

AGE AND GROWTH OF THE PHAETON DRAGONET, *SYNCHIROPUS PHAETON* (ACTINOPTERYGII: PERCIFORMES: CALLIONYMIDAE), FROM THE GULF OF ISKENDERUN, NORTH-EASTERN MEDITERRANEAN, TURKEY

Asiye BAŞUSTA¹, Ebru I. OZCAN^{2*}, and Nuri BAŞUSTA¹

¹ Department of Basic Sciences, Faculty of Fisheries, Firat University, Elazığ, Turkey

² Department of Basic Sciences, Faculty of Fisheries, Munzur University, Tunceli, Turkey

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Background. *Synchiropus phaeton* (Günther, 1861) is a sexually dimorphic, benthic species that inhabits mud bottoms. This fish is one of the important by catch species in the trawl fishing. There is no commercial value. But it has ecological importance in this area. The information about the biology of *S. phaeton* is very limited. This study was conducted to investigate the age and growth relation of phaeton dragonet inhabiting the Gulf of Iskenderun, north-eastern Mediterranean coast of Turkey.

Materials and methods. A total of 289 phaeton dragonets were collected as discards during the commercial trawl fishing at the depth range of 100–150 m in the Gulf of Iskenderun, north-eastern Mediterranean. The fish age was determined from sagittal otoliths. The age readings were performed using Leica S8APO microscope and were documented with the Leica Application Suite (Ver. 4.8.0) software. The index of the mean percentage error (IMPE) was calculated to assess the precision of the age determination between two independent readers. Growth parameters for all specimens were subsequently determined by fitting the observed and the length-at-age data using the von Bertalanffy growth equations. Total length–weight relations (LWRs) and the condition factor (CF) were determined.

Results. The total length and weight of *S. phaeton* ranged from 7.0 to 19.0 cm and from 2.01 to 22.0 g, respectively. The age of the studied individuals ranged from 2 to 7 years. The parameters of von Bertalanffy growth fitted to the mean observed total lengths-at age for each sex separately and were estimated as $L_{\infty} = 23.358$ cm, $K = 0.248$ year⁻¹, $t_0 = -0.501$ years for females and $L_{\infty} = 26.543$ cm, $K = 0.156$ year⁻¹, $t_0 = -0.662$ years for males, respectively. The overall growth performance index (G) value was determined as 3.46 for the combined sexes. The total length–weight relations were determined as $W = 0.0121TL^{2.55}$, $R^2 = 0.94$; 95% confidence intervals of $b = 2.395$ – 2.687 , t -test $P < 0.05$ for females and $W = 0.0094TL^{2.64}$, $R^2 = 0.93$; 95% confidence intervals of $b = 2.470$ – 2.803 , t -test $P < 0.05$ for males. The types of growth were found negatively allometric ($b < 3$). The highest condition factor was found at the age of 2 (0.62), while the lowest was found at the age of 6 (0.26).

Conclusions. The presently reported study provides the first data on the age and growth of the *S. phaeton* that had not been studied previously in the Gulf of Iskenderun, north-eastern Mediterranean of Turkey. This study will contribute significantly to the conservation and management strategies of the species of *S. phaeton* in the future.

Keywords: *Synchiropus phaeton*, growth parameters, length–weight relations, sagittal otolith, condition factor

INTRODUCTION

Dragonets of the family Callionymidae are represented by 193 valid species organized in 11 genera. The callionymids are small, bottom-dwelling fishes, usually living on sand and mud beds (Farias et al. 2016). They are a group of benthic fishes that occur in the upper 900 m of all temperate, subtropical, and tropical oceans (Fricke 2016). One of the callionymids is the phaeton dragonet, *Synchiropus phaeton* (Günther, 1861), known to inhabit muddy bottom at depths of 100–650 m and to feed on

small invertebrates. Spawning of this species occurs in the summer months. Males are territorial and they perform courtship activity before spawning. Eggs and larvae are planktonic. Phaeton dragonets inhabit Atlanto–Mediterranean regions, mainly the northern part of the Mediterranean but were also found in the Atlantic from Portugal to Gabon. According to Golani et al. (2006), their principal distinctive characters are preopercular spine with two tips, scaleless body, no membrane after last dorsal spine, and very small interorbital space.

* Correspondence: Dr Ebru Ifakat Özcan, Munzur Üniversitesi, Su Ürünleri Fakültesi, 62100 Tunceli, Turkey, phone: +90 5317409095, e-mail: (EIO) ebruozcer@munzur.edu.tr, (AB) agirgin@firat.edu.tr, (NB) nbasusta@firat.edu.tr. ORCID: (EIO) 0000-0003-2017-6647, (AB) 0000-0002-9903-1418, (NB) 0000-0002-4260-4772.

Only a few studies on the length–weight relation of *S.phaeton* have been published (Borges et al. 2003, Giacalone et al. 2010, Deval et al. 2013) and they all were from the other localities. There is only one study reporting the otolith dimensions–fish length relations and the maximum length (19.4 cm) of *S. phaeton* in the north-eastern Mediterranean (Karachle et al. 2015). No studies have been found on the age and growth relations of the phaeton dragonet. This is the first report on some growth parameters of *S. phaeton* inhabiting the north-eastern Mediterranean Sea.

Fisheries management is important for sustainable fisheries and needs updating for different fishing areas (Uzer et al. 2019). Some population parameters such as age and growth of fish must be studied for a better understanding of fisheries biology and management practices. The data of age and growth of fish populations are important for the future preservation of stocks. Many different methods have been used for age determination in fish (Treble et al. 2008), but the most common one is counting of annual zones on otoliths.

The main objective of this study was to provide the first information about the sex ratio, length distribution, age, growth, length–weight relation, and condition factor of phaeton dragonet from the Gulf of Iskenderun (north-eastern Mediterranean, Turkey). This data is the first to not only for Turkey but also for FishBase.

MATERIAL AND METHODS

Fish collection and measurements. The study was carried out in the Gulf of Iskenderun, north-eastern Mediterranean (Fig. 1). All specimens of the phaeton dragonets, *Synchiropus phaeton*, were collected in 2012–2016, as discards, by commercial trawlers operating at depth of 100–150 m. Following transportation of the samples to the laboratory of the Fisheries Faculty at the Firat University, Elazığ (Turkey); fish samples were immediately measured (total length, TL) to the nearest 0.1 cm and weighed to the nearest 0.1 g. Sexes were determined by macroscopic examination of gonads; sex ratios were checked by a chi-square test.

Age and growth estimation. Sagittal otoliths were removed, cleaned of their excess tissues, stored dry in Petri dishes and preserved in 70% ethanol before the age readings. The otoliths removal procedures were performed according to Secor et al. (1991). To increase the clarity of the image, otoliths were put into glycerin. Age was read using Leica S8APO brand microscope with Leica Application Suite (Ver. 4.8.0) software (Fig. 2). The opaque and transparent appearance for reading sagittal otoliths (transmitted or reflected light) depends on the light used. Opaque zones appear dark when viewed with transmitted light and bright when viewed with reflected light (Panfili et al. 2002). One opaque zone and one transparent zone together were counted as one year. The age readings of these sagittal otoliths were performed at least twice.



Fig. 1. The study area in the Gulf of Iskenderun, north-eastern Mediterranean, Turkey

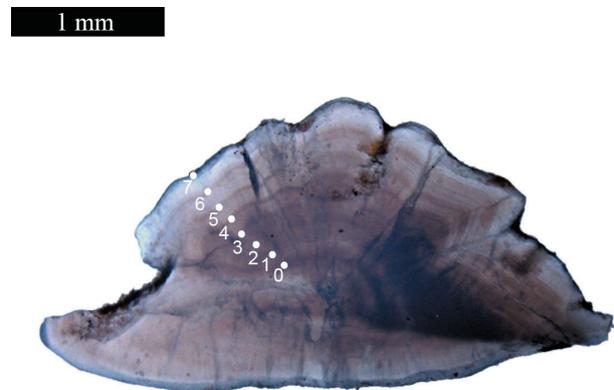


Fig. 2. Sagittal otolith centrum from an 18.2 cm TL *Synchiropus phaeton* and estimated to be 7 years from the Gulf of Iskenderun, north-eastern Mediterranean, Turkey

The index of the mean percentage error (IMPE)* was determined to ensure the accuracy of the age readings by two readers. The formula used (modified from Beamish and Fournier 1981) is as follows

$$IMPE_j = 100\% \times \frac{1}{R} \sum_{i=1}^R \frac{|X_{ij} - X_j|}{X_j}$$

where N is the number of fish aged, R is the number of readings, x_{ij} is the i th age determination of the j th fish, and x_j is the mean age calculated for the j th fish (Beamish and Fournier 1981).

The von Bertalanffy growth function (VBGF) was determined with the formula:

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

where L_t is the expected total length at age t years, L_∞ is the asymptotic mean maximum total length, K is the body growth coefficient, and t_0 is the theoretical age at zero length (von Bertalanffy 1938).

* The editor of this journal would like to acknowledge the contribution of Beamish and Fournier (1981) to ichthyology but at the same time, he would like to suggest a replacement of the “index of average percentage error (IAPE)” with more appropriate the “index of mean percentage error (IMPE)” (“average” is an imprecise colloquial expression).

The overall growth performance was estimated by the index

$$G = \log (K \cdot L_{\infty}^3)$$

displayed in the form of an auximetric grid of $\log (K)$ versus $\log (L_{\infty}^3)$, as described by Pauly (1979), Moreau et al. (1986), and Pauly et al. (1996).

Length–weight relations. The length–weight relation (LWR) was determined with the following equation (Ricker 1975)

$$W = a \cdot L^b$$

where W is the weight [g], L is the total length (TL) [cm], a is the intercept, and b is the slope. The b values of both sexes of *S. phaeton* 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. The degree of association between the variables was computed with R^2 (King 1995).

Condition factor. The condition factor (CF) was calculated with the formula below

$$CF = 100W \cdot L^c$$

where c is the coefficient of allometric (Fulton 1904).

RESULTS

Fish collection and measurements. A total of 289 phaeton dragonets, *Synchiropus phaeton* (145 females, 144 males), were collected during the presently reported study. The population consisted of 50.17% of females and 49.83% of males. The sex ratio of female to male was $1 \div 0.993$ and the chi-square analysis showed that the sex ratio was not significantly different from the expected $1 \div 1$ ratio (χ^2 , $P > 0.05$). The total length and weight of males ranged from 8.7 to 19.0 cm and from 2.26 to 22.0 g, respectively, while those of females from 7.0 to 18.5 cm and from 2.01 to 21.0 g. The maximum TL and weight of *S. phaeton* were 19.0 cm and 22.0 g, respectively. The total length frequency analysis of *S. phaeton* from the north-eastern Mediterranean Sea is given in Fig. 3.

Age and growth estimation. The age ranged from 2 to 7 years and the 4 age group was dominant (82 females, 81 males) in the population. Age-frequency distribution by sex is given in Fig. 4. The maximum length at age was determined as 19 cm at 7 years of age (Table 1).

According to the age estimations (IMPE), the index of the mean percentage error was found as 5.15% by two independent readers for *S. phaeton*. This means that the confidence intervals for the reliability of estimations made were within 5%–15%, indicating that our aging method represents a precision approach to the age determination (Campana 2001, Girgin and Başusta 2016).

Age bias plots between readers for all estimated age are given in Fig. 5. Both readers estimated the same age in 262 of 289 samples. The agreement between readers on all age assessment was 91%. The agreement between readers

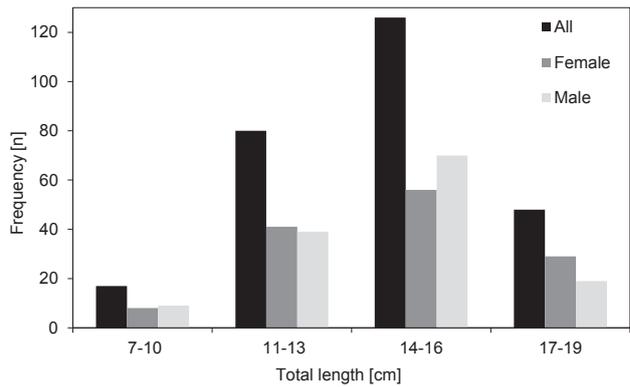


Fig. 3. Total length–frequency analysis of *Synchiropus phaeton* from the Gulf of Iskenderun, north-eastern Mediterranean, Turkey

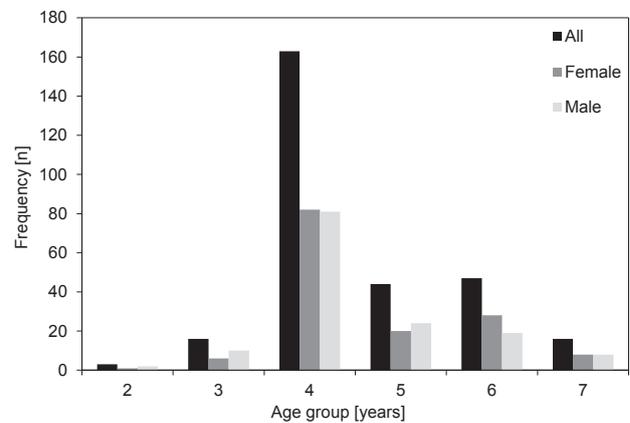


Fig. 4. Age group–frequency distribution of *Synchiropus phaeton* from the Gulf of Iskenderun, north-eastern Mediterranean, Turkey

was 96% within 4 years. The difference between readers in the accuracy of age assessment was found insignificant when repeated annuli counts were compared (paired t -test, $P > 0.05$).

The mean observed total lengths and weights-at-age estimated as:

$$L_t = 23.358[1 - e^{-0.248(t + 0.501)}]$$

$$L_t = 26.543[1 - e^{-0.156(t + 0.662)}]$$

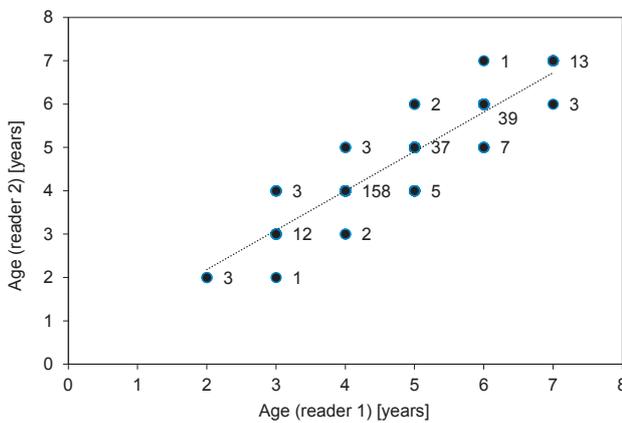
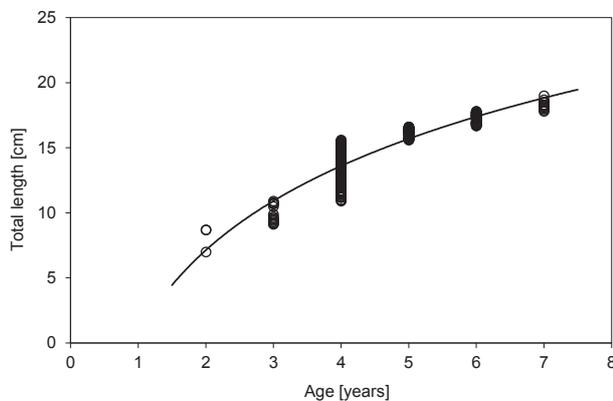
$$L_t = 24.770[1 - e^{-0.190(t + 0.796)}]$$

for females, for males, and for combined sexes, respectively (Table 2). There was no significant difference between sexes (t -test, $P > 0.05$). The length values calculated by von Bertalanffy equation were close to the measured length values of all ages and this was an indication that the age readings were done correctly (Fig. 6). The overall growth performance index (G) value was determined as 3.49 for females, 3.46 for males, and 3.46 for combined sexes.

Table 1Basic biometric data of *Synchiropus phaeton*, from the Gulf of Iskenderun, north-eastern Mediterranean, Turkey

Age group	Sex	n	Total length [cm]		Total weight [g]		Condition factor	
			Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
2	F	1	7.00		2.01		0.580	
	M	2	8.70 ± 0.00	8.7–8.7	3.16 ± 0.45	3.16–4.05	0.55 ± 0.060	0.48–0.62
3	F	6	10.06 ± 0.27	9.2–10.9	4.34 ± 0.42	2.70–5.88	0.42 ± 0.030	0.32–0.60
	M	10	9.83 ± 0.20	9.1–10.8	3.65 ± 0.28	2.26–4.56	0.39 ± 0.030	0.29–0.60
4	F	82	13.57 ± 0.14	10.9–15.6	9.73 ± 0.30	4.18–15.00	0.38 ± 0.006	0.27–0.48
	M	81	13.72 ± 0.14	11.0–15.5	10.04 ± 0.29	4.08–15.25	0.38 ± 0.006	0.29–0.54
5	F	20	16.23 ± 0.05	15.9–16.6	14.82 ± 0.38	11.40–18.19	0.35 ± 0.007	0.28–0.40
	M	24	16.05 ± 0.36	15.6–16.6	14.13 ± 0.59	10.40–18.54	0.34 ± 0.007	0.27–0.43
6	F	28	17.25 ± 0.09	16.7–17.7	16.49 ± 0.35	14.09–19.13	0.32 ± 0.004	0.27–0.41
	M	19	17.28 ± 0.08	16.7–17.8	17.14 ± 0.36	14.20–20.00	0.33 ± 0.006	0.26–0.37
7	F	8	18.28 ± 0.07	17.9–18.5	19.80 ± 0.36	19.00–21.00	0.32 ± 0.007	0.30–0.35
	M	8	18.39 ± 0.10	17.8–19.0	20.42 ± 0.38	18.90–22.00	0.33 ± 0.006	0.30–0.35

SD = standard deviation, F = females, M = males.

**Fig. 5.** Age bias plot between readers for all age estimates of *Synchiropus phaeton* from the Gulf of Iskenderun, north-eastern Mediterranean, Turkey; the numbers show repeated annuli counts**Fig. 6.** Age–total length relation of *Synchiropus phaeton* for combined sexes from the Gulf of Iskenderun, north-eastern Mediterranean, Turkey

Length–weight relations. The regression parameters of the *S. phaeton* are given in Table 2. The growth type of *S. phaeton* presented negative allometry ($b < 3$, t -test $P < 0.05$) for females, males, and combined sexes (Fig. 7). Regression analysis showed that fish length had a highly significant correlation with weight ($R^2 = 0.93$, $P < 0.001$) and it is possible to say that a 93 percentage-point increase in weight was due to length increase. The normality test, carried out by using the Kolmogorov–Smirnov two-sample test, showed no significant difference between sexes ($P > 0.001$). When the t -test results were analysed for the significance of regression coefficients ($P < 0.01$), it was found that fish length data could be used in high accuracy to estimate fish weight.

Condition factor. The condition factor was calculated for all age-groups and sexes. The difference between sexes by age groups was not significant ($P > 0.05$). The highest condition factor was found at the age of 2 (0.62), while the lowest at the age of 6 (0.26); (Table 1).

DISCUSSION

Fish collection and measurements. In this study, carried out in the north-eastern Mediterranean, the total length and total weight ranges of 289 (145 females, 144 male) *Synchiropus phaeton* dragonets, *Synchiropus phaeton*, were 7.0–19.0 cm and 2.01–22.0 g, respectively. The length and weight ranges, from the south coast of Portugal, were 6.9–13.4 cm and 1.8–9.9 g, respectively (Borges et al. 2003) while the lengths from the Gulf of Castellammare, NW Sicily, Mediterranean Sea ranged from 6.0 to 18.0 cm according to Giacalone et al. (2010); Deval et al. (2013) reported lengths of 4.8–13.3 cm and weights of 0.8–8.4 g from the Gulf of Antalya, eastern Mediterranean. A single specimen of *S. phaeton* measuring 22.0 cm TL, captured with bottom trawl at 254 m depth, was recorded near Peniche (Portugal), at 39°18'N, 009°55'W (Bañón et al. 2018). This difference could be attributed to the different sampling areas with different food density, as well as the differences in age, maturity, and sex. The

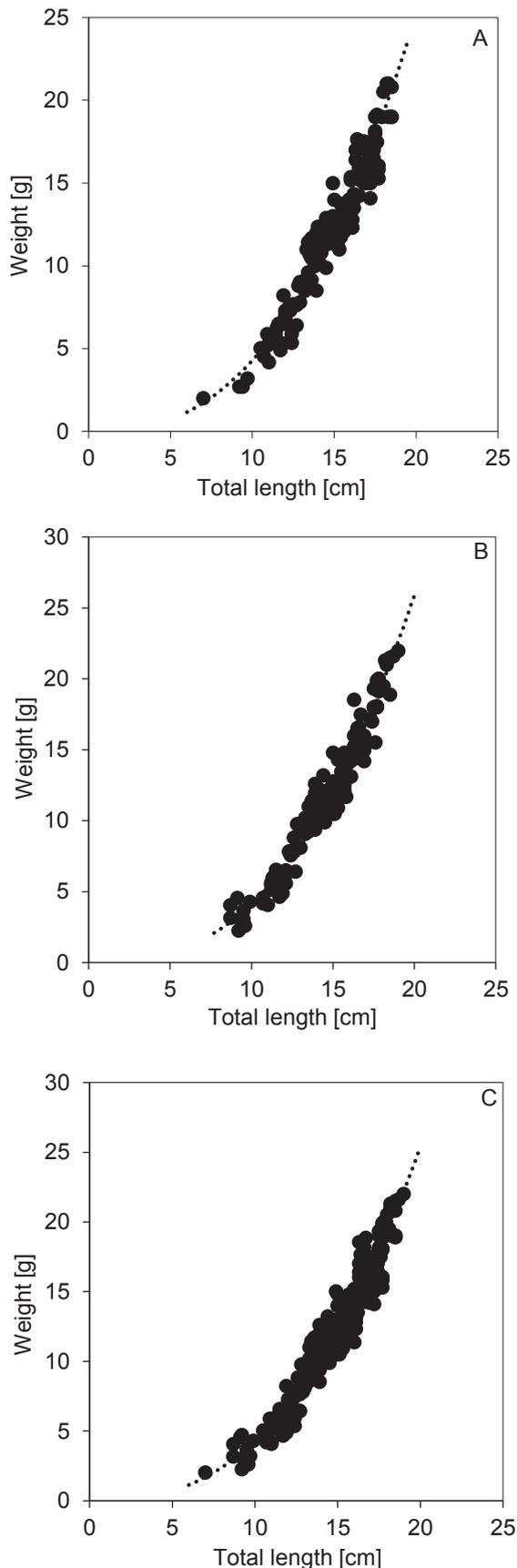


Fig. 7. Length–weight relations for female (A), male (B), and combined sexes (C) of *Synchiropus phaeton* from the Gulf of Iskenderun, north-eastern Mediterranean, Turkey

female to male ratio was $1 \div 0.993$. Information about sex ratio is important for understanding the relations between individuals, the environment, and the state of the population (Oliveira et al. 2012). In the presently reported study, the maximum lengths of females and males were found to be 18.5 to 19.0 cm, respectively, in the north-eastern Mediterranean.

Age and growth estimation. The age values of *S. phaeton* in the presently reported study ranged from 2 to 7 years. An estimated 56.40% of combined sexes represented the age of 4 years. Because of the absence of the other age studies of *S. phaeton*, a comparison was made with other species of this family. For instance, the maximum age of 5+ was stated for *Callionymus filamentosus* Valenciennes, 1837 (see Erguden et al. 2016). Age determination in fish is a basic step in understanding fish biology and population status (Beamish and McFarlane 1983) so it is quite important for fisheries management. Many different methods have been used for age assessment in fish (Treble et al. 2008), but in general, counting of annual zones on otoliths is one of the most preferred methods.

The von Bertalanffy growth parameters were calculated as

$$L_t = 24.770 [1 - e^{-0.190(t + 0.796)}]$$

for combined sexes in this study. Males reached a larger asymptotic total length ($L_\infty = 26.543$ cm) than females ($L_\infty = 23.358$ cm) and grew more slowly ($K = 0.156$ year⁻¹, $t_0 = -0.662$) for males and $K = 0.248$ year⁻¹, $t_0 = -0.501$ for females). Since there has not been a study concerning growth parameters of phaeton dragonet inhabiting the north-eastern Mediterranean, a comparison was made with other species of this family. For example; Erguden et al. (2016) found $L_\infty = 21.93$ cm, $K = 0.213$ year⁻¹ and $t_0 = -2.150$ for *Callionymus filamentosus* from Iskenderun Bay, north-eastern Mediterranean.

Length–weight relations. The b values were determined as 2.55 for females, 2.64 for males and 2.57 for the combined sexes. The growth of combined sexes presented negative allometry ($b < 3$). The lowest b values were reported as 2.306 by Giacalone et al. (2010) in fish obtained from the Gulf of Castellammare (NW Sicily, Mediterranean Sea) and 2.350 by Deval et al. (2013) in the Gulf of Antalya, eastern Mediterranean. On the other hand, the highest b value was given as 2.572 by Borges et al. (2003) from the South coast of Portugal that was consistent with our findings (Table 3). The differences can be attributed to the combination of several factors such as numbers of examined individuals and the size range of fish used (Moutopoulos and Stergiou 2002). The coefficient of determination (R^2) was found to be > 0.93 , a highly significant value of the result. These high values of R^2 show that the length–weight relations are linear. The regression analysis has shown that fish length had a highly significant correlation with weight ($P < 0.001$). The t -test results indicated that length data could be used to estimate weight in high reliability (Ozcan and Başusta 2018).

Condition factor. The mean condition factor values were found to range between 0.26 and 0.62. The condition factor

Table 2

The parameters of the age–length and regression for *Synchiropus phaeton*, from the Gulf of Iskenderun, north-eastern Mediterranean, Turkey

Sex	n	Age–length parameters				Regression parameters				
		L_{∞} [cm]	K [year ⁻¹]	t_0 (year)	G	a	b	95% CI (b)	R^2	GT
Female	145	23.358	0.248	–0.501	3.49	0.0121	2.55	2.45–2.88	0.94	A (–)
Male	144	26.543	0.156	–0.662	3.46	0.0094	2.64	2.39–2.89	0.93	A (–)
Combined	289	24.770	0.190	–0.796	3.46	0.0114	2.57	2.39–2.89	0.93	A (–)

n = number of individuals, L_{∞} = asymptotic length, t_0 = theoretical age, K = body growth coefficient, G = overall growth performance index, a = intercept, b = slope of the relation, R^2 = coefficient of determination; GT, growth type, A = allometry.

Table 3

A comparison of the length–weight relation parameters dragonet species representing genera *Synchiropus* and *Callionymus* in various geographical areas

Species	Region	n	L_{\max} [cm]	a	b	R^2	Reference
<i>Synchiropus phaeton</i>	S Portugal, ATL	12	13.4	0.01309	2.572	0.980	Borges et al. 2003
<i>Synchiropus phaeton</i>	Gulf of Castellammare, MED	76	18.0	0.03480	2.306	0.930	Giacalone et al. 2010
<i>Synchiropus phaeton</i>	Gulf of Antalya, E MED	65	13.3	0.01910	2.350	0.974	Deval et al. 2013
<i>Callionymus maculatus</i>	Cantabrian Sea, Spain, ATL	80	12.0	0.00674	2.846	0.940	Pereda and Villamor 1991
<i>Callionymus risso</i>	Strymon estuary, NW Aegean Sea	62	4.5	0.01710	2.536	0.937	Koutrakis and Tsikliras 2003
<i>Callionymus risso</i>	Cetina River estuary, Croatia	12	8.4	0.00190	2.675	0.950	Dulčić and Glamuzina 2006
<i>Callionymus pusillus</i>	Algarve, Spain, ATL	22	5.4	0.00222	2.360	0.967	Verdiell-Cubedo et al. 2006
<i>Callionymus reticulatus</i>	Arade River estuary, ATL	—	7.2	0.01780	2.550	0.952	Veiga et al. 2009
<i>Callionymus risso</i>	Erdek Gulf, Sea of Marmara	13	7.0	0.01370	2.705	0.938	Keskin and Gaygusuz 2010
<i>Callionymus filamentosus</i>	Gulf of Iskenderun, NE MED	341	17.5	0.01420	2.792	0.987	Erguden et al. 2016

n = number of individuals, L_{\max} , maximum length, a = intercept, b = slope of the relation; R^2 = coefficient of determination; ATL = Atlantic, MED = Mediterranean.

value has decreased by age. Blackwell et al. (2000) report that a high condition factor implies that the environmental conditions are quite suitable for a give fish population. As a result, since the condition factor value in our study was lower than 1, it may be deduced that the environmental conditions in the north-eastern Mediterranean were not very suitable for *S. phaeton*.

In conclusion, the presently reported investigation provides the first data on the age and growth of the phaeton dragonet, *Synchiropus phaeton*, from the Gulf of Iskenderun of the north-eastern Mediterranean of Turkey, which would be needed for fishery biologists for the sustainability of its remaining stocks. This study provides the first data on not only the Gulf of Iskenderun of the north-eastern Mediterranean of Turkey but also FishBase and will be helpful in future fisheries research.

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