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INFLUENCE OF ABIOTIC ENVIRONMENTAL FACTORS ON THE GROWTH RATE OF RED MULLET

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ABSTRACT

A study of the interannual variability of the size-age composition of *M. barbatus ponticus*, inhabiting the south-western shelf of the Crimea, was carried out over a five-year period (between 2016 and 2020). The influence of habitat temperature on growth rate is considered. Equations obtained characterize the size-weight growth of *M. barbatus ponticus*. The influence of the sea temperature on the development of individuals is considered. It is shown that with an increase in the average annual water temperature, the average annual length (correlation coefficient r = 0.97), weight (r = 0.96) and condition factor (r = 0.93) of individuals increase. It was found that red mullet has a positive allometric growth in the study area. The analysis showed that there was a close correlation between changes in the average annual temperature and the allometric growth rate b (r = 0.97). The equations of length growth of *M. barbatus ponticus* showed retarded linear growth of the fish living on the south-western shelf of the Crimea in comparison with other areas, Sinop region (Black Sea) and the Aegean Sea. The comparison of the effect of temperature on the size and weight parameters of *M. barbatus ponticus* living in the south-eastern part of the Black Sea (Sinop region) and the Aegean Sea is carried out; general patterns and differences are noted.

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INTRODUCTION

The growth and structure of a fish population is an integrated indicator of the impact of biotic and abiotic environmental factors. The change in growth rate determines the timing of puberty (as well as the quantity and quality of reproductive cells), life expectancy and the intensity of population reproduction. The study of growth processes makes it possible to reveal the characteristics of an organism at different stages of development, as well as to assess the response of a living organism to changes in environmental conditions, which becomes especially important as climatic change and anthropogenic pressures on ecosystems increase (Nikolsky, 1974).

Red mullet has been one of the most important species in global fisheries in recent decades. Species from the family Mullidae are characterized by relatively high abundance, wide geographic distribution and good taste of their flesh (Bat et al., 2008; Boltachev and Karpova, 2012).

Red mullet *Mullus barbatus* is a demersal species that has two subspecies: *Mullus barbatus* Linnaeus 1758 – distributed in the Mediterranean, Aegean, Marmara seas (Hureau, 1986; Özbilgin et al., 2004), and *Mullus barbatus ponticus* Essipov 1927 - inhabiting mainly the Azov-Black Sea basin (Bat et al., 2008; Kozhurin et al., 2018; Shlyakhov et al., 2018).

Red mullet has great economic importance in the Black Sea fisheries of coastal countries. For example, the volume of its catch by Turkey in the coastal waters of the Black Sea is 1/3 of the total catch of *Mullus barbatus* in the Mediterranean, Aegean, Marmara seas (Genç, 2014; TÜİK, 2017, 2018). In recent years, positive trends in annual catches of *M. barbatus ponticus* have also been observed on the south-western shelf of the Crimea (Kozhurin et al., 2018; Shlyakhov et al., 2018). So, in 2017 they amounted to 571.2 tons per year (Kozhurin et al., 2018), which exceeded the catches of 2014–2017 by 3–5 times.

There are publications in which issues related to population and morphophysiological parameters (Oven et al., 2009; Kuzminova et al., 2019), the effect of temperature on nutrition (Lipskaya, 1959; Onay and Dalgic, 2019), the peculiarities of oogenesis and the nature of spawning (Oven, 1961, 1976; Melnikova and Kuzminova, 2020), the content of toxic elements in tissues at pollution of the marine environment, reported plastic pollution in commercial fishes from the Black Sea (Rudneva et al., 2011; Onay and Dalgic, 2019), the dynamics and prospects of the *Mullus barbatus* catch (Domashenko, 1991; Kozhurin et al., 2018; Shlyakhov et al., 2018; TÜİK, 2017, 2018) have been considered.

Despite the available papers, the study of long-term changes in size and weight characteristics, growth patterns of red mullet *Mullus barbatus* living on the western shelf of the Crimea, taking into account the influence of climatic factors, has not yet been fully studied and requires further research.

The aim of these studies is to analyze the size and age composition, to reveal the features of the change in the size and weight characteristics of red mullet *M. barbatus ponticus*, inhabiting the south-western shelf of the Crimea, taking into account the influence of sea temperature (2016–2020).

MATERIALS AND METHODS

M. barbatus ponticus was caught using bottom traps with a mesh size of 12 mm on the south-western shelf of the Crimea in the coastal waters of Sevastopol between 2016 and 2020 in the area with the following coordinates: latitude - from 44.57 °N to 44.64 °N; longitude - from 33.37 °E to 33.56 °E (Fig. 1).

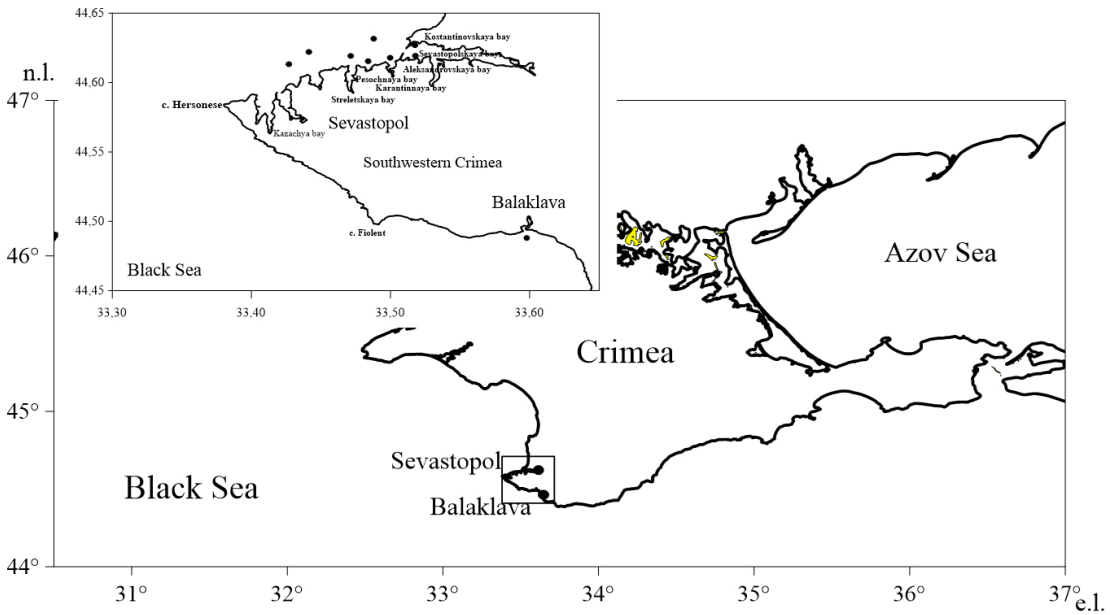

Fig 1. Map of the study area and location of sampling sites

The sample consisted of 10–20 freshly caught individuals of different sizes and ages. Samples were taken 2—3 times a month. All fish (1623 specimens) were subjected to complete biological analysis according to standard methods (Pravdin, 1966). The total length (*TL*) was measured with an error of up to 0.1 cm, and the weight - with an error of up to 0.01 g. The age of fish was determined by reading the scale (Pravdin, 1966).

Length-weight relationships were found using the formula (Ricker, 1979):

$$W = a \cdot TL^b, \quad (1)$$

where *W* is the total body weight, g; *TL* – total fish length, cm; *a* – coefficient associated with the shape of the body; *b* – growth indicator (indicator of allometric growth).

To calculate the condition factor, the size coefficients of the power dependence length-weight were used (Froese, 2006; Melnikova, 2007):

$$K = 100 * aL^{(b-3)}, \quad (2)$$

where *K* is the condition factor; *a* and *b* are coefficients determined from relation (1).

To analyze length growth, the von Bertalanffy equation (Bertalanffy, 1938) was used:

$$L_t = L_\infty \, [1 - e^{-k(t-t_0)}], \quad (3)$$

where L_t is the length of fish at the age *t*; L_∞ is the average maximum attainable (asymptotic) length; *k* is the growth constant; t_0 is the time constant; *t* is the age of the fish.

The growth index for linear sizes was calculated using the formula (Pauly et al., 1988):

$$\varphi = \lg k + 2 \lg L_\infty, \quad (4)$$

where *k* and L_∞ are parameters determined from equation (3).

The correlation coefficient was calculated using standard methods using the formula:

$$r = \frac{\sum (x-\overline{x})(y-\overline{y})}{\sqrt{\sum (x-\overline{x})^2 \sum (y-\overline{y})^2}}$$

where (x-$\overline{x}$) and (y-$\overline{y}$) are average deviations of parameters from average values. The significance of differences between the mean values of the parameters was assessed using the Student's t-test:

$$t = (\overline{x} - \overline{y}) \left(\frac{\sigma_x^2}{n-1} + \frac{\sigma_y^2}{m-1} \right)^{-1/2}$$

where $\overline{x}$ and $\overline{y}$ are average values of compared parameters; σ_x and σ_y are dispersion; *n* and *m* are the number of measurements.

Pearson's criterion was used in the study of sex ratio. Calculations were carried out according to the formula:

$$chi^2 = \sum \frac{(O-E)^2}{E}$$

where *O* is the observed ratio; *E* — theoretically expected ratio.

Information on the water temperature in the study area was taken from the Sevastopol Center for Hydrometeorology and Environmental Monitoring. Information on the water temperature in the south-eastern part of the Black Sea (coastal waters of Turkey) was obtained from information available on the Internet [https://www.seatemperature.org/], prepared on the basis of measurements in infrared and microwave bands produced by the ODYSSEA satellite.

RESULTS AND DISCUSSION

The results of studies of the age structure of the red mullet population living on the south-western shelf of the Crimea in 2016–2020 showed that the age composition of *M. barbatus ponticus* was represented by six age classes. At the same time, the main share of catches (more than 60%) was presented by two-year-old fish, the share of one-year-old individuals was more than 24%, the percentage of three- and four-year-olds did not exceed 13%, and five- and six-year-olds – on average 1%.

The length sizes of the fish studied varied between 7.2–20.7 cm. More than 45% were individuals 11.0–13.0 cm long (Fig. 2).

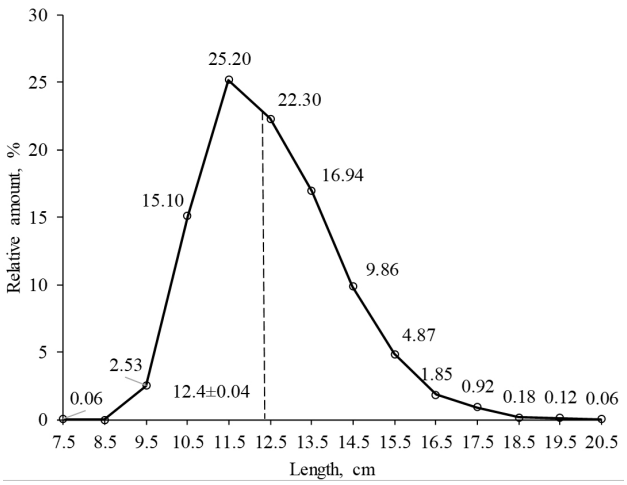

Fig 2. Relative length distribution of *M. barbatus ponticus* on the south-western shelf of the Crimea

The share of fish with a length of 13.0–17.0 cm accounted for about 34% of individuals. The largest fish, 17.0–21.0 cm long, were represented in the catches by a little over 1%.

The relative length distribution of *M. barbatus ponticus* found in catches was averaged for the period between 2016 and 2020 (Fig. 2).

In general, during the period of this study, the average length was 12.4±0.04 cm (Fig. 2). It should be noted that the low number of fish in the older age groups probably indicates a high fishing load and high fishing pressure for the large individuals.

It is known that in most fish species the sex ratio is close to 1:1 (Nikolsky, 1974). However, in some fish species, during phenotypic sex determination, in addition to genetic factors, the sex ratio can also be affected by temperature, water salinity, the ratio of periods of light and darkness in which the embryo and juvenile fish develop, as well some other factors (Nikolsky, 1974).

As noted above, puberty in male red mullet occurs at the end of the first year, and in females — at the beginning of the second year of life. Our studies have shown that the sex ratio of red mullet is affected by the water temperature during puberty, which coincides with the spawning period. Thus, in years when the average water temperature during the spawning period (May-July) was low (20.3 °C in 2017), males (56%) prevailed in the catches; in other years, at temperatures above 21.5 °C, females prevailed (differences from 1:1 are statistically significant, chi^2-test, df = 1, $\alpha < 0.05$) (Fig. 3). On average, in years with higher water temperatures, females accounted for 60.4% and males for 39.6% (differences from 1:1 are statistically significant, chi^2-test, df = 1, $\alpha < 0.05$).

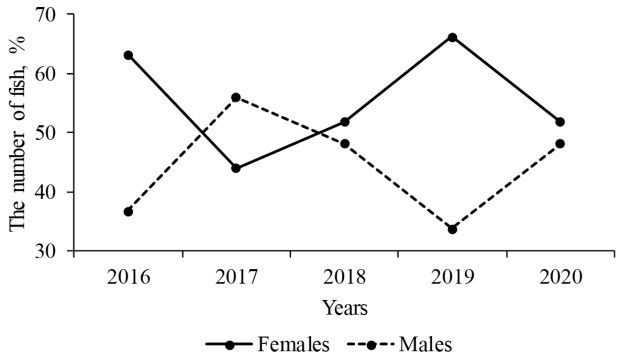

Fig 3. Sex ratio of females and males in the study period (May-August)

Our results on the change in the sex ratio of red mullet with changes in the temperature of the marine environment confirm the results presented in a number of works. Thus, it is noted that the sex ratio is influenced by both environmental parameters, including temperature at the beginning of spawning, as well as harmful emissions of industrial waste that pollute the water environment and thereby cause disturbances in the endocrine system of fish in the early stages of development, which changes the sex ratio in the direction of the predominant development of males.

The length and weight parameters, characterizing the development of an individual, are one of the most variable characteristics of an organism. The observed size diversity of fish is due to the influence of genetic and environmental factors on the processes of their development (Dgebuadze, 2001).

Let us consider the influence of the average annual temperature on the annual variations in the size and weight of *M. barbatus* living in the coastal waters of the Crimea (2016–2020), the south-eastern part of the Black Sea (Sinop) between December 2015 and December 2016 (Yılmaz et al., 2019) and in the Aegean Sea (Gökçeada Island) between September 2014 and June 2015 (Tüzün et al., 2019).

The mean annual water temperature in the study area (south-western Crimean shelf) varied between 15.3 °C to 16.4 °C (Table 1).

In 2017, when the average annual water temperature was the lowest at 15.3 °C during the study period, the average length of the fish was 1.2 cm (12.1 cm versus 13.3 cm) (differences are significant, t-test, $\alpha < 0.05$), and the weight was 5.26 g (18.03 g versus 23.29 g) (differences are significant, t-test, $\alpha < 0.05$). That is less than in the catches of 2018 when the average annual water temperature was 1 °C higher than in 2017 (Table 1). The analysis of the weight structure for 2016–2020 showed that the average weight of *M. barbatus ponticus* inhabiting the south-western shelf of the Crimea was 20±0.23 g.

It is estimated (Table 1) that in the years when the average annual water temperature increased, there was an increase in the average annual length and weight of the fish.

The analysis of literature data showed that in the south-east of the Black Sea in the Sinop region between December 2015 and December 2016 (Yılmaz et al., 2019), the water temperature was higher than on the south-western shelf in 2016 (Table 1), while the average length of fish in the Sinop area was 1 cm on average, and the weight was 5 grams more (differences are significant, t-test, $\alpha < 0.05$) than the length and mass of fish on the south-western shelf of the Crimea. In the Aegean Sea (Gökçeada Island) between September 2014 and June 2015 (Tüzün, et al., 2019), the water temperature was 2 °C higher, while the length of the fish was 1.4 and the weight was 14.61 grams more (differences are significant, t-test, $\alpha < 0.05$) than on the south-western shelf of the Crimea in the warmest year 2018 (Table 1). Thus, the average length and weight of red mullet in the warmer regions of the Black Sea exceeded the length-weight parameters of the fish from the south-western shelf of the Crimea.

The results obtained in our studies correspond to the pattern obtained by Pauli, which explains the effect of environmental temperature on the growth rate of fish (Pauly, 2021; Fig. 5). To determine the relationship between changes in the mean annual water temperature and changes in the mean annual length and weight parameters of *M. barbatus ponticus* during 2016–2020, the correlation coefficient was calculated. There is a high positive correlation between changes in the mean water temperature and changes in the length sizes of fish, as well as between changes in the mean temperature and the weight characteristics of red mullet (r = 0.97 and r = 0.96, respectively).

By the method of regression analysis, equations with the growth indicator according to the formula (1) length-weight dependence for *M. barbatus ponticus* were obtained. The parameters of the equations obtained for each year are shown separately in Table 1, and in general for the study period (2016–2020) are shown in Fig. 4.

The low scatter of the experimental data compared to the regression curve found by the analytical dependence in accordance with equation (1), is confirmed by a sufficiently high coefficient of determination (r^2 = 0.98).

Table 1. Main averaged characteristics and parameters of growth and condition factor of red mullet *M. barbatus* from different water areas

Area	Year	*t°C*	*TL± SE*	*W± SE*	*a*	*b*	r^2	*K*
	2016	15.7	12.3±0.09	20.70±0.46	0.0069	3.136	0.97	0.97
	2017	15.3	12.1±0.07	18.03±0.36	0.0072	3.111	0.97	0.95
South-west of Black Sea	2018	16.4	13.3±0.10	23.29±0.59	0.0065	3.1765	0.97	1.03
	2019	16.0	12.6±0.08	20.80±0.58	0.0067	3.1392	0.97	0.95
	2020	16.2	13.0±0.23	23.39±1.32	0.0065	3.1694	0.97	1.00
South-east of Black Sea (Sinop)	2015-2016	15.8	13.3±1.3	25.7±8.0	0.0137	2.902	0.92	1.06
Aegean Sea	2014-2015	18.4	14.7±0.09	37.9±0.74	0.006	3.220	0.97	1.08

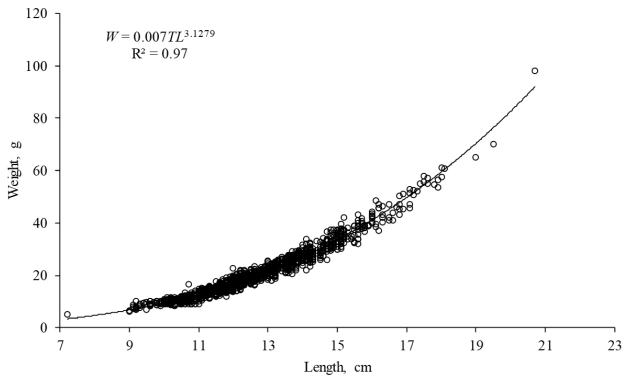

Fig 4. Average length-weight relationship for *M. barbatus ponticus* inhabiting the coastal waters of the Crimea in 2016-2020

It is seen from the equations of the length-weight relationship that *M. barbatus ponticus* has a positive allometric growth in the area of research. The average value of the parameter *b* (coefficient of allometric growth) for the study period and separately for each year is higher than three (b > 3, significance level α < 0.001), with slight deviations in some years. This evidences that, during life development, the fish becomes more rounded as the length increases (Ricker, 1979; Bagenal et al., 1978).

The analysis of interannual changes in the coefficient of allometric growth *b* showed that there was a close correlation between the fluctuation of the mean annual temperature in the study period and changes in the coefficient *b* (*r* = 0.96). Parameter *b* varies from 3.111 (the lowest value) in 2017 at an average annual water temperature of 15.3 °C to the highest value (3.177) at a water temperature of 16.4 °C in 2018 (Table 1). An increase in the allometric growth coefficient with an increase in the mean annual water temperature indicates a higher rate of mass growth of *M. barbatus ponticus* in warm years, as a thermophilic species belonging to the Mediterranean faunal complex.

The assessment of the effect of water temperature on the condition factor of individuals was done using expression (2); the results are shown in Table 1. The greatest condition factor of red mullet, living on the south-western shelf of the Crimea, was observed for 2018 (*K* = 1.03) when the highest average annual water temperature was noticed during the study period (t = 16.4 °C). The correlation coefficient was also calculated between changes in condition factor and average annual water temperature: *r* = 0.93.

The analysis of the literature data showed that in the Aegean Sea at a temperature of 18.4 °C, the coefficient for condition factor and the coefficient of allometric growth *b* for red mullet were higher than in 2018 on the south-western shelf of the Crimea at the highest temperature for the entire study period (16.4 °C).

The condition factor and coefficient *b* were also higher for red mullet living in the south-eastern part of the Black Sea (Sinop region), characterized by a warmer climate, in the period between December 2015 and December 2016 than that for the fish living in south-western shelf of the Crimea in the same time (Table 1). That is, *M. barbatus ponticus* living in regions with a higher water temperature is characterized by a higher condition factor.

Based on the analysis of our and literature data (Yılmaz et al., 2019; Tüzün et al., 2019), equations were done and graphs of the relationship between mass growth and length sizes were drawn for the fish from the south-eastern part of the Black Sea, Aegean Sea and the south-western shelf of the Crimea. In this case, the average annual temperature of the marine environment was taken into account. The resulting graphs of the length-weight relationship are shown in Fig. 5.

The analysis of Fig. 5 shows that the sea temperature on the south-western shelf of the Crimea, in the south-eastern part of the Black Sea (Sinop region) and in the Aegean Sea (Gökçeada Island) has no strong (obvious) influence on the length-weight characteristics of *M. barbatus* in the early developmental stages – at a length of less than 14 cm, the length-weight curves differ insignificantly. With further growth (an increase of TL over 14 cm), the length-weight curves begin to diverge and it can be noted that,

at the same length, the weight of the fish in the Aegean Sea at an average annual temperature of 18.4 °C is higher (curve 4, Fig. 5) than, for example, for the south-western shelf of the Crimea, where at a temperature of 15.3 °C fish gains weight more slowly (curve 1, Fig. 5). This confirms the result obtained from the analysis of the parameter *b* – with the length increasing, the fish gain weight faster, taking into account the influence of temperature.

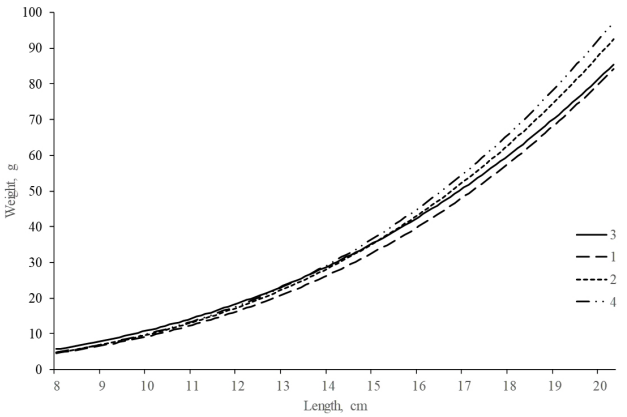

Fig 5. Length-weight relationship of *M. barbatus*: the south-western shelf of the Crimea (1 – 2017, 2 – 2018) (our data); the south-eastern part of the Black Sea (3) (Yılmaz et al., 2019); Aegean Sea (4) (Tüzün et al., 2019)

The lowest of the compared areas, the mean annual water temperature (15.3 °C) was observed on the south-western shelf of the Crimea in 2017, and the highest - 18.4 °C in the Aegean Sea (Gökçeada Island) between September 2014 and June 2015 (Tüzün et al., 2019). Accordingly, in Fig. 5, the length-weight curve for red mullet living on the south-western shelf of the Crimea (curve 1) is positioned below, and curve 4, which characterizes the development of the fish from the Aegean Sea, is positioned above others. The length-weight curve (curve 3) for the south-east of the Black Sea (Sinop region) (Yılmaz et al., 2019), where the water temperature was not high and was 15.8 °C, is lower than for 2018 in the south-western shelf of the Crimea, with an average annual seawater temperature (16.4 °C) (curve 2).

Comparative analysis of the plotted curves of the dependence of the mass of *M. barbatus* on its length from different water areas (Fig. 5) showed that in the Black Sea the fish are characterized by lower length and weight values, as compared to the Aegean Sea. This is confirmed by the earlier findings of Yu. G. Aleev: the main reason for the slow growth of some Mediterranean fish in the Black Sea (Aleev, 1956) is the pronounced continentality of the thermal regime.

The influence of temperature on the growth of fish has been pointed out by G. V. Nikolsky. He noted that low annual and seasonal temperatures make restrictions on the rate of metabolic processes that directly affect growth. In the development of red mullet in years with low average annual temperatures, a decrease in the average annual length and weight of individuals is observed. It should be noted that the high average annual water temperature leads to a faster length growth and an increase in the mass of *M. barbatus*, which provides the population with a faster increase in production characteristics and fertility. The body accumulates a greater amount of reserve substances, including those used for the gonad maturation (Nikolsky, 1974).

The von Bertalanffy equation of length growth (Bertalanffy, 1938; Ricker, 1979) is most often used to quantify fish growth parameters, which is important in studying the dynamics of fish resources. The obtained coefficients of the von Bertalanffy equation, as well as the growth index of length sizes for *M. barbatus* from the south-western shelf of the Crimea (curves 1 – 2017, 2 – 2018) (our data), the south-eastern part of the Black Sea (curve 3) (Yılmaz et al., 2019) and the Aegean Sea (curve 4) (Tüzün et al., 2019) are given in Table 2, and the graphs of the length growth of individuals from these regions are shown in Fig. 6.

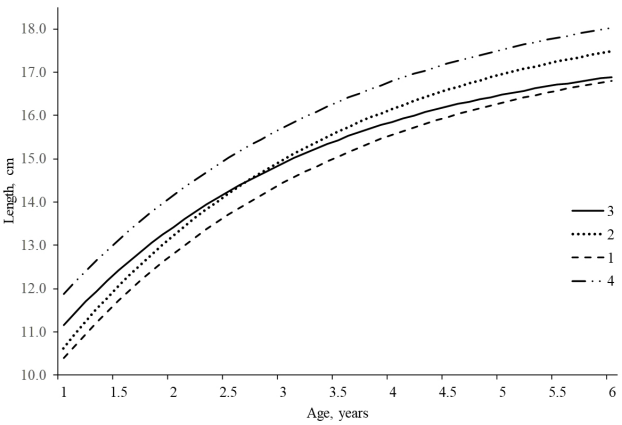

Fig 6. Growth curves of *M. barbatus* from the following regions: south-western shelf of the Crimea (1 – 2017, 2 – 2018) (our data); south-east of Black Sea (3) (Yılmaz et al., 2019); Aegean Sea (4) (Tü-zün et al., 2019)

All curves of length growth of *M. barbatus* are characterized by the rapid growth of individuals in the first years of life before sexual maturity and its slowdown at the age of 4.5–5.0 (Fig. 6).

Temperature is one of the factors affecting the rate of length growth. It can be seen that on the south-western shelf of the Crimea in 2017 and in the south-east of the Black Sea (2015–2016), when the average annual temperature was lower than 16.0 °C, the growth curves (curves 1 and 3) were positioned below the others (Fig. 6). The values of the average maximum attainable (asymptotic) length in these regions in cold years are also not high – 17.86 cm and 17.64 cm, respetively (Table 2). For red mullet living on the south-western shelf of the Crimea in 2017, the growth constant *k* was minimal (*k* = 0.390), and the growth index of length size was also minimal (φ = 2.095), which is explained by the low water temperature (see Table 2).

Table 2. Coefficients of von Bertalanffy equations, indices of growth of *M. barbatus* from the Black and Aegean Seas

Area	Year	*t* °C	L_∞, cm	*k*, year^{-1}	t_0, year	φ	Source of information
	2016	15.7	18.09	0.3919	-1.148	2.108	Our data
	2017	15.3	17.86	0.3902	-1.231	2.095	Our data
South-west of Black Sea	2018	16.4	18.6	0.394	-1.15	2.135	Our data
	2019	16.0	18.38	0.3903	-1.133	2.120	Our data
	2020	16.2	18.11	0.3937	-1.290	2.111	Our data
South-east (Sinop)	2015-2016	15.8	17.64	0.43	-1.33	2.126	Yılmaz et al., 2019
Aegean Sea (Gökçeada Island)	2014-2015	18.4	19.1	0.38	-1.56	2.142	Tüzün et al., 2019

In 2018, when the average annual temperature on the south-western shelf of the Crimea was above 16.0 °C (curve 2, Fig. 6), as well as in the Aegean Sea (curve 4) between September 2014 and June 2015, at an average temperature of 18.4 °C (Gökçeada Island), the growth curves were positioned higher than the others, and the asymptotic lengths were 18.6 and 19.1 cm, respectively (Table 2). According to our studies, the growth constant *k* = 0.394 and the growth index of linear size φ = 2.135 were maximal in 2018.

Calculations have shown that the correlation coefficient between the fluctuation of the mean annual temperature of seawater in the period studied and the asymptotic length of red mullet is *r* = 0.79.

The analysis of the curves of length growth of *M. barbatus* from different regions showed that yearlings caught on the south-western shelf of the Crimea at an average annual temperature of 15.3 °C have an average length of 10.0–10.5 cm (Fig. 6, curves 1 and 2), and in the south-east area (15.8 °C) (Fig. 5, curve 3) TL > 11.0 cm, in the Aegean Sea (18.4 °C) TL ≈ 12.0 cm (Fig. 5, curve 4). This indicates that with a temperature increase, the length growth of the fish increases in the first year of life.

In general, the comparison in the rate of length growth showed that *M. barbatus*, living on the south-western shelf of the Crimea, has the lowest position among individuals from other regions (Fig. 5). However, according to the values of the index of length growth φ, the differences in this indicator of fish from different regions are insignificant. The difference in this indicator, averaged over the entire study period for *M. barbatus* living on the south-western shelf of the Crimea (φ_{mean} = 2.112), in comparison with individuals from the south-eastern part of the Black Sea, differed on average by 0.75%, and for individuals from the Aegean Sea by 1.5% (Table 2).

It can be assumed that the Black Sea regions are characterized by lower length growth rates than the Aegean Sea regions with higher average annual temperatures, a mild Mediterranean climate and a more diverse diet. At the same time, the average and maximum lengths of Black Sea fish differ from those of the Aegean Sea fish, but not significantly. The reason for this may be an intensive selective fishery, which in a certain way affects the age and genetic structure, leaving young, fast-growing and early-maturing fish less affected.

CONCLUSIONS

The influence of environmental temperature on the interannual and regional features of *M. barbatus* development has been studied. It is shown that the average annual length sizes, weight and condition factor of red mullet increase with an increase in the average annual temperature. There is a fairly high correlation in the period 2016–2020 between the average annual water temperature and the average annual length (*r* = 0.97), and the mass of fish (*r* = 0.96).

The length-weight relationship and the condition factor coefficient were obtained for each year during the research period. Interannual changes in the body condition coefficient showed that there is a close correlation between the fluctuation of the average annual temperature and the body condition coefficient (*r* = 0.93). This indicates an improvement in conditions for the development of fish and a condition factor increase in warmer years.

In the quantitative assessment of growth parameters, based on the von Bertalanffy equation, the growth equations of *M. barbatus* were obtained during the study period. The influence of the average annual temperature on the growth parameters was revealed. A correlation was calculated between the temperature and the average asymptotic length of *M. barbatus* (*r* = 0.79), which indicates an increase in the maximum attainable length size under conditions of higher temperature values.

The analysis of the length growth of *M. barbatus* from different areas showed that the fastest-growing individuals inhabit the Aegean Sea. Slow-growing individuals of red mullet *M. barbatus* live on the south-western shelf of the Crimea, in conditions with relatively low average annual temperatures, clear seasonality and continental climate.

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UTJECAJ ABIOTSKIH ČIMBENIKA OKOLIŠA NA STUPANJ RASTA TRLJE BLATARICE

SAŽETAK

Istraživanje varijabilnosti veličinsko-dobnog sastava trlje blatarice (*M. barbatus ponticus*), koja nastanjuje jugozapadni šelfu Krima, provedeno je u razdoblju od pet godina (od 2016. do 2020.). Analizirao se utjecaj temperaturnog faktora staništa na brzinu rasta. Razmatran je utjecaj abiotskih čimbenika okoliša na stopu rasta. Dobivene jednadžbe karakteriziraju dužinsko maseni rast *M. barbatus ponticus*. Razmatran je utjecaj temperature mora na razvoj jedinki. Utvrđeno je da se porastom prosječne godišnje temperature vode povećavaju prosječna godišnja dužina (koeficijent korelacije r = 0.97), težina (r = 0.96) i faktor kondicije (r = 0.93) jedinki. Utvrđeno je da trlja blatarice ima pozitivan alometrijski rast na istraživanom području. Analiza je pokazala da postoji uska korelacija između promjena prosječne godišnje temperature i alometrijske brzine rasta b (r = 0.97). Dobivene jednadžbe rasta duljine *M. barbatus ponticus* pokazale su da je stopa linearnog rasta riba koje žive na jugozapadnom šelfu Krima smanjena prema ostalim uspoređenim područjima: regije Sinop (Crno more) i Egejsko more. Izvršena je usporedba utjecaja temperature na dužinsko-masene parametre *M. barbatus ponticus* koja živi u jugoistočnom dijelu Crnog mora (regija Sinop) i Egejskog mora gdje su zabilježeni opći obrasci i razlike.

Ključne riječi: godišnja varijabilnost, Crno more, temperatura, dužinsko-maseni odnos, koeficijent korelacije, Jugoistočni krimski šelf

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