 DOI: 10.3750/AIEP/02051

AGE, GROWTH, AND REPRODUCTION OF MEDITERRANEAN SCALDFISH, *ARNOGLOSSUS LATERNA* (ACTINOPTERYGII: PLEURONECTIFORMES: BOTHIDAE), IN THE EAST-CENTRAL AEGEAN SEA

Akın Türker İLKYAZ*, Gülnur METİN, Ozan SOYKAN, and Hasan Tuncay KINACIGİL

Faculty of Fisheries, Ege University, Bornova, İzmir, Turkey

İlkyaz A.T., Metin G., Soykan O., Kınacıgil H.T. 2017. Age, growth, and reproduction of Mediterranean scaldfish, *Arnoglossus laterna* (Actinopterygii: Pleuronectiformes: Bothidae), in the east-central Aegean Sea. Acta Ichthyol. Piscat. 47 (1): 53–61.

Background. In Turkey, the Mediterranean scaldfish, *Arnoglossus laterna* (Walbaum, 1792), is a discard fish species and it has a 'least concern' status on the IUCN Red List which indicates a low extinction risk. Although there are some studies investigating biology of this species, the knowledge of the mortality rates, spawning period, first maturity size, and age are not available for the study area. This paper, for the first time, provides some data on unknown population parameters for the east-central Aegean Sea. The aim of the presently reported study was to expand our knowledge on the biology of *A. laterna*.
Materials and methods. Specimens of *A. laterna* were collected at monthly intervals by bottom trawl hauls between July 2004 and June 2007 from İzmir Bay (Turkey). The total length (L, cm), total weight (W, g), gonad weight (W_G, g), and the sex were determined and the sagittal otolith pairs were removed for age reading. The length–weight relations were estimated by linear regression analysis on log-transformed data by equation: $W = aL^b$. The growth was analysed by fitting the VBGF to size-at-age data using standard nonlinear optimization methods. Spawning period was established with monthly variations of the GSI values. Length at first maturity was estimating by the logit function.
Results. A total of 2469 *A. laterna* individuals were sampled and the sex ratio was calculated as 1 ÷ 1.57 (F ÷ M). The length range of the sample was from 4.4 to 19.8 cm and the mean length was calculated as 9.4 ± 0.05 cm. For all samples, the length–weight relation was $W = 0.0074L^{3.04}$ and the growt type was deterined as positive allometic. The age distribution of individuals varied from 1 to 8 years and the growth equation was determined as $L_t = 20.62[1 - e^{-0.245(t+1.071)}]$. The first maturity lengths were estimated as 11.88 cm for females and 11.41 cm for males.
Conclusion. The presently reported study provides the age, growth, and reproduction parameters for *A. laterna* and the first information on the mortality rates, spawning period, first maturity size, and age parameters for the east-central Aegean Sea. These parameters can be useful for managers in the management and conservation of the stock.

Keywords: length distribution, sex ratio, length–weight relation, spawning season, mortality rate, size at first maturity

INTRODUCTION

The Mediterranean scaldfish, *Arnoglossus laterna* (Walbaum, 1792), is a demersal flatfish. Although there are 163 known lefteye flounder species in the world, only seven species are found in the Mediterranean and Black Sea—all of them present in Turkish waters (Froese and Pauly 2016): *Arnoglossus grohmanni* (Bonaparte, 1837); *Arnoglossus imperialis* (Rafinesque, 1810); *Arnoglossus kessleri* Schmidt, 1915; *Arnoglossus laterna*; *Arnoglossus rueppelii* (Cocco, 1844); *Arnoglossus thori* Kyle, 1913; and *Bothus podas* (Delaroche, 1809). *Arnoglossus laterna* lives at depths between 10 and 200 m (Nielsen 1986) but usually prefers the depth range of 10–100 m (Muus and Nielsen 1999). The maximum standard length and age were reported as a 25 cm (Muus and Nielsen 1999) and 8+ years (Gibson and Ezzi 1980). The habitat range for this species was described as eastern Atlantic (from Norway to Angola), Mediterranean and Black Sea (Froese and Pauly 2016). The species lives on mixed or muddy bottoms and feeds on small fish and invertebrates (Nielsen 1986). For Turkey, *A. laterna* is a demersal species discarded from trawls, purse seines, trammel nets, and gill nets. Although some studies have been carried out on this species for the same geographic area, there is no information on mortality rates, first maturity size and age, probably because of its inferior importance (a discard species).

* Dr Akın T. İlkyaz, Ege Üniversitesi, Su Ürünleri Fakültesi, 35100 Bornova, İzmir, Turkey, phone: +90 232-311-3840, fax: +90 232-388-3685, e-mail: (ATİ) *ilkyaza@gmail.com*, (GM) *gulnur.metin@ege.edu.tr*, (OS) *ozansoykan@hotmail.com*, (HTK) *h.tuncay.kinacigil@ege.edu.tr*.

The main objective of this study was to provide information on the length distribution, sex ratio, length–weight relation, age, growth, spawning period, mortality rates, exploitation ratio, length and age at first maturity of *A. laterna* for the east-central Aegean Sea. Furthermore, this study presents the mortality, spawning period, first maturity size and age parameters for the first time for this area.

MATERIALS AND METHODS

Fish collection. Samples of *Arnoglossus laterna* were collected from İzmir Bay (Fig. 1), by the research vessel R/V *Egesüf* (27 m LOA, ~372 kW main engine) at depths of 30–70 m. The sampling period was at monthly intervals from July 2004 through June 2007. The sampling gear was a traditional bottom trawl net and the codend was 8 m long knotless diamond shaped meshes made of polyamide material (PA) with 22 mm stretched mesh size netting (Tosunoğlu et al. 1996).

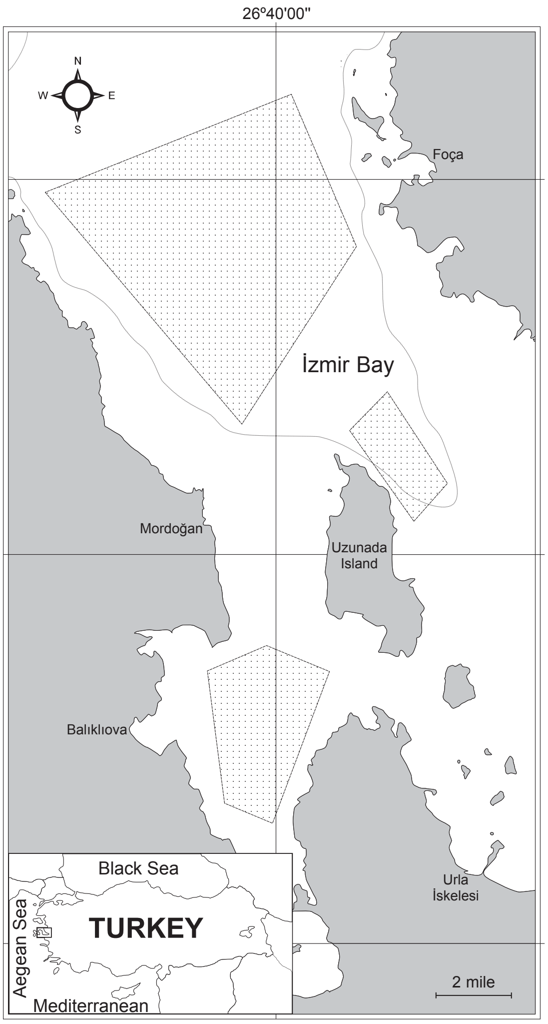

Fig. 1. The study area (dotted areas are sampling stations)

Fish measurements. Fish samples were brought to the laboratory and the total length (L) of each individual was measured in the natural body position and recorded with 1 mm precision. Total weight (W) and gonad weight (W_G) were determined to the nearest 0.01 g, and the sex was recorded. The lengths of the individuals were classified in 0.5 cm group intervals and a length-frequency diagram was drawn using the pooled data. One-way ANOVA was performed to analyse differences in the mean length of both sexes.

The determination of sex and maturity stages was carried out by macroscopic inspection of the gonads. The maturity stages were assessed according to Gunderson's (1993) scale: stage I (immature), stage II (resting), stage III (developing), stage IV (ripe), and stage V (spent). The sex ratio (female ÷ male) of the samples was calculated using only mature individuals, and a chi-square (χ^2) test was applied for determining the significance of the male to female ratio.

Length–weight relations. The parameters intercept (a) and slope (b) of length–weight relations were estimated by linear regression analysis on transformed data by Napierian logarithm

$$W = aL^b$$

where W is total body weight (g) and L is total length (cm) (Ricker 1973). The degree of relation between variables was calculated by the determination coefficient (R^2) and the growth type was identified by Student's t-test. The test was applied to determine the significance of differences between the isometry (b = 3) and the allometry ($b \neq 3$), and also the negative allometric growth ($b < 3$) and the positive allometric growth ($b > 3$).

Age and growth estimation. Sagittal otolith pairs were removed, cleaned, and stored in dry conditions inside microplates. Age determination was performed using a stereoscopic zoom microscope under reflected light against a black background, and the age readings were made by two experienced independent readers. The opaque and transparent rings were counted and an opaque ring together with a transparent zone was considered the annual growth indicator. Some otoliths, which were hard to observe because of calcium accumulation on their surfaces, were prepared for age readings by sectioning, rubbing, and polishing. They were embedded in polyester moulds, cut by an ISOMET™ low speed saw, polished with sandpaper (type 400, 800, and 1200), and finally polished with 3, 1, and 0.25 µ particulate alumina (Metin and Kinacıgil 2001).

Growth was analysed by fitting the von Bertalanffy growth function to size-at-age data using standard nonlinear optimization methods (Sparre and Venema 1998). The function

$$L_t = L_\infty \times \left(1 - e^{-k(t - t_0)}\right)$$

was applied to the data where L_t is the fish total length [cm] at the time t [year], L_∞ is the asymptotic total length [cm], k is the growth coefficient [year^{-1}], and t_0 [year] is the hypothetical time at which the length is equal to zero. The fish growth performance was estimated using Munro's growth performance (phi-prime) index (Pauly and Munro 1984)

$$\varphi' = \log(k) + 2 \times \log(L_\infty)$$

To find the statistical significance of differences between our and other researchers' findings the Student's *t*-test analysis was performed using phi-prime index values (Sparre 1987).

Spawning season estimation. The spawning period was established with monthly variations of the gonadosomatic index (GSI, %) from the equation

$$\mathrm{GSI} = 100W_\mathrm{G} \times (W - W_\mathrm{G})^{-1}$$

where W_G is the gonad weight [g] and W is the total weight [g] of the fish (Ricker 1975). The percentages of developing (III), ripe (IV), and spent (V) gonad stages were calculated to determine additional finding regarding the estimation of the spawning season.

First maturity length estimation. Length at first maturity (L_m) was defined as the length at which 50% of the population investigated was near to spawning (King 2007). The length at 50% maturity was determined with the L50 computer program by the logit function (İlkyaz et al. 1998). The equations:

$$R_\mathrm{m} = n_\mathrm{m} \times (n_\mathrm{m} + n_\mathrm{i})^{-1}$$

$$\mathrm{PR} = \ln(R_\mathrm{m} \times (1 - R_\mathrm{m})^{-1})$$

$$r(L) = e^{a+bL} \times (1 + e^{a+bL})^{-1}$$

$$L_\mathrm{m} = -a \times b^{-1}$$

were applied, where R_m is the maturity rate of each length class [%], n_m is the number of mature individuals, n_i the number of immature individuals, PR is the logarithmic transformation of the maturity rate for each length group, $r(L)$ is the proportion of mature individuals in each length class [%], L is the fish total length [cm], L_m is the mean total length at sexual maturity (50%, cm), a is intercept and b is slope.

Mortality rate estimations. The total mortality rate (Z) [year^{-1}] estimation was calculated by the equation

$$Z = F + M$$

where F is the rate of the fishing mortality [year^{-1}] and M is the rate of the natural mortality [year^{-1}]. The total mortality coefficient was estimated by fitting the survivor ratios (S) for the age with the equations

$$S = n_{t+1} \times n_t^{-1}$$

$$Z = -\ln(S)$$

where n_t is the number of the individuals belonging to the age group t and n_{t+1} is the next age group (Ricker 1975). The equations:

$$\beta = (3 - 3\omega) \times \omega^{-1}$$

$$M = \beta \times k$$

were used to estimate the natural mortality coefficient (Jensen 1996), β is the progression parameters that varied between 1.3 and 2.1, ω is the mean critical length to asymptotic length ratio according to the fish family as calculated by Cubillos (2003). However, it is not calculated for the family Bothidae, and it is suggested as 0.62 for all other fish species. The fishing mortality and exploitation ratio (E) [year^{-1}] were calculated by the equations:

$$F = Z - M$$

$$E = F \times Z^{-1}$$

RESULTS

Sampling and sex ratio. A total of 2469 *A. laterna* individuals were sampled during the study period and it was determined that 25.6% of the samples were female (n = 633), 40.3% male (n = 996) and 34.1% immature (n = 840). The sex ratio was calculated as 1 ÷ 1.57 (female ÷ male) and chi-square analysis showed that there was a statistically significant difference between the number of males and females (χ^2, $P < 0.05$).

The lengths of the sample ranged from a length of 4.4 cm that was sampled in May to a total length of 19.8 cm that was sampled in January. Although females ranged between 5.5 and 19.8 cm (10.05 ± 0.11), males varied from 5.6 to 17.6 cm (9.83 ± 0.06) total length ($\bar{x}$ ± SE). The test results showed that mean length was not significantly different between the sexes (F = 3.6, $P > 0.05$). For all samples, the mean total length and total weight of the individuals was calculated as 9.4 ± 0.05 cm and 8.2 ± 0.15 g, respectively. Furthermore, it was observed that the majority of the individuals were within the 8.5 to 10.0 cm length interval (42.7%) (Fig. 2).

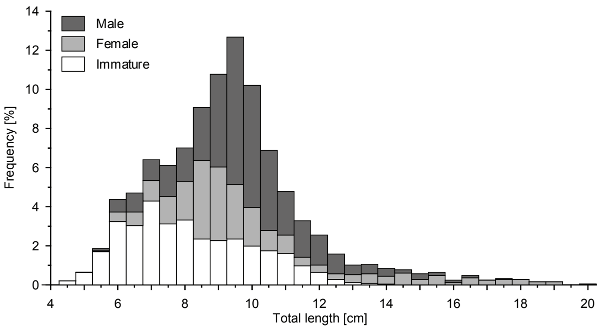

Fig. 2. Total length-frequency distribution of *Arnoglossus laterna* for female, male, and immature samples

Length–weight relation. The length–weight relation was $W = 0.0074L^{3.04}$ (R^2 = 0.969) for all samples (Fig. 3) and the calculated standard error of slope (b) was ±0.03. This result show that the 95% confidence limit of slope (95% CL_b) range was 3.01–3.07 and due to that confidence limit of slope the species' growth type was positive allometry (t-test, $P < 0.05$).

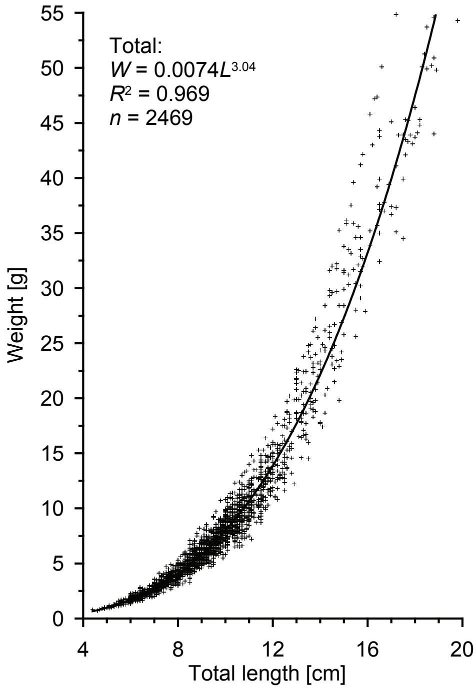

Fig. 3. The length–weight relation of *Arnoglossus laterna*

Age and growth. According to the results of otolith readings, the age distribution of individuals varied between 1 and 8 years. The age group 1 (47%) was dominant, followed by 2 (41%), 3 (8%), 4 (2%), and 5 through 8 (1% for each) age groups. The von Bertalanffy growth function parameters were estimated as the infinite length (L_∞) 20.62 cm; the infinite weight (W_∞) 72.31 g; the theoretical age of the fish prior to hatching from the egg (t_0) –1.071 year; and growth coefficient (k) 0.245 year^{-1} (R^2 = 0.967). As a result, the growth equation was determined as $L_t = 20.62[1 - e^{-0.245(t + 1.071)}]$ and the growth performance index (φ') was calculated as 2.02 (Fig. 4). The t-test result showed that there was no significant difference between the growth parameters of this and other studies' findings ($t = 0.072$, $P > 0.05$)

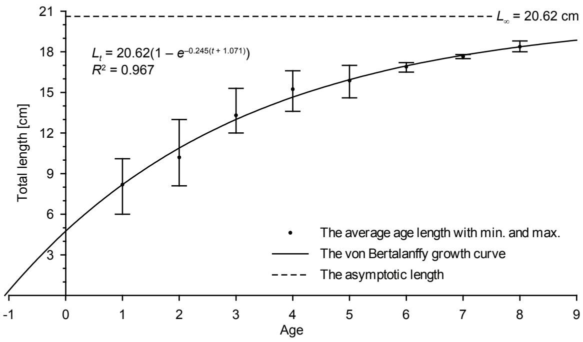

Fig. 4. The von Bertalanffy growth curve for *Arnoglossus laterna*

Spawning season. Monthly mean gonadosomatic index values of females and males are given in Fig. 5. For the female, high gonadosomatic index values were shown in February (2.26%), April (2.11%), and December (1.89%), however the maximum gonadosomatic index value was observed in August (2.97%). Similarly, high gonadosomatic index values were recorded in February (0.28%), September (0.35%), and December (0.33%) for males. The number of individuals with ripe gonad reached a maximum value in July (34.4%) and August (42.8%). Moreover, the majority of those with spent gonad were observed in September (46.0%).

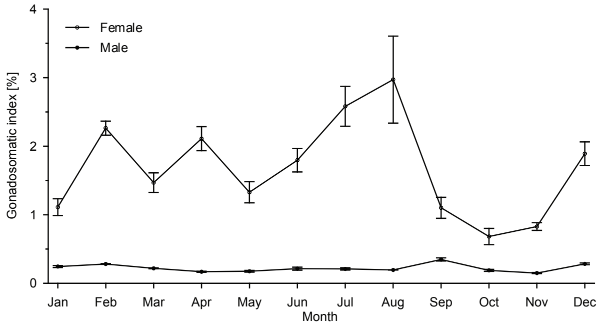

Fig. 5. Monthly gonadosomatic index values with standard error of males and females of *Arnoglossus laterna*

First maturity length and age. It was observed that the smallest female was 5.6 cm and the smallest male was 5.5 cm total length and both of them were one year old. Gonad maturity in 50% of the individuals was found at 11.88 cm total length for females (a = –19.948, b = 1.679, R^2 = 0.807) and 11.41 cm for males (a = –17.257, b = 1.513, R^2 = 0.770) (Fig. 6). The sexual maturity age was found at two years of age in both sexes.

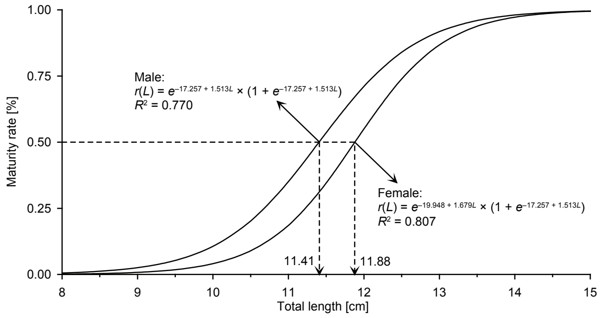

Fig. 6. Length at first maturity estimation of *Arnoglossus laterna* for female and male

Mortality rate. The total mortality ratio (Z) of the stock was calculated as 1.194 year^{-1}, the natural mortality (M) was 0.450 year^{-1}, and the fishing mortality (F) was 0.744 year^{-1}. Finally, the exploitation ratio (E) of the stock was estimated as 0.623 year^{-1}.

DISCUSSION

Although females tended to be slightly longer than males, the analysis of variance showed no significant difference between mean total lengths of males and females. On the other hand, the chi-square analysis showed that there was a significant difference between number of males and females. For the same study area, Uckun Ilhan et al. (2007), Bayhan et al. (2008a), and Uçkun İlhan et al. (2010) reported the sex ratio as 1 ÷ 1.72, 1 ÷ 1.62, and 1 ÷ 1.91, respectively. Similarly, Özütok and Avşar (2002) for Yumurtalık Bight (western Mediterranean, 1 ÷ 1.40), and Tičina and Matić-Skoko (2012) for Adriatic Sea (north central Mediterranean, 1 ÷ 1.65), reported that the sex ratio skewed in favour of males. In addition, all previous studies reported that the rate of males was higher than that of females except in Edremit Bay (northern Aegean Sea) where it was 1 ÷ 0.61 (Çakır et al. 2003). It is well known that the sex ratio is an important parameter for the fish stock and this ratio in the majority of species is close to 1 ÷ 1 (Nikolsky 1963). However, this rate varies considerably from species to species, differs from one population to another of the same species and may vary from year to year in the same population (Nikolsky 1963).

There have been a large number of studies on the length–weight relation of *A. laterna* and the results are given in Table 1. For all samples and the same study area, positive allometric growth type was reported by Özaydın and Taşkavak (2006) similarly as our findings, however, the isometric growth type was reported by Bayhan et al. (2008a, 2008b), and the negative allometric growth type was reported by Özaydın et al. (2007) and Uçkun İlhan et al. (2010). Although, the majority of researchers have reported the growth type as isometric (Cicek et al. 2006, Veiga et al. 2009, Keskin and Gaygusuz 2010, Bok et al. 2011), some of them have reported it as negative allometric (Karakulak et al. 2006, Sangun et al. 2007). None of them, however, reported positive allometric growth for other geographic areas. Merella et al. (1997) presented the highest slope value for Balearic Islands amounting to 3.45. On the other hand, the lowest *b* value for the Marmara Sea was given by Keskin and Gaygusuz (2010) as 2.67. The *b* values are often 3.0 or range between 2.5 and 3.5, and in each fish population may differ according to the species, sex, age, sexual maturity of fish, season, and fish feeding (Ricker 1975). Furthermore, because the data have included early juveniles which in the majority of fish have not yet attained the adult body shape (Safran 1992), or included very old specimens which often have distorted body forms with unusually high proportions of fat (Froese 2006), or included an insufficient sample size which has a very narrow length size, this can influence the growth type determination.

Throughout the procedure of ageing, some of the sagittal otoliths were problematic because of their physical structure that calcium accumulation on their surfaces. Some of the old samples in particular required special processing methods to allow accurate age reading. Because of this, some of the otoliths were prepared for age readings by the cross-section method. Similarly, Gibson and Ezzi (1980) and Tičina and Matić-Skoko (2012) reported this difficulty in age reading from the otolith for *A. laterna*. Consequently, considering the annual ring formations on the otolith, the maximum age was determined as 8 years. For *A. laterna*, Gibson and Ezzi (1980) gave the maximum reported age as 8+ for the west coast of Scotland. Özütok and Avşar (2002) reported the maximum as 8 years for western Mediterranean (Yumurtalık Bight, Turkey), the same as our finding. Deniel (1990; cited after Froese and Pauly 2016) for the north-eastern Atlantic (Douarnenez Bay, Brittany) and Djabali et al. (1993; cited after Froese and Pauly 2016) for the northern central Mediterranean (Adriatic Sea, Italy) reported the maximum age as 7.5 and 4 years, respectively.

The von Bertalanffy growth function parameters show that the predominant portion of the growth occurs in the first year of life, and *A. laterna* attained 39.7% of the asymptotic size (Fig. 4). Similar results were shown in the findings of other previous studies (Deniel 1990, Djabali et al. 1993 [both papers cited after Froese and Pauly 2016], Özütok and Avşar 2002). On the other hand, the infinite length (L_∞) was different from the findings of all previous studies. The results in these studies were smaller than our finding and we calculated the infinite length to be a little longer than our maximum sampled size. Similarly, the growth coefficient (k) was also different from the findings of all previous studies. The growth coefficient was reported as 0.570 by Deniel (1990; cited after Froese and Pauly 2016) and 1.032 by Djabali et al. (1993; cited after Froese and Pauly 2016), and these results are higher than our own and previous studies' findings. The high growth coefficient (k) value is indicator of rapid growth and short life time, however this fish species has relatively long lifespan. For this study, the growth performance index (φ') was calculated as 2.02 while the other studies' maximum and minimum growth performance index was calculated between 1.50 (Yumurtalık Bight) and 2.38 (Douarnenez Bay) (Deniel 1990 [cited after Froese and Pauly 2016], Özütok and Avşar 2002). These two values of the growth performance index indicate a lower growth in the western Mediterranean (Yumurtalık Bight) than in the northeast Atlantic (Douarnenez Bay), whereas the opposite was expected. On the other hand, the statistical test result indicates that there is no significant difference between this study and previous studies' findings, although there are very different findings on von Bertalanffy growth function parameters. This result showed that the differences of growth parameters by coast could probably be attributed to variations in the habitat. Similarly, Weatherley and Gill (1987) indicate that the growth of fish where fish live is directly or indirectly affected by the environmental conditions (supply of available food, temperature, and intensity of competition for food) and by fishing activities (Table 2).

The presently reported study provides the first information on spawning season, first maturity length and mortality rates of *A. laterna* for the east-central Aegean Sea. Based on the gonadosomatic index values, the reproduction of *A. laterna* continues throughout almost the year but the maximum spawning commences in August and continues until October. Furthermore, similar findings were demonstrated in the percentages of ripe and spent gonad numbers. The reproduction period was reported by Gibson and Ezzi (1980) to be from June and August in the northeast Atlantic (west coast of Scotland); by Özütok

Table 1

The length–weight relations of *Arnoglossus laterna* in published references

Reference	*S*	*n*	LR	*a*	*b*	R^2	GT	Study area
Pereda and Villamor 1991 FB	Σ	35	5.0–14.0	0.00236	3.389	0.940	—	Biscay Bay (NE Atlantic)
Djabali et al. 1993 FB	Σ	—	—	0.0045	3.0	—	—	Adriatic Sea (NC Mediterranean)
Merella et al. 1997	Σ	20	8.0–13.0	0.0025	3.45	0.925	—	Balearic Islands (W Mediterranean)
Mater and Bayhan 2000	Σ	643	6.0–15.3	0.00932	2.8975	0.94	—	İzmir Bay (EC Aegean Sea)
Özütok and Avşar 2002	Σ	390	3.9–13.8	0.005	3.1167	0.923	+A	Yumurtalık Bight (W Mediterranean)
	♀	161	—	0.005	3.1034	0.934	—	
	♂	225	—	0.006	3.0624	0.912	—	
Çakır et al. 2003	Σ	319	5.5–15.8	0.0065	3.1822	0.960	+A	Edremit Bay (N Aegean Sea)
Cicek et al. 2006	Σ	594	2.2–11.8	0.0080	3.007	0.972	I	Babadillimani Bight (NE Medit.)
Özaydın and Taşkavak 2006	Σ	721	6.8–21.9	0.0052	3.168	0.96	+A	İzmir Bay (EC Aegean Sea)
Karakulak et al. 2006	Σ	8	7.6–18.3	0.0150	2.747	0.991	–A	Gökçeada Island (N Aegean Sea)
Sangun et al. 2007	Σ	291	4.5–13.4	0.0122	2.835	0.95	–A	N Mediterranean
Uckun Ilhan et al. 2007	Σ	877	4.8–14.9	0.0087	2.949	0.980	—	İzmir Bay (EC Aegean Sea)
	♀	323	6.0–14.9	0.0081	2.986	0.974	—	
	♂	554	4.8–13.5	0.0093	2.925	0.980	—	
Özaydın et al. 2007	Σ	1078	4.5–14.9	0.0097	2.906	0.962	–A	İzmir Bay (EC Aegean Sea)
Bayhan et al. 2008a	Σ	1081	5.6–15.7	0.0073	3.011	0.968	I	İzmir Bay (EC Aegean Sea)
	♀	250	—	0.0035	3.301	0.962	+A	
	♂	406	—	0.0066	3.043	0.969	I	
Bayhan et al. 2008b	Σ	796	5.6–17.1	0.0073	3.009	0.966	I	İzmir Bay (EC Aegean Sea)
İlkyaz et al. 2008	♀	633	5.5–19.8	0.0067	3.09	0.976	+A	İzmir Bay (EC Aegean Sea)
	♂	996	5.6–17.6	0.0079	3.00	0.954	I	
Veiga et al. 2009	Σ	82	3.4–16.4	0.0088	3.04	0.99	I	Algarve (NE Atlantic)
Uçkun İlhan et al. 2010	Σ	1892	3.9–16.0	0.0096	2.9174	0.978	–A	İzmir Bay (EC Aegean Sea)
	♀	513	—	0.0096	2.9207	0.975	–A	
	♂	978	—	0.0111	2.8569	0.978	–A	
Keskin and Gaygusuz 2010	Σ	7	5.2–12.3	0.0207	2.670	0.976	I	Erdek Bay (Marmara Sea)
Bok et al. 2011	Σ	58	6.8–20.0	0.0068	3.016	0.963	I	Northern Marmara Sea
Tičina and Matić-Skoko 2012	Σ	773	—	—	—	—		Adriatic Sea
	♀	279	—	0.0032	3.372	0.985	+A	
	♂	460	—	0.0030	3.365	0.979	+A	
The presently reported study	Σ	2469	4.4–19.8	0.0074	3.04	0.969	+A	İzmir Bay (EC Aegean Sea)

S = sex, Σ = both sexes combined, ♀ = female, ♂ = male, *n* = number of specimens, LR = length range of specimens, *a* and *b* = intercept and slope of the length–weight relation, R^2 = coefficient of determination, GT = growth type, I = isometry, +A = positive allometry, –A = negative allometry, C = central, E = eastern, N = northern, W = western, FB = cited after FishBase (Froese and Pauly 2016).

Table 2

The growth parameters of *Arnoglossus laterna* for this study and different geographic areas

Reference	S	t_m	L_∞	*k*	t_0	φ'	Area
Deniel 1990 FB	♀	7.5	15.80	0.840	0.6900	2.32	Douarnenez Bay (NE Atlantic)
	♂		15.20	1.032	0.7700	2.38	
Djabali et al. 1993 FB	Σ	4.0	15.80	0.570		2.15	Adriatic Sea (NC Mediterranean)
Özütok and Avşar 2002	Σ	8.0	15.60	0.130	–1.5400	1.50	Yumurtalık Bight
	♀		14.55	0.150	–1.0000	1.50	(W Mediterranean)
	♂		15.88	0.140	–1.7100	1.55	
Tičina and Matić-Skoko 2012	Σ	6.0	17.30	0.258	–1.0026	1.89	Adriatic Sea (NC Mediterranean)
The presently reported study	Σ	8.0	20.62	0.245	–1.0710	2.02	İzmir Bay (EC Aegean Sea)

S = sex, Σ = both sexes combined, ♀ = female, ♂ = male, t_m = observed maximum age, L_∞ = the asymptotic total length [cm], k = the growth coefficient (year^{-1}), t_0 = the hypothetical time at which the length is equal to zero [y], φ' = Munro's growth performance index, FB = cited after FishBase (Froese and Pauly 2016), C = central, E = eastern, N = northern, W = western.

and Avşar (2004) to be between February and June in the western Mediterranean (Yumurtalık Bight, Turkey); and by Froese and Pauly (2016) to be from April to August in the North Sea and the Mediterranean. Our findings also show reproduction in the time periods indicated by previous studies. As a result, all the studies' findings indicate a different time interval for the spawning period of *A. laterna*. And these results show that the spawning period has a close relation to the ecological characteristics of the water system in which the species lives (Nikolsky 1963).

We found that the sexual maturity sizes were very close (F: 11.88, M: 11.41 cm total length) and the age (2 years) was the same for females and males. These results showed that there is no sexual dimorphism in sexual maturity between sexes. Giovanardi and Piccinetti (1984) reported the first maturity length at 6.8 cm for sex combined in the Adriatic Sea (Italy), which is a very low size with regard to this study and findings of other studies. These different results may be caused by the differences in the composition of the sampling size. On the contrary, Deniel (1984, 1990 [the latter paper cited after Froese and Pauly 2016]) reported the first maturity length and age at 11 cm total length and 3-year-old for females in Douarnenez Bay (Brittany). This can be explained because the regional differences in environmental factors mean that the seawater temperature in the study area of this study is higher than in the eastern north Atlantic.

Natural mortality can be influenced by two factors related to the genotype and environmental factors (biotic and abiotic) of the species. Although, *A. laterna* is a non-commercial fish species, it is regularly fished along the coastal areas as a discard species. Because of this the fishing mortality and exploitation ratio parameter were calculated. The mortality ratios show that fishing mortality is higher than natural mortality. Therefore, the exploitation ratio parameter indicates that there is a high catch pressure on the stock.

The presently reported study provides the mortality rates, spawning period, first maturity size and age for Mediterranean scaldfish, *Arnoglossus laterna*, for the first time for the east-central Aegean Sea. And it also provides the length distribution, sex ratio, length–weight relation, age and growth of the fish stock. These parameters, reported herewith, contribute to a better knowledge of the species, and are very important for successful fisheries' management. Consequently, this study serves as baseline data on Mediterranean scaldfish for the east-central Aegean Sea and will be helpful in future fisheries' studies.

ACKNOWLEDGMENTS

This study was carried out with financial support from the Scientific and Technological Research Council of Turkey (TUBITAK), project 103Y132, and Ege University Science and Technology Center (EBİLTEM), project 2005/BİL/003.

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Received: 27 July 2016
Accepted: 18 January 2017
Published electronically: 31 March 2017