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THE POPULATION STRUCTURE, PHYSIOLOGICAL AND BIOCHEMICAL INDICATORS OF THE CARASSIUS AURATUS GIBELIO *(BLOCH, 1782) IN THE WATER SALINITY GRADIENT*

ABSTRACT. The structure of the population, physiological and biochemical indices of C. a. gibelio have been researched in the lakes of Sladkovsky area with salinity range 1.8-12.0 g/dm³. The gender, size and age structure of the population have also been studied. It is proved that increase in the water salinity causes increase in the percentage of males; fish species of an older age begin to dominate. In the salinity range of 5,6-7,7 g/dm³ all ages, except 2/2, demonstrate reduction in growth and weight, while the feeding intensity increases. Biochemical analysis revealed the content of protein and fat in the muscular tissue of the carp. It is noted that increase in the water salinity raises protein content and reduces fat content in the fish muscle. To confirm these data the multivariate factor analysis was carried out which showed interrelation of the biological indicators in question with water salinity and the main hydrochemical water indicators.

KEY WORDS. Carassius auratus gibelio (Bloch, 1782), frequency of occurrence, mass fraction, salinity, water mineralization, functional performance, INC, a critical salinity, growth and weight gain.

The issue of the future climatic shifts conditioned by the greenhouse effect of anthropogenic origin has often been raised in the scientific literature over the past few years. A gradual temperature rise is claimed to be connected with this. Nowadays, the study of the influence of water of different salinity on the living communities as a prototype of possible changes in the biocenoses under the influence of possible warming is of special interest [1-3]. Mineralization of water basins is one of the most important ecological characteristics of the habitat of water life. The influence of salinity and the major types of water ions on the metabolic processes of hydrobionts and formation of the species composition of the water communities is shown in several researches [4].

The purpose of the research was to study the influence of varying degree of salinity on the population and biochemical indices of the Prussian carp (*Carassius auratus gibelio*) found in the lake ecosystems of the south of Tyumen region.

The area under study is located in the wooded steppe zone of the south of Tyumen region. The lakes in the wooded steppe zone of Tyumen region are various in their mineral composition ranging from salty to fresh. Under the conditions of slow-moving and enclosed lakes, insignificant precipitation and rather intensive evaporation water salinity in many lakes increases in the course of time [5]. The water basins in question are mainly standing, shallow and small. The largest are lake Buzan (270 ha) and Bolshoye (302 ha). The average depth does not exceed 2.5-2.6 m.

The native and commercial species of fish found in the lakes of the south of Tyumen region is the Prussian carp – *Carassius auratus*. We have selected the typical carp lakes: Malinovoye, Bolshoye, Buzan, Glubokoye and Shcherbakovo. The material was gathered in the spring-fall period of 2010 in the field conditions. We collected and processed the samples for the morphometric analysis according to the accepted ichthyologic methodologies [6]. The fish was caught with the help of nets with a mesh of 3.5 cm. The measurements and calculations were done for the fresh fish species from different size groups. On the whole we have analyzed 975 species.

In order to define protein and lipid concentrations in the muscle tissue we took 2 samples of the tissue from each fish species of the lakes in question. Definition of the protein concentration was done according to the photo-colorimetric method (Lowry method) [7]. We measured lipids by extraction of the sub-samples of the tissue under study [7].

To estimate variation of the biological parameters and elicit the main factors influencing on them we carried out a multi-dimensional factor analysis on the basis of STATISTICA software (Statsoft, USA) [8].

The lakes under study considerably differed in the mineralization level. The total amount of salt ranged from 1.8 to 12.0 g/l. Besides salinity the lakes differed in hardness, pH and the content of the major water ions. The hydrochemical indices of the lakes are shown in table 1.

Table 1

The hydrochemical indices of the lakes are (2010)

Variables	Low salinity 1.4-2.7 g/dm3		Moderate salinity 5.3-8.6 g/dm^3		Saline 12.0 g/dm^3
	M±m	Min-max	M±m	Min-max	
Mg^{2+} mg/dm^3	62.1±16.6	45.5-78.7	207.0±39.0.	168.0-245.7	451.0
Cl^- mg/dm^3	627.5±110.5	517.0-738.0	1923.0±322.0	1601.0-2245.0	3933.0
SO_4^{2-} mg/dm^3	54.2±34.9	19.2-89.13	153.6±134.4	19.2-288.0	556.8
Ca^{2+} mg/dm^3	39.5±5.5	34.0-45.0	77.0±21.0	55.9-97.9	56.0
HCO_3^- mg/dm^3	427.9±19.1	408.8-447.0	622.8±63.7	559.2-686.5	964.0
CO_3^{2-} mg/dm^3	19.2	-	-	-	-
Na^++K^+ mg/dm^3	466.9±123.7	343.0-590.6	1276.5±118.6	1157.9-1395.1	50.13
Cl^- mg/dm^3	7.0±1.2	5.65-8.0	20.4±4.2	16.2-24.5	38.9
Hardness mg-eq/dm^3	2215.0±375.0	1840.0-2590.0	6690.0±1020.0	5670.0-7710.0	12000
Ions mg/dm^3	62.1±16.6	45.5-78.7	207.0±39.0.	168.0-245.7	451.0

The character of the salinity dependence of the processes and phenomena can be more or less revealed only if the data are collected through short periods of salinity

[5]. In connection with this in this research we used the classification of water basins by Posokhov [9] with more narrow bounds of salinity ranges. According to this classification the water basins in question were divided into the following groups: low saline (1.4-2.7 g/dm3), moderately saline (5.3-8.6 g/dm3) and highly saline (12.0 g/dm3).

Analysis of the data obtained in the spring-fall period has shown that the age composition of the population of the Prussian carp in the indicated water basins is represented by the species 2/2+ - 6/6+ years old. In different seasons the catch consisted of two-, three-, four-, five- and six-year olds. Two- and three-year old species prevailed in lakes Malinovoye and Bolshoye, 26 and 23% correspondingly. In Buzan we caught mainly three-, two- and four-year old species (25, 22 and 22% correspondingly). 5/5+-year old species dominated in lake Shcherbakovo (27%). The share of other ages varied within 18-20%. In the low saline lake 5/5+-year old species prevailed; but their share in the population was significantly higher and reached 31%. Besides, the share of the four-year olds in the catch also increased up to 24%. Comparing the age structure of the Prussian carp from lakes of different salinity we can note a certain tendency: the change in salinity brings about the change in the age structure of the population. Older species prevail in highly saline waters which is connected with the adaptive capabilities of the organism. The balance of species of different ages in a population changes depending on the environment and presents in itself a self-adjusting system [10].

The gender structure of the populations is characterized by the balance of species of different genders. Percentage composition of the Prussian carp genders is shown at fig. 1 (A).

In the salinity range 1.8-5.6 g/dm^3 the percentage composition of the males and females did not differ significantly and was basically 1:6. The share of the females in the populations reached 85-87%. In the salinity range 7.7-12.0 g/dm^3 the sex ratio of the males and females was basically 1:3. The share of the females decreased to 75-72% which indicates a less favorable environment for the species [11]. *Sex ratio depends primarily on the hereditary properties of the species but is also considerably controlled by the external conditions*. Sex ratio can serve as an indicator of the population well-being as the number of males increases when the environment deteriorates and vice versa when it improves.

Depending on the ecological conditions the crucian carp usually reaches sexual maturity at the age of 3-4 years old and in very favorable conditions it can occur at the age of 2. Males become sexually mature a little earlier than females [11]. At picture 1 (B) we can see attainment of sexual maturity of the carp in the lakes under study. In the lakes Malinovoye, Bolshoye and Buzan the carp reaches sexual maturity at 2 years old (males) and 3 years old (females). In the lakes Glubokoye and Shcherbakovo both genders attain sexual maturity at 4 years of age. Thus, analysis of the material on the sex ratio and attainment of sexual maturity has shown that the lakes with water salinity of 1.8; 2.6 and 5.6 g/l are ecologically more favorable than the lakes with water salinity of 7.7 and 12.0 g/dm^3.

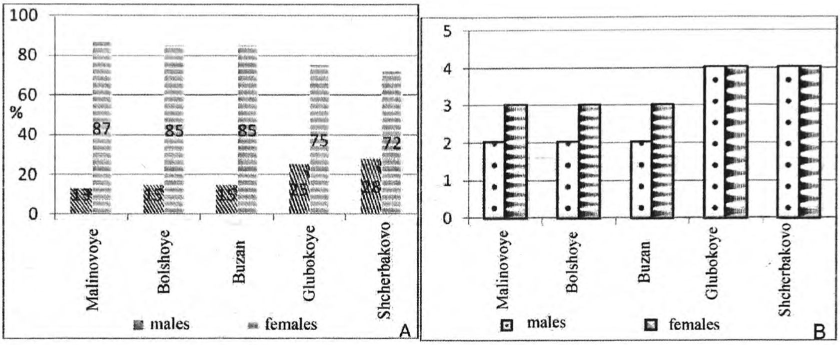

Fig. 1 A — Percentage composition of the genders in the population of *C. auratus*, B — Sexual maturity attainment in the population of *C. auratus*

The Prussian carp grows throughout its lifetime. This growth, as with all fish, depends on a number of factors, that include hydrological and hydrochemical conditions and food supply of the water basins. For the purpose of comparison of the individual growth of the carp we used the following indices as weight gain and tempo of growth. Judging by the obtained data in all the lakes in question the biggest weight gain of the Prussian carp occurred mainly in the age group 5/5+ and the length gain happened at an earlier age of 2-4 years old. Growth tempo of both length and weight decreases with age in the carp populations ranging from 2/2+ to 6/6+ in all the lakes which indicates a difference in the character of growth of the fish before and after the age of sexual maturity. As a rule before the sexual maturity fish grow the fastest. Therefore in the first years of life there is the fastest linear growth. After maturity the growth tempo decreases [11].

The data we received on the carp growth was compared with the water salinity. Dynamics of this dependence is shown at fig. 2. In the salinity range 5.6 to 7.7 g/dm^3 weight and length gain decreases for all the ages except 2/2+ year-old species. With salinity level over 7.7g/dm3 weight and length gain increases for all the ages. Dependence of the growth gain on the water salinity level is of a fluctuating nature with a decrease in the salinity range 5-8 $^0/_{00}$, which is confirmed by Khlebovich [4]. The data we obtained indicate rather drastic changes in the intensity and orientation of the metabolic processes in the narrow salinity range: 5-8 $^0/_{00}$.

We have calculated the total weight and length gain for the carp of all ages in all the lakes under study. Dynamics of the dependence of the obtained values of the water salinity is shown at picture 2(A). On the curve we can see a drastic decrease of the indices (weight and length gain) in the range 5.6-7.7 g/dm^3 which indicates suppression of the growth of organisms.

Picture 2(B) well illustrates the change in the feeding rate in the lakes of different mineralization levels. The more salient the water the higher the feeding rate. In the range of critical salinity the feeding rate does not decrease but continues to grow.

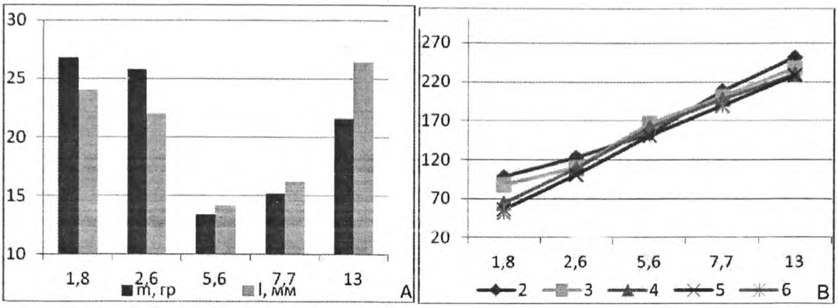

Fig. 2 A – Dynamics of the total weight and length gain of *C. auratus* in the lakes under study; B – Dependence INK ($^0/_{000}$) of different age groups of *C. auratus* on the water salinity

The functional status of the fish influences the protein and lipid content in their tissues. The biochemical analysis we have carried out revealed that in the lakes in question the protein and lipid content in the muscles of the carp species varied from 8.0 to 22.0g/100g; in summer it ranged from 10.0 to 23.0 g/100g, in fall from 11.0 to 23.0g/100g. These data confirm the results of Kuzmina [13] according to which protein content in the muscle tissue of fish of different species fluctuates from 6.2 to 23.0 g/100g. Comparing the data on salinity and protein concentration in the carp muscles of different age groups in the spring-fall period we have noted that the water salinity increase brings about protein concentration increase in the muscle tissue. Minimum concentration occurred at salinity 1.8g/dm3; maximum concentration was noted at salinity 12.0g/dm3. These data are proved by the correlation analysis (direct correlation r = 0.95).

Lipids play the main role of an energy source in the energy metabolism of fish [12]. The biochemical analysis has shown that in the studied lakes lipid content ranged from 2.0 to 11.5 g/100g in spring; from 2.5 to 11.7 g/100g in summer; and from 3.0 to 11.0/100g in fall. These data also confirm the discoveries of Kuzmina [13] according to which lipid content in the muscle tissue of fish of different species fluctuates from 1.2 to 15.0 g/100g. Comparing the data on salinity and lipid concentration in the carp muscles of different age groups we have registered that the water salinity increase brings about decrease in the protein concentration in the muscle tissue. Maximum concentration occurred at salinity 1.8g/dm3; minimum concentration was noted at salinity 12.0g/dm3. These data are proved by the correlation analysis (indirect correlation r = - 0.95).

Analysis of a number of scientific sources on fish physiology and biochemistry shows that any change in the water mineralization is accompanied by some change in the burden on the systems of osmotic, ion and acid-alkaline body balance. Cytoplasm tonicity is regulated by the change in the concentration of organic osmolytes (proteins, amino acids and their derivatives, urea etc.) the work of which is strictly coordinated under varying external osmotic conditions. It is typical for hydrobionts to have a socalled “sodium pump” which actively carries Na^+ through the membranes. Na^+ transportation is accompanied by an opposite transportation of some other ion (“counterion”) – usually K^+, NH^+ or H^+. Na^+ and K^+ transportation is catalyzed by Na+, K+ -ATPase and accompanied by energy consumption. Protein can accumulate as a result of muscle hypertrophy as with increased salinity water becomes more viscous for the fish movement, their muscles have to work harder i.e. experience strong exercise load. In order to get energy for movement ATP, which is synthesized owing to fat degradation, breaks down.

In connection with the study of a large number of indices the interactions between them are highly complicated. To confirm the aforementioned data, estimation of the variation of the indices in question and definition of the main factors influencing on them we have performed a multidimensional factor analysis using STATISTICA software (Statsoft, USA). 18 parameters have been analyzed. The results are shown in table 2.

The main variation of the studied indices is defined by 1 and 2 factors. As you can see in the table the first factor defines 63.7% of total dispersion; the second – 18.2%; the third – 6.4% and the fourth – 6.8%. The other factors do not give dispersion equivalent to the dispersion of one variable. Thus, in comparison with the other factors, bigger values of the correlation coefficients correspond to the first and second factors. These factors define 82% variation of the indices in question.

Table 2

Results of the factor analysis of C. auratus (n=1000, P=0.95)

Indices	Factor 1	Factor 2
Protein concentration	**0.92**	-0.04
Lipid concentration	**0.95**	0.05
Proportion of females	**0.92**	-0.24
Length gain	-0.29	**-0.82**
Weight gain	-0.36	**-0.75**
Sex ratio	**-0.94**	0.07
INK	**0.94**	-0.21
Total mineralization	**0.89**	0.07
Mg	**0.87**	-0.39
Ca	**0.71**	0.46
Fe	0.37	**-0.75**
Cl	**0.88**	-0.37
K	-0.11	-0.18
Na	0.19	**0.95**
SO_4	**0.86**	0.26
pH	**0.72**	0.26
Hardness	0.90	-0.33
Eigenvalues	13.38	3.82
% of the explained dispersion	63.76	18.20

The first factor is the most significant. It describes a strong dependence of the index of fish intestines fill rate, protein and lipid content in the muscle tissue in two- and five-year-olds, proportion of females and males, and sex ratio in the population (constraint level above 0.9). The first factor mainly describes mineralization and Mg, Cl and SO_4 content in the water basins (constraint level above 0.8). In this group of properties Ca and pH have a constraint level (0.7). Dispersion of the second factor is basically connected with Fe and Na cation concentration and fish development indicators: weight and length gain. The strongest links in this group of properties belong to Na (0.95). The constraint force with the other properties is not high. Dispersion of the third factor is weakly connected with the population and biochemical indices of the fish species in question. K cation content in factor 4 is described with a completely independent coordinate, which defines some variation of the carp indices development and does not exercise any significant influence on it.

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