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Current Status, Management, and Future Prospects of Whiting (*Merlangius merlangus*) in the Sea of Marmara

Marmara Denizi'ndeki Mezgit Balığının (*Merlangius merlangus*) Mevcut Durumu, Yönetimi ve Geleceğe Yönelik Çıkarımlar

Uğur Karadurmuş [1,*]

[1]Bandırma Onyedi Eylül University, Maritime Vocational School, Department of Underwater Technology, Balıkesir, Türkiye

[*] Corresponding author: ukaradurmus@bandirma.edu.tr

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Abstract: The current status of whiting (*Merlangius merlangus* Linnaeus, 1758) populations in the Sea of Marmara (Turkey) was evaluated by estimating growth and mortality rates in this study. The overall sex ratio (*M*:*F*) was calculated as 1:1.36. *b* value of *LWR* computed as 2.8904 for both sex groups, and *M. merlangus* showed a negative allometric growth type by Pauly's t-test result. The age of individuals in the population ranged from I to VI. The growth parameters were estimated as L_∞ = 35.74 cm, k = 0.124 yr^{-1}, and t_0 = -1.338 years for all individuals. Total mortality (*Z*), natural mortality (*M*), and fishing mortality (*F*) rates were calculated as 1.35 yr^{-1}, 0.34 $yr^{-1,}$ and 1.01 yr^{-1}, respectively. The Phi-prime growth index (φ') and exploitation rate (*E*) of the population were calculated as 2.20 and 0.75 yr^{-1}. According to the results, it is obvious that the whiting stocks in the Marmara Sea are currently used at a high capacity (*E* = 0.75 yr^{-1}). The impact of over-fishing can have increasingly detrimental effects on the overall population size of this population. Fisheries management practices in the Marmara Sea should be regulated by taking into account the ecosystem change, fishing fleet, and unreported catch data. In addition, temporal or spatial fishing bans can be applied by increasing the selectivity of fishing gear.

Keywords

- Age
- Growth
- Exploitation rate
- Marmara Sea
- LWR

Özet: Bu çalışmada, Marmara Denizi'ndeki (Türkiye) mezgit (*Merlangius merlangus* Linnaeus, 1758) popülasyonunun büyüme ve ölüm oranları tahmin edilerek mevcut durumu değerlendirilmektedir. Cinsiyet oranı (*E*:*D*) 1:1,36 olarak hesaplanmıştır. LWR *b* değeri her iki cinsiyet için 2,8904 olarak hesaplandı ve Pauly's t-testi sonuçlarına göre mezgit popülasyonu negatif allometrik büyüme gösterdi. Popülasyondaki bireylerin yaşları I ile VI arasında değişim göstermiştir. Büyüme parametreleri, tüm bireyler için L_∞ = 35,74 cm, k = 0,124 $yıl^{-1}$, and t_0 = -1,338 yıl olarak tahmin edilmiştir. Toplam ölüm (*Z*), doğal ölüm (*M*) ve balıkçılık ölüm (*F*) oranları sırasıyla 1,35 $yıl^{-1}$, 0,34 $yıl^{-1}$ and 1,01 $yıl^{-1}$ olarak hesaplanmıştır. Popülasyonun Phi-prime büyüme indeksi (φ') ve sömürü oranı (*E*) 2,20 ve 0,75 $yıl^{-1}$ olarak hesaplanmıştır. Sonuçlara göre Marmara Denizi'ndeki mezgit stoklarının şu anda yüksek kapasitede kullanıldığı aşikardır (*E* = 0,75). Aşırı avlanmanın etkisi, genel popülasyon büyüklüğü üzerinde giderek daha fazla zararlı etkiye sebep olabilir. Marmara Denizi'ndeki ekosistem değişimi, balıkçı filosu ve rapor edilmemiş av verileri dikkate alınarak balıkçılık yönetimi uygulamaları düzenlenmelidir. Av araçlarının seçiciliği artırılarak zamansal veya mekânsal avlanma yasakları uygulanabilir.

Anahtar kelimeler

- Yaş
- Büyüme
- Sömürülme oranı
- Marmara Denizi
- LWR

1. INTRODUCTION

The whiting (*Merlangius merlangus* Linnaeus, 1758) (Gadiformes, Gadidae) is bento-pelagic fish and widespread in the Black Sea, Adriatic Sea, Mediterranean Sea, and Aegean Sea (Akşıray, 1987). The adults of the whiting adapted to live in 5-16 °C water (Özdemir et al., 2018) and it is found in waters at a depth of 50 meters to 100 meters and on muddy, sandy bottoms (Frattini and Casali, 1998). The species reaches a maximum of 70 cm, and the average length is 23.5 cm (Nedreaas et al., 2014). Whiting fisheries mostly occurred by bottom trawls, gill nets, line fishing, and deep water cast nets in Turkey (Zengin, 2019; Karadurmuş et al., 2021). 93% of the whiting amount, which was 9363 tons in 2020, was obtained from the Black Sea (TÜİK, 2020). It is caught with gillnets in the Sea of Marmara and is among the most caught species as bycatch in shrimp fisheries by beam trawl. Previous studies on whiting were mostly concentrated in the Black Sea (Düzgüneş and Karaçam, 1990; Erkoyuncu et al., 1994; Samsun, 1995; Şahin and Akbulut, 1997; Samsun and Erkoyuncu, 1998; Kalaycı et al., 2007; Bilgin et al., 2012; Kasapoğlu and Düzgüneş, 2014; Mazlum and Bilgin, 2014; Samsun and Akyol, 2017; Taylan et al., 2018; Türker and Bal, 2018; Balık and Öztaş, 2019; Yıldız and Karakulak, 2019; Aksu, 2020).

Whiting is one of the important commercial demersal fisheries products in the Sea of Marmara. Annual catch statistics for whiting show a continuous decrease (about 90%) pattern in the Marmara Sea since the 2000s, especially since 2009 (TÜİK, 2020). Anthropogenic activities, environmental and biotic factors affect the dynamics of fish species in the Mediterranean and the Sea of Marmara (Brosset et al., 2015). High fishing pressure, poor fisheries management, and limited fishing regulations are responsible for the decline in stocks (Zengin and Akyol, 2009). In addition, the mucilage event seen in November 2020 seems to affect the entire ecosystem, especially fish species (Karadurmuş and Sarı, 2022). The previous main study (Atasoy et al., 2006) was carried out on the whiting growth and mortality in the Marmara Sea. The other studies (Bok et al., 2011; Demirel and Dalkara, 2012; Daban et al., 2020) only examined the length-weight relationship (*LWR*) of whiting in the Marmara Sea. Finally, Bal (2021) examined the limited population parameters of whiting in the Sea of Marmara. Despite its economic and ecological importance, the data on the growth, mortality, and exploitation rates of *M. merlangus* for the Sea of Marmara is not available in recent years. The study aimed to reveal the status of whiting stocks in the Sea of Marmara and examine them in fisheries management. National catch statistics indicate that whiting stocks in the Marmara Sea have decreased significantly. Data on the current status of populations (sex ratio, size, and age distribution), growth parameters, mortality, and exploitation rates will be used to provide essential input to demographic models that will be used to estimate the species recovery.

2. MATERIAL and METHODS

The field studies were conducted in GFCM (General Fisheries Commission for the Mediterranean) Geographical Sub-Area 28 (the Sea of Marmara) (Figure 1). Sampling studies were carried out intensively around the Kapıdağ Peninsula. A total of 33 beam trawls and 17-gill net operations were carried out in different points of the study area. The whiting specimens (n = 2522) were captured at depths ranging from 25 to 195 m by using a twin commercial shrimp trawl (10 m beam width and a 32 mm mesh size), gill nets (18-20-22-24 mm mesh size), and line fishing at monthly intervals between August 2020 and July 2021. These nominal mesh sizes were measured as the stretch measure (from knot to knot). This method allowed the sampling of the smallest individuals in the population. The MEDITS (Mediterranean International Trawl Survey) protocol was followed at all stages of the trawl survey (sampling gear characteristics, the design of the survey, the sampling methodology, and the processing of samples). Total length (*TL*) was measured using an ichthyometer with 0.01 cm precision, while body weight (W) was weighed using a scale with 0.01 g precision. Sex distinction was made according to the shape and color of gonads. All biological and morphometric studies were carried out in the laboratory. The overall sex ratio (M:F) was calculated as the proportion of males to females and the difference from a balanced ratio (1:1) (Conover and Van Voorhees, 1990; Vazzoler, 1996) was analyzed using the Chi-squared (χ^2) test (Düzgüneş et al., 1983). Changing sex ratios according to size group (cm) and age (year) were examined. The *LWR* was estimated according to Froese (2006), power equation as $W = a \times TL^b$. Where W is the body weight (g), TL is the total length measurement (cm), a and b are the regression parameters. This equation was used to transform its logarithmic form as In (W) = In (a) + b In (TL). The confidence limits (Cl) of regression parameters and the coefficient of determination (r^2) were used to evaluate the correlation between W and TL. Pauly's t-test was used to determine if coefficient b was significantly different from 3 (Zar, 1999). In the determination of growth rates of TL and W, the following formula TL increment (%) = $[(TL_n - TL_{n-1})/TL_{n-1}] \times 100$, and W increment (%) = $[(W_n - W_{n-1})/W_{n-1}] \times 100$ were used, where n is age-class (Ricker, 1975).

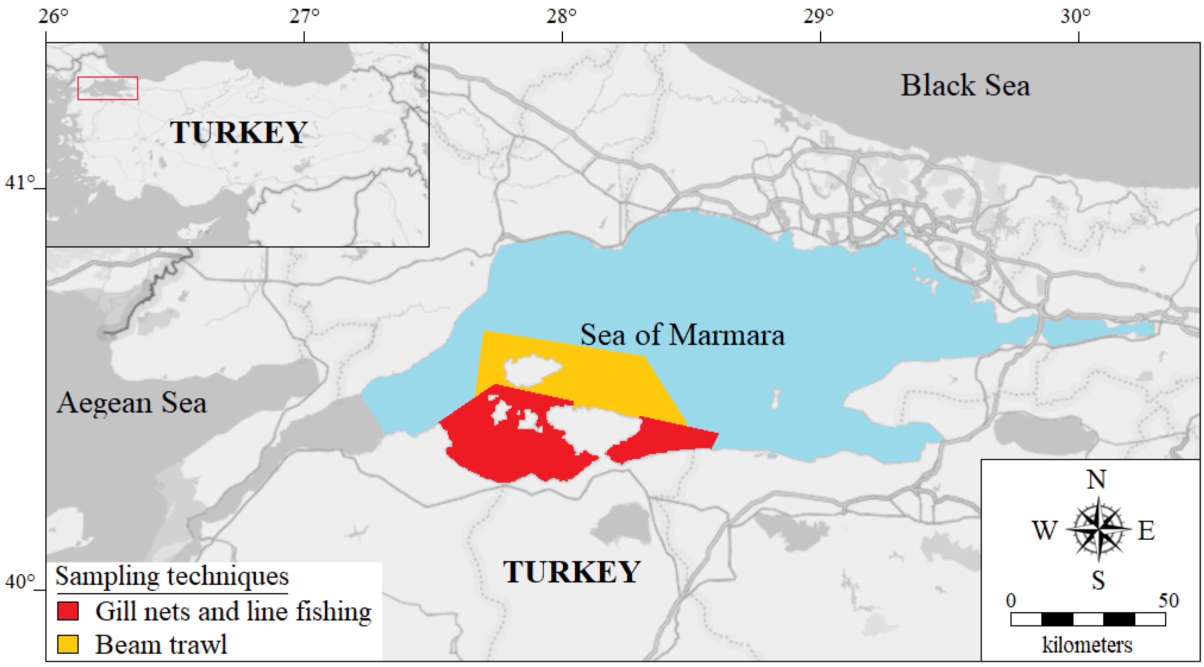

Figure 1. Map of the study area. The red area represents the sampling region made with gillnet and line fishing, and the orange area represents the region where trawl hauls were made.

All samples were grouped into length classes of 1 cm, and sagittal otoliths were removed for each size class. The otoliths were cleaned and stored for further processing and readings. Otoliths were ground manually with various abrasive papers to clarify the first annulus. These otoliths were immersed in glycerin in a petri dish and viewed under the light in a stereomicroscope. The age rings were counted according to Ross and Hüssy (2013) by using a monitoring system (Leica EZ4E (Leica Microsystems, Wetzlar, Germany) camera system). The association of one opaque zone and one translucent zone was regarded as an annulus (Campana, 2001; Ross and Hüssy, 2013). Age estimates were obtained from 618 individuals. Independent two readers undertook all readings for each otolith without prior information on length and sex. Growth curves were fitted using the least-squares method using the von Bertalanffy (1938) growth equation (VBGF):

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

where L_∞ is asymptotic length (cm), k is the growth rate (yr^{-1}), t is age (year), and t_0 is the hypothetical age at zero-length (year). These parameters are commonly used to evaluate the current status of the fish populations by associating the values of their mortality coefficients. Phi-prime growth index (φ') was calculated using the formula Munro and Pauly (1983):

$$\varphi' = \log k + 2 \log L_\infty$$

The growth index makes it possible to compare the growth of different populations. The total mortality rate (Z) was calculated using age-based catch curve analysis (Chapman and Robson, 1960). According to the Pauly (1980) model, the natural mortality (M) rate was calculated using the following equations:

$$\log M = -0.0066 - 0.279 (\log L_\infty) + 0.6543 (\log k) + 0.4634 (\log T)$$

The fishing mortality was calculated according to the formula: $F = (Z - M)$, and the rate of exploitation was calculated according to the formula: $E = (F / Z)$. The sea surface temperature was measured each month with a YSI® ProDss (Xylem, Rye Brook, NY) multimeter in all stations, the annual mean value (16.4 °C) was used to calculate the natural mortality rate (M). Significance levels for all statistical tests were established at $P = 0.05$ a prior with SPSS v0.26 (IBM Corp., Armonk, NY). The normality of the data was checked using the Kolmogorov-Smirnov test and the homogeneity was analyzed using the ANOVA (Analysis of Variance) test. Therefore, non-parametric test Mann-Whitney U and Kruskal Wallis H were used to analyze the statistical differences in data according to size class, age, and gender. Monthly and combined variables were analyzed using Pearson correlation and regression analysis to search for relationships among morphological characters (Sokal and Rohlf, 1969).

3. RESULTS

3.1. Population status

Sex, size, and age data were gathered from a total of 2522 *M. merlangus* samples, of which 1454 (57.65%) were females, 1068 (42.35%) were males. The overall sex ratio (M:F) was 1:1.36 which is highly significantly different from the balanced ratio of 1:1 ($\chi^2 = 59.079$; $df = 1$; $P < 0.001$). Males were dominant during the early ages, but after the age of 2 sex ratio changed in favor of females. Males dominated in the length intervals between 5 − 7 cm, and females those beyond 12 cm significantly. The sex ratio is balanced (1:1) in 2 age classes and 12 cm size classes (Table 1).

Table 1. Sex-ratios (*M*:*F*) of *Merlangius merlangus* according to size classes (*df*: 1, χ^2: Chi-square value, –: not calculated, *ns*: not significant, **: $P < 0.01$, ***: $P < 0.001$)

Size classes (*TL*, cm)	Female	Male	Sex ratio	χ^2	*Sig.*
5	0	3	-	-	-
6	3	10	1:0.30	3.77	*ns*
7	8	18	1:0.44	3.85	*ns*
8	26	32	1:0.81	0.62	*ns*
9	28	32	1:0.88	0.27	*ns*
10	42	58	1:0.72	2.56	*ns*
11	60	68	1:0.88	0.50	*ns*
12	106	108	1:0.98	0.02	*ns*
13	142	114	1:1.25	3.06	*ns*
14	266	162	1:1.64	25.27	***
15	254	176	1:1.44	14.15	***
16	196	140	1:1.40	9.33	**
17	150	72	1:2.08	27.41	***
18	76	38	1:2.00	12.67	***
19	54	21	1:2.57	14.52	***
20	19	6	1:3.17	6.76	**
21	9	6	1:1.50	0.60	ns
22	11	4	1:2.75	3.27	ns
23	3	0	-	-	-
24	1	0	-	-	-
Total	1454	1068	1:1.36	59.079	***

TL and *W* of the whiting specimens used in the analysis ranged between 5.35 − 24.2 cm and 2.40 – 98.35 g. Details on the length and weight of the whiting samples are given in Table 2. Significant differences occurred in the *TL* (*U*: z = -7.464; $P < 0.05$) and *W* (*U*: z = -7.263; $P < 0.05$) between females and males. Most fish (79.3%) were within the 12 − 18 cm length groups, and 76.14% of all samples with a mean of 14.67 cm *TL* were over minimum landing size (*MLS* > 13 cm) according to national fishery regulations (BSGM, 2020) (Figure 2). The statistical data relevant for the evaluating of the *LWR* of *M. merlangus* is included in Table 2, showing the estimated regression parameters along with their 95% confidence interval, growth type of populations, and the coefficient of correlation. The value of *a* varied between 0.0083 and 0.0122. According to the *b* value obtained from the LWR equations, Pauly's t-test result showed that *M. merlangus* ($t_{combined}$ = 1.961, $P < 0.05$) exhibit negative allometric growth ($b < 3$) for males, females, and combined sexes. The high values of coefficient of determination ($r^2 > 0.95$) were calculated for whiting.

Table 2. Descriptive statistics and total length (cm) and weight (g) relationships for *Merlangius merlangus* by sex.

Sex	***n***	**Mean *TL* ± *SE* (Min-max)**	**Mean *W* ± *SE* (Min-max)**	**Regression parameters**			**Confidence intervals (95%)**		***Sig.***	**Growth**
				a	***b***	***r^2***	***Cla***	***Clb***		
Female	1454	15.05 ± 0.07 (6.10 – 24.20)	28.00 ± 0.38 (2.50 – 98.35)	0.0090	2.9312	0.9569	0.0083 – 0.0098	2.8992 – 2.9632	< 0.05	A^-
Male	1068	14.14 ± 0.09 (5.35 – 22.80)	23.84 ± 0.41 (2.40 – 89.40)	0.0112	2.8509	0.9602	0.0102 – 0.0122	2.8160 – 2.8858	< 0.05	A^-
Combined	2522	14.67 ± 0.06 (5.35 – 24.20)	26.24 ± 0.28 (2.40 – 98.35)	0.0101	2.8904	0.9594	0.0095 – 0.0107	2.8671 – 2.9136	< 0.05	A^-

* *n*, sample size; ±*SE*, standard error; min, minimum; max, maximum; *a*, regression intercept; *b*, regression slope; *CI*, confidence interval; r^2, coefficient determination; A^-, negative allometric growth

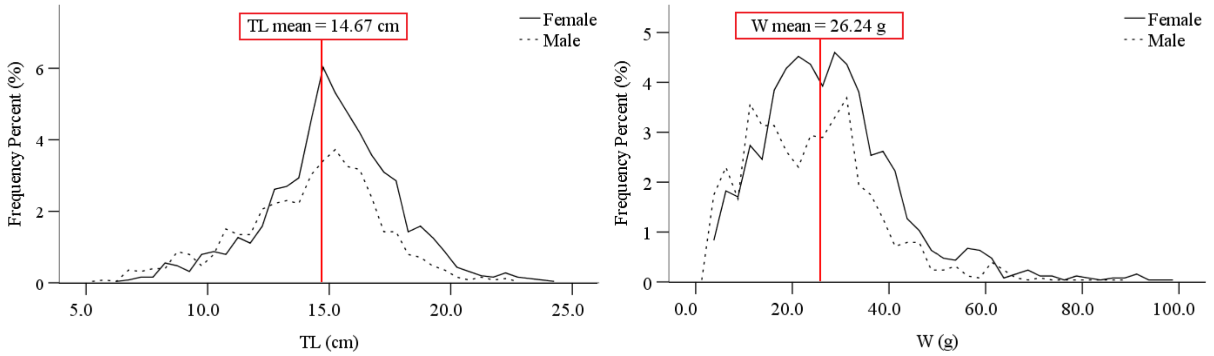

Figure 2. Sex-specific length and weight frequency distribution of *Merlangius merlangus*. Red lines indicate mean values for combined sexes (n = 2522).

The results of the otolith reading are given in Table 3. Six age classes (I − VI) were found for both sexes. Most of the samples (87.22%) consisted of younger fish below age V. Female fish were more abundant in the older age classes. Both females and males were dominant in age groups III and IV, and males more than IV years old were rare (3.39%) in the population (Figure 3). Descriptive statistics of *TL* and *W* of *M. merlangus* were given by age and sex in Table 4. The mean *TL* revealed significant differences between age groups both females (H = 583.9; df = 5; P < 0.05) and males (H = 460.5; df = 5; P < 0.05). Our results contained enough samples of the youngest fishes to accurately estimate growth at the earliest ages (below two years).

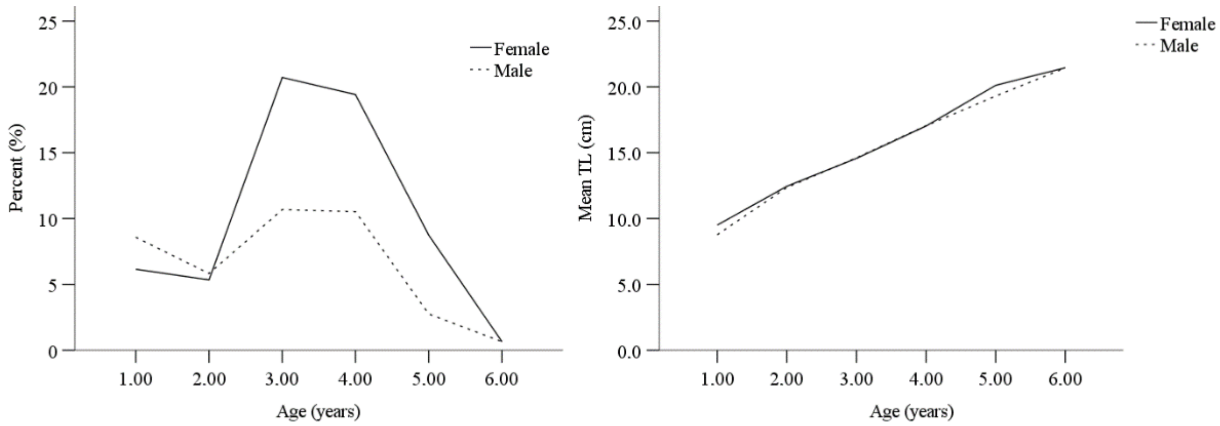

Figure 3. The proportion of specimens and length-frequency distributions by age groups.

Table 3. Age–length key of *Merlangius merlangus* from the Marmara Sea.

Total length (cm)	Age groups						
	1	**2**	**3**	**4**	**5**	**6**	**Total**
5	3						3
6	7						7
7	10						10
8	22						22
9	20						20
10	18	3					21
11	11	17					28
12		34	9				43
13		11	40				51
14		2	82	6			90
15		2	45	37	1		85
16			9	55	3		67
17			9	48	8		65
18				25	4		29
19				5	22	2	29
20				4	12	1	17
21				3	9	2	14
22				2	9	2	13
23					3		3
24						1	1
Total	**91**	**69**	**194**	**185**	**71**	**8**	**618**

3.2. Growth parameters, mortality, and exploitation rate

Age at length data was used to calculate the *VBGF* parameters (Table 5) and growth curves (Figure 4). No significant differences occurred between observed and predicted *TL* of different ages of specimens (U = 68.000; z = -0.231; $P > 0.05$). The population grew fairly slowly, achieving a mean observed size at age VI. The growth increments had no significant difference between sexes (F = 0.264; df = 2; $P > 0.05$); while the growth increments had significant differences between age groups (F = 36.310; df = 5; $P < 0.05$). Female fishes reach a significantly larger asymptotic length (L_∞ in cm) compared to males. The t_0 value was close to zero for both sexes, indicating a good growth for the smallest fish. However, estimates of the growth coefficient ($k \cdot yr^{-1}$) for both sexes (close to 1 per year) indicated slow growth in females and males. Growth parameters suggested that males (φ' = 2.20) grew relatively faster than females (φ' = 2.21). While the growth index (φ') of *M. merlangus* was estimated as 2.20 the exploitation rate (E) was calculated as 0.75. The mortality and exploitation rate of whiting are given in Figure 5.

Table 4. Variations in biometric measurements (Total length-*TL* in cm, Body weight-*W* in g) by age groups.

Sex	Summary	Age I		Age II		Age III		Age IV		Age V		Age VI	
		TL	***W***	***TL***	***W***	***TL***	***W***	***TL***	***W***	***TL***	***W***	***TL***	***W***
Female	*n*	38		33		128		120		54		4	
	Mean	9.51	7.10	12.45	14.15	14.57	23.74	17.03	37.59	20.11	62.01	21.45	75.76
	±*SE*	0.22	0.39	0.18	0.60	0.10	0.60	0.13	0.95	0.25	2.28	1.24	11.00
	Min	6.10	3.05	10.20	7.90	12.00	10.20	14.10	19.50	15.80	30.20	19.20	54.90
	Max	11.80	11.60	15.00	24.80	17.80	47.20	22.90	93.20	23.30	92.40	24.20	98.35
Male	*n*	53		36		66		65		17		4	
	Mean	8.77	5.97	12.36	14.23	14.61	24.59	17.05	38.01	19.30	55.04	21.44	67.15
	±*SE*	0.21	0.36	0.15	0.57	0.12	0.78	0.20	1.53	0.40	3.86	0.36	3.42
	Min	5.35	2.40	10.60	10.10	12.50	14.30	15.00	19.90	17.00	32.00	20.70	60.40
	Max	11.90	14.20	15.00	27.00	17.30	44.00	22.20	89.40	22.80	86.40	22.25	74.60
Combined	*n*	91		69		194		185		71		8	
	Mean	9.08	6.44	12.41	14.19	14.58	24.03	17.04	37.74	19.92	60.34	21.44	71.46
	±*SE*	0.16	0.27	0.12	0.41	0.08	0.47	0.11	0.81	0.22	1.98	0.60	5.58
	Min	5.35	2.40	10.20	7.90	12.00	10.20	14.10	19.50	15.80	30.20	19.20	54.90
	Max	11.90	14.20	15.00	27.00	17.80	47.20	22.90	93.20	23.30	92.40	24.20	98.35

n, sample size; ±*SE*, standard error; min, minimum; max, maximum

Table 5. Estimates of von Bertalanffy growth parameters by sexes.

Growth Parameters	Female	Male	Combined
L_∞ (cm)	39.61	35.36	35.74
W_∞ (g)	434.24	290.99	311.57
t_0 (year)	-1.622	-1.257	-1.338
$k \cdot yr^{-1}$	0.101	0.129	0.124
φ'	2.20	2.21	2.20

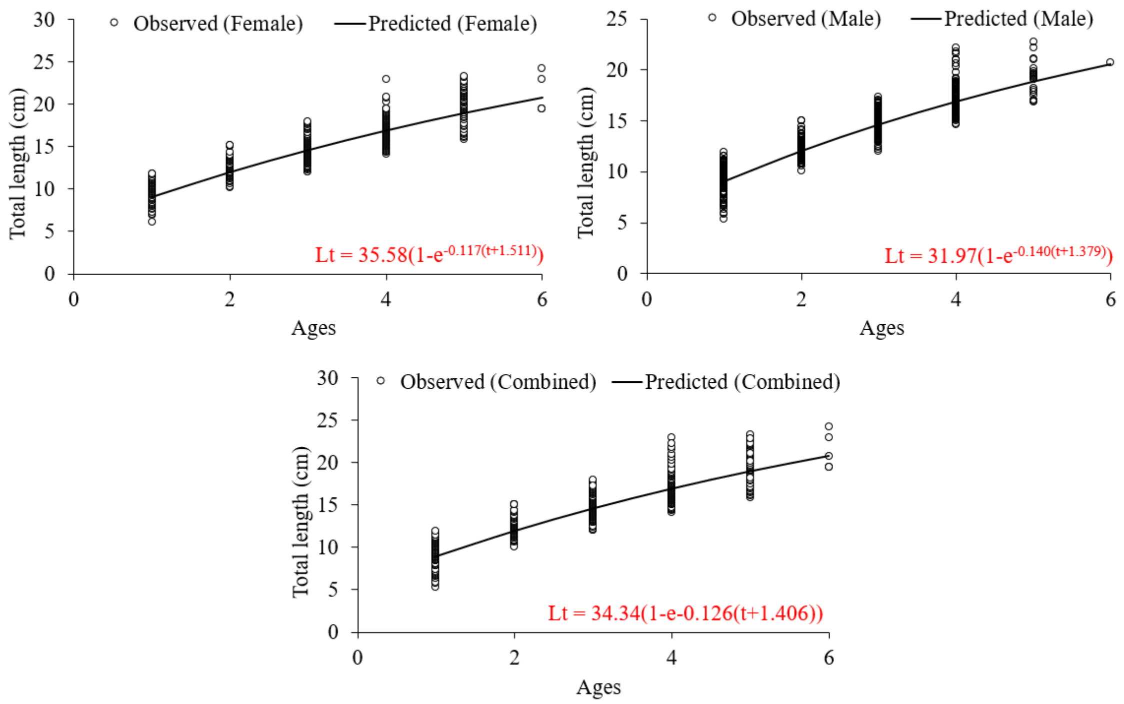

Figure 4. Length-at-age data of whiting used in the present study. Lines show estimated von Bertalanffy growth curves

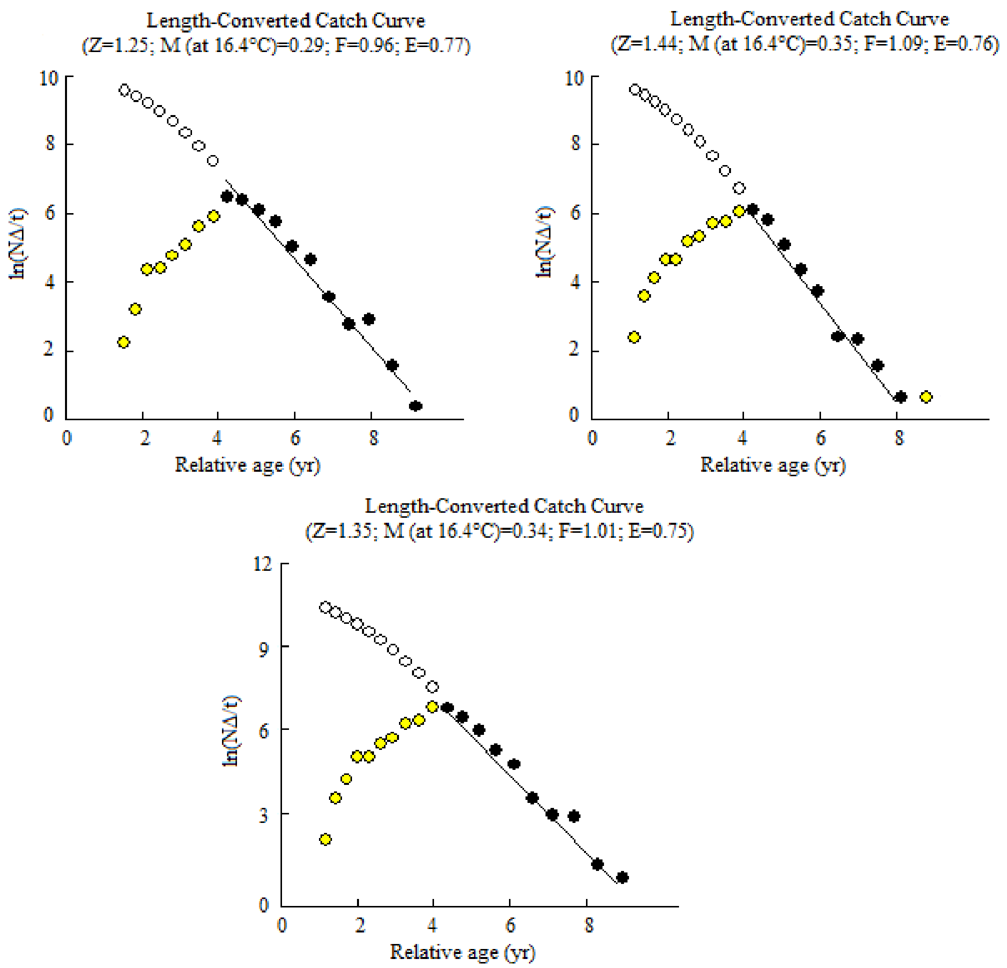

Figure 5. Estimation of mortalities using length converted catch curve analysis for whiting (○ = not used in the analysis; ● = used in the analysis).

4. DISCUSSION

The number of females was found higher than males with a ratio of 1:1.36 (*M*:*F*). Unlike this study, Atasoy et al. (2006) and Bal (2021) reported that males were more dominant in the Sea of Marmara as 1:0.78 (*M*:*F*) and 1:0.64 (*M*:*F*), respectively. Many fish species tend to invest equally in the production of females and males. In natural populations, a sex ratio of 1:1 is expected which generally occurs in more stable environments that do not suffer from frequent oscillations (Fisher, 1930). Several factors, such as sampling methods, predation, variations in environmental conditions, changes in recruitment or mortality of individuals of a particular sex, may also promote changes in the sex ratio in fish (Garcia et al., 2004). The sex ratio of whiting, in our opinion, is affected not only by the location surveyed, but also by the type of fishing gear utilized. Thus, commercial fishing gear is more selective in its size composition and can mislead the results by catching larger fish.

Whiting populations may differ in terms of density, distribution, or growth rates, even in small spatial scales. These differences could be attributed to local environmental factors such as hydro geography, depth, sediment particle size, and temperature. Some previous studies reported individuals with longer than 24 cm in the Sea of Marmara (Göksungur, 2004; Demirel and Dalkara, 2012; Bal, 2021). The expected range for *a* was reported between 0.001 and 0.05 for the natural fish populations by Froese (2006) and the obtained value for all species was in accordance with the expected range. The value of *a* may differ between environments, daily or seasonally (Bagenal and Tesch, 1978). The results show that *M. merlangus* invest more in length than in weight ($b < 3$), as has been observed for previous studies (Demirel and Dalkara, 2012; Çalık and Erdoğan Sağlam, 2017; Samsun and Akyol, 2017; Aksu, 2020). The *LWR* parameters vary too between locations, depending on the competitors, abundance of food and reproductive activity, and over time (Yankova, 2016). Contrary to our study, it has been reported that *M. merlangus* shows positive allometric growth ($b > 3$) in previous research conducted in the Sea of Marmara (Bok et al., 2011; Bal, 2021). Compared to the earlier studies (Demirel and Dalkara, 2012; Kasapoğlu and Düzgüneş, 2014; Yıldız and Karakulak, 2019; Bal, 2021), some slight differences in r^2 values in the present study were regular which may be based on many factors such as season, length range, fish physiology, sampling size and habitat (Froese, 2006).

Similar age groups (Özdamar and Samsun, 1995) and older (Samsun et al., 1994; Şahin and Akbulut, 1997; Çiloğlu et al., 2001) were reported for specimens from the Black Sea. However, several authors reported a shorter life cycle (below age VI) in the Sea of Marmara (Atasoy et al., 2006) and Black Sea (Düzgüneş and Karaçam, 1990; Yıldız and Karakulak, 2019), which may be attributed to the selectivity factor of fishing gear or sampling methods (Froese, 2006). However, Çiloğlu et al. (2001) found the oldest fish among 9 years old individuals in the literature. Because the Sea of Marmara is a closed basin, populations are extremely sensitive, and excessive fishing pressure destroys stocks without growth. Whiting is one of the most caught species as bycatch in shrimp beam trawl fishery (Zengin and Akyol, 2009; Aslan İhsanoğlu and İşmen, 2020), the whiting stocks in the Sea of Marmara cannot resist fishing pressure and are overexploited. Another probable reason may be the number of samples, sampling season, or the variations of sampling methods. In the Black Sea, especially individuals in the 5-7 cm length group corresponded to 0 years of age (Polat and Gümüş, 1996; Özdemir et al., 2006; Erdoğan Sağlam and Sağlam, 2012; Mazlum and Bilgin, 2014), but no individuals aged 0 years were found in this size group in the Sea of Marmara (Atasoy et al., 2006; this study). It should be noted that different stocks of the same species may display variables due to different feeding conditions (Erkoyuncu, 1995).

Growth parameters have been the main indicator to identify fishing pressure levels and growth on fish stocks. The theoretical length of the individuals in this study (L_∞ = 35.74 cm *TL*) was lower than values estimated for the Sea of Marmara (L_∞ = 38.5 cm *TL in* Atasoy et al., 2006). Although the possibility exists that the maximum length of *M. merlangus* is longer than 45.36 cm (Şahin and Akbulut, 1997), no evidence was to support this in literature. Due to variable results of growth parameters (k, L_∞), the growth index (φ') is commonly preferred for the estimated growth performance of fishes. Most studies (Erdoğan Sağlam and Sağlam, 2012; Yıldız and Karakulak, 2019) estimated growth index of whiting above 0.2 yr^{-1} in the Black Sea, as demonstrated in this study from the Sea of Marmara ($\varphi' = 2.2$ yr^{-1}). Differences in growth index between regions may be due to environmental conditions (such as temperature and food availability) between sampled areas (Tuck et al., 1997) or fishing pressure (Campana, 2001). Although geographical differences may affect growth parameters, further studies are needed to determine what factors account for these differences. Older populations up to 9 years of age have been reported in the Black Sea (İşmen, 1995; Süer, 2016). No individuals older than 6 years of age were found in the Sea of Marmara (Atasoy et al., 2006; this study). In addition, individuals corresponding to age 0 could not be sampled in these studies. The differences in growth parameters in the Black Sea and the Marmara Sea may be due to the smaller individuals in the populations in the Marmara Sea and the differences in the sampling method in which individuals aged 0 are neglected. It is worth noting that the higher growth rates (above 2.3 yr^{-1}) reported in the eastern Black Sea (Düzgüneş and Karaçam, 1990; Çiloğlu et al., 2001) were based on the low fishing pressure. Although geographical differences may affect growth parameters, it is unclear whether these differences are due to environmental factors or fishing pressure (Campana, 2001).

No studies have focused on the exploitation rate of the whiting fishery by estimating mortality in the Marmara Sea. In this study, the mortality parameters are mostly higher than the previous studies performed for the Black Sea (Samsun and Erkoyuncu, 1998; Yıldız and Karakulak, 2019). The total mortality rate ($Z = 1.35$ yr^{-1}) was similar to the one found by Erdoğan Sağlam and Sağlam (2012), in the southeastern Black Sea. They estimated the total mortality (Z) rate of 1.68 yr^{-1} and an exploration (E) rate of 0.84. Growth and mortality rates are important to understand the dynamics of populations and to evaluate possible sustainable harvests (Campana and Thorrold, 2001). The natural effects on mortality in the fished populations or the impact of fishing can be confused (Pauly, 1980). If the exploitation rate is higher than 0.5 may be a sign of a heavily fished population (Patterson, 1992). This observed high mortality in this study ($E = 0.75$) might be caused by food limitations, diseases, predators, or commonly illegal fishing activities. More studies are needed to determine which of these factors is responsible for the high mortality rate. As with all marine populations, the whiting will not show excessive resistance to overfishing exploitation, so management and conservation measures should be taken to minimize the impact of fishing gear on stocks (Ridgway et al., 2006).

4.1. Implications for whiting fishery management

The Marmara Sea is under the influence of significant anthropogenic activities that adversely affect the well-being of its ecosystem (Akoğlu, 2021). Fish species are also influenced by the adverse impacts of anthropogenic activities (Chassot et al., 2007). Environmental and biotic factors, such as sea surface temperatures, phytoplankton biomass, and primary productivity, play crucial roles in the dynamics of fish species in the Mediterranean (Brosset et al., 2015). As a result of these effects, the first mucilage event was reported in 2007 in the Sea of Marmara and this phenomenon reappeared in November 2020 (Savun-Hekimoğlu and Gazioğlu, 2021). As a result of causing several problems, including fisheries, ecological, social, and economic losses are inevitable (Karadurmuş and Sarı, 2022). Apart from this, it is necessary to approach this decrease in terms of fisheries management and examine the issue from an expert perspective. The catch (tons) of *M. merlangus* decreased overall in the Marmara Sea in the 2000s, and the catch amount exhibited relative stability between 2006 and 2010, followed by a sharp decline (Figure 6). No growth and mortality data recorded in this region since 2003. The high exploitation rate we have found can be attributed to overfishing, and this study determined high fishing mortality rate ($F = 1.01$ yr^{-1}) confirms this estimate. Unlike the eastern Black Sea, the Marmara Sea population of whiting is not protected by a trawl ban and is open for commercial shrimp trawl fishing seasonally. However, commercial fishers' use of this species has been low, as fishers have instead focused their attention on shrimp fishery. This situation should be put under consideration by the stakeholders since it could pose a potential threat to the sustainability of the stocks. However, it is important to acknowledge that compliance by fishers is integral to the success of fishery management. Therefore, more lenient but well-managed alternative management techniques might be required. There is no regulation regarding the mesh size of nets such as whiting and red mullet in commercial fisheries in Turkey, except for turbot gillnets. The mesh size of the whiting nets should be regulated referred to the first maturity length and the current status of populations. Such a regulation would allow most individuals to attain sexual maturity and spawn at least once before being exposed to catch. Such regulations will also protect larger and older individuals with high reproductive capacity.

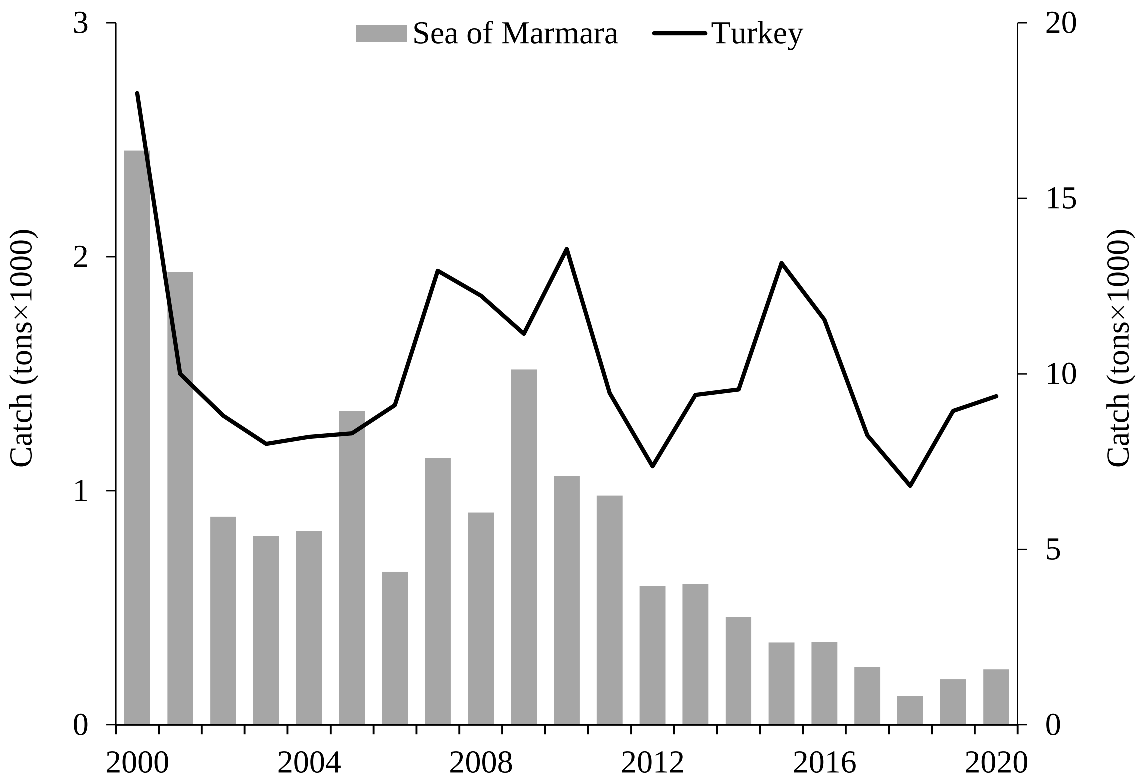

Figure 6. The catch amount (tons) of whiting in the Marmara Sea according to the data of the TÜİK (2020).

The Marmara Sea is also an important fishing ground with many commercially important fish species. Demersal fishes, especially whiting, remain an economically vital resource to the Marmara Sea fishing community and are also under the influence of the adverse impacts of anthropogenic activities. All evidence indicates that the whiting stock in the Sea of Marmara is currently being overexploited and used at a high capacity. Yet, although coupled assessment of fishing effort and catches is necessary, fisheries management practices should consider environmental aspects of the ecosystem in addition to conventional fisheries regulations. So, the risk of destruction of demersal fishes in the Sea of Marmara will remain an ongoing concern requiring long-term vigilance. Hence, effort should be directed towards the better management of the whiting stocks.

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CONFLICTS OF INTEREST

The author declares that for this article they have no actual, potential, or perceived conflict of interests.

ETHICAL STATEMENTS

Local Ethics Committee Approval was not obtained because experimental animals were not used in this study. All applicable international, national, and/or institutional guidelines for the care and use of animals were followed by the authors. The necessary permission for the trawl survey was obtained from the Republic of Turkey Ministry of Agriculture and Forestry (Date: 19.10.2020; No: E-67852565-140.03.03-2924781).

DATA AVAILABILITY STATEMENT

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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