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AGE-SIZE STRUCTURE AND GROWTH RATE OF *SQUALIUS ORPHEUS* (KOTTELAT & ECONOMIDIS, 2006) FROM THE RIVERS TOPOLNITSA AND LUDA YANA

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Abstract

This article presents the results of a study of the growth rates of Orpheus Dace from the rivers Topolnitsa and Luda Yana, tributaries of the Maritsa River's middle zone. The study assesses species' length and weight growth pattern. Samples were collected mainly in the autumns of 2006, 2007, 2010. A total of 552 fish were caught by electrofishing, 297 of which were caught in the Topolnitsa River and other 255 in the Luda Yana River. The oldest fish, caught in the Topolnitsa River, were four-year-old, while those from the Luda Yana River were three-year-old. More than 70 % of the specimens, caught in the Luda Yana River, were one-year-old. Average length of three-year-old Orpheus dace from the Topolnitsa River was 125 mm and average weight was 30 g. Average length of three-year-old fish from the Luda Yana River was 168 mm and average weight was 56 g.

Key words: length growth, weight growth, Orpheus dace, size-age composition.

Introduction

Orpheus dace (*Squalius orpheus* Kottelat & Economidis 2006) is a common species in the middle and lower parts of many rivers of the Aegean watershed and it is considered endemic to the Balkan Peninsula. The species distribution expands in Bulgaria, Greece and Turkey (Kottelat and Freyhof 2007, Economidis et al. 2009, Barbieri et al. 2015, Rozdina and Raikova 2020). It is a rheophilic species, but it also inhabits some dams (Michailova 1964, Marinov 1989, Economidis et al. 2009). Orpheus dace inhabits rivers with gravel and sandy bottoms and prefers areas with moderate water flow. The fish is omnivorous and remains active almost all year round (Michailova 1964). In Bulgaria's Struma River basin, the breeding season lasts from the beginning of April to the beginning of August. Data about the sexual maturation and fertility of Orpheus dace from the Struma River has already been published (Michailova 1964). The species' linear growth is relatively slow. In Bulgarian rivers, one-year-old fish reach about 60 mm standard length. Length of four-year-old fish usually exceeds 200 mm (Dikov and Zhivkov 1985, Marinov 1989,

Dikov et al. 1994, Stefanova et al. 2008, Kolev and Raikova 2015). Rate of mass growth is also slow and five-year-old fish weigh more than 100 g (Kolev and Raikova 2015).

There is no published data about the length and weight relationship of Orpheus dace from the rivers Topolnitsa and Stryama, so this paper studies the growth parameters of Orpheus dace in these two rivers, filling the knowledge gap that exist for this species.

Study area

The research project studies two tributaries of the Maritsa River. The first of them – the Topolnitsa River originates in Sashtinska Sredna Gora; its springs are located below the peak Bich (1447 m a.s.l.). In its upper course, the river flows to the northwest and is called Shirineyska. The river passes through the town of Koprivshtitsa and afterwards there are three dams along the river's watercourse: Dushantsi, Zhekov vir and Topolnitsa. Near the village of Muhovo, the river flows to the south and enters the Upper Thracian valley. The Topolnitsa River flows into the Maritsa River, not far from the town of Pazardzhik (Fig. 1). This water course has a total length of 154.8 km, and a catchment area of 1788.8 km^2 (Hristova 2012).

The other river, Luda Yana, also originates below the peak Beach in Sashtinska Sredna Gora, but flows southwest and crosses the town of Panagyurishte, where

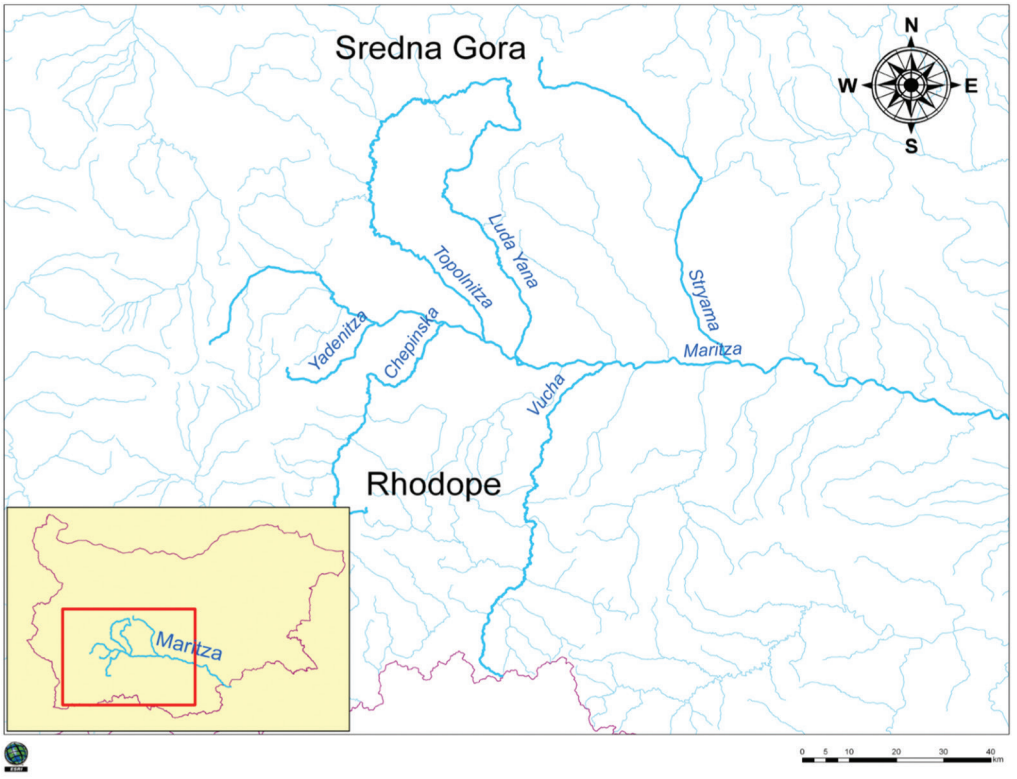

Fig. 1. Location of the riversTopolnitsa and Luda Yana River, Arc Map 10.0 (ArcGIS 2013).

it is called Panagyurska. Below the town, the river merges with its largest tributary Strelchenska and not far from the village of Rosen, enters the Upper Thracian valley. Near the village of Sinitovo its water course flows into the Maritsa River. The length of the river is 74 km and its catchment area is 685.3 km^2 (Hristova 2012).

In both studied rivers, water temperature reaches 25 °C in summer. The Luda Yana River is characterized by lower average water flow and small average altitude of its water bed, compared with the Topolnitsa River. The Topolnitsa River has the largest average annual water quantities compared to all other tributaries from the middle zone of the Maritsa River.

Materials

Specimens were collected mostly in the autumn, during the 2006–2011 period. A total of 522 Orpheus dace specimens were caught in the rivers Topolnitsa and Luda Yana by electrofishing. A SAMUS 725G converter was used. Usually during the sampling, the appliance is set to the following parameters: frequency of 50 Hz and output power between 150 and 200 W. The catch was performed according to the EN 14011:2004 instruction (Water quality – Sampling of fish with electricity). Five sampling areas, located at different parts of the studied rivers, were used (Table 1).

Table 1. Sampling areas along the rivers Topolnitsa and Luda Yana.

No	Location	Geographic coordinates		Altitude, m	Date of sampling
		N	E		
	Topolnitsa River				
1	In the vicinity of the village of Lesichevo	42°21’34.87’’	24°05’44.22’’	288	04.11.2006
2	In the vicinity of the village of Muhovo	42°24’39.77’’	23°59’55.44’’	346	05.11.2006
3	West of the town of Pazardzhik	42°12’25.24’’	24°17’44.77’’	214	29.10.2006 05.11.2006
	Luda Yana River				
4	East of the town of Pazardzhik	42°11’39.43’’	24°23’55.35’’	209	10.11.2006 13.10.2007
5	In the vicinity of the village of Chernogorovo	42°16’24.63’’	24°23’25.95’’	235	10.11.2006 14.06.2010

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

Methods

More than ten fish-scales were collected from each Orpheus dace specimen. They were taken from underneath the dorsal fin; an equal number of scales was taken from the left and right side of the dorsal fin. The scales were then examined under a microscope Olympus CX 31, at 40× magnification. Each scale was placed between two microscope slides. Fish age was determined by counting the annual rings of a scale. For this purpose, the diagonal caudal radius of a scale 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 1993). This relation is well described by a linear equation (1):

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

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

Net weight (W) values were estimated by equation (2), used by many authors (Zhivkov and Raikova-Petrova 1996, Kukushkin 1997, Belomacheva et al. 2005) and recommended by Zhivkov (1993, 1999):

$$W = a \cdot L^b, \text{ g} \quad (2)$$

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

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

To compare the weight growth (W) of fish from different populations, a method proposed by Zhivkov (1993, 1999) is used. A relationship is expressed by the following equation (3):

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

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, 250, 300, 350, and 400 mm) are successively substituted in place of L ($L=50$, $L=100$, $L=150$, …). Using equation (3) with the listed values of L (mm), allows obtaining the corresponding values of mass W – $W_{L=50}$, $W_{L=100}$, $W_{L=150}$, $W_{L=200}$, $W_{L=250}$, $W_{L=300}$, $W_{L=350}$, $W_{L=400}$. 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 are then compared (Zhivkov 1993, 1999; Zhivkov and Raikova-Petrova 1996, 2001).

Results

Age-size composition

The Orpheus dace samples from the rivers Topolnitsa and Luda Yana consists mainly of young fish. The oldest specimen is a four-year-old fish, with total length 205 mm and weight 129 g. A sample from the Topolnitsa River includes at most two- and tree-year-old fish. One- and four-year-old specimens are relatively few. It was found that most fish are 100–150 mm long. The largest specimen obtained from this river is a four-year-old fish, which is 225 mm long and weighs 171 g (figs 2 and 3). One-year-old Orpheus dace predominates in the Luda Yana River, constituting more than 77 % of the sample. These fish are shorter than 70 mm (figs 4 and 5).

Growth rate

A relationship between the average values of L (standard length) and S (fish-scale radius) was described by the equations for each river, as follow:

$L = 15.475+2.1985 \cdot S$; $r = 0.9931$, $n = 297$, the Topolnitsa River;

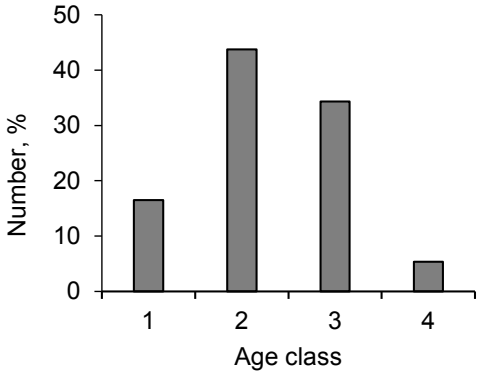

Fig. 2. Age structure of Orpheus dace, the Topolnitsa River.

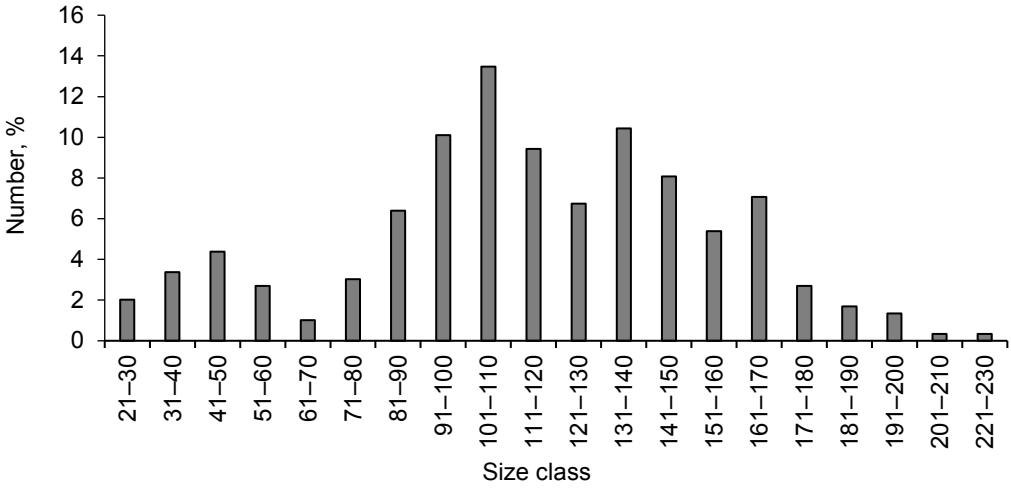

Fig. 3. Size classes of Orpheus dace, the Topolnitsa River.

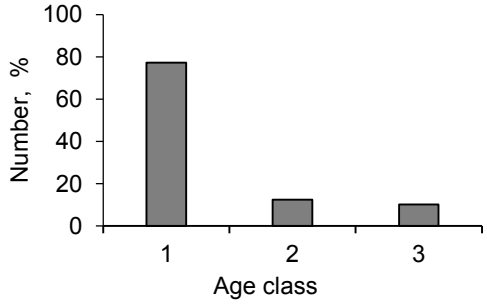

Fig. 4. Age structure of Orpheus dace, the Luda Yana River.

$L = 16.536+2.1041 \cdot S$; $r = 0.9944$, $n = 255$, the Luda Yana River.

Although during the first year of Orpheus dace's life, length growth is similar for both rivers, in general, fish reaches greater length in the Luda Yana River. Annual length growth is greater for fish from the Luda Yana River. Thus, three-year-old fish from the Luda Yana River reach greater length than four-year-old fish from the Topolnitsa River. In both rivers, in 2006, fish grew slightly faster (tables 2 and 3).

Generally, the length of one-year-old fish varies between 35 and 70 mm, of two-year-old fish – between 70 and 130 mm, of three-year-old fish between 140 and 170 mm.

A relationship between fish weight W (eviscerated weight) and L (standard length) is very well expressed by a power function with a high degree of reliability. The equations for each river are shown as follows:

$W = 0.000009 \cdot L^{3.1061}$; $r = 0.9998$, $n = 297$, Topolnitsa River;

$W = 0.00001 \cdot L^{3.0305}$; $r = 0.9940$, $n = 255$, Luda Yana River.

A comparison of an increase of mass between the two rivers shows that two- and three-year-old fish in the Luda Yana River grow faster than that in the Topolnitsa River. Annual growth in mass is greater in the Luda Yana River. Two- and three-year-old fish from the Luda Yana River weight twice as fast as those from the Topolnitsa River. Three-year-old fish from the Luda Yana River reach greater mass than four-year-old fish from the Topolnitsa River (tables 2 and 3).

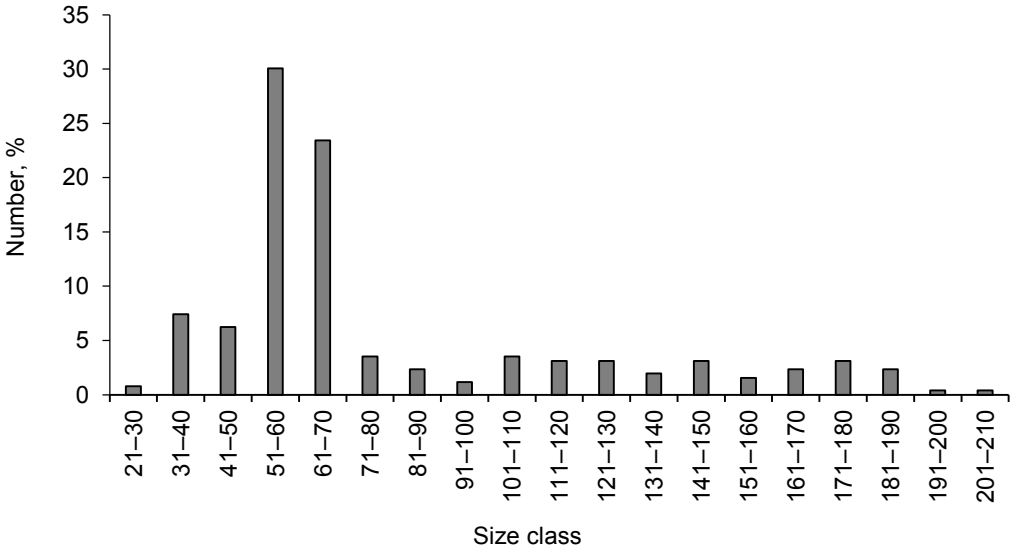

Fig. 5. Size classes of Orpheus dace, the Luda Yana River.

Table 2. Back-calculated body length of Orpheus dace from the Topolnitsa River.

Year	Age group	Back-calculated length (*L*, mm) at the end of each year of fish's lifespan.				Number
		L_1	L_2	L_3	L_4	
2006	I	46				40
2005	II	57	98			98
2004	III	65	90	131		65
2003	IV	64	78	119	148	94
Total						297
Average body length, mm		58	89	125	148	
Length increments, mm		58	31	36	23	

Table 3. Back-calculated body length of Orpheus dace from the Luda Yana River.

Year	Age group	Back-calculated length (*L*, mm) at the end of each year of fish's lifespan.			Number
		L_1	L_2	L_3	
2007	I	67			33
2006	II	37	67		180
2005	II	56	129		12
2004	III	66	112	168	30
Total					255
Average body length, mm		57	103	168	
Length increments, mm		57	46	65	

Discussion

The paper presents a systematic sample of the Orpheus dace populations from the rivers Topolnitsa and Luda Yana. Despite a significant number of caught specimens, the sample cannot cover the entire age diversity of the populations. However, the study shows a clear tendency for young fish to predominate, especially in the Luda Yana River. The populations in both studied rivers are very young. This is an indicator of significant fishing or predators' pressure and the elimination of older fish of mostly larger sizes (Pravdin 1966).

In the Topolnitsa River, length-growth is fast in the first year, after which it slows down. Two- and three-year-old fish from the Luda Yana River have greater length-growth (tables 2 and 3). Orpheus dace is characterized by gradual mass accumulation with age. The rate of weight growth increases with age in both rivers, but the increase is faster for the Luda Yana River population (tables 4 and 5). Faster growth and a presence of mostly one-year-old specimens indicate that the Luda Yana River population is reduced in numbers (Pravdin 1966). The population seeks to restore its numbers by accelerating growth and shortening the time to maturity (Nikolsky 1965).

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

Table 4. Back-calculated body weight of Orpheus dace from the Topolnitsa River.

Year	Age group	Back-calculated weight (*W*, g) at the end of fisher's lifespan.				Number
		W_1	W_2	W_3	W_4	
2006	I	1.3				40
2005	II	2.6	12.6			98
2004	III	3.8	10.4	34		65
2003	IV	3.7	6.9	24.9	49.6	94
Total						297
Average body weight, g		2.9	9.9	29.5	49.6	
Weight increment, g		2.9	7.0	19.6	20.1	

Table 5. Back-calculated body weight of Orpheus dace from the Luda Yana River.

Year	Age group	Back-calculated weight (*W*, g) at the end of fisher's lifespan.			Number
		W_1	W_2	W_3	
2007	I	3.4			33
2006	II	0.6	3.5		180
2005	II	2	24.7		12
2004	III	3.2	16.3	55.5	30
Total					255
Average body weight, g		2.3	14.8	55.5	
Weight increment, g		2.3	12.5	40.7	

Table 6. A comparison of the average length of same-aged Orpheus dace from different water bodies of its habitat.

Sources	River or Dam	Body length (L, mm) of Orpheus dace at the end of each year of its lifespan.										
		L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	L_9	L_{10}	L_{11}
Present data (2015)	Topolnitsa River	58	89	125	148	-	-	-	-	-	-	-
Dikov et al. (1994)	Arda River	58	104	137	159							
Kolev and Raikova (2015)	Stryama River	58	83	121	162	192						
Marinov (1989)	Chepinska River	61	115	152								
Dikov et al. (1994)	Mesta River	64	114	159	195	214						
Dikov et al. (1994)	Struma River	54	119	164	211	223	241	243				
Stefanova et al. (2008)	Maritsa River	60	95	130	240							
Present data (2015)	Luda Yana River	57	103	168	-	-	-	-	-	-	-	-
Zhivkov (1981)	Batak Dam	96	163	215	247	272	294	318	352	379	397	406
Boyadgiev (1966)	Pyasachnik Dam	89	155	218	298	316						
Marinov and Boyadjiev (1967)	Koprinka Dam	73	193	261	-	-	-	-	-	-	-	-

Table 7. Condition factor of Orpheus dace in different water bodies.

Sources	River or Dam	Population equation	Weight calculated at one the same length				
			W_{50}	W_{100}	W_{150}	W_{200}	W_{250}
Present data (2021)	Luda Yana	$W = 0.00001 \cdot L^{3.0305}$	1.4	12	39	94	185
Dikov et al. (1994)	Arda	$W = 0.00005 \cdot L^{2.7522}$	2.3	16	49	108	199
Present data (2021)	Topolnitsa	$W = 0.000009 \cdot L^{3.1061}$	1.7	18	52	126	253
Kolev and Raikova (2015)	Stryama	$W = 0.000009 \cdot L^{3.1154}$	1.8	15	54	133	266
Dikov et al. (1994)	Struma	$W = 0.00003 \cdot L^{2.9007}$	2.5	19	62	141	271
Zhivkov (1981)	Batak	$W = 0.000007 \cdot L^{3.1662}$	1.7	15	54	135	274
Dikov et al. (1994)	Mesta	$W = 0.00006 \cdot L^{2.7793}$	3.2	22	67	149	277
Stefanova et al. (2008)	Maritsa	$W = 0.0148 \cdot L^{3.0595}$	2.0	17	59	142	280
Michailova (1964)	Struma	$W = 0.00001 \cdot L^{3.1175}$	2.0	17	61	149	299
Dikov and Zhivkov (1985)	Dzerman	$W = 0.0116 \cdot L^{3.05}$	2.2	19	65	154	305

Length-growth of Orpheus dace differs in different water bodies. However, for different age groups length-growth varies within certain limits regardless of the water body, inhabited by the fish. Differences in length-growth between individual populations are affected by abundance of food, length of the growing season, altitude and length of winter, water quantity. In all three dams: Batak, Pyasacnik and Koprinka, length-growth is faster than that in rivers. This finding can be explained by the impact of a larger press of predators on fish populations (Zhivkov 1981, Kolev 2013) and the desire of fish to escape the press of predators. Greater length-growth is also due to a richer nutrient base in the dams. Fish from the Luda Yana River grows in length the fastest, in comparison with fish from all studied tributaries of the Maritsa River; its length-growth is close to that of Orpheus dace from the Maritsa River.

Orpheus dace accumulates mass relatively slow. One-year-old fish weigh only a few grams.

A comparison of the weight of Orpheus dace from different watercourses shows that weight growth is faster in the Batak Dam. In general, Orpheus dace increases in mass faster, when it is inhabiting main watercourses – the rivers Struma, Mesta and Maritsa, in comparison with their tributaries. In the rivers Topolnitsa and Luda Yana, Orpheus dace grows in weight more slowly than in other water bodies (Table 7).

Conclusions

Populations of Orpheus dace from the rivers Topolnitsa and Luda Yana are characterized by a small number of age groups. A fish population from the Luda Yana River consists mostly by juveniles. Compared to other Bulgarian rivers, Orpheus dace grows in length more rapidly in the Luda Yana River, but the accumulation of biomass in this river is the smallest of all studied Bulgarian water bodies. In both water courses: the rivers Topolnitsa and Luda Yana, accumulation of mass is relatively slow. Three-year-old specimens in these rivers reach an average weight of 30–50 g.

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