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Research Article

Age and Growth of European Hake, *Merluccius merluccius* in The Sea of Marmara

Güzin Gül*, Elif Murat-Dalkara, Ahsen Yüksek, Nazli Demirel

İstanbul University, Institute of Marine Sciences and Management, Istanbul, Turkey

*Correspondent: *guzngul@gmail.com*

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Güzin Gül: Orcid 0000-0001-5888-3211, Ahsen Yüksek: Orcid 0000-0003-3004-7443, Elif Murat-Dalkara: Orcid 0000-0002-8757-2532, Nazlı Demirel: Orcid 0000-0003-4542-9276

Abstract: Within this study, the most important species European hake which constitutes 50% of the Sea of Marmara demersal fisheries, has been subjected to estimate age, growth characteristics and natural mortality. Bottom trawl hauls were carried out in 19 stations representing the entire Marmara Sea. Sea surveys were performed in different time periods from 2009 to 2011 (September 2009, December 2009, December 2010 and December 2011). A total of 274 sagittal otoliths (117 females, 75 males and 82 unidentified individuals) were obtained from 2009, 2010 and 2011. Sex ratio was calculated 1:1.5 males to females. Age composition was 0+ to 4+ years, most observed age group was 2+ both for female and male (37%). Growth parameters determined by von Bertalanffy equation were found as L_∞= 57.51 cm K=0.27 y^{-1} and t_0=-0.57 y^{-1}. Natural mortality was estimated 0.41 y^{-1}. Our results obtained from the Marmara Sea strongly support the fast growth hypothesis of *M. merluccius*. Growth rates clearly differ between males and females in this sea which shows hake growth depends on sex.

Keywords: *Merluccius merluccius*, Age, Growth Parameters, Natural Mortality, The Sea of Marmara

Marmara Denizi'nde Berlam Balığının Yaş ve Büyümesi

Özet: Bu çalışmada, Marmara Denizi demersal balık avcılığının %50'sini oluşturan ve stoğu aşırı sömürülmüş berlam türünün (*Merluccius merluccius*) yaş ve büyüme parametreleri, doğal ölüm oranı belirlenmiştir. Farklı 4 zaman diliminde (Eylül 2009, Aralık 2009, Aralık 2010, Aralık 2011) Marmara Denizi'nin genelini yansıtacak 19 istasyonda dip trol çekimleri yapılarak elde edilen 274 adet bireyin sagitta otolitlerinden yaş okumaları gerçekleştirilmiştir (117 dişi, 75 erkek, 82 cinsiyeti belirsiz birey). Erkek dişi oranı 1:1.5 olarak belirlenmiştir. Yaş okumaları sonucunda bireylerin 0+ ile 4+ yaş aralığında olduğu, 2+ yaş grubunun hem dişilerde hem de erkek bireylerde baskın olduğu görülmüştür. von Bertalanffy büyüme parametreleri L_∞= 57.51 cm, K=0.27, y^{-1} t_0=-0.57 y^{-1} olarak hesaplanmıştır. Doğal ölüm oranı 0.41 y^{-1} olarak belirlenmiştir. Elde ettiğimiz bu sonuçlar Berlam'ın hızlı büyüme hipotezini güçlü bir biçimde desteklemektedir. Dişi ve erkek bireylerin büyüme oranındaki farklılık berlamın büyümesinin cinsiyete bağlı olduğunu göstermektedir.

Anahtar Kelimeler: *Merluccius merluccius*, Yaş, Büyüme Parametreleri, Doğal Ölüm Oranı, Marmara Denizi

Introduction

European hake (*Merluccius merluccius* Linnaeus, 1758), mainly distribute eastern coast of Atlantic Ocean including Mediterranean Sea. This species can be found usually between 70 and 370 m depth. Different length groups of European hake distribute in different depth; adults live in deeper waters. Adults mainly feed on fish while juveniles feed on crustaceans (Murua, 2010; Froese and Pauly, 2019). Several studies were carried on its growth characteristics and age estimation in Mediterranean Sea (Figueras, 1967; Iglesias & Dery, 1981; Erzini, 1991; Campillo, 1992; Orsi Relini et al., 1992; Morales-Nin & Aldebert, 1997; Uçkun et al., 2000; Piñeiro & Saínza, 2003; Akalın, 2004; De Pontual et al., 2006; Mellon-Duval et al., 2010; Soykan et al., 2015; Kahraman et al., 2017; Uzer et al.,2019), distribution pattern and stock assessment (Tsangridis et al., 1990; Belcari et al., 2006; Gücü & Bingel, 2011; Yalçın & Gurbet, 2016; Demirel et al., 2017).

European hake is economically important species for large-scale and small-scale fisheries all over the world. Its worldwide catch has been reported as

142190 tons in 2017 (FAO, 2019). As one of the most heavily exploited demersal fish (Soykan et al., 2015), Mediterranean Sea constitutes 15% of European hake's total production (FAO, 2014). Its total catch in Turkey, is 1011.3 for the year 2017 (TUIK, 2018). In the Marmara Sea, its production occupied over 50% percent of demersal fishery. However, its catch started decreasing in mid-2000s and drastically deteriorated below 10% percent in 2017. According to national catch statistics, only 79 tonnes European hake caught in the Marmara Sea (TUIK, 2018). As a demersal species, European hake fisheries is based on trawling. However, trawling has been forbidden by law since 1971 in the Marmara Sea, but beam trawl, beach seine, gillnets, dredge, longline and pots are used in certain part of this sea for fishing demersal species. The minimum landing size (MLS) of *M. merluccius* is regulated at 20 cm for Turkish waters according to the Republic of Turkey's Ministry of Agriculture and Forestry (TCFR, 2016).

The Marmara Sea is a small, enclosed basin that is connected to Mediterranean Sea via Dardanelles and to Black Sea via Istanbul Strait (Bosphorus). The hydrography of the Marmara Sea is dominated by the Mediterranean and Black Seas water. The bottom water is constituted by the Mediterranean waters and the surface water is generated by Black Sea waters (Beşiktepe et al., 1994). The Marmara Sea, is counted the second place in terms of Turkey's fish production after Black Sea despite its smallest area and it constitutes 8% of total fish production (TUIK 2018, Gül & Demirel, 2016).

Here, we aimed to provide age estimation, natural mortality and growth characteristics of an important demersal species, *Merluccius merluccius* from the Sea of Marmara.

Material and Methods

Bottom trawl hauls were carried out in 19 stations between the depths 40 and 100 m representing the entire Marmara Sea. Sea surveys were performed in different time periods from 2009 to 2011(September 2009, December 2009, December 2010 and December 2011) (Figure 1). Commercial bottom trawl net was used for sampling with 30 minutes hauling duration.

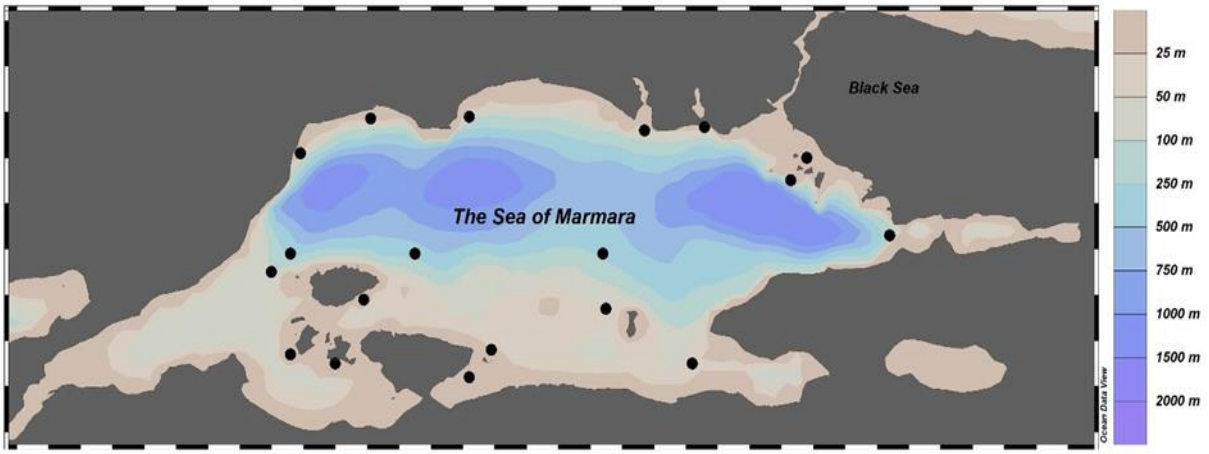

Figure 1. Study area and sampling stations

Total length (TL) and total body weight (TW) were measured to the nearest 0.1 cm and the nearest 0.1 g. For age reading, 274 sagittal otolith (117 females, 75 males and 82 sexual undefined individuals) samples were obtained from 2009, 2010 and 2011 individuals. Age estimates were made by two independent readers who did not previously have knowledge of the size of the fish. Because of the excessive calcium accumulation of their otoliths, it is very difficult to determine the age directly under the binocular microscope. The samples were first polished with 360, 600, and 1000 µm water resistant sandpaper. The age readings of otoliths were carried out by counting opaque and hyaline rings using a binocular microscope with an overhead illuminated microscope on a black ground with glycerin dripped on it. Each annual ring was defined as where the opaque zone meets the translucent zone. The growth parameters of von Bertalanffy were estimated according to Beverton and Holt (1959): $Lt=L_\infty\ (1\text{-}e^{-K(t-t_0)})$ where L_t is the length at age, L_∞ is the theoretical asymptotic length, K is the growth rate coefficient and t_o is the age at length 0. Growth parameters were estimated according to the non-linear method using the FISAT II (FAO-ICLARM Stock Assessment Tools) programme package (Sparre and Venema, 1998).

Natural mortality (M) was calculated by Pauly's (1980) empirical equation:

$$\text{Log (M)} = -0.0066 - 0.279 \log (L_\infty) + 0.6543 \log (K) + 0.4634 \log (T),$$

where M= natural mortality, L_∞ and *k* parameters of von Bertalanffy equation, T is the mean annual temperature (°C) which is assumed to reflect the local temperature and set T = 14.1 °C (Pauly, 1980). The

equation was calculated using the FISAT II program (Gayanilo et al., 1994).

	Male						Female					
TL (cm)	Age											
	0	I	II	III	IV	n	0	I	II	III	IV	n
13	1					1	1					1
14	3	1				4	3	3				6
15		2				2	3	3				6
16		6				6		14				14
17		6	1			7		9				9
18		3				3		10	5			15
19			5			5		2	7			9
20			3			3			10			10
21			4			4			3			3
22			5			5			6			6
23			11			11			1			1
24			2			2			3			3
25			3			3			5			5
26			3			3			2			2
27			3			3			6			6
28			3	2		5			2	1		3
29				2		2			1	1		2
30				1		1				3		3
31				3		3				2		2
32				1		1						
33										1		1
34										1		1
35										5		5
36												
37											1	1
38												
39											2	2
40					1	1					1	1
Total	**4**	**18**	**43**	**9**	**1**	**75**	**7**	**41**	**51**	**14**	**4**	**117**
%	**5.33**	**24**	**57.3**	**12**	**1**	**100**	**5.98**	**35.0**	**43.5**	**11.9**	**3.4**	**100**

Table 1. Age-total key for females and males of European hake from the Sea of Marmara

Results

A total of 275 European hake specimens were evaluated. Sex ratio was calculated 1:1.5 males to females. TL were found between 8 cm and 65 cm while TW were measured between 5 g and 1338 g. A total of 274 sagittal otoliths were used for age determination. Unfortunately, age reading of the largest individual (65 cm) could not be performed due to otolith damage.

Samples were found from 0+ to 4+ years. Most observed age group was 2+ both for female and male (Table 1). For the combined species most observed age group was 2+ (36%) following with 1+ age group (32%), 0+ age group (19%), 3+ age group (10 %), and, 4+ age group (3%) (Figure 2). Growth parameters estimated by von Bertalanffy equation were found as L_∞= 57.5 cm K=0.27 y^{-1}, and t_0=-0.57 y^{-1} for combined species, L_∞= 53.0 cm, K= 0.30 y^{-1}, and t_0=-0.47 for females and L_∞= 44.2 cm, K= 0.38 y^{-1}, t_0=-0.39 for males (Table 2). Natural mortality (M) was estimated 0.41 $year^{-1}$. Also, the K value is related to longevity and it is a good predictor of M, therefore we calculated logM vs. logK to confirm with the other studies results using the FishBase Growth tool (Froese & Pauly 2019) (Figure 3).

Table 2. von Bertalanffy parameters for males (M), females (F) and sexes combined

Sex	n	L_∞	k	t_o	M (y^-)
Combined	274	57.5	0.27	-0.57	0.41
Female	117	53.0	0.30	-0.47	-
Male	75	44.2	0.38	-0.39	-

Discussion

Growth characteristics and age estimations were made for European hake from the Marmara Sea samples obtained in 2009, 2010 and 2011. Population and life history parameters such as M, K, L_∞ are fundamental and given some basic information to ensure assessing the fish stocks status (Hobday et al., 2011; Hordyk et al., 2015). Biological studies that are concerned with life-history parameters of the fish species commonly constitute the first step estimation of the stock assessment (Hordyk et al., 2015). Reported growth parameters of European hake from different parts of Mediterranean are given in Table 3. In the Sea of Marmara, Kahraman et al., (2017) reported that L_∞= 103.9 cm, K= 0.08 $year^{-1}$ and to= -0.92 year, these results are extremely higher than our findings, this may be due to differences in the otolith interpretation and/or different sampling strategy. The asymptotic length (L_∞) is related to the maximum observed length (L_{max}) of the fish. Pauly (1984) suggested that $L_\infty \approx L_{max}/0.95$, this equation means asymptotic length was accepted to be about 5% longer than the observed maximum length. We also observed difference in growth rate between females and males as reported other studies (Table 3). Those differences that males grow faster than females until they are sexually mature but reverse afterwards (Lucio et al. 2000). Many demersal species were noted with reaching larger size with faster growth in females than in males (Landa & Piñeiro, 2000). Reported growth rates vary from one region to another in Mediterranean Sea (Table 3). Our K estimates are very close to those obtained in Strait of Sicily (Ragonese et al., 2004), Saronikos Gulf (Tsangridis et al., 1990; Stergiou & Moutopoulos, 2001) and in eastern Aegean Sea (Akalın, 2004; Soykan et al., 2015).

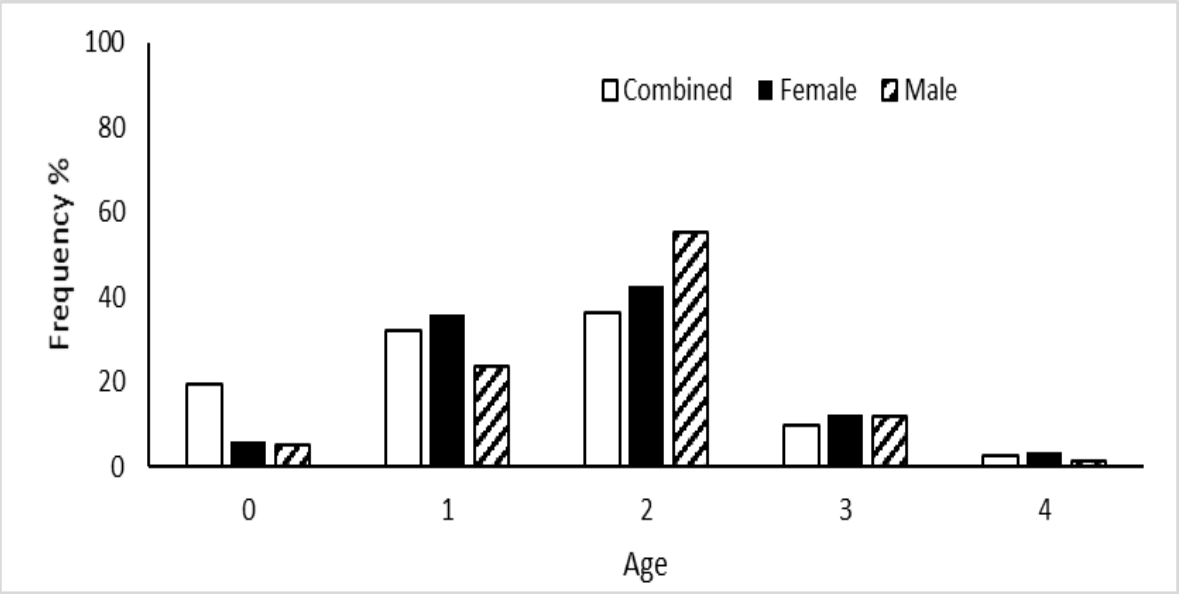

Figure 2. Age distribution of sexes and all individuals of European hake in the Sea of Marmara

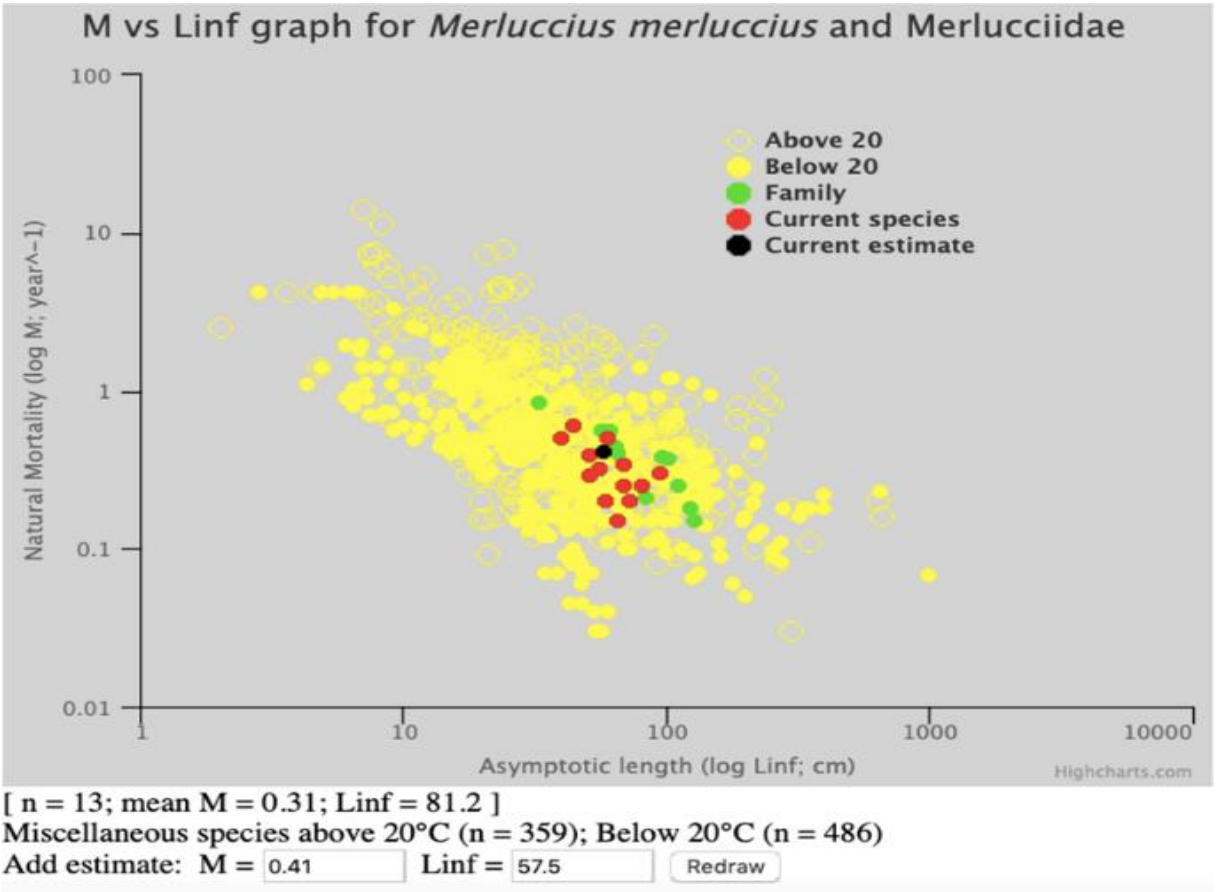

Figure 3. The FishBase graph. Natural mortality *vs* Asymptotic Length. (the values M and L_{inf} at below the graphic are our results and the black dote is mean current estimate with use our results. www.fishbase.org, (08/2019)

However, other Mediterranean areas, values of K reported are almost half of our estimate. This issue can be explained by an absence of older age groups in the sample. It is to say that sampling performed in this study restricted with a well-representative depth range for obtaining larger individuals. The largest fish sampled were limited to 1-2 individuals and considering previous studies the largest recorded value for the Marmara Sea is lower than in the Mediterranean.

In addition, when the stock status of European hake is taken into consideration, Demirel et al. (2017) reported that its stock was under critical level in the Marmara Sea and that large individuals may be subjected to heavy overfishing. In the fisheries studies, the most important value is the natural mortality (M) value of a fish species. This value can also be used as a proxy for sustainable mortality of fishing pressure (F_{msy}) (Froese et al., 2015). The natural mortality calculated using the formula given by Pauly (1980) was found 0.41 y^{-1} that is similar with the recorded value in the FishBase (Froese & Pauly, 2019) electronic database.

The natural mortality rate of the European hake is generally higher than the value given for many bony fish, which is thought to be due to cannibalism (Murua, 2010). Nevertheless, it is considered that the natural mortality rate was found higher in the Marmara Sea. This may be the result of anthropogenic factors such as pollution, habitat loss at a certain level under the effect of intensive urbanization in the Marmara Sea.

Our results obtained from the Marmara Sea strongly support the fast growth hypothesis of *M. merluccius*. Growth rates clearly differ between males and females in this sea which shows hake growth depends on sex. Considering significant collapse in hake catch which is a very important demersal fish source for small scale fisheries in the Marmara Sea, we conclude our findings should be taken into account for the planning of future management strategies in hake fishery in the Marmara Sea.

Table 3. Growth parameters of European hake from various geographic areas

Authors	**Sex**	**L_∞**	**k**	**t_0**	**Area**
Beverton & Holt, 1959	M	44	0.13		Marmara Sea
Beverton & Holt, 1959	F	60	0.10		Marmara Sea
Tsangridis et al., 1990	-	60	0.30		Saronikos Gulf
Campillo A., 1992	M	55.8	0.18	-0.42	Gulf of Lion
Biagi et al., 1994	M	55	0.25		Tyrrhenian Sea
Papaconstantinou et al., 1993	-	65.2	0.10	-0.17	North Aegean Sea
Papaconstantinou & Stergiou, 1995	-	65.9	0.07		Korinthiakos Gulf
Papaconstantinou & Stergiou, 1995	-	59.8	0.15	-1.6	Evvoikos Gulf
Tursi et al., 1996	F	62	0.19	-0.39	Ionian Sea
Uçkun et al., 2000	-	81.7	0.09	-1.16	Aegean Sea
Stergiou & Moutopoulos, 2001	-	60	0.30		Saronikos Gulf
Stergiou & Moutopoulos, 2001	-	63.8	0.08		Patraikos Gulf
Stergiou & Moutopoulos, 2001	-	104	0.08	-1.82	Aegean Sea
Pineiro & Sainza, 2003	-	70	0.18	-0.97	Spain
Ragonese et al., 2004	-	49.4	0.29	0.01	Strait of Sicily
Akalın, 2004	F	53.5	0.39	-0.08	Aegean Sea
Akalın, 2004	M	47.4	0.35	-0.11	Aegean Sea
Ligas et al., 2011	F	92.20	0.13	-	Tyrrhenian Sea
Ligas et al., 2011	M	53.20	0.22	-	Tyrrhenian Sea
Soykan et al., 2015	-	54.5	0.32	-0.22	Aegean Sea
Kahraman et al., 2017	F	106.36	0.08	-1.09	Marmara Sea
Kahraman et al., 2017	M	102.43	0.09	-0.82	Marmara Sea
Kahraman et al., 2017		103.9	0.08	-0.92	Marmara Sea
Uzer et al., 2019	F	102.3	0.09	-1.31	Northern Aegean
Uzer et al., 2019	M	88.54	0.10	-0.99	Northern Aegean
Uzer at al., 2019	-	102.6	0.09	-0.08	Northern Agean
Present study	-	57.5	0.27	-0.57	Marmara Sea
Present study	F	53.0	0.30	-0.47	Marmara Sea
Present study	M	44.2	0.38	-0.39	Marmara Sea

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