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Biometric analysis of food products of hybrid hypoophthalmichthys (*Hypophthalmichthys* spp.) to determine their nutritional value and use in the food industry

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ABSTRACT

This scientific work describes research, the purpose of which was to study the spectrum of nutrition and the composition of the food lump, as studies aimed at assessing specific weight (%) of essential nutrients (glycogen, proteins, and lipids) in particular organs and tissues of different size and mass groups of the hybrid of Silver carp and Bighead carp in ponds and reservoirs in different periods of the year. In 2018, and 2019, the juveniles of the hybrid of Silver carp and Bighead carp in ponds and reservoirs mainly consumed phytoplankton organisms (from 30 to 90% by mass), among which green, diatom, and euglena algae predominated by mass in the food group. Zooplankton occupied an insignificant place in fish nutrition (up to 5%), even though its quantity and biomass were sufficient in reservoirs. The hybrid of Silver carp and Bighead carp does not hurt zooplankton communities, so it can be included in the stocking volume of Silver carp. The feeding spectrum and rations of different groups of Silver carp and Bighead carp in ponds and reservoirs had a well-defined seasonal character related to the composition of feed objects. In all size and mass groups of the hybrid of silver and bighead carp from ponds and reservoirs in 2018, and 2019, mostly satisfactory values of general metabolism indicators were found – glycogen, proteins, and lipids in the liver, gills, and muscles of fish. The difference found in the availability of essential nutrients in the body of the studied fish indicates a change in the intensity and direction of their metabolic processes.

Keywords: nutrition value, carp, phytoplankton, zooplankton, liver, white skeletal muscle

INTRODUCTION

Fish and fish products are important for ensuring the normal development and vital activity of the human body, as they are a source of necessary vitamins, macro-, and microelements, and complete proteins of animal origin **[1]**, **[2]**, **[3]**.

One of the promising objects of cultivation in reservoirs of various types is a hybrid of Silver carp and Bighead carp because it has a fast rate of mass gain until the end of the cultivation period. High plasticity in the choice of food objects (phytoplankton, zooplankton, detritus, and in ponds, in addition, the remains of the dusty fraction of carp compound feed) allows hybrids to have significantly less tension in competition, compared to other species **[4]**, **[5]**, **[6]**.

The main factor affecting the growth of fish is providing it with nutritious food in sufficient quantity with effective use. The presence of natural food in the diet of fish is the main condition for normal growth and development. It should be noted that a lot of natural protein is necessary for fish growth. After all, the protein component is the building block for a living organism. The need for fish in a natural feed base, which includes animal protein, is 30% higher than the permissible need for this component of farm animals. There is also a great need for fish in vitamin and mineral nutrition, formed by their natural habitat. The fodder base of reservoirs should contain the necessary percentage of natural biologically active substances (amino acids, enzymes). Only in this case, can you count on the active growth of fish and an increase in the quality indicators of individuals. When the content of phytoplankton, zooplankton, and zoobenthos in the reservoir is insufficient, the following is often observed: slow growth of individuals; increase in fish departure; violation of metabolic processes in the organisms of individuals; fish diseases and a decrease in the quality of produced fish products; non-compliance of the grown product with modern environmental requirements. According to many authors, the minimum provision of natural food for fish should be at least 25-30%, and for young fish – up to 50% **[7]**.

One of the main components in the body of fish is protein, and its content depends on the rate of linear growth. In addition, in fish, proteins can be used as alternative energy sources, which, if necessary (with the participation of aminotransferases) play a role in the processes of adaptation to the negative factors of the environment **[8]**. Studies of internal organs, particularly the liver, provide objective information that can be used to determine the general physiological state of the body **[9]**.

The level of lipid accumulation is directly dependent on the fatness of fish, and the direction of lipid metabolism varies depending on the stage of ontogenesis, sex, and phase of the reproductive cycle **[10]**. Lipids are the basis for all intracellular membranes and play a significant role in cell metabolism **[11]**.

The glycogen content in the fish's liver tissues may decrease under the influence of pollution or deficiency of water-soluble oxygen caused by significant energy expenditure to overcome stress **[12]**. Under adverse conditions, detoxification and antioxidant protection systems change in fish tissues. Stimulation of detoxification mechanisms requires additional energy expenditure **[13]**, usually accompanied by suppression of energy metabolism. However, in the end, the effective work of regulatory and coordinating mechanisms ensures the organism's adaptation to changing conditions **[14]**.

Carps are a valuable industrial fish with high taste qualities. The meat is tender and tasty and belongs to the medium-fat group **[15]**, **[16]**, **[17]**.

Due to the characteristics of carp nutrition, the meat contains amino acids and polyunsaturated fatty acids of the omega-3 and omega-6 groups. Regular consumption, they help prevent the development of malignant tumors, and nervous disorders, improve the functioning of the heart, and strengthen the walls of blood vessels, to lower cholesterol and blood pressure in patients with hypertension **[18**], **[19]**.

Scientific Hypothesis

The obtained data on fish nutrition can serve as an assessment of the supply of the body with food components that are the main, i.e., their favorite food, a characteristic of fish diets and can provide a deeper insight into the use of feed resources by fish in reservoirs and the influence of fish on their diversity and population density, and in the final result in general on the functional state of the ecosystem.

The difference in the availability of essential nutrients (glycogen, proteins, and lipids) in the body of the silver and bighead carp hybrid may indicate a change in the intensity and direction of their metabolic processes. At the same time, among relevant research, this direction remains insufficiently studied. However, earlier works were widely carried out, which included the collection of ichthyological material with the subsequent study of fish nutrition and the chemical composition of their organs and tissues.

MATERIAL AND METHODOLOGY

The research was conducted in the spring, summer, and autumn periods from 2018 to 2019 in ponds based on the training-research-production laboratory of fish farming of the National University of Life and Environmental Sciences (TRPLF NULES of Ukraine) of Ukraine, village Nemishayevo, Kyiv region (zone Polissya); State Enterprise "Experimental Farm" Nyvka " of the Institute of Fisheries of the National Academy of Agrarian Sciences (SEEF "Nyvka" IF NAAS) of Ukraine, Kyiv is located on the border of the zones (it is on the river Nivka that the Forest-Steppe is divided -to the south and Polissya -to the north); Bila Tserkva Experimental Hydrobiological Station of the Institute of Hydrobiology of the National Academy of Sciences (BEHS IHB NAS) of Ukraine, Bila Tserkva (Forest-steppe zone), Kosiv, Kyiv region (Forest-steppe zone) and Velykoburlutsky, Kharkiv region (Forest-steppe zone) reservoirs.

Samples

The collection of ichthyological material was carried out during the stocking and catching of fish in ponds and reservoirs. The material for the study was: young-of-the-year, biennials, and triennials of the hybrid of Silver carp and Bighead carp (Figure 1, 2, 3).

Figure 1 A young-of-the-year hybrid of Silver carp and Bighead carp, which was caught in the spring from the wintering pond No. 2 of the NNVLR of the NULES of Ukraine.

Figure 2 Collection of ichthyological materials (biennials of the hybrid of Silver carp and Bighead carp) in the spring period during fishing of wintering pond No. 119 of the "Nyvka" DPDG of the IRG of the National Academy of Sciences of Ukraine.

Figure 3 Catching biennials of the hybrid of Silver carp and Bighead carp in the winter pond No. 119 DPDG "Nyvka" IRG of the National Academy of Sciences of Ukraine.

Chemicals

Formaldehyde (CH_2O, producer «Inter-Synthesis» Limited Liability Company, Ukraine, chemically pure for analysis).

Formalin (water solution formaldehyde, producer«Inter-Synthesis» Limited Liability Company, Ukraine).

Potassium hydroxide (KOH), (produced by "Inter-Synthesis" Limited Liability Company, Ukraine).
Anthrone ($C_{14}H_{10}O$), (produced by "Inter-Synthesis" Limited Liability Company, Ukraine).
Concentrated sulfuric acid (H_2SO_4), (produced by "Inter-Synthesis" Limited Liability Company, Ukraine).
Sodium hydroxide (NaOH), (produced by "Inter-Synthesis" Limited Liability Company, Ukraine).
Sodium carbonate (Na_2CO_3), (produced by "Inter-Synthesis" Limited Liability Company, Ukraine).
Potassium sodium tartaric acid ($KNaC_4H_4O_6x_4H_2O$), (produced by "Inter-Synthesis" Limited Liability Company, Ukraine).
Folin–Ciocalteu reagent (FC), (produced by "Inter-Synthesis" Limited Liability Company, Ukraine).
Vanillin reagent (produced by "Inter-Synthesis" Limited Liability Company, Ukraine).

Animals, Plants and Biological Materials

75 specimens of the hybrid of Silver carp and Bighead carp of different sizes and mass groups (young-of-the-year, biennials, and triennials) caught from ponds and reservoirs were processed.

Instruments

Set of grids with a mesh step from 0.03 to 0.1 m («CrayFish» Limited Liability Company, Finland).
Electronic laboratory scales (TBE-0.15-0.001-a-2, «Inter-Synthesis» Limited Liability Company, Ukraine).
Technical electronic scales (BTHE-6-H1K-1, "Inter-Synthesis" Limited Liability Company, Ukraine).
Measuring tape (1.5 m, "Inter-Synthesis" Limited Liability Company, Ukraine).
Laboratory filter paper (0.6 x 0.52 m, "Laboratory equipment" Limited Liability Company, Ukraine).
Counting chamber of Najotta ("Laboratory equipment" Limited Liability Company, Ukraine).
Binocular microscope (XSP-139B LED Ulab, "Laboratory equipment" Limited Liability Company, Ukraine).
Bogorov counting chamber ("ADS-Lab" Limited Liability Company, Ukraine).
Stereoscopic microscope (MBS-9, producer "Laboratory equipment" Limited Liability Company, Ukraine).
Spectrophotometer Unico 280 UV/VIS(ALTALAB Limited Liability Company, Ukraine).

Laboratory Methods

Processing of ichthyological materials was performed according to standard methods generally accepted in ichthyology **[20]**.

Determination of the taxonomic composition of algae was carried out according to the determinants **[21]**.

Phytoplankton biomass was determined by the calculation-volume method **[21]**. In-house processing of samples was carried out by the conventional hydrobiology counting-weight method in the Bogorov counting chamber under a stereoscopic microscope MBS-9. Phytoplankton samples were examined in a special Najott counting chamber 1.10^{-6} m under a light microscope, all detected algae species were determined and counted at 0.1 m^3.

Zooplankton organisms were identified to the species using determinants **[21]**.

The content of total proteins in tissue samples was determined by the method of Lowry et al. **[22]**, and the content of total lipids was determined using a phosphorovaniline reagent **[23]**. The anthrone method determined glycogen content in fish tissues **[24]**.

Description of the Experiment

Sample preparation: During the study of carp, 5 fish of different weights and ages were taken from ponds and reservoirs at certain time intervals.

Number of samples analyzed: We analyzed 45 gastrointestinal tracts of fish caught from ponds, and 30 from reservoirs, to determine the content of food lumps.

135 samples of tissues and organs (liver, white muscles, and gill petals) were taken from the fish caught in the ponds, and 90 samples were taken from the reservoirs to determine the number of proteins, fats, and carbohydrates.

Number of repeated analyses: Experiments were repeated once in experimental ponds and reservoirs.

Number of experiment replication: The number of repetitions of each experiment to determine one value was 5 times.

Design of the experiment: The gastrointestinal tract was cut from the oesophagus to the anus, and the degree of filling of the gastrointestinal tract was determined in points. Weighed on an electronic scale, measured the length with a measuring tape, and removed the contents by fixing with 4% formalin (1 part of 40% formalin to 9 parts of water). The fixed material was dried on filter paper until the trace of moisture disappeared and weighed on a scale. The content was weighed, mixed in water, and processed as a normal plankton sample. The species composition, number, and biomass of intact phytoplankton cells and zooplankton organisms were determined in the intestines of the studied fish **[25]**. Food similarity indices were calculated separately for groups of food organisms **[25]**.

The content of total proteins in tissue samples was determined by the method of Lowry et al. **[22]**. Briefly, 0.1 g of tissue and organ was hydrolyzed for 1 hour in 10 mL of 10% NaOH at a temperature of 60 °C. To 0.1 mL of the hydrolysate was added to 10 mL of solution No. 3, and staining was carried out for 15 minutes. Then, the sample added 1.0 mL of Folin's reagent diluted 1:1 with distilled water. The staining was carried out for 30 minutes. The extinction of the solution was determined on a spectrophotometer Unico 280 UV/VIS at 720 nm against control. The amount of protein was set according to the calibration schedule. Solution No. 3 was prepared from solutions No. 1 and No. 2 in a ratio of 9:1. Solution No. 1 was prepared based on 0.1 n NaOH with the addition of 0.02 g Na_2CO_3 and 0.005 kg of potassium, and sodium tartaric acid. Solution No. 2 contained 1 g CuSO4 per 1 liter of distilled water. The content of total lipids was determined using a phosphorovaniline reagent. Briefly, 100 mg of tissue was hydrolyzed in 1.5 mL of concentrated sulfuric acid for 15 minutes. About, 0.1 mL of the hydrolysate was added with 3 mL of vanillin reagent (10 mmol L^{-1} of vanillin and 11.5 mmol L^{-1} of phosphoric acid). The solution was stained for 40 min. The extinction of the solution was determined on a spectrophotometer Unico 280 UV/VIS at 530 nm against control. The amount of lipid was set according to the calibration schedule. The content of glycogen was determined by the anthrone method. Briefly, 0.1 g of tissue was hydrolyzed for 1 hour in 3 mL of 30% KOH at a temperature of 100 °C, then 0.9 mL of distilled water and 3 mL of 0.2% anthrone were added to 0.1 mL of the hydrolysate. Then the sample was boiled at 100 °C for 10 minutes. The extinction of the solution was determined on a spectrophotometer Unico 280 UV/VIS at 620 nm against control. The amount of glycogen was established according to the calibration graph.

Statistical Analysis

The results were evaluated by standard methods using statistical software Statgraphics Centurion XVII (StatPoint, USA) – multifactor analysis of variance (MANOVA), LSD test. Statistical processing was performed in Microsoft Excel 2016 in combination with XLSTAT. The statistical reliability of the results of the research was provided by analyzing samples with the number of fish 5 specimens.

RESULTS AND DISCUSSION

Scientists have proven that to fully support the body, a person should consume fish and fish products in the amount of 20 kg **[26]**, but, in recent years, it has been established thanks to an independent survey of the population that people consume no more than 10 kg of fish per year **[27]**, which is half below the required consumption rate **[28]**.

In modern conditions of fish farming, when growing fish, they mainly use a polyculture of carp and herbivorous fish, which ensures a balanced consumption of the entire complex of feed organisms and the formation of maximum fish productivity **[29]**.

The use of herbivorous fish cannot be limited to growing them only in ponds, these species are no less promising for reservoirs and other reservoirs of complex purposes.

All life processes occurring in the body of fish **[30]** are closely related to the external environment and are under its direct influence **[31]**, **[32]**.

An important place in fish farming belongs to the biotic conditions of the growing environment **[33]**.

Among the main biotic factors of the environment, that determine the efficiency of fish farming, is the natural fodder base of reservoirs **[34]**, which in terms of nutrient content and amino acid composition significantly exceeds the nutritional value of artificial fodder **[35]**.

The availability of feed resources is one of the main factors in the formation of optimal (from the ecological and fishery point of view) qualitative and quantitative characteristics of ichthyofauna **[36]** and maintaining its high industrial stock **[37]**.

Like any other reservoirs, the functioning and productivity of reservoirs are determined by the variety of trophic levels **[38]**, the main role of which belongs to the autotrophic, which is formed due to phytoplankton **[39]**.

By assimilating solar radiation and turning it into organic matter in photosynthesis, it creates primary products, due to which other hydrophones (organisms living in water) exist through food chains **[40]**.

When examining the contents of the intestines of young-of-the-year fish caught in the spring of 2018 from wintering pond No.101 and biennial fish caught in the spring of 2019 from wintering pond No.119 of the "Nyvka" DPDG of the National Academy of Sciences of Ukraine, it was a partially mucous mass. The share of algae in the biomass was estimated to be 40-50%.

17 species of algae were registered in the intestines of young-of-the-year fish, of which diatoms (4 species) and green, mainly flagellated (from the genera *Chlamydomonas*, *Pandorina*) – only 9 species, which abundantly vegetated in the reservoir. At the same time, euglenoids were practically not observed in the intestines (except for individual houses of the genus *Trachelomonas*), possibly due to rapid destruction. The shares in the biomass of

the algal component of the contents of fish intestines were: diatoms – 40%, green – 55%, others – 5%, while the content in ponds was: diatoms – 58%, and only green – 19% (Figure 4).

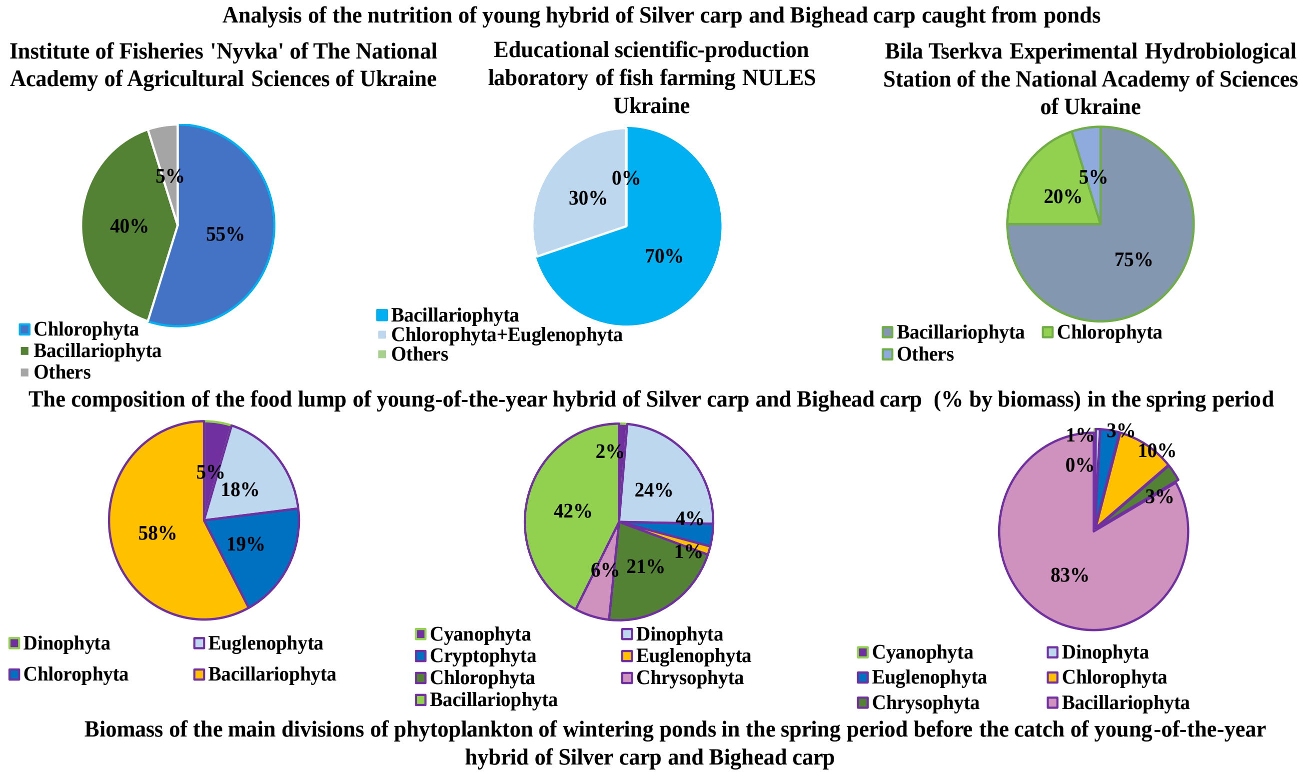

Figure 4 The composition of the food lump (% of the total mass) and phytoplankton biomass (%) of a young-of-the-year hybrid of Silver carp and Bighead carp in the wintering ponds of the studied farms in the spring of 2018.

In addition to 18 types of microscopic algae, the contents of the intestines of the biennial fish also included small fragments of filamentous green algae. Since no such fragments were found in the phytoplankton samples, it is most likely that they were not captured with the main mass of phytoplankton, but consumed "consciously". In the biomass of the algal component of the contents of the intestines of fish, the share of diatoms was 30% (in the pond only 7%), green microscopic – 30%, and green filamentous – 40% (in the pond 60%) (Figure 5).

The index of similarity between the species composition of phytoplankton and the contents of intestines for individuals of both age groups was 0.56.

The intestines of young-of-the-year fish caught in the spring of 2018 from the wintering pond No. 2 of the NNVLR of the NULES of Ukraine included about 30% of unicellular algae, mainly diatoms. The insignificant amount of green and euglenoids suitable for determination is most likely caused by rapid destruction when entering the digestive tract of fish. At the same time, not a single cell of dinophytic algae was noted in the contents of the intestines, although they have large sizes, and a rather strong shell, and their number in the reservoir was noticeable. The share of diatoms in the biomass of the algal component of the contents of fish intestines was 70% (in the pond – 42%), green + euglena – 3% (in the pond – 21+6%), others – <1% (Figure 4).

The contents of the intestines of small fish caught in the spring of 2019 from the wintering pond No. 1 of the NNVLR of the NULES of Ukraine had a yellowish tint and a significant proportion of mucus. The proportion of single-celled algae in the biomass did not exceed 20%, exclusively diatoms (8 species). The share of diatoms in the biomass of the algal component of the contents of the intestines of fish was 100% (in the pond – 58%) (Figure 5).

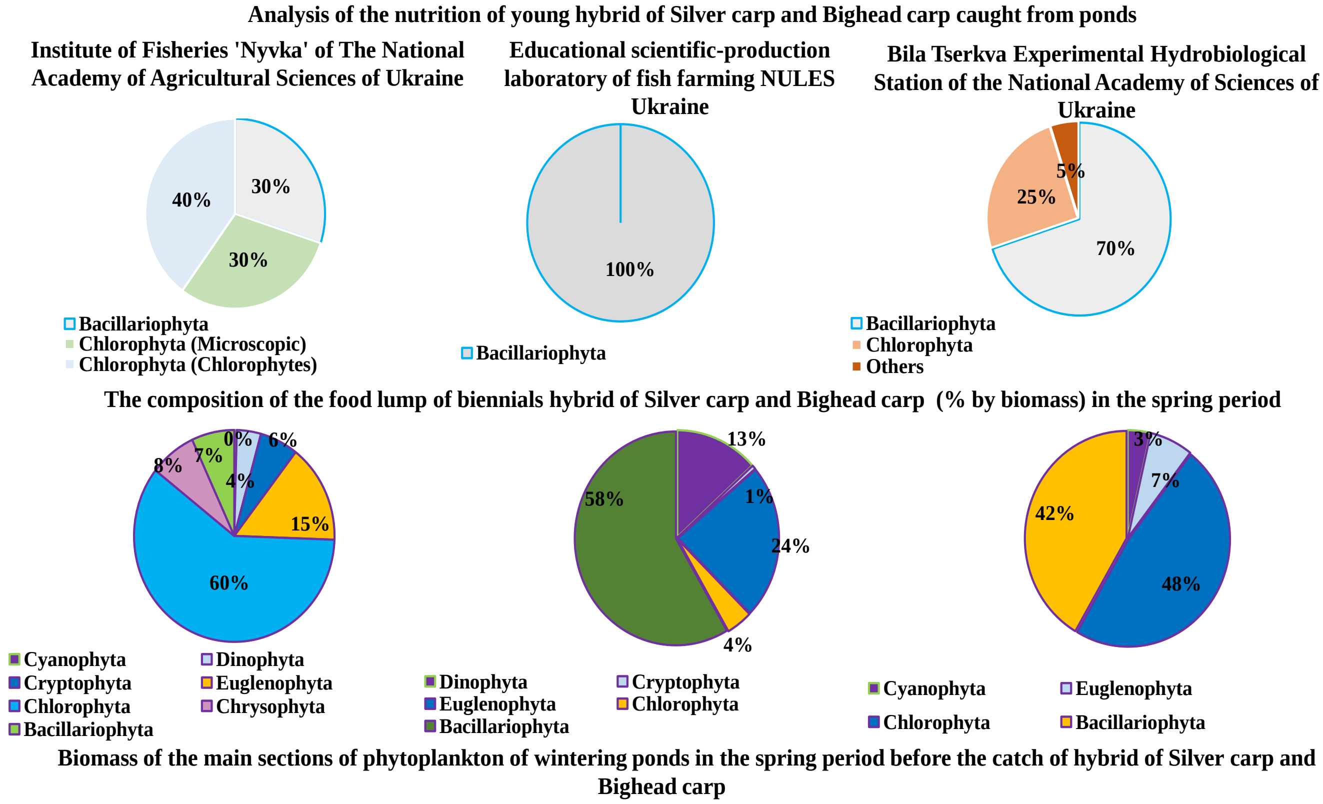

Figure 5 The composition of the food lump (% of the total mass) and the biomass of phytoplankton (%) in the yards of the Silver carp and Bighead carp hybrid in the studied farms' wintering ponds in the spring of 2019.

The index of similarity between the species composition of phytoplankton and the contents of intestines for young-of-the-year fish was 0.46, and for biennials fish – 0.26.

In the spring of 2018, the contents of the intestines of young-of-the-year fish caught from the wintering pond No. 5 of the National Agricultural Research Service of the National Academy of Sciences of Ukraine were green mass, 90% of which consisted of unicellular algae. At the same time, the number of diatom species even exceeded their number in the phytoplankton sample, possibly due to the consumption of benthic algae that did not enter the water column and, therefore into the phytoplankton samples (in particular, *Synedra ulna*, *Gyrosigma acuminatum*, *Caloneis silicula* and other large-celled forms were noted in the contents of the intestines). The shares in the biomass of the algal component of the contents of fish intestines were: diatoms – 75% (in the pond – 83%), green – 20% (in the pond – 10%), others – 5% (in the pond – 7%) (Figure 4).

The contents of the intestines of small fish caught in the spring of 2019 from wintering pond No. 11 of the BEGS IGB of the National Academy of Sciences of Ukraine were similar. At the same time, it should be noted that the estimated weight of the intestine sample of individuals of the two age groups was very close, which, given the larger body weight of small fish, indicates a less intensive consumption of phytoplankton, or a smaller share of it in the diet. The share of diatoms in the biomass of the algal component of fish intestines was 70% (in the pond – 42%), green – 25% (in the pond – 48%), others – 5% (in the pond – 10%) (Figure 5).

The index of similarity between the species composition of phytoplankton and the contents of intestines for individuals of both age groups was 0.76.

Hypophthalmichthys molitrix (Silver Carp) are abundant in the Mississippi River system, where they consume phytoplankton. There is concern that Silver Carp may influence phytoplankton community structure with cascading effects on other trophic levels. Information is needed regarding Silver Carp phytoplankton consumption rates and prey selection to assess their potential impact on the food web in the river. Investigated Silver Carp diets in a Lower Mississippi River backwater lake to quantify phytoplankton prey selectivity. Made measurements on 4 dates over a 2-y period, which spanned a range of hydrologic connectivity between the lake and the river and various fish sizes. Quantified selection by comparing phytoplankton community composition in the lake to prey in foreguts of captured Silver Carp using Vanderploeg and Scavia's relativized selection index. With a possible exception of diatoms on 1 date, there was no relationship between sample date or fish size on prey selection. However, there was a consistent pattern in prey selection: euglenoid algae were positively selected, the selection of colonial algae and diatoms was variable, and flagellates and filamentous cyanobacteria were negatively selected. Results are discussed in a conceptual model for Silver carp phytoplanktivory that incorporates the roles of habitat selection, prey availability, prey capture and processing, and digestive physiology **[41]**.

The average values of the share of glycogen in most organs and tissues of young-of-the-year of the hybrid of silver and bighead carp in 2018 were at the level of 0.5% and below. Exceptions were the indicators of the specific gravity of glycogen in the liver of bighead carp: in the winter pond No. 101 – above 2%; in winter ponds No. 2 and No. 5 – less than 2%. Thus, a higher level of glycogen in the liver of young-of-the-year fish is evident compared to its presence in the muscles and gills of the youth of the year of silver and bighead carp hybrids. The average values of the specific weight of protein in most organs and tissues of young-of-the-year hybrid of silver and bighead carp in 2018 were almost evenly distributed in them, at the level of 10-14%. Exceptions were the indicators of the proportion of protein content in winter pond No. 5 – they were lower (about 10%). The average values of the specific weight of lipids in most organs and tissues of a young-of-the-year hybrid of silver and bighead carp in 2018 were, like glycogen, at 0.5% and below. Exceptions were the indicator of the proportion of lipids in the liver of bighead carp: in winter pond No. 101 – above 3.5%; in winter ponds No. 2 and No. 5 – about 3%. Thus, a higher level of lipids (as well as glycogen) is present in the liver of young-of-the-year fish compared to its content in the muscles and gills of the youth of the year of the hybrids of silver and bighead carp. Thus, according to the results of studies conducted in 2018, it was found that the concentration of glycogen, total protein, and lipids in fish organs and tissues of fish from SEEF "Nyvka" IF NAAS and TRPLF NULES of Ukraine was satisfactory. The results indicate that the young-of-the-year hybrid of silver and bighead carp in the winter significantly reduces or stops the trophic activity and switches partially or completely to endogenous nutrition **[42]**.

The average glycogen values in most organs and tissues of biennials of the hybrid of silver and bighead carp caught from winter ponds in 2019 were about and above 0.5%. Exceptions were glycogen content in the liver of bighead carp wintering ponds: No. 119 about 3%; No. 1 more than 2.5%, and No. 11 more than 2%. As a result, a higher level of glycogen was found in the liver of biennial than its presence in the muscles and gills of the youth of the year hybrids of silver and bighead carp. The average values of the proportion of protein in most organs and tissues of biennials of the hybrid of silver and bighead carp caught from winter ponds in 2019, as well as biennials, fluctuated markedly, and in particular organs and tissues: in muscle levels of 14-14.5%; in the liver at the level of 12.5-14% (the highest pond fish No. 2); in gills at least at the level of less than 12.5-13%. The average lipids values in most organs and tissues of biennials of the hybrid of silver and bighead carp caught from winter ponds in 2019, biennials, were at 1% and below. The results of the biennials of the hybrid of silver and bighead carp in 2019 indicate that their physiological state at the time of the study was within the physiological norm **[42]**.

In the spring of 2019, during the stocking of the Kosiv Reservoir, it was noted that the proportion of single-celled algae in the intestines of young-of-the-year was about 30%, mainly diatoms and blue-green. Also, a small share was the remains of green and euglena algae, unsuitable for determination. About 30% of the mass of intestinal contents was formed by fragments of green filamentous algae and higher aquatic plants. In the contents of the intestines of fish, the share of the plant component was: diatoms – 40% (in the reservoir – only 7%), green filamentous + higher plants – 55% (in the reservoir – 60%), green + euglena – 5% (in the reservoir – 15 %) (Figure 6).

At the same time, when catching triennial fish (stocking with yearlings in 2018), the contents of the intestines showed a dark mass with a significant proportion of mucus and fat droplets. The share of unicellular algae in the contents of the intestines did not exceed 15%, and fragments of green filamentous algae and higher plants – 10%. In the contents of fish intestines, the share of diatoms in the plant component was 15% (in the reservoir – 21%), green microscopic ones – 78%, and fragments of green filamentous algae and higher plants – 7% (in the reservoir – 54%) (Figure 6).

In the fall of 2019, when triennial fish were caught (stocking in 2019), the mass of plant components in the intestinal contents was 70%, of which about 25% were single-celled algae and about 45% were fragments of green filamentous algae and higher aquatic plants. In the contents of the intestines of fish, the share of diatoms in the plant component was 25% (in the reservoir – 21%), green microscopic – 15%, and green filamentous + higher – 60% (in the reservoir – 54%) (Figure 6).

The index of similarity between the species composition of phytoplankton and the contents of intestines for young-of-the-year was 0.55, triennial fish (stocking with biennial in 2019) – 0.40, triennial fish (stocking with young-of-the-year in 2018) – 0.30.

Hypophthalmichthys molitrix (Silver carp) is an invasive fish that threatens ecosystem function by consuming basal food web resources. This study quantifies the gut contents of 83 Silver carp in the mainstem reservoir ecosystem of Kentucky Lake, Kentucky, Tennessee River Valley, United States. Silver carp guts contained phytoplankton (63.5%), zooplankton (33.8%), and heterotrophic flagellates (2.7%) based on volume. Study indicates that Silver Carp are planktivorous and consume organisms within multiple lower trophic levels across various habitats. However, shows that Silver carp diets differ at finer taxonomic scales and suggests these differences may be driven by forage availability **[43]**.

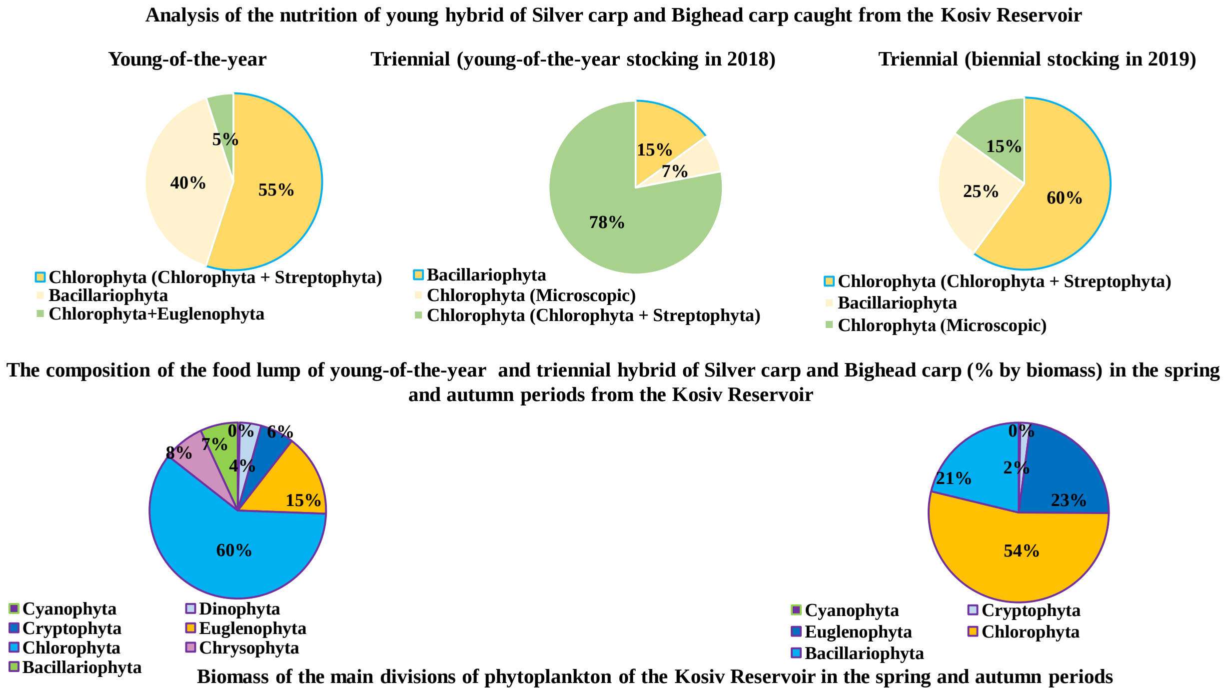

Figure 6 The composition of the food lump (% of the total mass) and phytoplankton biomass (%) of young-of-the-year and triennial hybrid of Silver carp and Bighead carp of the Kosiv Reservoir of the studied farms in the spring and autumn of 2018, 2019.

The average glycogen values in most organs and tissues of young-of-the-year and triennials of the hybrid of silver and bighead carp of the Kosiv Reservoir in 2019 were up to 0.4% and 1%, respectively. Exceptions were glycogen content in the liver of bighead carp of the Kosiv Reservoir, which was slightly more than 2% in one-year-olds and 5-5.5% in triennials in both years of research. Thus, a higher level of glycogen in the liver of annual fish is evident compared to its presence in the muscles and gills of the youth of the year of the hybrid of silver and bighead carp **[42]**.

The average values of protein content in most organs and tissues of young-of-the-year and triennials of the hybrid of silver and bighead carp from the Kosiv Reservoir in 2019 were lower in some organs and tissues in annuals, 12.5%, and higher in triennials, 15-22%. Moreover, the highest content was in the muscles of all age groups of fish, and the lowest protein content was in the gills. The average lipid content in the muscles and gills of young-of-the-year and triennials of the hybrid of silver and bighead carp from the Kosiv Reservoir in 2019 was at the level of annuals less than 0.5% and triennials about 1% or more. The lipid content in the liver was much higher: in young-of-the-year fish, they were about 3%, and in triennials from stocking in 2018, about 6%, and from stocking in 2019, more than 7% **[42]**.

The results of the young-of-the-year hybrid of silver and bighead carp in 2019 indicate that their physiological state at the time of the study was within the physiological norm. The studied triennial hybrids of silver and bighead carp from the Kosiv Reservoir in 2019 were marked by significant fluctuations in total protein content in muscles (20.04-22.16%), liver (18.00-18.56%), and gills (13.44-15.50%). The amount of glycogen in the liver (1.79-1.84 times) and lipids in the gills (1.19-1.36 times) increased slightly. A certain heterogeneity of the general physiological state of fish can explain the obtained data. This can be caused by hereditary factors determining a certain diversity of fish composition in reservoirs and the conditions of fish keeping **[42]**.

In the autumn of 2018, during the fishing of the Velikoburlutsky Reservoir, the contents of the intestines of biennial fish included about 45% of single-celled algae, mainly diatoms (12 species), Chlorococcum, and euglenoids, the latter of which were unsuitable for identification. In addition, a significant proportion of filamentous algae and fragments of higher aquatic plants were found in the intestines. From the weight of the contents of fish intestines, the share of diatoms was 50% (in the reservoir – 41%), green or *Chlorococcum* – 15% (in the reservoir – 6%), euglena – 10% (in the reservoir – 12%), filamentous algae and fragments of higher – 25%

(in the reservoir was not studied) (Picture 7). In addition to the mentioned algae, there was a significant share of blue-green biomass in the reservoir – 40%.

Considering the feeding characteristics of herbivorous fish, their use for melioration is the most effective for reducing areas of overgrowth and "blooming" of water **[44]**.

It should be noted that blue-green algae – *Microcystis*, and *Anabaena* emit toxins that negatively affect the natural self-cleaning of water bodies **[45]**.

At high air temperatures, intensive "blooming" of water occurs, condensation of water bodies occurs, and further increase has negative consequences for sanitary and biological water quality **[35]**, resulting in a deficit of oxygen in the lower water horizon and at night. The well-known organic and inorganic minerals are formed, including calcareous and toxic ones. **[46]**.

Blue-green algae species are the most resistant to temperature fluctuations: *Microcystis aeruginosa Kutz. emend. Elenkin i Anabaena flos-aquae* sp. **[47]**, **[48]**.

It was experimentally established that the toxins of blue-green algae inhibit the vital activity of nitrifying bacteria **[49]**, in connection with which the mineralization process ends in the first phase, which is accompanied by a decrease in the concentration of mineralized forms of nitrogen in the water **[50]**, as well as mass suffocation of fish in reservoirs. Some species of cyanobacteria produce toxins that affect people's health **[51]** when they consume contaminated water, fish, molluscs, or swim in a reservoir.

Freshwater cyanobacteria (blue-green algae) – *Microcystis aeruginosa* and *Anabaena flos-aquae* can produce hepatotoxic peptides that cause signs of poisoning in mice (LD50, 50 μg/kg) **[51]**, **[52]**.

In the summer of 2019, when triennial fish were caught, the intestinal contents also contained about 25% of diatoms, *Chlorococcum*, and euglena algae, while the share of filamentous algae and higher aquatic plants was much higher (up to 40%). In the contents of the intestines of fish, the share of diatoms by weight was 35% (in the reservoir – 54%), green or Chlorococcum – 15% (in the reservoir – 8%), euglena – 10% (in the reservoir – 6%), filamentous algae and fragments higher – 40% (in the reservoir was not studied) (Figure 7). There was also a significant share of blue-green biomass in the reservoir in summer – 31%.

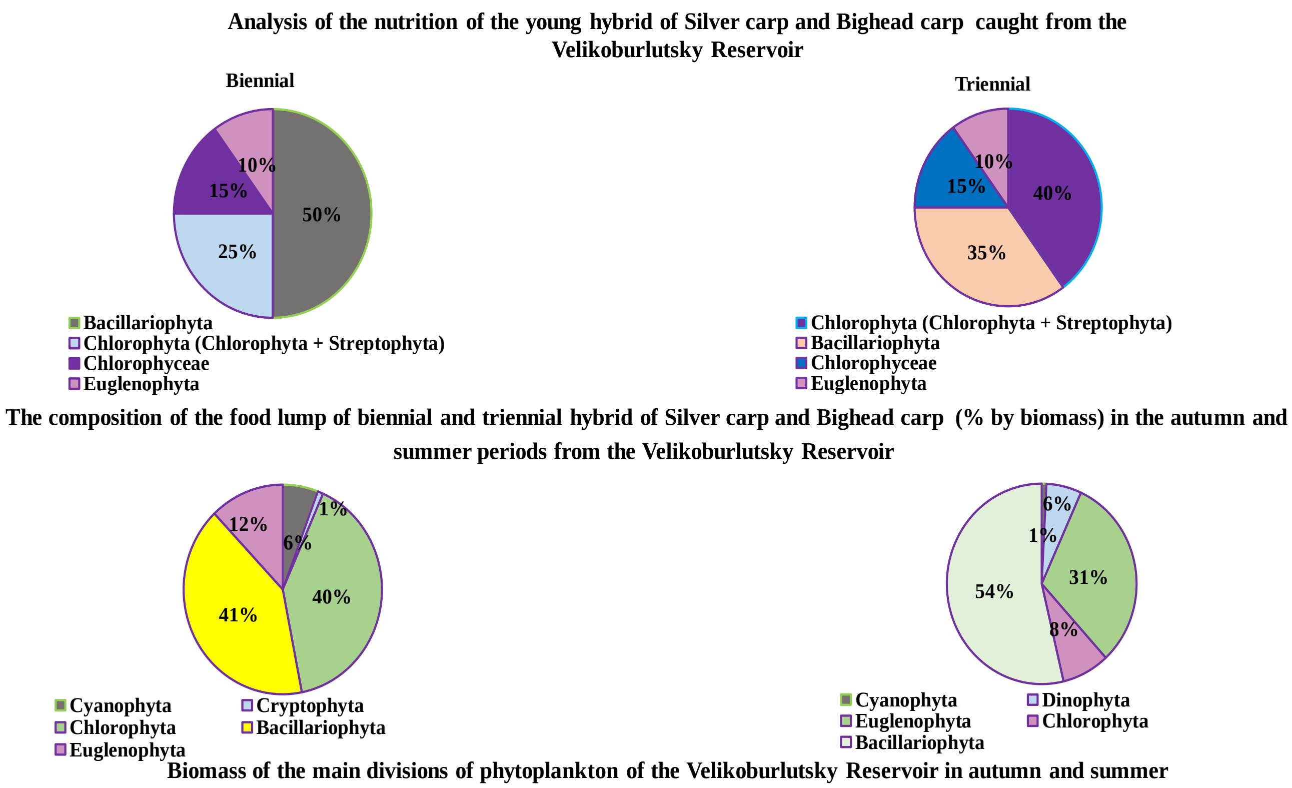

Figure 7 The composition of the food lump (% of the total mass) and phytoplankton biomass (%) of biennials and triennials of the hybrid of Silver carp and Bighead carp of the Velikoburlutsky Reservoir of the investigated farms in the fall of 2018 and summer of 2019.

The index of similarity between the species composition of phytoplankton and the contents of intestines for biennial fish was 0.48, triennial fish was 0.33.

Thus, the analysis of the food lumps of Silver carp and Bighead carp hybrid showed that phytoplankton plays a leading role (from 30 to 90% by mass) in its nutrition in all studied water bodies. Accordingly, when calculating the stocking volumes of the hybrid of Silver carp and Bighead carp, it can be attributed to phytophages, and their stocking at the expense of Silver carp will not hurt the zooplankton community, as an important food object for young fish and an agent of self-purification of water.

Common for individuals of both age groups was the presence of blue-green algae in the intestines, accumulated in the form of microscopic lumps covered with mucus. This was not observed in other reservoirs, even where the proportion of blue-greens in the biomass was higher.

The average values of glycogen in most organs and tissues of the youth of the year of the hybrid of silver and bighead carp of the Velykoburlutsky Reservoir in 2018, and 2019 increased from young-of-the-year to triennials and were, respectively, at the level: in muscle up to 0.5% or more; in gills 0.8% and more; the highest in the liver – 2.0-3.5% and more. The average values of protein content in most organs and tissues in biennials and triennials of hybrid of silver and bighead carp from VelykoburlutskyReservoir in 2018, and 2019 also increased with age and fluctuated in some organs and tissues of fish: in the highest muscles more than 12-17%; in the gills 12-14%; in the liver 12-16%. The average lipid content in the liver, muscles, and gills of the biennials and triennials hybrid of silver and bighead carp from the Velykoburlutsky Reservoir in 2018, and 2019 gradually increased from the youth of the year to triennials. It was at a lower level in muscles 0.2-1.2% and gills 0.2-1.5%. Lipid content in the liver was much higher: in biennials, 5.3%, and in triennials, more than 6%. Satisfactory levels of essential nutrients were characteristic of the experimental groups from the Velykoburlutsky Reservoir, not considering the slight excess of glycogen content in the gills of triennials **[42]**.

The feeding spectrum and rations of different groups of hybrid Silver carp and Bighead carp in ponds and reservoirs have a well-defined seasonal character related to the composition of feed objects. The composition of food largely depended on the qualitative composition and quantitative development of plankton only in ponds, in the conditions of reservoirs the indicator of "avoidance preference" for phytoplankton was expressed to a greater extent.

Thus, for the study, different size and weight groups of the hybrid of silver and bighead carp, caught from ponds and reservoirs are mainly characterized by satisfactory values of overall metabolic rates.

CONCLUSION

The analysis of the food lumps of the hybrid of Silver carp and Bighead carp showed that phytoplankton played a leading role (from 30 to 90% by mass) in its nutrition in all studied water bodies. Accordingly, when calculating the stocking volumes of the hybrid Silver carp and Bighead carp, it can be attributed to phytophages, and their stocking at the expense of white bullhead will not hurt the zooplankton community, as an important food object for young fish and an agent of self-purification of water. The feeding spectrum and rations of different groups of Silver carp and Bighead carp in ponds and reservoirs had a well-defined seasonal character related to the composition of feed objects. Food composition largely depended on the qualitative composition and quantitative development of plankton only in ponds. In the conditions of reservoirs, the "avoidance-advantage" indicator for phytoplankton was expressed to a greater extent. In all size and mass groups of the hybrid of silver and bighead carp from ponds and reservoirs in 2018 and 2019, mostly satisfactory values of general metabolism indicators were found - glycogen, proteins, and lipids in the liver, gills, and muscles of fish. In annual fish of winter ponds, total protein and glycogen content in all organs and tissues was slightly reduced. The organisms of biennial fish from feeding ponds were characterized by fluctuations in the content of glycogen in the liver (it was the highest in fish, 3.28-3.33%). Significant fluctuations in the total protein content of muscle, liver, and gills and a slight excess of glycogen in the liver and lipids in the gills of three-year-olds were observed in the reservoirs. The difference found in the availability of essential nutrients in the body of the studied fish indicates a change in the intensity and direction of their metabolic processes. The obtained results can be used for further research: studying the chemical composition of food products; research of functional characteristics of food products; optimization of the processes of production and storage of food products to ensure their maximum quality and preservation; studying the potential for creating new, functional food products and developing standards and quality control systems to ensure the safety and standardization of food products.

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Conflict of Interest:

The authors declare no conflict of interest.

Ethical Statement:

According to Protocol No. 10 of 18.04.2020 at the meeting of the Ethics Commission of the Faculty of Livestock Raising and Water Bioresources, National University of Life and Environmental Sciences of Ukraine, Act No. 3 and 4 were signed during the experimental research, i.e. in the process of the slaughter of cattle " all the rules of the current legislation of Ukraine were observed, following DSTU 4673: 2006.

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