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Growth, Diet and Fatty Acid Composition of Gibel Carp *Carassius Gibelio* in Lake Shira, a Brackish Water Body in Southern Siberia

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*For the first time the presence of gibel carp *Carassius gibelio* has been detected in the brackish meromictic Lake Shira (Southern Siberia, Republic of Khakassia). Lake Shira has been continuously studied since the late 19th century, and it has been considered so far that there is no ichthyofauna in the lake. This work investigates the growth and population characteristics, as well as food spectra and fatty acid composition of *C. gibelio* specimen at different ages that were fished out in the summers of 2007 and 2008. The water salinity at the fishing point was 15 g l⁻¹. The food spectrum of one- and two-year old *C. gibelio* was dominated by diatomic, green and blue-green algae, while four- to six-year old species had an increased share of copepods, beetles and chironomids in their food spectrum, and beginning from the age of six years the amphipods *Gammarus lacustris* consisted significant part of gibel carp diet. Thus, it was shown that *C. gibelio* is a carnivore with regard to the population of amphipods *Gammarus lacustris*, which have been regarded so far as the upper link in the trophic cascade of Lake Shira. One of the possible reasons for appearance of fish is the decreased water salinity caused by rising of the lake level. In the recent years, the level of Lake Shira exceeded all the values that had been registered since the late 19th century, and the lake's salinity decreased correspondingly to its smallest value for the whole period of observation.*

Keywords: *Carassius gibelio*, brackish lake, food spectrum, fatty acids.

Introduction

Fish introductions are amongst the greatest threats to freshwater biodiversity (Gherardi, 2010), and one of the most invasive freshwater

fish species is the gibel carp *Carassius gibelio* Bloch (Szczerbowski, 2002; Luskova et al., 2010) which has been recently found to have established a population in the brackish Lake

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Shira previously reported as a fish-less lake (Degermendzhy, Gulati, 2002; Degermendzhy et al., 2010). Gibel carp *Carassius gibelio*, being a stenohaline species, is rather often observed in brackish water, for example, in the littoral zones of the Black and Baltic seas (Abramenko, 2006; Vetemaa et al., 2005), in the delta of the Ob (Zhadin et al., 1961) etc. Lake Shira has been studied for decades by many researchers (Krivosheev, Khasanov, 1990; Degermendzhy, Gulati, 2002; and many others), but it has been considered until now that there is no permanent ichtyofauna in the lake (Degermendzhy, Gulati, 2002; Degermendzhy et al., 2010). In summer, the salinity of the epilimnion water was about 15 g l⁻¹ during last decade (Rogozin et al., 2010), however, lower salinity was observed near estuary of the river Son incoming to the lake. According to the oral evidence of local residents, gibel carp has been regularly observed in the lake lately. However, there have been no reliable facts proving this information so far. In 2007, we made trial sampling that confirmed the presence of gibel carp in the lake. Since the fish population may provide considerable impact on previously fishless ecosystem, it seems to be important to study the main characteristics and ecology of this population. At the first step, we tried to analyze the feeding spectrum, growth characteristics and fatty acids composition of gibel carp in the lake. Fish species, from different ecosystems, are known to differ in their fatty acids composition; therefore, studies of fatty acids contents of diverse fish from various locations are of great importance for revealing their potential value as sources of the essential ω 3 acids for human nutrition (Ahlgren et al., 1994; Gladyshev et al., 2009). Polyunsaturated fatty acids (PUFAs) of the ω 3 family became known as key dietary nutrients for preventing mental, neural and, especially, cardiovascular diseases of human (Arts et al., 2001; Garg et al., 2006). Besides, biochemical

analysis of fatty acid composition is widely used to trace trophic interactions between hydrobionts and to reveal food assimilation (Desvillettes et al., 1997; Sushchik et al., 2003). Therefore, the aims of present work were to provide the first evidence of presence of fish in Shira Lake, to analyze the diet of the fish and to give some basic information about growth characteristics and fatty acids composition.

Materials and Methods

Lake description

Lake Shira (90.11 E, 54.30 N) is located in the northern part of the Republic of Khakassia, South Siberia (Russian Federation). This elliptical (9.3 × 5.3 km) lake has an area of 35.9 km² and maximum depth of 23.8 m (2007-2010). The main inflow is from the Son River that provides about 42 % of fresh water supply to the lake; other sources of water are precipitation and seepage water (Parnachev et al., 2002). The lake has no outflow. The salinity of lake water during summer stratification is about 14-15 g l⁻¹ in epilimnion (upper 5-6 m of water column) and 18-19 g l⁻¹ in deeper waters. The detailed description of the lake is given elsewhere (Degermendzhy et al., 2002; Parnachev et al., 2002; Kalacheva et al., 2002; Rogozin et al., 2010). The surface elevation of Lake Shira has noticeably changed over the whole period of observation. The lake's salinity varied inversely with changes in water volume (Krivosheev, Khasanov, 1990; Rogozin et al., 2010). During the period from 1920-s to 1930-s the lake's level decreased by 7 m, which was caused by the decrease in the total amount of precipitation in the region. In this period, salinity reached the maximum of 27 g l⁻¹ in 1926. By the present moment, the lake level has exceeded all the values registered since the late 19th century, and the salinity has dropped, respectively, to its lowest value for the whole period of observation (Rogozin et al., 2010).

Sampling and water measurements

Fish sampling was carried out in 2007-2009 in Point A (54.28.767 N, 90.14.818 E), in several points of Area B, and in point C (54.29.053 N; 90.16.352 E) (Fig.1). Exact coordinates of Area B point were not defined, and the location of Area B was estimated visually on the basis of landmarks. The dates of fishing are given on Fig.1. Fish were captured with gill nets of various dimensions and mesh sizes, complemented for young specimens by drag-nets, bottle and can traps as well as rod and line angling. In all points the nets were set in the evening, along macrophyte beds, at a depth of approximately 1.5 m not far from the shore; the nets were checked early in the morning next day.

The temperature and specific conductance of water in points A and C (Fig.1) were measured with YSI 6600 (Yellow Springs, Ohio, USA) submersible profiler. The salinity was calculated as quadratic approximation of the dependence of ash content upon specific conductance measured for the Lake Shira water in laboratory:

$$S = -0.087 \text{ cond}^2 + 4.4403 \text{ cond} - 37.16,$$

$$R^2 = 0.95, n = 19,$$

where S is the salinity determined as ash content (g l⁻¹), $Cond$ is specific conductance at 25°C of the lake water samples (mS cm⁻¹). Conductivity sensors were calibrated against 3M KCl (YSI). Oxygen electrodes were calibrated against Winkler titration of the Lake Shira water with Aquamerck kit (Merck, Germany)

Back-calculated growth, weight-length relationship and Fulton's condition factor

The growth history was determined for 200 fish collected from the end of July to the beginning of August in Area B (Fig.1). After capture all the fish were individually weighted (wet) to the nearest

0.01 g on electronic balances and measured to the nearest millimeter. Scale samples for age and growth analysis were collected from each fish. Scales were taken above the lateral line dorsal to the tip of depressed left pectoral fin. Growth histories of individual fish were determined by aging and back-calculation of total lengths (TL) at previous ages from scales (Pierce et al., 1996). Twelve to fifteen scales per fish were cleaned and mounted between glass slides. All scales on slides were viewed when ages were assigned to fish, and a single reader did all aging. Anterior radii and interannular distances were measured to nearest 0.01 mm by using dissecting microscope (25× magnification). These radii are hereafter referred to as scale lengths. Replicate measurements were then averaged for each fish, providing the precise estimates of scale lengths for back-calculations. With the data on individual TL and mean scale length, we then back-calculated TL at previous ages using the Fraser-Lee formula (Pierce et al., 1996).

Weight-length relationship and Fulton's condition factor were calculated from the expressions:

$$(1) W = a TL^b$$

$$(2) K = 100 W/SL^3,$$

Where W is the whole body weight in grams, TL the total length, SL is the standard length in centimeters; a and b are the regression constants; the factor 100 is used to bring K close to unity (Froese, 2006).

Diet analysis

Diet was assessed on the basis of gut contents determined by dissection of 32 fish collected from the end of July to the beginning of August in Area B (Fig.1). All fish samples were weighted and measured as described above, and their guts were removed immediately, and

stored in formalin (4%) until the contents were analysed. The analysis of digestive tracts was performed in accordance with the standard method (Metodicheskoye rukovodstvo, 1974; Hyslop, 1980). Animal food items were identified to the lowest possible taxon. The diet was analyzed for the percentage composition by mass.

Analysis of fatty-acid composition

Detailed description of the analysis is given elsewhere (Makhutova et al., 2003; Sushchik et al., 2006). Briefly, lipids from samples were extracted with chloroform:methanol (2:1, v/v) three times simultaneously with mechanical homogenization of the tissues with glass beads. Before extraction, a fixed volume of an internal standard solution (19:0) was added to the samples. Methyl esters of fatty acids (FAMES) were prepared in a mixture of methanol: sulphuric acid (50:1, v/v) at 90 °C for 2 h. FAMES were then analysed using a GC–MS (model GCD Plus, Hewlett Packard, USA) equipped with a 30 m long × 0.32 mm internal diameter capillary column HP-FFAP. FAMES peaks were identified by their mass spectra, comparing to those in the data base (Hewlett–Packard, USA) and to those of available authentic standards (Sigma, USA). To determine double bond positions in monoenoic and polyenoic acids, GC–MS of dimethyloxazoline derivatives of FA were used.

Results

Fishing results

On July 24 2007, in the Point A (Fig. 1) the water temperature was 24 °C, and salinity was 15.1 g l⁻¹. The salinity in the central part of the lake at this period was 15 g l⁻¹, i.e. it was practically the same as in the fishing point. The captured fish included 33 specimens of 2- and 3-year-old *Carassius gibelio*, and one 7-year-old specimen of the same species. This was the first

ever documented proof of the presence of fish in Lake Shira. The age was determined for six specimens of this capture (Table 1).

On August 9 2008, in Point A the water temperature was 23 °C, and the salinity was 14.7 g l⁻¹. In this date, 130 two- to four-year-old specimens and 68 five- to eight-year-old specimens were captured using nets with a mesh size of 25 mm and 40 mm, respectively. The specimens of this capture were analyzed only for fatty-acid composition.

In area B (Fig. 1), 200 specimens of *Carassius gibelio* of different sizes and ages were captured from the end of July to the beginning of August 2008; the water temperature and salinity were not measured. The specimens captured in 2008 in Area B included fish aged from 1+ to 15+ years (Fig. 2, Table 1), with the predominance of 7-year-old specimens (26.5 %). Fish aged 5+ and 7+ make up a large part of the captured total – 15.5 and 18.0 %, respectively, of the total number of captured specimens. There were few specimens older than 8 years in catches. Almost in all age groups the sex ratio was practically 1:1. It was only in the 4+ and 7+ age groups that males dominated. The body length of the fish in this sample was from 54 mm to 460 mm, and the body mass was from 2.47 to 1358 g.

In May 2009, no specimens were caught in points A and C (Fig. 1). The water temperature at that time varied within the range of 10.7–13.2 °C, and the salinity was 13.7 – 14.5 g l⁻¹.

Weight–length relationship

and Fulton's condition factor

The length-weight relationship calculated for total length data (Table 1), was $W = 0.012 TL^{3.134}$, ($R^2 = 0.995$, $n = 124$) for females,

$W = 0.015 TL^{3.068}$, ($R^2 = 0.978$, $n = 76$) for males.

The relationship between TL and SL was $SL = 0.786 TL + 0.405$, ($R^2 = 0.998$, $n = 206$).

Fig. 1. Fish sampling sites at Shira Lake in 2007-2009: (A) – 24 July 2007, 9 August 2008 and 30 May 2009; Area (B) – 21-30 July and 3-5 August 2008; (C) – 30 May 2009; (I) – Town Zhemchouzhnyi and spa resort “Lake Shira”

Table 1. Length and mass of *Carassius gibelio* from Lake Shira collected on July, 2007, and July-August, 2008. M – total mass, m – mass without entrails

Age	TL±SE (cm)	SL±SE (cm)	M±SE (g)	m±SE (g)	n
2007					
2+	14.1 ± 0.3	10.2 ± 0.5	42.7 ± 4.6	35.3 ± 3.5	3
3+	14.8 ± 0.6	11.8 ± 0.3	61.8 ± 2.1	48.9 ± 1.6	2
7+	24.0	17.3	177	133	1
2008					
1+	7.3 ± 1.7	5.5 ± 1.3	6.4 ± 0.4	5.1 ± 0.3	34
2+	-	-	-	-	0
3+	14.9 ± 1.1	12.0 ± 1.0	54.4 ± 1.4	47.0 ± 1.3	21
4+	16.5 ± 1.8	13.5 ± 2.0	83.1 ± 3.0	68.8 ± 2.8	10
5+	18.4 ± 0.8	14.8 ± 1.2	114.1 ± 2.5	92.0 ± 2.1	31
6+	19.9 ± 0.7	16.1 ± 0.9	149.2 ± 2.0	122.7 ± 2.0	54
7+	21.8 ± 0.8	17.6 ± 0.8	182.3 ± 4.0	147.3 ± 3.8	36
8+	23.0 ± 1.3	18.6 ± 1.8	210.7 ± 5.3	170.4 ± 5.2	10
9+	25.2 ± 1.5	20.8 ± 2.0	308.5 ± 1.8	265.3 ± 3.3	2
10+	26.0	21.2	301	264	1
15+	46.0	36.0	1358	1108	1

Table 2. Fulton's condition index (K_f) of *Carassius gibelio* collected from Lake Shira in July and August, 2008

Age	Males		Females	
	K_f	n	K_f	n
1+	3.59 ± 0.03	30	3.79 ± 0.11	4
2+	-	0	-	0
3+	3.13 ± 0.05	13	3.22 ± 0.12	8
4+	-	0	3.41 ± 0.11	10
5+	3.33 ± 0.08	19	3.67 ± 0.08	12
6+	3.51 ± 0.04	33	3.51 ± 0.08	21
7+	3.37 ± 0.11	18	3.29 ± 0.10	18
8+	3.15 ± 0.09	8	3.6 ± 0.01	2
9+	3.43 ± 0.08	2	-	0
10+	-	0	3.16	1
15+	2.91	1	-	0

The Fulton's condition index (K_f) undergoes minor changes in specimens belonging to different age groups. The (K_f) varied from 2.91 to 3.79 (Table 2). The (K_f) of males and females was almost equal, except the 5+ and 8+ age groups, in which males were noticeably better-fed than females (Table 2).

Growth history

Generally, the relative length increment estimated from scales decreased with the age (Fig. 3, Table 3). The back-calculated patterns of length at the age were similar among six generations, and the year-to-year differences among the fish of equal age-class were not significant, except youngest group of 3+ (Fig. 3, Table 3). The relative length increment of 3+ fish in 2005 was significantly higher than for other generations at this age (Fig. 3). However, this may be explained by shortcoming of back-calculation method too (Pierce et al., 1996; Martinson et al., 2000).

Analysis of diet

The diet of *Carassius gibelio* in Lake Shira is rather diverse; it includes 4 divisions of algae, 9 groups of water invertebrates, remains of

terrestrial insects and higher aquatic vegetation (Table 4, Fig. 4). In addition, the guts of fish in all age groups contained sand which was obviously consumed with food.

The largest number of diatoms was found at the inflow of the River Son. These are diatoms that are preferred by juvenile fish. The algal flora of the lake typically includes algae of Pyrrophyta division, but they were not present in the guts of the caught gibel carps. The cyanobacteria of the genera *Spirulina*, *Oscillatoria*, and *Anabaena* dominating in the littoral zone of the lake were not present in gut contents.

The zooplankton of Lake Shira is characterized by a relatively small diversity of species. The dominating species are Copepoda and Rotatoria (Degermendzhy, Gulati, 2002) which are present in the diet of gibel carp. Several species of Cladocera are found in the south-eastern part of the lake (at the inflow of the River Son). Though their population size and biomass are low, these animals are the most favorite delicacy of gibel carp among all crustaceans. Benthic animals also display little diversity, but they constitute a considerable part of the *C. gibelio*'s diet (Table 4, Fig 4).

Fig. 2 Age and sex distribution of *Carassius gibelio* from Shira Lake collected on July-August, 2008. females; males

Fig. 3. Back-calculated relative increments of total length of *Carassius gibelio* from Shira Lake collected on August 2008. Numbers 8+.....3+ indicate age at capture

Table 3. The year of hatching, mean total length at capture, mean back-calculated lengths-at-age, standard errors, and mean annual growth increments of *Carassius gibelio* from Shira Lake collected in August, 2008. Ten fishes of each age class were analyzed

Year	TL at capture	Back-calculated lengths at age (mm)							
		1+	2+	3+	4+	5+	6+	7+	8+
Class	<u>TL</u> SE	<u>TL</u> SE	<u>TL</u> SE	<u>TL</u> SE	<u>TL</u> SE	<u>TL</u> SE	<u>TL</u> SE	<u>TL</u> SE	<u>TL</u> SE
2005	<u>149.0</u> 1.2	<u>57.2</u> 1.6	<u>108.2</u> 1.9	<u>149.0</u> 1.2					
2004	<u>165.2</u> 1.8	<u>58.7</u> 2.1	<u>95.2</u> 2.5	<u>129.8</u> 2.1	<u>165.2</u> 1.8				
2003	<u>183.7</u> 1.6	<u>66.4</u> 2.2	<u>97.6</u> 2.8	<u>131.1</u> 2.4	<u>155.5</u> 2.3	<u>183.7</u> 1.6			
2002	<u>196.6</u> 1.6	<u>61.1</u> 2.9	<u>95.1</u> 3.1	<u>124.8</u> 3.0	<u>151.7</u> 2.7	<u>173.8</u> 2.4	<u>196.6</u> 1.6		
2001	<u>218.0</u> 1.6	<u>53.0</u> 1.5	<u>81.1</u> 2.0	<u>109.8</u> 3.2	<u>139.9</u> 2.8	<u>171.0</u> 0.6	<u>194.1</u> 1.4	<u>218.0</u> 1.6	
2000	<u>230.3</u> 1.3	<u>45.3</u> 1.5	<u>74.3</u> 2.2	<u>100.1</u> 2.4	<u>125.1</u> 2.8	<u>155.0</u> 1.9	<u>181.7</u> 1.7	<u>208.7</u> 1.5	<u>230.3</u> 1.3
Mean TL increment (mm)		35.0	32.2	28.4	27.9	24.2	25.4	21.6	

Table 4. Food components of *Carassius gibelio* from Lake Shira collected on July and August, 2008. Numbers indicate weight percentages of a species in a food component

Food component	Fish age					
	1+	3+	4+	5+	6+	7+
1	2	3	4	5	6	7
Bacillariophyta						
1. <i>Navicula</i> sp.	39	-	-	73	-	-
2. <i>Cymbella</i> sp.	22	70	48	20	80	57
3. <i>Sinedra ulna</i>	8.8	20	18	-	-	20
4. <i>Sinedra acus</i>	6.9	-	14	7	-	23
5. <i>Melosira</i> sp.	1.0	-	-	-	-	-
6. <i>Pinnularia</i> sp.	1.0	-	10	-	-	-
7. <i>Gomphonema olivaceum</i>	0.7	-	-	-	-	-
8. <i>Cocconeis placentula</i>	2.0	-	-	-	-	-
9. <i>Achnanthes</i> sp.	0.3	-	-	-	-	-
10. <i>Eunotia</i> sp.	3.0	-	-	-	-	-
11. <i>Amphora ovalis</i>	2.0	-	-	-	-	-
12. <i>Rhopalodia gibba</i>	2.3	-	5	-	-	-
13. <i>Cyclotella</i> sp.	11	10	5	-	20	-
Chlorophyta						
14. <i>Staurastrum</i> sp.	8	50	-	-	-	-
15. <i>Ankistrodesmus</i> sp.	20	-	-	-	-	-

Table 4. (Continue)

1	2	3	4	5	6	7
16. <i>Tetraedon minimum</i>	2	-	-	-	-	-
17. <i>Scenedesmus quadricauda</i>	10	50	-	-	100	-
18. <i>Scenedesmus acumenatus</i>	5	-	25	100	-	-
19. <i>Pediastrum angulosum</i>	7	-	25	-	-	-
20. <i>Pediastrum tetras</i>	10	-	25	-	-	-
21. <i>Cosmarium</i> sp.	10	-	25	-	-	-
22. <i>Pandorina morum</i>	10	-	-	-	-	-
23. <i>Oedogonium</i> sp.	10	-	-	-	-	-
24. <i>Dictyosphaerium</i> sp.	8	-	-	-	-	-
Cyanophyta						
25. <i>Merismopedia tenuis</i>	79	-	-	-	-	-
26. <i>Gomphosphaeria</i> sp.	21	-	-	-	-	-
Euglenophyta						
27. <i>Phacus</i>	100	-	-	-	-	-
Nemathelminthes						
<u>Rotatoria</u>						
Family Asplanchnidae						
28. <i>Asplanchna</i> sp.	10	-	-	-	-	-
Family Branchionidae						
29. <i>Keratella</i> sp.	90	-	100	-	-	-
Type Annelida						
<u>Class Oligochaeta</u>						
30. Setae of <i>Oligochaeta</i>	100	-	100	-	100	100
Type Mollusca						
Sub type Conchifera						
31. Class Gastropoda	-	100	-	100	100	100
Type Arthropoda						
<u>Class Arachnida</u>						
Gen. Acarina						
32. Family Hydrocarinae	-	100	-	100	100	100
<u>Class Crustacea</u>						
Sub class Branchiopoda						
Gen. Cladocera						
Family Daphniidae						
33. <i>Daphnia</i> sp.	10	3	10	10	5	12
Family Bosminidae						
34. <i>Bosmina</i> sp.	10	5	10	10	5	10
Family Chydoridae						
35. <i>Chydorus</i> sp.	50	75	80	50	-	-
Sub class Copepoda						
Gen. Cyclopoida						
36. Family Cyclopoidae	20	10	-	30	-	-
37. Gen. Calanoida	10	7	-	-	-	-
<u>Class Malacostraca</u>						
Gen. Amphipoda						
Family Gammaridae						
38. <i>Gammarus lacustris</i>	-	-	-	-	90	78

Table 4. (Continue)

	1	2	3	4	5	6	7
Class Insecta							
Gen. Diptera							
Larvae of Chironomidae							
39. <i>Endochironomus</i> sp.		-	10	11	20	15	8
40. <i>Chironomus</i> sp.		-	80	69	70	60	64
41. <i>Polypedilum</i> sp.		-	10	10	-	15	18
42. <i>Cricotopus</i> sp.		100	-	10	10	10	
Gen. Coleoptera							
43. Larvae of beetles		100	100	-	100	100	100
44. Remains of terrestrial insects		-	-	100	100	100	100
45. Remains of macrophytes		-	100	100	100	100	100
46. Indeterminable substance		100	100	100	100	100	100
47. Sand		100	100	100	100	100	100

Fig. 4 Mass percentage of gut contents components of *Carassius gibelio* from Lake Shira collected on July-August 2008. Species compositions of components are given in table 4

The guts collected from Lake Shira were relatively evenly distributed by age groups, which allowed us to reveal differences in the diets of specimens of different ages (Fig. 4). Obviously, the diet is not the same throughout the whole life, the percentage of diet components varies depending on age (Fig. 4). The guts of 2-year-olds contain mostly algae, with the predominance of Bacillariophyta; there are also Rotatoria, Oligochaeta and equal percentage of Cladocera and Copepoda. At an age of 3+ , the percentage of small crustaceans and insects increases, while Gastropoda, Hydrocarina and the remains of higher aquatic vegetation appear in the diet of gibel carp. The percentage of algae is small, while worms are not absent. Chironomidae and Coleoptera are the dominant food category of 5- and 6-year-old specimens. Small crustaceans, gastropods, aquatic mites and worms are also common food for fish of this age group. Older *C. gibelio* prefer Amphipoda, Chironomida and Coleoptera. The percentage of small crustaceans and worms is insignificant; there are remains of higher aquatic vegetation and sporadic traces of algae (Fig. 4).

Fatty acid composition

More than sixty fatty acid (FA) species were identified in all muscle samples of *C. gibelio* from the Shira Lake, and percentage of 43 prominent acids are given in Table 5. The average level of saturated fatty acids (SFAs) was 27.8 %. Among them 16:0, 18:0 and 14:0 dominated. The percentage of markers of bacterial food, odd and branched acids was 4.7 %, among them ai17:0 and i17:0 dominated. Monounsaturated fatty acids (MUFAs) were in average 29.8 % (Table 5). Monoenoic acids were primarily represented by 18:1 ω 9, 16:1 ω 7, 18:1 ω 7, 20:1 ω 9. Polyunsaturated fatty acids (PUFAs) were in average 39.9 %. Docosahexaenoic acid (DHA, 22:6 ω 3), eicosapentaenoic acid (EPA,

20:5 ω 3), arachidonic acid (ARA, 20:4 ω 6) and linoleic acid (LIN, 18:2 ω 6) were the dominant species among PUFAs. The ratio of ω 3/ ω 6 was 2.8. It was shown that value of ω 3/ ω 6 depends on trophic positions of fish e.g., the optimal ω 3/ ω 6 ratio in the carnivorous-benthivorous freshwater fish is 3.8, for carnivorous-piscivorous fish the ratio is 2.6, and for herbivorous-omnivorous fish is 2.0 (Ahlgren et al., 2009). Thus, ω 3/ ω 6 ratio of *Carassius gibelio* from the Shira Lake corresponds with the ratio for carnivorous-piscivorous fish. The total FA concentration in muscle samples of *C. gibelio* from the Shira Lake was 7.2 $\pm$ 0.7 mg/g wet weight.

We compared FA content and composition of muscle samples of *C. gibelio* from saline Lake Shira and from the freshwater reservoir Bugach (a small reservoir situated 56°03 N and 92°43 E in the Bugach river, secondary tributary of the Yenisei river). FA composition of the freshwater and saltwater *C. gibelio* differed significantly (Table 5). *C. gibelio* from the Shira Lake had higher level of MUFA and BFA, but lower levels of SFA and PUFA in comparison with *C. gibelio* from Bugach Reservoir (Table 5). Among SFA the levels of dominant FAs, 16:0, 18:0 and 17:0 were significantly higher in freshwater fish. The levels of most fatty acids of MUFA were significantly higher in saltwater population. These differences may be the result of several causes. Firstly, desaturation of 18:0 to 18:1 ω 9 might be more effective in saltwater population. This result is in good agreement with our previous data on freshwater and saltwater populations of *Gammarus lacustris* (Makhutova et al., 2003). Secondly, differences in nutrition spectrum can take place. The acid 16:1 ω 7 is a marker of diatoms (Claustre et al., 1988/1989; Leveille et al., 1997; Shin et al., 2000). Fatty acids 20:1 ω 11, 20:1 ω 9, 20:1 ω 7, as well as 22:1 ω 11, 22:1 ω 9 and 22:1 ω 7 which obtained in saltwater fish in traces

Table 5. Average levels (M, %) of prominent fatty acids in muscles of *Carassius gibelio* from Shira Lake (n=9) and Bugach Reservoir (n=6), t – Student's test, * significant difference. The total, mg/g wet weight.

Fatty acids	Shira M±SE			Bugach M±SE			t
1	2			3			4
12:0	0.11	±	0.02	0.14	±	0.02	1.06
14:0	1.52	±	0.19	1.19	±	0.10	1.54
15:0	0.82	±	0.21	1.17	±	0.07	1.58
16:0	17.69	±	0.31	22.81	±	0.79	6.03*
17:0	0.74	±	0.10	1.57	±	0.11	5.58*
18:0	6.50	±	0.42	8.26	±	0.19	3.82*
20:0	0.23	±	0.03	0.19	±	0.01	1.26
ai15:0	0.22	±	0.03	0.18	±	0.02	1.11
i15:0	0.14	±	0.03	0.01	±	0.003	4.31*
i16:0	0.22	±	0.01	0.17	±	0.01	3.54*
ai17:0	0.79	±	0.04	1.52	±	0.11	6.24*
i17:0	0.30	±	0.01	0.23	±	0.01	4.95*
16:1ω9	0.18	±	0.05	0.75	±	0.19	2.90*
16:1ω7	6.93	±	0.71	3.24	±	0.15	5.08*
16:1ω5	0.38	±	0.02	0.33	±	0.03	1.39
17:1	0.80	±	0.16	0.37	±	0.04	2.61*
18:1ω9	13.09	±	0.99	6.94	±	1.30	3.76*
18:1ω7	5.68	±	0.17	3.73	±	0.24	6.63*
18:1ω5	0.29	±	0.03	0.05	±	0.01	7.59*
20:1ω11	0.23	±	0.04	0.09	±	0.01	3.40*
20:1ω9	1.07	±	0.07	0.58	±	0.03	6.43*
20:1ω7	0.44	±	0.03	0.14	±	0.01	9.49*
16:2ω4	0.43	±	0.07	0.04	±	0.003	5.57*
16:3ω4	0.26	±	0.05	tr.			
16:3ω3	0.04	±	0.01	0.01	±	0.004	2.79*
16:4ω3	0.06	±	0.01	0.03	±	0.005	2.68*
16:4ω1	0.02	±	0.01	tr.			
18:2ω6	3.43	±	0.40	3.90	±	0.86	0.50
18:2ω4	0.17	±	0.01	0.02	±	0.01	10.61*
18:3ω6	0.26	±	0.03	0.10	±	0.02	4.44*
18:3ω3	1.52	±	0.14	1.58	±	0.06	0.39
18:4ω3	0.62	±	0.10	0.27	±	0.02	3.43*
20:2ω6	0.34	±	0.03	0.41	±	0.09	0.74
20:3ω6	0.48	±	0.03	0.39	±	0.1	0.86
20:4ω6	4.19	±	0.27	5.46	±	0.34	2.93*
20:3ω3	0.24	±	0.02	0.37	±	0.03	3.61*
20:4ω3	0.86	±	0.06	0.56	±	0.02	4.74*
20:5ω3	7.87	±	0.32	6.26	±	0.49	2.75*
22:4ω6	0.29	±	0.04	0.09	±	0.02	4.47*

Table 5. (Continue)

1	2			3			4
22:5 ω 6	0.98	$\pm$	0.08	0.26	$\pm$	0.07	6.77*
22:4 ω 3	0.02	$\pm$	0.01	1.95	$\pm$	0.17	-11.33*
22:5 ω 3	2.50	$\pm$	0.16	2.38	$\pm$	0.33	0.33
22:6 ω 3	13.80	$\pm$	1.20	21.38	$\pm$	1.66	-3.70*
SFA	27.76	$\pm$	0.70	35.44	$\pm$	1.13	-5.78*
BFA	4.69	$\pm$	0.49	2.30	$\pm$	0.1	4.78*
MUFA	29.75	$\pm$	1.80	16.59	$\pm$	1.63	5.42*
PUFA	39.91	$\pm$	1.28	45.68	$\pm$	1.49	-2.94*
C18-22 ω 3 PUFA	27.52	$\pm$	1.27	34.76	$\pm$	2.11	-2.94*
C18-22 ω 6 PUFA	9.97	$\pm$	0.58	10.59	$\pm$	1.03	-0.52
Total	7.2	$\pm$	0.72	4.54	$\pm$	0.23	3.52*

are the markers of marine copepods (Mayzaud et al., 1999; Falk-Peterson et al., 2001; Nelson et al., 2001; Scott et al., 2002). Fatty acid 18:1 ω 7 is considered as marker of bacteria. Thus, perhaps *C. gibelio* from the Shira Lake fed diatoms and copepods more selectively or in a large quantity. Moreover, the level of PUFA markers of diatoms (16:2 ω 4, 16:3 ω 4, 16:4 ω 1 and 20:5 ω 3) were significantly higher in saltwater population. Among C18-22 PUFA the levels of 18:2 ω 4, 18:3 ω 6, 18:4 ω 3, 20:4 ω 3, 20:5 ω 3, 22:4 ω 6 and 22:5 ω 6 were significantly higher in saltwater fish. A high level of long-chained fatty acids may be the evidence of prevalence animals in nutrition of *C. gibelio* from the Shira Lake. It should be emphasized that the level of essential, physiologically important acid, 22:6 ω 3 was in two times higher in freshwater population.

The total FA concentration in muscles of *C. gibelio* from the Shira Lake was in one and a half times higher than in the fish from the Bugach Reservoir. A fattier animal contains a lot of triacylglycerols (TAG), which is characterized by a high level of SFA, though in our case fat less population of *C. gibelio* from the Bugach Reservoir had significantly higher levels of SFA and PUFA (Table 5).

Discussion

This paper for the first time refers to reliable facts indicating presence of ichthyo-fauna in Shira Lake. Although there is oral evidence that fishermen caught *C. gibelio* at the inflow of the Son River as early as in the 1980-s, we do not have any evidence referring to an earlier date. Total absence of *C. gibelio* in our catches of May 2009 can be explained by the low water temperature, whereas the salinity at this period had the lowest values as compared to the other dates of sampling.

The length-weight relationship indicates that population of *C. gibelio* in Shira Lake is relatively well-fed. For example, in female-dominated population of *C. gibelio* from Chimaditis Lake (Greece) the exponent *b* was 2.81 for TL (Leonardos et al., 2008) (compare to range, 3.13-3.07, in our study). As it was shown by Tsoumani with co-authors (2006), the exponent *b* may increase with trophic state of the lake. In eutrophic lakes these *b* values were significantly lower than those in oligotrophic or mesotrophic lakes (Tsoumani et al., 2006). In this respect, the value of *b* in Shira Lake is close rather to mesotrophic and eutrophic lakes than to oligotrophic ones. According to coefficient *b*

Fig. 5. Surface elevation and salinity of Lake Shira (delivered from Rogozin et al., 2010): (a) surface elevation ASL: (—) measured by meteoservice (1936–2007); (●) – previously reported (Krivosheev, Khasanov, 1990); (b) salinity: (—) average salinity calculated according to estimates of volume change; (▲) – previously measured and reported (Krivosheev, Khasanov, 1990; Kalacheva et al., 2002; Parnachev et al., 2002; Rogozin et al., 2010); (■) – upper value of *Carassius gibelio* tolerance according to literature

values, the females were more “succulent” than males (see Results).

Obviously, absence of other fish species makes gynogenetic reproduction of *C. gibelio* in Shira Lake impossible. Almost equal sex distribution (Fig. 2) indicates sexual reproduction of *C. gibelio* in the lake.

We suggest that elevated salinity level has been keeping gibel carp out of the lake. The salt concentration in the lake varied inversely to the lake level (Fig. 5) (Krivosheev, Khasanov, 1990; Rogozin et al., 2010). In the last two decades the trend has been towards level increase and salinity decrease; in 2007 the historical level maximum occurred, and, therefore, the historical salinity minimum was reached, about 14–15 g l⁻¹, measured in the epilimnion in summer (Fig. 5).

Therefore, we can assume that the fish range could have expanded throughout the lake in the recent years, and this trend can continue with the lake level increase (and salinity decrease) which might be caused both by increase of climate

humidity and inflow of man-made discharge into the lake (Krivosheev, Khasanov, 1990). Apart from the years-long changes, the water salinity in the upper layers of Shira changes during a year with minimum in May and early June (Rogozin et al., 2010). The upper limit of the *C. gibelio*’s salinity tolerance is about 15 g l⁻¹; this species cannot survive for a long time at higher values (Nico, Schofield, 2006). In steppe lakes of Western Siberia the *Carassius gibelio* is known to withstand the increases of salinity up to 11–14 g l⁻¹ (Yadrenkina, Interesova, 2010). However, the salt composition of Shira Lake water is dominated by sulphate-ion (Kalacheva et al., 2002), that makes difficult to compare the salinity tolerance of fish with sea water and other reservoirs where chloride-ion dominates.

Despite many information is available on occurrence of *Carassius gibelio* and other cyprinids in brackish and mildly saline waters of seas and lakes (Ishitobi et al., 2000; Vetemaa et al., 2005; Abramenko, 2006; Kanaya et al., 2009; Yadrenkina et al., 2010), we could not

find in literature any study of invasion the fish-free saline lake by fish. Obviously, the invasion of fish-free saline lake is not common event. Therefore, the opportunity to monitor the early point of the invasion stage in a saline lake seems to be very rare. It is not known, however, when exactly the gibel carp appeared in the lake. Apparently, the fish could always be present at the inflow of the river, where the water salinity is minimal.

However, even the minimal salinity values registered by us in the lake are not suitable for normal development of eggs and juveniles of this species (Nico and Schofield, 2006). Thus, the spawning place of the gibel carp living in Lake Shira is not known. Neither is known from what water bodies the gibel carp can enter the Shira Lake, what total biomass this species has in the lake, and what seasonal dynamics this biomass has, and therefore, to what degree *C. gibelio*

influences the biomasses of organisms being its diet components. To answer these questions, further studies are necessary.

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Рост, питание, и жирнокислотный состав серебряного карася *Carassius gibelio* в солоноватом озере Ши́ра, Южная Сибирь

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В солоноватом меромиктическом оз. Ши́ра (Южная Сибирь, Республика Хакасия) зарегистрировано присутствие серебряного карася *Carassius gibelio*. Озеро Ши́ра непрерывно изучается с конца XIX в., и до сих пор считалось, что ихтиофауна в данном озере отсутствует. В настоящей работе исследуются морфологические характеристики, спектр питания и жирнокислотный состав особей *Carassius gibelio* различного возраста, выловленных в оз. Ши́ра в летнее время 2007 и 2008 гг. Соленость воды в местах вылова была около 15 г/л. Среди пищевых компонентов особей возраста 1-2 лет преобладали диатомовые, зеленые и сине-зеленые водоросли. У особей от четырех до семи лет в пище увеличивалась доля копепод, жуков и хирономид. Начиная с шестилетнего возраста значительную долю в рационе составляли бокоплавы *Gammarus lacustris*. Таким образом, серебряный карась может быть хищником по отношению к популяции *Gammarus lacustris*, который до сих пор считался верхним звеном трофического каскада в экосистемы оз. Ши́ра. Одна из возможных причин появления карася в озере – снижение солености, обусловленное повышением уровня озера. В последнее десятилетие уровень оз. Ши́ра превысил все значения, известные для данного озера с конца XIX в. Соответственно, соленость воды в озере снизилась до минимального значения из всех зарегистрированных ранее.

Ключевые слова: серебряный карась, солоноватое озеро, спектр питания, жирные кислоты.