AGE, SEX STRUCTURE AND GROWTH RATE OF *CARASSIUS GIBELIO* (CYPRINIDAE) FROM THE ISKAR RESERVOIR OF THE DANUBE RIVER DRAINAGE IN BULGARIA

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Abstract

This is a study of population parameters of the Prussian carp (*Carassius gibelio* Bloch, 1782) from the Iskar Reservoir, the second largest dam on the territory of Bulgaria. For this purpose, in 2014-2017, a sample of 106 individuals was collected by angling, at different points along the dam's shoreline. Fish age was determined by squalimetry. Length growth was calculated by a relation between length (TL) and scale radius (TS). Mass accumulation was determined by a relation between length (TL) and mass with entrails (W). The results of the study show that due to the higher altitude of the Iskar Dam, the Prussian carp grows in length and mass more slowly than in other water bodies of the country. However, the population of the Iskar Reservoir is growing much faster than populations in Northern Europe, Siberia and the Far East. By examining 55 specimens caught at the same time in the same dam and at the same sampling points, a sex ratio of 1.7:1 in favor of females was determined.

Keywords: length and mass growth, Prussian carp.

JEL: Q23.

Introduction

The distribution of the Prussian carp (Carassius gibelio Bloch, 1782) extends from Western Europe (France) in the West to Siberia (including the Kolyma River) in the East. According to some European authors, the Prussian carp either originated in Central Europe or was introduced from Eastern Asia [9]. However, recent genetic data shows a close relation between European and Asian populations. This finding seems to support the theory that the Prussian carp came to Europe from Eastern Asia. In this case, the origin of the European populations is very recent, i.e. postglacial. In Bulgaria, the Prussian carp appeared for the first time in the Danube River in the 1940s [16]. Nowadays, the species is widespread in the country's standing and flowing inland water bodies [6–8, 18]. The wide spread and adaptation of the species in Bulgaria and throughout Europe is due to its high ecological resistance to environmental conditions. Prussian carp is tolerant to low oxygen concentration and pollution [9, 14]. The species can live even in brackish water, provided that sulfate rather than chloride ions dominate, and fish has access to freshwater spawning grounds [15]. The good adaptability of the Prussian carp is also due to its wide food spectrum and its ability to feed on plankton. In general, the main share – 67% of its food is detritus, 24% is phytoplankton, 8% – zooplankton and 1% is zoo benthos [12]. Algae predominates the diet of one and two-year-old fish. Characteristic of older fish' diet is that the share of planktonic invertebrates increases. Five-year-old individuals eat the greatest amount of animal benthic food [15]. The Prussian carp can spend the cold period in anabiosis, buried in bottom mud, where there is an almost complete lack of dissolved oxygen [19]. The species' expansion in Europe was also aided by its ability to reproduce by gynogenesis [6, 9]. During the last century, most of the Prussian carp populations in Europe were composed mainly of females [5, 16]. Although in recent years the sex ratio is once again tipped in favor of females, many males still appear in the populations [5, 15]. The emergence of sexual reproduction is a possible population response to habitat deterioration [12, 13], since subsequent generations have better adaptability to environmental changes [16].

Prussian carp competes for food and habitat with the Crucian carp (*C. carassius)* and other species of the Cyprinidae family. Displacement of Crucian carp by Prussian carp has been reported in many countries [1, 5, 11, 14]. By increasing water turbidity and supporting Cyanobacteria's growth, this species also worsens habitat conditions for Perch (*Perca fluviatilis*) and Pike (*Esox lucius*) [10]. However, Prussian carp is an important commercial and sport fish [6, 12]. In the Amur River (Russia), this is the main object of commercial fishing [17]. Production of Prussian carp in Chinese aquaculture amounts to 2 million tons per year [16].

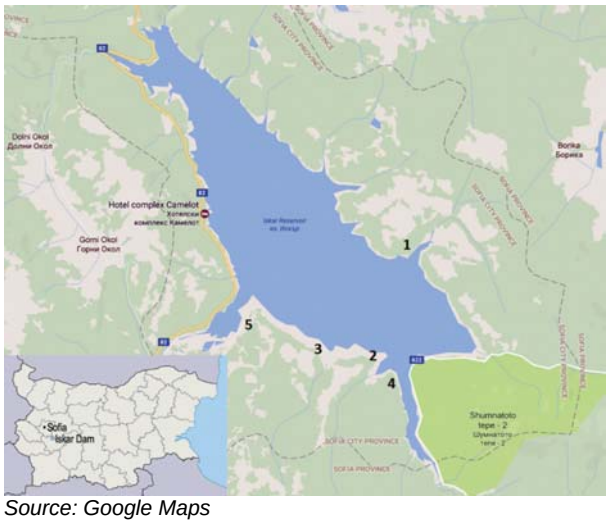
Purpose

The Iskar Reservoir is one of the biggest dams in Bulgaria. After dam overflows, a community of different fish species became established. Some of the most abundant ones were Common carp, European whitefish and Grass carp. Later, species such as Common bream, Pike, Pike-perch and European catfish were also introduced. Other fishes such as

Common perch, Pumpkinseed and Prussian Carp have also established themselves in the dam. Population data for some of these fish has not yet been estimated. Our aim is to explore some aspects of Prussian carp's biology in the Iskar Dam.

Study area

Iskar Reservoir is located South of the city of Sofia, in Southwestern Bulgaria (Fig. 1).



Source: Google Maps

Fig. 1. Location of the sampling sites along the shore of the Iskar Reservoir

Legend: Fish specimen collection locations: 1 – Ichtiman bay, 2 – Cement bunker, 3 – Willows bay, 4 – Shipochene bay, 5 – Fish farm's dike

The dam occupies part of the upper and middle zone of the Iskar River (right tributary of the Danube River). Iskar Dam collects water from the Northern slopes of the Rila mountain and from the southern slopes of the Vitosha mountain. The reservoir has been in operation since 1954. The catchment area of the dam is 1046 km^2 with an average altitude of 818 m. The maximum water depth reaches 75 m. With an area of 30 km^2 and water volume of 63 billion m^3, the Iskar Dam ranges the second largest in Bulgaria. The reservoir provides drinking and domestic water for the city of Sofia; the outflow is used to generate electricity. Angling is allowed in the Southern part of the reservoir, which is outside the sanitary zone.

Materials and Methods

The material for this study was obtained by angling from the lake shore. Fish was caught by a fishing legging method, using 6 rods, each 4 meters long. Stainless steel hooks №10–12, silver, limerick type and 0.30 mm monofilament fishing line are used. Red worms, maggots and boiled corn kernels have been used for bait. Specimens were collected during the day throughout the fishing season for a period of 4 years (2014–2017). Five sampling areas were used, located in the authorized fishing area of the Iskar Dam (Table 1). The material numbered 105 fish and all of them were used for growth estimation. Fish were measured immediately after the catch. For each specimen, a total length (*L)* with a precision of 1 mm was measured. Weight with entrails (*W*) with a precision of 1 g was weighed. Fish age was determined by counting scales' annual rings. For this purpose, the diagonal caudal radius of the scales was used. This analysis was performed in a laboratory, using a microscope Olympus CX 31, at a 20× magnification.

To establish the species' sex structure, 55 specimens were used, all caught in April 2014, at the study site 2. Fish sex was determined by examining fish's gonads.

Table 1. Sampling sites at the Iskar dam

№	Location	Geographic coordinates		Month/ Year
		N	E	
1	Ihtiman bay	42°46'63.11''	23°61'87.32''	April 2014, July 2016
2	Cement bunker	42°43'43.31''	23°60'06.78''	April, July 2014; July, October 2016
3	Willows bay	23°58'74.90''	42°43'94.11''	April 2016
4	Shipochene bay	42°42'76.69''	23°61'47.49''	July 2014, April 2015
5	Fish farm dike	42°44'30.41''	23°55'01.11''	April 2017

Fish linear growth was determined via a back-calculation of the length (*L)* from the diagonal caudal radius of the scales (*S)* [21]. 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 used by many authors [2, 22] and recommended by Zhivkov [21, 23].

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

where:

L – Length of the fish (mm);

a, b – Equation Coefficients.

A comparison of the length growth of different Bream populations is made by ranking them according to the average lengths at the same age [20].

Results

Species composition

In the period 2014–2017, 12 fishes from 6 families were caught in the Iskar Reservoir, in addition to Prussian carp. The Common bream dominated the catch, followed by the Prussian carp. Single specimens of the remaining fishes were also caught and are listed in Table 2. Five species, found in the Iskar Reservoir, including Prussian carp, were non-indigenous for Bulgarian inland waters (Common whitefish, Prussian carp, Stone moroko, Wels catfish, Pumpkinseed) (Table 2).

Table 2. Species' composition of the sample from the Iskar Reservoir

№	Species	Common name	Family
1	*Coregonus lavaretus* (Linneus, 1758)	Common whitefish	Coregonidae
2	*Esox lucius* (Linneus, 1758)	Northern pike	Esocidae
3	*Rutilus rutilus* (Linneus, 1758)	Common roach	Cyprinidae
4	*Alburnus alburnus* (Linneus, 1758)	Bleak	Cyprinidae
5	*Abramis brama* (Linneus, 1758)	Common bream	Cyprinidae
6	*Carassius gibelio* (Bloch, 1782)	Prussian carp	Cyprinidae
7	*Cyprinus carpio* (Linneus, 1758)	Common carp	Cyprinidae
8	*Pseudorasbora parva* (Schlegel, 1842)	Stone moroko	Cyprinidae
9	*Ictiobus cyprinellus* (Valeciennes, 1844)	Bigmouth buffalo	Cyprinidae
10	*Silurus glanis* (Linneus, 1758)	Wels catfish	Siluridae
11	*Perca fluviatilis* (Linneus, 1758)	European perch	Percidae
12	*Sander lucioperca* (Linneus, 1758)	Pike-perch	Percidae
13	*Lepomis gibbosus* (Linneus, 1758)	Pumpkinseed	Centrarchidae

Age, size and sex structure

Age was determined for 106 *C. gibelio* specimens. The age composition of the Iskar Dam's catch consisted of 6 age groups. The sample was dominated by four-year-old fish (48%). The share of two-, three- and five-year-old fish (all three age groups 54%) was also large. The participation of the older age groups, seven and height-year-old fish was less pronounced. Six-year-old fish, fish hatched during year (0+) and one-year-old fish were not present in the sample (Fig. 1). The maximum age was 7 for males and 8 for females.

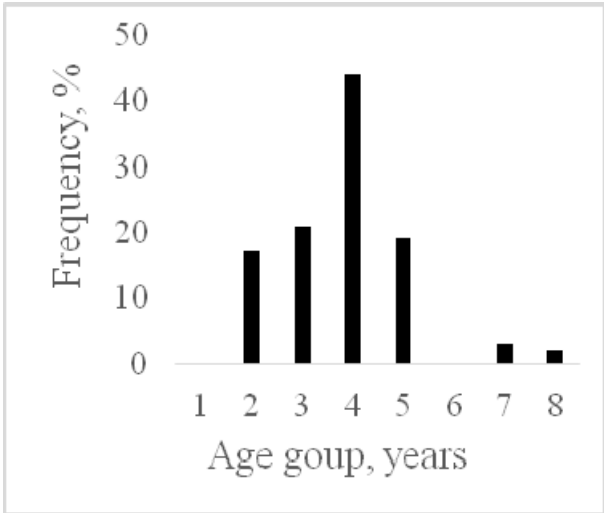


Fig. 1 Age structure of Prussian carp from the Iskar Reservoir

Within the whole sample total fish length varied between 140 and 445 mm. Fish with length from 200 to 250 mm (58%) were most abundant (Fig. 2). The largest specimen was a female fish with a length of 445 mm and a mass of 1420 g.

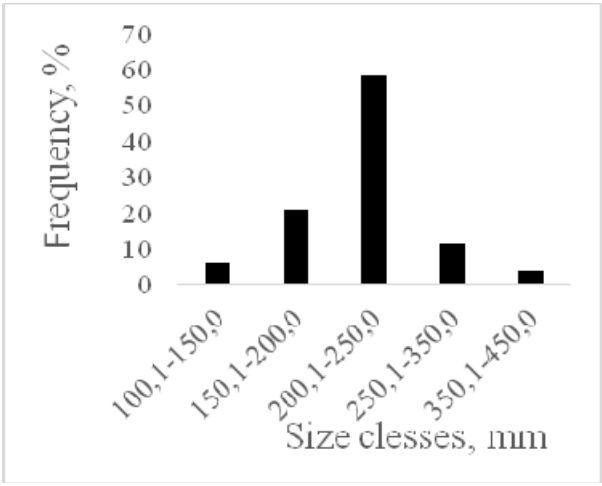


Fig. 2 Size classes of Prussian carp from the Iskar Reservoir

Total weight ranged between 60 and 1420 g. The dominant weight group of all samples (43%) was the smallest weight group from 100 to 200 g. The dominant weight group of males was the 100-200 g group (50% of males) and of females was the 200–300 g group (51% of females).

The sample for study of fish's sexual structure includes 55 specimens with length ranging from 170 to 248 mm and with an individual mass variation between 135g to 283g. One of the studied fish was two-year-old, two fish were five-year-old, 16 were three-year-old. The rest of this sample consisted of four-year-old specimens. Twelve of the fish were immature. The remaining part of the sample was sexually mature fish, with a sex ratio of 2.7:1 in favour of females. The youngest male and female was two-year-old individuals. The smallest matured fish was 170 mm long and weighted 200g for males and 175 mm long, weighing 190 g for females.

Length growth and weight growth

The TL-S ratio calculated for the entire sample is well expressed by a highly correlated linear equation (3).

$TL=1.90674S–60.149$, $r^2=0.96$, n=106. (3)

Total mean lengths were calculated by age classes used equation 3. Annual growth rate was greater for young fish. The differences between estimated and observed lengths were due to the fact that some fish were caught in summer and autumn. After the last scale radius there was an additional growth (e.g. 3+). Annual increase in length for younger fish was the largest; as age increased, it decreased (Table 3).

Table 3. Back calculated total body length TL (mm) of Prussian carpin from the Iskar dam

Size class	Mean calculated length TL (mm)								
	n	**TL1**	**TL2**	**TL3**	**TL4**	**TL5**	**TL6**	**TL7**	**TL8**
II	*17*	45	148						
III	*21*	26	66	155					
IV	*44*	52	110	169	213				
V	*19*	56	129	199	260	261			
VII	*3*	60	140	205	2612	268	327	348	
VIII	*2*	45	131	214	254	291	363	390	418
Mean calculated length TL (mm)	*106*	47	120	188	247	273	345	369	418
Mean observed length TL (mm		-	159	210	219	254	-	337	423
Annual increment (mm)		-	73	74	51	14	-	27	29

Between weight and length, in most cases, there is a well-expressed relation, through a power equation. For the Prussian carp population, this relation is expressed by a power equation (4) with exponent b<3.

$W=0.002TL^{2.2104}$, $r^2=0.92$, n=106. (4)

Using the W-L ratio (equation 4), mean fish weights by age were calculated. The oldest, eight-year-old fish exceed 1.2 kg in weight. The mass of one and two-year-olds was small. This result may also be due to the lack of 0-year-old fish and the small number (six) of two-year-old fish in the sample (Table 4). Six-year-old fish were also missing from the sample. The values of their lengths and masses were theoretically calculated (Tables 3, 4).

Table 4. Back calculated total body weight *W* (g) of Prussian carp in the Iskar dam

Size class	Mean calculated weight W (g) at age								
	n	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W7**	**W8**
II	*17*	9	125						
III	*21*	3	21	139					
IV	*44*	12	65	168	280				
V	*19*	15	93	241	436	439			
VII	*3*	17	111	258	443	466	723	830	
VIII	*2*	9	96	283	414	559	911	1067	1244
Mean calculated weight W (g)	*106*	11	85	218	393	488	817	949	1244
Mean observed weight W (g)		-	159	300	241	598	-	820	1358
Annual increment (g)		-	120	141	170	57	-	132	177

Discussion

The predominance of Common bream and Prussian carp in the catch is probably a consequence of the fishing method used. Therefore, only single specimen of plankton-eating species (Bleak, Common roach) were caught. It should be noted that four predatory fishes have been introduced into the Iskar Reservoir (Northern pike, European perch, Wels catfish, Pike-parch). Probably because of their taller body size, Common bream and Prussian carp are less affected by predation pressure in the dam. The alien species appears to have entered the Iskar dam through the importation of Common carp and Pike-perch stocking material. Some alien spe-

cies, such as Bigmouth buffalo, have escaped from a former carp farm next to the dam.

An absence of smallest size groups and zero-year-old Prussian carp specimen is due to the selectivity of the capture method. The youngest fish do not consume food like the bait, which was used. There are very few large and old fish in the catch. Larger fish in the catch are likely to be eliminated to a greater extent by angling and natural mortality effects.

There was a difference in the mass of male and female Prussian carp. Average weight of females is greater than that of males. In the study sample, almost all fish were sexually mature. Our study confirms the occurrence of a significant number of males in European populations of the species. Specifically, for the Iskar Dam, an appearance of sexual reproduction is rather a reaction to the environment. A presence of individuals of both sexes indicates a good adaptation of the species to the conditions in the dam.

Linear growth of Prussian carp in the Iskar Dam is lower than that in the Pyasachnik Reservoir, located in the Plovdiv field (with an altitude of 278 m above the sea level), as well as the average values for Bulgaria. The Iskar Dam is at a high altitude, over 800 m above the sea level However, in the Iskar Reservoir the species develops much faster than in reservoirs in Siberia and the Far East of Russia (Table 5). This is a result of the climate differences between Bulgaria and Northern Europe and Siberia.

Table 5. Mean total body length TL (mm) of Prussian carp in different water bodies

Author/ Water body	Mean body length (TL, mm) at age									
	n	TL1	TL2	TL3	TL4	TL5	TL6	TL7	TL8	TL9
Mikheev, 2006/ Kubyshev Dam	*712*	75	119	146	190	222	239	264	281	292
Kovalev et a. 2001/ Lebedinoe Lake	*270*	-	130	175	220	245	260	280	290	320
Our data, 2023/ Iskar Dam	*106*	47	120	188	247	273	345	369	418	-
Karapetkova and Zhivkov 1995/ Mean for Bulgaria	-	76–102	142–159	180–195	-	-	-	-	-	-
Boyadzhiev, 1969/ Pyasachnik Dam	*23*	102	159	191	-	-	-	-	-	-
Lorenzoni et al. 2007/ Trasimeno Lake	*30111*	90–150	160–210	220–270	260–320	320–390	-	-	-	-

Prussian carp grows very fast in Southern Europe, such as in Lake Trasimeno in Italy, where the climate is warmer (Table 5). Prussian carp is a heat-loving carp fish that prefers and thrives better in warmer water conditions. In the Iskar Reservoir, five-year-old fish approach 0.5 kg, and eight-year-old fish reach about 1 kg in weight (Table 4).

Our data are not sufficient to establish the presence of a competition between Prussian carp and other species in the dam. We can only note that in recent years the number of this species in the Iskar Dam has been relatively high.

Conclusions

Commercial fishing in the Iskar Reservoir is prohibited. Only amateur fishing is practiced at the dam. The main objects of sport fishing there are Prussian carp along with Common bream. The Prussian carp has a stable, reproducing population. The species benefited well from the dam's habitat.

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ВЪЗРАСТОВА, ПОЛОВА СТРУКТУРА И НАРАСТВАНЕ НА *CARASSIUS GIBELIO* (CYPRINIDAE) В ЯЗОВИР ИСКЪР ОТ ДУНАВСКИЯ ВОДОСБОРЕН БАСЕЙН НА БЪЛГАРИЯ

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Резюме

Настоящата статия представя проучване на някои аспекти от популационната биология на сребристата каракуда (*Carassius gibelio* Bloch, 1782) в язовир Искър, вторият по големина язовир в България. За тази цел е използван материал от 106 индивида, добити в няколко пробни точки в язовира по линия на любителския риболов в периода 2014-2018г. Възрастта на рибите е определена чрез сквалиметрия. Темпът на линейно нарастване е изчислен от отношението между дължина на тялото (TL) и радиуса на люспите (S). Натрупването на масата е установено чрез зависимостта на пълната дължина на тялото и масата с вътрешности (W). Поради по-голямата надморска височина на язовир Искър сребристата каракуда в него нараства на дължина и маса по-бавно в сравнение с другите водоеми в нашата страна. Все пак популацията на този вид в язовир Искър нараства много по-бързо в сравнение с популациите в Северна Европа, Сибир и Далечния Изток. Чрез изследване на 55 екземпляра, уловени по едно и също време в една и съща пробна точка от язовир, е определено полово съотношение 1,7:1 в полза на женските.

Ключови думи: нарастване на дължина и маса, сребриста каракуда.