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Age structure, growth rate and condition of *Barbus cyclolepis* (Cyprinidae) from the middle zone of the Maritsa River

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Abstract

This paper examines the age, growth and condition factors of *Barbus cyclolepis* from the middle reaches of the Maritsa River. The material contains 486 specimens collected in the river section from the town of Kostenets to the village of Zlokuchene. The aim of this study is to establish the population parameters of the Maritsa barbel from the middle zone of the Maritsa River. Seven age groups are established. One-year-old fish predominate the sample. The most numerous are fish of 81 to 110 mm length. Linear growth of Maritsa barbel from the middle course of the Maritsa River is similar to that of the same species from the lower course of the river in the vicinity of the city of Plovdiv. In comparison, Maritsa barbel from the more southerly flowing Arda River and from the Dospat Dam has greater linear growth. A comparison of same-length fish from different rivers reveals that the barbel reaches a larger mass in the Arda River and in a stretch of the Maritsa River in the vicinity of the city of Plovdiv. This observation may be due to the lower altitude, warmer climate and longer growing season in this part of the Maritsa River basin.

Key words: Maritsa barbel, weight gain, linear growth, size classes and age composition.

Introduction

The Maritsa River system is the largest in Bulgaria. Its source are the Maritsa Lakes in the Rila Mountain at an altitude of 2,378 m above the sea level. The Bulgarian catchment area (21,084 km^2) of the Maritsa River includes nearly a fifth of the Bulgarian territory (Tsachev et al. 1977). The river's watershed consists of two large parts - a northern one, draining the southern slopes of Sredna Gora and Stara Planina Mountains, and a southern one, formed by the northern and eastern slopes of the Rhodope Mountains. The Maritsa River has about one hundred tributaries located symmetrically along the northern and southern parts of its watershed. Amongst its tributaries are two of the largest Bulgarian rivers – the Tundzha and the Arda (Hristova 2012). Until two centuries ago, the Maritsa River was navigable for small vessels - boats and ships. Today, its water level is very low in summer and autumn, mainly as a result of dam construction in its catchment area, which is also characterised by a great number of towns and villages. The water of the river and its tributaries is characterised by pollution with domestic and industrial polluted water (Tsachev et al. 1977). In addition, some tributaries' river beds have been channeled and embanked.

Until 1955, commercial fishing took place in the Maritsa River, prior to it reaching the city of Plovdiv. Today, only recreational fishing is allowed in the course of the river on Bulgarian territory.

The Alpine Orogeny led to the appearance of the Alpine Mountain Range and the isolation of fish populations from Central Europe on the one hand and from Southern Europe on the other. This event also led to the appearance of many endemic fish in the rivers of the Mediterranean basin (Doardio 1990, Zardoya & Doardio 1999, Bianco 2012, Sanjur et al. 2003). The Stara Planina Mountains also made a barrier for fish in northern and southern Bulgaria. Therefore, some endemic fishes are

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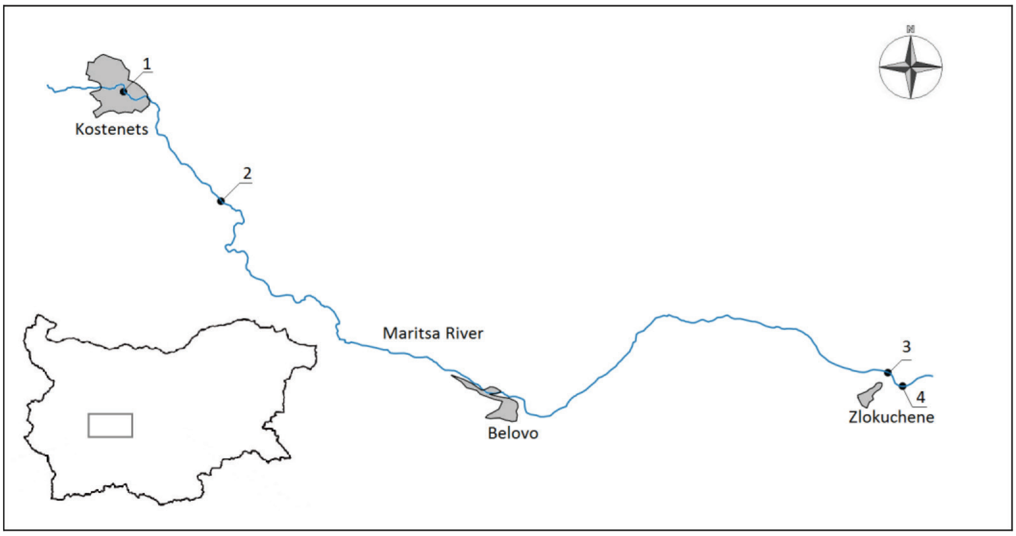

Fig. 1 Sampling area at the Maritsa River, in the inset the sampling area is presented relative to the map of the Republic of Bulgaria (lower left corner) (QGIS 1022)

found in the Bulgarian rivers of the Aegean watershed, including in the Maritsa River. (Heckel 1837, Kovatchev 1921, Drensky 1930, Shishkov 1939, Michaylova 1965, Kottelat & Freyhof 2007, Stefanov 2007). One of these endemic species, the Maritsa barbel is a recent form derived from previous populations of *Barbus barbus* isolated during the last glaciation (Bianco 2012). This species is distributed in rivers in the southern part of the Balkan Peninsula (Heckel 1837, Shishkov 1939). Apart from the rivers of the Aegean basin, the Maritsa barbel is also found in some watercourses, flowing through the territory of Strandja in Turkey and flowing into the Black Sea north of the Bosphorus (Kottelat & Freyhof 2007, Barbieri et al. 2015).

The Maritsa barbel is a typical rheophilic fish, preferring fast-flowing rivers with gravel and stony bottoms. This species lives in the middle reaches of rivers, but in spring and summer, it migrates to the trout zone. During the day, the fish stays in deeper places, behind rocks and stones, and in the morning and evening it is active and goes out into the rapids. The fish winters in deep places of the rivers, where it sometimes forms aggregations (Marinov 1986). The diet of the Maritsa barbel consists mainly of chironomid larvae, plant detritus, gammarus, dayworm larvae and, to a lesser extent, caddisflies, simulids and chironomid flies (Marinov 1986, Rozdina, Raikova-Petrova, Marinova & Uzunova 2008). Sexual maturation of the Maritsa barbel occurs mainly in the second year (Rozdina 2009, Kolev & Raikova-Petrova 2019, Kolev 2021). Sex ratio of the population of the species in the Maritsa River basin is ♂:♀-1:1 (Raikova & Kolev 2015, Raikova-Petrova & Rozdina 2012). Absolute fecundity of the species varies from 450 to 18,000 fish eggs. On average, individual fertility is about 5,000 eggs for one female fish. The absolute and relative fecundity of the Maritsa barbel increases with increasing age and mass of female fish (Rozdina 2009, Kolev & Raykova 2019, Kolev 2021). The back-calculated mean standard length of the species in some tributaries of the Maritsa River on Bulgarian territory is as follows: 1 year - 48 mm, 3 year - 94-100 mm and 5 year - 150-160 mm (Raikova & Kolev 2015, Kolev & Raykova 2019). In the investigated rivers in Bulgaria, one-, two- and three-year-old fish predominate. Despite intensive fishing, however, the Maritsa barbel has a relatively high survival rate: from 35% to 50% and above in some rivers (Raikova & Kolev 2015). The life history of the Maritsa barbel is characterized by: small body size, short life, low mortality, high fecundity and energy input for reproduction. According to some authors, this is an adaptation to the harsh and unstable conditions of the environment in which it lives (Vasiliou & Economidis 2005).

The aim of this study was to establish the growth parameters of the Maritsa barbel from the middle zone of the Maritsa River and fill a knowledge gap that exists for this species.

Materials and Methods

The research project studies the middle zone of the Maritsa River, situated 200 m a.s.l (Fugure 1).The study was based on a sample of 486 individuals of the Maritsa barbel. Investigation took place at four sampling sites along the river, near the town of Kostenets and the village of Zlokuchene (Table 1). Sampling material was collected in the autumn of 2006 by electrofishing. A SAMUS 725G converter was used, providing up to 640 V direct current (DC), frequency 50 Hz and output power reaching up to 200 W. Catch was performed according to the EN 14011:2004 instruction. Electrofishing was supplemented by line fishing. The ledgering fishing

Table 1. Sampling sites of the Maritsa River.

No	Sites	Geographic coordinates		Altitude, m a.s.l.
		N	E	
1	In the town of Kostenets	42°18′30″	23°51′39″	503
2	In the vicinity of the town of Kostenets	42°12′22″	23°53′46″	483
3	In the vicinity of village of Zlokuchene	42°13′24″	24°09′52″	230
4	In the vicinity of village of Zlokuchene	42°13′18″	24°10′29″	228

technique was used. One 3 m long rod were used, with stainless steel №10–12 limerick hooks and fixed spool reels of 0.18 mm fishing monofilament line. Red worms and maggots were used as bait.

In the watercourse of the Maritsa River, from the town of Kostenets to the village of Zlokuchene, eight species of fish from two families have been registered. Species identification was made according to Berg (1949), Drensky (1951), Kottelat & Freyhof (2007).

Measurements were conducted of total fish length (L) with a precision of 1 mm, as well as full body weight (W) with precision of 0,1 g. The scales ware collected from each studied specimen. They were taken from underneath the dorsal fin. An equal number of scales were taken from the left and right side of the dorsal fin. Next, the scales were dried up and stored in small papers bags. The scales were then examined with a microscope Olympus CX 31, at 40× magnification. Each scale was mounted between two microscope slides. Fish age was then determined by counting the annual rings of a scale. For this purpose, the diagonal caudal radius of the scales was used.

A fish's linear growth was determined via a back-calculation of length (L) from the diagonal caudal radius of a scale (S) (Zhivkov 1981). This relation is described by a linear equation (1):

$$L = a + b \cdot S \quad (1)$$

where: L – total body length, mm; S – diagonal caudal radius of a fish scale (eyepiece micrometer scales divisions); a, b – equation coefficients.

Absolute annual linear incensement was accepted as a growth characteristic (Zhivkov 1972):

$$t_L = L_n - L_{n-1} \quad (2)$$

where: t_L – absolute annual linear incensement, mm; Ln; Ln_{-1} – average total length of fish for two consecutive years, mm.

Weight (W) values were estimated by equation (3) Ricker (1979), used by many authors (Prodanov 1982, Zhivkov 1981, Raikova-Petrova & Zhivkov 1993, Zhivkov 1999, Belomacheva et al. 2005):

$$W = a \cdot L^b \quad (3)$$

Annual weight increment was calculated as the difference between the mass of the current and the previous year (Zhivkov 1972):

$$t_W = W_n - W_{n-1} \quad (4)$$

where: t_W – annual weight increment, g; Wn; Wn_{-1}– average gutted weight of fish for two consecutive years, g.

A length growth comparison of different fish populations is made by ranking them according to their average length at the same age. When two populations are compared, the age of the younger population is taken into account (Zhivkov 1972).

Condition of a population is studied in two ways:

- By calculating a classical coefficient (K_f) of the Fulton equation (5):

$$K_f = W*100(/L)^3 \quad (5)$$

where: L – weighted average total body length, cm; W – weighted average full body weight, g.

- By comparing weight growth (W) of fish from different populations, a method proposed by many authors (Goldspink 1979, Basami and Grove 1985, De Silva 1985, Raikova-Petrova 1992, Zhivkov 1981, 1999). A relationship is expressed by the equation (5):

$$W_L = a \cdot L^b \quad (6)$$

where: L – length of fish, mm; W – total weight of fish g; a, b – equation coefficients.

In order to obtain comparable values of W in equation (3), pre-selected rounded values of L (50, 100, 150, 200 and 250 mm) are successively substituted in place of L (L=50, L=100, L=150, ...). Using equation (6) with the listed values of L (mm), allows obtaining the corresponding values of mass W: $W_{L=50}$, $W_{L=100}$, $W_{L=150}$, $W_{L=200}$, $W_{L=250}$. The so-obtained mass values ($W_{L=50}$, $W_{L=100}$, $W_{L=150}$, $W_{L=200}$, $W_{L=250}$) for each of the studied populations are then compared (Zhivkov 1981, 1999; Raikova-Petrova & Zhivkov 1993).

Results and Discussion

Age and size composition

One-years-old fish comprised 44% of all samples (Figure 2). The number of specimens in the first three age groups is 91%. Older fish are very poorly represented. Five-year-old fish represents 1,2% from the sample and seven-year-old fish respectively 0,2% (only one individual). The size structure is relatively uniform (Figure 3). However, fish with size between 81-110 mm predominated. The most variable with regards to size were one-year-old fish. This is could be a result of the greater number of specimens in this age class. With regards to biomass, three-year-old fish (41%) were most abundant, followed by four-year-old fish (26%), as their individual weights were greater.

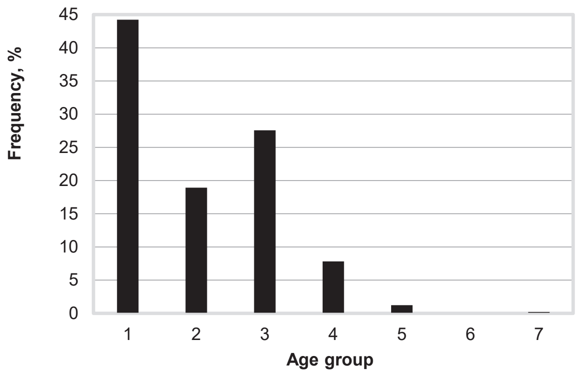

Fig. 2. Age structure of Maritsa barbel from the Maritsa River.

Seven age groups have been recorded in some populations of Maritsa barbel, such as that from the Dzerman River (Dikov and Zhivkov 1985) and even nine, such as that from the Doirani River (Vassiliou and Economidis 2005). Eight age groups have been identified along the course of the Maritsa River after the city of Plovdiv (Rozdina 2009). In the water course of the Maritsa River upstream of the village of Zlokuchene, we found five well-defined age groups and only one seven-year-old specimen. The absence of eight-year-old fish and the small number of five-year-old fish could be the result of greater fishing pressure in this part of the river. This part of the river is characterized by a lower discharge and a narrower bed and remains more fishable than further downstream. During the breeding season, adult fish can also be found in this part of the Maritsa River. After breeding, they are pulled downstream by the current.

Length and weight growth

Length growth was back calculated on the basis of the relationship of scale radius and length at time of catch. This relationship is described by the following linear equation:

$L = 3{,}27S+11{,}16;\ r^2 = 0{,}97;\ P < 0{,}05;\ n=486$ .... (7)

Annual length growth is highest during the first year of a fish's life (Table 2) when most of its body energy is used for growth, prior to sexual maturity. Bigger size allows the fish to escape pressure from predators. In the following years, the annual length increment decreases. The oldest seven-year-old fish has the smallest annual growth. This is related to the beginning of the aging process (Nikolsky 1965).

There is considerable variation in length growth of Maritsa barbel from different water bodies (table 3). Despite the fact that we used total body length (length to the end of the caudal fin) and other authors used the standard one (length to the end of the scaly cover and to the beginning of the caudal fin), comparisons are still possible. In our sample, the length of the caudal fin was 17% of total body length on average.

Information about the population biology of Maritsa River barbel has been published only by Rozdina (2009). The material for this study was collected in the lower course of the river, in the vicinity of the city of Plovdiv. The comparison of our results with Rozdina's (2009) data shows a similar species' length growth (Table 3). In the more southerly Doirani and Arda rivers, Maritsa barbel grows in length faster (Dikov et al. 1994 Vassiliou

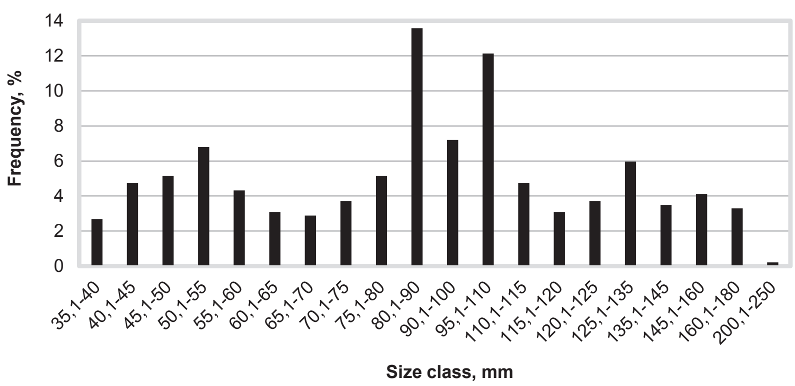

Fig. 3. Size classes of Maritsa barbel from the Maritsa River.

Table 2. Back-calculated total body length (L, mm) of Maritsa barbel.

Year	Age group	N	Mean calculated L, mm at age						
			L_1	L_2	L_3	L_4	L_5	L_6	L_7
2006	I	215	58						
2005	II	92	64	90					
2004	III	134	58	87	120				
2003	IV	38	59	86	115	143			
2002	V	6	58	87	114	157	186		
2000	VII	1	57	87	110	169	201	221	237
Mean calculated L, mm		486	59	87	115	156	194	221	237
Mean observed L, mm			62	95	116	150	181	x	245
Annual increment, mm			59	28	28	43	31	20	16

Table 3. Comparison of mean calculated body length of Maritsa barbel of the same age.

Source	River	Body length, mm								
		L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	L_9
Rozdina, 2009	Maritsa	35	62	91	116	140	152	171	204	
Raikova & Kolev 2015	Stryama	54	69	89	122	147	156			
Penczak et al. 1985	Mesta	55	80	107	138	178				
Vassiliou & Economidis, 2005	Doirani	68	98	121	144	166	188	213	226	236
Dikov & Zivkov, 1985	Dzerman	54	90	126	152	167	180	185		
Our study, 2022	Maritsa	59	87	115	156	194	221	237		
Dikov et al. 1994	Arda	64	106	140	182					
Dikov & Zivkov, 1985	Dospat Dam	92	125	187	241	257	261			

Note: Our study used total body length (TL), while other authors used standard body length (SL).

and Economidis 2005). Obviously the barbel has a higher linear growth in the more southerly flowing rivers. For example, the influence of the Mediterranean climate can be felt in the catchment basin of the Arda River, where the winter is warmer and rainy. The growing season there is longer. All this may have a beneficial effect on the fish's growth in the Arda River.

A few decades after the Dospat Dam was built on the river Dospatska (the dam was dammed in 1968), the Maritsa barbel was still found in the dam. In these first decades, the fish productivity of the dam was the greatest as a result of the flooded lands. Therefore, the rapid length growth of the barbel in the Dospat Dam is logical. Also fish populations inhabiting standing waters have better growth than populations inhabiting running waters, due to the homogeneity of ecological conditions such as food abundance, water flow and temperature (Alp et al. 2005). Body length of Maritsa barbel from the Dospat Dam differs from that of other populations for the same age groups (Table 3). However, nowadays there

Table 4. Back-calculated full body weight (W, g) of the Maritsa barbel.

Year	Age group	N	Mean calculated GW, g at age						
			W_1	W_2	W_3	W_4	W_5	W_6	W_7
2006	I	215	1,8						
2005	II	92	2,4	6,7					
2004	III	134	1,8	6,1	16,3				
2003	IV	38	1,8	5,8	14,2	27,2			
2002	V	6	1,8	6,0	14,0	36,4	60,8		
2000	VII	1	1,7	6,0	12,2	45,1	77,4	102,6	127,5
Mean calculated W, g		486	1,9	6,1	14,2	36,2	69,1	102,6	127,5
Mean observed W, g			2,7	8,3	16,0	35,1	62,5	x	130,0
Annual increment, g			1,9	4,2	8,2	22,8	28,4	25,2	24,9

Table 6. Weight calculated at the same length by length-weight relationship.

Source	River/ Dam	Equation of the total population	Average weights (W_L, g) calculated at the same rounded lengths (L, mm)				
			W_{50}	W_{100}	W_{150}	W_{200}	W_{250}
Present data. 2006	Maritsa	$W = 0{,}00002SL^{2{,}9765}$	1,1	9,3	31,7	75,8	149,1
Raikova and Kolev, 2015	Stryama	$W = 0{,}00002SL^{2{,}896}$	1,7	12,4	40,1	92,2	176,0
Dikov et al, 1994	Arda	$W = 0{,}00002SL^{2{,}9401}$	2,0	15,2	50,0	116,5	224,5
Rozdina, 2009	Maritsa	$W = 0{,}0144SL^{3{,}0588}$	2,0	16,5	56,7	137,4	271,9

is no data about the presence of Maritsa barbel in the dam. This is probably due to the transformation of dam waters from flowing to standing and the increase in the water column's height. Presumably, the altered dam hydrology does not already correspond to the barbel's biological requirements.

Weight growth was calculated using a W/L relation. This relationship is described by the follow equation:

$W = 0{,}000008 \cdot L^{3{,}0319}$; $r^2 = 0{,}99$; $P < 0{,}05$; n=486 .... (8)

In the middle zone of the Maritsa River the mass accumulation of the species is very slow during the first three years, after which it increases and stabilizes at a relatively constant level (Table 4). This may be related to the greater efficiency of adult fish in finding food and better adaptation to the environmental conditions.

The Fulton's coefficient varies according to age: I age group – 0,9; II – 0,9; III – 0,9; IV – 1,0; V – 1,1; VII – 0,9. In all age groups the condition of the fish remains almost constant. However, the inaccuracy of the Fultan's coefficient in calculating body condition has long been known. The exponent „b" of Fulton's equation is most often different from 3 (Morozov & Dubrovskaya, Le Cren 1951, Ricker 1979, Ivanov 1988, Zhivkov & Petrova 1988). In addition, it has been established by many authors that the two coefficients „a" and „b" of this equation are influenced by many factors: age, gender, seasonal and annual factors (Zhivkov & Petrova 1988, Zivkov 1999). Ricker (1975) believed that the coefficient „a" of the W-L relation could be used to compare fish of approximately the same length. Many researchers recommend comparing the mean weights of fish from different populations, calculated using the relevant population W-L equations for each population for the same rounded length values (Goldspink 1979, Basami & Grove 1985, De Silva 1985, Zhivkov & Petrova 1988, Raikova-Petrova 1992, Zhivkov 1981, 1999).

We compared the average weights of barbel in the vicinity of Kostenets and Zlokuchene on the one hand and the average weights of fish from the Arda River, as well as from the Maritsa River in the vicinity of Plovdiv on the other hand (Table 6). The results show that fish of the same size reaches larger mass in the lower reaches of the Maritsa River and in the more southern parts of the Maritsa River watershed. Probably the lower altitude, the warmer climate and the different hydrography of the rivers have a favorable effect on both barbel growth and the development and abundance of the organisms it feeds on.

Conclusions

The linear growth of the Maritsa barbel from the middle course of the Maritsa River is similar to that of the same species from the lower course of the river in the vicinity of the city of Plovdiv. The Maritsa barbel has a higher linear growth in the more southerly flowing Arda River.

At the same body length, the barbel reaches a larger mass in the Arda River and in the part of the Maritsa River in the vicinity of Plovdiv.

Authors' statement

The present study was conducted in accordance with the national legislation. Electrofishing was conducted with permit issued by the Ministry of Agriculture, Food and Forestry of Bulgaria

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Conflict of interest

The author declares no conflict of interest.

Data availability statement

The data, supporting the findings of this study, is available on request from the corresponding author.

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