* grow isometrically, although regional differences can be seen in the allometric parameter b of the LWRs in relation to latitude and/or food availability in the areas. The total sample of *T. mediterraneus* grows isometrically, while males and females showed slightly positive allometric growth. The lowest condition factors were recorded in immature specimens. The highest values of condition in males and females of both species were calculated in the range of 16 to 19 cm and 31 to 33 cm of TL, respectively. The presented data are a step ahead to improve knowledge of the biology of both species in the eastern Adriatic Sea.

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