RESEARCH ARTICLE

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Maturity, sex ratio and spawning time of *Mugil cephalus* Linnaeus, 1978 (Mugilidae) from the Bulgarian Black Sea coast

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ABSTRACT
Aspects of the reproductive biology of *Mugil cephalus* from the areas of Bulgarian Black Sea coast were studied between May 2010 and Jun 2013. Altogether 359 specimens of *M. cephalus* have been used to determine the main population-biology parameters, representing the reproductive potential of the fishes. The sex ratio of males : females in sexually mature part of the population is 1 : 1 ($\chi^2 = 0.61 < \chi^2_{st} = 10.83$ (P = 0.001)). The females are matured at the third year, while the males at the second year, with a minimum length of 19.5 cm and 16.9 cm and a minimum weight of 136.3 g for males and 60 g for females. The spawning period of an *M. cephalus* in the areas of the Bulgarian Black Sea coast starts from Jun to September with a peak in July. Gonad maturation has been studied separately for both sexes by the use of the gonadosomatic index (GSI = g/W*100) and the coefficient b from the equation g=a+b*W (g – gonad weight, g; W – fish somatic weight, g). It was determined the annual dynamics of GSI. The maximum values for the ovarian GSI are established in August while for the testes in July. Its values increase with the fish weight and range from 1.19 to 5.37 for females and for male the range it was from 0.51 to 7.48.

Key words: *Mugil cephalus,* Bulgarian Black Sea coast, maturity, gonadosomatic index, sex ratio

Introduction

Over the past 50 years, in different periods, studies have been conducted of biology and monitoring of stock of up to 8-10 Black Sea fish species. Fishing pressure constantly reinforces, the stock is falling down, but officially published data based on research almost absent.

The published data on the composition of catches of Mullets (Mugilidae) from areas of the Bulgarian Black Sea coast are 40-50 years ago (Aleksandrova, 1957; 1961; 1964; 1967; 1973).

Mullets are species with rapid growth rate and they are sensitive to various anthropogenic impacts and changes. The dynamics of the stocks of these species is highly dependent on both the magnitudes of the catches and by changing the ecological status of the Black Sea in different years (Aubrey et al., 1999; UNEP / MAP 2007; BSC 2008).

Mullets are herd fishes. Representatives of this family are distributed in various coastal aquatic habitats of the world's tropical, subtropical and temperate regions (Thomson, 1997; Harrison & Miller, 2003). Into the Black Sea on the Bulgarian coast are identified 3 genera with 6 species (Stoyanov, 1963; Ben-Tuvia, 1986; Ikomi, 1990; Kottelat & Freyhof, 2007).

The purpose of this article is to show the maturity, sex ratio and spawning time of *Mugil cephalus* Linnaeus, 1978 from the areas of Bulgarian Black Sea coast. The need of this study determines by the absence of available data. The obtained results make it possible to assess the effectiveness of natural reproduction of the fishes, while be bound with other data (environmental factors, growth, mortality, fertility, etc.) and their sustainable development.

These studies will give a solid background for closed seasons based on the minimum reproductive size. These fishing measures will allow the species to reproduce at least once, protecting the fishery from overexploitation.

Materials and Methods

M. cephalus specimens were collected during the period May 2010 – June 2013 from the areas of Bulgarian Black Sea

coast (Figure 1). The samples were collected by cast nets fishing – size of the eye 22-38 mm, length 50 m and height of the nets between 1.5 and 2 m.

Fish maturation was studied on 359 specimens and gonadosomatic index (GSI) on 154 individuals of which 71 female and 83 male.

Standard length (SL ± 1mm), total weight (TW ± 1g), gutted (somatic) weight (W ± 1g) and gonad weight (g ± 0.1 g) were measured.

The stage of gonad maturation was measured separately for both sexes in two ways:

1. By the gonadosomatic index (GSI): GSI = g/W*100, where g – gonad weight in g, W – gutted fish weight in g.
2. Coefficient of proportionality (b) in the equation g=a+b*W (Morozov, 1964; Zhivkov, 1985; Yankov & Zhivkov, 1989).

The statistical accuracy of the sex ratio was established by using Chi-square (χ^2) test (Lakin, 1973): $\chi^2=\sum(p-p')^2/p'$, where p is empirical, and p' is theoretical (expected) frequency (in the case of 50%).

The age was determined by the scales at a magnification of 17.5x with Projector Dokumatot, Lasergeret (Carl Zeiss, Jena).

Data were statistically processed with MS Excel.

Results

The catch of *M. cephalus* from the areas of Bulgarian Black Sea coast were made up of 129 juveniles, 71 males and 83 female or in % 45.58 : 25.09 : 29.33. The sex ratio of males : females of the population is 1 : 1 ($\chi^2 = 0.61 < \chi^2_{st} = 10.83$ (P = 0.001)).

The results confirm an existence of periods with specific sex ratio – the first period when the male-dominated, includes the fishes of two years; the second is when the ratio between the two sexes is 1 : 1 is observed at 3-7 annual fishes ♂ : ♀ = 52% : 48%; the third period includes fishes at the age of 8 years old who have only females, constituting 9.1% of sexually mature part of the population (Table 1).

The youngest sexually mature male and female were at the age of two and three years, respectively, with dimensions 16.9 cm and 60 g for male, and 19.5 cm and 136.3 g for female. On three years, all of the fish are mature.

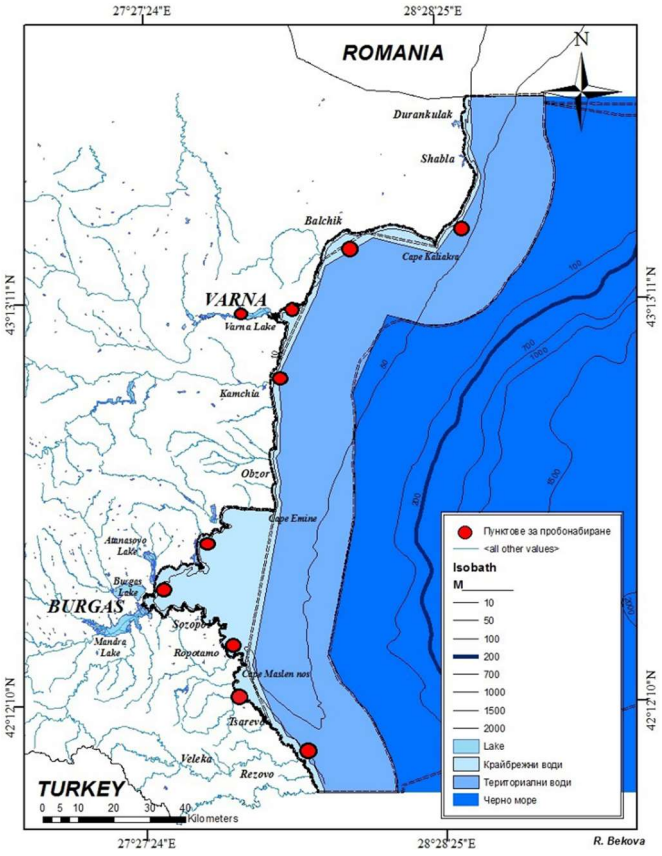

Figure 1. *Changes in seed coat colours in the M_2 generation and the control variant (upper left corner).*

The reason for the earlier maturation of *M. cephalus* from the areas of Bulgarian Black Sea coast is the low average age of the population (3.3 years). It is the result of an overfishing (Bekova & Raikova-Petrova, 2011). The permanent fishing of the biggest and respectively the oldest individuals of the population results in a reduction of the fish size and the life cycle of the population. The age at first spawning is inversely proportional to the length of life (Woodhead, 1979). The period of maturation for *M. cephalus* from Bulgarian Black sea coast is similar to the period reported from Stoyanov (1963) and Karapetkova & Zhivkov (1995). The same period reported in Bartulović et al. (2011). Similar results for the period of maturation were reported from Miller & Loates

Table 1. *Sex composition of Mugil cephalus L. from the areas of Bulgarian Black Sea coast.*

Age (years)	1	2	3			4		5		6		7		8		n	%
Sex	Juv.	Juv.	♂	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀		
Number	114	15	2	7	9	34	27	20	20	6	4	4	7		14	283	100
%	40.28	5.3	0.71	2.47	3.18	12.01	9.54	7.07	7.07	2.12	1.41	1.41	2.47	0	4.95	100	
♂:♀ (%)			100	43.8	56.2	55.7	44.3	50	50	60	40	36.4	63.6	0	100		
Total number			2	16		61		40		10		11		14		154	

(1997) for the Mediterranean Sea and Ameur et al. (2003) for Atlantic Coast (Morocco). But Assem et al. (2008) reported results for the period of maturation from September to November, McDonough et al. (2003; 2005) from October to April for South Carolina coast; Ibáñez-Aguirre & Gallardo-Cabello (2004) and Bernandon & Vall (2004) reported period of maturation from November to February for Gulf of Mexico and Mauritania.

Bearing in mind the prolonged breeding season, we can recommend to the NAFA to be entered a prohibitive period for catching from 1 August until September 15.

The annual dynamics of the GSI for females and males (Figure 2 and Figure 3) show the duration of the spawning. The spawning season of *M. cephalus* starts from June to September, with a peak in July

The spring-summer values of GSI for females varied between 1.88% and 8.93%. Its values were rising with fish weight (Table 2). This variability is due to not simultaneously maturation of the fish and the partial spawning of the species. In autumn-winter season gonads were in the latent period and the values of the GSI were relatively constant (from 1.18% to 2.69). Females with a weight between 300.1 g and 350 g had highest values of GSI for the spring-summer season. For the autumn-winter season, the females with a weight between 50.1 g and 150 g had highest values of GSI.

For the male part of the population, the values of GSI varied between 0.57% and 7.48% in spring-summer season and from 0.51% to 1.91% in an autumn-winter season (Table 3). There was a high variability of the index values for the index values for the different weight classes. Maximal index values for males were found in the highest weight class (300.1 g and 1400 g) during both seasons. This weigh class includes the most reproductively active.

The seasonal change of the ovaries GSI is represented in Figure 2. Highest dynamics was established from June to September with a peak in July (during the spawning season). Lower values in June were due to the partial spawning of the species and the non-simultaneous maturation of the individuals. From October to May the ovaries were in the latent period and the values of the GSI were constant.

The highest variability of the GSI for males was found during the spawning season (Figure 3) as for females. Its highest values were in July, and the minimum was established in December. After the spawning was completed the values of the GSI stayed constant.

According to data from Sikoki et al. (2001) at *M. cephalus* GSI show a peak in July, August and September, at the lowest values observed during the months of December to May.

The relation between the ovaries weight and gutted weight of the females was represented by the equations:

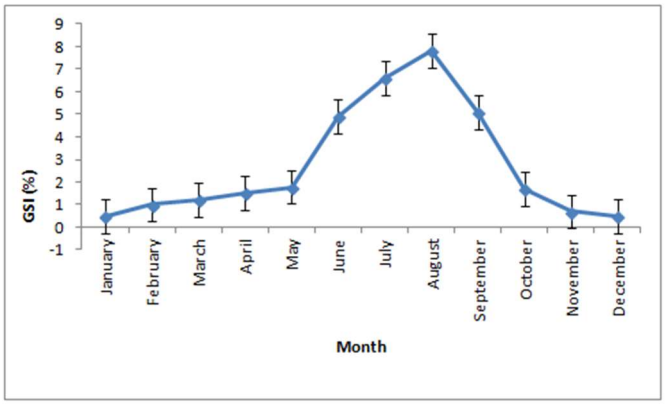

Figure 2. *Seasonal changes of the ovaries GSI for M. cephalus L from the areas of Bulgarian Black Sea coast.*

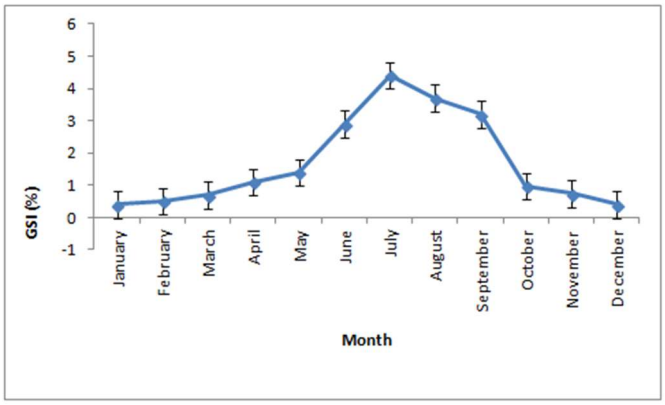

Figure 3. *Seasonal changes of the testicles GSI for M. cephalus L from areas of Bulgarian Black Sea coast.*

g= -0.0018 + 0.0558W, r = 0.92 (in spring-summer season) and g= 2.0436 + 0.0082W, r = 0.72 (in autumn-winter season). The equations for males were as follows:

g= -13.521 + 0.0953W, r = 0.99 in spring-summer season and g= 0.1327 + 0.0124W, r = 0.76 in autumn-winter season (Table 2 and Table 3). The coefficient b from the equation of the regression between gutted weight and gonad weight has been recommended by Morozov (1964) and Zhivkov (1985) as more precise indicator of the gonad maturation.

Discussion

The gonadosomatic index (GSI) is the basic indicator for the condition of the gonads. For more accurate tracking of reproductive activity was investigated GSI separately for both sexes. The values of the index are compared over the summer (during to the breeding period) and in the autumn (the post-breeding season) having followed and the dynamics of the index during to the year.

The values of GSI for the females fishes during the spring-summer season ranging. This variability is due firstly to the fact that fish do not ripen at the same time and on the other, the species breed portioned. Upon completion of the

Table 2. *Indices of ovaries maturity by size classes in spring-summer and autumn-winter seasons for M. cephalus Linnaeus from the areas of Bulgarian Black Sea coast.*

Weight class (g)	Average somatic weight (g)	Average ovaries weight (g)	Average GSI by weight class	Average GSI	b*100	n
Spring-summer season						
50.1 - 150	102.6	1.930	1.88			5
150.1 - 200	183.1	6.549	3.58			8
200.1 - 250	226.9	10.901	4.80			15
250.1 - 300	269.5	16.002	5.94	4.89	5.58	11
300.1 - 350	318.1	28.416	8.93			16
350.1 - 600	435.4	23.969	5.51			7
600.1 - 1500	984.0	52.824	5.37			21
Autumn-winter season						
50.1 - 150	142.2	3.830	2.69			3
150.1 - 200	199.0	2.354	1.18			17
200.1 - 250	245.2	4.398	1.79	1.74	0.82	19
250.1 - 300	267.6	4.427	1.65			4
300.1 - 350	337.1	5.111	1.52			7
350.1 - 600	522.8	6.240	1.19			7

Table 3. *Indices of testicles maturity by size classes in spring-summer and autumn-winter seasons for M. cephalus from the areas of the Bulgarian Black Sea coast.*

Weight class (g)	Average somatic weight (g)	Average testicles weight (g)	Average GSI by weight class	Average GSI	b*100	n
Springsummer season						
90.1 - 200	171.9	0.978	0.57	5.44	9.53	7
200.1 - 250	226.1	7.629	3.37			24
250.1 - 300	276.7	11.925	4.31			12
300.1 - 500	344.1	23.674	6.88			15
500.1 - 1400	717.3	53.687	7.48			12
Autumn-winter season						
90.1 - 200	171.9	0.870	0.51	1.54	1.24	10
200.1 - 250	226.1	1.998	0.88			13
250.1 - 300	276.7	4.452	1.61			22
300.1 - 500	344.1	6.567	1.91			6
500.1 - 1400	717.3	8.223	1.15			2

reproduction, gonads pass into the latency period before to the next cycle. The duration of this period varies for different genders.

It's established a trend of increase of the values of GSI with increasing the mass of fish. The lower values in the first weight class can be explained by the fact that here are included fishes at a young age, the majority of which breed for the first time.

The coefficient b from the equation of the regression between gutted weight and gonad weight has been recommended by Morozov (1964) and Zhivkov (1985) as a more precise indicator of the gonad maturation. The increase in the mass of the ovaries by an increase the mass of females in the autumn, when the gonads are in a latency period is much more gradual compared to the spring when the regression line is much steeper.

The values of GSI a lot of accurately describe the degree of maturity of the ovaries in the spring. This is determined by the very close averages of GSI and the coefficient b during this season due to the fact that the straight line describing the relationship W-g runs almost throughout the coordinate system origin, i.e. we have nearly a perfect (theoretical) case when GSI shows an actual degree of maturity.

For the male representatives of the population, the values of GSI varied by both seasons maximum values were detected in fish of average weight classes. This is explained by the fact that this comes the most reproductively active specimens of medium size, the average ages, the quantity and quality of sex products is best.

After completion of the reproduction for males, the GSI values of remaining nearly constant with a slight upward trend since for period March – June. Then the gonads are restored and begin to prepare for the next breeding season. Unlike of the females, for males the GSI values are more accurately describes the degree of maturity of the gonads in the fall than in the spring, as an inventory autumn depending on W-g passes very close to the origin.

Our results for the seasonal dynamics of the GSI ovaries and testes confirmed the theoretical position that the males of the population mature earlier than females.

The difference in the time of the maturation, GSI and the coefficient b at the various specified authors is due to the fact that these are the species signs whose values change in the process of ontogenesis and in depending on the environmental conditions.

Conclusion

The GSI for males fishes more accurately describes the degree of maturity of the gonads during to an autumn-winter season than in a spring-summer period, as an autumn inventory in depending on the weight of a fish (without giblets) to the weight of the gonad passing very close to the coordinate system origin.

Thanks to the predominance of young fish and relatively early maturation of individuals thus formed structure has successfully maintained the reproductive capacity of populations, although the numerically low presence of specimens of a larger age.

In the 60s and 70s of the last century as a result of overfishing and the continued poor ecological condition of habitats on a mullets fishes their populations have a short life cycle. For the improvement of their condition (increasing the stock, size and length of life) is necessary to increase the minimum size for the catch, to introduce catch restrictions during the spawning period and to introduce annual quotas for catches.

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