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Growth Rate and Condition of Riffle Minnow (*Alburnoides bipunctatus* Bloch) from the Middle Stream of Iskar River (Bulgaria)

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Abstract: The population status of Riffle Minnow (*Alburnoides bipunctatus*) from the middle stream of Iskar River was investigated using some biological parameters as linear and body mass growth rate and condition. The maximum age, length and body mass of Riffle Minnow were 6 years, 13.8 cm and 28 g, respectively. The back calculations of the length and body mass growth rate were made by equations $L = 1.4813 + 2.184R$, $r = 0.98$ and $W = 3.4^{x}10^{-2}L^{2.79}$, $r = 0.96$, respectively. The condition coefficient of Riffle Minnow (**k**) from Iskar River was calculated by relationship between **W-L**. Also the fish's conditions of the populations from different water bodies were compared by the body mass at the same length. The linear and body mass growth were compared by von Bertalanffy's equations: $L_t = 11.55\ [1 - e^{-0.48(t+0.08)}]$, $r = 0.998$ and $W_t = 134.52\ [1 - e^{-1.59(t+0.57)}]^{2.79}$ $r = 0.96$, respectively. The coefficient of Hohendorf for the linear and body mass growth showed low values (0.987 and 0.268, respectively). The linear and body mass growth parameters (**ω**) were: ω_L=5.54 and ω_w= 21.34, respectively.

Key words: Riffle Minnow; growth rate; condition; Iskar River

Introduction

The industrial pollution in Iskar River and its tributaries after 1990 decreased considerably. A gradual rehabilitation of the wildlife living conditions begun but during the period 1996-2003 the ichthyofauna species number was less then in 1939-1955 (Raikova-Petrova *et al.* 2004).

Riffle Minnow is an important element of the trophic chain of the river. That species is an object of sport fishing. The species is included in the Supplement III of Berne Convention. With regard to the Frame General Instruction on the waters of EU the Riffle Minnow should be successfully used for test on nearly all types water bodies.

Data about age and size structure of *Alburnoides bipunctatus* are published for: Niemiec Lake, Poland (Bauch 1963) and the rivers – Western Dvina – Russia (Žukov 1965); Wyzny Lodzkiej and San & Dunajec – Poland (Skora 1972); Rokytna – Czech Republic (Johal 1979); Turiec (Bastl *et al.* 1965), Radimna and Eliseva – Romania (Papadopol, Cristofor 1980); Velika Morava (Soric & Ilic 1985); Ogosta (Johal 1979) and Iskar – Bulgaria (Raikova-Petrova *et al.* 2006); the Rivers in Croatia (Treer 2000).

The purpose of this study is to determinate the relationship between length, body mass and age of

Riffle Minnow in the process of forming the population in Iskar River after 1990.

Study Area

Iskar River is the longest one in Bulgaria. It is 368 km long and has 8646 km^2 catchments area. It rises from Rila Mountain and is formed by three major tributaries: Cherni, Levi and Beli Iskar. Iskar River flows from South to North and drains into Danube River.

Materials and Methods

The material is obtained along Iskar River valley between Lakatnik station and the halt of Prolet at the following way stations – Lakatnik station, the village of Opletnia, Levishte station, Prolet halt in April – June 2003. The fishing is accomplished with a spoon-net – size of the eye 6 mm, and by a direct pulsating current draught with a current intensity of 400-700A and a frequency of 60-120 Hz.

A total of 69 *Alburnoides bipunctatus* were captured. The length (L); with a precision up to 1 mm and the body mass (W); with a precision up 1 g were measured. Scale at magnification of 17.5x were used to determine the age.

Results and Discussion

The relationship between average body lengths and radii of Riffle Minnow's scales described by the equation L = 1.4813 + 2184S, r = 0.98 (Table 1). The average annual linear growth (t) decreased with increasing age of fish – 3.24 cm during the first year, 1.7 cm in the second, 1.14 cm in the third, and then slightly increased to 1.59 cm in the fourth year, 1.5 cm in the fifth year and again decreased to 1.21 cm in the sixth year. The sharp reduction in growth in the third year of age is due to the deteriorating living conditions during low-water-level period in 2000. In the fifth and sixth years the growth decreased because the optimal length for this age reached. The alternation of the increasing and decreasing of growth (**t**) can be explained by the inclusion of compensatory regulatory mechanisms that determined the growth rate (Živkov *at al*. 1999).

The Riffle Minnow's linear growth rate in other water bodies is characterised by gradual reduction also: in Rokytna River basin – from 4.6 cm in the first year to 0.2 cm in the seventh year (Johal 1979); in V. Morava River – from 3.2 cm in the first year to 1.4 cm in the second year, in the third and fourth year is a constant – 1 cm, and then reduced to 0.8 cm in the seventh year (Soric, Ilic 1985); in Radimna River – from 2.9 cm in the first year to 1.2 cm in the fourth year (Papadopol, Cristofor 1980).

Linear growth is described by Bertalanffy's equation very well because the relationship between length of age **t** years (L_t) and the age t+1 years (L_{t+1}) is straight line.

$L_t = 11.55\ [1 - e^{-0.48(t+0.08)}]$

The growth rate of Riffle Minnow from Iskar River was compared with those of other populations of the species range by Bertalanffy's equation, using references' data:

Rokytna River (Johal 1979) $L_t = 24.7\ [1 - e^{-0.6\ (t-1.4)}]$,

San & Dunajec Rivers (Skora 1972) $L_t = 20{,}1\ [1 - e^{-0.15(t-1.34)}]$,

For the Rivers of Croatia (Treer 2000) $L_t = 15.2\ [1 - e^{-0.28(t+0.93)}]$

The parameters of Bertalanffy's equation obtained for linear growth of Riffle Minnow from different rivers confirmed the theoretical position, that as much as rapid rate of population growth (the highest coefficient k) is faster, so asymptotic size (L_∞) was smaller and *vice versa* (Table 2). A slower rate of growth was in San & Dunajec Rivers k was 0.15 and L_∞ 20.1 cm. Exception to this statement was Rokytna River fish, which rapid growth rate k = 0.6 and high asymptotic size L_∞ = 24.7 cm. The data obtained for Iskar River were most similar to those of Sava River, as the values of k were 0.48 and 0.59, and L_∞ was 11.55 cm and 11.5 cm, respectively.

The growth rate is compared also with an omega parameter – $\omega = L_\infty.k$ (Gallucci and Quinn 1979). According to this parameter the most rapid growth rate have Riffle Minnow of Rokytna River (ω = 14.8), followed by fish from Sava River (ω = 6.79) and Iskar River (ω = 5.54). Slowest growth was in San & Dunajec Rivers ω = 2.08. Also was found, that when increasing k and ω increasing too (Table 2).

Asymptotic mean length (L_∞) of Iskar River Riffle Minnow was 11.55 cm. When compared this value with the maximum length of a specimens L_{max} /

Table 1. Mean body lengths (L1, L2, L3….cm) and mean annual growth of different generations and ages (t, years)

Mean body lengths (cm)								
Generation	**Ages**							**Number**
	years	**L_1**	**L_2**	**L_3**	**L_4**	**L_5**	**L_6**	**(n)**
2001	II	2,28	4,14					10
2000	III	3,17	4,74	5,68				27
1999	IV	3,37	5,4	6,45	7,6			22
1998	V	3,53	5,27	6,36	7,78	9,09		8
1997	VI	3,48	5,27	6,36	7,92	9,47	10,38	2
L_n		3,24	4,94	6,08	7,67	9,17	10,38	
$t = L_{n+1} - L_n$		3,24	1,7	1,14	1,59	1,5	1,21	

Table 2. Coefficients $\mathbf{L_\infty}$, **k** and **ω**, calculated using references' data.

River, Author	k	L_∞	ω
San & Dunajec Rivers (Skora 1972)	0,15	20,1	3,02
Dobra River (Treer 2000)	0,16	20,5	3,28
Korava River (Treer 2000)	0,23	16,45	3,21
Turiec River (Bastl *et al.* 1975)	0.28	15,6	4,37
Radimna River (Papadopol & Cristofor 1980)	0,3	14,4	4,32
Bednja River (Treer 2000)	0,33	15,5	5,12
Iskar River (this study)	0.48	11,55	5,54
Sava River (Treer 2000)	0,59	11,5	6,79
Rokytna River (Johal 1979)	0,6	24,7	14,82

L_∞, ratio obtained was 0.987 (Hohendorf 1966). This shows that the population realised almost the utmost growth potential.

Another method to compare the growth rate of different populations is through absolute average length of fish of the same age (Živkov 1972; Petrova, Živkov 1988). Comparing 11 populations of the species range (Table 3) revealed that the rate of growth Riffle Minnow of Iskar River is very fast. With a faster growth rate are only the populations of Wyzyny Lodzkiej River (Skora 1972), Niemiec Lake (Bauch 1963) and San & Dunajec Rivers, Poland (Skora 1972).

The Bank's start (the average length of fish with average body mass of 1 g, calculated using population specific L/W relation) for Iskar River was 3.2 cm.

Length (L) – body mass (W) relationship of Riffle Minnow's population was described best by equation $W = 3.4x10^{-2}L^{2.79}$, at r = 0.96. The back calculation body mass for the different generations and ages of Riffle Minnow from Iskar River is presented in Table 4.

The average annual body mass increment (t) continuously increased with age increasing, from 0.87 g in the first year, 2.12 g in the second, 2.3 g in the third, 4.7 g in the fourth, 6.46 g in the fifth and 6.81 g in sixth year of age (Table 4). The growth in other water bodies of the species range increased similarly. In the basin of San River the weight growth increased gradually from 0.97 g in the first year up to 4.7 g in sixth year of age (Skora 1972). For basin of Dunajec River the body mass gradual increased from 1.8 g in the first year to 3.4 g in the sixth year (Skora 1972). The growth of the oldest age group of Iskar River was 1.5 – 2 times higher that in other water bodies.

The body mass increasing as the linear one has asymptotic pattern and was described by Bertalanffy's equation:

$W_t = 134.52\ [1 - e^{-1.59(t+0.57)}]^{2.79}$ for Iskar River;

$W_t = 1187.97[1\text{-}e^{-0,.033(t+5.59)}]^{3.14}$ for basin of San River (Skora, 1972);

$W_t = 46.07[1\text{-}e^{-0.18(t+1.51)}]^{2.98}$ for basin of Dunajec River (Skora, 1972).

The comparison of the parameters of the equation of von Bertalanffy for body mass growth of the Riffle Minnow from Iskar River and two other popu-

Table 3. Growth rate of Riffle Minnow (*Alburnoides bipunctatus*) in the separate age groups from different water bodies.

Basin and Author	Mean body length (L , см) for the separate age groups									n
	I	II	II	IV	V	VI	VII	VIII	IX	
V. Morava r., Yugoslavia	3,2	4,6	5,6	6,6	7,3	7,8	8,6	-	-	146
(Soric and Ilic 1985)										
West Dvina`r., Russia	3,4	5,9	-	-	-	-	-	-	-	53
(Zukov 1965)										
Ogosta river, Bulgaria	6,0	6,3	6,5	-	-	-	-	-	-	54
(Johal 1979)										
Eliseva r., Romania	3,7	5,1	7,0	7,9	-	-	-	-	-	22
(Papadopol, Cristifor 1980)										
Radimna r., Romania	2,9	5,2	6,9	8,1	-	-	-	-	-	47
(Papadopol, Cristifor 1980)										
Rokytna r., Czech Republic	4,6	5,6	6,9	8,1	7,8	9,9	10,1	-	-	33
(Johal 1979)										
Dorzecze Sunu r., Poland	-	7,95	7,9	8,75	9,5	10,35	-	-	-	n
(Skora 1972)										
Iskat, our data	-	4,94	6,08	7,67	9,14	10,38	-	-	-	69
San and Dunajec rver,	4,8	6,4	7,9	8,7	9,6	10,4	11,0	11,2	12,9	423
Poland (Skora 1972)										
Wyzyny Lodzkiej r., Poland	6,4	7,2	8,9	9,9	10,5	-	-	-	-	n
(Penezak, Pezasnyska1969)										
Niemiec Lake, Poland	3,5	7,1	9,1	11,5	12,7					
(Bauch 1960)										

Table 4. Average body mass of fish (W_1, W_2, W_3, g) and average annual growths at the end of every vegetative season, in different generations.

Generation	Ages		Mean body mass (g)					Number
		W_1	W_2	W_3	W_4	W_5	W_6	(n)
2001	II	0.34	1.79					10
2000	III	0.85	2.61	4.33				27
1999	IV	1.01	3.76	6.17	9.75			22
1998	V	1.15	3.51	5.93	10.41	16.06		8
1997	VI	1.10	3.51	5.93	10.94	18.01	23.26	2
W_n		0.87	2.99	5.29	9.99	16.45	23.26	
$t=W_{(n+1)}-W_n$		0.87	2.12	2.3	4.7	6.46	6.81	

lations (Table 5) confirmed the theory, that as more as faster body mass increased (higher value of coefficient k), so asymptotic body mass W_∞ are smaller and *vice versa*. Extremely slow rate of body mass increasing was observed in the basin of San River (k = 0.033), which leads to absurd asymptotic body mass (W_∞ = 1187.97 g). Rapid rate of body mass increasing was observed in the basin of Dunajec River, where k = 0.18 and W_∞ = 46.07 g. Riffle Minnow of Iskar River have smaller coefficient (k = 0.159) and greater asymptotic body mass (W_∞ = 134.52 g).

By omega parameter ($\omega = W_\infty.k$) the highest rate of body mass increasing had the fish in basin of San River (ω =39.2), followed by the fish from Iskar River (ω =21.34) and basin of Dunajec River (ω =8.29).

The correlation of empirical maximum weight (W_{max}=36 g) and asymptotic weight (W_∞=134.52 g)

Table 5. Coefficients of the equation of von Bertalanffy for body mass increase of Riffle Minnow from different water bodies.

River	Author	W_∞	κ	t_o
Iskar	This study	134.52	0.159	- 0.57
San	Skora (1972)	1187.97	0.033	- 5.59
Dunajc	Skora (1972)	46.07	0.18	- 1.51

Table 6. Condition of Riffle Minnow (*Alburnoides bipunctatus*) by Fulton formula and by weights, calculated for the same body lengths (L= 2, 5, 10, 15 cm) from different basins.

Basin, Author	Formula	k	k (by Fulton)	L2	L5	L10	L15
San River Basin	$W = 5.2x10^{-2}L^{3.14}$	0.052	0.016	0.45	8,14	71.78	256.7
Skora (1972)							
Dunajc River Basin	$W = 4.6x10^{-2}L^{2.98}$	0.046	0.017	0.36	5,57	43.93	147.1
Skora (1972)							
Iskar River	$W = 3.4.10^{-2}L^{2.79}$	0.034	0.026	0.24	3,03	20.96	64.9
(this study)							

W_{max}/W_∞ was 0.268 (Hohendorf, 1966) and shows that population does not realise its utmost level of its growth potential.

The coefficient 'condition' calculated by equation $W=kL^n$ (modified Fulton's formula) for Iskar River population was $3.4x10^{-2}$, for basin of San River (Skora 1972) – $5.2x10^{-2}$, for basin of Dunajec River (Skora 1972) – $4.6x10^{-2}$. The coefficient k, calculated by Fulton is the highest for the fish of Iskar River and lowest for those of basin of San River. They are opposite to the results obtained by calculating 'condition' using the first method. According to Živkov (1993) and Raikova-Petrova, Živkov (1998) this coefficient does not reflect truly the condition. According to their results the fish conditions of different populations compared more accurately by calculating the weight of fishes in the same random chosen lengths (L= 2, 5, 10, 15 cm) and in a better condition is considered the heaviest fish (Table 6).

Riffle Minnows of Iskar River had the least weight and they are arranged in the same order as the coefficient k from the equation for weight increasing. For the lengths L= 5, 10, 15 cm a substantial difference were observed, as Riffle Minnows of Iskar River have a least weight at lowest k. When L= 10 cm, weight for Iskar River fish was 20.96 g, for basin of San River fish was 70 g, and for basin of Dunajec River – 143.2 g. When L= 15 cm, W values are: for Iskar River – 64.9 g, Basin of San River – 256.0 g and basin of Dunajec River – 147.1 g.

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