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Spawning, Sex Ratio and Relationship between Fecundity, Length, Weight and Age of Chub (*Squalius cephalus* L., 1758) in the Middle Stream of Iskar River (Bulgaria)

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Abstract: The reproductive biology of chub (*Squalius cephalus* L.) was studied. Results were compared with data from other water bodies within its natural European range. It is suggested that age at the first maturity is determined by growth rate and temperature. Relationship between fecundity length, weight and age were described by fouling equations lnF= 6.749 + 0.011L, r = 0.99; F = -5868 + 78W, r=0.98; lnF = 7.446 + 0.597t, r = 0.92. The chub spawn from April until the end of August, at water temperature between 8 °C and 18 °C. The sex ratio was ♂:♀ = 43.43%:56.57% but it is no different to 1:1 because $\chi^2 = 0.86 < \chi^2_{st} = 3.8$, P=0.95.

Key words: chub, spawning time, sex ratio, fecundity, Iskar River

Introduction

Iskar River is the longest one in Bulgaria. It is 368 km long, and has 8646 km^2 catchment 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.

The chub (*Squalius cephalus* Linnaeus, 1758) is numerically dominant species in middle stream of Iskar River. There are data on the reproductive biology of it for Struma River (Mihailova, 1964), Batak Dam (Živkov, 1983) and Iskar River (Hamwi, Raikova-Petrova 2005, Hamwi *et al.* 2009) only.

Materials and Methods

The material was collected from 2002 to 2003 in the middle stream of Iskar River (Fig. 1). A total of 507 chubs were captured by angle and electro-fishing. Standard length (SL ±1 mm), total mass (W±1 g), gutted body mass (W±1 g) and gonad mass (w±0.1 g) were measured. The fecundity (F, number of eggs) was determined gravimetrically. Relationship between fecundity length, weight and age was described by exponential and linear equations: $F= ab^L$; $F= ab^t$ and F = a + bW.

Results and discussion

Spawning time

The chub in the middle stream of Iskar River has a short life cycle. Therefore fish matured at a relatively small minimum size. The smallest mature male and female individuals had length 108 mm and 137 mm and body mass 25 and 50 g, respectively. First maturity age varied from 1-4 years (Table 1). Usually males matured 1 or 2 years earlier than the females.

Table 1. Smallest size, weight and age of chub (*Leuciscus cephalus*) at first maturity and in different water bodies.

Water body and authors	First maturity (years)		Smallest length (mm)		Smallest weight (g)	
	♂	♀	♂	♀	♂	♀
Struma River (Mihailova 1964)	I	II	83	113		50
Batak Dam (Živkov 1980)	I – III	III – IV	117	197	23	150
Lake Tödürge (Turkey) (Ünver 1998)	I-IV	II-V	67	74		
Iskar River (Our data)	I-IV	II-IV	108	137	25	50
Svratka River (Libosvarský 1959)	II	II – III				
Rouhovanka River (Habashy 1974)	II	III	110	120		
Karasu River (Erdoğan *et al*. 2002)	II	III	130	160	31	57
Lake Topçam (Şaşı 2004)	II	II	145	144	54	42
Aras River (Türkmen *et al.* 1999)	II-III	III-IV	118	140		
Rokytná River (Lelek 1959)	III	III-IV	96	135	22	88
Oravskej reservoir (Kirka 1965)	III-V	III-VI	110	251		
Stour River (Mann 1976)	III-V	V-VIII	120	120	33	
Water bodies in Moldavia (Popa 1977)	IV-V	IV-V				
Lug River (Mann 1976)	VI-VII	VII – VIII				

This early ripening of males has been held to be due to their higher rate of metabolism perhaps through endocrine influence in response to genetic and environmental forces (Raikova-Petrova, Živkov 1998).

A comparative analysis of 12 populations in different water bodies showed that the size of smallest males and females varied from 67-130 mm and from 74-251 mm, respectively (Table 1). The reason for these differences is that fish maturity is determined by the combined influence of two factors: temperature regime and growth rate. Thus at higher water temperature and higher growth rate fish mature earlier (Živkov 1980, Sokolova 1990).

The beginning of spawning was determined by water temperature and the stage of gonad development mainly. The spawning period in Iskar River was between April and end of August. It was longest compared to other water bodies (Table 2). The average temperature in these months was 8, 9, 12, 17 and 18 °C, respectively (average for the period 12.8 °C). The spawning occurred on late evening or in early morning at quiet weather.

Sex ratio

The chub population in Iskar River was 35.50% (180) juveniles, 36.49% (185) females and 28.01% (142) males. The sex ratio was ♂:♀ = 43.43: 56.57% i.e. 1:1.3. The prevalence of male species was not statistically significant because $\chi^2=0.8<\chi^2_{.st}=3.8$, P=0.05. Three sex ratio periods were established: males dominated in the youngest age classes, followed by balanced sex ratio period 1: 1 and dominating females in the last period.

Fecundity/length, body mass and age relationship

Relationship between fecundity, length and age was described by the exponential equation (lnF = 6.749 + 0.111L, r = 0.99 (Fig. 2) and lnF = 7.446 + 0.597t, r = 0.92 (Fig. 3).

Relationship between fecundity and body mass was described by the linear function F = – 5868 + 78W, r = 0.98 (Fig. 4)

The absolute fish fecundity from different water bodies was compared at the same lengths (100, 200 ... etc.) (Table 3). The populations presented in Table 3 are at descent order of the eggs' number in the highest size (the last one) class. Several conclusions could be made based on this Table: 1. The absolute fecundity of the population from Topçam lake (Şaşı 2004) – 982 011 eggs, was the highest at all compared sizes; 2. The absolute fecundity of the population from Iskar River was higher than the one of the population from Tödürge lake (Zara/Sivas) (Ünver 1998) only at the last two sizes; 3. The fecundity in Tödürge lake (Zara/Sivas) (Ünver 1998) – 69 143

Table 2. Spawning period of chub in different water bodies.

Water body and authors	Mounth	Water temperature, t° C
Water bodies (South Russia) (Kojin 1949)	March – April	
Topçam lake (Şaşi 2004)	March – April	13.5 – 20.6
Bulgarian rivers (Drenski 1926)	April – May	
Moscow River (Sabaneev, 1965)	April – May	
Iskar River (Paspalev & Peshev 1955)	April – June	18
Altinkaya lake (Bircan, Ağirağaç 1995)	April – June	
Sariyar lake (Ekmekçi 1996)	April – June	
Water bodies of Middle Russia (Kojin 1949)	April – June	
Struma River(Mihailova 1964)	April – August	
Middle stream of Iskar River (**our data**)	April – August	12,8
Dnepr River (Berg 1949)	May	
Bulgarian water bodies (Morov 1931)	May – June	
Volga River (Zashev 1961)	May – June	
Bulgarian water bodies (Zashev 1961)	May – June	
Batak Dam (Živkov 1980)	May – June	
Müceldi River (Öztaş 1989)	May – June	
Savur River (Ünlü & Balci 1991)	May – June	
Akşehir lake (Altindağ 1997)	May – June	
Jihlava River (Türkmen *et al.* 1999)	May – June	
Tödürge lake (Zara/Sivas) (Ünver 1998)	May – July	
Aras River (Türkmen *et al.* 1999)	May – July	16 – 23
Karasu River (Erdoğan *et al.,* 2002)	May – July	15 – 22
Oder-Havel-kanal (Arlinghaus, Wolter 2003)	May – July	
Kizirmak basin (Erkàkan & Akgül 1986)	May – September	

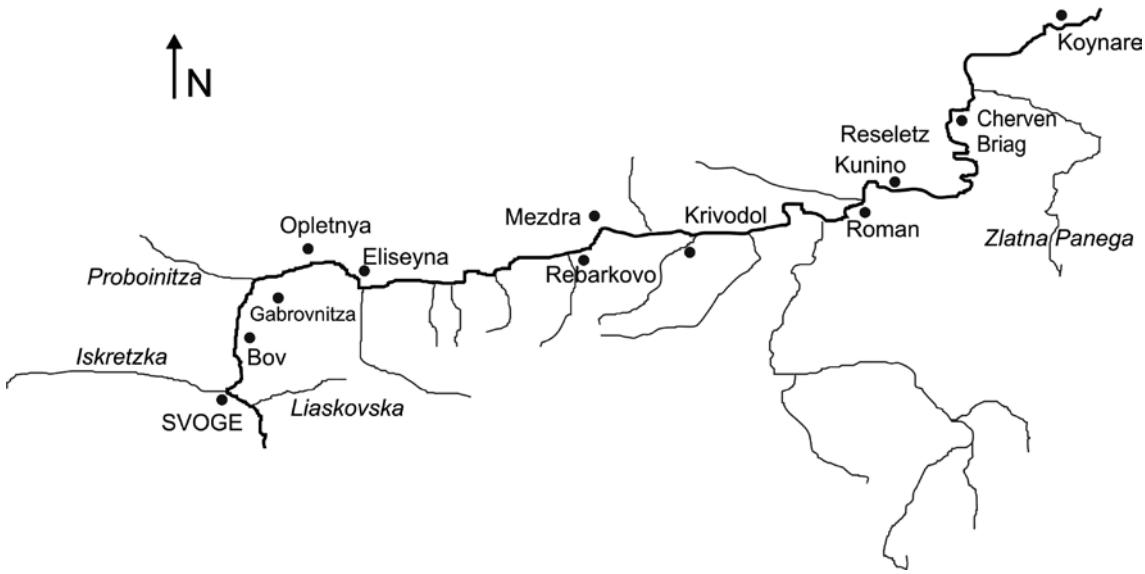

Fig. 1. Map of the middle stream of Iskar River.

eggs was the lowest and 4. The tendency that populations with lower start fecundity (at L=100 and 200 mm) in the next size classes have higher values of (F) and the opposite at higher start fecundity show lower values of (F) (for example the populations from Iskar River and Topçam lake) is confirmed.

The numerous studies of the tendency F/W at different fish species showed its linear character (Zotin 1961; Astanin, Podgorniy 1968; Lusk 1968; Bagenal 1968; Bastl 1970; Brilinska, Brilinski

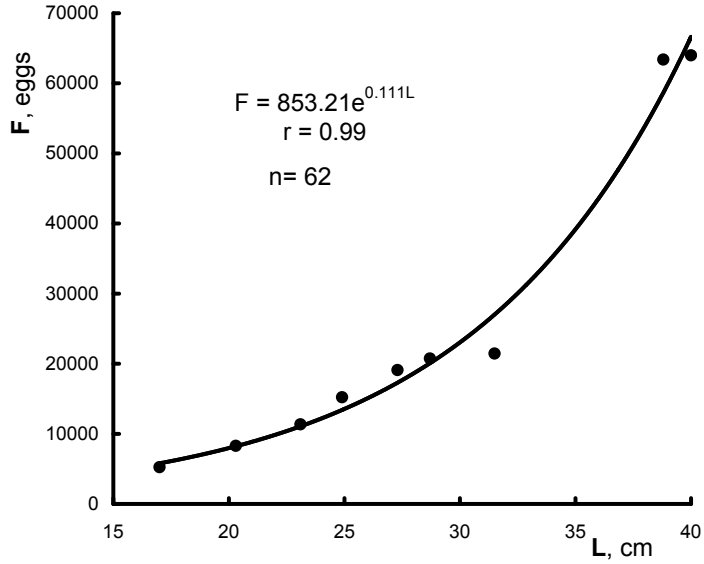

Fig. 2. Relationship between fecundity (F) and length (L) of chub (Leuciscus cephalus) from Iskar river.

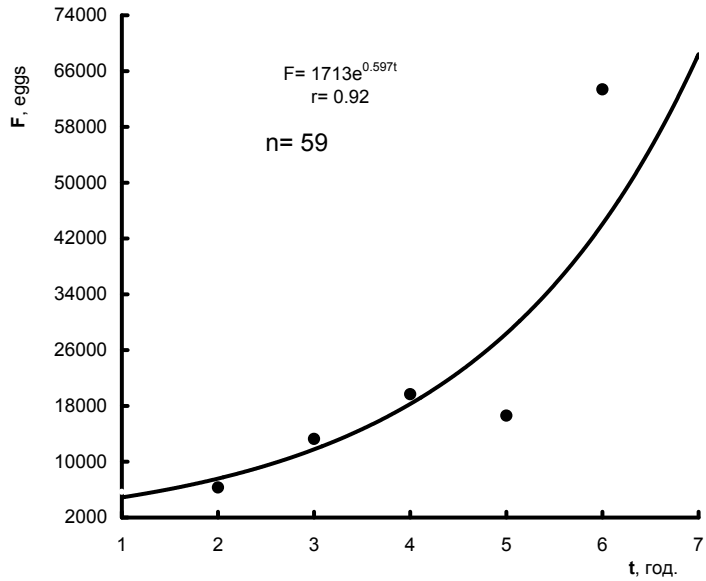

Fig. 3. Relationship between fecundity (F) and age (t) of Chub from Iskar river.

1974; De Silva 1973; Spanovskaia, Grigorash 1976; Živkov, Raikova-Petrova 1983, 1995). In Iskar River this tendency has also linear character (Fig. 4). The correlation-regression analysis of chub tendency F-W from other water bodies, based on references data, also has linear character (Table 4).

According to us the dependency fecundity (F) and body mass (W) has the most important methodical importance at the comparative investigations of the absolute fish fecundity from different populations. The average values of the absolute fecundity at the same, randomly chosen, values of gutted body mass (from 250 to 1500 g) were the most significant for the absolute fecundity of a given population. (Table 4).

Applying this approach we obtained the results given in Table 4. It is seen that the fecundity of the chub from different water bodies at all body masses is ordered in the same way (at the same row). The fecundity in Struma River was the highest and this one in Iskar River was the lowest. Therefore the absolute fecundity of the chub from different populations from geographically and ecologically different water bodies differed too much (from 5.3 to 4.6 times in different size classes): at 250 g average body mass the absolute fecundity varied from 13 632 (in Iskar River) to 72 495 eggs (in Struma River); at 1500 g – from 111 132 (in

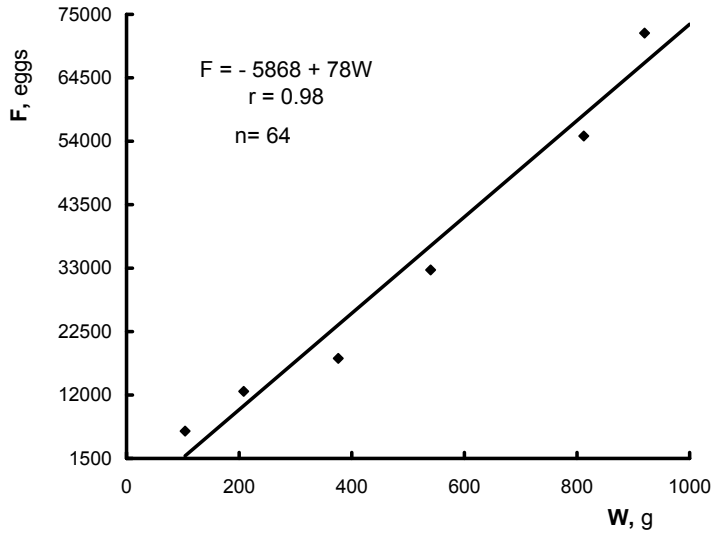

Fig. 4. Relationship betveen fecundity (F) and body mass (W) of Chub from Iskar river.

Iskar River) to 516 245 eggs (in Struma River).

Hence the dependency F/W is the most constant, because the same body mass was achieved at different lengths and ages in different water bodies (at different conditions).

In addition, the L/F relationship, in the other water body, using the references empirical data, is depicted with satisfactory mathematical accuracy by several types of equation: linear, power and exponential (Table 3). There was an extremely high correlation between average (F) and average body length (L), with the correlation coefficient (r) values being near to 1.0 (r = 0.92-0.99).

Diversity of functions describes the relationship between the fecundity and length or age of chub. Our results, and those for other species (Živkov, Raikova-Petrova 1993), indicate that this diversity is more apparent than real. In fact, the general regularity of increase of fecundity (F) with size (L) and age (t) fits the logistic low. The power, exponential, and logarithmic function can be presented as segments of the sigmoid curve. To a great extent, the diversity is determined by the differences in the maturation periods, lengths of life cycles, types of age structure of females of different populations, the representativeness of the materials sampled, and by the precision of their statistical processing. For this reason, the relationship between F and L (t), for populations and species which mature early, with no individuals of the oldest and largest size groups, is depicted either by power or exponential function (our data). The logarithmic function is a characteristic of populations which mature later (or when there are no individuals of the lowest size and youngest age groups).

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Table 3. Absolute fecundity (F, eggs) of chub (*Leuciscus cephalus*) from different water bodies at the same lengths (L, mm).

Water body and autor	**F/L relationship**	**Body length** (mm)				
		100	**200**	**300**	**400**	**500**
Topçam lake (Şaşi, 2004)	$F= 0.1279L^{4.0526}$	1 444	23 957	123 895	397 538	982 011
Batak Dam (Živkov, Raikova-Petrova , 1983)	ln F = -5.44+2.93 ln L	3 144	23 958	78 597	182 589	351 091
Middle stream of Iskar River (**our data**)	**ln F = 6.749 + 0.011L**	**2 563**	**7 700**	**23 133**	**69 494**	**208 772**
Tödürge lake (Turkey) (Ünver,1998)	F = -17782 + 173.85L		16 988	34 373	51 758	69 143

Table 4. Absolute fecundity (F, eggs) of chub (*Leuciscus cephalus*) from different water bodies at the same body mass (W, g).

Water body and autor	F/W relationship	Body mass (W, g)				
		250	500	750	1000	1500
Struma River (Mihailova,1964)	F = -16255 +355W	72 495	161 245	249 995	338 745	516 245
Topçam lake (Şaşi, 2004)	$F = 52.907\ W^{1.2558}$	54 306	129 682	215 782	309 680	515 286
Batak Dam (Živkov, Raikova-Petrova , 1983)	F = 7279 + 135 W	41 029	74 779	108 529	142 279	209 779
Tödürge lake (Turkey) (Ünver, 1998)	F = 1589 + 121 W	31 839	62 089	92 339	122 589	183 089
Middle stream of Iskar River **(our data)**	F = -5868 + 78W	**13 632**	**33 132**	**52 632**	**72 132**	**111 132**

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