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RESEARCH PAPER

Age, Growth and Mortality of Whiting (*Merlangius merlangus* Linnaeus, 1758) from the Western Black Sea, Turkey

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Abstract

The aim of this study was to determine the age and growth, length–weight relationship, sex ratio and mortality rates of the whiting, *Merlangius merlangus*, in the western Black Sea coast of Turkey. On-board sampling was conducted on the commercial bottom trawl fishery from October 2012 to April 2014. Total length ranged from 6.0 to 25.9 cm, while weight varied between 1.6 and 135.54 g. *M. merlangus* has a lifespan of 5 years using the ground otoliths reading, but over 60% of fish consisted of 1 and 2 years old. The growth parameters were L_∞=37.05 cm, k=0.10 year-1, and to= -1.63 year for pooled data. Total, natural and fishing mortality were Z=1.19 year–1, M=0.37 year–1 and F=0.82 year-1 respectively according to age-structured analysis. The exploitation rate, E=0.69 year-1, exposed a high fishing pressure on the whiting stock in the studied area. It is believed that this study provides deeper and new conclusions for the management of whiting stock in the western Black Sea.

Introduction

The whiting, *Merlangius merlangus* Linnaeus, 1758, is bento-pelagic fish belonging to the gadidae family. It has a widespread distribution throughout the Black Sea, the Azov Sea, Sea of Marmara, Aegean Sea and Adriatic (Whitehead, Bauchot, Hureau, Nielsen, & Tortonese, 1986). In the Black Sea, the whiting is one of the most abundant species among the demersal fishes (STCEF, 2012), thus the Black Sea whiting has been defined a key species for the basin ecosystem (Bradova & Prodanov, 2003). Not surprisingly, whiting is one of major commercial importance as a fishery resource in Turkey (Saglam & Saglam, 2012) and Turkey is the only country in the region, where the annual target trawling fisheries for this fish has been conducted (STCEF, 2014). 92.1% of landed whiting is obtained from Black Sea coasts of Turkey. Trawl fishery are responsible for 82.1% of total landings, and gill nets were also used in whiting fishery especially in the middle and eastern parts of Turkish coasts (Zengin, Genç, & Tabak, 1997). According to the long term official data, minimum landings were recorded as 6637 t in 2005 while the maximum as 20326 t in 1996. In 2015, total whiting catch was 7133.1 and 5478.4 tons for the Black Sea (TUIK, 2016).

The whiting biomass reached a peak of 48930 tons in 1978 and declined to the point of 73000 tons in 1990 in the northern Black Sea (Prodanov *et al*., 1996). In further, İşmen (2002) calculated the whiting biomass in the western Black Sea was 2881 tons and significantly obtained from the 50-100 m depth range.

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It has a relatively low market value, however, the volume landed can be assumed abundant year round means that it is the most economically valuable component of mixed demersal fisheries in the Black Sea.

Studies conducted around the Turkish Black Sea coast are on the distribution, abundance and stock assessment of whiting (Düzgüneş & Karaçam, 1990; Erkoyuncu, Erdem, Samsun, Özdamar, & Kaya, 1994; Samsun, 1995; İşmen, 1995; Bingel *et al*., 1996; Aydın, 1997; Şahin & Akbulut, 1997; Genç *et al*., 1998; Samsun & Erkoyuncu, 1998; Genç *et al*., 2002; Samsun, 2005; Kalaycı, Samsun, Bilgin, & Samsun, 2007; Bilgin, Bal, & Taşcı, 2012). These earlier studies on biology, distribution and population parameters of whiting in the Black Sea were mainly carried out in eastern part of Turkish Black Sea coast. However, the data on population dynamical parameters of whiting for the western Turkish Black Sea coast are scarce for last two decades. Accordingly, the exploitation status of the stocks is unknown for the western coasts of Turkey. The aim of this study is to describe age and growth, and mortality rates of *M. merlangus* in the western Black Sea.

Materials and Methods

Sampling Area and Data Collection

Monthly biological data were collected during commercial trawl operations conducted from October 2012 to April 2013 and from October 2013 to April 2014 in the İğneada and Rumelifeneri localities on the western Black Sea coast of Turkey. İğneada locates the Bulgarian border of Turkey while Rumelifeneri is in the Black Sea exit of the Istanbul Strait. The structural characteristics of the traditional type of bottom trawl nets are the same in both regions and have an asymmetric structure with a low opening and cod-ended by a rhomboid shape and 40-mm mesh. Fishing depth covers between 29 and 90 meters.

Data Analyses

4003 whiting individuals were measured for total length (0.1 cm), weight (0.01 g) and sexed in the Fishery Biology Laboratory of Faculty of Aquatic Sciences, Istanbul University. A Fish measuring board and electronic balance was used to measurements. Sex

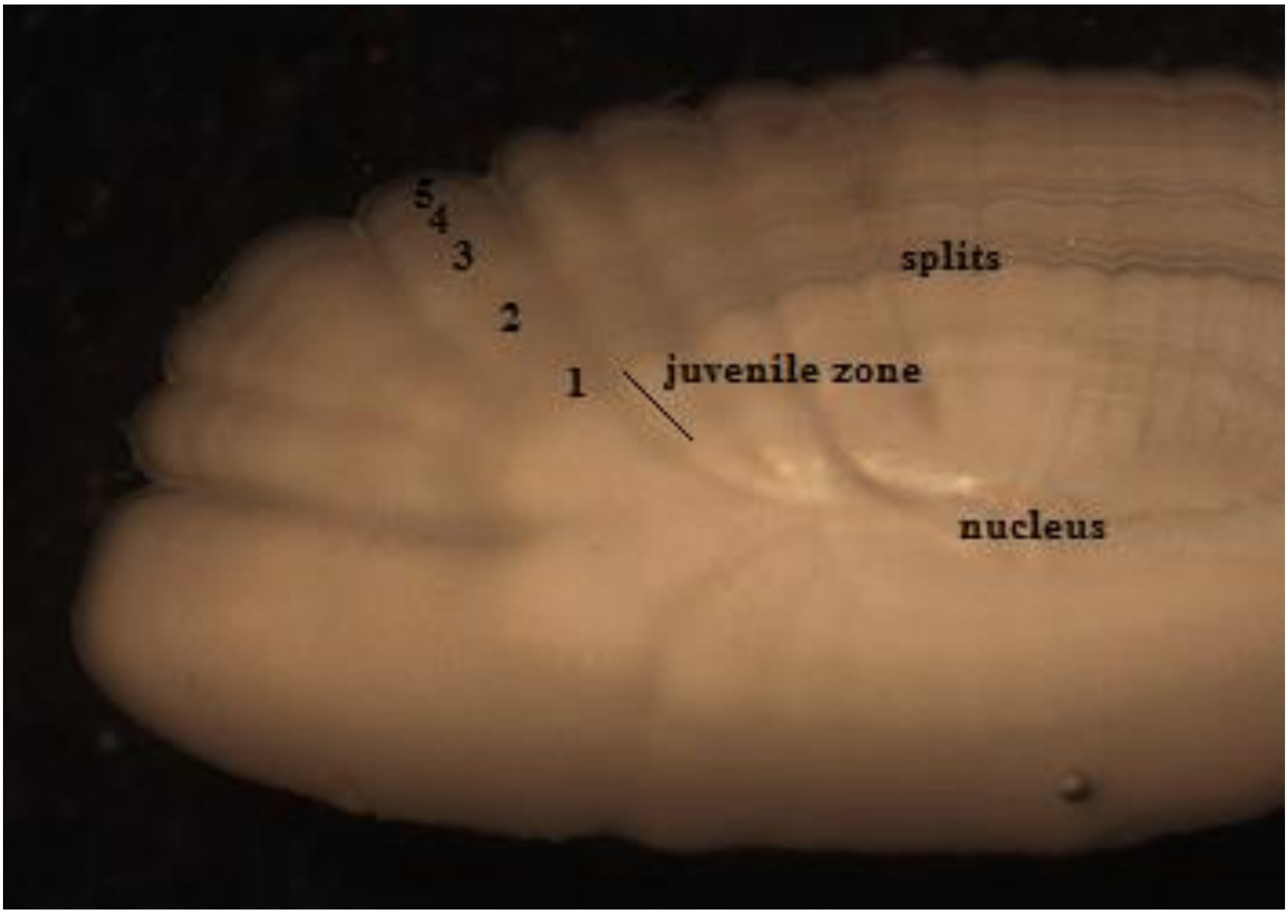

Figure 1. Ageing by ground otolith of *M. merlangus*.

were macroscopically assigned according to a macroscopic visual scale. Individuals that could not be sexed were recorded as unidentified. The Chi-square test was used to compare sex ratios from the expected 1:1 (♂/♀) ratio (Sümbüloğlu & Sümbüloğlu, 2005).

Length-Weight Relationship

The length-weight relationship, represented by the formula $W = a\ TL^b$ (Ricker, 1975) was log transformed into the following: In W = In q + b (In TL). Student's t-test was used to determine if the coefficient b was significantly different from 3 (Zar, 1999). A one-way ANCOVA was used to determine if there were significant differences in the length-weight relationships between the sexes.

Age Estimation

All the sampled fishes were grouped into size classes of 1 cm. Then, sagittal otoliths were removed by 10 individuals (if possible) for each length classes. Age of 1699 individuals was assessed by two readers through otolith readings without referring to information except the date of capture. As whiting grow larger, calcium carbonate is accumulated around the nucleus, inhibiting the visibility of the 1st and possibly also 2nd winter ring (Ross & Hüssy, 2013). Hereby, otoliths were ground manually with two different abrasive papers (35.0 µm and 25.8 µm median diameter) to clarify the first annulus (Figure 1). Then, ground otoliths were immersed in glycerine in a petri dish with a black background and observed under incident light in a stereoscopic microscope. Annuli were counted from the core outwards with a special attention to remark the juvenile/settling zone. To be able to judge the juvenile/settling zone directions of Ross & Hüssy (2013) followed: (a) The juvenile zone was only visible in the ground otoliths and was narrower than the winter rings; (b) as the juvenile zone appeared close to the nucleus (approximately 1500 lm). Each annulus was defined as where the opaque zone meets the translucent zone on the basis of a 1 January theoretical birthday by using an image analysis system (Leica DFC295 camera attached to a Leica S8APO stereomicroscope with LAS software). If the fish was captured; (a) before January 1st, the translucent edge is not counted (b) After January 1st, the translucent edge is included in the count.

Growth Parameters

The von Bertalanffy growth parameters calculated by the Least Square method was used to describe the growth of whiting for male, female and all (Avşar, 2005); $L_{(t)}=L_\infty(1-e^{-k(t-to)})$ where L_t is the total length as

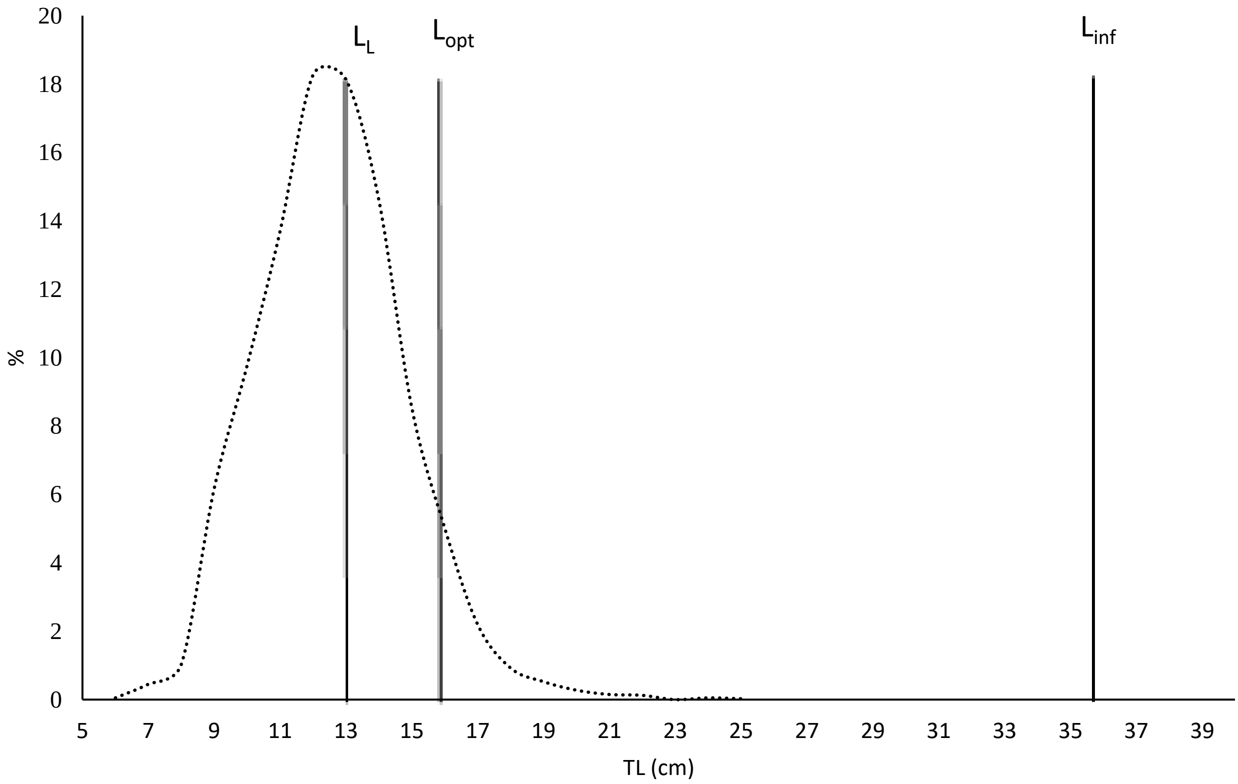

Figure 2. Total length–frequency data of *M. merlangus* with indication of L_L (Minimum landing size), L_{opt} and L_{inf}

cm at-age t, K is the Brody's growth coefficient as yr^{-1}, L_∞ is the asymptotic length as cm, and t_0 is the theoretical age as yr at length zero. For the growth in weight, the same function was used: $W_{(t)}=W_\infty(1-e^{-k(t-t_0)})^b$, where W_t is the total weight (g) at age t, W_∞ is the asymptotic weight (g) and b is the constant of the length-weight relationship. In order to facilitate the comparison of the results with those of other studies, growth performance index (Φ') was estimated by the Pauly & Munro's (1984) equation: Φ'= log (k) + 2log (L_∞). The length L_{opt} at which the total biomass of a year-class reaches a maximum value was derived from growth parameters as $L_{opt} = L_\infty * [3 / (3 + M/K)]$ according to Froese (2004). Arguably, the body length L_{opt}, where the biomass of a cohort and its fecundity are maximum, is the most important point in the life of adult fish.

Mortality

Total mortality (Z) was estimated by using the catch curve method recommended by Pauly, Moreau, & Abad (1995). The natural mortality (M) was estimated using Pauly's (1980) empirical equation: log (M) = -0.0066-0.279 log (L_∞) + 0.6543 log (k) + 0.4634 log T °C=16). Natural mortality for per age classes was also estimated following Gislason, Daan, Rice, & Pope, (2010) equation [ln (M) = 0.55 - 1.61 ln (L) + 1.44 ln (L_∞) + ln (K)] by using average total length of age class (1-5), as required by this method. Fishing mortality rate (F) was calculated as F=Z-M. The exploitation rate (E), was computed by dividing F by Z. Total and natural mortality were also estimated by using length converted catch curve method as implemented in ELEFAN I.

Results

Length and Weight Distribution

Fish ranged in size from 6.0 to 25.9 cm, and weighed between 1.60 and 135.54 g. Males ranged between 9.1 and 19.5 cm, and between 5.16 and 59.92 g. Females ranged from 7.8 to 25.9 cm, and from 2.94 to 135.54 g. Optimum length (L_{opt}) was calculated as 16.6 cm however bulk of the individuals ranged below the L_{opt} value (Figure 2). Females dominated size classes higher than 12 cm (mean=13.88±2.05 cm), whereas males (mean=12.88±1.66 cm) were more abundant than females in the lower size classes.

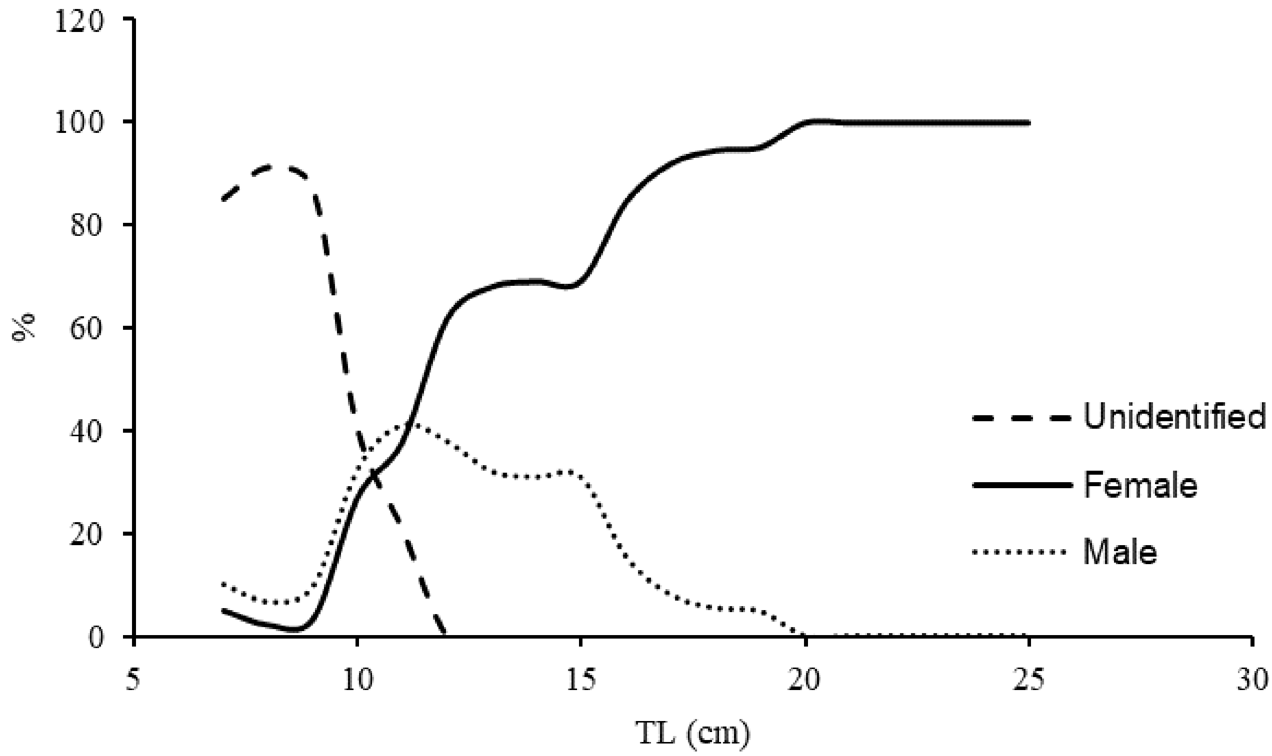

Figure 3. Sex-specific length frequency distribution of *M. merlangus.*

Therefore, almost all the longer specimens were females (20 to 25 cm) (Figure 3).

Length-Weight Relationship

The total length–weight relationships were: for females $W=0.0054\ L^{3.144}$ (N=2215, $r^2=0.954$), for males $W=0.0053\ L^{3.140}$ (N=1193, $r^2=0.952$) and for both sexes $W=0.004\ L^{3.253}$ (N=4003, $r^2=0.969$). The slopes (*b*) of the total length–weight relationships differed significantly between sexes (P<0.05). r^2 value of relations for males, females and sex combined indicate an efficient fit ($r^2>0.95$). The value of b for males, females and sexes combined were significantly different from 3 (P<0.05).

Sex Ratio

Among the fish examined 4003 fishes, 1193 were males, 2215 were females and 595 were unidentified. The sex of the unidentified specimens were not be determined macroscopically as 482 were immature, while 113 were as damaged. The overall sex ratio was 1.85:1 which is highly significantly different from the expected ratio of 1:1 (P< 0.05). Males were dominant during the early ages, but after age of two sex ratio changed in favour of females.

Age Composition

The results of otolith reading are given in Table 1. The bulk of the samples was represented by relatively young fish. According to the frequency of occurrence, age-class 2^+ (33.54%) was dominant followed by age 1^+ (27.78%), 3^+ (25.19%), 4^+ (11.24%) and 5^+ (2.23%) age groups, respectively.

Growth Parameters

The von Bertalanffy growth curve was fitted to observed lengths-at-age for all fish, and separately for each sex. The von Bertalanffy growth model for all whiting sampled from the Black Sea is illustrated in Figure 4. The estimated von Bertalanffy growth constants are: L_∞ = 37.05 cm, K=0.10 yr^{-1}, t_0 = -1.63 yr for pooled data. The calculated value of L_∞ is higher than the maximum observed length in this study.

Mortality

The age frequency distribution of the overall sampled population is presented using a catch curve. Total mortality (Z) was calculated using the descending

Table 1. Age–length key of *M. merlangus* from the south-western coasts of the Black Sea, Turkey between 2012 and 2014

	Age groups					
Total length (cm)	1^+	2^+	3^+	4^+	5^+	Total
6	1					1
7	18					18
8	39					39
9	196					196
10	153					153
11	64	137				201
12	1	234	1			236
13		198	55	1		254
14		1	121			122
15			186	2		188
16			56	79		135
17			9	68		77
18				35		35
19				6	14	20
20					11	11
21					5	5
22					5	5
23						
24					2	2
25					1	1
Total	472	570	428	191	38	1699

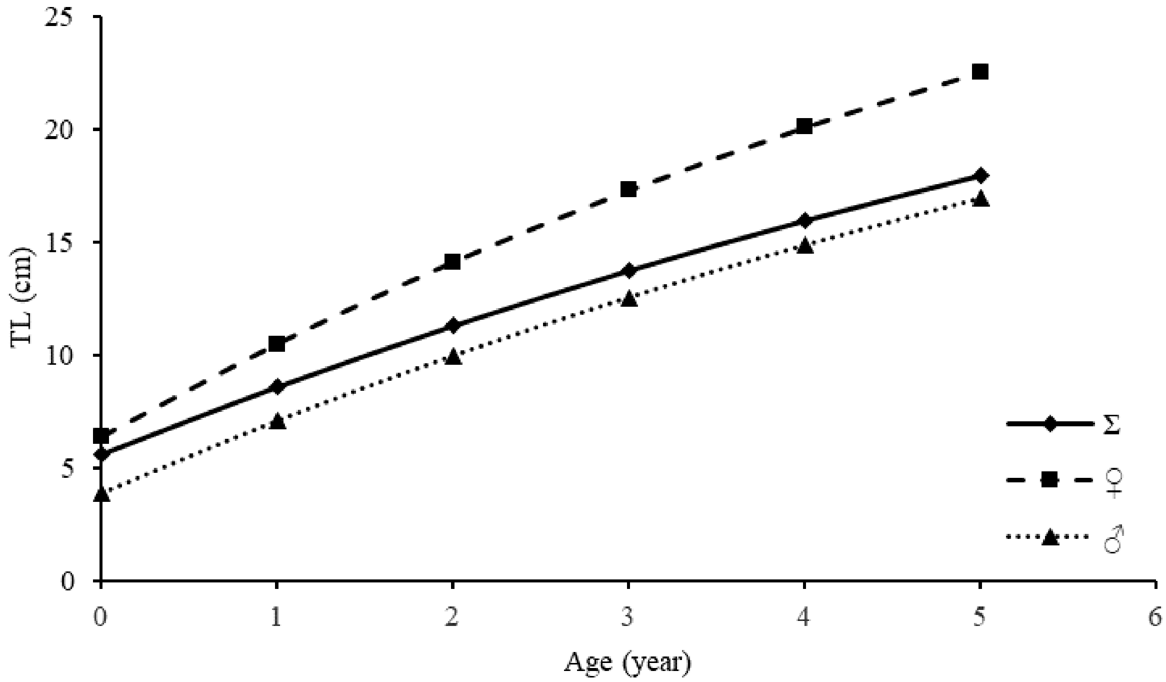

Figure 4. The von Bertalanffy growth curve of all *M. merlangus* samples and their sexes.

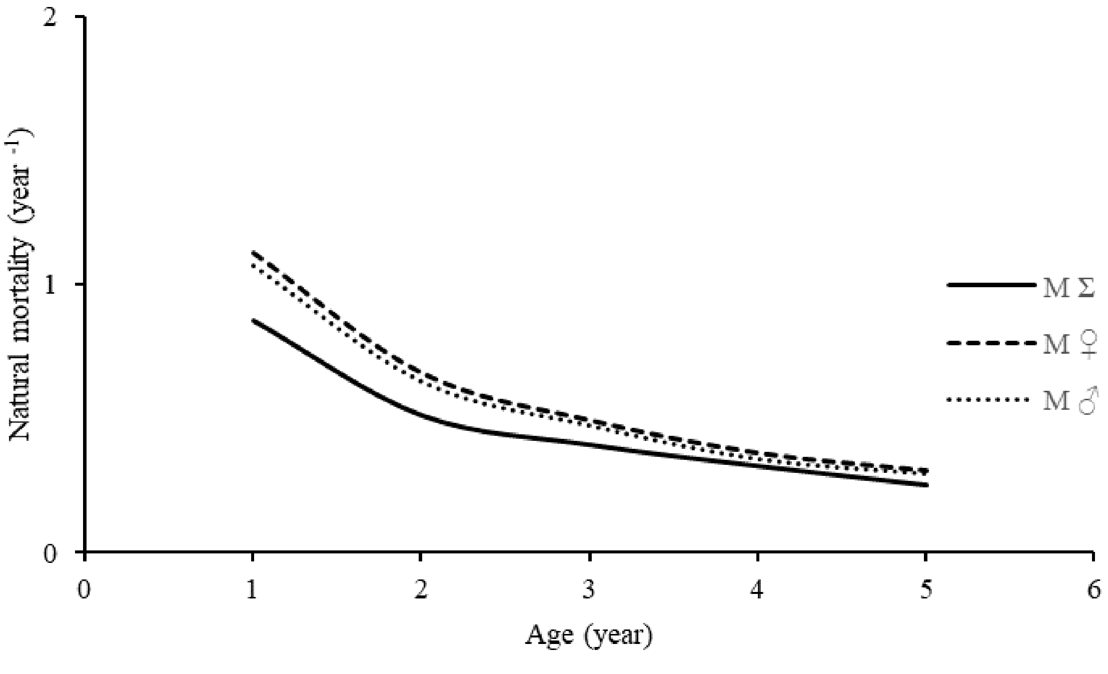

Figure 5. Natural mortality by age in each sex group and their pooled data according to Gislason *et al*. equation (2010).

leg of the catch curve. Z for the overall population was 1.19 yr^{-1}. Total natural (M) was to be 0.37 yr^{-1} according to Pauly (1995) equation and to be 0.86 yr^{-1} for age-1, 0.51 yr^{-1} for age-2, 0.40 yr^{-1} for age-3, 0.32 yr^{-1} for age-4, 0.25 yr^{-1} for age-5 according to Gislason *et al*. (2010) (Figure 5). Fishing (F) mortalities and exploitation ratio (E) were 0.82 $yr^{-1}$and 0.69 yr^{-1}, respectively. Additionally, the length-converted catch curve revealed the instantaneous rates of mortality for all fish were Z=1.24 yr^{-1}, M=0.42 yr^{-1} and F=0.82 yr^{-1}. The exploitation ratio was E = 0.66 yr^{-1} as result of the length-converted catch curve.

Table 2. Sex ratios of *M. merlangus* given by various authors in the Black Sea

Reference	Region	♀	♂	♀:♂	Period
Düzgüneş & Karaçam (1990)	Eastern BS*	71	29	2.44:1	
Samsun *et al*. (1994)	Middle BS*	59.36	40.64	1.46:1	
İşmen (1995)	Whole BS*	57	43	1.33:1	1990-1993
Samsun (1995)	Middle BS*	47.3	52.7	1:1.11	1991-1994
Özdamar & Samsun (1995)	Middle BS*	57.62	42.38	1.36:1	
Şahin & Akbukut (1997)	Eastern BS*	60.96	39.31	1.55:1	
Samsun & Erkoyuncu (1998)	Middle BS*	46.08	53.92	1:1.17	1995-1996
Çiloğlu *et al*. (2001)	Eastern BS*	64.86	35.14	1.85:1	1996
Samsun (2005)	Middle BS*	53.39	46.51	1.15:1	2001-2003
Ak *et al*. (2009)	Eastern BS*	66	34	1.95:1	2007-2008
Radu & Maximov (2013)	Romanian coast	57	43		2010-2011
This study	Western BS*	65	35	1.85:1	2012-2014

Table 3. The length–weight relationships obtained from different areas of the Black Sea for *M. merlangus*

Reference	Region	Period	Sex	Length range	a	b
Düzgüneş & Karaçam (1990)	Eastern BS*		♀		0.0182	2.717
			♂		0.0797	2.220
			Σ	13.2-24.9	0.2721	2.573
Samsun (1995)	Middle BS*	1991-1994	♀		0.0038	3.248
			♂		0.0049	3.182
			Σ		0.0045	3.187
Bingel *et al*. (1996)	Middle and Eastern BS*	1990-1992	Σ		0.0052	3.126
Aydın (1997)	Eastern BS*	1996	Σ	11.0-22.9	0.0039	3.217
Genç *et al*. (1998)	Eastern BS*	1991-1994	♀	6.6-43.2	0.0046	3.181
			♂	6.8-30.5	0.0056	3.111
			Σ	5.6-43.2	0.0052	3.142
Erkoyuncu *et al*. (1994)	Middle BS*		Σ		0.0034	3.300
İşmen (1995)	Whole BS*	1990-1993	♀	5.5-32.5	0.0040	3.255
			♂	6.5-18.8	0.0043	3.225
			Σ	5.5-32.5	0.0042	3.241
Şahin & Akbulut (1997)	Eastern BS*		♀		0.0048	3.151
			♂		0.0054	3.110
Samsun & Erkoyuncu (1998)	Middle BS*	1995-1996	Σ	9.0-24.0	0.0039	3.238
Genç *et al*. (2002)	Eastern BS*	1998-2002	Σ	7.5-25.4	0.0058	3.077
Bradova & Prodanov (2003)	Bulgaria coast	1983-2000	Σ		0.0083	2.930
Samsun (2005)	Middle BS*	2001-2003	♀	8.4-31.5	0.0043	3.196
			♂	8.7-22.9	0.0043	3.193
			Σ	8.4-31.5	0.0042	3.201
Kalaycı *et al*. (2007)	Middle BS*	2004-2005	♀	8.8-22.7	0.0070	3.011
			♂	8.1-22.4	0.0840	2.930
			Σ	8.1-22.7	0.0067	3.024
Maksimov *et al*. (2007)	Bulgaria coast	2007	Σ		0.0050	3.110
Yankova *et al*. (2011)	Bulgaria coast	2006-2008	Σ	5.5-22.5	0.0040	3.151
Bilgin *et al*. (2012)	Eastern BS*	2011-2012	♀	11.1-30.7	0.0050	3.145
			♂	10.8-20.4	0.0120	2.813
Zengin *et al*. (2012)	Middle BS*	200-2011	♀	7.7-23.2	0.0050	3.149
			♂	7.6-18.1	0.0060	3.059
			Σ	5.8-23.2	0.0050	3.172
This study	Western BS*	2012-2014	♀	7.8-25.9	0.0054	3.144
			♂	9.1-19.5	0.0053	3.140
			Σ	6.0-25.9	0.0040	3.253

Table 4. The percentage distribution of age groups for *Merlangius merlangus* in different studies along the Black Sea

Kaynak	Age groups									
	0	1	2	3	4	5	6	7	8	9
Düzgüneş & Karaçam (1990)		6.5	24.9	51.9	14.5	2.2				
Samsun *et al*. (1994)		19.7	37.5	28.9	8.33	4.5	0.5	0.6		
Özdamar & Samsun (1995)		31.4	37.2	21	7.89	1.6	0.5			
Şahin & Akbulut (1997)		31	47.6	16.8	3.3	1	0.2	0.1		
Çiloğlu *et al*. (2001)		36	24	23.7	13.2	2.3	0.4	0.4		0.1
Samsun (2005)	9.43	18.3	41.8	21	7.76	1.4	0.2	0.1		0.1
Özdemir *et al*. (2006)	43.2	40.5	10.1	3.3	2.7					
STECF (2012)/Romania	42.1	46.4	11.5							
STECF (2013)/Romania	12.3	41.9	33.8	8.1	2.8					
Radu *et al*. (2013)/Romania	4	40	46	7	1	2				
This study		27.6	33.4	25.1	11.2	2.2				

Table 5. The von Bertalanffy growth parameters and growth performance index values (Φ') obtained from different areas of the Black Sea for *M. merlangus*

Reference	Study area	Length range		W∞	L∞	K	Φ'
Prodanov (1980)	Western BS		Σ		31.42	0.145	2.15
Düzgüneş & Karaçam (1990)	Eastern BS*	13.2-24.9	Σ	239.00	31.9	0.020	2.32
Samsun *et al*. (1994)	Middle BS*	8.5-40.0	Σ	568.69	40.04	0.148	2.36
Uysal (1994)	Middle BS*		Σ		41.8	0.140	2.38
Samsun (1995)	Middle BS*		Σ		39.73	0.147	2.37
İşmen (1995)	Whole BS*	5.5-32.5	♀		40.4	0.150	2.39
		6.5-18.8	♂		33.5	0.170	2.28
		5.5-32.5	Σ		39.1	0.150	2.36
Bingel *et al*. (1996)	Middle and Eastern BS*		Σ		33.56	0.300	2.52
Şahin & Akbulut (1997)	Eastern BS*	9.0-27.7	♀		45.36	0.101	2.31
		8.8-21.7	♂		35.93	0.124	2.20
Samsun & Erkoyuncu (1998)	Middle BS*	9.0-24.0	Σ		35.45	0.138	2.23
Genç *et al*. (1998)	Eastern BS*	6.6-43.2	♀	736.46	43.26	0.108	2.31
		6.8-30.5	♂	332.75	34.24	0.136	2.20
		5.6-43.2	Σ	720.23	43.74	0.103	2.29
Çiloğlu *et al*. (2001)	Eastern BS*	11-30.4	♀		52.5	0.092	2.40
		11- 25.3	♂		37.2	0.114	2.19
İşmen (2002)	Whole BS*		♀		37.3	0.170	2.37
			♂		29.1	0.160	2.13
			Σ		37.9	0.160	2.36
Genç *et al*. (2002)	Eastern BS*	7.5-25.4	Σ		39.51	0.115	2.25
Bradova & Prodanov (2003)	Western BS		Σ		26.63	0.223	2.19
Özdemir *et al*. (2006)	Middle BS*		Σ		31.33	0.201	2.29
Maximov *et al*. (2007)	Romania		Σ		26.3	0.160	2.04
Raykov *et al*. (2008)	Bulgaria		Σ		29.83	0.157	2.14
	Ukrania		Σ		39.0	0.106	2.20
Samsun (2005)	Middle BS*	8.4-31.5	♀	413.85	39.0	0.114	2.24
		8.7-22.9	♂	284.34	32.29	0.143	2.17
		8.4-31.5	Σ	530.13	39.0	0.115	2.24
This study	Western BS*	7.8-25.9	♀	597.3	40.2	0.111	2.24
		9.1-19.5	♂	350.9	34.8	0.135	2.19
		6.0-25.9	Σ	507.9	37.05	0.106	2.13

*Turkish coast

Table 6. Results of previous studies concerning mortality rates and exploitation rate of *M. merlangus* from different localities in the Black Sea

Reference	Region	Z	M	F	E	Period
Prodanov (1980)	Bulgaria		0.4/0.5			
Düzgüneş & Karaçam (1990)	Eastern BS*	1.41				
Samsun *et al*. (1994)	Middle BS*	1.20	0.29	0.91	0.76	
Samsun (1995)	Middle BS*	2.01	0.29	1.72	0.86	
İşmen (1995)	Whole BS*	2.18	0.43	1.74	0.74	1990
		1.43	0.38	1.05	0.73	1991
		1.29	0.36	0.93	0.72	1992
		1.63	0.39	1.24	0.76	1990-1992
Özdamar & Samsun (1995)	Middle BS*	1.36	0.38	0.98	0.72	
Bingel *et al*. (1996)	Middle and Eastern BS*	4.25	0.58	3.67	0.86	1991
		3.59	0.59	3.00	0.84	1992
Samsun & Erkoyuncu (1998)	Middle BS*	1.15	0.26	0.89	0.77	
Genç *et al*. (1998)	Eastern BS*	1.05	0.23	0.82	0.78	
Genç *et al*. (2002)	Eastern BS*	0.86	0.25	0.61	0.71	
Samsun (2005)	Middle BS*	1.34	0.23	1.11	0.83	
This study (length)	Western BS*	1.24	0.42	0.82	0.66	2012-2014
This study (age)	Western BS*	1.19	0.37	0.82	0.69	2012-2014

*Turkish coast

Discussion

This is the first comparative study on the age and growth of populations of whiting from western Black Sea coast of Turkey. Sex ratios reported by some recent studies based on trawl samplings are given in Table 2. As it is seen, females generally are dominant in the Black Sea. In this study, M:F ratio differed significantly from the theoretical 1:1. İşmen (1995) indicated that females were dominant sex in all age groups except of age 1 in the Black Sea and this ratio increased with age. Cooper (1983) concluded that variations in the sex ratio can probably be related to differences in the age composition of the stock associated with greater mortalities in older males and the preference of larger fish for deeper water.

The length-weight relationship of the whiting has been reported for different temporal and spatial samplings. The parameter ‘b’ calculated for whiting ranges between 2.22 and 3.30. However, the general trend of L-W relationship was isometric and positive allometric in most studies (Table 3). According to the *t-test* results the parameter b is not different considering western, middle and eastern parts of the Black Sea (P>0.05).

Whiting has different growth rates for each sex, with females growing slower, reaching larger sizes and living longer than males. Both this study and others shows that the asymptotic length (L_∞) was larger in females than that of males. Therefore, the difference in maximum observed sizes could be attributable to the different rate of mortality. The different inputs with respect to maximum age and age composition were reported depending on spatial and temporal variations in the Black Sea. Dominant age classes were age 2 and 1 according to other studies conducted in Black Sea in a similar results of this study (age 2 as 33.54% and age 1 as 27.78%). The oldest specimen in this study was 5 years old whereas İşmen (1995), Ciloglu (2001) and Samsun (2005) reported oldest specimens of up to 9 years from the middle and eastern Black Sea (Table 4). These values are the maximum observed age for *M. merlangus*. Since demersal trawl fishery is forbidden in eastern Black Sea coast of Turkey for all the year around, whiting stocks have been exploited by only gill nets. Hence, stocks are represented with high age classes in eastern part.

The growth parameters are likely the most investigated point in studies related whiting. In all study, females have higher L_∞ values. Males always attained their L_∞ faster than females with higher K values. Various authors reported the parameters of von Bertalanffy growth equation on a certain range (Table 5). It is clear, some variation in the L_∞ of whiting was found between studies, with the largest size being 52.5 cm. The *t-test* showed a significant difference between growth performance indexes in the different localities (P<0.05) within the Black Sea. The index of phi prime ranges between 2.04 and 2.52 for whiting distributed along the Black Sea. Mean of phi prime was 2.29, 2.27 and 2.16 for eastern, middle and western of Black Sea, respectively. Lower phi prime indices were estimated that implying a lower growth performance for the western populations. The growth performance is higher in the eastern part of Black Sea because of existing of two big rivers Yeşilırmak and Kızılırmak supply more feeder than other parts for whiting. In this study conducted in western Black Sea k value defined between 0.11 yr^{-1} and 0.14 yr^{-1}. According to Froese & Pauly (2009), k values between 0.05 yr^{-1}–0.15 yr^{-1} indicate slow growth of fish population.

The estimated fishing mortality rate and exploitation rate (E=0.66 yr^{-1}) obtained in this study and in all other cases indicate a fairly high fishing pressure on the whiting stocks (Table 6). The highest fishing mortality was identified as 3.67 yr^{-1} in 1997 by Bingel *et al*. (1996) while the lowest fishing mortality was detected as 0.61 yr^{-1} in 2002 by Genç *et al*. (2002) for the eastern Black Sea where bottom trawl fishing are completely prohibited. In general, exploitation rate was found over 0.5 yr^{-1} in all studies. According to these results, it can be concluded that whiting stocks are under over fishing pressure in the Black Sea. As a result of this study, exploitation rate seems comparatively lower than central and eastern part of the Black Sea. It could be because of the lower catch amounts of whiting in western than eastern, and also bottom set nets have been not used in the western part for whiting. No comparisons were possible for length and age classes for which no current mortality existed.

L_{opt} indicated that the whiting catch was largely based on sexually immature fishes and that the fisheries are at risk of recruitment and/or growth overfishing. Yıldız & Karakulak (2017) defined that 55% of whiting catches by bottom trawling was discarded due to their small size. Zengin *et al*. (1997) as well presented the Lc_{50} values as 13.1, 14.8 and 15.0 cm obtained for diamond mesh size of 36, 40 and 44 mm, respectively and as 16.2 cm for square mesh size of 44 mm. Genç *et al*. (2002) also revealed Lc_{50} as13.54 cm for the diamond cod end size of 40 mm. These studies revealed that the 44 mm mesh size is most proper for whiting populations. Mesh size selectivity can be used to control size of catch and to modify the mortality rates for different size classes. To decrease fishing mortality, selectivity of bottom trawl nets should be developed and survival rates of escaping individuals from cod end should be determined.

According to the FAO experts the whiting stocks must be protected from over-fishing because of a great importance for the pointed commercial fish species (Bradova & Prodanov, 2003). The whiting stock suffer growth overfishing which results in a reduction in yield regardless of increased effort. Majority of the catch is composed of individuals below the optimum length (L_{opt}) where the maximum possible yield per recruit is obtained. In contrast, starting fishing at L_{opt} leads to greater stock sizes and greater profits, albeit with a slightly increased cost of fishing (Froese *et al*. 2008). The advisory report of STECF (2014) indicated that F should not be exceeding 0.46 yr^{-1} for a sustainable fishery and recommend a catch not more than 331 tons for 2015. However, whiting stocks are not subject to total allowable catches (TACs) and quotas. Moreover, number of trawlers should be discussed in order to decrease fishing pressure on the whiting stocks in the Black Sea. Fisheries management regarding a sustainable approach should obviously need to take into account the fishing pressure to provide the stock assessments of whiting populations.

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