

Red Mullet (*Mullus barbatus ponticus* Essipov, 1927) Stock Exploitation in Georgian Coastal Waters (2019-2021)

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Abstract

The aim of this study is to assess the level of the red mullet stock exploitation in Georgian coastal waters using the CMSY, LBB and LB-SPR modeling methods. The samplings were carried out using bottom trawls in 2019-2021. In total 4957 individuals were sampling (1 508 cases age was determined using scales and otoliths). Average annual catch of the red mullet make up 11.7±3.3 t (0.3% of the total annual Black Sea countries landings). The total length ranged from 6.1 to 20.7 cm. 70% of landings consisted of 3+, 4+ and 5+ age. The length-weight relationship was calculated as $W=0.0072 \times L^{3.20}$. Average von Bertalanffy growth parameters were $L_{\infty}=18.00\pm0.27$ cm, $k=0.31\pm0.03$, and $t_0=-0.93\pm0.26$. LBB method demonstrate that the red mullet stock was overexploited ($F/M=2.7$ more than optimal level $F/M=1.0$). According to CMSY analysis, biomass has been decreasing to B_{lim} for the researched period. The LB-SPR result showed that the estimated SPR was 23%. The exploitation of the stock was steadily intensive according to CMSY and LB-SPR methods. Increase in fishing mortality is not recommended.

Introduction

According to numerous ichthyological investigations the red mullet is a gregarious, demersal species, found on muddy bottoms or gravels and sandy bottoms of the continental shelf between 1-5 m and 100 m depth (Svetovidov, 1964; STECF, 2013). It prefers waters with the temperature higher than 8°C and salinity not less than 14-17‰ (Svetovidov, 1964; Froese & Pauly, 2021; STECF, 2013). In spring, at temperature of 7-8°C, it appears near to the shore; when the water is warming at 15-16°C, it's going back to bigger depths (STECF, 2013). Reproduction of the Black Sea red mullet occurs in the period from May till September with a maximum in mid-summer in July-August (Svetovidov,

1964; Domashenko, 1991; STECF, 2013; Froese & Pauly, 2021). By October-November it prefers deeper waters to spend the winter (STECF, 2013). The Black sea red mullet reaches a length of 20 cm and more, and the age of 10-12 years, usually until 4-5 years old (Svetovidov, 1964; Domashenko, 1991; STECF, 2013). Males are dominant during the early ages, but after age of 3 and size of 14.5 cm, ratio changes into favour of females. Maximum age is 9 years for females and 8 years for males. Fish from 0+, 1+ and 2+ age groups consist of approximately 80% of the population (Genç, 2000).

As observed in the vicinity of the Crimean and Caucasian coasts, two particular forms of the red mullet are distinguished: "settled" and "migratory" ones (Domashenko, 1991; STECF, 2013; Georgieva, 2022).

“Migratory” red mullet moves to the Kerch Strait and the Sea of Azov for fattening and spawning in spring and returns to the coasts of the Crimea for wintering. Along coasts of Romania and Bulgaria in September–November the red mullet migrates to the Turkish waters of the Black Sea and Sea of Marmara for wintering (Domashenko, 1991; STECF, 2013; Georgieva, 2022). The “settled” form in Georgia lives mainly in the southeastern region near Batumi, Supsa, New Afon and makes local migrations: in spring – to shallow depths (10–20 m) for spawning and feeding, in autumn – to depths of 50–80 m for wintering. It is generally accepted that “settled” groups are usually not numerous and they are usually singled out as independent units of stock (Domashenko, 1991).

The red mullet is one of the most important commercial fish species in the all Black Sea countries (STECF, 2013; STECF, 2017; FAO, 2020). It is mostly caught by bottom trawls as a target fish species. Various passive fishing gears, such as gillnets, pound and fyke nets are also used to fish the red mullet (Yıldız & Karakulak, 2016; Domashenko, 1991; Kasapoğlu, 2018; Kutsyn, 2022). Sometimes in significant amounts this species is found in purse seines and mid water trawls as a by-catch. Accordingly, to the GFCM experts, assessment the status of the red mullet stock in the Black sea is defined in a state of overexploitation. In 2019–2021 were observed worrying trends with increased catches coupled with decreases in SSB and Recruitment. The F_{msy} is 0.7. The F current (2019–2021) was estimated to be 0.81 and the ratio $F_{current}/F_{msy}=1.2$ (Georgieva, 2022).

The main landings of the red mullet were observed in Turkish coastal waters (STECF, 2013; STECF, 2017; Georgieva, 2022). Average annual catch (2000–2021) makes up 2284.7 ± 168.7 t within 1073 – 3880 t, representing 54 to 94% of the total annual red mullet catch in the Black Sea. Catches of this fish species in EU waters are taken primarily by Bulgaria (in average 231.7 ± 168.7 t per year – near 6.2% of the annual Black Sea red mullet landings), with only small amounts landed by Romanian fishers – 3.9 ± 1.6 t (0.1%). Landings of the red mullet are very low in Ukraine after Crimea annexation in 2014. Due to the loss of fishing territories, the catches of red mullet in Ukraine decreased by more than 30 times and currently do not exceed 1.3 t. The red mullet landings in the Russian Federation, on the contrary, increased by 6.5 times and in the last 3 years has reached to 1059 – 1639 t which makes up 29.9 – 38.1% of the annual red mullet landings (Shlyakhov, 2021). According to the official fishery statistics data catches of the red mullet in the Georgian coastal waters are insignificant. In 1989 – 1996 catches of the red mullet in the Georgian coastal waters were absent or was categorized within the “other fish” group (STECF, 2013). In 1997 – 2005, its mean annual catch was equal to 28 tons (STECF, 2013). As stated in the STECF (2013) report with reference to Komakhidze et al. (2003), the red mullet was captured recently in higher amounts that

provided an indirect evidence of increasing abundance. At present, target fishery of the red mullet in Georgia is carried out using bottom trawls in separate specifically designated areas. The area of these sites is about 10% of the total area of Georgian coastal waters. Average annual catch makes up 11.7 ± 3.3 t, representing only 0.3% of the total annual red mullet landings in the all Black Sea countries. However, it should be taken into account that the Georgian legislation does not envisage the mechanism for the full accounting of catch volumes. Only bottom trawl catches are fully accounted. A significant part of the Georgian landings, primarily gillnet landings, that are considered traditional coastal fisheries, remain unaccounted. According to expert estimates, the catch of unaccounted fish is 3–4 times higher than the official statistic.

It should be especially noted that in Georgia, as in other Black Sea countries, the red mullet is a delicacy product in terms of its taste. This fish species is in great demand not only among the local population, but also among numerous tourists. Rational exploitation of the red mullet stock for stable supply of market needs is one of the priority tasks of the National Environmental Agency of Georgia (Komakhidze et al., 2003). Therefore, the aim of this study is to assess the level of the red mullet stock exploitation using the CMSY, LBB and LB-SPR modeling methods, which, according to the GFCM (General Fisheries Commission for the Mediterranean) recommendations, have recently been widely used for assessment of the state of the Black Sea commercial fish resources.

These methods have found wide application and are used to assess the status of various species of Black Sea fish. Unlike complex stock assessment methods requiring fisheries-independent data sets, such as obtained from research surveys, and catch-at-age data, these methods uses only a time series of catches and ancillary qualitative information to quantify biomass, length-frequency data, exploitation rate, Maximum Sustainable Yield (MSY) and related fisheries reference points for a given population (Wang et al., 2020; Liang et al., 2020).

Materials and Methods

All fish samples were collected from bottom trawls. All observations were made on board at fishing vessels. Landings data are calculated based on the materials of the Department of Fisheries, Aquaculture and Water Biodiversity of the National Environmental Agency of Georgia. A total of 8 samples were taken (1535 fish individuals, 479 of them with determination of age) in 2019, 17 samples (2233 fish individuals, 644 of them with determination of age) in 2020 and 13 samples (1189 fish individuals, 385 of them with determination of age) in 2021. All individuals were measured using total length (from the beginning of the snout to the end of the rays of the caudal fin) for the construction of length-frequency distributions with a class intervals of

0.5 cm. The general weighing of fish was carried out in each class of the variation rows. Scales were used to determine the age. In some cases, for age determinations otoliths were used also.

In the present study, mathematical models such as LBB (Length-based Bayesian Biomass) (Froese et al., 2018 a), LB-SPR (Length-Based Spawning Potential Ratio) (Hordyk et al., 2015) and CMSY (Catch Maximum Sustainable Yield) (Froese et al., 2017) were used to assess the state of the Black Sea red mullet in Georgian waters. Methods of LBB and CMSY mathematical models are given in great detail in Wang et al. (2020) and Liang et al. (2020). All the models mentioned above are implemented as R-scripts and have been widely tested by the community of fishery biologists.

LBB is a newly developed estimation method requiring length frequency distributions that are representative of the fishery. The core of LBB is the von Bertalanffy growth function (VBGF) (Bertalanffy, 1938) connecting fish age and body length. It uses the Bayesian Monte Carlo Markov Chain (MCMC) (Gilks et al., 1996) to estimate growth and mortality parameters, relative exploitation level and stock size. In addition, LBB allows to obtain important parameters for fishery

management such as the optimal length for the first capture L_{c_opt} and the length at maximum possible yield per recruit L_{opt} . Moreover, LBB results (relative biomass B/B_0 and natural mortality rate M/K) were used as priors for LB-SPR and CMSY methods requiring independent estimates as inputs.

For assessment of the status of marine biological resources where limited data on a species are available, CMSY is an appropriate approach allowing estimations of MSY, exploitation level and biomass with corresponding confidence intervals from catches and resiliencies of researched species. This method is based on the Schaefer surplus production model (Schaefer, 1954) and uses the Bayesian MCMC. CMSY method is well combined with LBB which provides stock status priors. Priors for resiliencies were taken from (Froese & Pauly, 2021). This model is widely tested and has a detailed technical description to be verified by the community of fisheries biologists. Such approach was applied for assessment of many European stocks, e.g. (Froese et al., 2018 b).

In the context of the modern transformation of the marine ecosystem, SPR index (Goodyear, 1993) allows better taking into account not only the effect of fishing

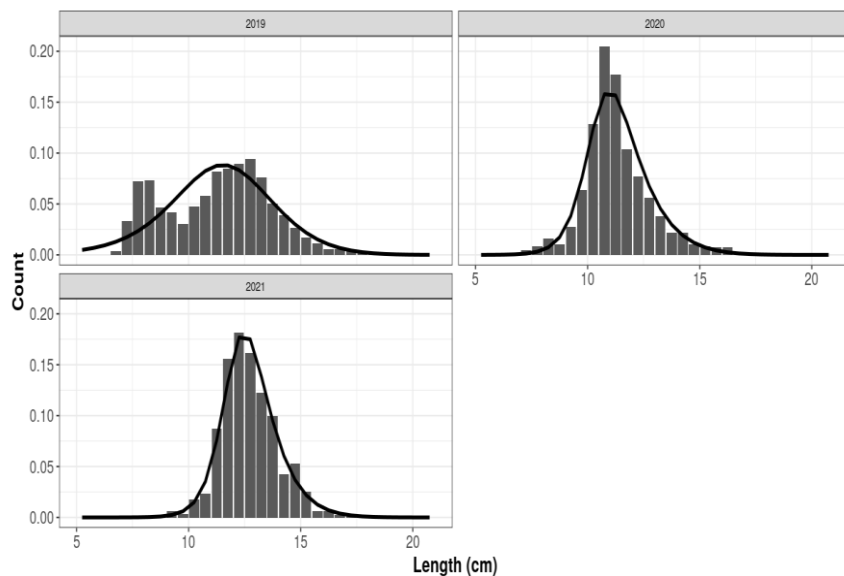


Figure 1. Fitting of the red mullet length distributions.

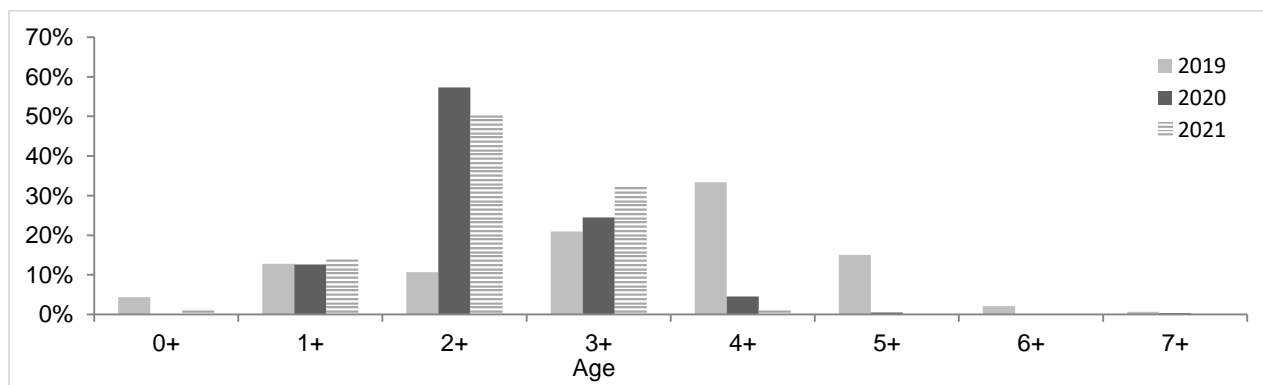


Figure 2. The red mullet age-frequency distributions.

on stocks but also the impact of environmental factors on them. The status of stock can be classified into three different groups, which are: under ($SPR > 0.4$), moderate ($0.2 < SPR < 0.4$) and over ($SPR < 0.2$) exploited (Prince, 2015). SPR can be used to set targets and limit reference points for monitoring of population statuses. Moreover, SPR_{MSY} can be considered as the main reference point instead of F_{MSY} for fisheries (Goodyear, 1993).

The prior information of model parameters:

the resilience range was taken from 0.42 to 1.04 according to (FishBase, 2021);

the ratio $M/K=1.58$ and $L_{\infty}=20.5$ given by the LBB were used in LB- SPR method;

$Lm_{50}=9.3$ cm and $Lm_{95}=11.0$ cm were used as lengths at which 50% and 95% of the fish are mature respectively.

Results

According to official statistics the red mullet landings in Georgian coastal waters was 10.8 t in 2019. Decreased slightly in 2020 – 8.2 t and decreased even more in 2021 – 3.98 t. At the same time, the catch of unreported fish, according to expert estimates, remained high, demonstrating an upward trend.

The total length of the red mullet individuals was ranged from 6.1 cm to 20.7 cm in 2019, from 6.4 cm to 20.2 cm in 2020 and from 7.4 cm to 17.5 cm in 2021. Individuals of modal groups 7.5-8.0 cm (14.5% of the total number of individuals caught) and 11.0-13.0 cm (42.5%) are dominated in the red mullet catches in 2019. The basis of the catches in 2020 were fish of modal groups 10-11.5 cm (61.5%). In 2021 the fish were slightly

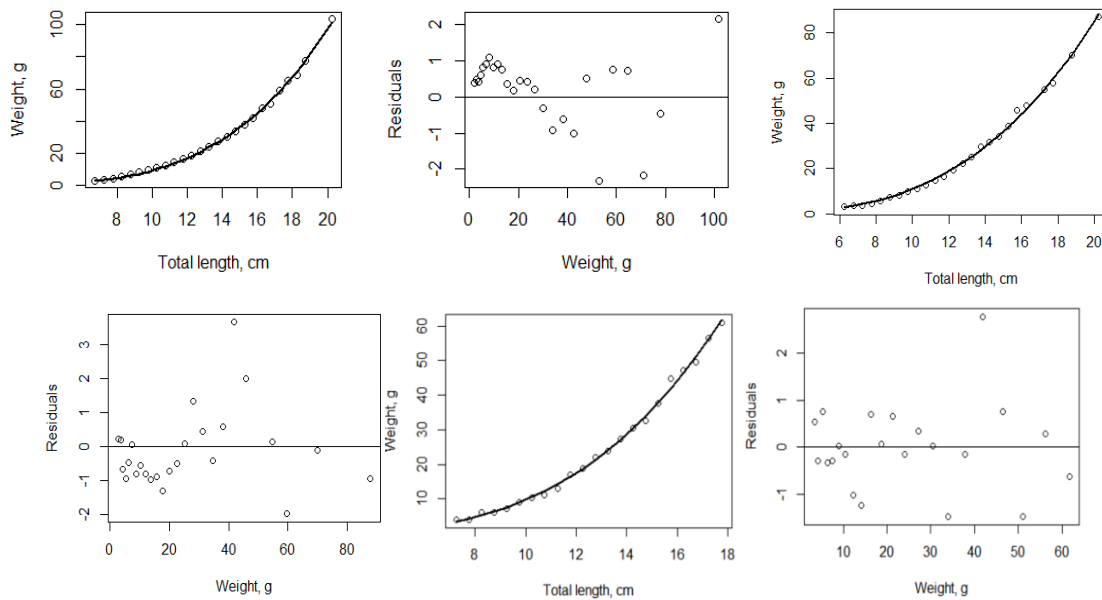


Figure 3. The red mullet length-weight relationship, 2019, 2020 and 2021 (from the top panel to the bottom one).

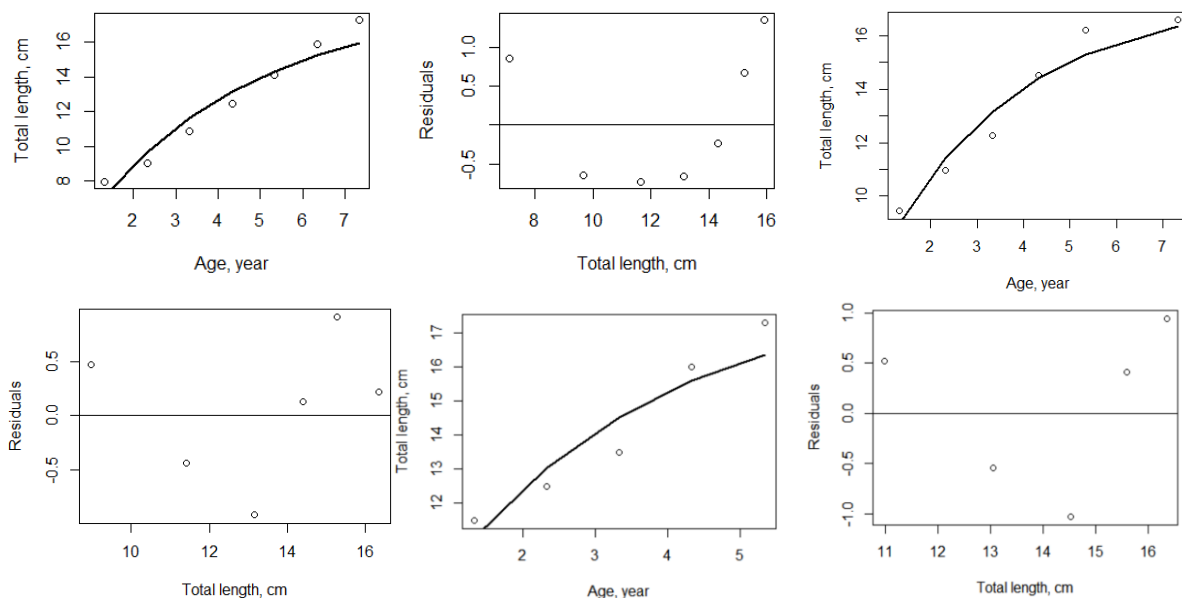


Figure 4. The red mullet growth curve, 2019, 2020 and 2021 (from the top panel to the bottom one).

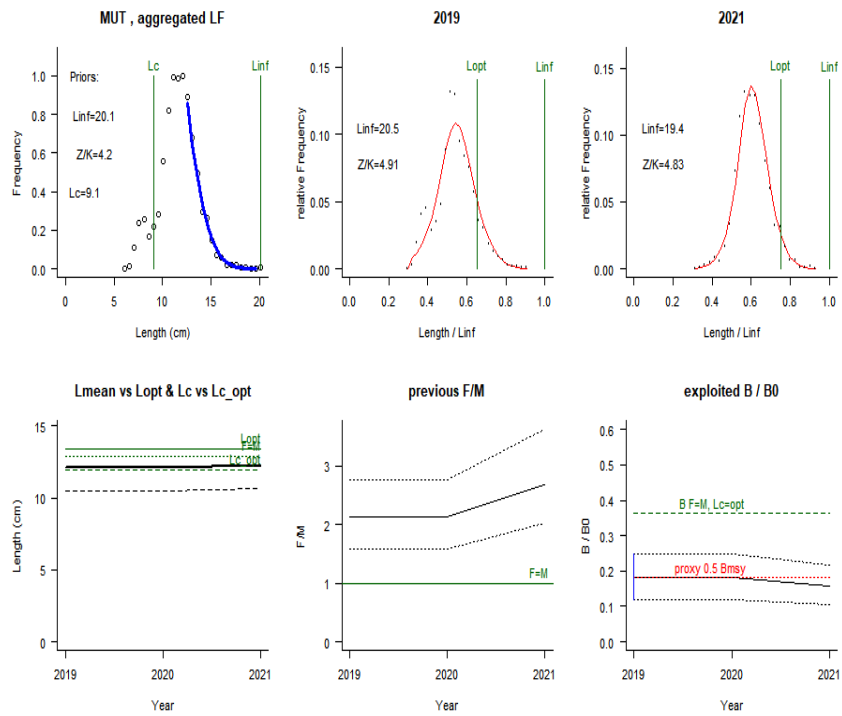


Figure 5. Results of LBB analysis for the red mullet in Georgian coastal waters.

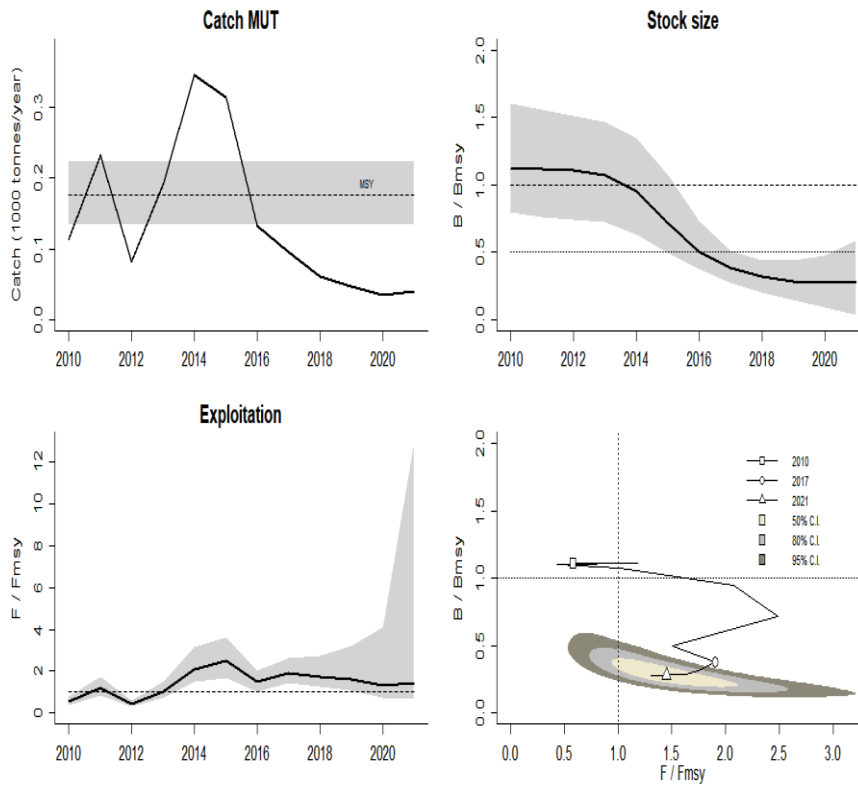


Figure 6. Results of CMSY analysis for the red mullet in Georgian coastal waters.

Table 1. Results of CMSY analysis for the red mullet in Georgian coastal waters in 2020-2021.

2020					2021		
MSY	B _{MSY}	B, t	B/B _{MSY}	F/F _{MSY}	B, t	B/B _{MSY}	F/F _{MSY}
176	486	135	0.28	1.3	136	0.28	1.4

* – Standard length

larger – 11.5-13.0 (62.2% of the total number of individuals caught). Quality of the assessment. The length frequency distributions were reconstructed quite well (Figure 1).

As shown by biological analyzes, the most part of landings, almost 70% of the total amount, consisted of 3+, 4+ and 5+ age groups in 2019 (Figure 2). The 6+ and 7+ age groups also were presented but were few in number. However, individuals of the younger age groups significantly prevailed in the catches in 2020 and 2021. So the red mullet catches consisted at 97% of fish aged 1-3 years in 2021 (Figure 2).

The length-weight relationship (LWR) is shown in Figure 3. The average LWR parameters (a and b) on the period 2019-2021 were amounted 0.0072 ± 0.0027 , 3.20 ± 0.14 , respectively. The corresponding fitted growth curves with residuals are depicted in figure 4. The residuals are quite low without particular patterns. The estimated average von Bertalanffy growth parameters with standard errors were $L_{\infty} = 18.00 \pm 0.27$ cm, $k = 0.31 \pm 0.03$, and $t_0 = -0.93 \pm 0.26$.

The estimation of $F/M = 2.7$ with LBB method based on the aggregated length distribution (Figure 5) demonstrates that the red mullet stock was overexploited (LBB considers $F/M = 1.0$ as the optimal level), while the estimation of $B/B_0 = 0.16$ and $B/B_{MSY} = 0.43$ indicates that the biomass was lower than the optimal level in 2021. The estimated ratios $L_{mean}/L_{opt} = 0.89$ ($L_{opt} = 13.0$ cm) and $L_c/L_{c_{opt}} = 0.92$ ($L_{c_{opt}} = 12.0$ cm) were both under unity. It means that length of fished individuals was not big enough.

CMSY stock assessment method was used to estimate biomass of the red mullet, fishing pressure and proxies for MSY. The resilience range was taken from 0.42 to 1.04 according to (Froese & Pauly, 2021). The model run with prior values of B/B_0 obtained from LBB analysis and without ones shows very close results. They are presented in Table 1 and in figure 6.

According to CMSY analysis, biomass has been decreased to B_{lim} for the researched period. Fishing

mortality rate reached the maximum value in 2015-2016 season but remained close to F_{MSY} level for a few recent seasons. MSY value was estimated as approximately 176 tons with 95% confidence limits as 135 and 223 tons.

The result of LB-SPR analyze showed that the estimated SPR was 23% above limit 20% as the biological reference point but far from target 40% as the sustainable reference point (Figure 7)

The retrospective analysis was applied up to 3 years back. The values of Mohn's rho-index (the average relative bias of retrospective estimates) (Mohn, 1999) were -0.01 for biomass B and 0.13 for fishing mortality F over the last three years. We should notice, that the values of Mohn's higher than 0.30 or lower than -0.22 for shorter-lived species might be caused for concern and taken as indicators of retrospective patterns (Hurtado-Ferro et al., 2015). Thus, there are no patterns in the estimation but F/F_{MSY} varied widely.

Discussion

The red mullet is a priority target fishery species in the Black Sea, which explains the increased interest in the study of this species. Many aspects of ecology and biology of this fish species primarily such as age, growth and fish mortality have been thoroughly studied in different parts of the Black Sea and especially in Turkish coastal waters (Aksu et al., 2011; Aydin & Karadurmuş, 2013; Domashenko, 1991; Genç, 2000; Kutsyn, 2022; Maximov et al., 2008; Samsun 1992; Yıldız & Karakulak, 2016; Yılmaz et al., 2019). In the coastal waters of Georgia, the results of red mullet studies are few and fragmentary. This results are the first over the past 30 years detailed study of the size-age composition of catches and the level of exploitation of the stock of this species in the Black Sea waters in Georgia. Accordingly, fishery statistics of Department of Fisheries, Aquaculture and Water Biodiversity of the National Environmental Agency of Georgia the highest landings value in 2019-2021 was obtained in July-August (16.3-

Table 2. The von Bertalanffy growth parameters, “a” and “b” coefficients of the length-weight relationships of the red mullet individuals obtained from different Black Sea areas.

Study period	Region	L_{∞}	K	t_0	a	b	Reference
1988-1990	Ukraine BS	17.9*	0.32	-1.88	0.0085	3.34	STECF, 2013
2020	Crimea BS	26.3	0.16	-2.52	0.0088	3.02	Kutsyn, (2022)
2003-2004	Romanian BS	16.3	0.38	-1.39	0.0084	3.12	Maximov et al., (2015)
1982-1988	Bulgarian BS	21.3*	0.23	-0.87	0.0123	3.14	Domashenko, (1991)
2020	Bulgarian BS	18.3	0.31	-2.02	0.0063	2.97	Georgieva, 2021
2015-2016	Turkish BS	17.6	0.43	-1.33	0.0137	2.90	Yılmaz et al., (2019)
1986-1987	Turkish BS	29.5	0.10	-3.22	0.0086	3.09	Samsun, (1992)
1991-1996	Turkish Eastern BS	23.8	0.23	-1.62	0.0074	3.11	Genç, (2000)
2008-2011	Turkish Southeastern BS	24.6	0.22	-1.82	0.0071	3.12	Kasapoğlu, (2018)
2010-2011	Turkish Eastern BS	27.4	0.14	-2.35	0.0088	3.03	Aydin & Karadurmuş, (2013)
2012-2014	Turkish Western BS	24.1	0.17	-1.98	0.0109	2.99	Yıldız & Karakulak, (2016)
1982-1988	Northern Caucasus	17.97*	0.32	-1.87	0.0085	3.34	Domashenko, (1991)
1982-1988	Georgian BS	28.6*	0.09	-3.62	0.0124	3.15	Domashenko, (1991)
2019	Georgian BS	18.3	0.26	-0.58	0.0032	3.45	Own data
2020	Georgian BS	17.5	0.34	-0.79	0.0125	2.95	Own data
2021	Georgian BS	18.9	0.34	-1.18	0.0055	3.25	Own data

19.4% of the total annual landings), and in February-March (9.7-12.1%). In other periods, the landings were 6.3-8.3% of the annual catches. Fishery is not carried out in May-June. As in the Turkish Black Sea waters, the red mullet catches in Georgia are consisting predominantly of younger ages.

The von Bertalanffy growth parameters and also “a” and “b” coefficients of the length-weight relationships obtained from different Black Sea areas are presented in the Table 2. The analysis of these results shows that the coefficients “a” and “b” of the length-weight relationships of the red mullet individuals in Georgia are within the limits of the values obtained by other researchers. The von Bertalanffy growth parameters in some cases are significantly different. As noted by many authors, on the one side this probably may be due to the biotic and abiotic features of the red mullet habitat in different areas of the Black Sea (Yıldız & Karakulak, 2016; Yılmaz et al., 2019). On the other side, it may be confirming the previously considered hypothesis of the existence of relatively isolated groups of the red mullet in different parts of the Black Sea (Domashenko, 1991; STECF, 2013; Georgieva, 2022). Obviously, the study of morphometric features and genetic studies of the red mullet from different areas of the Black Sea will help in determining the integrity of its stock and allow a more reliable assessment of the level of its commercial exploitation.

It is interesting to note that asymptotic length (L_{∞}) of red mullet in Georgian waters in 1982-1988 – 28,6 cm (standard length) according to Domashenko, 1991, was significantly higher than our results – 17,5-18,9 cm (total length). The differences in this estimation values may be related to the methods error of calculation and also sampling – the sensitivity of von Bertalanffy parameters to the number of age groups used. On the other hand, a decrease in asymptotic length, as well as a decrease in the age composition of the catch, may be a direct consequence of an increase in the fishery intensity. According to Domashenko, the red mullet stock in the coastal waters of Georgia was underutilized at the end

of the last century. While according to the current estimates of the international group of experts, the state of the red mullet resource in Black Sea considered as overexploited (STECF, 2013; Georgieva, 2022). The amount of spawning biomass decreased from 13 th. tons in 1994 to 4.5 th. tons in 2020. Average fishing mortality rate in over the last 3 years was 0.81, which is 1.25 higher than the recommended value of 0.65 (GFCM, 2021). Turkish researchers also note a high level of exploitation of the red mullet, however do not indicate overfishing ($E=0.36$ according to Yılmaz et al., (2019) and $E=0.65$ from the data obtained Yıldız and Karakulak (2016) from the commercial trawlers). In one of the recent publication Yılmaz et al., (2019) cites as a fact the assertion that the overfishing on the red mullet stock seems in the Black Sea depends on the annual catch data.

The results of our research also testify to the intensive exploitation of the red mullet commercial stock. According to the LBB model results during the research period (2019-2021) the individuals smaller than the optimal estimated length were dominated in the catches. Results CMSY model shows that the current biomass B was lower than the recommended value B_{MSY} and fishing mortality exceeded the F_{MSY} level (Table 1). According to LB-SPR results the red mullet stock was exploited sustainably intensive in Georgian waters – SPR was 23% above limit 20% as the biological reference point. So increase in fishing mortality of the red mullet in the coastal waters of Georgia as in other parts of the Black Sea is not recommended.

In conclusion, it should be especially noted that bottom trawl fishery is allowed and is carried out only on 10% of the Georgian coastal waters. Thus, the Legislation of Georgia provides for serious measures for the protection of this species, which are carried out at a high level of protection of its habitat. Obviously, under such conditions, the commercial loss of the red mullet population can be significantly replenished by individuals from protected areas, what can compensate for its intensive exploitation.

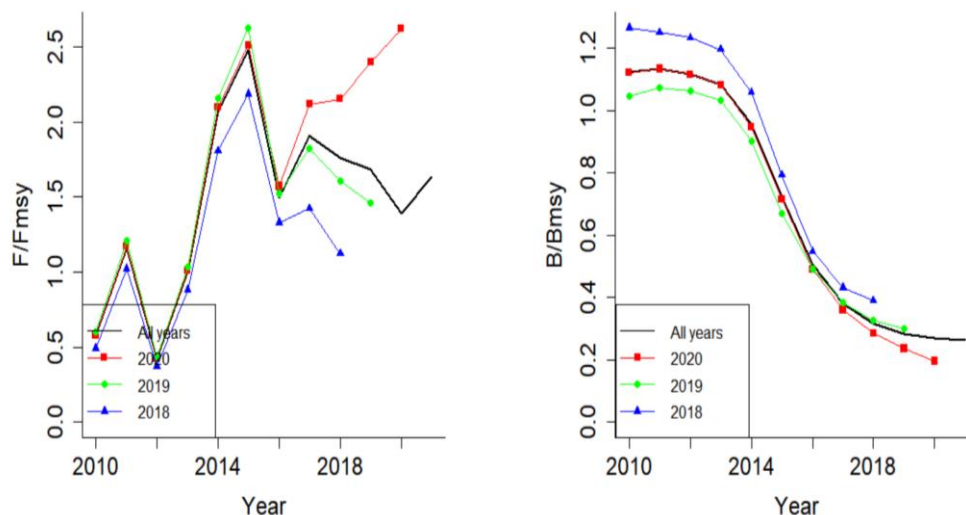


Figure 7. The retrospective analysis for the red mullet CMSY model.

Ethical Statement

No ethical statement is needed.

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Author Contribution

RM, TJ, PV and LS performed samplings and biological analysis. SS, YL performed biological and mathematical analysis and evaluated outputs. SS and GM reviewed literature data, RM provided management information. SS, YL and GM wrote the paper with contributions from all authors.

Conflict of Interest

The authors have no conflict of interests to declare.

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