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GROWTH RATE OF *SQUALIUS ORPHEUS* (KOTTELAT AND ECONOMIDIS 2007) IN THE RIVERS CHEPINSKA AND VACHA

SUMMARY

This paper presents a study of Orpheus dace (*Squalius orpheus*) populations from the rivers Chepinska and Vacha, right tributaries from the middle zone of the Bulgarian part of the Maritsa River's watershed. The research was conducted in the summer and autumn months of 2006–2011. A total of 470 specimens of Orpheus dace from the Chepinska River were caught. The study material from the Vacha River is relatively small. It includes 61 individuals. Fish populations from both rivers are characterized by disturbed age structure and predominance of young individuals. The average body length by size class was calculated using a relationship between the average values of *L* (standard length) and *S* (scale radius). The analysis showed that fish grow faster in their first year. A back calculated standard length of the Chepinska River fish is as follows: year 1: 50 mm, 2: 82mm, 3: 131 mm an 4: 192 mm. In the Vacha River it is - 1: 42 mm, 2: 78 mm, 3: 118 mm, 4: 149 mm and 5: 175 mm. Two hundred mm long individuals in the Chepinska River have average weight 80g and in the Vacha River - 126g. As it concerns these two rivers, the study found that fish growth in length and weight is relatively low in comparison with many other Bulgarian water bodies.

Keywords: agritourism, Orpheus dace, size-age composition, growth in length, growth in weight

INTRODUCTION

Orpheus dace (*Squalius orpheus* Kottelat & Economidis 2007) is widely distributed in the Balkan Peninsula. The fish's range includes the Aegean catchment area in Bulgaria, Greece and Turkey (Kottelat and Freyhof 2007). Orpheus dace is widespread in rivers with constant and medium fast water flow; the species also thrives in some dams (Mikhailova, 1964, Marinov, 1986). This is one of the most abundant fish in the middle zone of the Maritsa River tributaries (Dikov *et al*., 1994; Kolev, 2013). During the warm period of the year the fish

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stays near the water jet in search of food. Orpheus dace is omnivorous, its diet includes many planktonic and demersal organisms: insects, insect larvae, leeches, worms. The fish also consumes larger animal organisms such as small frogs and small fish. Moreover, the species feeds on algae and fruits of coastal plants (Mikhailova, 1964). In winter, Orpheus dace hides in deep waters, but remains active for most of the cold period (Mikhailova, 1964). In spring and during the first half of the summer, the fish enter small and shallow streams for breeding. Sexual maturation and fertility of this species in the Struma River in Bulgaria have been studied by Mikhailova (1964). In 2021 Kolev has published research data about the fecundity of Sq. orpheus populations of the rivers Chepiska and Stryama. Data about the length growth of Orpheus dace in Bulgarian territory have also been published by Mikhailova (1964), Dikov and Zhivkov (1985), Marinov (1986), Dikov *et al*. (1994), Stefanova *et al*. (2008), Kolev and Raikova (2015). However, these studies lack data on species growth in the Chepinska and Vacha rivers.

In Bulgaria, recent research about Sq. orpheus has focused on the species' helminth parasites (Kirin et. al, 2019; Chunchukova et. al, 2020), while studies of species population biology have not been as popular. Nonetheless, in Turkey's European part, Saç et. al. (2020) have investigated the W-L (mass-length) ratio of Sq. orpheus of four rivers in the Turkish part of South Thrace and Strandja. The authors do not establish relevant population parmeters for each individual population - i.e. the population inhabiting each of these rivers. Instead, the scholars combine all available data and estimate the a and b coefficients of the W-L ratio for the combined four populations of the Orpheus dace (one of each river) altogether. In contrast, the present study takes the opposite approach - it focuses on a Sq. orpheus population, which inhabits one river, a single water body, in order to establish the population parameters for this particular habitat.

The aim of this study is to determine some of the most important population characteristics of Orpheus dace from the rivers Chepinska and Vacha: species' growth in length and in weight. The results will then be compared with relevant data published by other scientists, who have studied other rivers of the Aegean watershed.

MATERIAL AND METHODS

The research project studies the rivers Chepinska and Vacha; both are parts of the Maritsa River basin.

The Chepinska River originates in the West Rhodopes Mountains; its springs are located underneath the peak Mala Siutkia (2078.7 m a.s.l.) (Figure 1). In its upper reaches, the river flows to the Northwest and is called the Bistritsa River. Once it reaches the town of Velingrad, the river runs northwards and near the village of Vetren it enters the Upper Thracian Valley. The studied river flows into the Maritsa River near the village of Kovachevo (near the town of Pazardzhik). This Maritsa River tributary is 81.7 km long with a catchment area of 899.6 km^2. It is a medium sized mountain Bulgarian river (№ Н-4 /14.09.2012

MOSV) with an average altitude of 1228 m. Declination of the river bed is 68%, and the Chepiska River's average flow rate is 18 m^3/s^{-1} (Stoyanov *et al*., 1981; Hristova, 2012). In summer, the water temperature reaches 20° C (BD-IBR 2015).

The Vacha River marks the border between the Eastern and the Western parts of the Western Rhodope Mountains. It is a 111.5 km long river with a catchment area of 1644.7 km^2. The beginning of the Vacha River is the Buynovska River, which springs below Bukovik Peak (1805 m above sea level) in the Western Rhodope Mountains, near the border with Greece. The second studied river flows into the Maritsa River near the village of Kadievo. The river's waters are used to generate electricity through the Dospat-Vacha cascade. As a result, water outflow after the cascade is strongly influenced by an operation of a hydropower plant. This Maritsa River tributary belongs to the category of large mountain Bulgarian rivers (№ H-4 /14.09.2012 MOSV). Its average altitude is 1441 m. Declination of the river bed is 14%. The Vacha River's average flow rate is 9,3 m^3/s^{-1} (Stoyanov *et al*. 1981; Hristova, 2012).). In summer, water temperature in this river does not exceed 20° CBD-IBR 2015).

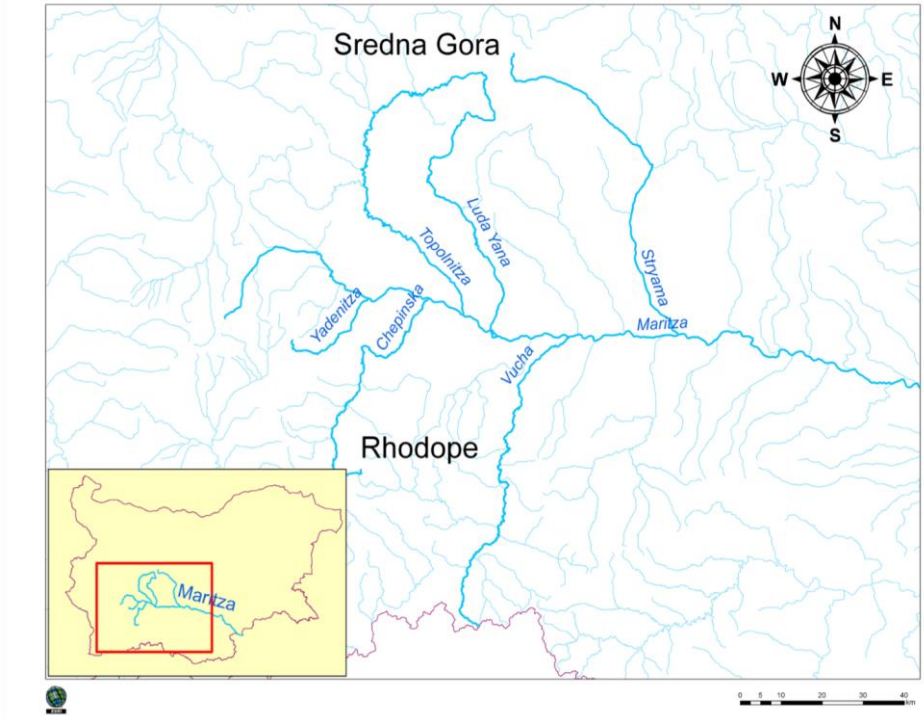

Fig. 1. Location of the rivers Chepinska and Vacha, Arc Map 10.0 (ESRI – ArcGIS 2013).

Specimens were collected in the spring and in the autumn of the period of 2006-2011. Using the method of electrofishing 470 Orpheus dace specimens were caught in the Chepinska River and 61 respectively in the Vacha River. A SAMUS 725G converter was used, providing up to 640 V direct current (DC), with a frequency of 50 Hz and output power reaching up to 200 W. The catch was performed according to an EN 14011: 2004 instruction (Water quality – Sampling of fish with electricity). Four sampling areas, located in different parts of the studied rivers, were used (Table 1).

Standard length (L) was measured with a 1 mm precision, while weight (W) was measured with a 1 g precision.

Table 1. Sampling areas along the rivers Chepinska and Vacha.

№	Location	Geographic coordinates		Alti-tude (m)	Date of sampling
		N	E		
1.	In the vicinity of the village of Kovatchevo	42°12'28,79"	24°10'54,69"	523	09.04.2011
2.	In the vicinity of the village of Lozen	42°11′09,62″	24°09′45,65″	240	08.04.2011 18.11.2011
3.	In the vicinity of the village of Yoakim Grouevo	42°06'59,28"	24°33'06,89"	182	12.10.2007
4.	In the vicinity of the town of Krichim	42°01'25,87"	24°28'22,49"	209	12.10.2007

More than ten scales ware collected from each Orpheus dace 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 sandwiched 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.

Fish linear growth was determined via a back-calculation of the length *(L)* from the diagonal caudal radius of the scales (S) (Zhivkov, 1993). This relation is well described by a linear equation:

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

where:

L – Length of fish (mm)

S – Diagonal caudal radius of the fish scales (eyepiece micrometer scales divisions)

a, b – Equation Coefficients

Net weight (*W*) values were estimated, using the equation described by Ricker (1975) and applied by many authors (Zhivkov 1993, 1999, Raikova-Petrova and Zhivkov 1993, Kukushkin, 1997, Belomacheva *et al*. 2000).

$W = a.L^b$ (2)

where:

L – Length of the fish (mm)

W – Weight of the fish with entrails (g)

a, *b* – Equation Coefficients

A comparison of the length growth of different Orpheus dace's populations is made by ranking them according to the average lengths at the same age. The length of the last age group of the youngest population is used for comparison. (Zhivkov, 1972).

To compare the weight growth (*W*) of fish from different populations, a method proposed by Goldspind (1979), De Silva (1985), Zhivkov (1993, 1999) and Raikova-Petrova and Zhivkov (1993) is used. The relationship is expressed by the following equation:

$logW = loga + b.logL,$ (3)

where:

L – Length of fish (mm)

W – Weight of fish, together with the entrails (g)

a, *b* – Equation Coefficients

Equation 3 is obtained by taking the logarithm of the equation: $W = a.L^b$.

In order to obtain comparable values of *W* in equation 3, pre-selected rounded values of L (L = 50, L = 100, L = 150, L = 200, L = 250, L = 300, L = 350, L = 400, mm) are successively substituted on place of L. Using equation 3 with the listed values of *L (mm*) allows obtaining the corresponding values of the mass W - $W_{L = 50}$, $W_{L = 100}$, $W_{L = 150}$, $W_{L = 200}$, $W_{L = 250}$, $W_{L = 300}$, $W_{L = 350,}$ $W_{L = 400}$. The so-obtained mass values ($W_{L = 50}$, $W_{L = 100}$, $W_{L = 150}$, $W_{L = 200}$, $W_{L = 250}$, $W_{L = 300}$, $W_{L = 350,}$ $W_{L = 400}$) for each of the studied populations were then compared.

Due to the fact that some authors have measured total length (to the end of the caudal fin) and others have measured standard length (to the end of the scale cover) it is necessary to use both in the comparison tables.

The association degree between *L* and *S*, as well as between *W* and *L* variables, was determined by a correlation coefficient (r). All data were calculated by using MS-Excel 2010.

RESULTS AND DISCUSSION

The age composition of the Chepinska River's population is simple. There are four age groups, but young fish are the most abundant. Ninety six percent of the fish belongs to the first and second age groups. The presence of

predominantly young fish is also well illustrated by the size of the catch. Most fish (87 % of the total sample) are less than 110 mm long (Figure 3, 5).

In the Vacha River five age groups are recorded. The small sample catch, however, definitely does not represent the whole variety of age and size groups, characteristic of the population. Therefore, it is not possible to clearly identify any trends and draw conclusions. (Figure 2, 4).

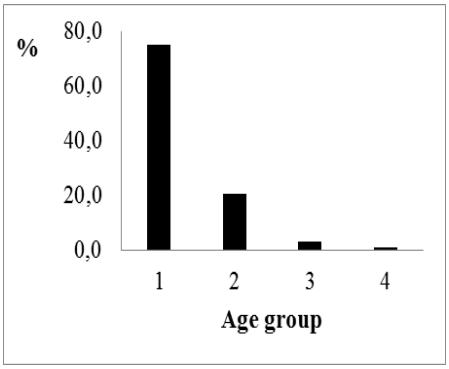

Fig. 2. Age structure of Orpheus dace from the Chepinska River

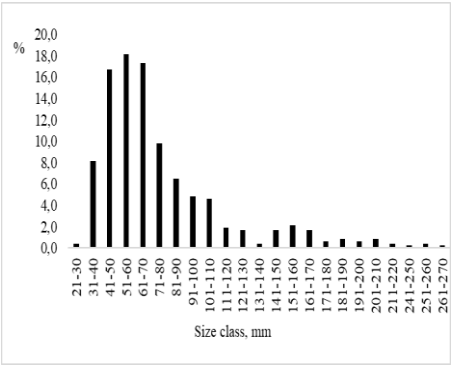

Fig. 3. Size classes of Orpheus dace from the Chepinska River.

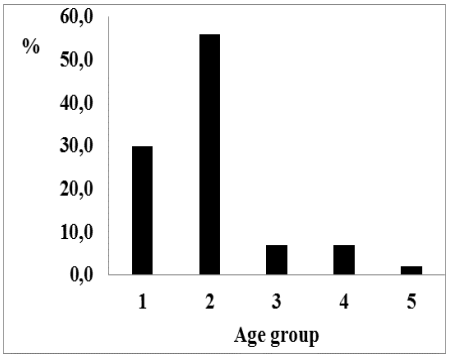

Fig. 4. Age structure of Orpheus dace from the Vacha River

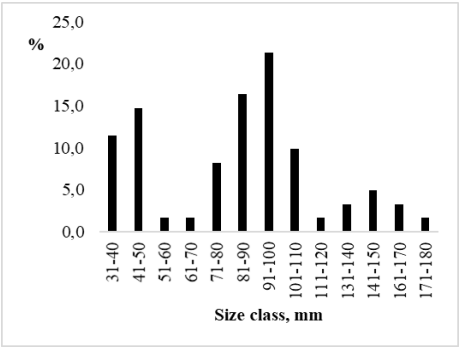

Fig. 5. Size classes of Orpheus dace from the Vacha River

The biggest specimen registered in the Chepinska River is 270 mm long (319 mm full length) and weighs 333 g (375g weight with entails). This is four-year-old fish. The smallest one is 27 mm long (34 mm full length) and weighs 0.2g (0.3 g weight with entails). This is an annual fish.

The biggest Orpheus dace caught in the Vacha River is 178 mm in length (210 mm full length) and weighs 81 g (91g weight with entails). This is the only five-year-old specimen caught in the Vacha River. The smallest one is 32 mm

long (44 mm full length) and weighs 0.5g (0.8 g weight with entails). This is an annual fish.

The relationship between fish standard body length (*L*) and scale radius (*S*) (measured in divisions of the eyepiece – micrometer) is very well expressed by a linear function, which has a high degree of reliability (equation 4, the Chepinska River; equation 5, the Vacha River.

$L = 15.28+2.0712 \cdot S$; correlation $r = 0.9964$, n=470 (4)

$L = 6.4981+2.5162 \cdot S$; correlation $r = 0.9960$, n=61 (5)

In both studied rivers, a faster growth of Orpheus dace is observed in the first year of life.

Generally the species reaches bigger length in the Chepinska River. For all age groups, average fish length exceeds that of fish from the Vacha River. Average length of four-year-old specimens from the Chepinska River is greater than the average length of five-year-old specimens from the Vacha River (Tables 2, 3). In the both rivers, in 2004 and 2006, fish grew slightly faster.

Table 2. Back-calculated standard body length (*L*) of Orpheus dace from the Chepinska River.

Years	Age group	Back-calculated standard body length (mm)				Number
		L_1	L_2	L_3	L_4	
2007	I	51				5
2006	II	49	94			258
2005	II	35	77			169
2004	III	59	81	155		22
2003	IV	57	76	106	192	16
∑						470
Average body-length (L_{av}), mm		50	82	131	192	
Growth in length (t'), mm		50	32	49	62	

Table 3. Back-calculated standard body-length (*L*) of Orpheus dace from the Vacha River.

Years	Age group	Back-calculated standard body length (mm)					Number
		L_1	L_2	L_3	L_4	L_5	
2007	I	40					17
2006	II	40	91				30
2005	III	32	44	102			6
2004	IV	54	82	126	145		7
2003	V	44	95	125	152	175	1
∑							61
Average body-length (L_{av}), mm		42	78	118	149	175	
Growth in length (t'), mm		42	36	40	31	26	

The relationship between fish weight and length (*L*) is very well expressed by a parabolic function with a high degree of reliability. The general equation for

the Chepinska River population is equation number 6 and for the Vacha River – number 7.

$$W = 0.00001 \cdot L^{3.0002};\ r = 0.9973,\ n=470 \quad (6)$$

$$W = 0.000007 \cdot L^{3.1533};\ r = 0.9997,\ n=61 \quad (7)$$

A comparison of mass growth rate between the two rivers indicates that there is a slightly faster mass accumulation for all age groups from the Vacha River. In 2004, in both rivers, mass rate growth is relatively higher, in comparison with other years. However, species' weight growth in both rivers is relatively slow (Tables 4, 5).

Table 4. Back-calculated body-weight (*W*) of Orpheus dace from the Chepinska River

Years	Age group	Back-calculated body-weight (g)				Number
		W_1	W_2	W_3	W_4	
2007	I	1.3				5
2006	II	1.2	8			258
2005	II	0.4	5			169
2004	III	2.1	5	38		22
2003	IV	1.8	4	12	71	16
∑						470
Average body weight (W_{av}). g		1.4	6	25	71	
Weight growth – (t'). g		1.4	4	19	46	

Table 5. Back-calculated body-weight (*W*) of Orpheus dace from the Vacha River

Years	Age group	Back-calculated body-weight (g)					Number
		W_1	W_2	W_3	W_4	W_5	
2007	I	1.2					17
2006	II	1.1	17				30
2005	III	0.5	2	24			6
2004	IV	3.1	12	48	75		7
2003	V	1.6	19	46	89	139	1
∑							61
Average body weight (W_{av}). g		1.5	13	39	81	139	
Weight growth – (t').g		1.5	11	27	42	58	

DISCUSSION

The age structure of the Orpheus dace' population in the Chepinska River is disturbed. The presence of mostly small and young fish is an indicator of a significant elimination of fish due to angling (mostly of larger sizes) (Pravdin, 1966). This observation is also confirmed by the low survival rates of Orpheus dace - 25% for in the Chepisnska River. As a result, most of the population in the river consists of replenishment (annual fish).

The length-growth of the Orpheus dace is relatively slow in the Chepinska River. Length-growth is fast in the first year, after which it slows down. A rapid increase in size in the first year of a fish's life allows it to escape the press of predators (Table 2). During the following year, length-growth decreases. This phenomenon is associated with a sexual maturation of a large number of individuals at this age (Nikolsky, 1965). The rate of weight growth of the Orpheus dace in Chepinska River increases with age. Since the populations is young, a delay in mass accumulation for older age group is not observed (Tables 4).

Similar results about fish's length-growth and mass accumulation are estimated to characterize the Vacha River's population of Orpheus dace (Tables 3, 5). Regrettably, the current study's small sample size does not allow for reliable conclusions to be drawn about the entire population.

A comparison of length-growth of Orpheus dace from different water bodies, using the Zhivkov's method (1972), shows that the species grows faster in dams, rather than in rives (Table 6).

Table 6. A comparison of average lengths at equal age of Orpheus dace from different water bodies of its habitat range.

Author/s and year	River Dam	Back-calculated standard body length (mm)										
		L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	L_9	L_{10}	L_{11}
Dikov *et al.*, 1994	Arda River	58	104	137	159	-	-	-	-	-	-	-
Kolev and Raikova, 2015	Stryama River	58	83	121	162	192	-	-	-	-	-	-
Michailova, 1964	Struma River	83	115	148	175	202	215	-	-	-	-	-
Dikov and Zhivkov, 1985	Dzerman River	52	101	141	183	-	-	-	-	-	-	-
Present data, 2021	Chepinska River	50	82	131	192	-	-	-	-	-	-	-
Marinov, 1986	Chepinska River	61	115	152	-	-	-	-	-	-	-	-
Dikov *et al.*, 1994	Struma River	54	119	164	211	223	241	243	-	-	-	-
Dikov *et al.*, 1994	Mesta River	64	114	195	214	-	-	-	-	-	-	-
Stefanova *et al.*, 2008	Maritsa River	60	95	130	240							
Zhivkov, 1973	Batak Dam	96	163	215	247	272	294	318	352	379	397	406
Boyadgiev, 1966	Pyasachnik Dam	89	155	218	289	316	-	-	-	-	-	-
Marinov and Boyadjiev, 1967	Koprinka Dam	73	193	261	-	-	-	-	-	-	-	-

In all three dams: Batak, Pyasachnik and Koprinka, length-growth is faster than that in rivers. This finding can be explained by taking into account the influence of a larger number of predators, especially perch and pikeperch, found in the dams (Zhivkov, 1973) and consequently - the larger press of predators on fish populations. Growth conditions also have an impact. Orpheus dace grows faster in the dams Koprinka and Pyasachnik, which are located at an altitude of about 300 m in comparison with the Batak Dam, located at 1108 m above sea level. Thus, the two dams have longer warm period and more favourable temperatures (Table 6). In the rivers Struma and Mesta Orpheus dace grows faster in length than in the Maritsa River and its tributaries, the rivers: Arda, Chepinska and Stryama. A study by Marinov (1986) presents an exception to this trend, as it concerns the Chepinska River. However, the author studied only ten Orpheus dace specimens and the study's accuracy is lower in comparison with the present study, which includes 470 specimens from this river (Table 6).

In the Table 7 are presents the calculated masses of fish for the same length from different water courses, by means of the formula: $W = a.L^b$, according to above-mentioned method (Zhivkov, 1993, 1999).

Table 7. Comparison of the average mass (*W*) of Orpheus dace from different rivers, calculated at pre-selected rounded standard body length values (*L*).

Author/s and year	River. Dam	Equation of the whole Population	Average weight (W_L. g) calculated with the same rounded lengths (*L*. mm)				
			W_{50}	W_{100}	W_{150}	W_{200}	W_{250}
Present data, 2021	Chepinka	$W = 0.00001L^{3.0002}$	1.3	10	34	80	156
Dikov *et al*., 1994	Arda	$W = 0.00005L^{2.7522}$	2.3	16	49	108	199
Kolev and Raikova, 2015	Stryama	$W = 0.000009L^{3.1154}$	1.8	15	54	133	266
Dikov *et al*., 1994	Struma	$W = 0.00003L^{2.9007}$	2.5	19	62	142	271
Zhivkov, 1973	Batak	$W = 0.000007L^{3.1662}$	1.7	15	54	135	274
Dikov *et al*., 1994	Mesta	$W = 0.00006L^{2.7793}$	3.2	22	67	149	277
Stefanova *et al*., 2008	Maritsa	$W = 0.0148L^{3.0595}$	2.0	17	59	142	280
Mikhailova, 1964	Struma	$W = 0.00001L^{3.1175}$	2.0	17	61	149	299
Dikov and Zhivkov, 1985	Dzerman	$W = 0.0116L^{3.05}$	2.2	19	64	154	305

Legend: W_L – weight of the fish with rounded values of body length (50 to 250 mm)

Orpheus dace's mass increases faster in main watercourses: the rivers Struma, Mesta and Maritsa, in comparison with their tributaries: the rivers Arda, Stryama and Chepinska. Species mass growth is also relatively fast in the Batak Dam. Probably the greater weight of fish, with the same length from the rivers Maritsa, Struma and Mesta, as well as from the Batak dam, is a result of the richer food base there. Moreover, in the Maritsa River the speed of water flow is lower than in its smaller tributaries: Arda, Chepinska and Stryama. Water in the Batak Dam is stagnant. In such habitats fish use less energy for their movements.

CONCLUSIONS

The populations of Orpheus dace of the rivers Chepinska and Vacha are characterized by disturbed age structures. Fish stocks are predominated by 1- to 2-year old specimens. In recent years, there has been comparatively relatively less research focus on the biology of *Squalius orpheus*. In many Bulgatian rivers the fish's population structure has changed and younger fish dominate.

Compared to other Bulgarian water bodies, the linear growth of Orpheus dace of the rivers Chepinska and Vacha is relatively slow. Mass accumulation is also slow. Four-year-old specimens of both rivers reach an average weight of 70-80g.

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