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**ARAŞTIRMA MAKALESİ** **RESEARCH PAPER**

# Abundance and Stock Management of Whiting (*Merlangius merlangus*) in Southeastern Black Sea Fisheries

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**Abstract:** In this study, 1579 *Merlangius merlangus* were obtained from bottom trawling operations (12 mm cod mesh size) using the research vessel 'Karadeniz' at depths between 5 m and 60 m off the coasts of Rize, Southeastern Black Sea. The collected samples' growth, recruitment, and stock structure were assessed using the ELEFAN-I, Y/R, B/R, VPA, and Thompson and Bell models within the FISAT-II software package. The von Bertalanffy growth parameters, including asymptotic length ($L_\infty$), growth constant (K), and $t_0$, were calculated as 40.89 cm, 0.10 cm, and -1.1411 cm, respectively. The first catch length ($Lc_{50}$) varied between 11.82 cm and 13.40 cm. Total, natural, and fishing mortality rates were estimated at 0.85, 0.29, and 0.56, respectively. Three distinct recruitment periods were identified, occurring in March, August, and November. Based on VPA data, the fixed biomass was estimated at approximately 569.620,7 tonnes. The analysis suggests that the maximum sustainable yield (MSY) for whiting could be reached with an exploitation rate of 0.66. At the current exploitation level, calculated at 449.70 tonnes using the Thompson and Bell method with an F-factor of 0.56, the biomass has decreased. An F-factor of 1.0, representing the MSY, corresponds to 498.180 tonnes. At the current fishing rate (F = 0.56), the biomass has been reduced by 25% (168,026 tonnes) from its unfished state of 666,206 metric tonnes.

**Keywords:** Whiting, maximum sustainable yield (MSY), relative yield per recruit (Y′/R), relative yield per biomass (B′/R), stock, southeastern black sea.

# Güneydoğu Karadeniz Balıkçılığında Mezgit (*Merlangius merlangus*) Bolluğu ve Stok Yönetimi

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**Öz:** Bu çalışmada, 1579 *Merlangius merlangus*, Güneydoğu Karadeniz, Rize sahillerinde 5 m ile 60 m arasındaki derinliklerden araştırma gemisi 'Karadeniz' kullanılarak yapılan dip trolü operasyonlarından (12 mm morina ağı boyutu) elde edilmiştir. Toplanan örneklerin büyüme, yeni birey katılımı ve stok yapısı FISAT-II yazılım paketindeki ELEFAN-I, Y/R, B/R, VPA ve Thompson ve Bell modelleri kullanılarak değerlendirilmiştir. Toplanan örneklerin büyüme, stoka katılım ve stok yapısı FISAT-II yazılım paketindeki ELEFAN-I, Y/R, B/R, VPA ve Thompson ve Bell modelleri kullanılarak değerlendirilmiştir. Asimptotik boy ($L_\infty$), büyüme sabiti (K) ve $t_0$ dahil olmak üzere von Bertalanffy büyüme parametreleri sırasıyla 40,89 cm, 0,10 cm ve -1,1411 cm olarak hesaplanmıştır. İlk yakalama boyu ($L_{c50}$) 11,82 cm ile 13,40 cm arasında değişmiştir. Toplam, doğal ve balıkçılık ölüm oranları sırasıyla 0,85, 0,29 ve 0,56 olarak tahmin edilmiştir. Mart, Ağustos ve Kasım aylarında meydana gelen üç farklı katılım dönemi tespit edilmiştir. VPA verilerine dayanarak, sabit biyokütlenin yaklaşık 569.620,7 ton olduğu tahmin edilmiştir. Analiz, mezgit için maksimum sürdürülebilir verime (MSY) 0,66'lık bir sömürü oranı ile ulaşılabileceğini göstermektedir. Thompson ve Bell yöntemi kullanılarak 0,56 F faktörü ile 449,70 ton olarak hesaplanan mevcut sömürü seviyesinde biyokütle azalmıştır. MSY'yi temsil eden 1,0'lık bir F faktörü 498,180 tona karşılık gelmektedir. Mevcut avlanma oranında (F = 0,56), biyokütle avlanmamış durumdaki 666,206 metrik tondan %25 (168,026 ton) azalmıştır. Balıkçılık çabaları mevcut seviyede devam eder veya artarsa, *M. merlangus* stoklarının önemli ölçüde azalması beklenmektedir. Balıkçılık verimliliğindeki bu düşüşün, *M. merlangus* popülasyonlarına zarar verebilecek aşırı avlanma veya sürdürülemez uygulamalara işaret etmektedir. *M. merlangus*'un uzun vadeli sürdürülebilirliğini sağlamak için balık stoklarının ve balıkçılık faaliyetlerinin etkin yönetimi gereklidir.

**Anahtar kelimeler:** Mezgit, maksimum sürdürülebilir verim (MYS), stoklara katılım başına nispi verim (Y′/R), biyokütle başına nispi verim (B′/R), stok, güneydoğu karadeniz.

## INTRODUCTION

Whiting (*Merlangius merlangus*) is widely distributed throughout the eastern Atlantic, including the North, Baltic, Black, and Mediterranean Seas. Its stock status varies regionally, with this cold-water species adapting to the temperate waters of the Black Sea, where it is commonly found in sandy, muddy substrates at depths of 60–80 meters and temperatures between 5–16 °C (Karahanlı, 2024; Ross et al., 2018). Whiting's spawning peaks between January and August, though it can occur year-round (Murua & Sabarido, 2003; Çiloğlu et al., 2001). Its distribution is dynamic as the fish move in and out of spawning grounds (Heino et al., 2005). Numerous studies have focused on whiting's reproductive patterns, population parameters, and distribution within Türkiye and globally (Yıldız & Karakulak, 2018; Ross et al., 2018; Salihoğlu et al., 2017; Raykov et al., 2008; Prodanov & Bradova, 2003).

Small-scale fishing is crucial for Black Sea nations, and whiting is a significant catch. In the 1960s, 26 fish species were economically fished in the Black Sea, but this has since declined to 21 due to decreased production of valuable species along the coasts of Bulgaria, Romania, Ukraine, Georgia, and Türkiye, which share Black Sea fishery resources (Zengin, 2019; 2000). Black Sea fisheries have traditionally focused on pelagic stocks, but ecological changes and fishing pressure have caused stock declines. With pelagic stocks collapsing, fishing efforts have increasingly shifted to limited demersal stocks through trawl modification (Avşar, 1998). In Türkiye, whiting production was 30.488 tonnes in 1988 but dropped to 9.074 tonnes by 2023 (BSGM, 2023), reflecting increased fishing pressure and ecological shifts that have raised serious sustainability concerns (Bat et al., 2005; Gücü et al., 2017). Whiting, a semi-pelagic species, is caught with bottom trawls in Turkey's central and western Black Sea coasts. In contrast, bottom trawling is prohibited in the Eastern Black Sea, where whiting is fished using trammel nets, handline, and gill nets. In this region, whiting is a primary target species for small-scale fisheries (Bat et al., 2005; Erdem et al., 2006; Kalaycı & Yeşilçiçek, 2014; Aydın & Hacıoğlu, 2017).

Research by Gönener and Özdemir (2013) and Gönener and Bilgin (2010) indicated that whiting dominated total biomass in the Black Sea's coastal waters, crucial data for understanding the ecosystem's dynamics and guiding sustainable fishery management. Another study revealed that whiting accounted for 98.8% of the fish caught in the Black Sea, underscoring its dominance in the region's fishery (BSGM, 2023). Global studies on whiting biomass and stock sizes also indicate recent increases in Black Sea whiting stocks, which may benefit the fishing industry and ecosystem. However, further research is necessary to understand this trend's drivers and potential effects (Nedreas et al., 2014). This study evaluates the stock status, management practices, and population structure of whiting in the Eastern Black Sea, given its economic importance for Türkiye and neighbouring Black Sea countries.

## MATERIAL AND METHOD

***Sampling area and data source:*** This study was conducted along Türkiye's southeastern Black Sea from March 2017 to February 2018 (Figure 1). For stock assessment, 1579 *Merlangius merlangus* were obtained from depths between 5 m and 60 m along the Rize coast of the Southeastern Black Sea (Figure 1). The samples were obtained from bottom trawling operations (12 mm cod mesh size) using the 'Karadeniz Araştırma' vessel of Recep Tayyip Erdoğan University.

**Figure 1.** Study area

Bottom trawling is prohibited across extensive sections of Turkey's Black Sea coastline to safeguard the marine environment. Whiting is exclusively fished beyond the restricted trawling zones (BSGM, 2024).

***Laboratory examinations and data analysis:*** The length of each sample was recorded in the frequency data set after being measured with a precision of 1.0 cm; electronic scales with a precision of 0.01 grams were used to measure body weights. The following non-linear equation was used to establish the relationship between total length and weight for both sexes: $W = aL^b$ (Ricker, 1973). The allometric equation was considered when calculating the length-weight relationship. W stands for body weight (g), L for total length (cm), "***a***" for the regression coefficient, and "***b***" for the allometry coefficient (Ricker, 1973).

***Population dynamics model:*** The Virtual Population Analysis (VPA) software, integrated into the FISAT II package, was utilized to process the data. The FISAT II package facilitated data analysis (Gayanilo et al., 1997). By using the ELEFAN-I software included with FISAT II, we determined the asymptotic length ($L_\infty$) and growth coefficient (K) (Saeger & Gayanilo, 1986). This estimation was made with the ELEFAN-I tool, part of the FISAT II package (Saeger & Gayanilo, 1986).

The value of $t_0$ was calculated using Pauly's empirical equation (Pauly, 1979).

$$log_{10}(-to) = -0.3922 - 02752 log_{10} L\infty - 1.038 log_{10} K$$

The length-converted catch curve method was used to determine total mortality (Z) (Pauly, 1984). The natural mortality rate (M) was calculated using the empirical relationship below (Pauly, 1986).

$$log_{10} M = -0.0066 - 0.279 log_{10} L\infty + .06543 log_{10} K + 0.4634 log_{10} T$$

Where $L_\infty$ represents the asymptotic length (cm), K denotes the VBGF growth coefficient, and T indicates the average annual temperature (°C). The required input for the study months was an average seawater temperature of 16.3 °C for 2017 and 2018 (Anonymous, 2023).

Fishing mortality (F) was calculated using the following relationship:

$F = Z - M$ (Avşar, 2005).

F is fishing mortality, Z is total mortality, and M is natural mortality.

The exploitation rate (E) was determined using Gulland's formula:

$E = {}^{F}/_{Z}$ (Gulland, 1971).

The length at first capture ($L_{c50}$) was calculated from the length frequency by applying the length-converted catch curve approach in the FISAT-II software. The ascending left arm of the length-converted catch curve was used to determine the capture probability of each length class using the FISAT-II package. By plotting the cumulative probability of capture against the mid-length of the generated curve, the length at the first capture ($L_{c50}$) was determined. Additionally, the lengths of the 25% and 75% catches were determined to represent the 25% and 75% cumulative possibilities, respectively. The Thompson and Bell method used the first capture lengths ($L_{c50}$) and ($L_{c75}$) as inputs.

The NORMSEP (Normsep component separation of normally distributed length-frequency samples) module attached to the FISAT-II package was used to determine the recruitment pattern of the *M. merlangus* population using the maximum probability method.

Y'/R and B'/R were determined using the "Beverton and Holt Y′/R Analysis" method integrated into the Fisat-II software. The capture probabilities ${}^{Lc}/_{L\infty}$ and ${}^{M}/_{K}$ values for the various length classes were used to determine the relative yield per recruit (Y'/R) and the relative biomass per recruit (B'/R).

The Beverton and Holt method provides the framework for the relative yield per recruit for the stock model given below (Beverton & Holt, 1966).

Relative yield-per recruit $({}^{Y'}/_{R}) = EU^{M/K}[1 - {}^{3U}/_{(1+m)} - 3U^3(1+m)]$

Where $U = 1 - ({}^{Lc}/_{L\infty})$; $m = \frac{1-E}{M/K} = {}^{K}/_{Z}$; $E = {}^{F}/_{Z}$

Relative biomass per-recruit = $({}^{Y'}/_{R})/F$

The first derivative of this function was used to determine $E_{0.1}$, $E_{0.5}$, and $E_{max}$. The linearised capture curve used to calculate Z was then estimated backward using the natural mortality rate (M) as an input in the FISAT-II package. Pauly's catch-curve analysis estimates the capture probability by projecting parameters and using moving averages (Jones & Van Zalinge, 1981).

Moving average $P_{L,i(new)} = P_{L,i-1} + P_{L,i(old)} + P_{L,(i+1)}/3$

Length-based virtual population analysis (VPA) is an appropriate approach for population reconstruction using fishing data. The VPA was computed using Whiting's length-based data.

The length-based virtual population analysis (VPA) provided fishing estimates of population densities by length class. The FISAT-II package used M, F, L, and K parameters as inputs (Pauly, 1984; Jones & van Zalinge, 1981). Thompson and Bell Yield-Stock estimation software is connected to the FISAT II package.

## RESULTS AND DISCUSSION

***Growth analysis:*** As this study aimed to estimate the whiting stock, no distinction was made between male and female samples. A total of 1579 whiting were sampled. Total length and weight ranged from 7.5 to 32.6 cm (mean 14.08±2.88) and 2.71 to 281.25 g (mean 25.19±20.79 S), respectively. When examining the sex of all specimens, 668 were identified as male (42.30%), 877 as female (55.54%), 28 as immature (1.77%), and 6 as of undetermined sex (0.37%). The female-to-male ratio was 1.31:1, and a Chi-square test indicated this ratio significantly deviated from an even 1:1 distribution ($\chi^2$ df=1 = 28.72; $p<0.05$). Additionally, the Kolmogorov-Smirnov (K-S) test revealed a significant difference in the size distribution between males and females ($p<0.05$). The regression coefficient (a) and coefficient of allometry (b) in whiting growth were calculated as 0.0047 and 3.171, respectively (Table 1). Applying Pauly's empirical formula, $t_0$ was -2.14111 (Pauly, 1979).

***Probability of capture :*** The length at first capture ($L_{c50}$) for whiting was 13.04 cm. In this sequence, the probabilities of $L_{c25}$ and $L_{c75}$ were estimated at 11.82 and 14.26 cm, respectively (Figure 2).

**Table 1.** Growth and population parameters of *Merlangius merlangus* in the southeastern Black Sea.

| N | a | b | $L_\infty$ | $W_\infty$ | K | φ | $t_0$ | Lc | Z | F | M | E | M/K | $L_{c50}/L_\infty$ | $E_{0.1}$ | $E_{0.5}$ | $E_{max}$ | $Y_{(t)}$ | $Y/U_{(t)}$ | $Y/F_{(t)}$ | $MSY_{(t)}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3394 | 0.0047 | 3.1709 | 40.89 | 605.85 | 0.10 | 2.22 | –2.1411 | 13.04 | 0.85 | 0.56 | 0.29 | 0.66 | 2.9 | 0.32 | 0.507 | 0.311 | 0.61 | 252.55 | 669.89 | 450.98 | 498.180 |

Y: Yield; Y/U: Total annual stock; Y/F: Standing stock; MSY: Maximum sustainable yield t: Thousand tons

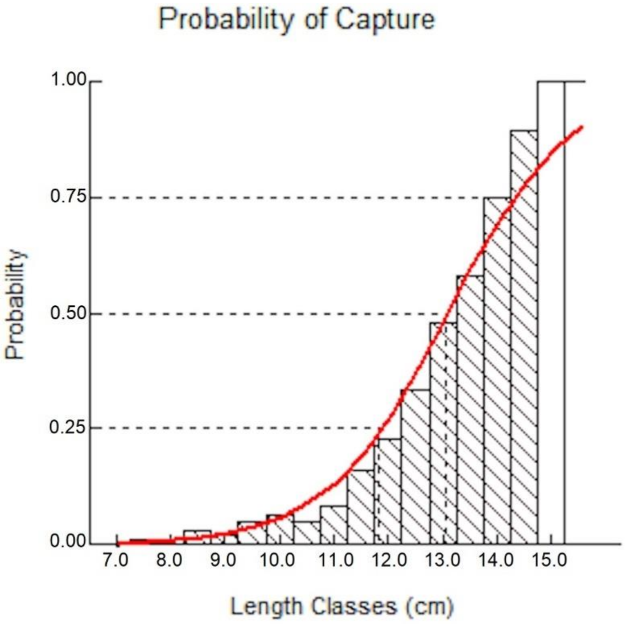


**Figure 2.** Logistic selection curve for the probability of capture, displaying 25, 50, and 75% selection lengths for *Merlangius merlangus.*

***Mortality:*** Using the length-converted catch curve method, the total mortality rate (T), the natural mortality rate (N), and the fishing mortality rate (F) of the whiting in the southeastern Turkish waters of the Black Sea were estimated to be 0.85, 0.29, and 0.56, respectively. The exploitation rate (E) was estimated to be 0.66 using the same method (Figure 3, Table 1).

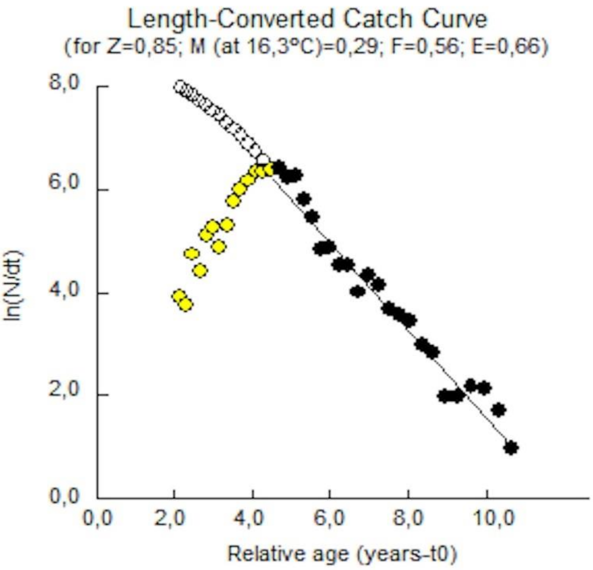


**Figure 3.** Length-converted catch curve for *Merlangius merlangus.*

***Recruitment:*** Whiting recruitment peaked on the southeastern coast of the Black Sea, Turkish waters in March (16.28%), August (13.13%), and November (14.74%), respectively. However, recruitment fluctuates continuously throughout the year (Figure 4).

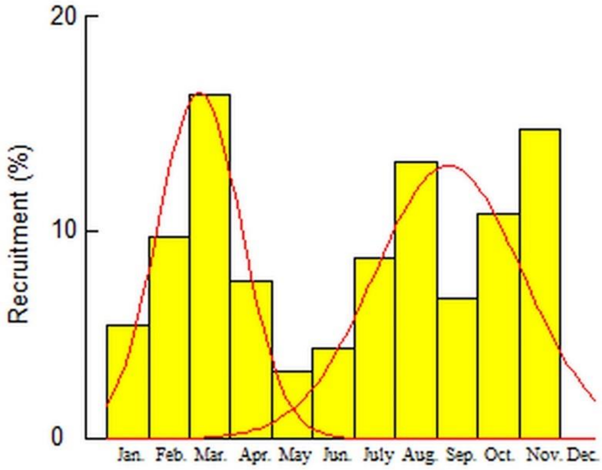


**Figure 4.** Recruitment pattern for *Merlangius merlangus.*

***Length-based Virtual Population Analysis (VPA):*** Maximum natural mortality (M) and fishing mortality rates (F) in length classes were found to be between 7.5 cm and 11.5 cm and 12.0 cm and 14.5 cm, respectively (Figure 5). The largest length classes most affected by fishing were estimated to be between 14.0 cm and 16.5 cm, 20.0 cm and 25.5 cm, and 32.0 cm and 32.5 cm, respectively (Table 2). Based on the VPA data, the estimated steady-state biomass was 103,384.8 tons.

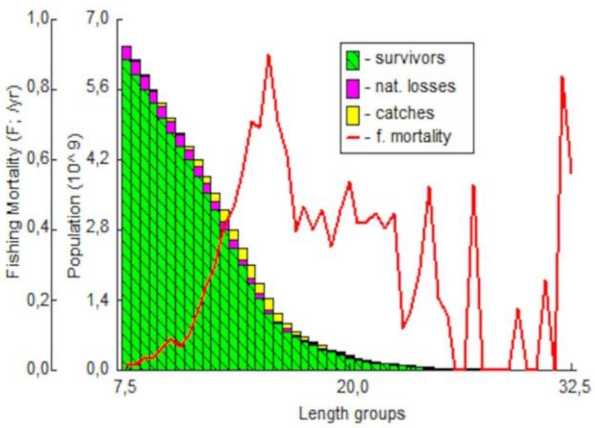


**Figure 5.** The length-structured VPA for *Merlangius Merlangus* in the southeastern Black Sea

**Table 2.** Length-based virtual population analysis (VPA).

| Mid-Length (cm) | Catch (in numbers) | Population (N) | Fishing mortality (F) | Steady-state Biomass (tonnes) |
|---|---|---|---|---|
| 7.5 | 16000000 | 6469807104 | 0.0169 | 1348.45 |
| 8.0 | 13000000 | 6179201024 | 0.0142 | 1604.75 |
| 8.5 | 36000000 | 5899979776 | 0.0405 | 1881.88 |
| 9.0 | 29000000 | 5606476288 | 0.0338 | 2178.28 |
| 9.5 | 51000000 | 5328914944 | 0.0618 | 2491.16 |
| 10.0 | 70000000 | 5038520832 | 0.0885 | 2809.96 |
| 10.5 | 50000000 | 4739102720 | 0.066 | 3141.18 |
| 11.0 | 71000000 | 4469475840 | 0.0981 | 3480.95 |
| 11.5 | 119000000 | 4188539136 | 0.1737 | 3794.78 |
| 12.0 | 151000000 | 3870826240 | 0.2358 | 4060.01 |
| 12.5 | 178000000 | 3534120192 | 0.3011 | 4267.09 |
| 13.0 | 223000000 | 3184689664 | 0.4158 | 4385.25 |
| 13.5 | 220000000 | 2806158592 | 0.4595 | 4413.73 |
| 14.0 | 238000000 | 2447311872 | 0.5657 | 4353.71 |
| 14.5 | 256000000 | 2087304704 | 0.7106 | 4167.95 |
| 15.0 | 210000000 | 1726830208 | 0.6912 | 3914.78 |
| 15.5 | 226000000 | 1428725504 | 0.9011 | 3586.73 |
| 16.0 | 146000000 | 1129993088 | 0.7099 | 3253.44 |
| 16.5 | 106000000 | 924352064 | 0.6127 | 3017.99 |
| 17.0 | 59000000 | 768182272 | 0.3938 | 2873.51 |
| 17.5 | 61000000 | 665738048 | 0.4641 | 2764.55 |
| 18.0 | 46000000 | 566620672 | 0.4004 | 2642.94 |
| 18.5 | 46000000 | 487301344 | 0.459 | 2514.94 |
| 19.0 | 31000000 | 412240192 | 0.354 | 2392.04 |
| 19.5 | 35000000 | 355845728 | 0.4586 | 2264.01 |
| 20.0 | 35000000 | 298715232 | 0.5397 | 2085.14 |
| 20.5 | 23000000 | 244909264 | 0.4171 | 1917.76 |
| 21.0 | 20000000 | 205918560 | 0.422 | 1779.76 |
| 21.5 | 18000000 | 172172880 | 0.445 | 1636.62 |
| 22.0 | 14000000 | 142443664 | 0.4066 | 1498.99 |
| 22.5 | 13000000 | 118457904 | 0.4453 | 1364.98 |
| 23.0 | 3000000 | 96991744 | 0.1171 | 1284.8 |
| 23.5 | 4000000 | 86560672 | 0.1716 | 1251.39 |
| 24.0 | 6000000 | 75801064 | 0.291 | 1183.5 |
| 24.5 | 9000000 | 63822060 | 0.5218 | 1057.13 |
| 25.0 | 3000000 | 49820300 | 0.2067 | 948.6 |
| 25.5 | 2000000 | 42611216 | 0.1552 | 897.22 |
| 26.0 | 0 | 36873016 | 0 | 873.55 |
| 26.5 | 0 | 33451282 | 0 | 869.77 |
| 27.0 | 5000000 | 30244536 | 0.5303 | 786.96 |
| 27.5 | 0 | 22510468 | 0 | 705.01 |
| 28.0 | 0 | 20199908 | 0 | 694.5 |
| 28.5 | 0 | 18050504 | 0 | 681.5 |
| 29.0 | 0 | 16056726 | 0 | 666.03 |
| 29.5 | 1000000 | 14213023 | 0.1772 | 624.05 |
| 30.0 | 0 | 11576899 | 0 | 580.79 |
| 30.5 | 0 | 10133417 | 0 | 559.84 |
| 31.0 | 1000000 | 8813233 | 0.2568 | 504.21 |
| 31.5 | 0 | 6684111 | 0 | 449.48 |
| 32.0 | 2000000 | 5727488.5 | 0.8384 | 341.72 |
| 32.5 | 2000000 | 3035714.25 | 0.56 | 537.47 |
| Total | 284.800.000.0 | 761.520.529,34 | | 103.384,83 |

***Yield per–recruit (Y′/R) and biomass per–recruit (B′/R):*** The study concludes that the Maximum Sustainable Yield (MSY) for whiting can be achieved with current fishing at an exploitation rate of 0.66. E0.1, the exploitation level, led to a marginal increase of 10% in relative yield per recruit, reaching 0.507. The study confidently estimates that the exploitation level at E0.5, equivalent to 50% of the relative biomass per recruit of the unexploited stock, is 0.311. Implementing proper management measures, such as adjusting fishing gear selectivity for larger fish, is essential to minimize the catches of small fish. Relative yield per recruit (Y'/R) analysis results for whiting in the Turkish seas off the eastern Black Sea indicate that increased fishing efforts will yield minimal additional harvest, suggesting a slight economic gain. Moreover, the study findings on biomass per recruit (B'/R) demonstrated a dramatic decrease as the exploitation rate increased (Figure 6).

***Stock structure:*** The VPA analysis based on fish length was utilized for Thompson and Bell's long-term prediction (Thompson & Bell, 1934). This analysis produced the F-factor array, which provides yield, biomass, and values. The current level of fishing (approximately 449.70 tonnes) was predicted by an F-factor of 0.56. An F-factor of 1.0 corresponds to the maximum sustainable yield (MSY) of 498,180 tonnes (Table 3). As fishing pressure increased, the amount of product decreased inversely. However, after reaching the fishing level with an F-factor of 1.0, the amount of product declines by an average of about 2.0–2.5 tonnes for each incremental increase in the fishing level (F-factor) (Table 3). At the current fishing level (F = 0.56), the biomass is reduced by 25% (168.026 tonnes) of the unexploited biomass (666.206 tonnes). In terms of value, the maximum economic return is achieved at an F-factor of 1.0 and then declines (Figure 7).

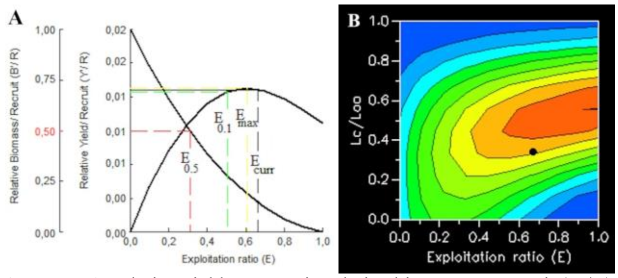


**Figure 6. A)** Relative yield per recruit, relative biomass per recruit (B′/R), and **B)** Yield isopleth per recruit (Y′/R) of *Merlangius merlangus* in the southeastern Black Sea.

**Table 3.** Predicted yield and biomass for different fishing mortality rates of *Merlangius merlangus* by the Thompson and Bell method.

| F-factor | Yield (tonnes) | Mean biomass (tonnes) |
|---|---|---|
| 0.0 | 000.000 | 666.206 |
| 0.2 | 279.567 | 431.246 |
| 0.4 | 411.701 | 298.624 |
| 0.5 | 447.349 | 254.901 |
| 0.6 | 470.860 | 221.129 |
| 0.7 | 484.853 | 194.763 |
| 0.9 | 497.101 | 157.308 |
| 1.0 | 498.180 | 143,852 |
| 1.2 | 495.037 | 123.695 |
| 1.4 | 488.295 | 109.522 |
| 1.6 | 480.219 | 99.096 |
| 1.9 | 467.806 | 87.785 |
| 2.0 | 463.814 | 84.798 |
| 2.2 | 456.186 | 79.656 |
| 2.3 | 452.563 | 77.423 |
| 2.4 | 449.071 | 75.375 |
| 2.6 | 442.469 | 71.744 |
| 2.8 | 436.348 | 68.617 |
| 3.0 | 430.669 | 65.889 |
| 3.2 | 425.388 | 63.485 |
| 3.4 | 420.466 | 61.345 |
| 3.6 | 415.866 | 59.426 |
| 3.8 | 411.554 | 57.692 |
| 4.0 | 407.502 | 56.115 |

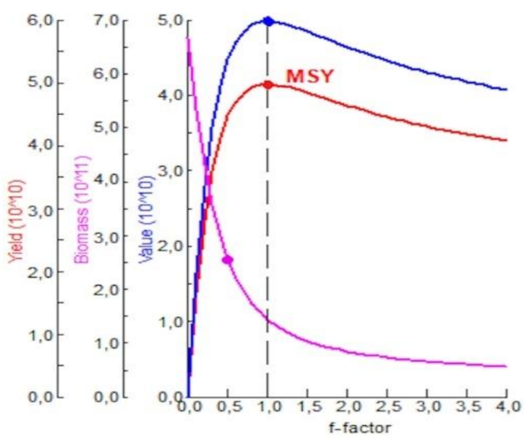


**Figure 7.** *Merlangius merlangus* yield-stock prediction in the southeastern Black Sea via the Thompson and Bell method.

Our study examined the growth and population parameters of *M. merlangus*, which are essential for practical stock assessment. The length distribution observed in our research ranged from 7.6 cm to 32.9 cm. In comparison, Samsun and Akyol (2017) reported a length range of 8.8 cm to 22.8 cm, while Sağlam and Sağlam (2012) found it to be between 10.0 cm and 26.0 cm. More recently, Şahin et al. (2021) documented a length range of 7.5 cm to 32.6 cm along Turkey's Eastern Black Sea coast, which closely matches our findings. In contrast, the results from Samsun and Akyol (2017) and Sağlam and Sağlam (2012) were narrower. Additionally, a study conducted in the Marmara Sea by Erdem et al. (2006) reported a length distribution for Whiting between 8.89 cm and 24.72 cm, which is more limited than our observed range. These variations may be due to differences in nutrient availability, temperature, and predator presence (Salihoğlu et al., 2017). Importantly, our growth estimates for the fish population provide valuable insights for fisheries management, enhancing understanding of population structure, size distribution in catches, and the size at maturity during fishing.

**Table 4.** Growth and population parameters of *Merlangius merlangus* in different habitats

| Study area | $L_\infty$ | $W_\infty$ | K | $t_0$ | Z | M | F | E | $E_{max}$ | $Y_{(t)}$ | $MSY_{(t)}$ | Biomass (1000 t) | Literature |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Marmara sea | 35.74 | | 0.124 | –1.338 | 1.35 | 0.34 | 1.1 | 0.75 | | | | | Karadurmuş, 2022 |
| Black sea | 31.87 | 271.01 | 0.130 | –3.071 | | | | | | | | | Şahin et al., 2021 |
| Western Baltic sea | 97.3 ♀ | | 0.07 | | | | | | | | | | Ross et al., 2018 |
| | 58.0 ♂ | | 0.16 | | | | | | | | | | |
| North sea | 74.2 ♀ | | 0.16 | | | | | | | | | | |
| | 57.9 ♂ | | 0.19 | | | | | | | | | | |
| Western Black sea | 37.05 | | 0.106 | –1.63 | 1.19 | 0.37 | 0.82 | 0.69 | | | | | Yıldız et al., 2018 |
| SE Black sea | 33.05 | | 0.13 | –2.93 | 0.98 | 0.22 | 0.76 | 0.77 | | | | | Kasapoğlu, 2018 |
| Northeast Atlantic Ocean | 44.77 ♀ | | 0.35 | –0.95 | | | | | | | | | Barrios et al.. 2017 |
| | 36.11 ♂ | | 0.35 | –1.06 | | | | | | | | | |
| Black sea | | | | | | | | | | | 4.941 | | Salihoğlu et al.. 2017 |
| Mid. Black sea | 28.69 | | 0.21 | –1.91 | 0.97 | 0.50 | 0.47 | 0.48 | | | | | Samsun and Akyol, 2017 |
| Mediterranean and Black sea | | | | | | | 0.87-2.50 ($F_{curr}$) | | | | | | Cardinale and Osio, 2013 |
| | | | | | | | Fmsy/Fcurr=1.06-4.14 | | | | over exploited | | |
| | | | | | | | Fmsy/Fcurr=1.06 0.37 ($F_{curr}$) | | | | over exploited | | |
| SE Black sea | 33.56 | | 0.141 | | 1.68 | 0.27 | 1.41 | 0.84 | | | | | Sağlam and Sağlam, 2012 |
| Southeast Black sea | 20.29 ♀ | | 0.805 | –0.76 | | | | | | | | | Bilgin et al.. 2012 |
| | 18.95 ♂ | | 0.900 | –0.24 | | | | | | | | | |
| Southeast Black sea | | | | | | | | | | 40.421 | | | Gönener and Bilgin, 2010 |
| Western Black sea | | | | | | | | | | | 595.6–606.966 | 51–68 | Raykov et al.. 2008 |
| Northeast Atlantic | | | | | | | | | | | | 8 (mill.t) | Heino et al.. 2005 |
| Black sea | | | | | | | | | | | | 10-40 | Ünlüata, 2005 |
| Marmara sea | 38.5 | 431.0 | 0.15 | –1.47 | | | | | | | | | Erdem, 2006 |
| US and Canadian Pacific waters | | | | | | | | | | 190.400 | | 1.851.400 | Ishimura, 2003 |
| Bulgarian waters | 26.63 | 141.3 | 0.1981 | –1.81 | | | | | | | | | Bradova and Prodanov, 2003 |
| Western Black sea | | | | | | | | | | | | 2.870,6 | Prodanov and Bradova, 2003 |
| Black sea | 39.1 | | 0.15 | –1.53 | 1.63 | 0.39 | 1.24 | | | 30188 | | | İşmen, 2002 |
| Southeast Black sea | 52.50 ♀ | | 0.092 | –2.39 | | | | | | | | | Çiloğlu et al.. 2001 |
| | 37.19 ♂ | | 0.114 | –1.75 | | | | | | | | | |
| Southeast Black sea | 40.89 | 605.8 | 0.10 | –2.14 | 0.85 | 0.29 | 0.56 | 0.66 | 0.61 | 252.55 | 450.98 | 666.206 | This study |

mill.t: million tonnes, mt: Metric tonnes, MYS: maximum sustainable yield, *SSB: Spawning stock biomass (mt).

A study conducted along Türkiye's Black Sea coast determined the von Bertalanffy seasonal oscillatory growth parameters as $L_\infty$ = 39.1 cm, K = 0.15, $t_0$ = -1.05, C = 0.23, and $t_s$ = 0.48, revealing differences in growth rates between males and females. Females grew faster and achieved a greater maximum length than males (Işmen, 2002). Similarly, research by Çiloğlu et al. (2001) on the southeastern Black Sea reported asymptotic length ($L_\infty$) and growth constant (K) values of 52.50 cm and 37.19 cm for males and females, respectively, with $t_0$ calculated as -1.75 for males and -2.39 for females.

Aksu (2020) provided further insights into whiting growth parameters and length-weight relationships in the Central Black Sea region. For males, the length-weight relationship was $W = 0.0047L^3.1694$ ($r^2$ = 0.97), while for females, it was $W = 0.0058L^3.077$ ($r^2$ = 0.96). The study estimated von Bertalanffy growth parameters for all sexes as $L_\infty$ = 30.57 cm, K = 0.937 $y^{-1}$, $t_0$ = -2.0407, and a growth performance index (φ) of 2.9423. Another study by Mazlum and Bilgin (2014) on the southeastern Black Sea highlighted that the Gompertz model was the most effective method for estimating whiting growth. Female growth parameters were determined as $L_\infty$ = 32.3 cm, K = 0.1414 $y^{-1}$, $t_0$ = -4.69, and φ = 2.258, while combined-sex estimates were $L_\infty$ = 22.3 cm, K = 0.2668 $y^{-1}$, $t_0$ = 3.87, and φ = 2.123. Sağlam and Sağlam (2012) found that male whiting can live up to 5 years, while females can reach 4 years of age. They calculated the weight-length relationship as $W = 0.0064L^3.0441$ and described the von Bertalanffy growth equation for both sexes as $L_t = 33.56(1 – e^{-0.141}(t+2.654))$. The study also determined mortality rates, with total mortality (Z) at 1.68, natural mortality (M) at 0.27, and fishing mortality (F) at 1.41. In another study, Yıldız and Karakulak (2018) found that most of the whiting population consisted of individuals aged 1 to 2 years. They calculated growth parameters for all individuals as $L_\infty$ = 7.05 cm, K = 0.10 $y^{-1}$, and $t_0$ = -2, with mortality rates of Z = 1.19 $y^{-1}$, M = 0.37 $y^{-1}$, F = 0.82 $y^{-1}$, and an exploitation rate (E) of 0.69 $y^{-1}$.

Bilgin et al. (2012) investigated whiting growth and reproductive biology on the southeastern Black Sea, calculating von Bertalanffy growth parameters as $L_\infty$ = 18.95 cm and K = 0.900 for males and $L_\infty$ = 20.29 cm and K = 0.805 for females. These studies collectively emphasize the significance of understanding the growth dynamics of whiting to support effective fishery management and conservation efforts in the region.

Research on fish growth parameters along Türkiye′s Black Sea coast has highlighted consistent trends across multiple studies. For example, İşmen (2002) observed that females generally grow faster and reach larger sizes than males, with von Bertalanffy seasonal growth parameters recorded as $L_\infty$ = 39.1 cm, K = 0.15, $t_0$ = -1.05, C = 0.23, and $t_s$ = 0.48. Similarly, Çiloğlu et al. (2001) studied the southeastern Black Sea and reported asymptotic lengths ($L_\infty$) of 52.50 cm for males and 37.19

cm for females, with growth rates (K) of 0.0092 and 0.114 and $t_0$ values of -1.75 for males and -2.39 for females. On the southeastern Black Sea, Erdem et al. (2006) estimated an $L_\infty$ of 31.87 cm, an asymptotic weight ($W_\infty$) of 271.01 g, and a growth rate (K) of 0.130. These findings are broadly consistent with studies along Türkiye′s Black Sea and the eastern Black Sea region (Radulescu, 2023; Şahin et al., 2021; İşmen, 2002; Çiloğlu et al., 2001). In contrast, studies conducted in the Bulgarian and Turkish waters of the Western Black Sea revealed lower growth parameter values (Bilgin et al., 2012; Bradova & Prodanov, 2003). This discrepancy underscores the need for further research. For instance, Barrios et al. (2017) studied the Northeast Atlantic region and reported asymptotic lengths ($L_\infty$) of 44.77 cm for males and 36.11 cm for females, with identical growth rates (K) of 0.35. The $t_0$ values were calculated as -0.95 and -1.06 for males and females, respectively. Meanwhile, a study in the Western Baltic reported higher $L_\infty$ values for females, attributed to environmental factors such as water temperature, nutrient availability, and predation pressure (Ross et al., 2018).

Numerous studies have also highlighted the negative impact of intensive fishing on *M. merlangus* populations in the Black Sea, the Sea of Marmara, and the Mediterranean Sea (Yıldız et al., 2018; Kasapoğlu, 2018; Cardinale & Osio, 2013; Erdem et al., 2006). Samsun and Akyol (2017) reported mortality rates for fish in the Central Black Sea, with total mortality (Z) at 0.97, natural mortality (M) at 0.50, and fishing mortality (F) at 0.47. In the eastern Black Sea, Sağlam and Sağlam (2012) reported higher rates: total mortality (Z) at 1.68, natural mortality (M) at 0.27, and fishing mortality (F) at 1.41, resulting in exploitation rates (E) of 0.48 and 0.84, respectively. Similarly, Kasapoğlu (2018) found mortality rates in the southeastern Black Sea of 0.98 for total mortality (Z), 0.22 for natural mortality (M), and 0.76 for fishing mortality (F).

In the Marmara Sea, Karadurmuş (2022) observed mortality rates of 1.35 for total mortality (Z), 0.34 for natural mortality (M), and 1.10 for fishing mortality (F), with an exploitation rate of 0.75. İşmen (2002) reported similar trends in the Black Sea, with total mortality (Z) at 1.63, natural mortality (M) at 0.39, and fishing mortality (F) at 1.24. A separate study in the Sea of Marmara recorded a natural mortality rate (M) of 1.35 and fishing mortality (F) of 1.10, resulting in an exploitation rate (E) of 0.75 (Karadurmuş, 2022). Our study found lower total mortality (M) and fishing mortality (F) rates than previous research, aligning closely with other studies on *M. merlangus* populations. This consistency highlights the significance of our findings in advancing the understanding of fish population dynamics and informing fisheries management.

The alarming trend in the Black Sea is driven by increasing pollution, the negative impacts of climate change on fish populations, the global decline in fish stocks, and the simultaneous reduction in fishery products. This study also assessed the relative yield and biomass per fish based on initial catch length. The maximum exploitation rate (Emax), representing the highest relative yield per juvenile fish (Y′/R), was calculated as 0.61, which fell short of the expected value of 0.66. Additionally, the current exploitation rate ($E_{curr}$) for *M. merlangus* exceeded Gulland's optimum exploitation rate of 0.50 (Gulland, 1971). Although *M. merlangius* catches were high in the eastern Black Sea until 2017, the western Black Sea was reported to have provided more catches after 2017 (Samsun, 2024).

These findings indicate that the *M. merlangus* stock in the study area is being exploited beyond sustainable levels, emphasizing the urgent need for effective fisheries management measures. Modifying fishing gear is recommended to enhance selectivity for larger fish and raise the minimum catch size to reduce the bycatch of smaller fish. The study also identified seasonal peaks in fish recruitment occurring in March, November, and August, underscoring the importance of accounting for seasonal fluctuations when designing fisheries management strategies to protect fish populations during critical life stages.

A study conducted in Bulgarian coastal waters revealed that the biomass and food web dynamics of whiting, which share similar breeding periods and depths with sprat, significantly impact sprat consumption along the coast. During the breeding season, whiting was observed to feed on giant ten-legged crabs and sprat, highlighting substantial competition between these species for shared food resources. Since 1985, reduced replenishment rates for both species have contributed to declining stocks of whiting and sprat (Prodanov & Bradova, 2003).

The survival of *M. merlangus* sperm is heavily influenced by environmental conditions, as it cannot persist in low-salinity, low-oxygen waters. Consequently, the recruitment of eastern Baltic whiting stocks was reported to be poor during periods of water stagnation. Strong year classes, supported by favorable environmental conditions in the late 1970s, were linked to a peak in spawning stock biomass (SSB) of nearly 700,000 metric tons in the early 1980s. However, this was followed by a steady decline, reaching approximately 100,000 metric tons in 1992-the lowest level recorded since 1966 (FAO, 2005).

Continuous recruitment monitoring is vital for evaluating the health and sustainability of fish populations. It offers critical insights for fisheries managers to implement effective harvest regulations and conservation strategies. A study by Henderson (2019) in Bridgwater Bay, UK, identified an intriguing pattern: haddock recruitment peaked five times annually between June and October, with the most pronounced peak occurring in June. This unique finding raises questions and warrants further investigation. Whiting recruitment, influenced by nutrient availability, habitat conditions, predators, and water temperature factors, adds another layer of complexity to marine ecosystems (Henderson, 2019).

In the Pacific waters off the USA and Canada, whiting biomass was estimated at 1.851.400 metric tons (Mt) (Ishimura, 2003). By comparison, our study recorded a whiting stock biomass of 666,203 Mt. The discrepancy between these findings could be attributed to differences in habitat size, water temperature, nutrient levels, fishing pressure, predator presence, and other ecological factors.

The biomass of *Merlangius merlangus* along the Bulgarian coast was recorded as 27,273 tonnes in 1976, 10,893 tonnes in 1988, and 16,072 tonnes in 1991 (Prodanov & Daskalov, 1995). These fluctuations were attributed to findings that the natural reproduction of whiting was severely impacted between 1987 and 1989 (Arkhipov & Rovnina, 1990), leading to a notable decline in juvenile fish after 1987. Similarly, research conducted in the northern Black Sea reported that whiting biomass in the coastal waters of Ukraine and Romania ranged from 595.6 to 606,966 tonnes (Raykov et al., 2008).

In contrast, studies on the west coast of North America reported a whiting yield of 264,000 tonnes, with a maximum sustainable yield (MSY) estimated between 127,000 and 193,000 tonnes (Hollowed & Francis, 1987). The present study estimated whiting biomass of 666,206 tonnes and an MSY of 498,180 tonnes, significantly higher values than those observed along the Bulgarian coast (FAO, 2022; Arkhipov & Rovnina, 1990).

Variations in biomass across regions can be attributed to factors such as pollution, temperature fluctuations, nutrient availability, and predation pressures. Understanding these influences is essential for effective fisheries management and conservation. For example, a study in the Pacific Ocean involving the USA and Canada reported a whiting yield of 264,000 tonnes, with a stock surplus ranging from 127,000 to 193,000 tonnes (Hollowed & Francis, 1987). Furthermore, two studies conducted in the Black Sea estimated that whiting biomass and yield range between 10 and 40 tonnes (Gönener & Bilgin, 2010; Ünlüata, 2005). These differences highlight the importance of environmental factors such as prey availability, habitat temperature, predator dynamics, and fishing pressure, underscoring the relevance of this research in understanding regional and global variations in whiting populations.

## CONCLUSION

The resources of *M. merlangus* are being exploited to their maximum capacity, and any increase in fishing efforts is unlikely to lead to higher production. If fishing efforts continue at the current level or increase, *M. merlangus* stocks are expected to decline significantly. This decline in fishing efficiency indicates overfishing or unsustainable practices that could harm *M. merlangus* populations. Effective management of fish stocks, and fishing activities is essential to ensure the long-term sustainability of *M. merlangus*. Balancing fishing and sustainability will require implementing fishing limits, establishing protected areas, promoting responsible fishing methods, and monitoring population health.

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