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Some Indicators of Metabolism in the Muscles, Liver, and Gonads of Pike-Perch *Sander lucioperca* and Sichel *Pelecus cultratus* from the Gorky Reservoir

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Abstract—The content of total moisture, dry matter, lipids, proteins, ash, and nitrogen-free extractive substances in the muscles, liver, and gonads have been analyzed for pike-perch *Sander lucioperca* and sichel *Pelecus cultratus* of Gorky Reservoir. In the muscles of the females of these fish species, the products of the lipid and protein metabolism accumulate more intensively than in males. In both pike-perch and sichel, the accumulation of lipids, proteins, nitrogen-free extractive substances in the liver, as well as protein and nitrogen-free extractive substances in the gonads, are similar in males and females. During the maturation of pike-perch and sichel, substances of various chemical nature are assimilated in the gonads. The nature of the accumulation of metabolic end products in the muscles and liver with age is similar. In the sichel muscles, a direct dependence of the lipid content on age is found, while it is the opposite in the pike-perch muscles, which may be due to the peculiarities of the fish nutrition.

Keywords: pike-perch *Sander lucioperca*, sichel *Pelecus cultratus*, metabolism, muscle tissue, liver, gonad, gender, age, maturity stage, Gorky Reservoir

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INTRODUCTION

In the animal body, including that of fish, there is a continuous process of metabolism, when chemicals of different nature are synthesized and decomposed. An idea of the relationship between synthesis and assimilation can be obtained by determining the content of organic and mineral substances, which is necessary for vital activity and proliferation of the somatic cells, and the content that is deposited in the body and then egested as the metabolism end products over a certain period of time (Kizevetter, 1973; Malyarevskaya, 1979). Metabolism is influenced by environmental conditions, feed resources, fish life cycle, and other environmental factors (Sidorov, 1977; Kalay et al., 2008; Miroshnichenko, 2016; Payuta, 2016; Payuta and Flerova, 2017a). Normally, synthesis processes dominate in the somatic cells. Under the influence of various factors, the rates of these processes may be different. For example, under adverse conditions, they are slowed down, and the assimilation of the organic substances in the cells and tissues can then be observed (Malyarevskaya, 1979; Payuta, 2016).

Water plays a significant role in the metabolic processes; therefore, the moisture content is an indicator reflecting the state of biocolloids in the fish body. Proteins, lipids, and carbohydrates are the main substrates, their dynamics in the animal tissues characterize the ratio of constructive and energy metabolism (Malyarevskaya, 1979).

Among the other reservoirs of the Volga-Caspian Basin, the Gorky Reservoir plays an important role as the area of the commercial fishing due to its wide species diversity. Its main commercial resources are at a consistently high level and are significantly underutilized (Postnov, 2013). In the fish population of the reservoir, pike-perch *Sander lucioperca* and sichel *Pelecus cultratus* are valuable commercial species and also the objects of recreational fishing. Pike-perch is a large pelagic predator of the family Percidae, which feeds on small fish species (Konovalov, 2004). Sichel belongs to the family Cyprinidae; it is a facultative planktivorous predator. Its food spectrum is quite wide: the young fish feed on plankton; as they grow, they begin to consume insects, and adult fish mainly feed on the fry of the other fish species (Poddubnyi, 1955).

The study aims to assess the dynamics of the metabolic products in muscles, liver, and gonads of pike-perch and sichel from Gorky Reservoir.

Table 1. Body size, body weight, and condition factor of the studied fish specimens (*n*) of pike-perch *Sander lucioperca* and sichel *Pelecus cultratus* of Gorky Reservoir

Sex-age group	*n*, ind.	Body length (*SL*), cm	Body weight, g	Condition factor	
				Fulton's	Clark
			Pike-perch		
Mature males	13	42.0 ± 1.8	1185 ± 190	1.41 ± 0.02	1.30 ± 0.02
Mature females	14	37.7 ± 1.3	795 ± 124	1.35 ± 0.04	1.22 ± 0.03
			Sichel		
Juveniles	7	18.1 ± 0.6	55 ± 8	0.90 ± 0.05	0.81 ± 0.03
Mature males	15	23.4 ± 1.2	144 ± 24	0.99 ± 0.02	0.90 ± 0.02
Mature females	27	24.5 ± 0.9	171 ± 23	1.01 ± 0.02	0.88 ± 0.02

MATERIALS AND METHODS

The specimens of pike-perch and sichel have been caught at the standard trawling stations of Gorky Reservoir, starting with the Kostroma expansion and ending with a station near the city of Chkalovsk, at the end of September and beginning of October 2012 and 2013. A total of 27 mature pike-perch specimens aged 3+–8+ and 49 (seven juveniles and 42 mature specimens) of sichel aged 2+–8+ have been analyzed.

After the fish were sampled, they were transferred to the onboard laboratory in the containers filled with river water. The standard length (*SL*), body weight (total and without intestines), and the stage of gonad maturity were determined by the generally accepted method (Pravdin, 1966). Muscle tissue was then cut out on the refrigerant along the spine, the liver and gonads were dissected from the internal cavity, the weight of the sample was determined, and the tissues were then frozen. Samples were stored at –8°C until analysis. The fish age was determined by the growth zones on the scales.

In the muscles and organs of the fish, the relative content of moisture, dry matter, lipids, proteins, mineral substances (ash), and nitrogen-free extractive substances (NFES) were determined. The samples of liver and gonads were pooled for the analysis as an integral sample. The content of moisture and dry matter were determined using a two-step method. The lipid content was determined by the method of the lipid-free residue using the Soxhlet extractor, and the extraction was performed using the petroleum ether; the content of nonpolar lipids, which mainly perform the function of reserve energy substances, have been determined. The protein content was determined by the Kjeldahl method. Mineral substances were extracted using a gravimetric method of burning a sample in a muffle furnace until the white color of ash at a temperature of 550°C. The content of NFES (carbohydrates) was determined by calculation (Flerova, 2014).

Data are presented as mean values and their errors ($M \pm m$). The significance of differences was assessed using Student's *t*-test at $p < 0.05$.

RESULTS

The Fulton's condition factor in the studied specimens of pike-perch varied within 1.19–1.52 (1.38 on average), the Clark's condition factor was 1.08–1.36 (1.26); it was 0.76–1.29 (0.99) and 0.73–1.18 (0.87), respectively, in sichel (Table 1).

The muscles of pike-perch contained 80.21 ± 0.14 of moisture on average, 19.79 ± 0.14 dry matter, 0.68 ± 0.05 lipids, 16.67 ± 0.15 proteins, 1.18 ± 0.08 mineral substances, and 1.25 ± 0.16% NFES. Muscles of males contain significantly more dry matter, ash, and NFES and less lipids compared those in females; at the same time, the protein content in the female muscle tissue was somewhat higher (Table 2). A higher content of dry matter, including lipids, protein, and NFES, was found in the liver of the pike-perch males compared with those in females.

In the gonads of pike-perch males, the content of dry matter, protein, lipids, and NFES was lower, and the content mineral substances was higher compared with those in females (Table 2). In the ovaries of the third stage of maturity, an increase in the content of dry matter, lipids, and NFES was observed together with a decrease in the proportion of proteins and ash substances relative to the level of these indicators in the second stage ovaries (Table 3).

Muscle tissue of sichel contained 75.55 ± 0.26 moisture, 24.45 ± 0.26 dry matter, 3.94 ± 0.28 lipids, 17.87 ± 0.15 protein, 1.04 ± 0.03 ash, and 1.60 ± 0.13% NFES. The content of dry matter and lipids significantly increased in the following series: juveniles → males → females (Table 2). The proportion of protein increased in the following series: males → females → juveniles. There were significantly less mineral substances in the muscles of males than in females and juveniles. The content of NFES in the muscles decreased in the following series: juveniles → males →

Table 2. Chemical composition of the muscles, liver, and gonads in males and females of pike-perch *Sander lucioperca* and sichel *Pelecus cultratus* of Gorky Reservoir

Organ, sex	Relative content, %					
	total moisture	dry matter	lipids	proteins	ash	NFES
	Pike-perch					
Muscles:						
—males	79.92 ± 0.24	20.08 ± 0.24	0.58 ± 0.07	16.60 ± 0.30	1.36 ± 0.15	1.54 ± 0.28
—females	80.49 ± 0.12*	19.51 ± 0.12*	0.77 ± 0.06*	16.74 ± 0.12	1.02 ± 0.05*	0.99 ± 0.13*
Liver:						
—males	63.74 ± 0.58	36.26 ± 0.58	9.24 ± 0.49	13.25 ± 0.78	1.17 ± 0.16	12.60 ± 0.36
—females	72.15 ± 2.25*	27.85 ± 2.25*	4.91 ± 0.44*	13.15 ± 0.95	1.61 ± 0.27*	8.19 ± 1.06*
Gonads:						
—males	78.21 ± 0.03	21.79 ± 0.03	2.55 ± 0.12	15.28 ± 0.66	2.34 ± 0.04	1.63 ± 0.85
—females	72.79 ± 0.30*	27.21 ± 0.30*	6.90 ± 0.69*	15.86 ± 0.48	1.60 ± 0.08	2.86 ± 0.23
	Sichel					
Muscles:						
—males	75.76 ± 0.32	24.24 ± 0.32	3.79 ± 0.41	17.75 ± 0.21	0.99 ± 0.05	1.71 ± 0.19
—females	75.23 ± 0.40*	24.77 ± 0.40*	4.34 ± 0.41*	17.89 ± 0.23	1.06 ± 0.04*	1.47 ± 0.20*
—juveniles	76.41 ± 0.64*, f	23.59 ± 0.64*, f	2.66 ± 0.42*, f	18.02 ± 0.30	1.07 ± 0.04*	1.85 ± 0.23f
Liver:						
—males	50.87 ± 0.47	49.13 ± 0.47	22.71 ± 0.43	19.47 ± 0.66	1.49 ± 0.11	5.47 ± 0.74
—females	79.79 ± 0.40*	20.21 ± 0.40*	7.92 ± 0.29*	8.94 ± 0.88*	1.22 ± 0.02	2.14 ± 0.76*
Gonads:						
—males	64.00 ± 2.30	36.00 ± 2.30	24.37 ± 4.82	8.74 ± 3.76	0.61 ± 0.28	2.29 ± 1.66
—females	65.87 ± 1.72	34.13 ± 1.72	10.36 ± 3.86*	16.78 ± 1.44*	1.79 ± 0.31*	5.21 ± 0.75*

Here and in Tables 3–5: NFES are nitrogen-free extractive substances; *, f indicate the differences significant at $p < 0.05$ from males and females, respectively.

females. In the liver of females, there were less dry matter, lipids, protein, minerals, and NFES than in the liver of males.

In the sichel male gonads, the lipid content was higher, and the content of protein, ash, and NFES were lower compared with those in females (Table 2). During the gonad maturation, both in males and females, there was a significant decrease in the proportion of dry matter and lipids and an increase in protein and minerals, whereas the NFES content decreased in the testes and increased in the ovaries (Table 3).

The quantitative changes in metabolic rates depending on age were found in the muscles and liver of the studied fish species. The same dynamics of the total moisture and lipid content were observed in pike-perch muscle tissue at the age of 3+–8+: an increase in indicators from 3+ to 4+ followed by their decrease (Table 4). The proportion of proteins in the pike-perch muscles decreases from age 3+ to 5+, then it increased again until 8+. The content of minerals in the muscles has an upward trend. The proportion of NFES increased from age 3+ to 6+, after which it decreased (7+) and increased again (8+).

In pike-perch liver, the accumulation of dry matter and lipids had a similar tendency: from age 3+ to 4+, the indicators increased then decreased. The content of protein and ash increased significantly until the age of 6+ then decreased. After increasing the level of NFES from the age 3+ to 5+, there was a sharp decrease at the age of 6+ to a minimum at the age of 7+.

In the muscle tissue of sichel, the content of dry matter and lipids generally increased with age, and a slight decrease of these parameters was noted at the age of 5+ (Table 5). The protein content reached its highest value at the age of 5+ within the general downtrend. The age-related changes in the content of mineral substances were weakly expressed, whereas the proportion of NFES in sichel muscles decreased by 75% from the age of 2+ to 8+.

In the sichel liver, the content of dry matter and lipids decreased with increasing age. The protein content increased to the age of 5+ and then dropped down to the minimum value in the 7-year-old specimens. The ash content was characterized by an upward trend,

Table 3. Chemical composition of the gonads of different maturation stages in males and females of pike-perch *Sander lucioperca* and sichel *Pelecus cultratus* of Gorky Reservoir

Sex	Gonad maturation stage	Relative content, %					
		total moisture	dry matter	lipids	proteins	ash	NFES
		Pike-perch					
Males	III	78.21 ± 0.03	21.79 ± 0.03	2.55 ± 0.12	15.28 ± 0.66	2.34 ± 0.04	1.63 ± 0.85
Females	II	74.48 ± 0.10	25.52 ± 0.10	3.02 ± 0.01	18.41 ± 0.66	1.95 ± 0.08	2.14 ± 0.65
	III	72.36 ± 0.05*	27.64 ± 0.05*	7.87 ± 0.11*	15.22 ± 0.21*	1.51 ± 0.05*	3.04 ± 0.23
		Sichel					
Males	II	60.56 ± 0.15	39.44 ± 0.15	31.60 ± 0.29	3.21 ± 2.06	0.18 ± 0.01	4.46 ± 2.48
	III	67.43 ± 0.67*	32.57 ± 0.67*	17.14 ± 0.06*	14.28 ± 0.66*	1.03 ± 0.03*	0.13 ± 0.10
Females	II	57.02 ± 0.08	42.98 ± 0.08	31.44 ± 1.89	9.28 ± 2.16	0.35 ± 0.19	1.92 ± 0.54
	III	66.51 ± 0.74*	33.49 ± 0.74*	8.49 ± 0.56*	17.35 ± 0.52*	1.90 ± 0.18*	5.76 ± 1.24*
	IV	69.64 ± 1.51*	30.36 ± 1.51*	1.69 ± 0.18*	19.97 ± 0.83*	2.40 ± 0.43*	6.30 ± 0.63*

* Indicates the significant differences from the maturation stage II at $p < 0.05$.

Table 4. Chemical composition of the muscles and liver of pike-perch *Sander lucioperca* of different age groups of Gorky Reservoir

Age, years	Relative content, %					
	total moisture	dry matter	lipids	proteins	ash	NFES
	Muscles					
3+	$80.27 \pm 0.22^{1, 2}$	$19.73 \pm 0.22^{1, 2}$	0.70 ± 0.06^{1}	$17.02 \pm 0.16^{1, 2, 3}$	$1.09 \pm 0.08^{1, 2}$	$0.92 \pm 0.15^{1, 2}$
4+	$80.85 \pm 0.22^{1, 2, 3, 4}$	$19.15 \pm 0.22^{1, 2, 3, 4}$	0.83 ± 0.15^{2}	$16.40 \pm 0.34^{1, 4}$	$0.95 \pm 0.03^{1, 2, 3}$	0.96 ± 0.41
5+	$80.45 \pm 0.16^{3, 5}$	$19.55 \pm 0.16^{3, 5}$	0.68 ± 0.11^{3}	$16.29 \pm 0.52^{2, 5}$	$1.07 \pm 0.07^{3, 4}$	$1.50 \pm 0.46^{1, 3}$
6+	79.97 ± 0.54^{4}	20.03 ± 0.54^{4}	0.67 ± 0.11^{4}	$16.49 \pm 0.26^{3, 6}$	1.14 ± 0.22	$1.72 \pm 0.49^{2, 4}$
7+	$79.74 \pm 0.39^{1, 3}$	$20.26 \pm 0.39^{1, 3}$	0.66 ± 0.12^{5}	$17.22 \pm 0.34^{4, 5, 6}$	$1.55 \pm 0.38^{1, 3}$	$0.82 \pm 0.17^{3, 4}$
8+	$79.40 \pm 0.37^{2, 5}$	$20.60 \pm 0.37^{2, 5}$	$0.29 \pm 0.11^{1, 2, 3, 4, 5}$	17.32 ± 0.72	$1.49 \pm 0.19^{2, 4}$	1.51 ± 0.91
	Liver					
3+	67.93 ± 1.11^{1}	32.07 ± 1.11^{1}	7.72 ± 1.08^{1}	13.22 ± 0.13	$0.36 \pm 0.21^{1, 2}$	$10.78 \pm 0.10^{1, 2}$
4+	$64.62 \pm 0.07^{1, 2}$	$35.38 \pm 0.07^{1, 2}$	$8.72 \pm 0.83^{2, 3}$	13.47 ± 0.92^{1}	1.05 ± 0.16^{1}	$12.14 \pm 0.30^{1, 3}$
5+	65.05 ± 1.98^{3}	34.95 ± 1.98^{3}	6.70 ± 0.84^{2}	14.34 ± 0.75^{2}	1.47 ± 0.06^{1}	$12.44 \pm 0.63^{2, 4}$
6+	$70.58 \pm 0.22^{2, 3}$	$29.42 \pm 0.22^{2, 3}$	5.64 ± 0.27^{3}	14.94 ± 0.27^{1}	$2.95 \pm 0.06^{1, 2}$	$5.89 \pm 0.28^{1, 4}$
7+	$78.73 \pm 3.12^{1, 2, 3}$	$21.27 \pm 3.12^{1, 2, 3}$	$3.52 \pm 0.44^{1, 2, 3}$	$10.74 \pm 1.68^{1, 2}$	1.25 ± 0.30^{2}	$5.77 \pm 0.74^{2, 3}$

Here and in Table 5: the values with the same indices differ significantly at $p < 0.05$.

with the highest value observed in the specimens aged 5+, while the lowest was in those aged 4+. The minimum NFES content in the sichel liver was observed in the 3-year-old specimens; from the age of 4+ to 7+ there were minor fluctuations of this parameter.

DISCUSSION

Fish condition factor depends on many environmental factors (Kulachenko et al., 2011; Kovalenko, 2015; Payuta and Flerova, 2017a, 2017b). In pike-perch from different reservoirs, the Fulton's condition factor varies within 1.04–2.41, the Clark condition factor within 0.65–1.70 (Landyshevskaya and Zhivonkina, 1977; Kulachenko et al., 2011; Popov, 2013); that in sichel was 0.60–0.97 and 0.50–0.70, respectively (Kozhabaeva, 2008; Kuznetsov, 2011). The condition factor of the pike-perch from Gorky Reservoir falls within the indicated ranges, in sichel, this parameter was higher than that of the specimens from the other water bodies.

The accumulation of proteins, lipids, NFES, and minerals in the organs and tissues of fish is influenced by the conditions of their habitat (Kostyleva and Flerova, 2015; Payuta, 2016). The pike-perch and sichel inhabiting Gorky Reservoir have less content of

Table 5. Chemical composition of the muscles and liver of sichel *Pelecus cultratus* of different age groups of Gorky Reservoir

Age, years	Relative content, %					
	total moisture	dry matter	lipids	proteins	ash	NFES
	Muscles					
2+	75.95 ± 0.49^{1}	24.05 ± 0.49^{1}	$2.78 \pm 0.28^{1,2,3}$	$18.09 \pm 0.25^{1,2,3}$	1.04 ± 0.03^{1}	$2.13 \pm 0.13^{1,2}$
3+	75.90 ± 0.29^{2}	24.10 ± 0.29^{2}	3.64 ± 0.23^{1}	$17.73 \pm 0.31^{1,4}$	1.04 ± 0.06^{2}	$1.69 \pm 0.30^{1,3}$
4+	75.63 ± 1.07^{3}	24.37 ± 1.07^{3}	3.80 ± 0.81^{2}	$18.03 \pm 0.42^{5,6}$	$1.10 \pm 0.06^{1,2}$	$1.45 \pm 0.17^{1,3}$
5+	75.68 ± 0.66^{4}	24.32 ± 0.66^{4}	3.44 ± 0.57^{3}	$18.34 \pm 0.49^{4,7,8}$	$1,06 \pm 0.06$	1.47 ± 0.37^{2}
7+	75.48 ± 0.89^{5}	24.52 ± 0.89^{5}	$5.42 \pm 1.21^{1,3}$	$17.24 \pm 0.50^{2,5,7}$	$0.87 \pm 0.13^{1,2}$	0.99 ± 0.22^{1}
8+	$72.45 \pm 0.25^{1,2,3,4,5}$	$27.55 \pm 0.25^{1,2,3,4,5}$	$8.51 \pm 0.08^{1,2,3}$	$17.47 \pm 0.20^{3,6,8}$	1.06 ± 0.14	$0.52 \pm 0.30^{2,3}$
	Liver					
3+	78.46 ± 0.37^{1}	21.54 ± 0.37^{1}	10.77 ± 0.07^{1}	8.13 ± 0.09^{1}	0.29 ± 0.21	2.35 ± 0.60
4+	78.84 ± 0.15^{2}	21.16 ± 0.15^{2}	9.54 ± 0.69	8.66 ± 0.66	0.22 ± 0.04^{1}	2.74 ± 0.17
5+	79.07 ± 0.04^{3}	20.93 ± 0.04^{3}	$8.44 \pm 0.06^{1,2}$	8.90 ± 0.02^{1}	0.84 ± 0.04^{1}	2.76 ± 0.03
7+	$82.29 \pm 0.05^{1,2,3}$	$17.71 \pm 0.05^{1,2,3}$	6.91 ± 0.02^{2}	7.64 ± 0.01^{1}	0.46 ± 0.03^{1}	2.70 ± 0.02

protein and mineral substances in the muscle tissue but more lipids and have similar content of total moisture in the skeletal muscles compared with their relatives inhabiting the Caspian region (Kleimenov, 1952).

Metabolism is influenced by the qualitative and quantitative composition of food (Malyarevskaya, 1979; Kalay et al., 2008; Payuta and Flerova, 2017a). Lipids in the body of aquatic organisms are mainly formed from the lipids they obtained with the food. Lipids are very rarely synthesized from carbohydrates, since there are no vitamins A and B in the body of hydrobionts (Kleimenov, 1962). Plankton is rich in nutrients that are necessary to build the body of aquatic organisms. Therefore, a high content of proteins and lipids is found in the muscles of planktivores (Sidorov, 1977). Microalgae and organisms of zoobenthos are rich in proteins that contain a lot of nitrogen (Platonov et al., 2014). Lipids accumulate more intensively in predators eating large fish rather than juveniles (Sidorov, 1977).

In addition to this difference, the accumulation of metabolic products is due to the specific features. Thus, in pike-perch, the abdominal lipid lies in the abdominal cavity, enveloping the internal organs, mainly the intestines. In Cyprinidae, some assimilated lipidty acids are deposited as the esterified forms—as the storage lipids in the mesentery (Kleimenov, 1962; Baidalinova and Yarzhombek, 2011). Muscles of carp are characterized by a high mineral content, which may be due to the presence of small intermuscular bones, which cannot be separated (Kizevetter, 1973).

When comparing the fish of different systematic and trophic groups inhabiting Gorky Reservoir, we have found that the lipid content increased in the following series: pike-perch → bream *Abramis brama* → sichel (Payuta and Flerova, 2017a). The inverse correlation between the content of moisture and lipids in the muscle tissue of fish (Ljubojevic et al., 2013; Kostyleva and Flerova, 2015), which is known for different fish species, has also been observed in our study: the moisture content of muscles increased in the following series: sichel → bream → pike-perch. It should be noted that the muscle tissue of sichel contains more proteins than the muscles of the bream and pike-perch and less ash (Payuta and Flerova, 2017a).

There is evidence that the content of moisture, proteins, and lipids in the muscles of the bony fish of different sexes differ insignificantly (Medford and Mackay, 1978; Kostyleva and Flerova, 2015), which corresponds to the results of our study. At the same time, there is evidence that lipids and proteins accumulate in the muscle tissue of the females slightly more intensively than in males (Medford and Mackay, 1978; Lipidkhullin, 2013; Payuta and Flerova, 2017a). The obtained results are confirmed by our studies of the chemical composition of the muscles of pike-perch and sichel. In the muscle tissue of juveniles, lower lipid content and a higher content of proteins are found compared with mature fish (Khawaja, 1966; Payuta and Flerova, 2017a). The muscles of the males and females of sichel from Gorky Reservoir contain more dry matter and lipids but less proteins than immature specimens.

According to our data, the content of lipids, proteins, and NFES in males of pike-perch and sichel is higher than that of females, which corresponds to the results reported by several authors (Shatunovskii et al., 1975; Vdovin and Antonenko, 2014).

Information on lipid accumulation in the fish gonads of different sexes is ambiguous: in the Baltic

herring *Clupea harengus membras*, cod *Gadus morhua*, and flounder *Pleuronectes platessa*, the content of lipids in the ovaries is larger than that in testes (Krivobok and Shatunovskii, 1971; Shatunovskii et al., 1975). On the contrary, in bream, herring *Clupea harengus*, and spotted scat *Scatophagus argus*, the lipid content in the female gonads is lower than that in males (Bruce, 1924; Venkatesan et al., 2013; Payuta and Flerova, 2017a). According to our data, the gonads of the pike-perch females contain more lipids than male gonads; an opposite pattern is observed for sichel. Males of pike-perch and sichel have a less-protein content and NFES in gonads, which corresponds to literature data (Krivobok and Shatunovskii, 1971; Payuta and Flerova, 2017a).

During the process of fish gonad maturation, both an increase and a decrease in the content of dry matter, lipids, protein, ash, and NFES may be observed (Rao, 1967; Krivobok and Shatunovskii, 1971; Shatunovskii et al., 1975; Zaboukas et al., 2006; Venkatesan et al., 2013; Payuta and Flerova, 2017a). Similar changes in the chemical composition (except NFES) of the gonads of both males and females were found in sichel: a decrease in the proportion of dry matter and lipids and an increase in protein content and minerals; on the contrary, during maturation of the gonads of pike-perch females, the content of protein and mineral substances decreased, while lipids increased.

The moisture content in the muscles decreases with age in both pike-perch and sichel, which corresponds to the results reported by several authors (Malyarevskaya, 1979; Hanna, 1984; Payuta and Flerova, 2017a).

The content of lipids in the skeletal muscles of the pike-perch decreases with age, while, on the contrary, it increases in sichel. There is evidence that the lipid reserves in the fish body are highly variable due to their lability (Nikol'skii, 1963; Baidalinova and Yarzhombek, 2011; Lipidkhullin, 2013). Their content largely depends on habitat conditions, the quantity and quality of the food, life cycle, and other factors (Kizevetter, 1973; Payuta, 2016; Payuta and Flerova, 2017a). The increase of the lipid content in the muscle tissue with the fish age was observed in a number of studies (Nikolskii, 1963; Sidorov, 1977; Hanna, 1984; Payuta and Flerova, 2017a). At the same time, there is evidence of a decrease of the lipid reserves with age in roach *Rutilus rutilus* (Lipidkhullin, 2013).

The dependence of the protein content in skeletal muscles on the age of the pike-perch has the appearance of a parabola, while it has a downward trend in sichel. In many fish species, an increase in protein content with age is observed: in the specimens with a short and average life expectancy, this parameter has a form of a parabola or of a straight line (Shul'man, 1972; Courant, 1984; Payuta and Flerova, 2017a). A decrease in the intensity of protein metabolism with increasing fish age has been reposted (Kalay et al., 2008; Payuta and Flerova, 2017b).

In the muscle tissue of pike-perch and sichel, no clear dependence of the content of mineral substances and NFES on age was found. In different fish species, there are both a marked increase and a decrease of these parameters with age, while the changes in some cases were abrupt (Stroganov, 1962; Hanna, 1984; Payuta and Flerova, 2017b).

In the liver of pike-perch and sichel, the total moisture content increases with age, and dry matter and lipid content decrease, while the latter two parameters in pike-perch increase up to the age of 4+. There is evidence of an uneven change in the content of total moisture and dry matter in the liver with fish age and with an increase in the body size (Kozlov, 1972; Payuta and Flerova, 2017a). A number of authors note a higher content of lipids in the liver of adult fish as compared with young ones (Krivobok and Tarkovskaya, 1964; Vinogradov, 1985; Payuta and Flerova, 2017a). There are also data both on the alternation of increasing and decreasing lipid accumulation (Kozlov, 1972) and only on the decrease in this parameter (Bogoyavlenskaya and Veltischeva, 1972) in the fish liver with age.

In our study, an increase in the content of proteins, ash, and NFES was found in pike-perch and sichel to a certain fish age with a subsequent decrease. Similar age-related changes in the content of proteins and carbohydrates in the liver of aquatic organisms are also noted in other studies (Shatunovskii, 1980; Rath and Patnaik, 1981; Payuta and Flerova, 2017a). In addition, there is information about the accumulation of carbohydrates with age (Coban and Sen, 2011), and about the absence of carbohydrate content's dependence on the age in the fish liver (Krivobok and Tarkovskaya, 1964).

Water is the most mobile substance; therefore, the moisture content in similar tissues can vary considerably (Kizevetter, 1973; Payuta and Flerova, 2017a). In the body of aquatic organisms, lipid accumulation occurs selectively; in the same type of tissues and organs, the content of lipids may vary depending on the species, sex, age, food supply, and other environmental factors (Kizevetter, 1973; Sidorov, 1983; Payuta, 2016). Muscle tissue consists mainly of nitrogen-containing substances, while the content of carbohydrates is much smaller (Sidorov, 1977; Courant, 1984). The main reserve carbohydrate of animals—glycogen—is formed mainly in the fish liver and accumulates there accordingly with an increase of the liver size. The content of mineral substances in the body of aquatic organisms also vary (Stroganov, 1962; Kizevetter, 1973). The results of our research are consistent with the above data. The moisture content in the body of pike-perch and sichel was very variable, while the lipid accumulation was more active in sichel, whose food base is more nutritious. The sichel muscles con-

tain less minerals than that of pike-perch. The carbohydrates accumulate mainly in the liver of the studied fish. The differences between the same type of pike-perch and sichel tissues are significant, with the exception of the content of NFES in the muscle tissue and gonads of males, ash in the liver of males, and proteins and ash in the ovaries.

Therefore, a comparative analysis of the obtained data revealed both general patterns of accumulation of metabolic products in the tissues and organs of the fish of different systematic and ecological groups as well as specific features for each species, which are probably related to their dietary habits. The content of dry matter, lipids, and proteins in the pike-perch muscle tissue is lower than those in the sichel muscles. In pike-perch, as compared with sichel, the liver contains more NFES but less dry matter, lipids, and proteins. Sex differences in lipid and protein metabolism in the muscles and liver of pike-perch and sichel are expressed in a similar way: in muscles, lipids and proteins accumulate more intensively in females, while in the liver in males. In the gonads of pike-perch females, the content of these two components is higher compared with males; this is true only for the protein content in sichel. During the maturation of the ovaries of pike-perch, the content of proteins and ash decrease, while dry matter and lipids decrease in the gonads of both males and females of sichel.

The ratio of total moisture in the muscle tissue of pike-perch and sichel decreases with age, and the proportion of dry matter increases accordingly; the content of lipids decreases in pike-perch but increases in sichel; in pike-perch, the protein content varies in the form of a parabola, while it has a downward trend in sichel. In the liver of both species, a similar age-related dynamics of metabolic indices are revealed: the content of dry matter and lipids decrease, the content of proteins and NFES increase to a certain age and then decrease.

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COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interests. The authors declare that they have no conflict of interest.

Statement on the welfare of animals. All applicable international, national, and/or institutional guidelines for the care and use of animals were followed.

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