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Growth Parameters and Reproductive Biology of *Citharus linguatula* (Linnaeus, 1758) from the Sea of Marmara (Turkey)

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Research Article

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Abstract

An economically important species of *Citharus linguatula* was investigated in the Sea of Marmara (Eastern Mediterranean, Turkey). Length-weight relationships, growth parameters, reproductive time, and first sexual maturity length of the species were determined. A total of 236 individuals were analyzed, total length and weight varied from 7.5 to 26.5 cm TL (17.11±3.62 cm) and 2.67 to 180.81 g (44.07±1.84 g), respectively. The length-weight relationship was calculated as $W=0.0047*TL^{3.17}$ in total. The growth type was positive allometry for both sexes. Total individuals were ranged in age between 1 and 4. According to sexes, von Bertalanffy growth parameters were calculated as L_∞=23.44 cm, K=0.74 per year, and t_0=-0.09 year for females and L_∞=20.75 cm, K=0.56 per year, and t_0=-1.14 year for males. The size at first maturity was 17.6 cm TL for males, and 16.7 cm TL for females. When sexual maturity, K, and GSI values were evaluated together, the reproduction period of *C. linguatula* was determined between September and December.

Keywords: Marmara Sea, spotted flounder, growth, length-weight relationships, sexual maturity

Marmara Denizi'nde *Citharus linguatula* (Linnaeus, 1758)'nın Büyüme Parametreleri ve Üreme Biyolojisi

Özet

Marmara Denizi'nde ekonomik açıdan önemli bir tür olan *Citharus linguatula* araştırılmıştır. Türün boy-ağırlık ilişkisi, yaş, büyüme, üreme zamanı ve ilk eşeysel olgunluk boyu belirlenmiştir. Toplam 236 birey analiz edilmiştir, toplam boy ve ağırlık değerleri sırasıyla 7,5 – 26,5 cm TL (17,11 ± 3,62 cm) ve 2,67 – 180,81 g (44,07 ± 1,84 g) arasında değişmiştir. Boy-ağırlık ilişkisi parametreleri tüm bireyler için $W=0,0047\times TL^{3,17}$ olarak hesaplanmıştır. Büyüme tipi her iki cinsiyet için de pozitif allometridir. Bireylerin yaşları 1 ile 4 arasında değişmektedir. Cinsiyetlere göre von Bertalanffy büyüme parametreleri, dişilerde L_∞=23,44 cm, K=0,74 $yıl^{-1}$ ve t_0=-0,09 yıl, erkeklerde L_∞=20,75 cm, K=0,56 $yıl^{-1}$ ve t_0=-1,14 yıl olarak belirlenmiştir. İlk eşeysel olgunluk boyu erkekler için 17,6 cm TL, dişiler için 16,7 cm TL bulunmuştur. Eşeysel olgunluk, K ve GSI değerleri birlikte değerlendirildiğinde, *C. linguatula*'nın üreme dönemi Eylül ve Aralık ayları arasında belirlenmiştir.

Anahtar Kelimeler: Marmara Denizi, kancaağız pisi balığı, büyüme, boy-ağırlık ilişkisi, eşeysel olgunluk

INTRODUCTION

Spotted flounder (*Citharus linguatula* Linnaeus, 1758) is a member of the Citharidae family that distribute confined geographical areas in worldwide. It occurs in Eastern Atlantic and Mediterranean. It is a common flatfish around the Turkish coasts except for the Black Sea. The adults of this species common in soft, muddy, and sandy habitats and generally catch at depths lower than 200 m (Nielsen, 1981). The members of the family Citharidae distinguish from all other flatfish families (Bothidae, Cynoglossidae, Pleuronectidae, and Soleidae) with its single spine in pelvic fin (Nielsen, 1981). The family has six members worldwide, whereas it is represented single species in Turkish waters (Nelson, 1994).

C. linguatula is a target species of the local trawl fisheries (Demestre, 2006) but vulnerable for fishing activities (de Juan et al., 2006). It is identified as a highly selective predator (de Juan et al., 2007) and feeds on small fish and crustaceans (Fischer et al., 1987). It is ranked as the least concern status in the IUCN Red List (Tous et al., 2015). It is well represented in trawl catches and has a moderate commercial interest.

The length-weight relationship parameters about *C. linguatula* have been estimated in several studies (Campillo, 1992; Dulčić and Kraljević, 1996; Merella et al., 1997; Stergiou and Moutopoulos, 2001; Abdallah, 2002; Cicek et al., 2006; Sangun et al., 2007; Özekinci et al., 2009; Demirel and Dalkara, 2012).

Previous studies related to age, growth, and reproduction biology for C. linguatula is scarce (Stergiou et al., 1997; Garcia–Rodriquez and Esteban, 2000; Çakır et al., 2005; Bayhan et al., 2009; Cengiz et al., 2012; Cengiz et al., 2014; Cengiz and Ismen, 2018).

To our knowledge, this study reveals the first findings on the population parameters of this species in the Sea of Marmara, Turkey. This study aimed was to determine the age, growth, mortality, and reproductive biology of *C. linguatula* in the Marmara Sea.

MATERIALS and METHODS

Monthly trawl surveys were conducted between March 2017 and December 2018 from 34 stations in the Sea of Marmara (Turkey) (Figure 1). Sampling stations were selected to represent varied depth structures (0-50 m, 50-100 m, and 100-200 m depths). Trawl tows were realized according to MEDITS's standards. Each tow was conducted in daylight with 3 miles tow speed and 30 m duration.

The total length (TL) was measured to the nearest millimeter and the total weight (TW) was recorded to the nearest gram. Sex and maturity stages were determined by examining the gonads macroscopically. The length-weight relationship was estimated by the Sparre et al. 1989's equation.

$W=a\times TL^b$ where *W is the total weight (g)* and *TL is the total length (cm), a and b are regression parameters*. The growth type was identified according to equation (Sokal and Rohlf, 1987): $ts=(b-3)/SE(b)$ where *ts is t-test value*, *b is a slope*, and *SE(b) is a standard error of the slope*.

The catch per unit effort (CPUE) values (kg h^{-1}) were determined and the mean values were computed based on depths. Biomass (kg km^{-2}) estimations were calculated by the swept area method (Sparre & Venema, 1998).

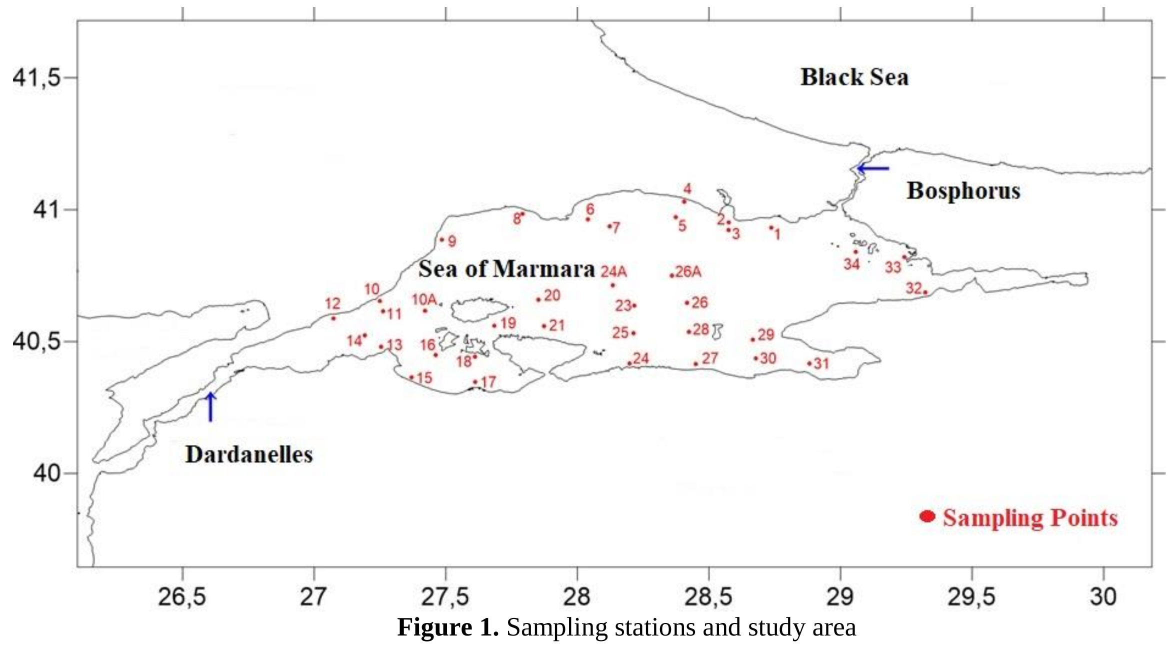

Figure 1. Sampling stations and study area

Sagittal otoliths from the blindside were used for age determination. In flatfishes, the otoliths from the blindside were used for age estimation, as the nucleus is more central and the zones were easier to be interpreted compared to otoliths from the ocular side (Cengiz et al., 2012a, 2012b; Cengiz et al., 2013). Growth parameters were estimated using the von Bertalanffy growth equation: $L_t = L_\infty [1-\exp(k(t-t_0))]$ where *L(t) is the length at age,* L_∞ *is the asymptotic length, K is the growth factor*, and t_0 *is the theoretical age when the size of fish is zero*. Growth parameters were estimated using the FISAT II program package (Sparre and Venema, 1998). The ϕ growth performance index was calculated as follows; $\phi = \log K + 2\times\log L_\infty$

Total mortality (Z) was found with the linearised catch curve using the mean age composition (Sparre and Venema, 1998). Natural mortality (M) was determined using Pauly's (1980) formula:

$\mathrm{Log}(M) = (-0.0066) - 0.279\times\log(L) + 0.6543\times\log(K) + 0.4634\times\log(T)$ where *the T (15 °C) is* the *annual average temperature*.

Fishing mortality was calculated using the following formula $F=Z-M$. The exploitation rate (E) was obtained using the formula E=F/Z.

Stages of maturity were determined by Holden and Raitt (1974): immature, maturing, ripening, ripe, and spent. To calculate the Gonadosomatic index values (GSI), the formula was used by Gibson and Ezzi (1980): $GSI = (GW/(BW-GW))\times 100$. The length at first maturity (L_{50}) was estimated by fitting a logistic function using the Newton algorithm which is defined as $P(1) = 1/1+e^{-(a+b1)}$ where *P (1) was the proportion of mature specimens at length 1, and a and b the parameters of the logistic equation* (Piñeiro and Saínza, 2003).

RESULTS

Sex Ratio, Length-Frequency, Length-Weight Relationships, and Biomass

In total, 236 individuals of *C. linguatula* were evaluated for analyses. The sex of individuals was determined as 125 females (52.9%) and 83 males (35.2%). The sex of the remaining 28 (11.9%) individuals was not determined due to immature gonads. The sex ratio was 1:1.5.

The total length and weight of individuals varied from 7.5 to 26.5 cm TL (17.11±3.62 cm) and 2.67 to 180.81 g (44.07±1.84 g), respectively. According to sexes, females ranged in length between 8.0 and 26.8 cm TL with a mean of 18.17±3.55 cm TL and in weight from 3.74 to 180.81 g with a mean of 52.3±2.76 g, whereas males ranged in length between 8.7 and 24 cm TL with a mean of 16.1±2.9 cm TL and in weight from 4.6 to 102.4 g with a mean of 35.3±3.88 g. The length-frequency distribution showed a normal curve and 23% of the total individuals were situated in 17 and 18 cm TL length groups. In some length groups such as 12 cm (males) and 21 cm (females), dominance was observed high upon sex (Figure 2). The LWR parameters were calculated as $W=0.0043\times L^{3.21}$ for males, $W=0.0041\times L^{3.21}$ for females, and $W=0.0047\times L^{3.17}$ for both sexes (Table 1, Figure 3). The growth types were determined as a positive allometric (t-test, $p<0.05$).

Mean biomass and catch per unit effort (CPUE) values were determined as 0.12 kg h^{-1} and 1.65 kg km^{-2}. In terms of depth contours, it has been determined that as the depth increases, the biomass and CPUE also increases. The biomass and CPUR values were calculated as 0.27 kg h^{-1}, 3.72 kg km^{-2} between 100 and 200 m depths. While biomass and CPUE were calculated as 0.13 kg h^{-1}, 1.79 kg km^{-2} for 50-100 m and 0.05 kg h^{-1}, 0.69 kg km^{-2} in 20-50 m depth contours.

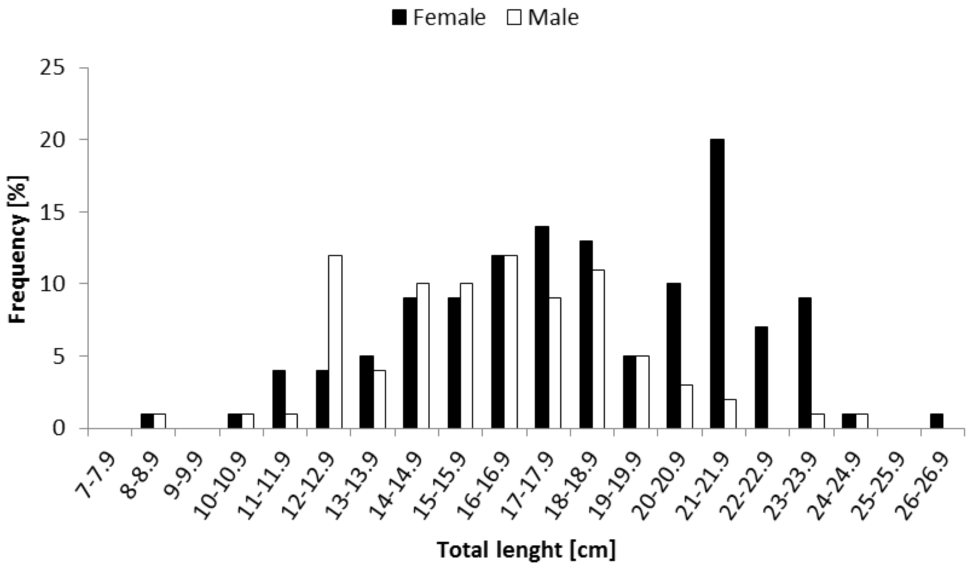

Figure 2. Length-frequency distribution of *C. linguatula* for females and males

Table 1. Length-weight relationship parameters of *C. linguatula* for female, male and combined.

Sex	a	b	R^2	N	Growth type
F	0.0043	3.21	0.97	125	A+
M	0.0041	3.21	0.98	83	A+
C	0.0047	3.17	0.98	236	A+

F: female, M: male, C: combined, A+: positive allometry

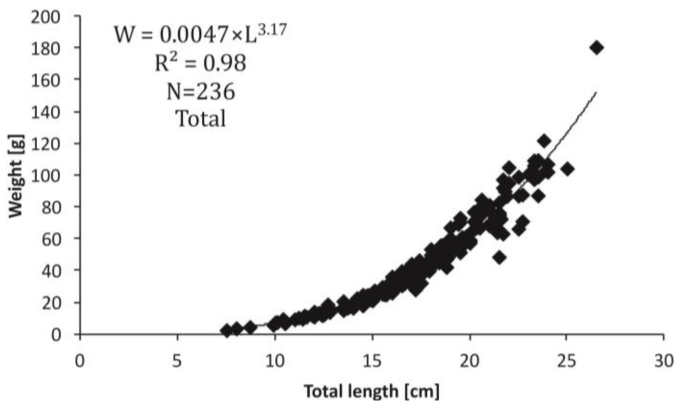

Figure 3. Length-weight relationship of *C. linguatula* for both sexes

Age, Growth, and Mortality

Spotted flounder aged I up to IV taers were present in the samples. The maximum age was determined as III and IV for males and females, respectively (Table 2). In total, the most represented age class was II, representing 48.1% of the total.

According to sexes, the von Bertalanffy growth parameters were calculated as L_∞=23.44 cm, K=0.74 y^{-1}, and t_0=-0.09 y for females, and L_∞=20.75 cm, K=0.56 y^{-1}, and t_0=-1.14 y for males. The von Bertalanffy growth curves were shown in Figure 4.

The total mortality (Z), natural mortality (M), fishing mortality (F), and exploitation rate (E) were calculated as 1.03, 0.79, 0.24, and 0.23, respectively.

Table 2. The age-length key of *C. linguatula*

Ages	Female			Male		
	Min- Max	Mean	N	Min- Max	Mean	N
1	14.3	14.3	1	13.5-17.5	15.13±0.85	4
2	15-21.7	18.72±0.81	9	14.7-19.6	16.96±0.42	11
3	18-22.7	20.58±0.46	11	19-19.8	19.4±0.40	2
4	20.3-26.5	22.86±0.82	6	-	-	-

Sexual Maturity and Reproductive Biology

The size at first maturity was 17.6 cm TL for males and 16.7 cm TL for females (Figure 5). The condition factor (KF) of females was higher than males during the sampling period. According to sexes, GSI values were ranged between 0.27 and 2.91 with a mean of 1.46 for females and ranged from 0.16 to 2.16 with a mean of 0.71 for males. In terms of seasonal variation, GSI was highest in October, whereas the minimum in April for both males and females. The mature gonads were found between October and December for females and were observed between July and December for males. When the sexual maturity, KF, and GSI values are evaluated together, the spawning period of *C. linguatula* was determined between September and December and its peak in November.

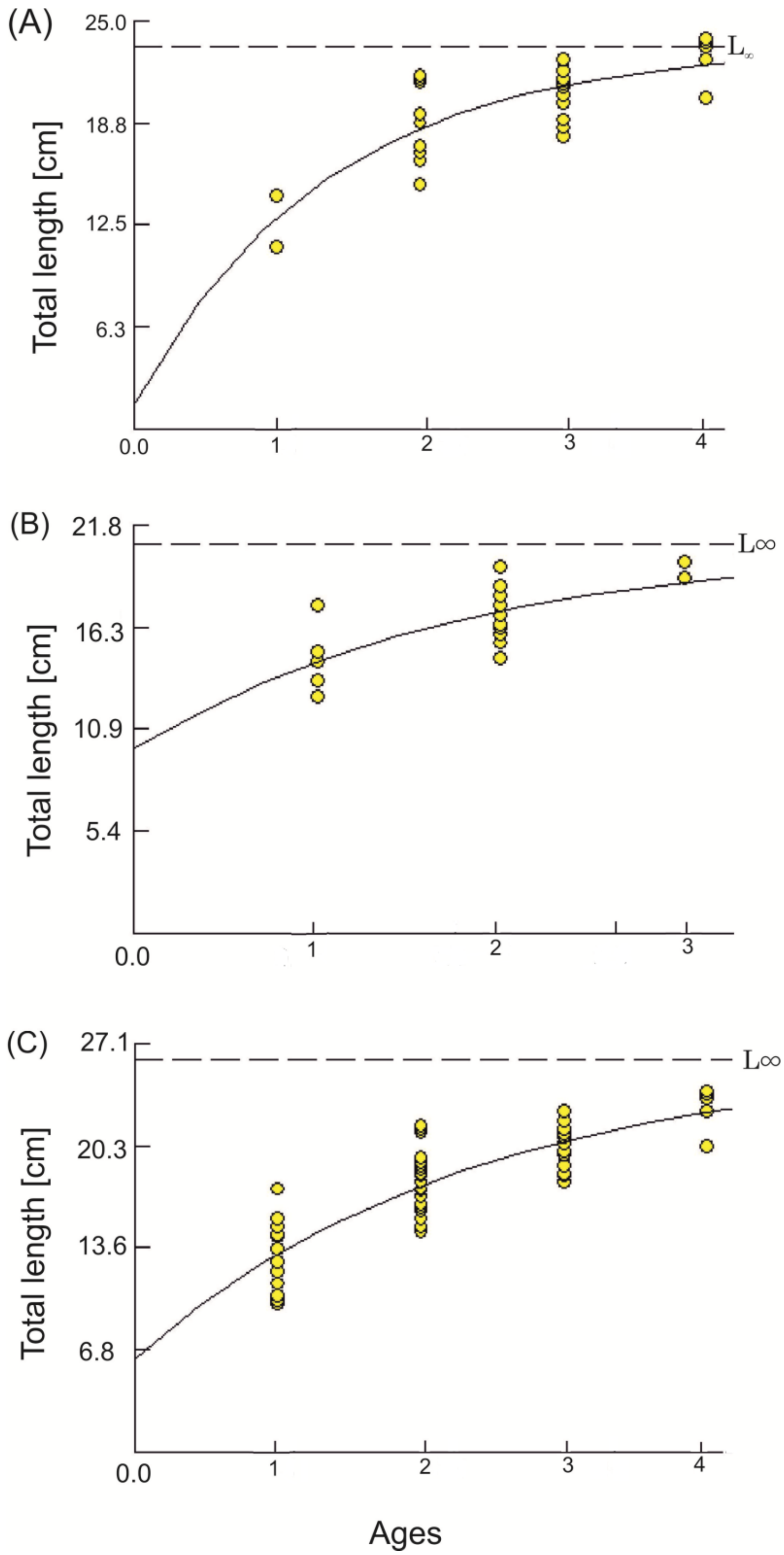

Figure 4. Von Bertalanffy growth curve for female (A), male (B) and, whole data set (C)

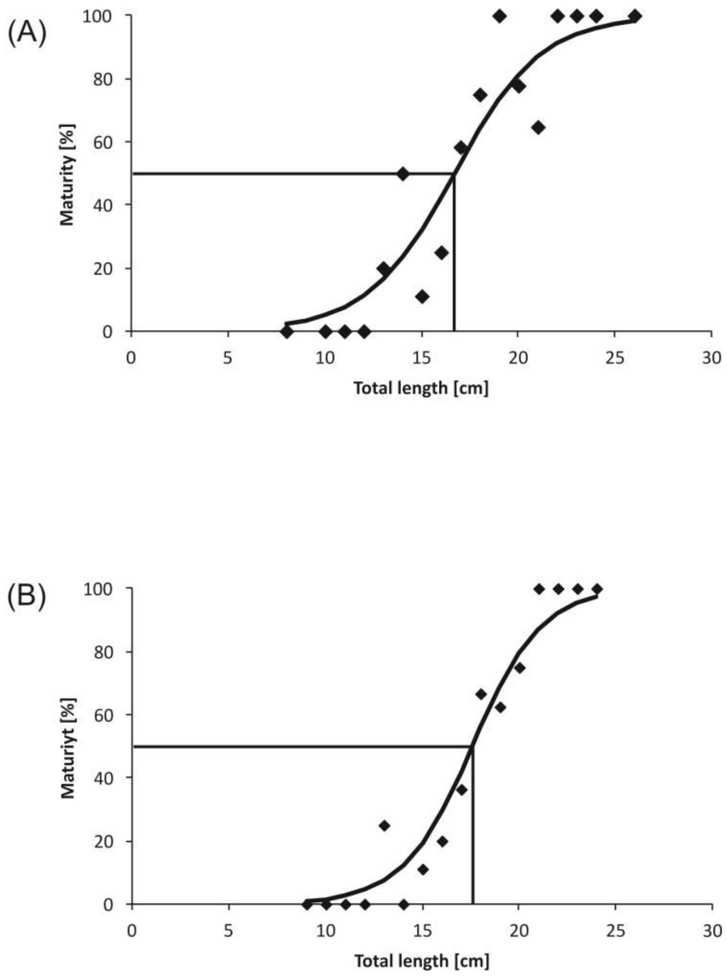

Figure 5. The logistic curve for estimating the size at first maturity (L_{50}) for female (A) and Male (B)

DISCUSSION

This study constitutes the first data deal with population parameters and reproduction biology of *C. linguatula* for the Sea of Marmara. Although trawling is restricted, beam trawls and illegal fishing of trawls are damaging all living creatures of demersal habitat in the Sea of Marmara. The slow-motion capability of *C. linguatula* makes difficulties for escaping dragnets such as trawl and beam trawls. Besides, Marmara Region hosts a great population, lots of industrial facilities, and commercial ports. Industrialization and dense marine traffic create marine pollution and damage benthic life of the Sea of Marmara.

Considering the population parameters, it must be known that biomass and stock structure of *C. linguatula* gives negative signs in this study. Mean catch per unit effort (CPUE) was determined as 0,12 kg h^{-1} and 1,65 kg km^{-2}. With increasing depth, biomass was increased as 0,27 kg h^{-1}: 3,72 kg km^{-2} between 100 and 200 m depths. It was determined that the *C. linguatula* was mostly distributed around the Southwest part of the Sea of Marmara. In this respect, *C. linguatula* keeps oneself a lot of from the polluted area (Northeastern part). Torcu Koç et al., (2012) were determined that 4.49% of the total demersal fish biomass of the Marmara Sea consisted of *C. linguatula*. In this study, *C. linguatula* constituted 0.1% of the total biomass. As can be seen biomass values *C. linguatula* is under threatened in the Sea of Marmara. According to TUIK, catch reports on *C. linguatula* validate this risk. While the catch value was 53 tons in 2010, it decreased to 3.6 tons in 2018 (TUIK, 2018). Thus, knowledge of population parameters becomes more critical for understanding the stock structure and taking measures for sustainability.

C. linguatula ranged in age between 1 and 4. The von Bertalanffy growth parameters were determined as L_∞=26.1 cm, K=0.43 y^{-1}, and t_0=-0.63 y. The total mortality (Z) was determined as 1.03 t^{-1} and the natural mortality (M) was estimated as 0.79 t^{-1}. The fishing mortality (F) was calculated as

0.24 t^{-1} and the exploitation rate (E) was determined as 0.23 t^{-1}. As can be seen that, contrary to expectations, the fishing mortality and exploitation rate were calculated low. Similarly, Türker-Çakır et al., 2005 determined the mortality rates as Z = 0.60, M = 0.75, F = 0.15, and E = 0.25 in the Edremit Bay and showed that the *C. linguatula* stock is being exploited at a lower than optimal level. When compared with the growth parameters, the results were not different in terms of the phi-prime index. According to the growth parameters, the females grow faster than the males similar to other results. (Table 3). In all flatfishes, females grow larger and faster than males. This may be due to the differences in metabolism between females and males, such as differences in oxygen consumption differences in excess energy levels between reproduction and somatic growth, and different food intake (Cengiz et al., 2014).

Türker-Çakır et al. (2005) were determined that *C. linguatula* was ranged in age between 1 and 5, and nearly the same exploitation rate was given in Edremit Bay, Turkey. In another study, Bayhan et al. (2009) were stated the same pattern with regards to age distribution. It was observed that in the studies conducted around Turkish coasts, the asymptotic length values were close, whereas, in the studies that revealed around Western Mediterranean (Teixeira et al., 2010; Garcia-Rodriguez and Esteban, 2000), the values were high. It may be a result of varied seawater characteristics stemmed from geographical differences. Besides, the fishing effort and the existence of sheltered areas may affect it. The comparison of the length-weight relationship parameters of *C. linguatula* was shown in Table 4. In previous studies, the b values were ranged between 2.82 and 3.45. It can be thought that this great difference is caused by the abundance of nutrients in the environment. Besides the stomach fulness at the time of fishing may be caused by this variation. As it is known, fish stomachs may explode due to squeezing in the trawl bags, and in this case, it cannot possible to measure true weight.

Table 3. Comparison of the von Bertalanffy growth parameters of *C. linguatula* with previous studies

Author (s)	Area	Sex	L∞	Length	K	t_0	Ø
Stergiou et al., 1997	Middle Aegean Sea	M	22.9	TL	0.296	-0.46	2.19
		F	25.9	TL	0.257	-0.42	2.24
Garcia-Rodriquez and Esteban, 2000	From Gibraltar to Creus Cape	M	30	TL	0.25	-0.04	2.35
		F	33	TL	0.25	-0.16	2.43
Türker-Çakır et al., 2005	Edremit Bay	Both Sexes	25.3	TL	0.25	-1.68	2.2
Ulutürk, 2007	Izmir Bay	Both Sexes	27.4	TL	0.21	-1.64	2.2
Bayhan et al., 2009	Izmir Bay	Both Sexes	26.2	TL	0.3	-0.62	2.31
Teixeira et al., 2010	Portuguese Coasts	M	30.8	TL	0.15	-4.4	2.15
		F	30.2	TL	0.19	-3.4	2.24
Cengiz and Ismen, 2018	Saros Bay	M	21.7	TL	0.29	-1.96	2.14
		F	25.6	TL	0.24	-1.64	2.2
This study	**Sea of Marmara**	**M**	**20.8**	**TL**	**0.56**	**-1.14**	**2.19**
		F	**23.44**	**TL**	**0.74**	**-0.09**	**2.38**
		Both Sexes	**26.1**	**TL**	**0.43**	**-0.63**	**2.61**

The spawning period of *C. linguatula* was determined between September and December and its peak in November. The spawning period of *C. linguatula* was determined between August and November in the Western Mediterranean (Sabatés, 1988); on Autumn in Portuguese Coasts (Teixeira et al., 2010). In nearby areas, Kınacıgil et al. (2008) were determined that the highest GSI values between September and October in the Aegean Sea. Cengiz et al. (2014) were found the spawning season of *C. linguatula* between September and November in the northern Aegean Sea. The results that deal with the spawning period were consistent with the previous studies. It may be thought that *C. linguatula* is a strong autumn spawner.

Table 4. Comparison of length-weight relationships of *C. linguatula* with previous studies

Author	Area	Length-weight relationship parameters			
		Sex	a	b	R^2
Campillo, 1992	Adriatic Sea	M+F	0.011	2.87	
Dulčić and Kraljević, 1996	Eastern Adriatic	M+F	0.009	3.24	0.910
Merella et al., 1997	Balear Island, Spain	M+F	0.003	3.30	0.986
Stergiou and Moutopoulos, 2001	Evvoikos, Greece	M+F	0.009	2.98	0.980
	Evvoikos and Trikeri Strait, Greece	M+F	0.001	3.45	0.820
	Northern Aegean Sea, Greece	F	0.005	3.11	0.970
		M+F	0.005	3.12	0.980
Abdallah, 2002	Alexandria, Egypt	M+F	0.008	3.04	0.986
Santos et al., 2002	Algarve, Portugal	M+F	0.011	2.87	0.810
Borges et al., 2003	Algarve, Portugal	M+F	0.012	2.78	0.846
Mendes et al., 2004	Nazaré to St André, Portugal	M+F	0.004	3.21	0.747
Çiçek et al., 2006	Babadil Limanı Bight, Turkey	M+F	0.006	3.08	0.979
Karakulak et al., 2006	Gökçeada Island	M+F	0.001	3.73	0.954
Sangun et al., 2007	Eastern Mediterranean, Turkey	M+F	0.011	2.82	0.980
Giacalone et al,, 2010	Castellammare Bay, Italy	M+F	0.006	3.14	0.990
Demirel and Murat-Dalkara, 2012	Sea of Maramra, Turkey	M+F	0.029	2.83	0.915
Torres et al., 2012	Cadiz Bay, Spain	M+F	0.006	3.08	0.980
Moutopoulos et al., 2002	Korint Bay, Greece	M+F	0.007	3.01	0.962
This study	**Sea of Marmara, Turkey**	**M**	**0.0043**	**3.21**	**0.97**
		F	**0.0041**	**3.21**	**0.98**
		M+F	**0.0047**	**3.17**	**0.98**

Length at first maturity was determined as 17.6 cm TL for males and 16.7 cm TL for females. The previous results on length at first maturity was determined by Vassilopoulou and Papaconstantinou (1994) as 12.4 cm for males and 15.1 cm for females; by Kınacıgil et al. (2008) as 12.9 cm for males and 12.0 for females and by Cengiz et al. (2014) as 15 cm for males and 14 cm for females. In some studies, it was identified that male flatfish reach the length at first maturity earlier than females (Roff, 1982; Cengiz et al., 2014). This situation was observed in some studies for *C. linguatula* but was not observed in this study and Kınacıgil et al. (2008)'s study.

Consequently, the knowledge of growth parameters and reproduction biology of fish is a vital tool for evaluating the stock status in a given area. Due to its variable nature, these works should be determined for all species in all independent areas. It could complete the important missing parameters related to the biology of the *C. linguatula* in the Sea of Marmara and provide necessary information to fisheries authorities. And is considered to be the basis for the revision and amendment of regulations regarding the capture and sustainable production. Therefore, this study is thought to fill a gap in this sense.

CONCLUSION

The fisheries management authority can regulate minimum catch length according to L_{50} information if applicable. In Turkey, there is no valid knowledge of the first catch length of *C. linguatula*. According to our L_{50} results, the minimum catch length can be regulated as not less than 17 cm TL for each sex. The fishing mortality and exploitation rate results of this study showed that *C. linguatula* stock in the Sea of Marmara is not in great danger in terms of sustainability. The low values related to fishing mortality against high fishing pressure in the Sea of Marmara are remarkable. According to CPUE values due to distribution depths, *C. linguatula* is mostly distributed in deeper areas. Whereas beam trawls are generally fishing shallower depths than the distribution depths of *C. linguatula*. This situation may cause less exposure to high catch pressure.

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