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PRELIMINARY STUDY ON AGE, GROWTH AND REPRODUCTION OF *MUSTELUS MUSTELUS* (ELASMOBRANCHII: CARCHARHINIFORMES: TRIAKIDAE) INHABITING THE GULF OF ISKENDERUN, NORTH-EASTERN MEDITERRANEAN SEA

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Background. Shark populations within the eastern Mediterranean are declining due to overfishing. Unfortunately, our knowledge on the biology of sharks and specifically dogfishes within eastern Mediterranean is extremely limited due to the lack of landings. *Mustelus mustelus* (Linnaeus, 1758) is one of such deficiently known cartilaginous fishes and the relevant information on its age and growth in the eastern Mediterranean is missing. The understanding of growth and reproductive behaviour is important for management and conservation of this species. The presently reported study was intended to determine age, growth, and some reproductive parameters of *Mustelus mustelus* collected in the Gulf of Iskenderun, the north-eastern Mediterranean Sea.

Materials and methods. In this study, a total of 155 *Mustelus mustelus* were caught in the north-eastern Mediterranean Sea between March 2012 and October 2015. Fish age was determined based on band counts of sectioned vertebrae. The periodicity of band pair formation was examined using the marginal increment analysis. Growth parameters for all specimens were then determined by fitting the observed and the length-at-age data using the von Bertalanffy Growth Equation. The size and age at which 50% of both sexes reached maturity was estimated by a logistic model for maximum likelihood process and the gonadosomatic index was determined.

Results. The total length and weight of the specimens examined ranged from 44.3 to 162.6 cm and from 241.3 to 12 060 g, respectively. The presently reported study provides new maximum lengths (162.6 cm) for *M. mustelus* from the north-eastern Mediterranean. The fish studied represented age groups from 0 through 25. The observed sex ratio was 1 ÷ 1.04 (females ÷ males). Von Bertalanffy growth parameters were estimated to be $L_\infty = 195.13$ cm, $W_\infty = 20\,060$ g, $K = 0.06$, and $t_0 = -4.27$ for all specimens. Length–weight relation was found to be $W = 0.0027L^{3.0054}$ ($R^2 = 0.98$) and 95% confidence intervals of $b = 2.936$–3.075, t-test $P < 0.05$. All studied specimens of *M. mustelus* represented isometric growth ($b = 3$). Condition factor ranged from 0.148 to 2.87 for females and from 0.103 to 1.024 for males. The length at 50% maturity and the age at 50% maturity were 109 cm and 8 in females and 92 cm and 7 in males, respectively. It was observed that mean GSI values were low in September and July, reaching a maximum in January to February.

Conclusion. The results of this study could give useful insight for management plans and conservation of *M. mustelus* in the Mediterranean coast of Turkey.

Keywords: smoothhound, *Mustelus mustelus*, length–weight relations, gonadosomatic index, condition factor

INTRODUCTION

Smooth-hound sharks belong to the genus *Mustelus* (family Triakidae), which includes 34 valid species occurring in all major oceans. Five of those species can be found in the Mediterranean. *Mustelus mustelus* (Linnaeus, 1758) is a demersal species inhabiting sandy or muddy bottom down to the depths of 150 m (Golani et al. 2006). This species is caught in small numbers by bottom trawl and they have minor commercial value in Turkey (Başusta and Erdem 2000). The most important prey-groups for the species in the north-eastern Mediterranean are crustaceans and fishes (Özcan and Başusta 2016).

Sharks and specifically dogfishes have become an important commodity as a fishery resource in today's world, where alternative seafood supplies have gained importance. In spite of this, there is almost no detailed biological information about this species. It is known that dogfishes have low growth rate, reach sexual maturity at later age, and their fecundity is rather low (Cailliet et al. 1993). *Mustelus mustelus* is a widespread species,

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although not abundant. The species may be threatened with extinction in the future (Serena et al. 2009).

Length–weight relations (LWRs) are of high importance to compare life histories of fishes between different areas (Hossain et al. 2013). The results will be useful for sustainable management and protection of the limited stocks in the north-eastern Mediterranean Sea.

The aim of this study was to determine, for the first time, age, growth, length–weight relations, and reproductive biology of *M. mustelus* in the north-eastern Mediterranean Sea.

MATERIALS AND METHODS

The samples were obtained monthly by gill nets and long-lines between March 2012 and October 2015 in the north-eastern Mediterranean Sea including the Gulf of Iskenderun, Turkey (Fig. 1). Following transportation of the samples to the laboratory, the identification of species was made according to Golani et al. (2006). For each fish total length (TL) and weight were determined to the nearest 0.1 cm or 0.1 g, respectively. Presence or absence of claspers aided sex identification.

A total of 12 vertebral centra were dissected from above the abdominal cavity of 155 *Mustelus mustelus*, stored frozen (for methodology see Türkmen et al. 2005). Vertebrae were then separated from each other and immersed in warm distilled water (Martin and Cailliet 1988, Cailliet and Goldman 2004, Cailliet et al. 2006, Duman and Başusta 2013). Large vertebrae, exceeding 5 mm in diameter were divided using a gem saw (Ray Tech) with two diamond blades separated by a 0.6 mm spacer (Başusta and Sulikowski 2012). Smaller vertebrae were sanded with a Dremel tool to replicate a sagittal cut (Sulikowski et al. 2005, Başusta et al. 2008). Reading of the vertebral sections was done using a light-reflecting microscope. One growth band was defined as an opaque and translucent band pair that traversed the intermedialia and clearly extended into the corpus calcareum (Fig. 2).

The index of the mean percentage error* (IMPE) was calculated to assess the precision of the age determinations between 2 independent readers. The equation is expressed as follows:

$$\mathrm{IMPE} = \frac{1}{n}\sum_{j=1}^{N}\left(\frac{1}{N}\sum_{i=1}^{R}\frac{\left|X_{ij}-X_{j}\right|}{X_{j}}\right)\times 100\%$$

where n is the number of fish aged, N = number of times each fish was aged, X_{ij} is the ith age determination of the jth fish, X_j is the mean age calculated for the jth fish (Beamish and Fournier 1981). Age determination bias between readers was assessed using an age-bias plot (Campana 2001, Cailliet and Goldman 2004).

The periodicity of band pair formation was examined using the marginal increment ratio (MIR) (Sulikowski et al. 2003). The MIR was calculated as the ratio of the margin between the last and penultimate opaque bands as measured with an optical micrometre. The marginal increment ratio (MIR) was calculated by the following equation of Natanson et al. (1995)

$$\mathrm{MIR} = (\mathrm{VR} - \mathrm{VR}_n) \times (\mathrm{VR}_n - \mathrm{VR}_{n-1})^{-1}$$

where VR is the vertebral radius, and VR_n and VR_{n-1} are the last and penultimate opaque bands, respectively. A sub-sample of 48 vertebrae was selected comprising both juvenile and adult specimens collected nearly every month except August. Kruskal–Wallis one-way analysis of variance on ranks was used to test for differences in marginal increment by month (Cailliet et al. 1990, Sulikowski et al. 2003).

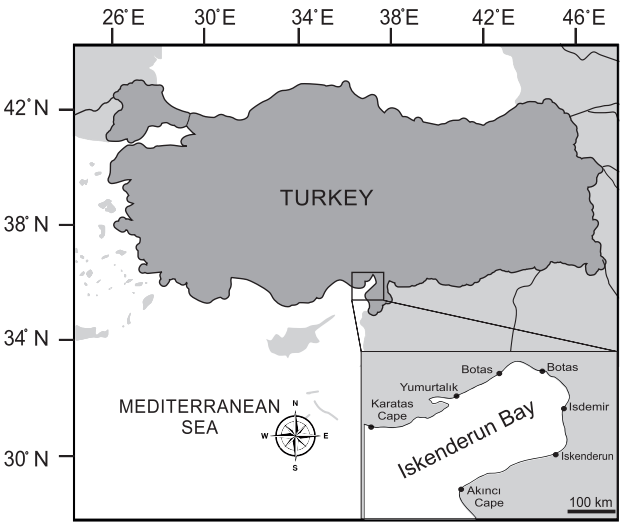

Fig. 1. The sampling area of *Mustelus mustelus* in the Gulf of Iskenderun, north-eastern Mediterranean Sea

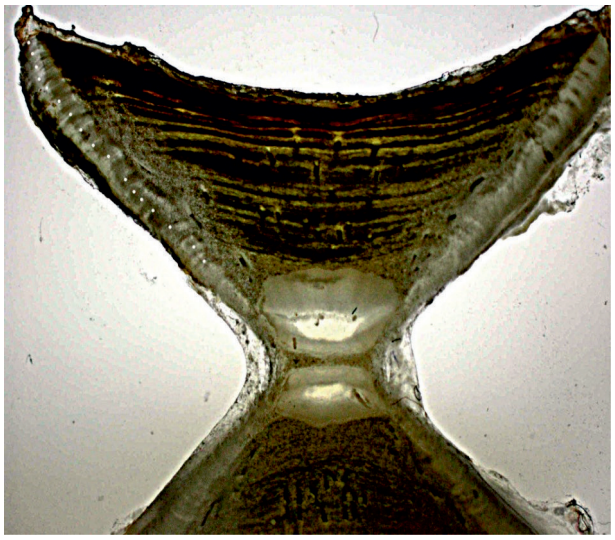

Fig. 2. Longitudinal cross-section of vertebral centrum of *Mustelus mustelus* (150.2 cm TL, estimated age 17 years) from the Gulf of Iskenderun, north-eastern Mediterranean Sea

* The original authors Beamish and Fournier (1981) and many subsequent ones referred to this index imprecisely as the "index of the average percentage error" (IAPE).

Length-based von Bertalanffy growth function (VBGF) was determined with the formula (von Bertalanffy 1938)

$$L_t = L_\infty[1 - e^{-K(t-t0)}]$$

where L_t is the expected total length at age t years and L_∞ is the asymptotic mean maximum total length, K is the growth coefficient, and t_0 is the theoretical age at zero length.

The growth in weight was also described by the weight-based von Bertalanffy growth function

$$W_t = W_\infty[1 - e^{-K(t-t0)}]^b$$

where W_t is total weight at time t, W_∞ is the maximum theoretical weight of fish, and b is power constant of length weight relations.

The relation between length and weight was calculated using the expression

$$W = aL^b$$

where W is the total weight (TW) [g], L is the total length (TL) [cm], a is the intercept of the regression, and b the slope or regression coefficient. The b values of both sexes for *Mustelus mustelus* were tested by using the Kolmogorov–Smirnov two-sample test, and the b value variation from 3 was tested with the one sample t-test ($P < 0.001$). The degree of association between the variables was computed by the determination coefficient R^2 (King 1995).

Condition factor K was determined by the formula

$$K = (W \times \mathrm{TL}^{-b}) \times 100$$

where W is the total weight, TL is the total length, and b is the coefficient of allometric relation (Bagenal and Tesch 1978).

The size and age at which 50% of both sexes reached maturity (TL50% and A50%, respectively) were estimated by a logistic model for maximum likelihood process (Ghorbel et al. 1996, Conrath and Musick 2002). This method utilizes binomial maturity stage (immature = 0, mature = 1), so all specimens that were not capable of breeding (juveniles and maturing specimens) were grouped as immature.

The gonadosomatic index [%] was determined using the formula

$$\mathrm{GSI} = 100 W_g \cdot W_t^{-1}$$

where W_g is the gonad weight [g], and W_t is the total weight of fish [g] (Bagenal 1978).

RESULTS

A total of 155 individuals of *Mustelus mustelus* (76 females, 79 males) were collected during the study. The female ÷ male ratio was found to be 1 ÷ 1.04. Females ranged from 44.3 to 162.6 cm in total length (TL) and 241.3 to 12 060 g in total weight (W). Males ranged from 47.1 to 1490 cm in TL and 315.6 to 8776 g in W. The length differences between females and males were not statistically significant (Student's t-test, $P > 0.05$). The total length-frequency distribution by sex is given in Fig. 3. The strong linear relation between centrum diameter and TL indicates that the vertebrae provided a continuous record of body growth ($R^2 = 0.95$) and therefore is a suitable structure for age interpretation in both male and female *M. mustelus* (Fig. 4).

The age of *M. mustelus* specimens was determined by vertebral band counts. The age ranged from 0 to 25 years. IMPE, which is the index of mean percentage error determined by two independent age readers, was found to be 3.03% for *M. mustelus*. This means that the confidence interval for the reliability of estimations was between 5% and 15%, indicating that our ageing method represents a precise approach to the age determination of *M. mustelus* (Campana 2001, Girgin and Başusta 2016).

Marginal increment widths were significantly different between all months (Kruskal–Wallis, $P < 0.001$), with increment growth beginning in January and peaking in July (Fig. 5). This peak was followed by a large decline in marginal increment growth, reaching minimum values in October. As such, these data suggest that a single opaque band is formed annually on the vertebral centra between

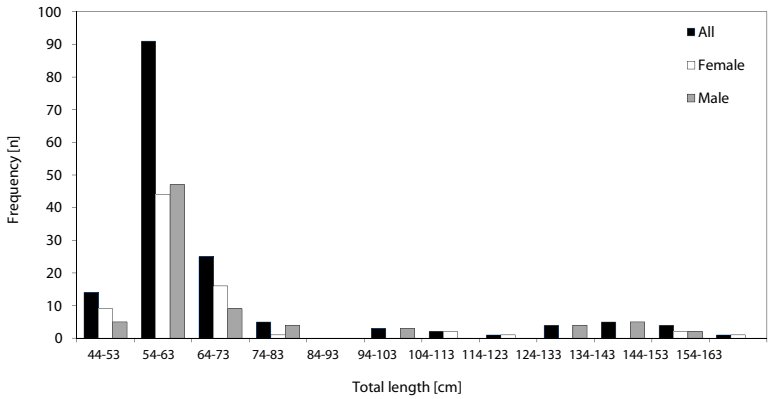

Fig. 3. Total length frequency analysis of *Mustelus mustelus* from the Gulf of Iskenderun, north-eastern Mediterranean Sea

July and October. Age bias plot between readers for all age estimated is given in Fig. 6. Both readers estimated same age in 122 of 140 samples. The agreement between readers on all age assessment was 87%. The agreement between readers was 89% within 1 year and 95% within 2 years. The difference between readers in the accuracy of age assessment was found insignificant when repeated annuli counts were compared (paired *t*-test, $P > 0.05$).

In total, 75 individuals represented this age group (38 females and 37 males) and age 2 was the dominant age group among all (Table 1). Age, total length, and weight distribution of *M. mustelus* are given in Table 1. Age-frequency distribution by sex is given in Fig. 7. The maximum length at age was determined as 162.6 cm at 25 years of age and 150.2 cm at 17 years of age (Fig. 2).

In this study, the estimated von Bertalanffy Growth Equation (VBGE) was $L_t = 195.13\,[1 - e^{-0.06(t+4.27)}]$ for both sexes combined by considering the length of fish based on the population of *Mustelus mustelus* in the north-eastern Mediterranean (Fig. 8). The maximum absolute growth of fish in 1-year age group was found to be 8.79 cm; relative growth was calculated as 19.94%. On the other hand, the minimum absolute growth in fish within the 25 years of age was found as 2.08 cm; relative growth was calculated as 1.30%.

The length and weight measurements, sample sizes (*n*), regression parameters *a* and *b* of the LWR, 95% confidence intervals of *b*, and coefficients of determination (R^2) of the *M. mustelus* are given in Table 2. The calculated *b* value of the LWR indicated isometric growth ($b = 3$) and the

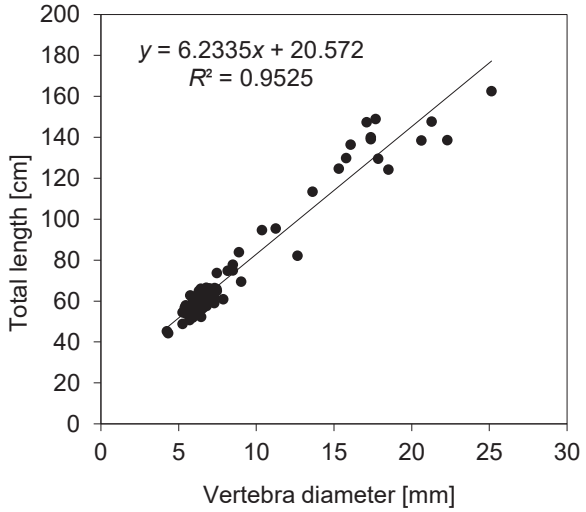

Fig. 4. The relation between the vertebral diameter and the total length of *Mustelus mustelus* from the Gulf of Iskenderun, north-eastern Mediterranean Sea

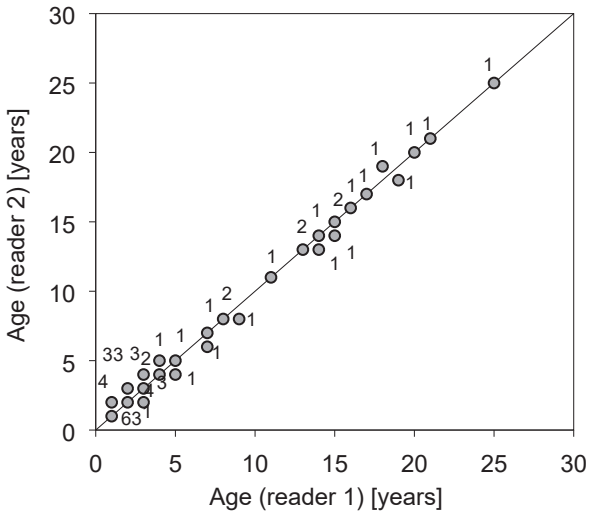

Fig. 6. Age bias plot between readers for all age estimates for *Mustelus mustelus* from the Gulf of Iskenderun, north-eastern Mediterranean Sea; the numbers show repeated annuli counts

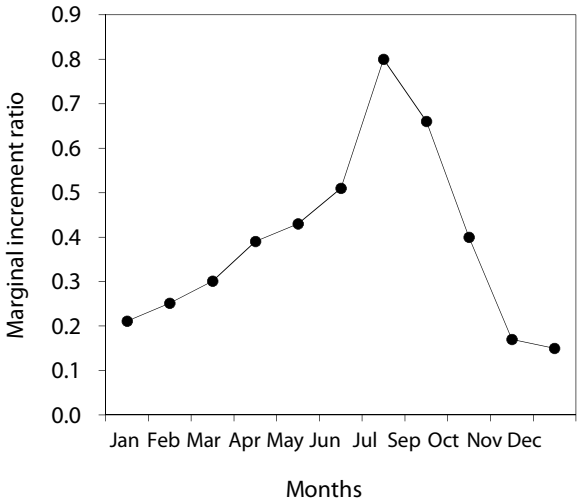

Fig. 5. Monthly variation values of the marginal increment ratio of *Mustelus mustelus* from the Gulf of Iskenderun, north-eastern Mediterranean Sea

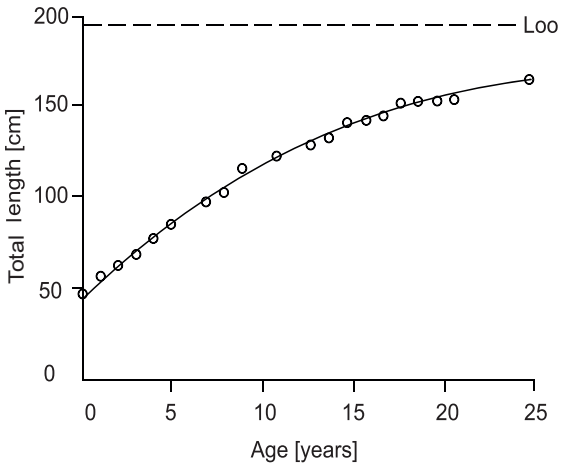

Fig. 7. Relation between the age and the total length of *Mustelus mustelus* from the Gulf of Iskenderun, north-eastern Mediterranean Sea

Table 1

Length and weight of individual age groups of *Mustelus mustelus* from the Gulf of Iskenderun, north-eastern Mediterranean

Age group	*n*	Total length [cm]		Total weight [g]	
		Mean	Range	Mean	Range
0	4	46.05	44.3–47.6	306.61	241.3–422.0
1	43	55.25	48.8–58.2	477.62	278.0–602.0
2	75	61.44	57.3–65.9	663.11	324.0–860.0
3	6	67.08	66.1–69.5	851.33	600.0–1006.0
4	5	75.02	73.7–77.8	1130.6	960.0–1295.0
5	2	83.00	82.1–83.9	1501.0	1486.0–1516.0
7	2	95.00	94.6–95.4	2241.0	2126.0–2356.0
8	2	100.5	96.0–105.0	3229.0	2666.0–3792.0
9	1	113.4	—	4516.0	—
11	1	119.6	—	6000.0	—
13	2	124.5	124.3–124.7	5483.5	5204.0–5763.0
14	2	129.7	129.6–129.9	6303.0	5794.0–6812.0
15	3	137.8	136.4–138.6	7025.6	6018.0–8314.0
16	1	139.1	—	6775.0	—
17	1	140.0	—	7245.0	—
18	1	147.4	—	9108.0	—
19	1	147.7	—	9621.0	—
20	1	149.0	—	9776.0	—
21	1	150.2	—	11408	—
25	1	162.6	—	12 060.0	—

n = number of individuals studied.

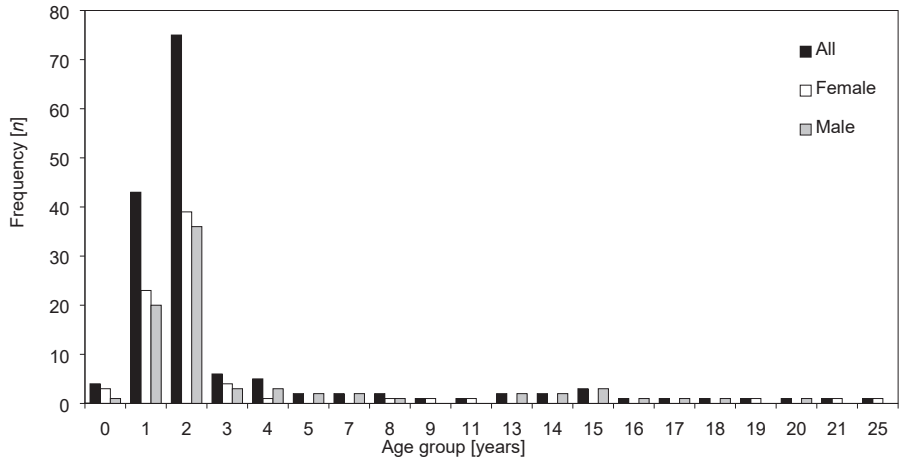

Fig. 8. Age-frequency distribution of *Mustelus mustelus* from the Gulf of Iskenderun, north-eastern Mediterranean Sea

Table 2

Length–weight relations for *Mustelus mustelus* from the Gulf of Iskenderun, north-eastern Mediterranean

Sex	*n*	Total length [cm]	Total weight [g]	*a*	*b*	95% CI of *b*	R^2
Female	76	44.3–162.6	241.3–12060.0	0.0020	3.087	2.95–3.21	0.97
Male	79	47.1–149.0	315.6–8776.0	0.0030	2.977	2.90–3.05	0.98
All	155	44.3–162.6	241.3–12060.0	0.0027	3.005	2.93–3.07	0.98

n = number of individuals studied, *a* = intercept, *b* = slope, CI = confidence limit, R^2 = coefficient of determination.

coefficient of determination (R^2) was 0.98 for *M. mustelus* (Fig. 9). Regression analysis showed that fish length has high significant correlation with weight ($R = 0.99$, $R^2 = 0.98$, $F_{1,138} = 7372.259$, $P < 0.001$) and it is possible to say that 98% increase in weight was due to length increase. Normality test was done by using the Kolmogorov–Smirnov two-sample test. When the *t*-test results were analysed for the significance of regression coefficients (*t*-test = 204.916, $P < 0.01$), it was found that fish-length data could be used with high accuracy to predict fish weight.

Condition factor was calculated for all age groups. The highest condition factor was found at the age of 11 (0.3507), while the lowest was found at the age of 16 (0.2517).

Length at 50% maturity was found as 109 cm in females and 92 cm in males for *M. mustelus* in the north-eastern Mediterranean Sea (Fig. 10). Based on length data, the sexual maturity age was found to be 8 years for females and 7 years for males. As a result, it was determined that *M. mustelus* has reached the ability to reproduce at 7–8 years of age in the north-eastern Mediterranean Sea.

Gonadosomatic index (GSI) values varied from 0.1485 to 2.878 for females, and from 0.1038 to 0.2385 for males. It was observed that mean GSI values were low in September and July, reaching a maximum from January through February (Fig. 11).

In this study, two pregnant females of *M. mustelus* captured in January and in February were examined. In the first pregnant female captured in January, totally 15 embryos (10 females and 5 males) were found. Eight of them were in the right uteri and other seven were in the left uteri. The total lengths of these embryos ranged from 23.8 to 29.3 cm (Fig. 12a). On the other hand, in the second pregnant female caught in February, totally 10 embryos (5 females and 5 males) were observed. Five of them were in the right uteri and other five were in the left uteri. The total lengths of these embryos ranged from 23.2 to 35.6 cm (Fig. 12b).

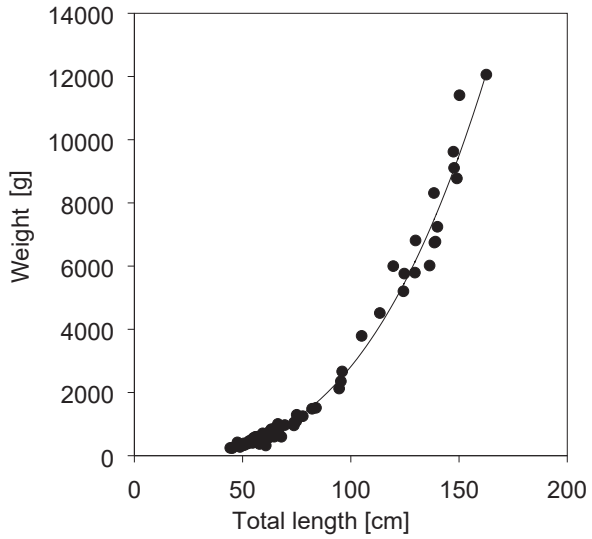

Fig. 9. Length–weight relations of *Mustelus mustelus* (based on all individuals) from the Gulf of Iskenderun, north-eastern Mediterranean Sea

DISCUSSION

In the presently reported study, the lengths and weights of *Mustelus mustelus* ranged from 47.1 to 149.0 cm and from 315.6 to 8776.0 g for males and from 44.3 to 162.6 cm and from 241.3 to 12 060 g for females, respectively. The maximum lengths of the same species were reported as 165 cm for female off South Africa (Smale and Compagno 1997); 164 cm in Mossel Bay, South Africa (Goosen and Smale 1997); 165 cm in the Adriatic Sea, Mediterranean (Maddalena et al. 2001); 148.3 cm in the Adriatic (Pallaoro et al. 2005); 123 cm in the Gulf of Gabès (Saïdi et al. 2008); 122 cm in the Gulf of Gabès again (Saïdi et al. 2009). The maximum lengths reported around the Turkish coasts are given Table 3. In this study, the maximum lengths of females and males were found to be 162.6 to 149.0 cm, respectively, in the north-eastern Mediterranean. These values are the highest reported for the Turkish coasts.

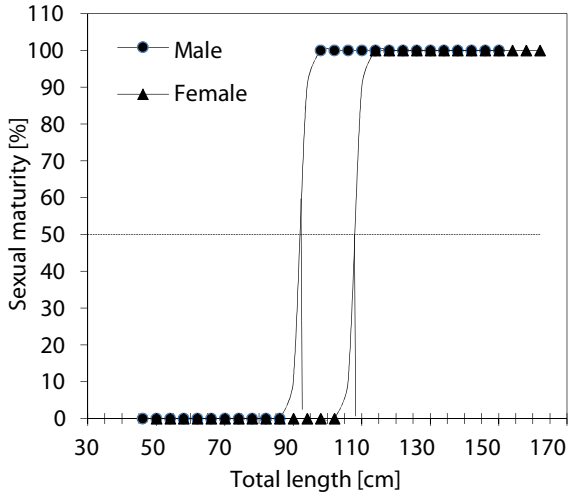

Fig. 10. Sexual maturity length of *Mustelus mustelus* from the Gulf of Iskenderun, north-eastern Mediterranean Sea

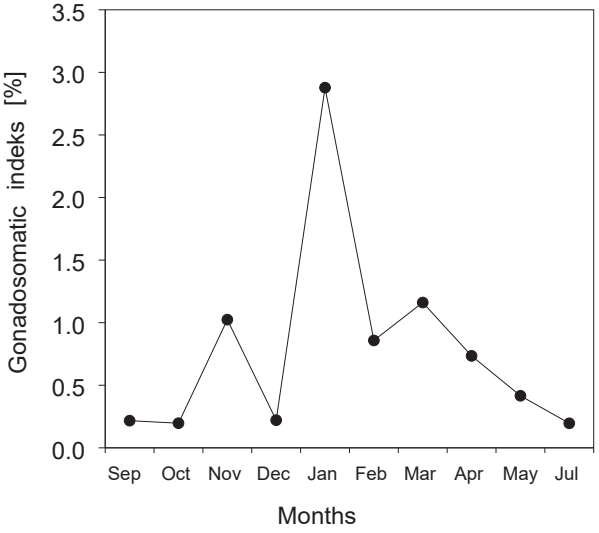

Fig. 11. Monthly fluctuations of gonadosomatic index of *Mustelus mustelus* from the Gulf of Iskenderun, north-eastern Mediterranean Sea

The vertebral band age readings showed that the female age ranged from 0 to 25; 51.51% of them were in the age group 2; while males were in the range of 0 to 20 years of age; 43.24% of them were in the age group 2. Goosen and Smale (1997) found that the age range of their females was between 0 and 24 years of age and males were between 1 and 17 years of age. Since there has been no other age study concerning this species, a comparison was made with another species of this family. For instance, a maximum age of 16 years was reported for *Mustelus antarcticus* Günther, 1870 (see Moulton et al. 1992); 13 for *Mustelus henlei* (Gill, 1863) (see Yudin and Calliet 1990); 12 for *Mustelus lenticulatus* Phillipps, 1932 (see Francis and Francis 1992); 9 for *Mustelus californicus* Gill, 1864 (see Yudin and Cailliet 1990), 9 for *Mustelus manazo* Bleeker, 1855 (see Tanaka and Mizue 1979); 16 for *Mustelus canis* (Mitchill, 1815) (see Conrath et al. 2002); 13 for *Mustelus asterias* Cloquet, 1819 (see Farrell et al. 2010); 16 for *Mustelus walkeri* White et Last, 2008 (see Rigby et al. 2016); and 11 years for *Mustelus schmitti* Springer, 1939 (see Molina et al. 2017).

The overall length and weight growth parameters, estimated based on the von Bertalanffy equation, assumed the following values: L_∞=195.13 cm, W_∞=20 060 g, K=0.06, t_0=−4.27 years. Since there were not enough samples in the study, the above-mentioned calculations were not done separately for both sexes (females and males). All these parameters calculated for different species of the same family are summarized in Table 4.

Length–weight relations may show temporal or spatial variations due to their size range, reproductive activities, and stage or environmental factors such as water temperature, food quality and availability, diseases, and competition (Wootton 1990).

Table 3

Comparison of total length–weight relations of *Mustelus mustelus* in various regions

Region	*n*	L_{max}	*a*	*b*	R^2	Reference
Eastern Adriatic	16	75.0	0.0010	2.758	0.94	Dulčić and Kraljević 1996
Northern Aegean Sea	48	97.5	0.0008	3.32	0.97	Filiz and Mater 2002
Northern Aegean Sea	35	97.5	0.0011	3.25	0.94	Filiz and Bilge 2004
Gulf of Izmir, Aegean Sea	17	95.5	0.0044	2.91	0.98	Özaydın et al. 2007
North Atlantic	46	132.0	0.0017	3.174	0.98	Pereira et al. 2012
Aegean Sea	148	125.1	0.0030	3.05	0.97	İlkyaz et al. 2008
Gulf of Izmir, Aegean Sea	139	141.1	0.1060	2.27	0.98	Hepkafadar unpublished
Gulf of Saros, Aegean Sea	70	152.2	0.0034	2.97	0.98	Ismen et al. 2009
Gulf of Antalya, Mediterranean	4	87.4	0.0974	2.77	0.99	Güven et al. 2012
North-eastern Atlantic	37	113.5	0.0330	3.02	0.99	Wilhelms 2013
Sığacık Bay, Aegean Sea	41	113.3	0.0010	3.27	0.971	Eronat and Özaydın 2014
Southern Aegean Sea	74	101.7	0.0053	2.84	0.98	Bilge et al. 2014
North-eastern Mediterranean	76	162.6 ♀	0.0020	3.08	0.97	This study
	79	146.0 ♂	0.0030	2.97	0.98	
	155	162.6	0.0027	3.00	0.98	

Hepkafadar unpublished = see footnote on page 34.

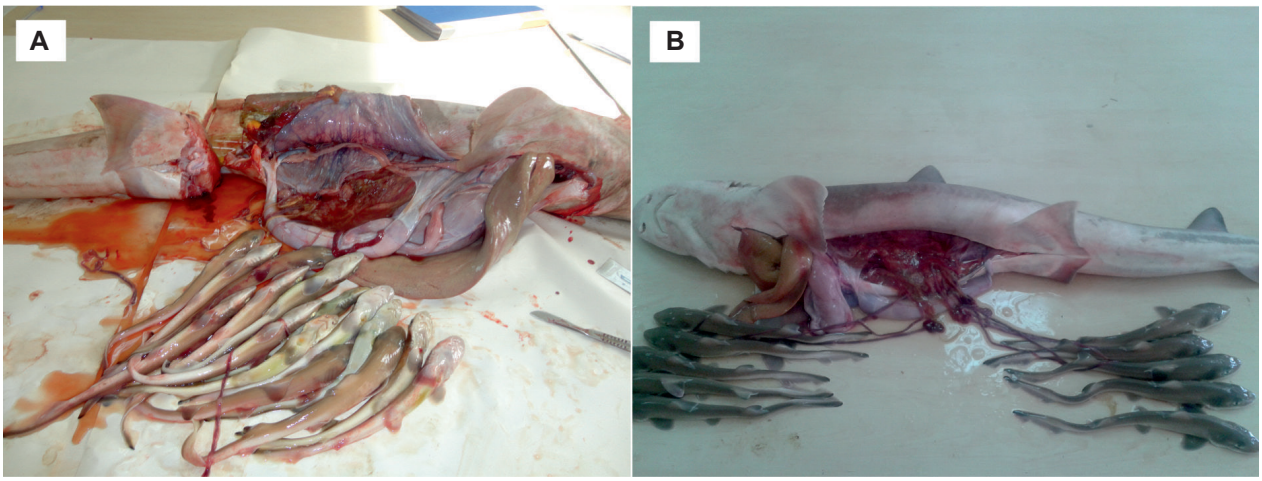

Fig. 12. Examples of dissected pregnant females of *Mustelus mustelus* caught in January 2014 (**A**) and February 2014 (**B**) from the Gulf of Iskenderun, north-eastern Mediterranean Sea

Table 4

Comparison of asymptotic length ($L\infty$), and growth coefficient (k) of the von Bertalanffy growth function for 9 species of the genus *Mustelus* from this study and other studies

Species	Region	L_∞	k	Reference
M. schmitti	Rio Grande do Sul, Brazil	102.8	0.08	Batista unpublished
M. manazo	Southern Japan	200.0	0.10	Cailliet et al. 1990
M. henlei	California	97.70	0.24	Yudin and Cailliet 1990
M. antarcticus	Southern Australia	200.0	0.10	Moulton et al. 1992
M. lenticulatus	New Zealand	147.2	0.12	Francis and Maolagáin 2000
M. canis	North-western Atlantic	120.0	0.29	Conrath et al. 2002
M. asterias	North-eastern Atlantic	104.0	0.22	Farrell et al. 2010
M. walkeri	Australia	200.0	0.07	Rigby et al. 2016
M. schmitti	Anegada Bay, Argentina	89.40	0.06	Molina et al. 2017
M. mustelus	Mossel Bay, South Africa	200.0	0.07	Goosen and Smale 1997
M. mustelus	North-eastern Mediterranean	195.1	0.06	This study

Batista unpublished = Batista V.S. 1988. Determinação de idade e análise do crescimento do cação *Mustelus schmitti* Springer 1939 (Elasmobranchii, Triakidae) da plataforma continental do Rio Grande do Sul. [Age determination and growth analysis of *Mustelus schmitti* Springer 1939 (Elasmobranchii, Triakidae) from the continental shelf of Rio Grande do Sul.] Universidade Federal do Rio Grande, Brazil. [In Portuguese.]

The lowest b value was reported to be 2.77 by Hepkafadar (unpublished*) in the Gulf of Izmir, while the highest was given by Filiz and Mater (2002) in the northern Aegean Sea. The comparison of the total length–weight relations of *Mustelus mustelus* (Table 3) shows the differences between the patterns of growth between regions. The differences can be attributed to the combination of several factors such as the number and size of examined individuals.

Lengths at 50% maturity (L_{50}) were found as 109 cm at 8 years of age for females and 92 cm at 7 years of age for males. The length at sexual maturity was reported as 125–130 cm for females and 95–130 cm for males in South Africa (Smale and Compagno 1997); 59–93 cm for females and 52–57 cm for males in Mauritania (Khallahi unpublished**); 90–104 cm for females and 82–95 cm for males in Senegal (Capapé et al. 2006); 107.5–123.0 cm for females and 88.0–112 cm for males in the Gulf of Gabès (Saïdi et al. 2008). Saïdi et al. (2008) reported that although both gonads were active in males, only right ovaries were active in females. When GSI and condition factor are evaluated together, the reproduction period of *M. mustelus* is estimated to take place from January to February in the north-eastern Mediterranean Sea.

These reproduction data should be taken into account for reproduction and nursery areas of *M. mustelus* in the north-eastern Mediterranean and decision makers dealing with fisheries management should consider establishment of marine protected areas with regional fisheries organizations. The results of this study could give useful insight for management plan and conservation of *M. mustelus* in the Mediterranean coast of Turkey.

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REFERENCES

Bagenal T.B. 1978. Aspects of fish fecundity. Pp 75–101. *In*: Gerking S.D. (ed.) Ecology of freshwater fish production. Blackwell Scientific, Oxford, UK.

Bagenal T.B., Tesch F.W. 1978. Age and growth. Pp. 101–136. *In*: Bagenal T.B. (ed.) Methods for assessment of fish production in fresh waters. 3rd edn. Blackwell Scientific Publications, Oxford, UK.

Başusta N., Demirhan S.A., Çiçek E., Başusta A., Kuleli T. 2008. Age and growth of the common guitarfish, *Rhinobatos rhinobatos*, in Iskenderun Bay (north-eastern Mediterranean, Turkey). Journal of Marine Biological Association of the United Kingdom **88** (4): 837–842. DOI: 10.1017/S0025315408001124

Başusta N., Erdem U. 2000. İskenderun körfezi balıkları üzerine bir araştırma. [A study on the pelagic and demersal fishes of İskenderun Bay.] Turkish Journal of Zoology **24** (Suppl.): 1–19. [In Turkish.]

Başusta N., Sulikowski J.A. 2012. The oldest estimated age for roughtail stingray [*Dasyatis centroura* (Mitchill, 1815)] from the Mediterranean Sea. Journal of Applied Ichthyology **28** (4): 641–642. DOI: 10.1111/j.1439-0426.2012.01940.x

Beamish R.J., Fournier D.A. 1981. A method for comparing the precision of a set of age determinations. Canadian Journal of Fisheries and Aquatic Sciences **38** (8): 982–983. DOI: 10.1139/f81-132

Bilge G., Yapici S., Filiz H., Cerim H. 2014. Weight–length relations for 103 fish species from the southern Aegean Sea, Turkey. Acta Ichthyologica et Piscatoria **44** (3): 263–269. DOI: 10.3750/AIP2014.44.3.11

Cailliet G.M., Goldman K.J. 2004. Age determination and validation in chondrichthyan fishes. Pp. 399–447.

* Hepkafadar O. 2008. İzmir Körfezi'nde adi köpekbalığı (*Mustelus mustelus* L., 1758) avcılığı ve bazı biyolojik özellikleri üzerine araştırmalar. [Research on fishery and some biological aspects of smooth-hound shark (*Mustelus mustelus* L., 1758) in Izmir Bay.] MSc Thesis. Department of Fisheries and Processing Technology, Ege University, Turkey. [In Turkish.]

** Khallahi B. 2004. Ecologie et biologie de lemissole lisse *M. mustelus* (Linné, 1758) sur les côtes de Mauritanie. PhD Thesis. Universite´ de Bretagne Occidentale, France.

In: Carrier J., Musick J.A., Heithaus M.R. (eds.) Biology of sharks and their relatives. CRC Press, Boca Raton, FL, USA.

Cailliet G.M., Holts D.B., Bedford D. 1993. A review of the commercial fisheries for sharks on the west coast of United States. Pp. 13–29. *In*: Pepperell J., West J., Woon P. (eds.) Shark conservation: Proceedings of an International Workshop on the Conservation of Elasmobranchs, 24 February 1991, Taronga Zoo, Sydney. Conservation Research Centre, Sydney, NSW, Australia.

Cailliet G.M., Smith W.D., Mollet H.F., Goldman K.J. 2006. Age and growth studies of chondrichthyan fishes: The need for consistency in terminology, verification, validation, and growth function fitting. Environmental Biology of Fishes **77** (3–4): 211–228. DOI: 10.1007/s10641-006-9105-5

Cailliet G.M., Yudin K.G., Tanaka S., Taniuchi T. 1990. Growth characteristics of two populations of *Mustelus manazo* from Japan based upon cross-readings of vertebral bands. Pp. 167–176. *In*: Pratt H.L.jr., Gruber S.H., Taniuchi T. (eds.) Elasmobranchs as living resources: Advances in the biology, ecology, systematics, and the status of the fisheries. NOAA Technical Report NMFS 90.

Campana S.E. 2001. Accuracy, precision and quality control in age determination, including a review of the use and abuse of age validation methods. Journal of Fish Biology **59** (2): 197–242. DOI: 10.1111/j.1095-8649.2001.tb00127.x

Capapé C., Diatta Y., Diop M., Vergne Y., Guélorget O. 2006. Reproductive biology of the smoothhound, *Mustelus mustelus* (Chondrichthyes: Triakidae) from the coast of Senegal (eastern tropical Atlantic). Cybium **30** (3): 273–282.

Conrath C.L., Gelsleichter J., Musick J.A. 2002. Age and growth of the smooth dogfish (*Mustelus canis*) in the northwest Atlantic Ocean. Fishery Bulletin **100** (4): 674–682.

Conrath C.L., Musick J.A. 2002. Reproductive biology of the smooth dogfish, *Mustelus canis*, in the northwest Atlantic Ocean. Environmental Biology of Fishes **64** (4): 367–377. DOI: 10.1023/A:1016117415855

Dulčić J., Kraljević M. 1996. Weight–length relationships for 40 fish species in the eastern Adriatic (Croation waters). Fisheries Research **28** (3): 243–251. DOI: 10.1016/0165-7836(96)00513-9

Duman O.V., Başusta N. 2013. Age and growth characteristics of marbled electric ray *Torpedo marmorata* (Risso, 1810) inhabiting Iskenderun Bay, north-eastern Mediterranean Sea. Turkish Journal of Fisheries and Aquatic Sciences **13** (3): 551–559.

Eronat E.G.T., Özaydın O. 2014. Length–weight relationship of cartilaginous fish species from central Aegean Sea (Izmir Bay and Sığacık Bay). Ege Journal of Fisheries and Aquatic Sciences **31** (3): 119–125. DOI: 10.12714/egejfas.2014.31.3.01

Farrell E.D., Mariani S., Clarke M.W. 2010. Age and growth estimates for the starry smoothhound (*Mustelus asterias*) in the Northeast Atlantic Ocean. ICES Journal of Marine Science **67** (5): 931–939. DOI: 10.1093/icesjms/fsp295

Filiz H., Bilge G. 2004. Length–weight relationships of 24 fish species from the north Aegean Sea, Turkey. Journal of Applied Ichthyology **20** (5): 431–432. DOI: 10.1111/j.1439-0426.2004.00582.x

Filiz H., Mater S. 2002. A preliminary study on length–weight relationships for seven elasmobranch species from north Aegean Sea, Turkey. Ege Journal of Fisheries and Aquatic Sciences **19** (3–4): 401–409.

Francis M.P., Francis R.I.C.C. 1992. Growth rate estimates for New Zealand rig (*Mustelus lemiculatus*). Australian Journal of Marine and Freshwater Research **43** (5): 1157–1176. DOI: 10.1071/MF9921157

Francis M.P., Maolagáin C. 2000. Age, growth and maturity of a New Zealand endemic shark (*Mustelus lenticulatus*) estimated from vertebral bands. Marine and Freshwater Research **51** (1): 35–42. DOI: 10.1071/MF99012

Ghorbel M., Jarboui O., Bradaï M.N., Bouaïn A. 1996. Détermination de la taille de première maturité sexuelle par une fonction logistique chez *Limanda limanda*, *Pagellus erythrinus* et *Scorpaena porcus*. Bulletin de l'Institut National des Sciences et Technologies de la Mer **3**: 24–27.

Girgin H., Başusta N. 2016. Testing staining techniques to determine age and growth of *Dasyatis pastinaca* (Linnaeus, 1758) captured in Iskenderun Bay, northeastern Mediterranean. Journal of Applied Ichthyology **32** (3): 595–601. DOI: 10.1111/jai.13077

Golani D., Öztürk B., Başusta N. 2006. Fishes of the eastern Mediterranean. Turkish Marine Research Foundation, Istambul, Turkey.

Goosen A.J., Smale M.J. 1997. A preliminary study of age and growth of the smooth-hound shark *Mustelus mustelus* (Triakidae). South African Journal of Marine Science **18** (1): 85–91. DOI: 10.2989/025776197784161072

Güven O., Kebapçioğlu T., Deval M.C. 2012. Length–weight relationships of sharks in Antalya Bay, eastern Mediterranean. Journal of Applied Ichthyology **28** (2): 278–279. DOI: 10.1111/j.1439-0426.2011.01823.x

Hossain M.Y., Rahman M.M., Abdallah E.M., Ohtomi J. 2013. Biometric relationships of the pool barb *Puntius sophore* (Hamilton 1822) (Cyprinidae) from three major rivers of Bangladesh. Sains Malaysiana **42** (11): 1571–1580.

İlkyaz A.T., Metin G., Soykan O., Kinacigil H.T. 2008. Length–weight relationship of 62 fish species from the central Aegean Sea, Turkey. Journal of Applied Ichthyology **24** (6): 699–702. DOI: 10.1111/j.1439-0426.2008.01167.x

Ismen A., Yigin C.C., Altinagaç U., Ayaz A. 2009. Length–weight relationships for ten shark species from Saros Bay (north Aegean Sea). Journal of Applied Ichthyology **25** (Suppl. 1): 109–112. DOI: 10.1111/j.1439-0426.2009.01263.x

King M. 1995. Fisheries biology, assessment and management. Fishing News Books, Blackwell Science, Oxford, UK.

Maddalena A., Piscitelli L., Malandra R. 2001. The largest specimen of smooth-hound, *Mustelus mustelus* (Linnaeus, 1758), recorded from the Mediterranean Sea. Bilješke – Notes **2001** (84): 1–8.

Martin L.K., Cailliet G.M. 1988. Age and growth determination of the bat ray, *Myliobatis californica* Gill, in central California. Copeia **1988** (3): 762–773. DOI: 10.2307/1445399

Molina J.M., Blasina G.E., Lopez Cazorla A.C. 2017. Age and growth of the highly exploited narrownose smooth-hound (*Mustelus schmitti*) (Pisces: Elasmobranchii). Fishery Bulletin **115** (3): 365–379. DOI: 10.7755/FB.115.3.7

Moulton P.L., Walker T., Saddlier S.R. 1992. Age and growth of gummy shark, *Mustelus antarcticus* Gunther, and school shark, *Galeorhinus galeus* (Linnaeus), from southern Australian Waters. Australian Journal of Marine and Freshwater Research **43** (5): 1241–1267. DOI: 10.1071/MF9921241

Natanson L.J., Casey J.G., Kohler N. 1995. Age and growth estimates for the dusky shark, *Carcharhinus obscurus*, in the western North Atlantic Ocean. Fishery Bulletin **93**: 116–126.

Özaydın O., Uçkun D., Akalın S., Leblebici S., Tosunoğlu Z. 2007. Length–weight relationships of fishes captured from Izmir Bay, central Aegean Sea. Journal of Applied Ichthyology **23** (6): 695–696. DOI: 10.1111/j.1439-0426.2007.00853.x

Özcan E.İ., Başusta N. 2016. Kuzeydoğu Akdeniz bölgesinde yaşayan adi köpekbalığı, *Mustelus mustelus* (Linnaeus, 1758)'un mide içeriği. [Digestive system contents of *Mustelus mustelus* (Linnaeus, 1758) inhabiting northeastern Mediterranean.] Fırat Üniversitesi Fen Bilimleri Dergisi – Firat University Journal of Science **28** (1): 7–12. [In Turkish.]

Pallaoro A., Jardas I., Šantić **M.** 2005. Weight–length relationships for 11 chondrichthyan species in the eastern Adriatic Sea. Cybium **29** (1): 93–96.

Pereira J. N., Simas A., Rosa A., Aranha A., Lino S., Constantino E., Monteiro V., Tariche O., Menezes G. 2012. Weight–length relationships for 27 demersal fish species caught off the Cape Verde archipelago (eastern North Atlantic). Journal of Applied Ichthyology **28** (1): 156–159. DOI: 10.1111/j.1439-0426.2011.01915.x

Rigby C.L., White W.T., Smart J.J., Simpfendorfer C.A. 2016. Life histories of two deep-water Australian endemic elasmobranchs: Argus skate *Dipturus polyommata* and eastern spotted gummy shark *Mustelus walkeri*. Journal of Fish Biology **88** (3): 1149–1174. DOI: 10.1111/jfb.12891

Saïdi B., Bradaï M.N., Bouaïn A. 2008. Reproductive biology of the smooth-hound shark Mustelus mustelus (L.) in the Gulf of Gabès (south-central Mediterranean Sea). Journal of Fish Biology **72** (6): 1343–1354. DOI: 10.1111/j.1095-8649.2008.01801.x

Saïdi B., Enajjar S., Bradaï M.N., Bouaïn A. 2009. Diet composition of smooth-hound shark, Mustelus mustelus (Linnaeus, 1758), in the Gulf of Gabès, southern Tunisia. Journal of Applied Ichthyology **25** (Suppl. 1): 113–118. DOI: 10.1111/j.1439-0426.2009.01306.x

Serena F., Mancusi C., Clò S., Ellis J., Valenti S.V. 2009. *Mustelus mustelus*. The IUCN Red List of Threatened Species 2009: e.T39358A10214694. DOI: 10.2305/IUCN.UK.2009-2.RLTS.T39358A10214694.en

Smale M.J., Compagno L.J.V. 1997. Life history and diet of two southern African smoothhound sharks, *Mustelus mustelus* (Linneaus, 1758) and *Mustelus palumbes* Smith, 1957 (Pisces: Triakidae). South African Journal of Marine Science **18** (1): 229–248. DOI: 10.2989/025776197784160992

Sulikowski J.A., Kneebone J., Elzey S., Jurek J., Danley P.D., Howell W.H., Tsang P.C.W. 2005. Age and growth estimates of the thorny skate (*Amblyraja radiata*) in the western Gulf of Maine. Fishery Bulletin **103** (1): 161–168.

Sulikowski J.A., Morin M.D., Suk S.H., Howell W.H. 2003. Age and growth estimates of the winter skate (*Leucoraja ocellata*) in the western gulf of Maine. Fishery Bulletin **101** (2): 405–413.

Tanaka S., Mizue K. 1979. Studies on sharks—XV. Age and growth of Japanese dogfish *Mustelus manazo* Bleeker in the East China Sea. Bulletin of the Japanese Society of Scientific Fisheries **45**(1): 43–50. DOI: 10.2331/suisan.45.43

Türkmen M., Başusta N., Demirhan S.A. 2005. Balıklarda yaş tayini. [Age determination in fish.] Pp: 121–148. *In*: Karatas M. (ed.) Balık biyolojisi araştırma yöntemleri. [Research techniques in fish biology.] Nobel Akademik Yayıncılık, Ankara, Turkey. [In Turkish.]

von Bertalanffy L. 1938. A quantitative theory of organic growth (inquiries of growth laws II). Human Biology **10** (2): 181–213.

Wilhelms I. 2013. Atlas of length–weight relationships of 93 fish and crustacean species from the North Sea and the North-East Atlantic. Thünen Working Paper No. 12. Thünen-Institut, Bundesforschungsinstitut für Ländliche Räume, Wald und Fischerei, Braunschweig, Germany. DOI: 10.3220/WP_12_2013

Wootton R.J. 1990. Ecology of teleost fishes. Chapman and Hall, Upper Saddle River, NJ, USA.

Yudin G.K., Cailliet M.G. 1990. Age and growth of the gray smoothhound, *Mustelus californicus*, and the brown smoothhound, *M. henlei*, sharks from central California. Copeia **1990** (1): 191–204. DOI: 10.2307/1445835

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