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Age structure, growth rate and condition factor of *Squalius orpheus* (Cyprinidae) of Maritsa river's middle zone, Bulgaria

Vasil Kolev

University of Forestry, Faculty of Forestry, Department of Hunting and Game Management, 10 Kliment Ochridski Blvd., 1797 Sofia, Bulgaria.

Abstract

Age, growth and condition factor were determined for *Squalius orpheus* of the Maritsa River's middle zone. A comparison was made of length differences for the same age group of stream and reservoir populations. A total of 114 *S. orpheus* were caught and examined. The fish were classified in six age groups (1-6 years). One-year-old fish dominated the samples. Standard body lengths (SL) ranged from 3.4 to 30.5 cm and the length of the majority of the samples was between 5.0 and 7.0 cm. A length-weight relationship was described as $W = 0.000009 \cdot SL^{3.0934}$, ($r^2 = 0.9796$, $P < 0.05$). Length growth was expressed as SL = 2.1554S+16,588, ($r^2 = 0.9927$, $P < 0.05$). Condition factors and the coefficient from Fulton's equation ranged from 1.26 to 1.53, with a mean value of 1.28. Fulton's coefficient increased from one-year-old to five-year-old fish. The present study of Orpheus dace's population parameters contributes to the knowledge of the species' population biology.

Key words: Orpheus dace, weight growth, linear growth, size and age composition.

Introduction

The Maritsa River is one of the Balkan Peninsula's most important water systems. This is the largest watercourse flowing south of the Balkan Mountains. Most of the river passes through Bulgaria. It collects water from the mountains Rila, Sredna Gora, Stara Planina and Rhodopes. The river flows through the Thracian valley and then south to the Aegean Sea. Its catchment area includes 19% of the Bulgarian territory (Hristova 2012). The largest tributaries of the Maritsa River are the rivers Tundzha and Arda. Additionally, there are over a hundred smaller tributaries, located on both sides of the riverbed. In the past, the Maritsa River was navigable for small vessels southeast of the city of Plovdiv. However, in recent decades the Bulgarian catchment area of this river system has undergone major changes of its runoff due to increased hydro construction. Cases of water pollution are also not uncommon (Tsatchev et al. 1977).

Since the Maritsa River flows south of the Balkan Mountains, its ichthyofauna includes fish which is endemic to the Aegean watershed (Drensky 1951; Kottelat & Freyhof 2007; Stephanov 2007). One of them is the rheophilic species Orpheus dace (*Squalius orpheus*), which is widespread in the middle zone of the Maritsa River's tributarie. It inhabits a wide range of habitats, from the upper river zone to the southern Bulgarian border (Shishkov 1939; Michaylova 1964, 1965, 1970; Dikov et al. 1994; Velcheva & Mehterov 2005; Stephanov 2007; Kolev 2013). In the beginning of the century Kottelat & Economidis (2006) used morphometric data to determine that Orpheus dace is a new species. This species is separated from the European chub (*Squlius cephalus* L.) living in Northern Bulgaria. The recent information on the population biology of the Orpheus dace from the Stryama River was published by Kolev & Raikova (2015), Stefanova et al. (2008) made also investigation on the growth rate of this species based on

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* Author for correspondence: *vassilie@abv.bg*

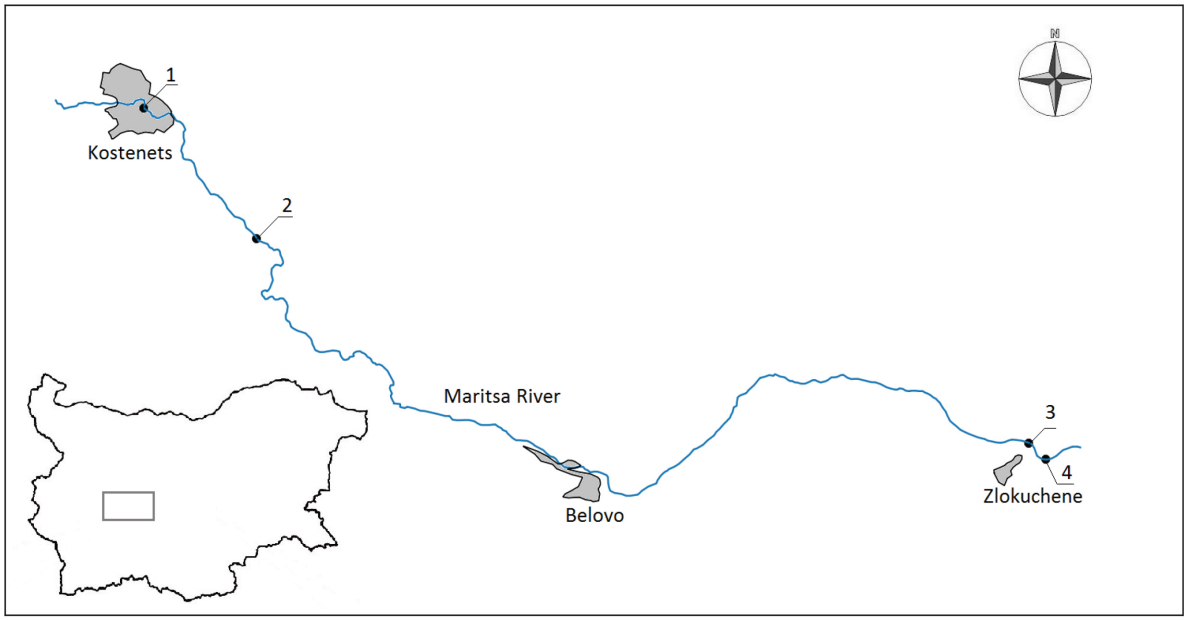

Figure 1. Location of the sampling sites on the Maritsa River (QGIS 1022)

the material collected in the lower parts of the Maritsa River, near the town of Harmali.

The aim of this study was to establish the growth parameters of Orpheus dace of the middle zone of the Maritsa River and fill in a knowledge gap, which exists for this species.

Materials and Methods

In the autumn of 2006, four sampling sites were selected in order to perform an empirical investigation. They were located at the Maritsa River's middle zone, in vicinity of the city of Kostenets and the village of Zlokuchene (Table 1). At the sampling sites the river bed was paved with rocks and sand. The riverbed has been modified by hydrotechnical constructions. There are two barrages: the first is located at the town of Kostenets and the second in vicinity of the Zlokuchene village. River thresholds are located near the villages of Dolna Bania and Menenkiovo and at the towns of Kostenets and Belovo. These hydrotechnical structures obstruct fish migration upstream. Domestic pollution from settlements along the river, as well as industrial pollution from the pulp factories at the towns of Kostenets and Belovo also negatively impact the fish (Tsatchev et al. 1977). The ichthyofauna of this part of the Maritsa River is dominated by Maritsa barbel (*Barbus cyclolepis*) and Orpheus dace.

Sampling material was collected by electrofishing SAMUS 725G, 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 (Water quality Sampling of fish with electricity). During the survey 114 samples of Orpheus dace were collected and later measured in the laboratory.

Total fish length (TL) and standard fish length (SL) were measured with precision of 1 mm. Gutted weight (GW) was measured with precision of 1 g. Age was determined by measuring fish scales, using an Olympus CX 31 microscope at a 40× magnification.

For each fish, linear growth was determined via a back-calculation of its length (SL) from the diagonal caudal radius of a scale (S) (Zhivkov 1981). This relation is described by a linear equation (1):

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

Table 1. Geographic coordinates and altitude of the sampling sites.

No	Location	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°16'37"	23°53'55"	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

where: SL – standard length of fish, 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 characteristic of the growth (Zhivkov 1972):

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

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

Gutted weight (W) values were estimated by equation (3) Ricker (1979), which has been used by many authors (Prodanov 1982; Zhivkov 1981; Raikova-Petrova and Zhivkov 1993; Zhivkov 1999; Belomacheva et al. 2005):

$$GW = a \cdot SL^b \quad (3)$$

where: SL – standard length of fish, mm; a, b – equation coefficients.

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

$$t_W = GW_n - GW_{n-1} \quad (4)$$

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

A comparison of the length growth of different populations of the Orpheus dace is made by ranking them according to their average length at the same age (Zhivkov 1972).

The condition of a population is studied in three ways:

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

$$K_f = GW*100/\cdot(SL)^3 \quad (5)$$

where: SL – weighted average standard body length, cm; GW – weighted average gutted body weight, g.

By calculating a coefficient K_n, using the Fulton equation, but instead of exponent 3, exponent b from the population weight-length relationship from equation (3) is used.

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

$$GW_L = a \cdot SL^b \quad (6)$$

where: L – length of fish, cm; 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 (10, 15, 20, 30 and 40 cm) are successively substituted in place of L (L=10, L=15, L=20, ...cm). Using equation (5) with the listed values of L (mm), allows obtaining the corresponding values of mass W: $W_{L=10}$, $W_{L=15}$, $W_{L=20}$, $W_{L=30}$, $W_{L=40}$. The so-obtained mass values ($W_{L=10}$, $W_{L=15}$, $W_{L=20}$, $W_{L=30}$, $W_{L=40}$) for the studied populations of the Orpheus dace in the Maritsa River are compared with available literature data for this species. (Zhivkov 1981, 1999; Raikova-Petrova and Zhivkov 1993).

Results and Discussion

Age and size composition

The analysis identified six age groups (Figure 2). One-year-old fish were the most abundant (68%). The number of specimens in others age groups did not exceed 10-13%. Only one six-year-old fish was found. Fish, which had a size between 51-60 mm predominated (Figure 3). This is natural, taking into consideration that this is the size of one-year-old fish, which is most numerous in the sample. The first four size classes consisted entirely of one-year-old fish. However, as it concerned biomass, four-year-old fish (44%) dominated, followed by six (16%) and five-year-old (13%), due to the impact of their greater individual weight.

Probably, parts of the river, located over 200-300 m a.s.l, are used by the species as a breeding ground. After the breeding season, mature fish likely to migrates downstream, while the replenishment remains in this section of the river longer.

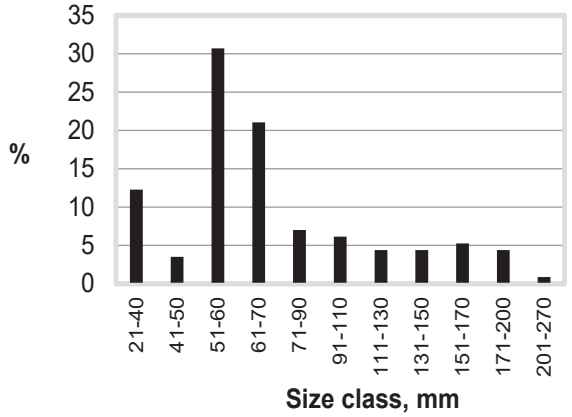

Figure 2. Age structure of Orpheus dace of the Maritsa River.

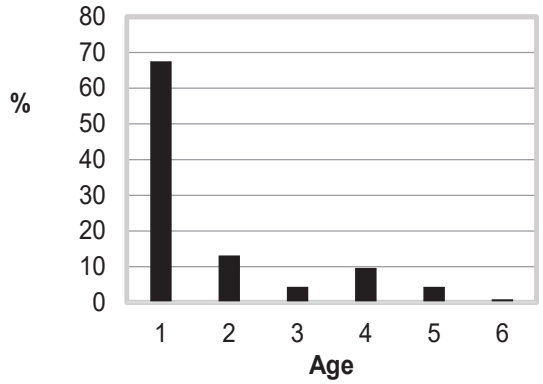

Figure 3. Size classes of Orpheus dace of the Maritsa River.

Length and weight growth

Length growth was back-calculated on the basis of a relationship of scale radius and length, at the times of the catch. This relationship is described by the linear equation shown below:

$$SL = 2.1554S+16.588,\ R^2 = 0.9927,\ P < 0.05,\ n=114, \quad (7)$$

where: SL is standard body length (mm), S diagonal caudal radius of a fish scale (eyepiece micrometer scales divisions).

Annual increment is highest during a fish's first two years, prior to reaching sexual maturity. One and two-year-old fish need to grow to larger sizes in order to escape the predators' press. In the subsequent years, annual length increment is slightly lower (Table 3).

A comparison with fish populations from other water bodies reveals the following differences. Fish from habitats of the Maritsa River's southeastern course, such as these in vicinity of the towns of Simeonovgrad and Harmanli (Stefanova et al. 2008), has greater length. Fish grows faster in the Stryama River (Kolev and Raikova 2015) than in the explored section of the Maritsa River.

Weight growth was calculated by using the W-L relation. This relationship is described by the following equation:

$$GW = 0.0117SL^{3.0934},\ R^2 = 0.9979,\ P < 0.05,\ n=114 \quad (8)$$

Table 2. Back-calculated length (SL) of Orpheus dace from a Maritsa River's section between the town of Kostenets and the village of Zlokuchene (current study).

Year	Age group	Mean calculated SL, mm at age						N
		L_1	L_2	L_3	L_4	L_5	L_6	
2006	I	58						77
2005	II	55	88					15
2004	III	51	101	116				5
2003	VI	45	79	116	148			11
2002	V	42	96	139	174	198		5
2001	VI	36	86	137	198	223	264	1
Mean calculated SL, mm		48	90	127	173	211	264	114
Mean observed SL, mm		55	88	120	150	184	270	
Annual increment, mm		48	44	37	43	25	41	

Table 3. Back-calculated weight (GW,mm) using GW-SL relation (SL, cm) of Orpheus dace of a Maritsa River's section between the town of Kostenets and the village of Zlokuchene (current study).

Year	Age group	Mean calculated GW, g at age						n
		W_1	W_2	W_3	W_4	W_5	W_6	
2006	I	2						77
2005	II	2	9					15
2004	III	2	14	21				5
2003	VI	1	6	21	45			11
2002	V	1	12	37	73	109		5
2001	VI	1	8	35	109	160	269	1
Mean calculated GW, g		2	10	29	76	135	269	114
Mean observed GW, g		3	9	24	50	95	265	
Annual increment, g		2	9	18	45	44	109	

Table 4. Condition factor of Orpheus dace of the middle zone of some Bulgarian rivers' of the Aegean watershed as well as of the Batak Dam, Bulgaria.

Source	River/ Dam	Values of the coefficients K_f and K_n	
		K_f	K_n
Present data 2022	Maritsa River	1.28	1.07
Kolev and Raikova 2015	Stryama River	1.45	1.10
Stefanova et al. 2008	Maritsa River	-	2.5
Dikov and Zivkov 1985	Dzerman River	1.53÷1.86	1.03÷1.54
Zivkov 1973	Batak Dam	1.4÷1.82	-
Michaylova 1964	Struma River	1÷1.27	-

Note: Values of the coefficients Kf and Kn vary by age group; the mean coefficients' value for the whole population is provided.

Table 5. Weight of Orpheus dace of the Maritsa River's middle zone, Bulgaria (our data, 2022) and of the lower zone of the same river, Kovakchesme Stream and Sazli dere Stream, Turky, taken together (Saç et al. 2018). The weight is calculated at the same length, by the weight - length (W-L) relationship.

River	Source	Equation of the total population	Average weights (W_L, g) calculated at the same rounded lengths (L, cm)				
			W_{10}	W_{15}	W_{20}	W_{30}	W_{40}
Maritsa – middle zone, Bulgaia	Present data 2022	$W = 0.0107SL^{3.0934}$	13	47	113	397	966
Maritsa – lower zone, Kovakchesme Stream, Sazli dere Strea, Turkey	Saç et al. 2018*	$W=0.014SL^{3.131}$	19	67	166	590	1453

* To calculate the W-L ratio, the authors used total body weight (TW, g). Our data on S. orpheus shows that gutted body weight (GW) amounts to an average 84% of the total weight (TW).

where: GW is gutted body weight (g), SL is standard body length (cm).

In the middle zone of the Maritsa River, fish naturally gains weight with age, but in older age groups annual weight growth also increases (Table 3).

Condition factor

The Fulton's coefficient varies according to age as follow: I age group – 1.26; II and III – 1.27; IV – 1.4; V-1.53. The value of the coefficient for six-year-old fish is not relatable due to the presence of only one specimen in the group. Comparisons of this parameter of Orpheus dace, calculated from published data for several Bulgarian rivers from the White Sea watershed, as well as from the Batak Dam (Table 4), show that, in general, the condition coefficient of the species from the middle zone of the Maritsa River is smaller than that calculated for most other water bodies. It is smaller also than the coefficient described by Stefanova et al. (2008).

A weight-based ranking of same-length fish population provides a better opportunity to compare their condition. Here we make a comparison with data obtained by Saç et al. (2018) of Orpheus dace populations found in Turkey's European part (Table 5).The authors have calculated the W-L ratio for populations from three watercourses: the Kovakchesme streams, the Sazle Dere stream and the lower reaches of the Maritsa River. The comparison shows that Orpheus dace accumulates mass more rapidly in the more southern regions of its range.

This finding is probably related to ecological conditions' variations, such as the longer growing season in the southern part of the Balkan Peninsula.

Conclusions

The population dynamics of Orpheus dace of the middle zone of the Maritsa River is characterized by a pattern according to which replenishment dominates over residue. Fish of the river's middle zone grow slower in length and in weight than fish of the lower parts of the same river. In the southern parts of its range, Orpheus dace have a better condition.

Authors' statement

The present study was conducted in compliance with the national legislation. Electrofishing was allowed by a permit, issued by the Minister of 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 upon request from the corresponding author.

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