

## ERRATA CORRIGE

This paper has been erroneously published without the three tables. Herewith we present the paper *in toto*.

MORTALITY OF RED MULLET (*MULLUS BARBATUS* LINNAEUS, 1758)  
ON THE MONTENEGRIN SHELF (SOUTH ADRIATIC)

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**Abstract** — Red mullet, *Mullus barbatus* Linnaeus, 1758, is an economically very important species in trawl fisheries in the Adriatic Sea. Material for analysis was collected from October 2002 until May 2004 with a bottom trawl net from commercial trawlers on the Montenegrin shelf. Mortality of this species was analyzed for the first time in this area, separately for males and females and for both sexes together. Until now, only the spatial distribution and catch per unit of effort (CPUE) of *Mullus barbatus* have been studied in Montenegrin waters. Estimated total mortality rates were  $Z_{\text{males}} = 0.653$  and  $Z_{\text{females}} = 0.712$ . The average mortality rate for both sexes was  $Z_{\text{m+f}} = 0.749$ , while the natural mortality rate was  $M_{\text{m+f}} = 0.342$ . Values of  $Z$  in the Montenegrin shelf area are considerably lower than  $Z$  values for the Croatian and Italian parts of the Adriatic Sea, indicating that on the Montenegrin shelf fishing of this species is significantly less intensive than in other trawl-fishing areas of the Adriatic Sea.

**Key words:** *Mullus barbatus*, mortality rates, Montenegrin shelf, Adriatic Sea

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## INTRODUCTION

Since 1998, the beginning of continuous monitoring of demersal resources on the Montenegrin shelf has marked initiation of the first studies on population dynamics of economically important species of fishes and crustaceans in the local trawl fishery. Knowledge of parameters of growth, mortality, gear selectivity, biomass, and the period and intensity of reproduction contributes to proper estimation of resources and managing of the marine fishery on principles of sustainable development.

Red mullet, *Mullus barbatus* (Mullidae, Perciformes), with 23.1% in the total trawl catch and 5.4 kg/h in CPUE (Joksimović et. al., 2005), is one of the economically most important species in the trawl fishery along the Montenegrin coast. So far, there are no data on the biology and population dynamics of the given species in this part of the Adriatic Sea. Only data on the distribution and composition of economically important species in trawl

catches in the Montenegrin shelf area, including data on *Mullus barbatus*, were presented by Merker and Ninčić (1973), Jovanović and Stjepčević (1982), and Jukić and Arneri (1983).

In order to estimate the optimal level of exploitation, it is necessary to know both the growth rate and the mortality rate. As a rule, during the period between the arrival of young specimens to the fishing area ( $t_f$ ) and age of the first catch ( $t_c$ ), natural mortality factors are the only ones. After the first catch of young specimens ( $t_c$ ), fishing mortality also begins to be influential. Mortality of the species from that moment is therefore the result of combined action of natural and fishing mortality. Thus, the total mortality rate equals:

$$Z = F + M \quad (1),$$

where  $Z$  is the total instantaneous mortality rate, while  $F$  and  $M$  are the fishing and natural mortality rates, respectively.

One of the still unsolved problems of fisheries biology is the estimation of natural mortality, that is, the natural instantaneous mortality rate ( $M$ ). The natural instantaneous mortality rate can be precisely estimated only when exploitation of a given population is absent or negligible, because then:

$$Z = M \quad (2).$$

In all other cases, as already shown in formula (1), both components are expressed through  $Z$ , and it is impossible to separate them. With increase of age and length of individuals,  $F$  gradually increases due to selectivity of fishing gears. On the other hand, in older individuals with a smaller number of predators, the value of  $M$  usually decreases (Kolding and Ubal Giordano, 2002).

This paper presents the results of estimating red mullet mortality parameters during studies of this species on the Montenegrin shelf. Results of

our research are compared with data on mortality rates of this species in other areas of the Adriatic Sea (Haïdar, 1970; Marano et al., 1994, 1998; Ungaro et al., 1994; GMS-GRUND, 1998; Vrgoč, 2000, 2004).

## MATERIAL AND METHODS

Material was collected in the Montenegrin shelf area during the period October 2002 - June 2004 by commercial trawlers. Altogether, 38 trawl hauls were analyzed. The surface of the area covered by these hauls was about 900 km<sup>2</sup> (Fig. 1). Duration of the hauls was from 0.6 to 4 hours. For every haul, data were taken on characteristics of the boat (LOA, beam, engine power) and of the net (length of the net and codend, mesh sizes of the net and codend). Local times, as well as the coordinates of the beginning and end of the hauls were noted.

The collected material was almost entirely processed on board. Total length (TL) of the fish from

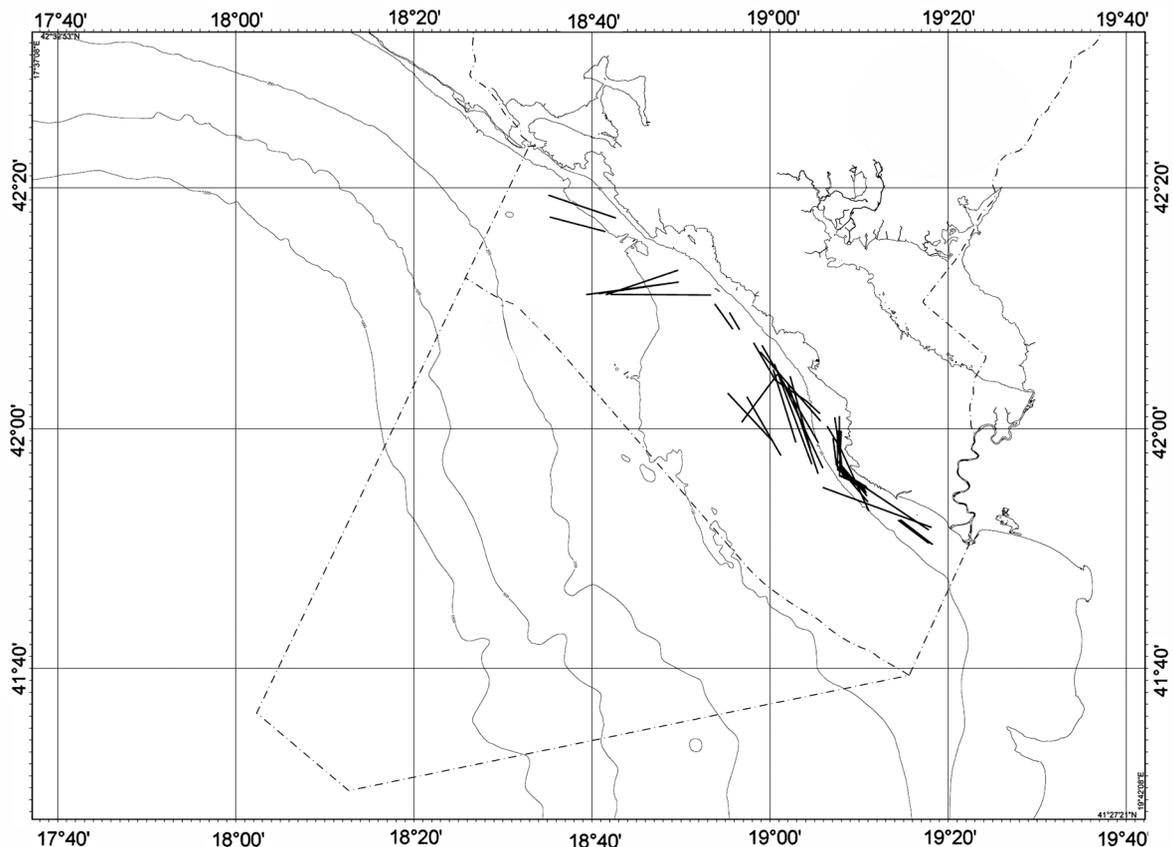


Fig. 1. Map of trawl hauls on the Montenegrin shelf.

the peak of the mandible to the stretched ends of the caudal fin, was measured to the nearest millimeter, and data on weight (to the nearest gram) were taken for 671 specimens. All these specimens were dissected for sex determination, and 375 otoliths were taken for determination of age.

In addition, 10,082 fish from every haul performed from July 1998 to May 2004 were grouped into 1-cm length intervals for further modal decomposition analysis.

Two methods were used to estimate total instantaneous mortality rates.

The first method was analysis of the length-converted catch curve (Pauly, 1983). With this method, length intervals are converted in age intervals using the inverse von Bertalanffy's growth function (von Bertalanffy, 1934, 1938). Parameters of the von Bertalanffy growth function (VBGF) of the obtained growth curves, after Joksimović et al. (2008) were:

$$\text{Males: } L_{\infty} = 17.811, K = 0.282, t_0 = -3.013$$

$$\text{Females: } L_{\infty} = 29.131, K = 0.122, t_0 = -3.013$$

$$\text{Males + Females: } L_{\infty} = 30.118, K = 0.118, t_0 = -3.181$$

The second method was estimation of the total mortality rate from growth parameters obtained by modal decomposition of the length frequencies (Bhattacharya, 1967). The instantaneous rate of natural mortality  $M$  was estimated using the empirical formula of Pauly (1980).

## RESULTS

Table 1 presents the values of estimates of total instantaneous mortality rates by the method of linearized catch curves converted from length data and growth parameters (Pauly, 1983). The values of instantaneous mortality rates determined by this method are presented in Table 1 and in Figs. 2, 3, and 4.

Due to the impact of selectivity and decreased natural mortality of older age classes, we used data from the following length intervals to calculate regression: 13-14 to 16-17 for males; 14-15 to 20-21 for females; and 13-14 to 19-20 cm for both sexes together.

Results of estimating the total mortality rate, as calculated directly from the modal decomposition of length frequencies for both sexes together, are shown in Table 2.

Thus, the average total mortality rate for both sexes obtained by two independent methods was 0.749.

Pauly's empirical formula (Pauly, 1980) was used to estimate natural mortality rates:

$$\ln M = -0.0152 - 0.279 \cdot \ln L_{\infty} + 0.6543 \cdot \ln K + 0.463 \cdot \ln T \quad (3),$$

where  $T$  is the mean annual temperature at the surface of sea or land waters in °C. For the open sea off Montenegrin coast, it is 16.2°C (Regner et al., 2008). After the values of  $L_{\infty}$ ,  $K$ , and mean annual temperature were inserted into formula (3), the value of

**Table 1.** Estimated parameters of mortality of males, females and both sexes together of the Red Mullet by length converted method.

Sex	Z	Sz	+95%	-95%	$F_s$	P<	$r^2$
Males	0.653	0.0505	-0.8712	-0.4360	167.04	0.0059	0.988
Females	0.712	0.1081	-0.9902	-0.4341	43.345	0.0012	0.896
M+F	0.662	0.0596	-0.8153	-0.5086	123.12	0.0001	0.960

**Table 2.** Estimated parameters of total mortality Z of Red Mullet by Bhattacharya's method.

Sex	Z	Sz	+95%	-95%	$r^2$
M + F	0.835	0.015	-8.884	-0.0786	0.995



Fig. 2. Red mullet mortality curve of males by the method of length converted catch curve. Solid line is the estimated curve of total mortality.

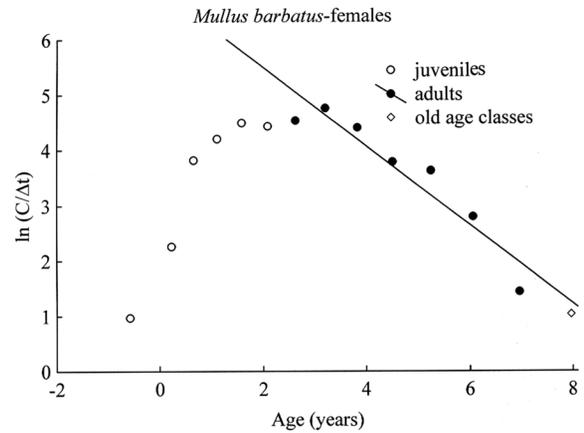


Fig. 3. Red mullet mortality curve of females by the method of length converted catch curve. Solid line is the estimated curve of total mortality.

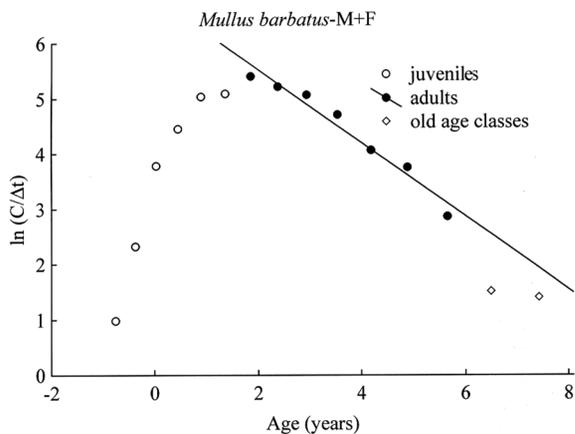


Fig. 4. Red mullet mortality curve of both sexes by the method of length converted catch curve. Solid line is the estimated curve of total mortality.

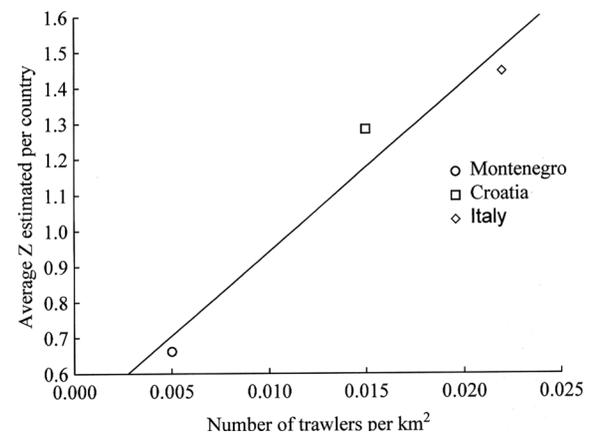


Fig. 5. Relationship between number of trawlers per surface unit by country and total mortality estimated.

instantaneous natural mortality rate was found to be  $M = 0.342$ .

#### DISCUSSION AND CONCLUSIONS

Estimation of the instantaneous total mortality rate ( $Z$ ) is very important in fish biology, as it is further used to estimate the selectivity of tools and the maximum sustainable yield (MSY). Because of possible methodological errors, usually two or more methods of estimation are employed, and then their mean value is used for further analysis. This procedure was used in the present study as well.

Estimates of instantaneous total ( $Z$ ), natural ( $M$ ), and fishing ( $F$ ) mortality rates for several areas of the Adriatic Sea are very different, as shown in Table 3.

These differences between the values obtained in different areas may be a consequence of various factors, such as possible ecological differences between the areas and unequal precision of the employed methods. However, they are more likely a consequence of different intensity of fishing in different areas of the Adriatic.

It is evident that the  $Z$  estimated in our studies

is much lower than in recent studies in Italian and Croatian waters. In fact, it is much closer to that reported by Haïdar (1970).

Haïdar (1970) estimated total mortality of red mullet using material collected in the Split Channel during the period 1959-1961, when trawling in that area was still undeveloped. Our estimate of  $Z$  is not considerably higher than that of Haïdar, particularly when compared with recent estimates in other fishing areas of the Adriatic. That implies that recent fishing on the Montenegrin shelf is not too much more intensive than it was in the channel area of the Central Adriatic in the period 1959-1961, when according to Basioli (1976) only 30 trawlers operated along the entire Yugoslav coast.

According to published data (FAOAdriaMed, 2004), the number of trawlers per country was as follows:

Country	Number of trawlers	Surface of fishing areas (km <sup>2</sup> )
Italy	1,417	39,114
Croatia	855	56,000
Montenegro	17	3,700

It follows that the number of trawlers per unit of fishing ground surface was:

Country	Number of trawlers per km <sup>2</sup>
Italy	0.022
Croatia	0.015
Montenegro	0.005

Plotting the average estimated mortality rates against the number of trawlers per unit of surface shows a positive correlation of  $Z$  with the density of trawlers. It can therefore be concluded that the total mortality rate in this case was a linear function of the number of trawlers per unit of surface (Fig. 5).

High mortality rates indicate that red mullet in Italian and Croatian waters is heavily exploited. It is obvious that the fishing capacity and (consequently) fishing efforts of the Italian and Croatian fleets are enormously greater than those of the Montenegrin

fleet. Since almost the entire catch of red mullet comes from the trawling fishery, it is quite clear that trawling is the main cause of fishing mortality of this species.

This indicates that recent exploitation of *Mullus barbatus* on the Montenegrin shelf is much less intensive than in other areas of the Adriatic Sea. It can be concluded that the red mullet stock in this area is so far preserved and possibly even underexploited.

As far as natural mortality is concerned, recent estimates are very different: depending on the authors and areas in question, it varies from 0.31 to 0.91 (Table 3). These differences may be caused by different values of the VBGF parameters used for estimation of  $M$  in different areas.

Beverton and Holt (1959) proved that the constant ( $K$ ) of VBGF is in direct correlation with physiological longevity in certain species. It was later demonstrated (Tanaka, 1960; Holt, 1965; Saville, 1977) that physiological longevity and instantaneous rates of natural mortality are inversely proportional. These two ratios show that  $K$  and  $M$  are in direct functional relationship, which is also logical, since short-lived species grow fast, so both the instantaneous growth rate  $K$  and instantaneous rate of natural mortality  $M$  are high. On the other hand, there is also a functional relationship between asymptotic length,  $L_{\infty}$ , and  $K$ . Within the same species, higher  $L_{\infty}$  is usually linked with lower values of  $K$ .

Available data on estimation of VBGF parameters for *Mullus barbatus* in the Adriatic also show this relationship:

Marano et al. (1994)  $L_{\infty} = 19.70$ ;  $K = 0.360$

Vrgoč (2000)  $L_{\infty} = 26.86$ ;  $K = 0.295$

Vrgoč (1995)  $L_{\infty} = 27.75$ ;  $K = 0.274$

Marano et al. (1998)  $L_{\infty} = 31.5$ ;  $K = 0.182$

Our estimate of  $M$  is almost equal to that of Marano et al. (1998) (Table 3). This is obviously because our estimates of  $L_{\infty}$  and  $K$ , as shown before, were very similar too.

**Table 3.** Estimated total Z, natural M and fishing F mortality rates from Middle and West Adriatic Sea.

Author	Z	M	F
Haïdar, 1970	0.64		
Ardizzone, 1998		0.91	
Arneri and Jukić, 1986	2.47-4.37 (age 0-1)		
Marano et al., 1994	0.53-1.07	0.43	0.1-0.64
Ungaro et al., 1994	1.13-1.28	0.43	
Marano, 1996	1.88	0.77	1.11
GMS-GRUND, 1998	2.99		
Marano et al., 1998	1.23	0.31	0.92
Vrgoč, 2000	1.61	0.58	
Vrgoč, 2004	1.60	0.74	

It has to be mentioned that in heavily exploited populations, old individuals are scarce or even absent. In these cases, fitting VBGF to age-length data yields a low value of  $L_{\infty}$  and (consequently) a high value of K. A further consequence is overestimation of the natural mortality rate.

Thus, overestimated M causes underestimation of exploitation rates, which may prompt the wrong decisions for management of exploited stocks. Ways to avoid this shortcoming may be either to use historical data (if any) or to estimate natural mortality of the nearest less exploited stocks. In this case, the Montenegrin red mullet stock could serve this purpose well.

Finally, the low total and natural mortality rates show that the Montenegrin shelf can at present be considered as a refuge for *Mullus barbatus* and (probably) for other Adriatic demersal species as well.

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## СМРТНОСТ БАРБУНА (*MULLUS BARBATUS* LINNAEUS, 1758) НА ШЕЛФУ ЦРНОГОРСКОГ ПРИМОРЈА (ЈУЖНИ ЈАДРАН)

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Барбун, *Mullus barbatus* (Linnaeus, 1758), је економски важна врста у кочарском риболову на Јадранском мору. Материјал за анализу сакупљан је у периоду од октобра 2002. године до маја 2004. године, из улова комерцијалних кочарских бродова на подручју црногорског приморја. По први пут су на овом подручју процењени параметри популационе динамике, одвојено за мужјаке и женке, барбуна, *Mullus barbatus*. У ранијим истраживањима на црногорском при-

морју за ову врсту процењивани су само подаци о улову по јединици напора и дистрибуција. Процењене стопе тренутне смртности  $Z$  су,  $Z_{\text{мужјаци}} = 0.653$ ,  $Z_{\text{женке}} = 0.712$ , док је средња вредност за оба пола заједно  $Z = 0.749$ , а стопе природне смртности  $M = 0.342$ . Ове вредности су значајно ниже од вредности  $Z$  за хрватски и италијански део Јадранског мора, што указује на прилично богата и очувана насеља врсте *Mullus barbatus* на шелфу црногорског приморја.