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Original Article

Data-limited stock assessment of red mullet (*Mullus barbatus*) from the Iskenderun Bay, the north-eastern Mediterranean Sea

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Abstract
Stock size and status of red mullet *Mullus barbatus* were assessed via virtual population analysis and yield prediction analysis using on-board observed length-frequency catch data from the north-eastern Mediterranean Sea. The von Bertalanffy growth parameters obtained were L_∞ = 35.4 cm, k = 0.42, t_0 = 0.64, t_{anc} = 0.59 and Φ' = 2.72. Trawl-type selectivity ogive was calculated as 1.57 years corresponding to 17.1 cm TL. The virtual population analysis of *M. barbatus* indicated that the minimum and maximum fishing mortalities were 0.01 yr^{-1} and 11.1 yr^{-1} for the mid-length groups for 8.5 cm and 21.5 cm respectively. The estimated lowest mean biomass and yield were 3.541 t and 31 t at length 8.5, and the highest mean biomass and yield were 13.880 t at length 22.5 cm and 46.086 t at length 21.5 cm respectively. Biological reference points were F_{MSY} = 5.85, $F_{0.5}$ = 2.3, E_{MSY} = 0.89, $E_{0.5}$ = 0.77. The values for the current fishing mortality coefficient (F_{cur}) and the current exploitation rate (E_{cur}) calculated were 5.3 and 0.89 respectively. The present biological reference points indicate that the stock of *M. barbatus* in the investigated area is overexploited status and needs urgent management considerations.

Keywords: red mullet; stock assessment; virtual population analysis; yield prediction analysis

1 | INTRODUCTION

Sustainable use of fishery stocks depends on having an ability to assess stocks and make some predictions about how fisheries catches are likely to affect future stock states (Bentley 2015). Fishery stocks having large amounts of processed knowledge and data time series including fishery-independent surveys and rigorous catch data collection programmes, there is often enough information to fit statistical stock assessment models to make some prediction about how fisheries catch are likely to affect future stock states (Chong *et al.* 2020; Fujita 2021). Unfortunately, most stocks due to lack of knowledge and data are not well known which is being classified as data-limited stocks. In these stocks, sustainable stock exploitation and sustainability reference points are required (van Deurs *et al.* 2021).

Length-structured data for assessing stock and population dynamics study were commonly used where age structure data are limited (Sparre and Venema 1998; Mildenberger *et al.* 2017; Turan 2021). Electronic length-frequency analysis (ELEFAN) is a system of stock assessment methods using length-frequency (LFQ) data (Pauly and David 1980, 1981; Taylor and Mildenberger 2017) which are commonly available from catch data and scientific surveys and merged with length-based fish stock assessment, developed at the FAO (Sparre 1987). Electronic length-frequency analysis is used to estimate life history parameters relating to growth and mortality, which can be subsequently used as input into other models regarding optimal harvest strategies such as yield-per-recruit and virtual population analysis.

The red mullet *Mullus barbatus* Linnaeus, 1758 (Mullidae) is a benthic species, inhabiting mostly in the gravel, sandy and muddy bottoms at a depth range of 5 to 300 m, and spread from the northeastern Atlantic, British Isles (occasionally Scandinavia) to Senegal, Canary Islands, along the Mediterranean, and Black Sea (Relini *et al.* 1999; Turan *et al.* 2007; Froese and Pauly 2020). Since red mullet is of major commercial importance to the bottom trawl fisheries in the Mediterranean Sea, the relative index of the population abundance decreases with depth (Jukić-Peladić *et al.* 1999; Vrgoč 2000). The landings of this species in Turkey were reported as 2450 tons in 2000, and 1719 tons in 2019 (TUIK 2020). The fishing catch of red mullet is different among the four adjacent seas of Turkey; the Mediterranean coast of Turkey has the highest total catches, 37.5%, and the rest of the total catch are 30% from the Black Sea, 26.5% from the Aegean Sea and 5.5% from the Marmara Sea. There are reports (e.g. Gücü and Bingel 1994; Çicek 2015) that stocks of red mullet have been almost exclusively fished by the bottom trawl fisheries in Turkish coasts.

Assessing the status of the stocks of red mullet in Turkish marine waters is fairly challenging due to the lack of available data. In order to have the sustainable exploitation of fish stock, knowledge of the demographic parameters for a given species can assist in developing management models. Therefore, the principal objective of this study is the assessment of the stock status of red mullet via virtual population analysis and yield prediction analysis using on-board observed length-frequency catch data.

2 | METHODOLOGY

2.1 Sample collection

Red mullet (*Mullus barbatus*) samples were randomly collected on the board of commercial trawl monthly from April 2017 to March 2018 from the Iskenderun Bay, the northeastern Mediterranean Sea. Red mullet samples were measured for their total length (the nearest lower 0.1 cm) with a measuring board. A total of 3484 individual specimens of red mullet were collected from the Iskenderun Bay, north-eastern Mediterranean. The total landing of red mullet in the Turkish Seas was also collected from the TURKSTAT (TUİK 2020).

2.2 Data analysis

Length-frequency catch data (LFCD) of red mullet was analysed using a bootstrapped version of the Electronic Length Frequency Analysis (ELEFAN) I&II in the R package "TropFishR" (version 1.6.2) (Taylor and Mildenberger 2017). The size at morphometric maturity ogive was calculated using sizeMat in R package (R Core Team 2021) to estimate size at sexual maturity.

2.3 Growth parameters

The von Bertalanffy's growth parameters (VBGP) were calculated for each species with the seasonalised von Bertalanffy's growth function using the LFCD (Somers 1988): the used formula $L_t = L_\infty*(1\text{-e-}(K\ (t\text{-}t_0)+S\ (t)\ \text{-}S\ (t_0)))$, where $S(t) = (CK/2\pi) \times \sin 2\pi(t - ts)$, *C* is a constant indicating the amplitude of the oscillation, ranging from 0 to 1, and *ts* is the fraction of a year (relative to the age of recruitment, *t* = 0) where the sine wave oscillation begins, L_t and *t* describe the length at the predicted time, the asymptotic length was symbolised as L_∞, *K* depict the growth coefficient in year^{-1}, and t_0 was the hypothetical age or time where length was equal to zero (Sparre and Venema 1998; Taylor and Mildenberger 2017). In the ELEFAN (Sparre and Venema 1998; Schwamborn *et al.* 2019) used for the fitting process, tanchor describes the fraction of the year where the von Bertalanffy growth function crosses length = 0 for a given cohort (Taylor and Mildenberger 2017). Moreover, the growth performance index (Φ') was estimated: $\Phi' = \log(K) + 2 \times \log(L_\infty)$, where an initial seed value of L_∞ was measured based on L_{max}, derived from the mean of the 1% largest fish in the sample, using the formula; $L_\infty = L_{max} / 0.95$ (Pauly and Munro 1984). The best-fitting moving average (MA) value for each data was estimated by restructuring the data based on different MA values (Taylor and Mildenberger 2017), concerning the number of bins spanning the youngest cohorts.

2.4 Virtual population analysis

The length-based virtual population analysis (VPA) model (Sparre and Venema 1998) was used to estimate recruitment (Lassen and Medley 2001). Once the VBGP was estimated, the entire data was used for subsequent analysis. Total instantaneous mortality rate (*Z*) was estimated using the equation of Beverton and Holt (1956), calculating the slope of the regression line of the descending part of the catch curve where the selection of points was based on the length-derived age classes represented in the catch in each case. The instantaneous natural mortality rate (*M*) was estimated using the empirical formula developed by Then *et al.* (2015): $M = 4.118\ K\ 0.73\ L_\infty - 0.33$. Fishing mortality (*F*) and exploitation rate (*E*) were estimated based on the estimated *Z* and *M* values: $F = Z - M$ and $E = F / Z$ respectively (Pauly 1980).

2.5 Selectivity and maturity ogive

A trawl-type selectivity ogive with a given length at first capture (Lt_{50}, length at which 50% of fishes caught) was calculated with "trawl-ogive" selectivity model in addition to the length at both 25 and 75 captures, indicating the cumulative probability at 25% and 75% respectively (Taylor and Mildenberger 2017). The estimation of the size at morphometric maturity ogive (Lm_{50}, the size at 50% maturity) was estimated as the length at which a randomly chosen specimen has a 50% chance of being mature (Somerton 1980; Roa *et al.* 1999).

2.6 Yield-per-recruit analysis

The outputs of the above VPA procedures were used as input data for the Thompson and Bell (1934) prediction model to assess the optimum factor for increase or decrease of fishing effort to achieve maximum sustainable and economic yield of red mullet (Thompson and Bell 1934; Pauly and Morgan 1987; Schnute 1987; Sparre and Venema 1992). Biological reference points such as the limit reference point (F_{MSY}) and the target reference point ($F_{0.5}$) were estimated according to Cadima (2003). The estimated current exploitation rate (E_{cur}) was compared to a reference value of $E_{0.5}$, which has been proposed as an upper level of sustainable exploitation for fish species (Gulland 1971). The maximum sustainable level (E_{MSY}) and current fishing level (F_{cur}) were used to evaluate the state of the stock (Sparre and Venema 1998).

3 | RESULTS

Yearly landing of red mullet from the Turkish coastal waters, comprising the Mediterranean, Aegean, Marmara and Black Sea with 10%, 50% and 90% confidence intervals indicate that there are high fluctuations between the years and sharp continuing decline in the landing at recent years (Figure 1).

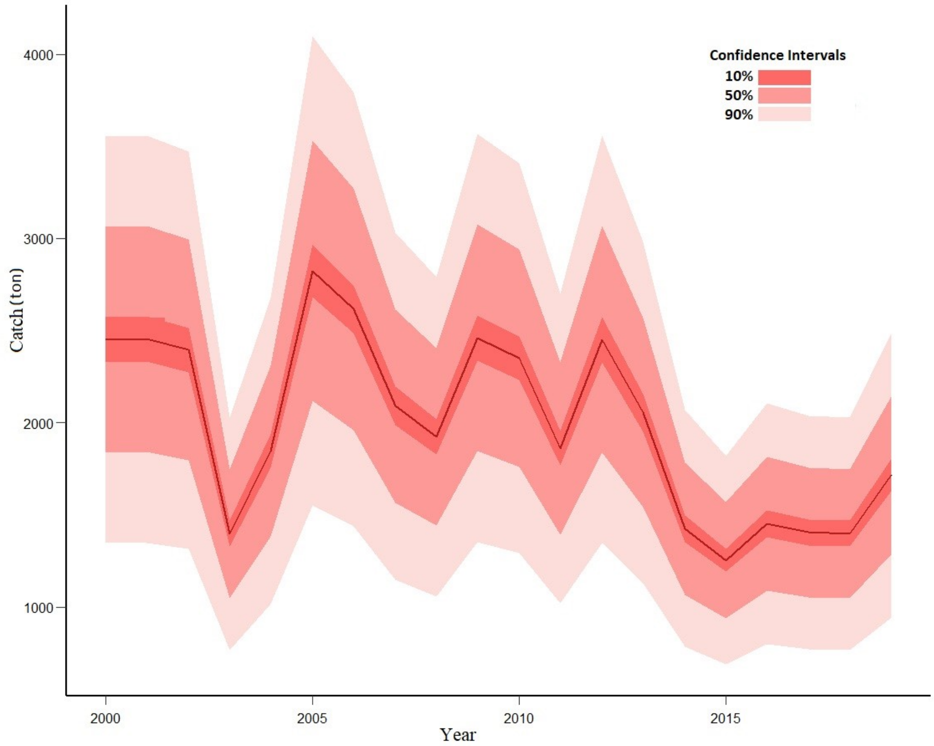

FIGURE 1 Total landing of red mullet *Mullus barbatus* from the Turkish coastal waters, comprising the Mediterranean, Aegean, Marmara and Black Sea with 10%, 50% and 90% confidence intervals.

3.1 Growth

The von Bertalanffy growth parameters obtained for red mullet were L_∞ = 35.4 cm, k = 0.42, t_0 = 0.64, t_{anc} = 0.59 and Φ' = 2.72. Monthly length-frequency data and VBG growth curve are presented in Figure 2.

3.2 Ogive

Trawl-type selectivity ogive (Lt_{50}, age at which 50% of red mullet becomes vulnerable to the gear) was calculated as 1.57 years corresponding to 17.1 cm TL (Figure 3). The lengths at which 75 and 95% of red mullet are retained in the gear were estimated as Lt_{75} = 18.14 cm at age 1.7 and Lt_{95} = 19.69 cm at age 1.9 year for *M. barbatus*.

3.3 Virtual population analysis (VPA)

Results of the length structured virtual population analysis parameters of *M. barbatus* are given at Figure 4. The VPA of *M. barbatus* indicated that the minimum and maximum fishing mortalities were 0.01 year^{-1} and 11.1 year^{-1} for the mid-length groups for 8.5 cm and 21.5 cm respectively (Figure 5). The estimated lowest mean biomass and yield were 3.541 t and 31 t at length 8.5, and the highest mean biomass and yield were 13.880 t at length 22.5 cm and 46.086 t at length 21.5 cm respectively. The estimated lowest and highest mean body weight were 6.25 g at length 8.5 cm and 292.8 g at length 22.5 cm respectively (Table 1).

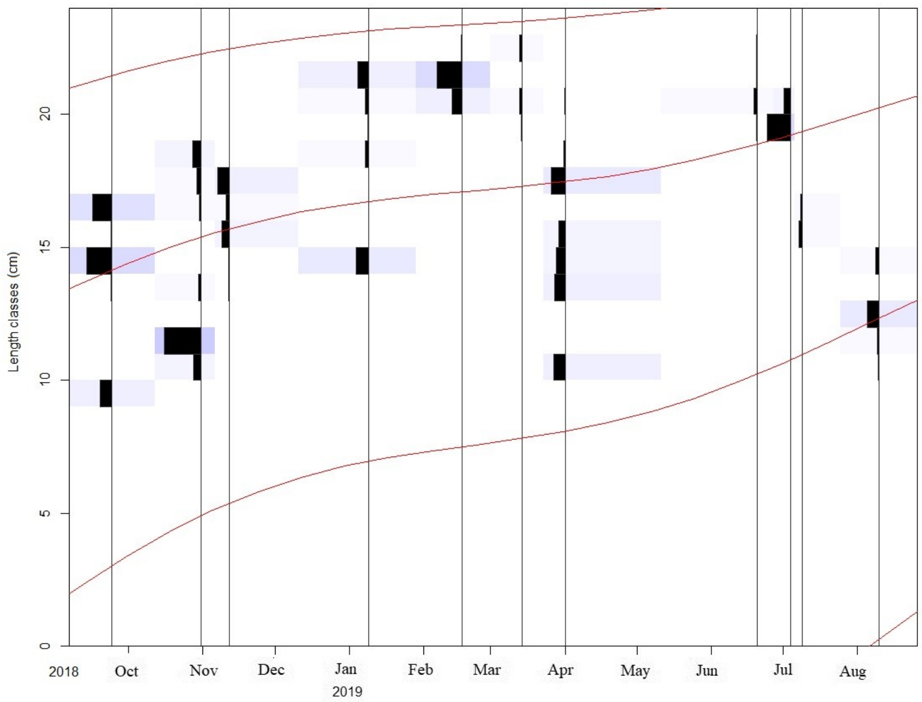

FIGURE 2 Monthly length-frequency histograms of *Mullus barbatus* with lines superimposed VBG growth curve (red). Successive peaks of growing cohorts are extrapolated by the model.

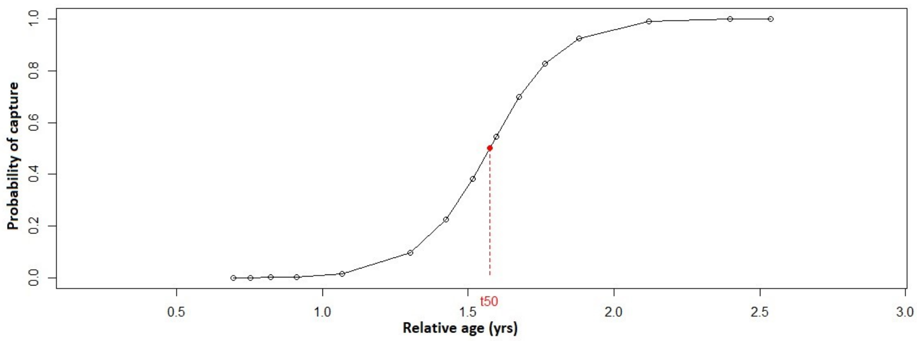

FIGURE 3 The size at trawl-type selectivity ogive of *Mullus barbatus*.

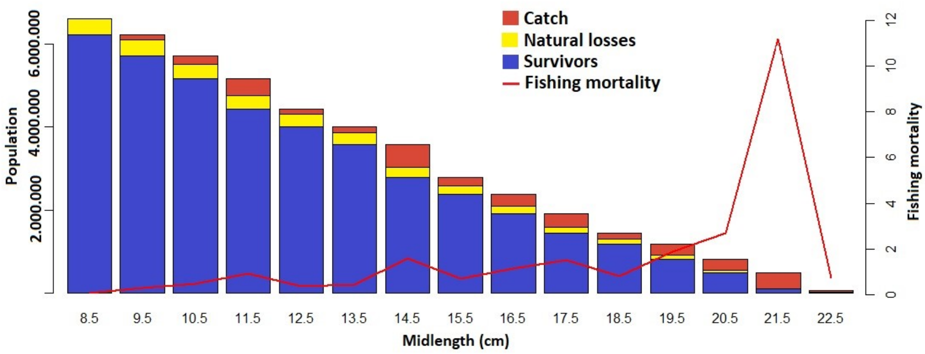

FIGURE 4 Virtual population analysis of *Mullus barbatus* fishery with fishing mortality rate by length classes and resulting reconstructed population structure (survivors, natural losses and catch) in the percentage of numbers per length class.

TABLE 1 The virtual population analysis parameters of *Mullus barbatus*.

Parameters / length classes	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	19.5	20.5	21.5	22.5
Survivors × 1000	6222	5722	5165	4433	4006	3578	2785	2378	1909	1443	1183	814	480	64	0
Natural losses × 1000	382	369	350	321	295	277	242	207	181	149	124	100	68	23	32
Catch × 1000	5	130	207	411	131	151	550	199	288	316	136	270	266	392	32
Mean body weight (g)	6.3	8.9	12.2	16.3	21.2	27.0	33.8	41.8	50.9	61.3	73.1	86.3	101.1	117.6	292.8
Fishery mortality	0.01	0.24	0.40	0.86	0.30	0.37	1.53	0.65	1.07	1.43	0.74	1.83	2.64	11.10	0.68
Mean biomass (t)	3541	4865	6328	7740	9256	11093	12174	12852	13667	13560	13460	12741	10200	4150	13880

3.4 Yield prediction analysis

The present estimated natural mortality coefficient and instantaneous total mortality coefficient (Z) of *M. barbatus* were M = 0.68 and Z = 5.98. Biological reference points of *M. barbatus* obtained in this study were F_{MSY} = 5.85, $F_{0.5}$ = 2.3, E_{MSY} = 0.89, $E_{0.5}$ = 0.77 (Figure 5). The values for the current fishing mortality coefficient (F_{cur}) and the current exploitation rate (E_{cur}) calculated were 5.3 and 0.89 respectively. The resulting estimates of the impact of mesh size restrictions on yield in red mullet explored by changing Lt and F revealed that the yields at the Lt_{50} and current F were 32 g (Figure 6).

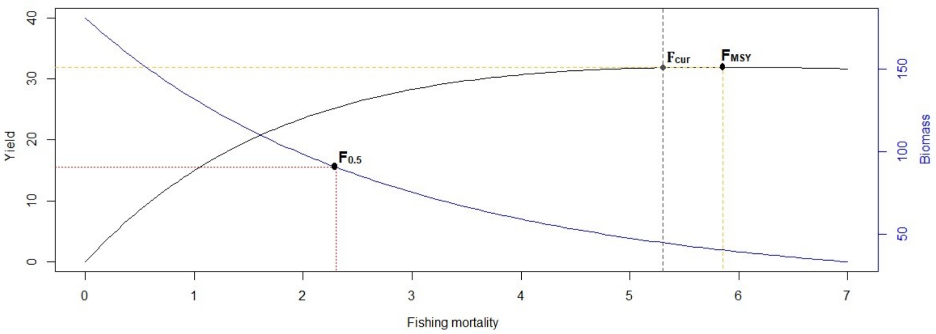

FIGURE 5 Curves of yield and biomass per recruit for *Mullus barbatus* in the function of the fishing mortality rate.

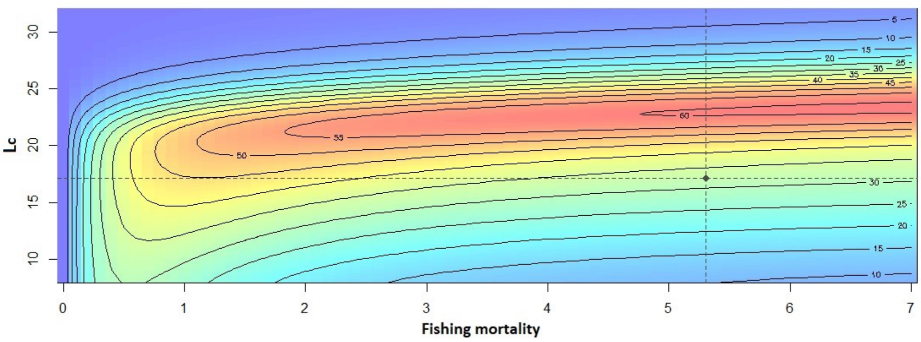

FIGURE 6 Yield-per-recruit isopleth diagram of *Mullus barbatus*. X-axis and Y-axis correspond to changing fishing mortality and the mean length at first capture (L_C), respectively. The black dots represent the current fishing regime.

4 | DISCUSSION

The preliminary assessment of stock size and status of red mullet *M. barbatus* via virtual population analysis and yield prediction analysis using on-board collected LFQ data in the Iskenderun Bay, north-eastern Mediterranean revealed that the red mullet stock is overexploited. Moreover, increasing the current fishing effort would not provide any higher yield and biomass. The yield prediction analysis of red mullet does provide a clear sign of overfishing, which could be the reason for the drop-down of the catches in the last decades in Turkish marine waters since the Mediterranean coast provides the highest catches to the total catch of red mullet in Turkey.

4.1 Growth parameters

The growth of *M. barbatus* was described by a von Bertalanffy model with an asymptotic length (L_∞) of 35.4 cm and a growth coefficient (K) of 0.42 year^{-1}. The present L_∞ estimated in this study was higher than the estimates from the same region in 2015 of Çicek (2015) (L_∞ = 21.98, K = 0.19), the Black Sea of Yılmaz (2019) (L_∞ = 17.64, K = 0.43), the Antalya Bay from the other side of Turkish Mediterranean coast of Taşlı *et al.* (2006) (L_∞ = 30.3, K = 0.10), Cyprus of GFCM (2014) (L_∞ = 24.2, K = 0.41) and the Tyrrhenian Sea of Bianchimi and Ragonese (2011) (L_∞ = 31.6, K = 0.37). The differences in the estimation values among the present and previous reports from different regions may be related to the sensitivity of von Bertalanffy parameters to the number of age groups used (Xiao 1994). The fit can be affected by the largest and smallest fish, generally poorly represented in the samples. The relatively higher estimation of L_∞ in the present study could be lack of small individuals since a deficiency of small individuals generates a positive bias in the estimate of K.

Furthermore, the observed differences between studies could be due to differences in the geographical location and the other factors such as regional climate, trophic status, diet and exploitation rates (Gheshlaghi *et al.* 2012; He *et al.* 2016). The estimated value of the growth performance index (Φ') was 2.72 for *M. barbatus* which are considered to specify slow growth. The magnitude of the growth performance is a matter of multiple factors such as growth rate (K) and the asymptotic length (L_∞). Pauly and Munro (1984) reported that the parameter Φ' acts as an indicator of the inconsistency on the accuracy of the estimated growth parameters of the same or related species of stocks. The current fishing regime, dietary patterns in the region may affect the detected growth performances.

4.2 Ogive

Sizes at trawl-type selectivity ogive (L_{t50}) were 17.1 cm corresponding to 1.57 year in the present study that the current regulated allowable catch size of both species in Turkish marine waters are 13 cm which is too short for giving a chance to the majority at least one time birth for both species. Different length at first sexual maturity (L_{m50}) were reported in the previous studies ranged from 10.2 to 13.87 cm (Türeli and Erdem 1997; Cherif *et al.* 2007; Çiçek 2015). Cherif *et al.* (2007) estimated L_{t50} of females and males from Gulf of Tunis was 13.94 and 13.87 cm. Genç *et al.* (2002) indicated the age at first maturity of this species is considered II years old, and 86.8% of the total catch consisted of immature or just matured individuals from the Eastern Black Sea coast. The present finding and the other studies indicate that most of the catch consisted of immature and fast-growing specimens, therefore, there is overfishing on the stock of *M. barbatus* off the Iskenderun Bay coasts.

4.3 Virtual population analysis

The length structured VPA of *M. barbatus* results revealed that the fishing pressure in the stock starts up to 11.5 cm size, and the fishing mortality highly increases only after attaining the length 20.5 cm, which may suggest increasing exploitation with an increase in the size of the fish. The length at first maturity (L_{m50}) of *M. barbatus* reported in other studies (ranged from 10.2 to 13.87 cm) (Türeli and Erdem 1997; Çiçek 2015) was found to be lower than the trawl-type selectivity ogive (L_{t50} = 17.1 cm TL). It could be therefore concluded that the gear being used for its capture is not a threat for its growth as well as recruitment of *M. barbatus* in the Iskenderun Bay, northeastern Mediterranean Sea.

4.4 Yield prediction analysis

The consistency of the estimated *M* was ascertained with the *M/K* ratio, which should be within the range of 1.12 – 2.5 for most fishes (Macer 1977). In this study, the *M/K* ratio was 1.62 falls within the acceptable defined range. Additionally, the range of *M/K* ratio for both species is below the Beverton and Holt (1959) range of 1.0 – 2.5 for fish indicating a poor environmental state.

The biological reference points of *M. barbatus* indicated that the current fishing mortality (F_{Curr} = 5.3) is higher than the fishing mortality for the target reference point ($F_{0.5}$) and near to MSY (F_{MSY}), which is confirmed here by the current exploitation rate (E_{Curr} = 0.89) that is also higher than the other reference point target benchmarks $E_{0.5}$ and E_{MSY}, showing the stock of *M. barbatus* during the study period in the investigated area is overexploited status. Thompson and Bell yield stock prediction analysis indicate that any increase in fishing mortality cannot increase both yield and biomass.

The yield isopleth diagram indicates that the yield can be double increased with increasing the length (about 19 cm) at first capture with one third less fishing mortality. Therefore, if the current mesh size (44 mm) could be increased, the yield from the red mullet stock can be double increased even with one third less fishing effort. The estimated *F* of *M. barbatus* (5.3 year^{-1}) is comparable to the estimates reported for the other Mediterranean stocks. The estimate was 0.26 for the southern Cyprus coasts (GFCM 2014), 1.43 for the Turkish coast of the Black Sea (Yılmaz *et al.* 2019), indicating that the fishing mortality in the Iskenderun Bay is relatively much higher than that from the other parts of the Mediterranean Sea.

5 | CONCLUSIONS

Data-limited stock assessment methods have been getting increased attention (Cortés and Brooks 2018; Moreau and Matthias 2018; Turan 2021). Here, the data-limited stock assessment based on length-frequency data is effectively estimated the stock size and status of *M. barbatus* off the Iskenderun Bay coasts. Studying population dynamics and parameters such as the asymptotic length and growth coefficient, mortalities (natural and fishing), and exploitation levels are crucial for effective management of marine resources. Limited knowledge of population structure and exploitation levels of marine resources demands a detailed study to facilitate better management of the resources (Francis 2017; Öğreden and Yağlıoğlu, 2017; Chong *et al.* 2020). The EC and GFCM are promoting a regional approach to fisheries management on the use of statistical analysis of biomass, catch and effort trends to expand monitoring of fisheries in unit areas, and the use of reference points based on statistical analyses in the Mediterranean (EU 2012; GFCM 2020).

From the fisheries management point of view, the present biological reference points of *M. barbatus* indicate the stock of *M. barbatus* during the study period in the investigated area is overexploited status. An increase in fisheries mortality in *M. barbatus* does not affect the yield and biomass. The selectivity needs to be lowered to increase the yield with one-third time less fishing mortality. Therefore, there should be regulations to increase the current mesh-size regulation (44 mm). Besides, changes in the exploitation regime in addition to the mesh size would improve *M. barbatus* exploitation pattern in the north-eastern Mediterranean.

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CONFLICT OF INTEREST

The author declares no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author.

REFERENCES

Bentley N (2015) Data and time poverty in fisheries estimation: potential approaches and solutions. ICES Journal of Marine Science 72(1): 186–193.

Beverton RJH, Holt SJ (1956) The theory of fishing. In: Graham M (Ed) Sea fisheries: their investigation in the United Kingdom. Arnold, London. pp. 372–441.

Beverton RJH, Holt SJ (1959) A review of the lifespans and mortality rates of fish in nature, and their relation to growth and other physiological characteristics. In CIBA Foundation colloquia on ageing, volume 5. Chichester, UK. pp. 142–180.

Bianchini ML, Ragonese S (2011) Establishing length-at-age references in the red mullet, *Mullus barbatus* L. 1758 (Pisces, Mullidae), a case study for growth assessments in the Mediterranean Geographical Sub-Areas (GSA). Mediterranean Marine Science 12(2): 316–332.

Cadima EL (2003) Fish stock assessment manual. FAO Fisheries Technical Paper 393. FAO, Rome, Italy. 83 pp.

Cherif M, Zarrad R, Gharbi H, Missaoui H, Jarboui O (2007) Some biological parameters of the red mullet, *Mullus barbatus* L., 1758, from the Gulf of Tunis. Acta Adriatica: International Journal of Marine Sciences 48(2): 131–144.

Chong L, Mildenberger TK, Rudd MB, Taylor MH, Cope JM, ... Stäbler M (2020) Performance evaluation of data-limited, length-based stock assessment methods. ICES Journal of Marine Science 77(1): 97–108.

Chong L, Mildenberger TK, Rudd MB, Taylor MH, Cope JM, ... Stäbler M (2020) Performance evaluation of data-limited, length-based stock assessment methods. ICES Journal of Marine Science 77(1): 97–108.

Çicek E (2015) Age, growth and mortality parameters of *Mullus barbatus* Linnaeus, 1758 (Perciformes: Mullidae) in Iskenderun Bay, northeastern Mediterranean. Iranian Journal of Ichthyology 2(4): 262–269.

Cortés E, Brooks EN (2018) Stock status and reference points for sharks using data-limited methods and life history. Fish and Fisheries 19: 1110–1129.

EU (2012) The role of GFCM in regional fisheries management (IP/B/PECH/IC/2012-070), Rome, Italy.

Francis RC (2017) Revisiting data weighting in fisheries stock assessment models. Fisheries Research 192: 5–15.

Froese R, Pauly D (2020) FishBase. World Wide Web electronic publication. www.fishbase.org, version (12/2020).

Fujita R (2021) The assessment and management of data limited fisheries: future directions. Marine Policy 133: 104730.

Genç Y, Mutlu C, Aydin I, Zengin B, Tabak I (2002) Determination of the fishing effects on the bottom fish source in Eastern Black Sea. Turkish Republic, Ministry of Agriculture and Rural Affair, TAGEM/IY/97/17/03/006, Trabzon. 114 pp.

GFCM (2014) Stock assessment form demersal species. Stock Assessment Form version 1.0 (January 2014). Uploader: Charis Charilaou.

GFCM (2020) General fisheries commission for the Mediterranean. The State of Mediterranean and Black Sea Fisheries 2020, Rome, Italy.

Gheshlaghi P, Vahabnezhad A, Taghavi Motlagh SA (2012) Growth parameters, mortality rates, yield per recruit, biomass, and MSY of *Rutilus frisii* Kutum, using length frequency analysis in the southern parts of the Caspian Sea. Iranian Fisheries Science 11: 48–62.

Gücü AC, Bingel F (1994) Trawlable species assemblages on the continental shelf of the northeastern Levant Sea (Mediterranean) with an emphasis on LessepTian migration. Acta Adriatica 35(1): 83–100.

Gulland JA (1971) Science and fishery management. ICES journal of Marine Science 33(3): 471–477.

He JX, Stewart DJ, Rudstam LG (2016) Growth parameters as growth indices in time-varying environments: comparisons among approaches to using von Bertalanffy growth functions. In: Rudstam L, Mills E, Jackson R, Stewart D (Eds), Oneida Lake: long-term dynamics of a managed ecosystem and its fisheries. American Fisheries Society, Bethesda, MD. pp. 475–496.

Jukić-Peladić S, Vrgoč N, Dadić V, Krstulović Šifner S, Piccinetti C, Marčeta B (1999) Spatial and temporal distribution of some demersal fish populations in the Adriatic Sea described by GIS technique. Acta Adriatica 40: 55–66.

Lassen H, Medley P (2001) Virtual population analysis: a practical manual for stock assessment (No. FAO FTP-400). FAO, Rome.

Macer CT (1977) Some aspects of the biology of the horse mackerel (*Trachurus trachurus* L.) in waters around Britain. Journal of Fish Biology 10 (1): 51–62.

Mildenberger TK, Taylor MH, Wolff M (2017) TropFishR: an R package for fisheries analysis with length frequency data. Methods in Ecology and Evolution 8: 1520–1527.

Moreau CM, Matthias BG (2018) Using limited data to identify optimal bag and size limits to prevent overfishing. North American Journal of Fisheries Management 38: 747-758.

Öğreden T, Yağlıoğlu D (2017) Catch composition of bottom trawl fisheries in Düzce Coast, southwestern Black Sea. Natural and Engineering Sciences 2(3): 158–167.

Pauly D (1980) On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. ICES Journal of Marine Science 39: 175–192.

Pauly D, David N (1980) An objective method for determining fish growth from length-frequency data. ICLARM Newsletter 3(3): 13–15.

Pauly D, David N (1981) ELEFAN I, a basic program for the objective extraction of growth parameters from length-frequency data. Berichte Der Deutschen Wissenschaftlichen Kommissuib Für Meeresforschung 28(4): 205–211.

Pauly D, Morgan GR (1987) Length-based methods in fisheries research, ICLARM Conference Proceedings 13. 468 pp.

Pauly D, Munro JL (1984) Once more on the comparison of growth in fish and invertebrates. Fishbyte 2(1): 1–21.

R Core Team (2021) R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.URL https://www.R-project.org/.

Relini G, Ferrara G, Massaro E (1999). Sintesi delle conoscenze sulle risorse da pesca dei fondi del Meditarraneo centrale (Italia e Corsica): synthesis of the knowledge on bottom fishery resources in Central Mediterranean (Italy and Corsica). Società Italiana di Biologia Marina. (in Italian).

Roa R, Ernst B, Tapia F (1999) Estimation of size at sexual maturity: an evaluation of analytical and resampling procedures. Fishery Bulletin 97(3): 570–580.

Schnute J (1987) A general fishery model for a size-structured fish population. Canadian Biology and Fisheries 44(5): 924–940.

Schwamborn R, Mildenberger TK, Taylor MH (2019) Assessing sources of uncertainty in length-based estimates of body growth in populations of fishes and macroinvertebrates with bootstrapped ELEFAN. Ecological Modelling 393: 37–51.

Somers I (1988) On a seasonally oscillating growth function. Fishbyte 6: 8–11.

Somerton DA (1980) A computer technique for estimating the size of sexual maturity in crabs. Canadian Biology and Fisheries 37(10): 1488–1494.

Sparre P (1987) Computer programs for fish stock assessment: length-based fish stock assessment for Apple II computers (Vol. 2). Food and Agriculture Organization of the United Nations, Rome.

Sparre P, Venema C (1992) Introduction to tropical fish stock assessment. FAO Fisheries Technical Paper, 306, FAO, ROme. 376 pp.

Sparre P, Venema SC (1998) Introduction to tropical fish stock assessment. Part 1. Manual. FAO Fisheries Technical Paper 306.1, Rev. 2. 407 pp.

Taşlı A, Pehlivan M, Yasemin K (2006) Antalya Körfezi'nden Avlanan Barbunya Balığı (*Mullus barbatus* L., 1758)'nın Büyüme Özellikleri Üzerine Bir Araştırma. Ege Journal of Fisheries and Aquatic Sciences 23(1): 113–118.

Taylor MH, Mildenberger TK (2017) Extending electronic length frequency analysis in R. Fisheries Management and Ecology 24(4): 330–338.

Then AY, Hoenig JM, Hall NG, Hewitt DA (2015) Evaluating the predictive performance of empirical estimators of natural mortality rate using information on over 200 fish species. ICES Journal of Marine Science 72(1): 82–92.

Thompson WF, Bell FH (1934) Effect of changes in intensity upon total yield and yield per unit of gear. Report of the International Fisheries Commission 8: 7–49.

TUİK (2020) Türkiye İstatistik Kurumu (in Turkish) (https://www.tuik.gov.tr) .

Turan C (2021) Data-limited stock assessment of two horse mackerel species (*Trachurus mediterraneus* and *T. trachurus*) from the northeastern Mediterranean. Regional Studies in Marine Science 44: 101732.

Turan C, Ozturk B, Erguden D, Gurlek M, Yaglioglu D, Uygur N (2007) Atlas of marine bony fishes of Turkey. Atlas and systematic of marine bony fishes of Turkey. Nobel Publishing House, Adana. pp. 83–485.

Türeli C, Erdem Ü (1997) The growth performance of red mullet (*Mullus barbatus* Linnaeus, 1758) and brushtooth lizardfish (*Saurida undosquamis* (Richardson, 1848)) from the coastal region of Adana Province (İskenderun Bay, Turkey). Turkish Journal of Zoology 21: 329–334.

van Deurs M, Brooks ME, Lindegren M, Henriksen O, Rindorf A (2021) Biomass limit reference points are sensitive to estimation method, time-series length and stock development. Fish and Fisheries 22: 18–30.

Vrgoč, N (2000) Structure and dynamics of demersal fish communities of the Adriatic Sea. Doctoral dissertation, Prirodoslovno-matematički fakultet, Sveučilište u Zagrebu, Croatia.

Xiao Y (1994) von Bertalanffy growth models with variability in, and correlation between, K and L_∞. Canadian Biology and Fisheries 51(7): 1585–1590.

Yılmaz B, Samsun O, Akyol O, Erdem Y, Ceyhan T (2019) Age, growth, reproduction and mortality of red mullet (*Mullus barbatus ponticus* Essipov, 1927) from the Turkish coasts of the Black Sea. Su Ürünleri Dergisi 36(1): 41–47.

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