

Growth characteristics of the European hake, *Merluccius merluccius* (Linnaeus, 1758), inhabiting northeastern Mediterranean

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In this study, the age and some growth characteristics of the European hake, Merluccius merluccius, from the northeastern Mediterranean were examined during 2015-2016 fishing season. A total of 661 European hake ranging from 9.8 to 51.6 cm in total length was captured by commercial trawler. Female/male ratio was 1/1.15. Age determination was conducted using the sagittal otoliths. Ages of examined individuals ranged from 1 to 7 years. The von Bertalanffy growth parameters fitted to the average measured total lengths-at-age for each sex separately and estimated as $L_{\infty} = 93.98$ cm, $k = 0.114$ year⁻¹, $t_0 = -0.597$ year for females, as $L_{\infty} = 77.65$ cm, $k = 0.153$ year⁻¹, $t_0 = -0.343$ year for males and as $L_{\infty} = 84.44$ cm, $k = 0.135$ year⁻¹, $t_0 = -0.469$ year for combined sexes. The growth performance value (Φ) of the European hake population was computed as 2.98 for combined sexes. Mean condition factor value for population was 0.654 ± 0.021 ; the highest condition factor was found as 1.01 in fish at age 7.

Key words: European hake, *Merluccius merluccius*, age, growth, northeastern Mediterranean, condition factor

INTRODUCTION

The European hake *Merluccius merluccius* (Linnaeus, 1758) is a demersal and bathypelagic fish inhabiting muddy substrates, from 100 to 1000 m (GOLANI *et al.*, 2006). It is known as Atlanto-Mediterranean and is distributed from Norway and Iceland to Mauritania. European hake is an important commercial species in the European Union and Turkey (SOYKAN *et al.*, 2015). European Hake is declining due to fishing pressure from commercial fisheries in the eastern Mediterranean and declines were greater

than 30% over the past 20-40 years based on reported FAO landings (FAO, 2017). According to SOYKAN *et al.*, (2015) European hake is among the most heavily exploited fish species in the western European demersal fisheries and in Turkish Seas. Landings of *M. merluccius* in Turkish seas have declined from 20.810 tons in 2001 to 706 tons in 2015 (TUIK, 2015). Unfortunately, biological data pertaining to *M. merluccius* within this region is extremely limited. However, published studies on age and growth in the northeastern Mediterranean Sea are not currently available. Only information on its distribution and length-

weight relationships (BAŞUSTA & ERDEM, 2000; SANGÜN *et al.*, 2007; GIRGIN & BAŞUSTA, 2016) is available.

The aim of the current study is to give information on growth characteristics and condition factor of European hake from northeastern Mediterranean Sea.

MATERIAL AND METHODS

European hake specimens were captured by commercial trawler (FV-Nihat Baba) from northeastern Mediterranean (36°07'148 N-035°17'978 E, 36°13'720 N-035°22'998 E) (Fig. 1). Fish sampling took place May 2015 and June 2016 at depths ranging from 200 m to 380 m. A total of 661 *M. merluccius* were sampled during the study period. Fish specimens were transferred to ecophysiology laboratory, Faculty of Fisheries in Firat University. Total length (TL) was measured to the nearest 0.1 cm and total weight (W) was weighted to the nearest 0.01 g. Sex of the fish specimens was determined by macroscopically examining of gonads.

Whole sagittal otoliths were used for age determination (Fig. 2). However, some otoliths, which were hard to read because of calcium deposition on their surfaces, were prepared for age determinations by sectioning, sanding and polishing (SOYKAN *et al.*, 2015). For this, the otoliths were embedded in epoxy resin with hardener, cut by Ray Tech gem saw and polished with sandpaper (types 400, 800 and 1200) (METIN & KINACIGIL, 2001) and age determination was applied on these sectioned otoliths. Opaque and transparent rings were counted; 1 opaque zone and 1 transparent zone together were considered 1 annual ring (TURKMEN *et al.*, 2005). The otolith sections were photographed using Leica S8APO brand microscope with Leica Application Suit (Ver. 4.8.0) software. The otoliths parameters such as length and width were measured using Digimizer image analysis software (Ver. 4.8.0) program.

The index of the average percentage error (IAPE) was used to assess the precision of the age determinations between two independent age readers. The equation of IAPE is defined as



Fig. 1. *Merluccius merluccius* sampling area in the north-eastern Mediterranean Sea

follows: $IAPE = 1/N \sum (1/R) \sum (x_{ij} - x_j/x_j)$; where N is the number of fishes aged, R is the number of times each fish was aged, 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 & FOURNIER, 1981).

The von Bertalanffy growth curve function (VBGF) was fitted to the data with the following model $TL_t = TL_{\infty}[1 - e^{-k(t-t_0)}]$ (Von Bertalanffy, 1938). TL_t is the expected total length at age t years. TL_{∞} is the asymptotic average maximum total length, k is the growth coefficient, and t_0 is the theoretical age at zero length.

In order to compare L_{∞} and k with those estimated by other authors for the same species, the growth performance index (Φ) was used, ($\Phi = \ln(k) + 2 \times \ln(TL_{\infty})$) where k and TL_{∞} are the von Bertalanffy growth parameters (PAULY & MUNRO, 1984).

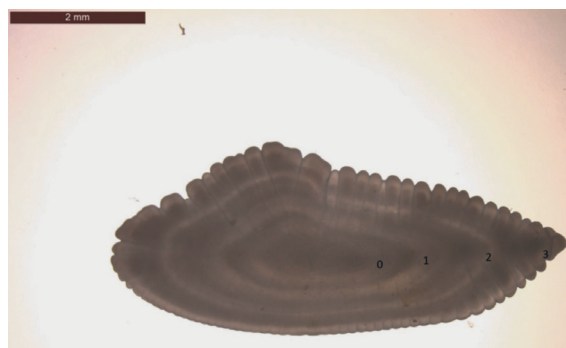


Fig. 2. Sagittal otolith from *M. merluccius* (30.1 cm TL) and estimated to be 3 age

The absolute length growth (ALG) and the relative length growth (RLG) of fish were computed to RICKER (1975): $ALG = L_n - L_{n-1}$; $RLG = (L_n - L_{n-1} / L_{n-1}) * 100$, where L_n is total length at the start of the time interval, and L_{n-1} is total length at the end of the time interval.

The values of condition factor were obtained with the formula $K = (W / TL^b) * 100$, where W is total weight; TL is total length and b is the coefficient of allometric of relationship (LE CREN, 1951).

Student's t-test was used in order to test differences in total lengths between the sexes.

RESULTS

Total 661 individuals of *M. merluccius* (308 female, 353 male) were collected during the study. The female to male ratio was 1/1.15. Females ranged between 9.8 to 51.3 cm in total length and 4.96-1430.00 g in weight and males ranged between 8.1 to 51.6 cm in total length and 2.60-1726.00 g in weight. The longest female and male measured at 51.3 and 51.6 cm in TL, respectively, and their ages ranged from 1 to 7 years. There were no significant differences in total lengths between males and females (t-test, $P < 0.05$).

The total length-frequency distribution according to sexes combined is given in Fig. 3. The results showed that most of the individuals were in age group 1 (Table 1).

The index of the average percent error (IAPE) was found by two independent readers that were

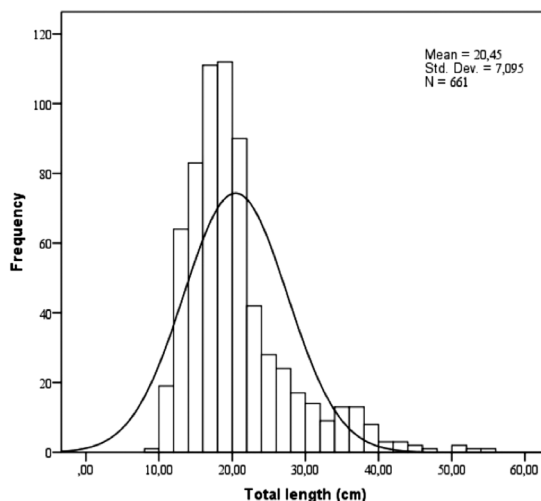


Fig. 3. Total length frequency of *M. merluccius* from north-eastern Mediterranean

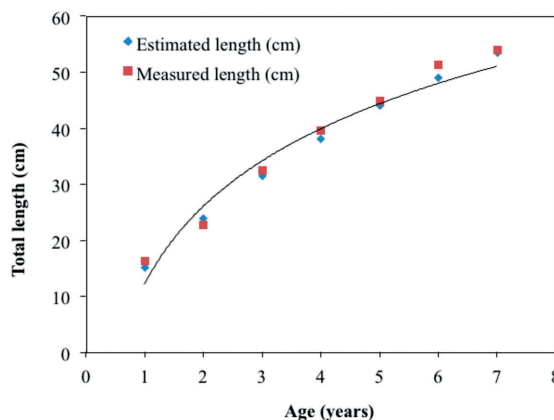


Fig. 4. Age-total length relationship of *M. merluccius* from northeastern Mediterranean

Table 1. Average total length and weight at age for *M. merluccius*, sexes combined.

Age groups	N	Average total length (cm)	Size range (cm)	Average total weight (g)	Weight range (g)
1	407	16.37	10.20 – 19.80	30.49	5.26 - 79.88
2	171	22.88	19.20 - 28.80	88.04	35.33 – 230.00
3	60	32.64	28.00 – 37.80	272.36	108.92 - 462.44
4	15	39.70	36.30 - 44.80	465.47	205.75 – 796.63
5	4	44.90	43.50 – 47.00	704.75	617.00 - 818.00
6	2	51.45	51.30 - 51.60	1202.00	1030.00 – 1374.00
7	2	54.00	53.00 – 55.00	1578.00	1430.00 - 1726.00

Table 2. von Bertalanffy growth parameters for *M. merluccius*

Region	Sex	L_{∞}	k	t_0	n	Φ	References
Izmir Bay (Central Aegean Sea, Turkey)	All	54.53	0.315	-0.223	2108	2.97	Soykan <i>et al.</i> , 2015
Edremit Bay (North Aegean Sea)	Female	53.50	0.385	-0.08	-	3.04	Akalin, 2004
	Male	47.40	0.349	-0.11	-	2.90	
	All	53.90	0.377	-0.05	2375	3.04	
Aegean Sea	All	81.70	0.08	-1.16	336	2.75	Uçkun <i>et al.</i> , 2000
Evoikos (Greece)	All	59.80	0.15	-1.60	-	2.71	Stergiou <i>et al.</i> , 1997
	All	65.20	0.10	-0.17	-	2.64	
North Aegean	All	104.0	0.08	-1.87	-	2.91	
Middle Aegean	Female	103.0	0.07	-1.53	-	2.93	
Thermaikos Bay	Male	117.0	0.06	-1.57	-	2.89	
Northern Tyrrhenian Sea	Female	92.20	0.131	-0.615	958	3.04	Ligas <i>et al.</i> , 2011
	Male	53.30	0.224	-0.974	753	2.80	
Gulf of Alicante	Female	108.0	0.21	0.115	-	3.42	Garcia-Rodriquez & Esteban, 2002
	Male	93.00	0.20	-0.091	-	3.24	
	All	108.0	0.21	0.12	41461	3.39	
Atlantic Coast of Iberia (Spain)	Female	89.00	0.13	-1.15	469	3.01	Pineiro & Sainza, 2003
	Male	70.00	0.18	-0.97	315	2.95	
Bay of Lion (France)	Female	80.20	0.11	-0.52	958	2.84	Compillo, 1992
	Male	55.80	0.18	-0.42	753	2.75	
Bay of Biscay	All	89.90	0.36	-	-	3.46	de Pontual <i>et al.</i> , 2006
Marmara Sea (Turkey)	Female	106.36	0.08	-1.09	341	2.96	Kahraman <i>et al.</i> , 2017
	Male	102.43	0.09	-0.82	192	2.83	
	All	103.9	0.08	-0.92	767		
Northern Aegean (Turkey)	Female	102.3	0.09	-1.31	708	2.97	Uzer <i>et al.</i> , 2019
	Male	88.54	0.10	-0.99	1126	2.93	
	All	102.6	0.9	-0.80	1834	3.01	
Marmara Sea (Turkey)	Female	53.0	0.30	-0.47	117	-	Gül <i>et al.</i> , 2019
	Male	44.2	0.38	-0.39	75	-	
	All	57.5	0.27	-0.57	193		
North-eastern Mediterranean (Turkey)	Female	93.98	0.114	-0.597	316	3.00	This study
	Male	77.65	0.153	-0.343	356	2.96	
	All	84.44	0.135	-0.469	672	2.98	

Table 3. Age-total length structure of *M. merluccius*

Lengths (cm)	Age Classes								Total
	I	II	III	IV	V	VI	VII		
≤10	F	1							
	M								
10.1-14	F	27							
	M	59							
14.1-18	F	94							
	M	109							
18.1-22	F	59	41						
	M	55	42						
22.1-26	F	3	25						
	M		37						
26.1-30	F		7	8					
	M		18	6					
30.1-34	F		1	12					
	M			10					
34.1-38	F			16	3				
	M			8					
38.1-42	F				8				
	M				2				
42.1-46	F				2	1			
	M					2			
46.1-50	F					1			
	M								
>50	F						1	1	
	M						1	1	
Combined sexes	N	407	171	60	15	4	2	2	661
	N%	61.57	25.87	9.08	2.27	0.61	0.30	0.30	100.00
	Mean TL (cm)	16.37	22.88	32.64	39.70	44.90	51.45	54.00	
	SD	2.58	2.49	3.02	2.35	1.68	0.21	1.41	
Female	N	181	74	36	13	2	1	1	308
	N%	27.38	11.20	5.45	1.97	0.30	0.15	0.15	46.60
	Mean TL (cm)	16.78	22.67	32.85	39.82	46.25	51.30	53.00	
	SD	2.40	2.43	2.98	2.52	1.06	0.00	0.00	
Male	N	226	97	24	2	2	1	1	353
	N%	34.19	14.67	3.63	0.30	0.30	0.15	0.15	53.40
	Mean TL (cm)	16.04	23.05	32.33	38.95	43.55	51.60	55.00	
	SD	2.68	2.54	3.10	0.07	0.07	0.00	0.00	

Table 4. Average condition factors, absolute growth and relative growth values of *M. merluccius*

Age Groups	Condition Factors	Absolute Growth	Relative Growth (%)
1	0.63		
2	0.70	6.51	39.80
3	0.76	9.76	42.64
4	0.73	7.06	21.63
5	0.78	5.20	13.10
6	0.88	6.55	14.59
7	1.01	2.55	4.96
Average±SD	0.784±0.047		

oblivious of each other. IAPE was found as 5.22 % for *M. merluccius*.

In this study, the von Bertalanffy growth equation (VBGE) was estimated to be $TL_t=84.44[1-e^{-0.135(t+0.469)}]$ taking all specimens (Fig. 4), $TL_t=93.98[1-e^{-0.114(t+0.597)}]$ for females and $TL_t=77.65[1-e^{-0.153(t+0.343)}]$ for males by considering the total length of fish based on the population of *M. merluccius* found in the northeastern Mediterranean (Tables 2 and 3). According to the VBGE, calculated lengths were found similar to measured lengths.

The maximum absolute growth and relative growth rate in *M. merluccius* were calculated as 9.76 cm and 42.64 % between 2 and 3 age groups, respectively. After age 3, both absolute and relative growth started to decrease by increasing of age. The least growth was appeared between 6 and 7 age groups with 2.55 cm absolute growth and 4.96% relative growth rate (Table 4).

The growth performance value (Φ) of the European hake population was calculated as 2.98 for combined sexes, 3.0 for females and 2.96 for males.

The condition factor of *M. merluccius* was calculated for all age groups and is presented (Table 4). Mean value and standard deviation (SD) of the condition factor of the population

was 0.784±0.047 and the highest value was found as 1.01 in age group 7.

DISCUSSION

There is no information on the growth studies for European hake in the northeastern Mediterranean. The lack of biological information hinders implementation of fishery management strategies for European hake in the northeastern Mediterranean Sea. Our data showed that males are more numerous than females (1.15/1). GÜL *et al.* (2019) reported the male to female ratio as 1/1.15 from the Sea of Marmara. This may be due to differences in the sampling time periods that were performed in different years. GRINOLS & TILLMAN (1970) reported that in spawning *Merluccius productus* schools, the sex ratio favors males and may be twice that of non-spawning schools.

Sagittal otoliths were read at least twice to confirm the age estimations by independent age readers. Index of APE value (5.22 %) was within acceptable limits. In this study, the age range of the fish samples was 1-7 years old. The highest age for this species was firstly recorded in Turkish seas in this study.

The maximum total length (51.6 cm) in our study were more than those of reported (TL,

43.5 cm and 45.5 cm) from the Central Aegean Sea by UÇKUN *et al.* (2000) and SOYKAN *et al.* (2015) respectively.

There have been some scientific researches on the growth parameters of the European hake (Table 2), and these parameters were found as L_{∞} = 84.44 cm, k = 0.135 year⁻¹, t_0 = -0.469 year for combined sexes in the present study. The longest asymptotic length (L_{∞}) was estimated for Turkish Seas in this study (Table 2). L_{∞} value for females (93.98 cm) was relatively greater than that for males (77.65 cm), indicating that the females grew relatively faster than the males. These values relatively agree with many estimated parameters from the western Mediterranean and other areas. According to BECKMAN & WILSON (1995), these differences could be attributed to the different fishing area and dependent on both abiotic and biotic environmental factors. Males were found longer and heavier than females and the Brody growth coefficient (k) was higher in males than that in females.

The growth performance values (Φ) of the other studies from different areas ranged between 2.64 and 3.46 (Table 2), and show similarities especially with the findings of other studies. There was no statistically significance between our growth performance value and the values in other studies (t -test; $P > 0.05$).

Studies on the growth and condition factor of *M. merluccius* is very scarce in the eastern Mediterranean and so more studies should be done to establish their stock availability. Thus, information on growth parameters and condition factor of European hake in the north-eastern Mediterranean was firstly found out during 2015-2016 fishing season in this study. According to relative growth values, growth rate decreases after 2 years old. Size range in 2 years old is between 19.20 and 28.8 cm (average 22.88). It is evaluated that the minimum length limit for fishing should be 23 cm. UZER *et al.* (2019) reported that the minimum landing size in the Turkish waters should be increased from 20 cm to 25 cm to ensure at least single breeding of *Merluccius merluccius*. These values are very close to our findings. These results can be used as biological parameters in further stock evaluations in this region.

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Značajke rasta oslića, *Merluccius merluccius* (Linnaeus, 1758.), u sjeveroistočnom dijelu Sredozemnog mora

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SAŽETAK

U ovom radu istraženi su starost i neke značajke rasta oslića, *Merluccius merluccius*, u sjeveroistočnom dijelu Sredozemnog mora, tijekom ribolovne sezone 2015-2016.

Kočom je ukupno ulovljeno 661 jedinka oslića čija je ukupna duljina kolebala u rasponu od 9,8 do 51,6 cm. Omjer između ženki i mužjaka je iznosio 1:1,15. Procjena starosti je provedena pomoću očitavanja sagitalnih otolita. Starost jedinki se kretala u rasponu od 1 do 7 godina.

Parametri rasta prema von Bertalanffy-jevoj jednadžbi prilagođeni su prosječno izmjerenim ukupnim duljinama po starosti za svaki spol odvojeno i procijenjeni kao $L_{\infty} = 93,98$ cm, $k = 0,114$ godina⁻¹, $t_0 = -0,597$ godina za ženke, te kao $L_{\infty} = 77,65$ cm, $k = 0,153$ godina⁻¹, $t_0 = -0,343$ godina za mužjake i $L_{\infty} = 84,44$ cm, $k = 0,135$ godina⁻¹, $t_0 = -0,469$ godina za oba spola.

Vrijednost rasta (Φ) u populaciji oslića izračunata je kao 2,98 za oba spola. Srednja vrijednost kondicijskog čimbenika populacije iznosila je $0,654 \pm 0,021$; najveći utvrđeni kondicijski čimbenik iznosio je 1.01 kod riba u dobi od 7 godina.

Ključne riječi: oslić, *Merluccius merluccius*, starost, rast, sjeveroistočno Sredozemlje, kondicijski čimbenik

