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Fishery and environmental situation assessment of water bodies in the Dnipropetrovsk region of Ukraine

Olena Fedonenko, Volodymyr Yakovenko, Tamila Ananieva, Tetiana Sharamok, Natalia Yesipova, Oleh Marenkov

Oles Honchar Dnipro National University, P.M.B. 49050, Dnipro, Ukraine

E-mail address: hydro-dnu@ukr.net

ABSTRACT

The article presents the results of a long-term research of water ponds biocenosis in the southeastern part of Ukraine. The Department of General Biology and Aquatic Bioresources at Oles Honchar Dnipro National University specialists carried out all the researches. The paper provides a detailed analysis of hydroecological situation in the large and small water bodies, which are used for fishery purposes. It is shown that in the water bodies of different types the total environmental problems are the pollution with organic substances, eutrophication, and anthropogenic pollution with heavy metal salts. Under conditions of increased anthropogenic pressure on water bodies, the biocenoses have gradually degraded. This is manifested in the disappearance of ecologically sensitive species of hydrobionts and the dominance of species with high adaptive abilities. An important problem of current water ecosystems is also the getting and mass distribution of spontaneous fish in fish pools, which actively compete with inhabitat species for the nutrition base and spawning grounds. Separate chapters of the monograph are devoted to physiological and biochemical indicators of industrial fish species, their health status and parasite infestation. In this work the practical recommendations have been given for increasing fish productivity in reservoirs and improving their ecological status at the southeastern Ukraine.

Keywords**:** Zaporizke Reservoir, small water bodies, hydrochemical regime, heavy metals, nutrition base, ichthyofauna, fish biochemistry, epizootics, artificial spawning grounds

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Prof. I. Yu. Buzevich[1] and ***Prof. Yu. I. Hrytsan***[2]

[1]The Institute of Fisheries of the National Academy of Agrarian Sciences of Ukraine, Kyiv, Ukraine
[2]Dnipro State Agrarian and Economic University, Dnipro, Ukraine

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INTRODUCTION

Nowadays, in Ukraine, the fish consumption in different regions varies from 3 to 10 kg per person for year, which is several times lower than physiologically grounded norm. The main reasons for this are the insufficient amount of growing and catching domestic fish products, its high cost and limited assortment. The technologies of artificial fish-breeding used are morally outdated and do not meet the current socio-economic and environmental requirements. A large fisheries fund is used, in most cases, not effectively, which causes the low productivity [1].

The rational use of fish stocks through scientific regulation and the resource base depletion prevention, the promising biotechnologies use for obtaining high-quality, competitive fish products require an integrated research of the aquatic living resources state and the appropriate recommendations development for solving the problem of providing the population with high-grade fish products.

On the territory of Dnipropetrovsk region there are about 114.4 thousand hectares of fishing grounds. In addition to large reservoirs, the total area of which in the region is 70% of the water fund's area, small fishponds and stakes with a total area of about 39.6 thousand hectares are part of the fish farm [2].

The overwhelming majority of these water objects have a complex purpose, which involves their fishery use. Statistics show that for the last ten years the area of the water mirror used for fish breeding in the region has increased by 42%, but fishing activities in most water objects are still unordered.

Monitoring fisheries surveys indicate that the average fish productivity of small reservoirs and ponds is about 80 kg/ha, although the natural fodder resources potential in the reservoirs can increase the amount of fish growing and harvesting in 2–3 times. The share of valuable aboriginal fish species in the total ichthyoma is negligible – does not exceed 10%. Quite often, reservoirs low fish productivity leads to an unsatisfactory correlation of trophic groups in the ichthyofauna, as well as a low-value and garbage fish significant percentage. The poor quality of fish-planting material and uncontrolled waterlogging often cause infections and parasitic infections in fish that inhibit their growth and spoil the product appearance.

It should also be taken into account that virtually all small and medium reservoirs are reserved as future environmental objects, therefore activities in their water areas should be limited to means that do not cause environmental damage to aquatic ecosystems. Thus, there is an urgent need to carry out an inventory of fish-water reservoirs and to bring the processes of fish-breeding in small and medium-sized reservoirs in the region to the current Ukrainian legislation requirements.

The scientific work objective is the hydroecological state comprehensive reserch, bioproductivity and fish productivity in various types of reservoirs in the Dnipropetrovsk region, the development of practical recommendations for improving the fisheries management.

To achieve the objective, the following tasks are planned:

– to research the hydroecological conditions and peculiarities of the natural forage base development in different types of industrial fishery reservoirs;

– to research the biological and physiological features of industrial fish populations and their reproductive capacity;

– to investigate the state of fish industrial species reproduction and young fish physiological and biochemical indicators;

– to determine the fish productivity potential of water objects; to investigate the epizootic state of fishery reservoirs;

– to develop practical recommendations for improving the efficiency of fisheries management in reservoirs and ponds in order to increase their fish productivity and obtain high-quality fishery products.

1. MATERIALS AND METHODS

Hydroecological and fishery studies were carried out in the Zaporizke Reservoir and its tributaries, small reservoirs and fishing ponds of the Dnipropetrovsk region (Ukraine).

Hydrochemical analysis of water was performed by conventional standard methods [3].

- Measuring pH had been done with glass-electrode method.
- Dissolved oxygen level was measured with Winkler's method.

Ammonium ion concentrations were determined by a colorimetric indophenol titration method. Determination of nitrite nitrogen amounts in water samples had been done with basic Griess method, relies on the reaction of nitrites with sulphanilic acid giving diazo compounds, which couples with 1-naphthylamine. The reaction gives an azo dye of intense red colour. The concentration of nitrates was determined with colorimetric method after the reaction of nitrate nitrogen with sulfate-phenol reagent in an acidic environment.

The phosphate contents were analyzed by modified method of Deniges-Atkins based on the extraction of phospho-molybdate $P_2Mo_7O_6{\cdot}4H_2O$ with butanol and reduction with tin bivalent chloride in alcoholic solution. The extinction of the blue solution was measured with a colorimeter.

Permanganate oxidability of organics present in water samples was determined by Kubel method with 0.01 N solution of potassium permanganate ($KMnO_4$) in sulfuric acid at boiling medium. The color intensity was measured at 520 nm.

Preparation of water samples for toxicological analysis was performed by conventional methods and contained the following steps: water was filtered through a 0.45-µm membrane filter to separate suspended solids, especially clean acidified by hydrochloric acid to pH 2.5 and kept for laboratory processing. Thereafter, 1 l of water samples were evaporated to dryness and then the residue was dissolved in 1 N nitric and hydrochloric acids.

Samples of sediments were collected with Ekman-Burge dredger from horizon of 0–5 cm. The content of heavy metals in the sample was determined by spectrophotometer C-115M1. Collection and processing of samples was performed by conventional methods, whilst fish toxicological studies conducting heavy metals in the samples was determined by atomic absorption spectrophotometry after a dry ashing. In preparation for the analysis of biological samples of fish tissue and sediments, they were homogenised, dried at 105 °C to constant weight and then incinerated at 450 °C until the white ash that was treated with 1 N nitric acid and 1 N hydrochloric acid. The solute was filtered through a filter 'blue ribbon' and transferred to a container, bringing the volume to 10 ml, after that the sample was examined for heavy metals on a spectrophotometer C-115M. Bottom accumulation coefficient (BAC) and the accumulation rate (AR) of pollutants in aquatic organisms were calculated as follows:

$$K = \frac{Cs}{Cw}, \qquad (1)$$

where: Cs – the concentration of pollutants in sediments or aquatic organisms; *Cw* – the concentration of pollutants in the water.

The environmental assessment of water quality for parameters chemical composition had been done according to the 'Environmental Assessment Method of surface water for different categories' and 'Common Implementation Strategy for the Water Framework Directive (2000/60/EU), Guidance document № 10'

Zooplankton was sampled with the use of the Epstein planktonic sieve № 73 (50 μm mesh) by straining through the sieve from 50 to 100 liters of water. Sampled material was fixated in 4% solution of formaldehyde and settled in graduated cylinder. Qualitative and quantitative investigation of the material sampled was carried out in the laboratory using binocular microscope MBS-2 and microscope MBI-2 in Bogorova cell. To study the jellyfish population *Craspedacusta sowerbii* in the Zaporizke Reservoir samples were taken according to standard methods using planktonic mesh sieve № 25 in 2015. Zooplankton was identified down to genera or species. Species composition of zooplankton was identified with the use of the determinants. Nauplii (including copepodites) of calanoid and cyclopoid copepods were counted separately. Upon studying of jellyfish impact on qualitative and quantitative composition of zooplankton correlation coefficient (r) and its reliability was determined. To study seasonal dynamics of zooplankton during 2017 year samples of zooplankton were taken taken at two sites of the Zaporizke Reservoir: 1) Monastyrsky island (upper section), 2) Near Viys'kove villiage (lower section) (Fig. 1.1). To study vertical distribution of zooplankton samples of zooplankton were taken taken in six layers of the water column in the lower section of the Zaporizke Reservoir near Viys'kove villiage.

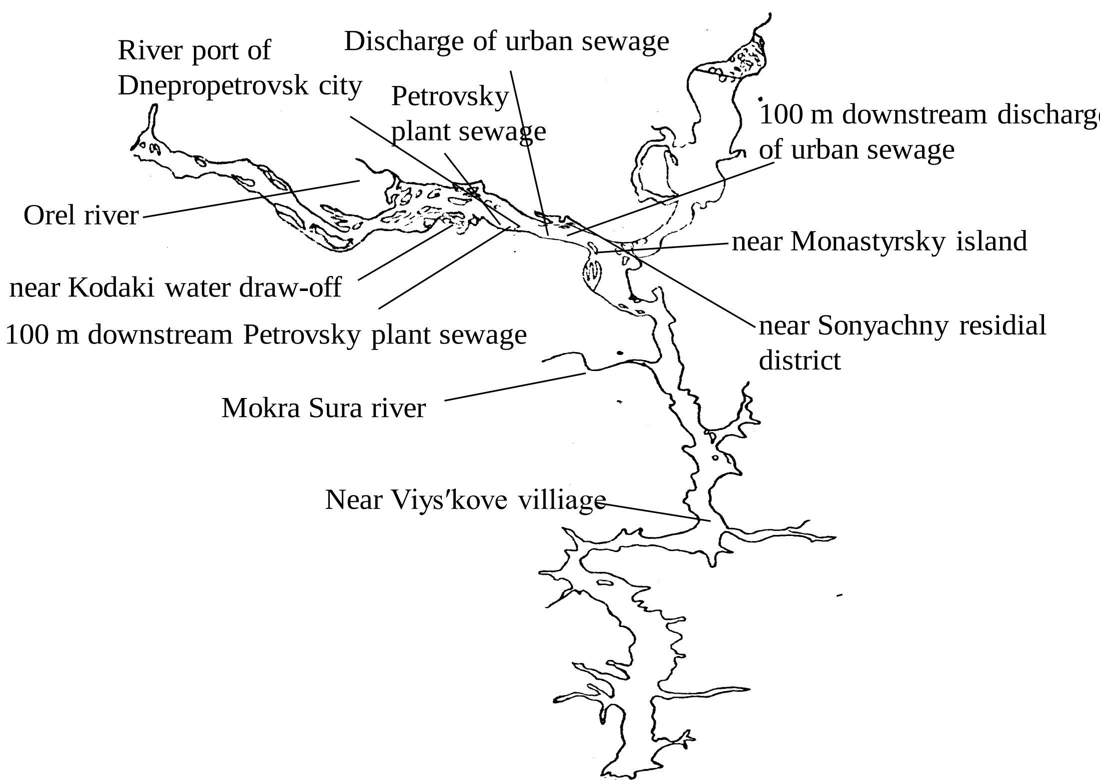


Figure 1.1. The sites of sampling along the Zaporizke Reservoir and its tributaries (47°57′36″N, 35°06′52″E)

To study littoral zooplankton samples of zooplankton were taken in the largest littoral biotops of the Zaporizke Reservoir: 1) Open littoral biotope, 2) Biotope of cane (Phragmites), 3) Biotope of pondweed, 4) Biotope of spatterdock beds.

Upon studying zooplankton of Samara bay samples of zooplankton were taken in the largest littoral biotops of the bay: 1) Pelagic zone, 2) Biotope of cane (Phragmites), 3) Biotope of pondweed, 4) Biotope of spatterdock beds.

To study zooplankton of Mokra Sura river samples of zooplankton were taken in September 2014 and in May 2015. Zooplankton distribution along the river was studied in the six sites: 1) Near the tire plant, 2) Near the Dnepropetrovsk – Zaporizhzhya highway, 3) Near the pontoon bridge, 4) 3 km upstream from the river mouth, 5) 2 km upstream from the river mouth, 6) mouth of Mokra Sura river (Fig. 1.2).

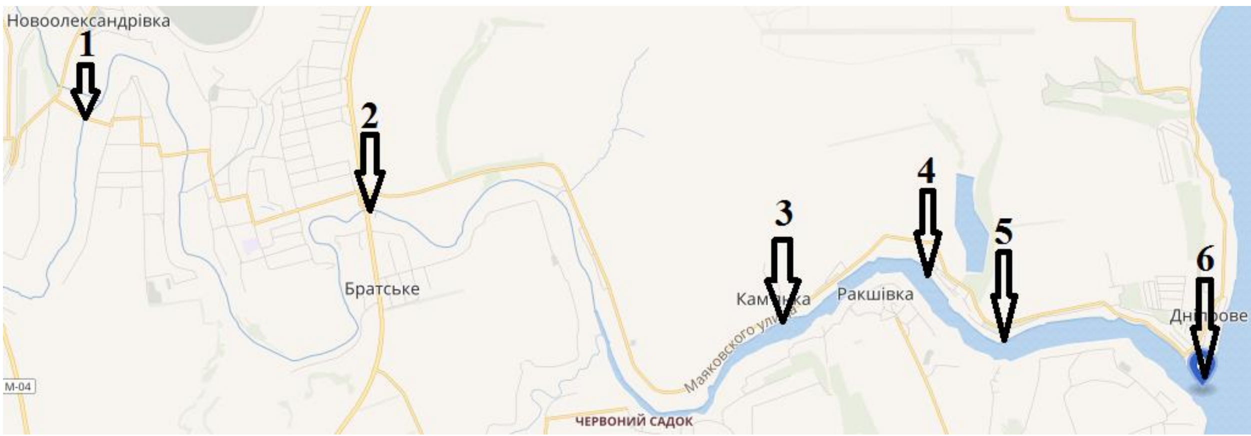


Figure 1.2. The sites of zooplankton sampling along Mokta Sura river (48°19′26″N, 35°08′35″E). 1 – Near the tire plant, 2 – Near the Dnipro – Zaporizhzhia highway, 3 – Aeration plant sewage discharge, 4 – 3km upstream the river mouth, 5 – 2 km upstream the river mouth, 6 – mouth of Mokra Sura river.

At each site the samples were taken at the triple replication. Samples for biotesting were taken in May 2015 and biotesting of water from the river sites was performed using the recommendations. Water quality of the river sites was estimatied was in accordance with the recommendations.

Distribution of zoobenthos along the Zaporizke Reservoir and its tributaries has been studied in the spring 2015 by zoobenthos sampling at 8 sites (Fig.1): 1) Orel' river 2) near Kodaki water draw-off, 3) near Solnechny residental district, 4) near discharge of urban sewage, 5) near Monastyrsky island, 6) Samara bay, 7) near the stream of Tonelna beam, 8) near Viys'kove villiage.

Seasonal dynamics of zoobenthos has been studied in littiral and profundal near Monastyrsky island during 2015. Birge-ekman dredge was used to take samples of zoobenthos according to standard technique. Sampled material was washed through mesh sieve № 25 and fixated in 4% solution of formaldehyde. Weighting of zoobenthos groups was performed on torsion scales. Identification of species composition has been carried out in the laboratory using binocular microscope MBS-2 and microscope MBI-2. Species composition of zoobenthos was identified with the use of the determinants. Based on species composition and abundance of zoobenthos groups at the sites of Zaporizke reservoir and its tributaries degree of contamination was estimated by the combined index of the state of communities (CISC) [4], which had 3 intervals. Ecological state of the sites with CISC value from 1 to 3 was characterized as ‘good’ state of the sites with CISC value from 4 to 7 as ‘satisfactory’ and state of the sites with CISC value from 8 to 11 as ‘bad’.

Distribution of phytoplankton along the Zaporizke Reservoir has been studied in September 2016 by sampled at 8 sites of upper part of the reservoir within Dnipro city (Fig. 1.1): 1) near Kaydaki water draw-off 2) Petrovsky plant sewage, 3) 100 m downstream from Petrovsky plant sewage, 4) River port of Dnipro city, 5) near discharge of urban sewage at the Festival pier, 6) 100 m downstream from discharge of urban sewage, 7) near Monastyrsky island, 8) near Viys’kove village. At each site the samples were taken at the double replication accordingly to the recommendations. Seasonal dynamics and vertical distribution of phytoplankton has been studied in profundal at a distance of 25 m from the shore at a depth of 5 m near Monastyrsky island during 2015. Samples were taken at the surface and bottom layers of the water column during the hydrological year from 01.03.15 to 6.11.16 with an interval of 3-10 days. The total number of samples was equal to 52. Temperature and water transparency according to Secchi disk were determined at the same time.

Phytoplankton was sampled for investigation of species composition with the use of the Epstein planktonic sieve № 73 (50 μm mesh) by straining through the sieve from 50 to 100 liters of water. Net samples were fixed with several drops of 40% formaldehyde up to 2% concentration for microscopic observations. Molchanov bathometer was used to take samples of phytoplankton for quantative investigation from surface and bottom layers according to standard technique. Batometric samples were fixed with Lugol solution and concentrated with the help of precipitation method. After precipitation in cylinder during 7–10 days the samples were processed using the Nazhotta’s camera (0.02 cm^3) in the laboratory using Carl Zeiss Jena microscope. Numerical abundance of cells was counted for each species. Species composition of algae was identified with the use of the keys. Phytoplankton biomass was determined for each species by cell volumes computing using simple geometric formulae for each cell form. Species with biomass 10% and more of the total algae biomass considered dominating. The degree of organic pollution (saprobity) of reservoir was evaluated by the saprobity index of Pantle and Bukk (in Sladecek modification) [5]. Species diversity was characterized using the Shannon index by phytoplankton abundance according to the formula:

$$H = -\sum_{i=1}^{n} \frac{n_i}{N} \cdot log_2 \frac{n_i}{N}$$

where: n_i is the number of individual species i, N – is the total number of individuals. Water quality of the reservoir sites was estimated in accordance with the recommendations.

The protein content in biological samples was measured by the Lowry method, the content of glycogen – by modified Zeifter’s method [6]. The resulting digital data were analyzed mathematically by standard methods of variation statistics, significant differences between the means was evaluated using Student t-test at a significance level of $p \leq 0.05$.

The content of total lipids in biological samples was measured gravimetrically by the Folch method after extraction with 2:1 chloroform-methanol mixture during 12 hours (DSTU 4897: 2007). One mass of tissue added to 20 parts chloroform-methanol mixture and left for extraction. Non lipid impurities were removed with 1% KCl solution [7].

Fishparasitological researches were carried out using the classical method of complete parasitological autopsy. For quantitative treatment of parasites, the same species experimental fish following indicators were used: the invasion extensiveness – EI (the infected fish ratio to the the total number, %); the invasion intensity – II (the number of parasites of the same species per fish), the abundance index – AI (the parasites average number of a particular species in one reseached individual).

Research fishing was carried out on the basis of permits issued by the State Agency of Fisheries of Ukraine, Department of Protection, Use and Reproduction of Water Bioresources and regulation of fishing in the Dnipropetrovsk region (№ 0001, № 0002 – 2015, № 000037, № 000038 – 2016, 2017) within the limits of allocated quotas and approved work programs of scientific research works. Fish were caught with a standard set of stack nets in accordance with classical ichthyological techniques in accordance with the current legislation.

The fish were caught with a standard set of stacked nets with a mesh size of 30, 36, 40, 50, 60, 70, 75, 80, 90, 100, 110, 120 mm. At each observation point for the entire period of work it was analyzed at least 25 netting days of each mesh size. In the catches the species composition and mass fraction of each species was determined.

The biological analysis of fish was carried out in accordance with the classical methods of the ichthyology according to the following indices: standard and absolute body length, individual weight, sex, fattening factor, maturity stage, mass of sexual products, weight of individuals (both with and without entrails). Age of fish was determined according to standard ichthyological methods. To determine the age of the fish, the scales were taken from at least 10 individuals (5 females and 5 males) from each class interval of the size series. In order to determine the size and age structure of populations Morozov-Mayorova method was used. To prepare the preparation, several pieces of scales from the middle part of the body between the base of the first dorsal fin and the lateral line were taken and washed in a weak solution of ammonia (1–10 %). Then they were dusted with a soft cloth and placed between the two glass panes. The specified age was recorded in a biological journal or entered into a database of biological indicators of fish.

The physiological state of fish was estimated by the coefficients of fattening. Fatality of fish was calculated by Fulton (1) using the formulas:

$$K_f = \frac{m}{l^3} \times 100\% \qquad (2)$$

where: K_f – is Fulton fattening factor; m – is fish body weight, g; l – is standard fish length, cm.

To study the fertility of fish, ovaries were taken from females at IV stage of maturity. The stage of maturity of the gonads was determined visually. Individual absolute fertility was determined by the weight method; for this, samples of eggs weighing 1 g were taken in the middle section of the gonads and fixed with ethyl alcohol with a 2 % solution of formalin in a ratio of 1:1. The number of eggs in the sample was counted and multiplied by the total weight of the ovary. To determine the individual relative fertility, the values of individual absolute fertility were divided by the weight of the body of fish without internal organs. Statistical data was processed by conventional methods using software packages for personal computers Microsoft Excel 2007 and Statistica 8.0 (StatSoft. Inc, USA). All results are presented as the means ± standard deviation (SD).

2. FEATURES OF THE HYDROCHEMICAL AND TOXICOLOGICAL MODES OF FISHING RESERVOIRS IN DNIPROPETROVSK REGION

2.1. Zaporizke Reservoir

The Zaporizke (Dniprovske) Reservoir is located on the territory of Dnipropetrovsk and Zaporizhzhya administrative regions of Ukraine. The length of the reservoir is 129.7 km, the minimum width is 0.6 km, the maximum – 7.0 km, the average – 3.2 km, the area at the normal holding level (NHL) is 246 km^2. The maximum depth of the reservoir (near the dam of the Zaporizhzhya Hydrological Power Plant – DniproHPP) is 53, the average is 8 m. The height of the NPR is 51.4 m, the daily and weekly fluctuations of the level are up to 0.7 m. According to the classification of V. I. Zhadin, the reservoir belongs to the plain-river by its genesis and location, and to the valleys or channels reservoir by its configuration.

The reservoir is characterized by an asymmetric structure of the basin and is considerably elongated in the longitudinal direction at 129.7 km, has many tributaries in the mouths of the tributaries. The largest inflow – the Samara river – forms an independent boundary plaza with a surface of 57 km^2.

The main sources of water supply are water melt in the period of spring flood, to a lesser extent, autumn and summer rains, and partly groundwater. The rise of water in the reservoir during the spring flood is the most intense first in March and until the end of April – early May, then there is a further slow decrease in water level. The lowest water level in the reservoir is often observed in February. In July – October, water exchange in the Zaporizke Reservoir is insignificant. Water masses are fully exchanged in summer for 2–3 months [8].

The main tributaries of the Zaporizke reservoir are the Samara, Orel', Mokra Sura, Vorona, Ploska Osokkorovka, and Vilnyanka rivers. They form the runoff on its territory.

The formation of the hydrochemical regime of the Zaporizke Reservoir at the present stage takes place under the influence of external factors such as surface runoff, rainfall, anthropogenic load; as well as the speed of water exchange and inland processes. By the Alyokin's classification water of the Zaporizke Reservoir is a hydrocarbon-calcium of second type ($C^{Ca}{}_{II}$). In the Samara Bay ions of SO_4^{2-}, Cl^- and Na^+ prevail, and the water index is SNa by Alyokin's classification.

Seasonal fluctuations in the total mineralization of water in the reservoir were 263–394 mg/dm^3. In Samara Bay, these figures were several times higher: 1780–2460 mg/dm^3. High rates of mineralization of water in Samara Bay are due to the impact of waste mine water.

Seasonal changes in the pH value are mainly due to the state of carbonate equilibrium. The content of free CO_2 in water depended on the intensity of photosynthesis. Photosynthesis processes, which intensively occurred in the summer, resulted in an increase in pH to the maximum values of 10.5 (the lower part of the reservoir). In the summer, under conditions of oxygen deficit in the bottom layers, the pH values dropped to 6.2. The average seasonal pH values for the reservoir were 7.5–8.6.

The content of dissolved oxygen in water is one of the most important hydrochemical indicators, which determines the intensity of reducing and oxidative biochemical processes in the reservoir. Locally, the oxygen content dropped to critical values in sewage desalinization zones: below Kam'ianske city – from 3.2 to 4.8 mg O_2/dm^3, and in Dnipro city – from 2.2 to 6.8 mg O_2/dm^3. Critical concentrations of oxygen were observed in the summer (August) in the Samara Bay – 2.4–3.4 mg/dm^3. The lack of oxygen here was due to the intensification of mineralization processes of organic and mineral substances against the backdrop of high water temperatures and poor water exchange.

Organic matter in the water of the Zaporizke Reservoir is formed both at the expense of the alohtonous organic matter of waste household and domestic water, as well as autochthonous, which is formed at the expense of the life of hydrobionts. Seasonal changes in permanganate oxidation were characterized by an increase in values in the summer-autumn period (from 8–12 to 28–32 mg O/dm^3 in the central and lower parts of the reservoir), when phytoplankton is actively developing in the water reservoir and the intrinsic processes are of great importance.

Biogenic substances, which include mineral forms of nitrogen and phosphorus, silicon and iron, are of particular importance in the life of hydrobionts, since the productivity of aquatic ecosystems depends on their accumulation. At the same time, they are indicators of the sanitary state of the reservoir. The number of biogenic elements of greatest magnitude reached the end of summer, when the most intense mineralization processes of organic substances occur. The content of ammoniac nitrogen in water during the experimental period varied from 0.22 to 0.97 mg/dm^3 at different points (average 0.54 mg/dm^3 in the reservoir); nitrites – from 0.01 to 0.14 mg/dm^3 (0,019 mg/dm^3), nitrates – 0.11–2.8 mg/dm^3 (0.47 mg/dm^3), phosphates – from 0.25 to 0.62 mg/dm^3 (0.39 mg/dm^3). At the levels of the content of the main nutrient elements, the reservoir is characterized by a fairly high level of eutrophication.

According to the average annual data, the water of the lower part of the Zaporizke Reservoir belongs to the III class (moderate) on the content of phosphates and permanganate oxidability. The obtained values are not exceeded the norms of the Fisheries MAC, however, the impact of anthropogenic factor on the site is felt, as evidenced by the dynamics of the phosphate contents.

The tributary of the Dnipro river – Samara river is under significant influence of the coal mining industry of the Western Donbas. Constantly increasing anthropogenic pressure on the river (since 60 years) has caused significant changes in the chemical composition of water. According to many years of research, mineralization of Samara water has increased by an average of 2.2 times (from 1490 mg/dm^3 to 2888 mg/dm^3) due to chlorides, sulfates, sodium and magnesium – the main components of mine water. Changed ecological conditions of the river led to profound hydrobiological changes: depletion of species composition hydrobionts, freshwater forms which are replaced by saline and seaweed.

The pH values at different points of selection varied, on average, in the range from 6.85 to 8.4, with a strong predominance in the alkaline range. In general, this is typical of the Zaporizke Reservoir, where, for many years of observation, the average pH was 7.0–8.0. Only in the summer, in conditions of oxygen deficit in the bottom layers, the pH values there are reduced to 6.0. The Samara Bay water belongs to Class III (moderate) for the content of ammonia nitrogen and the level of permanganate oxidability, and to Class IV (poor) by phosphate content. The hydrochemical regime of this site is formed under the significant influence of the coal mining industry, effluent, industrial and domestic waste of large cities (Dnipro, Pavlograd), as evidenced by the worst investigated indicators and a high level of eutrophication. However, high content of phosphates did not exceed the MAC, and therefore it is possible to consider that the differences of the basic hydrochemical parameters are permissible, and the investigated area is suitable for use in fishery management.

Thus, according to the environmental assessment, the water of the Zaporizke Reservoir belongs to 3 classes of quality, 4 categories (satisfactory), eutrophic, α-β mezosaprobic. According to the fishery characteristics, the hydrochemical parameters, in general, corresponded to the MAC.

At present, anthropogenic factors have changed globally and continue to change the conditions for the fish habitat [9].

Among the anthropogenic factors affecting hydrobionts, the greatest danger is industrial wastewater containing heavy metal salts. Heavy metals Toxicity closely relates to their physical and chemical properties. They are characterized by high biological activity, the ability to accumulate in tissues and organs of living organisms [10,11].

Biological effects of heavy metals pollution on the environment are primarily due to direct toxic effects on hydrobionts, which leads to the damage to their physiological systems and mass death of organisms. In addition, there is a violation of primary products and trophic bonds, as well as equilibrium between auto- and heterotrophic organisms, which leads to a breach of biotic circulation and aquatic ecosystems destabilization.

In the Zaporizke Reservoir and its tributaries water, there is always a discrepancy of regulatory documents. By content of Cd, Mn, Cu and in some sites by content of Zn and Ni [12]. These heavy metals are able to reduce the number, suppress development and cause the death of planktonic groups, primarily – filterers, sensitive to the toxicants action. Polluting factors, getting into reservoirs, actively accumulate suspended particles by bottom sediments, hydrobionts: bacterioplankton, phytoplankton, zooplankton, zoobenthos, higher aquatic vegetation, and fish. [13]. On the quality of water significantly affect polluted bottom sediments, which under certain conditions may become a source of water masses secondary pollution with heavy metals [14]. The low efficiency of some industrial enterprises existing treatment plants has Negative impact on water quality.

Often, heavy metals get to the reservoirs with sewage from galvanic workshops, mining enterprises, ferrous and nonferrous metallurgy, machine-building plants, food industry enterprises, and surface runoff from agricultural fields treated with agro-chemicals. Heavy metals are constantly in aquatic ecosystems, change the form of compounds and biological availability, are characterized by high toxicity to the biota and the ability to cumulation, dangerous for ecosystems and organisms, even at low concentrations. Compounds of heavy metals in water exist in different forms, but most settle down to the bottom of the reservoirs and remain in the bottom sediments. High content of xenobiotics in bottom sediments leads to a violation of the reservoirs self-cleaning processes (in particular, reducing the number of bacteria, actinomycetes and total enzymatic activity).

We carried out the ecological and toxicological assessment of the Zaporizke Reservoir water of the on the heavy metals content. According to our many-years research in the reservoir, zones with high concentration of heavy metals have been identified. The most dangerous part in this plan is Samara Bay [15]. Our recent researches have shown that the Samara Bay water is classified as ‘contaminated’ and ‘heavily dirty’ by the level of heavy metal pollution [16].

During the research, the average annual concentrations of manganese and cadmium in the water of the Samara Bay exceed the MAC for fish farming reservoirs water by 1.7 and 1.2 times respectively (Fig. 2.1.1).

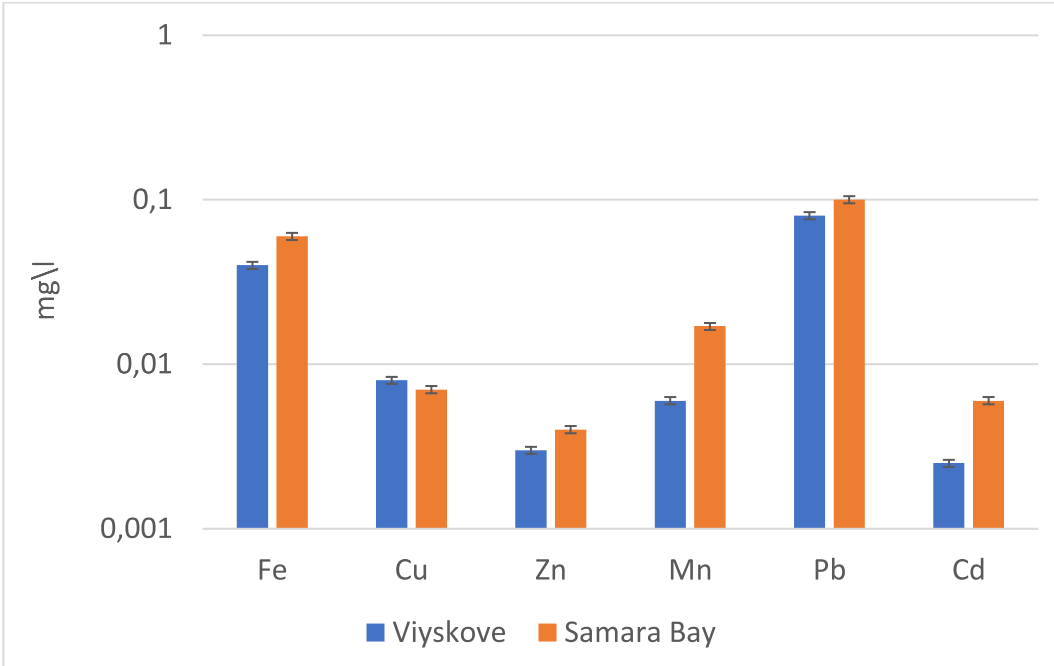


Figure 2.1.1. The content of heavy metals in the Zaporizke Reservoir water (mg/l).

Since 1998, the high content of copper in the Zaporizke Reservoir entire water area has been recorded in comparison with the fishery's MAC [16]. During the investigated period, the concentration of copper in both parts of was 7 and 8 MAC in the Samara Bay and the reservoir lower part, respectively. Sustainable copper contamination can occur because of sewage emissions from chemical, metallurgical, mine water, aldehyde reagents used to destroy algae.

The general concentration and forms of iron compounds in aquatic ecosystems depend on the catchment area geological features, the water exchange nature, the precipitation amount and its compounds arrival with sewage and atmospheric precipitations. In recent years, a decrease in the iron concentration in the Zaporizke Reservoir water has been observed in comparison with the data of previous researches.

The content of the heavy metals majority in the Samara Bay water was significantly higher compared to the lower section (the district of v. Viys'kove): iron – 50%, zinc – 25%, lead – 25%, manganese and cadmium – 2.8 times and 2.4 times respectively ($p \leq 0.05$).

The water quality in the reservoirs is one of the most important indicators that determine the prospects and possibilities of using water and biological resources both in the reservoirs itself and in the river lower parts. Based on the obtained data, an estimation of the Zaporizke Reservoir water quality was carried out according to toxic action specific indicators. According to zinc contents, the water of the reservoir both parts belongs to the quality II class, the 2 category and is characterized as 'good' and 'very good', the copper content of in the III class, the fourth category – 'satisfactory', 'little contaminated', and the content of lead – to Class IV, category 6 – 'bad' ('dirty'). According to other special indicators, the water quality of the two explored areas is different.

Assessment of the toxicological situation of the lower part of the reservoir allows us to assert that the water in this area according to the indicators of manganese and iron belongs to the II class of quality, the 2 category and is characterized as ‘good’ and ‘very good’, and cadmium – to the IV class, the 6 category – ‘bad’ (‘dirty’).

The environmental situation in Samara Bay is worse by some specific indicators. By the level of cadmium content, the Samara Bay water quality belongs to the V class and the 7 category – ‘very poor’, ‘very dirty’, and the content of manganese and iron – to the II class 3 category and is characterized as ‘good’ and ‘fairly clean’.

The heavy metal contents in bottom sediments are the objective and reliable indicators of the total anthropogenic loading upon reservoirs and their pollution levels. At two explored areas of the Zaporizke Reservoir the bottom sediments are represented by clayey silt. Under the condition of the water masses slowed flow, the most finely divided fractions of suspensions and dying phytoplankton settle down. In this connection there is a high content of organic substances from 5.1 to 10.0%. Clay soils are active heavy metal accumulators due to their high sorption capacity. Therefore, bottom sediments of the reservoir can be considered as a pollution indicator of the entire hydroelectric system [17].

Increasing the concentration of cadmium in the bottom sediments of the reservoir can be an extremely dangerous danger due to the secondary contamination of the aquatic environment. It is known that cadmium is one of the most mobile metals, from 26% to 36% (even up to 52%) of it in the Dnipro reservoirs bottom sediments is in the ion-exchange form. According to our research in the Samara Bay, the mobility of cadmium is 69.9, and in the reservoir lower part is 70.96 (Table 2.1.1). Increasing the water mineralization that is in contact with bottom sediments can help increase the migration of the metal and transfer it to the water column.

An increase in the concentration of lead in the bottom sediments of the Samara portion of the Zaporizke Reservoir is observed in comparison with the reservoir lower part – by 40% ($p \leq 0.05$).

The main factor determining the zinc distribution is the degree of soil dispersion and the content of organic matter in it. Anthropogenic factor plays a significant role in the distribution of zinc in the bottom sediments of the Zaporizke Reservoir. According to the current data, there is a tendency towards a decrease in the zinc content in the bottom sediments comparing with previous researches. In the bottom sediments of the reservoir lower part a large concentration of zinc is observed in comparison with the Samara Bay sediments.

The difference is 84%. The copper distribution of in the bottom sediments of the reservoir is determined, as for zinc, the amount of organic matter and dispersion degree. A large part of copper is assimilated with planktonic organisms, in which it participates in the substances circulation in aquatic ecosystems. Almost 30-50% of the copper total amount coming from the river runoff to the Dnipro reservoirs interacts with suspended particles, which gradually settle down to the bottom. Therefore, in the reservoirs bottom sediments, much more copper were concentrated than in the water column. In the bottom sediments of the reservoir lower part, the copper concentration prevails by 83% ($p \leq 0.05$) compared to the bottom sediments of the Samara Bay.

Table 2.1.1. Modern data on the heavy metals content in the Zaporizke Reservoir bottom sediments (mg/kg of dry weight)

№	Study area / Forms of heavy metals	Iron	Copper	Zinc	Manganese	Lead	Cadmium
1	The lower part (overall content)	2205.8 ±204.0	194.61 ±13.0	20.32 ±2.0	264.86 ±20.8	22.91 ±2.1	0,31 ±0.031
2	The lower part (mobile form)	184.64 ±10.0	19.31 ±2.31	2.01 ±0.02	102.07 ±90.0	8.92 ±1.92	0.22 ±0.021
3	The lower part (mobile coefficient)	8.37	9.92	9.89	38.53	38.93	70.96
4	Samara Bay, (overall content)	5331.5 ±441.5	33.31 ±9.02	3.27 ±1.02	1886.59 ±163.40	38.33 ±8.01	2.29 ±1.05
5	Samara Bay (mobile form)	525.80 ±20.04	1.96 ±0.65	0.17 ± 0.017	242.57 ±56.5	8.12 ±1.05	1.6 ±0.2
6	Samara Bay (mobile coefficient)	9.86	5.88	5.19	17.85	21.18	69.86

The manganese content in bottom sediments is closely related to the concentration of organic matter in them. According to obtained results, the manganese content in the reservoir mud increased by approximately 14%, which is a consequence of both sedimentation processes and anthropogenic impact. This trend can be traced in the Samara Bay area. The manganese concentration in this area exceeds its content in the reservoir lower part by 86% ($p \leq 0.05$). The increase in the manganese concentration in the reservoir bottom sediments can constitute an extreme danger, since oxygen deficiency begins its migration from sediments into the water column.

Concerning the iron content in the Zaporizke Reservoir silts, there is a tendency to increase it. Moreover, the Samara Bay bottom sediments contain almost 2.4 times more iron than the bottom sediments of the reservoir lower part.

Thus, on the toxicological analysis basis of the Zaporizke reservoir two main fishery areas – the lower part (the Viskove village) and the Samara Bay, a high average annual copper content (7–8 fishery MACs) was found. In the Samara Bay water, the manganese and cadmium concentration was found to be 1.7 and 1.2 times, respectively. the Zaporizke Reservoir water quality assessment for specific indicators of toxic effects was carried out. For most indicators, the water of the sites under study corresponds to the II – III quality class (‘pure’ – ‘moderately polluted’), and the lead content for class IV, the 6 category – ‘bad’ (‘dirty’) and cadmium for quality classes IV and V (‘dirty’ and ‘very dirty’).

The reservoir bottom sediments can be considered as a pollution indicator of the entire hydroecosystem. In the Samara Bay bottom sediments, more cadmium, lead, manganese and iron were observed, the reliable differences were 86 %, 40 %, 86 % and 58 %, respectively.

The concentration of copper and zinc prevailed in the reservoir lower part bottom sediments (83–84%, $p \leq 0.05$).

A high coefficient of cadmium mobility in the reservoir bottom sediments (about 70) is established. Increasing the mineralization of water in contact with bottom sediments can increase the migration mobility of this metal and transfer it into the water column. Minimum values of the coefficient of mobility are established for iron, zinc and copper (5–10).

2.2. Small Reservoirs and Ponds

Small reservoirs Pivdenne and Khristoforivske are located in the western south of Dnipropetrovsk region (Kryvyi Rih district) and have an area of water surface of 1130 and 62 hectares, respectively. The nutrition of the South reservoir takes place by filling the water from the Dnipro-Kryvyi Rih canal, Khristoforivske one due to the surface runoff of the Bokovenka River and the arrival of water masses from the catchment area.

According to hydrochemical indicators, the water of the Pivdenne reservoir belongs to the hydrocarbon-magnesium type. The gas regime in the reservoir during the year does not go beyond the limits of the fishery norms. The concentration of dissolved oxygen in the water is kept at the level of 5.2–7.9 mg/dm^3, carbon dioxide content does not exceed 10.2 mg/dm^3. Rigidity is 2.12 mg-eq/dm^3, mineralization – 420–480 mg/dm^3, pH = 7.8–8.2. The level of organic matter permanganate oxidability index ranges from 5.12 to 9.2 mg O/dm^3. Thus, the level of water saturation with organic matter does not go beyond the existing fishing regulations (15–20 mg O/dm^3).

The content of nutrients was evaluated for the content of nitrogen and phosphorus. The level of nitrogen forms did not exceed the values allowed in fishing and was optimal for the development of phytoplankton (0.8–1.6 mg/dm^3). The content of phosphorus was slightly lower and was 0.10 mg/dm^3. In the aggregate of all ecological and sanitary indicators, the water of the Pivdenne reservoir is characterized as mediocre, mezosaprobic.

In accordance with the hydrochemical classification, the Khristoforivske reservoir water refers to the sulfate-sodium-magnesium type. Total mineralization ranges from 1445.2 to 1615.4 mg/dm^3. The contents of nutrients are follows: nitrates – 0.2–0.6 mg/dm^3, ammonia nitrogen – 0.1–0.4 mg/dm^3. Permanganate oxidability values are 8.4–16.2 mg O/dm^3. The content of dissolved oxygen ranges from 5.4 to 8.8 mg/dm^3 in water.

The level of water saturation with an easily oxidizing organic matter is on the brink of existing fishing regulations. But, compared to other reservoirs in the region, this indicator is rather typical and does not endanger the continuation of fishing activities. In the aggregate of all ecological and sanitary indicators, the water of Khristoforivske reservoir is characterized as eupolithropic.

Kam'yanske reservoir is located near the Izluchyste village of Dnipropetrovsk region Sophiivka district, with a total water surface area – 298.0 hectares, total volume – 16.2 million m^3, storage capacity – 14.7 million m^3, average depth – 6.5 m (Fig. 2.2.1).

Figure 2.2.1. The scheme of Kam'yanske reservoir.

The reservoir formed by earthen dam of 21 m height on a small river Kam'yanka, the Dnipro right tributary of second order. The riverbed is rocky, the outputs of crystalline rocks such as granite, which determined the name of the river, are on the banks. Basin is located on the area of granite and magmatite contains deposits of iron ore and construction materials are represented with granite, quartzite, refractory clays, building sand. Complex hydrogeological conditions cause poor groundwater quality (higher than normal dry residue, water tight) and affects the formation of the chemical composition of surface waters. Power supply reservoir is formed from Kam'yanka river, drain surface water from rain and snowmelt, groundwater sources. For beam Shyroka effluents from sewage treatment plants from Kryvyi Rih city are carried out.

Kam'yanske reservoir was built in 1976, on an individual government project as a public storage of treated wastewater of Kryvyi Rih with their subsequent use for irrigation of crops and at present is also used for fish farming.

According to the research of hydrochemical parameters high concentrations of solids (content of dissolved solids) – 6355.00 mg/dm^3 and nitrogen nitrate – 3.48 mg/dm^3 were set. High rates of salinity in the Kam'yanske reservoir water might be explained within the presence of highly reservoir line sources that have significant contribution to the supply of the reservoir. Elevated level of nitrates is associated with excessive use of fertilizers on farms and washings away from the fields located on the banks of the reservoir.

According to the 'Environmental Assessment Method of surface water for different categories' and 'Common Implementation Strategy for the Water Framework Directive (2000/60/EU), Guidance document № 10', the environmental assessment of water quality on parameters of chemical composition had been done in Kam'yanske reservoir (Table 2.2.1).

Table 2.2.1. Environmental characteristic of the water quality on chemical composition in Kam'yanske reservoir, M ± m, n = 5.

Indicator of chemical composition of water	Class of water quality				
	I high	II Good	III moderate	IV Poor	V Bad
Hydrogen pH		7.9±0.16			
Dissolved oxygen content, mg/dm^3		8.15±0.12			
Ammonia nitrogen, mg/dm^3			0.95±0.03		
Nitrite nitrogen, mg/dm^3		0.03±0.001			
Nitrate nitrogen, mg/dm^3					3.48±0.01
Phosphorus phosphate mg/dm^3			0.11±0.01		
Permanganate oxidability, mg O/dm^3		7.44±0.11			
Total iron mg/dm^3					9.64±0.15
Zinc, mg/dm^3			0.071±0.0035		
Copper, mg/dm^3			0.022±0.0011		
Lead, mg/dm^3					0.14±0.007
Cadmium, mg/dm^3					0.021±0.0011
Manganese, mg/dm^3		0.022±0.001			

It can be concluded that by the criteria of salt content (salinity), Kam'yanske water reservoir is classified as brackish α-mesohaline according to the quality of II class 4 category. For the majority of the environmental and health criteria, Kam'yanske reservoir water state can be classified as I–II classes 'high–good'. In terms of permanganate oxidation of water belongs to II class 3 category of ‘good water’. The concentrations of phosphate and ammonia nitrogen in water determine its belonging to III class 5 category – ‘satisfactory and moderate’. For large excess of nitrate nitrogen, Kam’yanske reservoir water quality belongs to 7 class V category – ‘very bad’. Increasing levels of nitrates and phosphates in water is a negative sign because it accelerates eutrophication and promotes the processes of algal blooms, siltation and overgrowing the bottom of the reservoir.

Based on these data, we assessed the water quality of the Kam’yanske reservoir on specific indicators of toxic effects. For the content of manganese, researched water belongs to the II class and 2 category and has been characterised as ‘good’ and ‘clean’. For the contents of zinc and copper, water belongs to III class 5 category – ‘satisfactory’; for the content of lead, it belongs to ‘dirty – moderately polluted’; and for the cadmium and total iron contents, it belongs to the V class 7 category of water quality – ‘very bad’ and ‘very dirty’. Thus, significant influence on the elemental composition of the Kam’yanske reservoir water has anthropogenic factor and natural geochemical conditions.

This data made it possible to calculate the chemical index of water quality, including code quality salt content, which was equal to 4; trophic–saprobiological indicators – 3.71; and for the indicators of specific toxic effects – 5.5. So balanced (averaged) chemical indexwas 4.4, characterising the quality of the Kam’yanske reservoir water as ‘satisfactory’ and ‘slightly polluted’ [3].

One of the objective and reliable indicators of water pollution and the total anthropogenic loading is the content of heavy metals in the sediments. Kam’yanske reservoirsediments are clayey silt, which in the case of sustained flow of water masses accumulatethe most fine fractions suspensions and dying phytoplankton that is why there is a highcontent of organic substances. Clay mules are active accumulators of heavy metals due totheir high sorption capacity. Therefore, reservoir sediment could be considered as an indicator of pollution of whole hydroecosystem. Heavy metals accumulated in the sedimentsadversely affect the water quality because of their transition into the water column andsecondary pollution. The proximity of the location of ironstone and iron intake from groundwater contributes to the accumulation of sediments in Kam’yanske reservoir, the content of which is 7,020.48 ± 351.024 mg/kg (Table 2.2.2).

Table 2.2.2. Content of heavy metals in sediments of Kam’yanske reservoir, mg/kg, M ± m, n = 5.

Heavy metals	Zinc	Copper	Lead	Cadmium	Manganese	Iron
Concentration, mg/kg	42.90 ±2.145	3.02 ±0.151	16.74 ±0.837	0.29 ±0.0145	52.68 ±2.634	7020.48 ±351.024
BAC	604	145	117	14	2395	728

To characterise the processes occurring in the reservoir, BAC was calculated by takinginto account the ability to accumulate heavy metals in the sediments.Analysis of the results showed that manganese has the highest level of accumulation inthe sediments, when

BAC is 2,395, which might be because of the fact that most of migrations are conducted in suspended state [3].

The investigated ponds are located on the territory of Novomoskovsk district, and have an area from15 to 48 hectares. They had been formed by regulating the small rivers of the Dnipro basin. Hydrochemical regime of ponds is oriental: water is weakly alkaline (pH = 7.5–8.3); the content of organic matter does not go beyond the permissible values, permanganate oxidability – 8–10 mg O/dm^3. The total content of mineral nitrogen is 1.89–2.2 mg/dm^3, phosphorus – 0.42 mg/dm^3, which is quite sufficient for the development of producers. The content of other substances also does not go beyond the limits of the fishery norms.

The ponds of the Verkhnedniprovsky district of the Dnipropetrovsk region are formed by regulating the Domotkan river in the Dnipro basin. They have an area of water surface from 26 to 127 hectares. The supply of water is mainly due to rain and thawed waters. By chemical composition, water refers to a sulfate class, calcium group. Average mineralization is 380–470 mg/dm^3.

The active medium reaction is low-alkaline, pH = 7.9–8.6, alkalinity is 8.4–9.2 mg-eq/dm^3. The content of organic matter does not exceed the limits of permissible values, permanganate oxidability – 8–10 mg/dm^3. The total content of mineral nitrogen was reduced – 0,35–0,65 mg/dm^3 (at normal – up to 2 mg/dm^3), phosphorus – 0.36 mg/dm^3. The gas regime of the reservoir is generally favorable for hydrobionts. The content of water dissolved in oxygen was 5.5–7.7 mg/dm^3, carbon dioxide – 5.7–7.5 mg/dm^3. The phenomena of strangulation was not observed. The content of other substances also does not go beyond the limits of the fishery norms.

Thus, according to the basic hydrochemical parameters, the water of the investigated small reservoirs and ponds of Dnipropetrovsk region meets the requirements related to fish farming facilities and is suitable for growing the main objects of aquaculture in Ukraine.

By the integrated environmental assessment using chemical water quality indexes of fishing reservoirs in Dnipropetrovsk region, they was characterised as ‘satisfactory’ and ‘slightly polluted’.

3. THE PRODUCTIVITY AND ECOLOGICAL ASSESSMENT OF FOOD SUPPLY COMPONENTS OF THE WATER BODIES OF DNIEPER REGION

3.1. Zooplankton

In the long-term aspect the total abundance of zooplankton in the surface layer of the Zaporizke Reservoir water column has a tendency to increase due to the fact that the percentage of small forms has been increasing lately [18]. On the one hand this is the consequence of eutrophication process in the reservoir and on the other hand because of predominance of the detrital food chain. In conditions of blue-green algae bloom the dominance of small detritophagous species become noticeable because the detrital food chain become the main way of energy flow transforming [19,20]. Also, large species of crustaceans are more sensitive to reservoir toxic substances compared to rotifers.

During the investigated period at the sites of the Zaporizke Reservoir 114 species of zooplankton have been identified including 63 rotifers, 12 copepods, 38 cladocerans and 1 molluscs (veliger stage of *Dreissena polymorpha* (zebra mussel) or *Dreissena bugensis*). Detritophagous species from Chydoridae made up most of the species of Cladocera while percentage of filter-feeder species was extremely low (8.7%). Almost all species from Rotatoria and Copepoda were detritophagous and and the remaining ones were predators. Thus by food selectivity the dominance of detritophagous species in zooplankton community was evident.

The following dominant zooplankton species have been indefinied: *Euchlanis dilatata*, *Keratella quadrata, K. cochlearis*, *Brachionus calyciflorus*, *Acanthocyclops americanus*, *Eurytemora velox*, *E. affinis*, *Heterocope caspia*, *Chydorus sphaericus*, *Bosmina longirostris*, *Alona rectangula*, *Podonevadne trigona*. All these dominant species are quite small and even large species *Eurytemora velox, E. affinis, Heterocope caspia* were represented by mostly small individuals Another reason for the small size of the species is that in the conditions of contamination large species are replaced by small ones which are much more adaptable to the conditions of the environment due to short life cycle [21–24]. By comparing zooplankton species composition of the Zaporizke Reservoir at the beginning of the XXI century with species composition in the 60’s - 80’s of the twentieth century it should be noted the disappearance from zooplanktocenosis of the such species as *Kellicotia longispina*, *Cyclops strenuus, C. vicinus, Diacyclops bisetosus, Diaptomus graciloides, D. gracilis, Bythotrephes cederstoemi*. At the same time the species previously not noted in the reservoir were discovered in the reservoir: *Brachionus variabilis*, *Br. nilsoni*, *Keratella tropica*, *Conochiloides natans*, *Conochilus hippocrepis*, *Collotheca pelagica*, *Lacinularia flosculosa*, *Filinia terminalis*, *Trichocerca elongata*, *Diurella rousseleti*, *Alona intermedia*, *Bryocamptus pygmaeus*, *Enhydrosoma sp.* The list of zooplankton species in the reservoir has been enriched due to planktonic forms of southern and northern origin that come from upstream and downstream reservoirs in the cascade. All of them are capable of withstanding significant contamination [25,26]. Copepoda now made up most of zooplankton biomass.

Based on the long-term data of Laboratory of hydrobiology, ichthyology and radiobiology of Research Institute of Biology, Oles Honchar DNU the upper part of the reservoir has been under intense technological pressure impact [27,28]. That is why it is important to study zooplankton separately in the upper and lower part of the Zaporizke Reservoir. Pelagic zooplankton in winter and early spring was characterized by minimum quantitative figures. Juvenile and nauplial stages of copepods had the highest weight in total biomass according to the CSI (cenotic significance index). During this period, no significant difference was observed in the development of zooplankton in the parts of the reservoir. The increase in the biomass of zooplankton in the spring was due to bloom of *Melozira* diatoms took place from the beginning of April and lasted for 2-3 weeks. During this period small individuals of *Synchaeta, Polyarthra, Notholca* rotifers and juvenile forms of Copepoda were the most numerous. Biomass of zooplankton in this period reached 37.4 mg/m^3 in the upper part of the reservoir and 85.8 in the lower part of the reservoir (Fig. 3.1.1). An increase in the content of organic matter in the water column because of *Melosira* lifetime excrements created favorable conditions for rotifers reproduction. The seasonal curve of indicators of pelagic zooplankton development after *Melosira* bloom had a sharp decline because of Melosira die-away if reached 9 °C. In the middle of May after the decline of zooplankton development there was an increase in its quantitative indices initially at the expense of reproduction of copepods genus *Eurytemora, Heterocope*. By the end of June an intensive development was noted for cladocerans of the genus *Podonevadne, Corniger, Chydorus*.

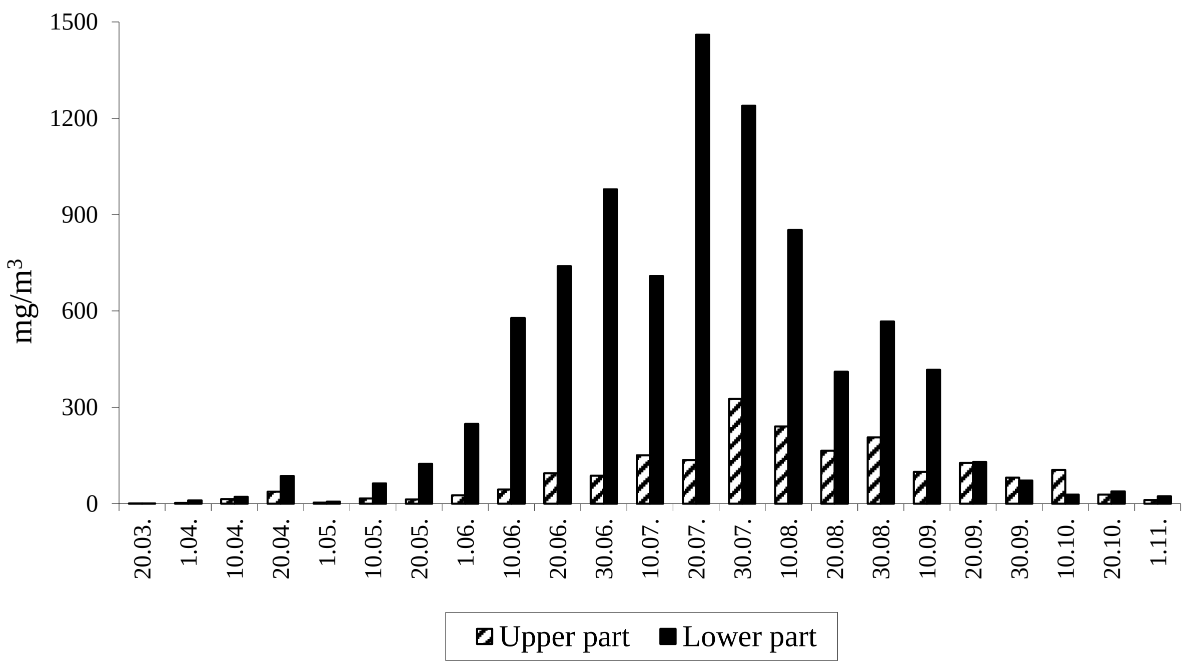


Figure 3.1.1. Seasonal dynamics of biomass of zooplankton in the parts of the Zaporizke Reservoir.

The maximum difference between the zooplankton biomass between parts of the reservoir occurred in July and August, when the development of copepods and cladocerans was intensive. In summer middle biomass of pelagic zooplankton in summer was 147.8 mg/m^3 in the upper part of the reservoir while it was equal 758.4 mg/m^3 in the lower part of the reservoir. Biomass of zooplankton at the lower part of the Zaporizke Reservoir exceeded it at the upper part at 5% significance level. In the upper part of the reservoir the abundance of polyphemids from cladocerans as well as *Bosmina longirostris* and *B. coregoni* was well below than in the lower part of the reservoir for the first due to significant slowdown on the flow velocity in the lower part of the reservoir and also because of inhibition by high concentration of toxic substanses in the upper part of the reservoir [29].

In the second decade of July there was a depression of zooplankton associated with the negative effects of long-term impact of high temperature [30,31]. The peak of zooplankton development in autumn was also noted in the lower part of the reservoir while it was not noted in the upper part. In summer vertical distribution of zooplankton biomass decreased from 758.4 mg/m^3 to 47.8 mg/m^3 in direction from the surface to the bottom that corresponded to water temperature decrease (Fig. 3.1.2).

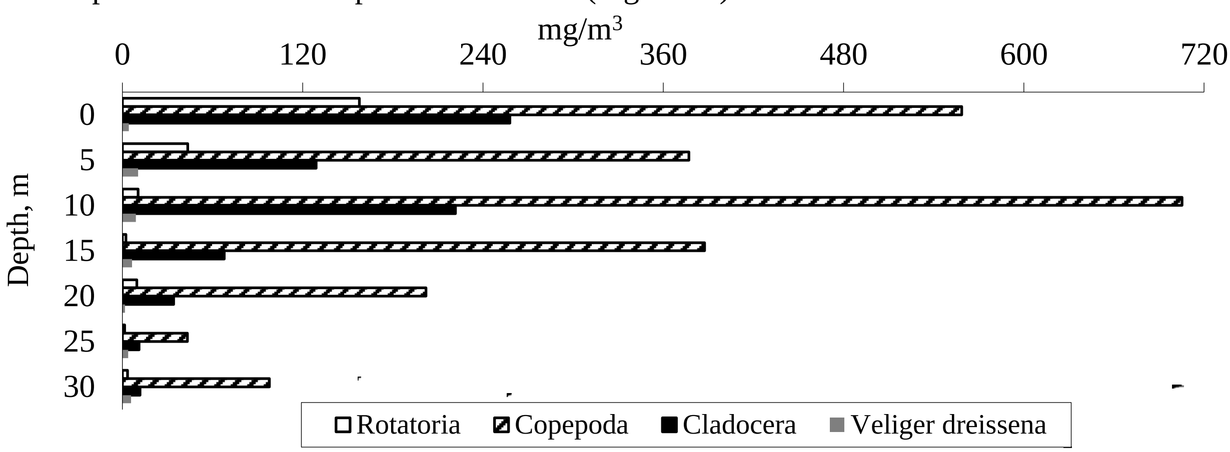


Figure 3.1.2. Vertical distribution of zooplankton in the lower part of the Zaporizke Reservoir in summer.

At the depth of 10 meters increasing of zooplankton biomass was observed because of the presence of thermocline layer in the metalimnion. Weith of the species *Eurytemora velox, E. affinis, Heterocope caspia, Daphnia cucullata, Bosmina coregoni* in total biomass of zooplankton increased at the depth of 5-10 m. Biomass of zooplankton at the depth of 30m was higher in comparison with the depth of 12 m due to accumulations of copepods in the bottom layer of water column.

The littoral zone is the most important for the fish populations of juvenile fish which are spawning and feeding there [32]. The main diet of juvenile fishes is zooplankton therefore from a practical point of view it is important to have information on zooplankton stocks on the main littoral biotopes. On the other hand the littoral zone of the Zaporizke Reservoir is the most influenced by both industrial and domestic wastewater on the modern stage of anthropogenic impact. Therefore the actual issue is the monitoring of zooplankton as the most sensitive bioindicator in conditions of littoral biotopes.

In the largest littoral biotops the following indicators of biomass were recorded: in the biotope of spatterdock beds – 554,3 mg/m^3, in open littoral biotope – 769.3 mg/m^3, in the biotope of cane (Phragmites) beds – 675.9 mg/m^3, in the biotope of pondweed (Potamogeton) beds – 2278.9 mg/m^3 (Fig. 3.1.3).

In the first three biotops the copepods (*Eucyclops serrulatus*, *Mesocyclops leuckerti, Megacyclops viridis, Macrocyclops fuscus, M. albidus*) was the dominant group in zooplankton biomass while rotifers (*Euchlanis dilatata, E. deflexa, Lecane luna, Brachionus* *calyciflorus, B. quadridentatus, Asplanchna priodonta, Keratella quadrata, K. cochlearis, Rotaria rotatoria*) were more numerous. Species of cladocerans (*Simocephalus vetulus, Scapholeberis macronata, Moina macrocopa, M, brachiata, Camptocercus rectirostris*) dominated in pondweed beds. The dominance of copepods and rotifers in the conditions of open water caused by their adaptation to the conditions of pollution of the Zaporizke Reservoir. Pondweed being immersed macrophytes have high absorption capacity that largely reduces the suppressive effects of toxicants. In addition pondweed beds provide a cover from waves and fishes that explains large biomass of cladocerans in these beds. A large leaf surface of pondweed beds contributes to the development of crustaceans who live and breed here as well as hide from predators [33]. The lowest biomass in the beds of cane and spatterdock caused by allelopathic influence of these macrophytes together with accumulation of detritus in these biotopes resulting in crustaceans filtration apparatus clogging [34].

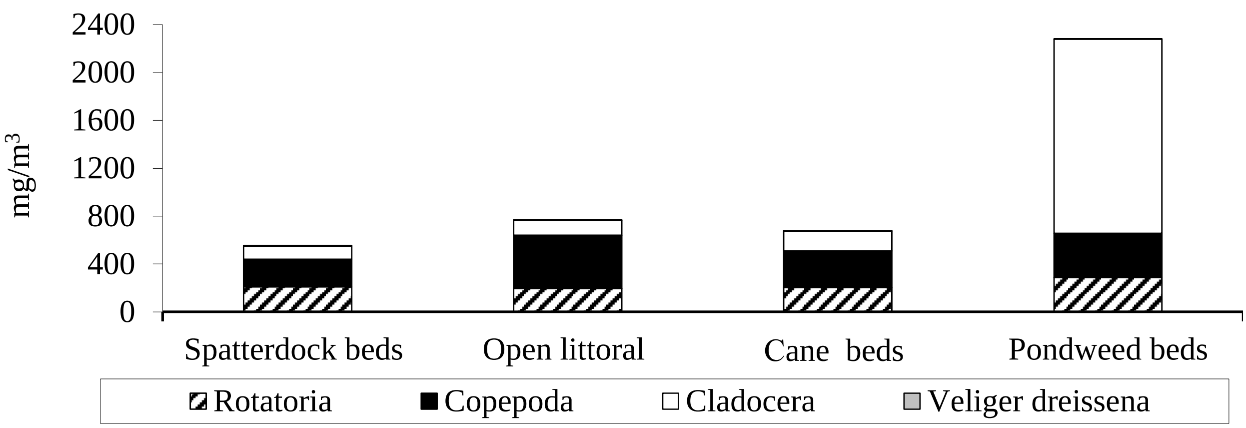


Figure 3.1.3. Biomass of zooplankton in littoral biotopes of the Zaporizke Reservoir.

Finally the highest production of zooplankton in summer was in pondweed beds (9.6 g/m^3 • season), and the lowest was in the thickets of spatterdocks (4.81 g/m^3 • season) (Fig. 3.1.4).

Potential fish production which is formed at the cost only of littoral zooplankton during summer is 74.4 tonnes or 32.3 kg / hectare and it is 2.14 times higher than the official value of total fish catches in the reservoir. Thus, the reservoir has rich food reserve in the form of littoral zooplankton, which is a precondition for increasing of fish productivity in the reservoir by stocking of planktivorous fishes (bighead and silver carp).

The inhabitants of the litoral biotopes are noticeably affected by sewages saturated with toxic substances. The most significant sewages of the reservoir are Petrovsky plant sewage and the discharge of urban sewage at the Festival pier [35]. Both of the sewages has mixed origin containing both toxic inorganic and organic matter. Biomass of zooplankton in contaminated sites of the Zaporizke Reservoir differed significantly from relatively clean sites of open littoral. Biomass of zooplankton at the sites Near Petrovsky plant sewage and Near the discharge of urban sewage at the Festival pier were 32.5 mg/m^3 and 27.1 respectively that is much below compared to average annual biomass of zooplankton in open littoral. Biomass of zooplankton in these sites according to food capacity estimation of water bodies corresponds to the category "very low". At the sites 100 m downstream the sewages biomass of zooplankton increased up to 645.1 and 943.5 mg/m^3 respectively (eutriphication effect upon sewage dilution). At these sites rotifers of genus *Rotatoria*, *Asplanchna*, *Synchaeta*, *Brachionus*, *Filinia* were very abundant due to high concentration of organic matter. Herewith rotifers percentage from total biomass of zooplankton increased up to 91.3% because of saprobiontic rotifers development.

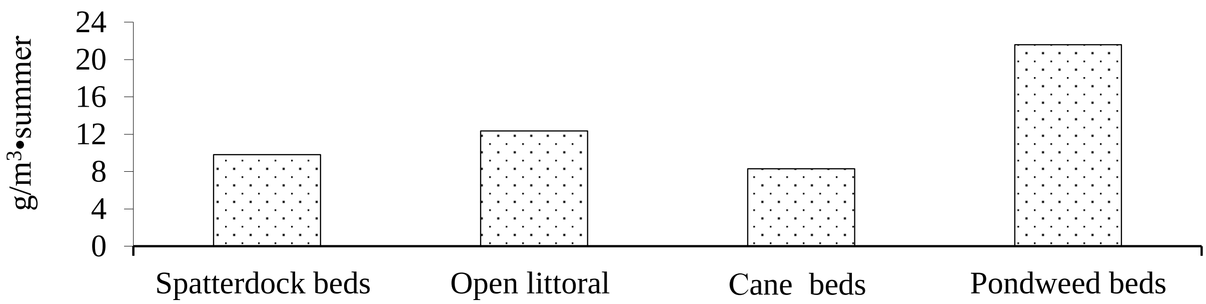


Figure 3.1.4. Production of zooplankton of the Zaporizke Reservoir littoral biotopes in summer.

The conducted analysis of the dominant complexes of zooplankton species formed in the reservoir sites allowed to establish measure of similarity among the sites studied. An analysis of summer distribution of zooplankton species along the sites of the reservoir (Fig. 3.1.5) showed that the most similar by species composition were the sites near Kodaki water draw-off and near Monastyrsky island, which are united in one cluster at 0.75 level.

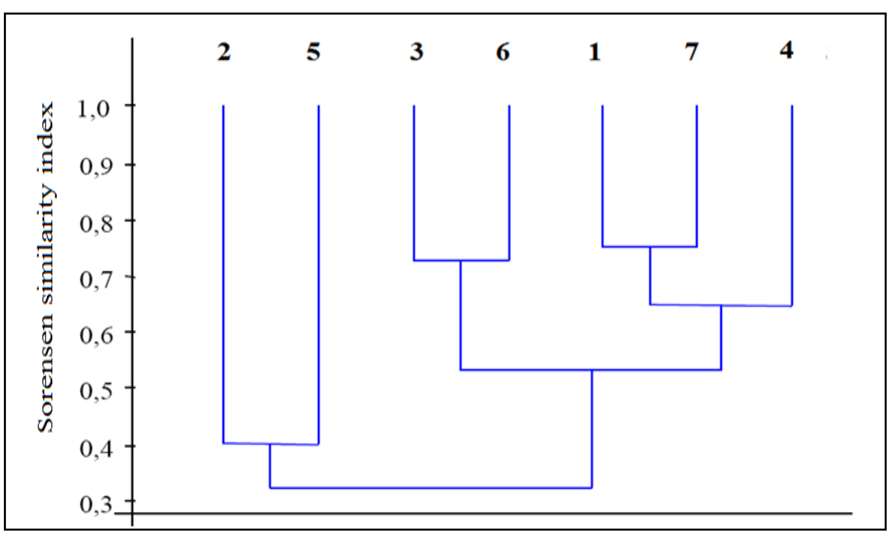


Figure 3.1.5. Claster analysis of zooplankton species composition in open littoral sites of Zaporizke reservoir.

Note: 1 – Near Kodaki water draw-off, 2 – Petrovsky plant sewage, 3 – 100 m downstream Petrovsky plant sewage, 4 – River port of Dnipro city, 5 – Discharge of urban sewage at the Festival pier, 6 – 100 m downstream discharge of urban sewage, 7 – near Monastyrsky island.

These sites and the site near the river port are combined into one clear cluster at the level of 0.67. The branches of the endrograms corresponding to these sites and the sites of the reservoir 100 m downstream sewage discharges are combined into a general cluster at 0.54 level by Sorensen index. The graphic representation of species composition similarity of the two sites with sewages direct impact reflects their differences from other sites of open littoral. These sites form a cluster at the level of 0.4, and join to other sites of the reservoir only at the level of 0.31.

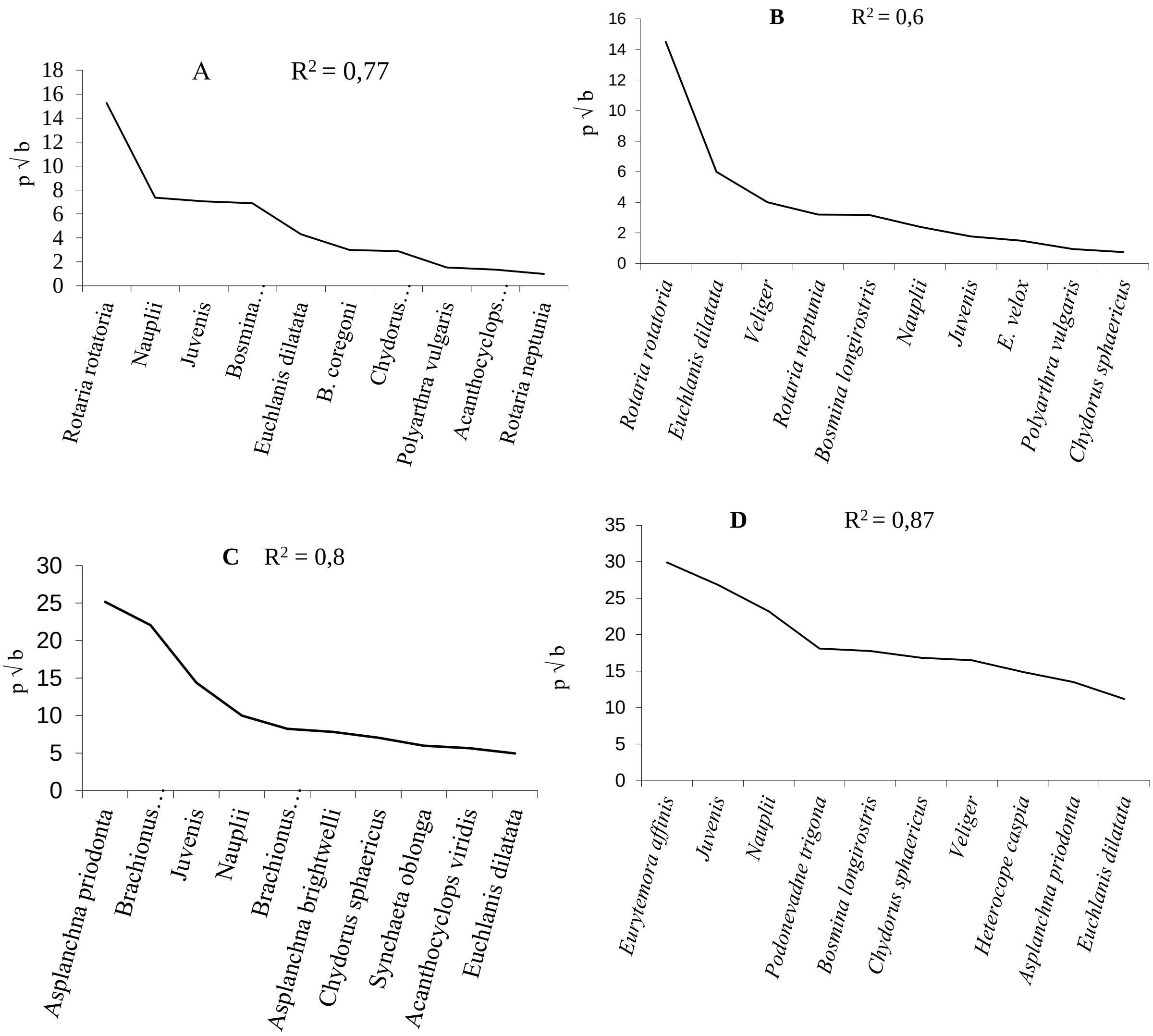


Figure 3.1.6. CSI of zooplankton species at the sites of the Zaporizke Reservoir Note: A – Petrovsky plant sewage, B – Discharge of urban sewage at the Festival pier, C – 100 m downstream discharge of urban sewage, D – average CSI in open littoral.

The index of determination showing distribution of zooplankton species according to the CSI (cenotic significance index) was high in relatively clean areas of open littoral (R^2 = 0.87); decreasing to at the site "Petrovsky plant sewage" "Discharge of urban sewage at the Festival pier": R^2 = 0.77 fig. 6 A and R^2 = 0.6 (Fig. 6 B) respectively. Decreasing of CSI at the sites under sewage impact was caused by both high stage of saprobiontic rotifers dominance and low biomass of zooplankton species. On the other hand increasing of CSI up to 0.8 at the site of 100 m downstream discharge of urban sewage demonstrates good potential for ecosystem restoration (Fig. 3.1.6, C). At this site distribution of zooplankton species according to CSI became more uniform. At the relatively clean sites of the open littoral the species *Eurytemora affinis* together with nauplial and juvenile copepod stages predominated (Fig. 3.1.6, D).

Contaminated areas of open littoral have been ranked according to water quality assessment by zooplankton in which saprobity is a determining criterion (Tab. 3.1.1).

Table 3.1.1. Indicators of zooplankton at the sites of open littoral of the Zaporizke Reservoir the Zaporizke Reservoir with different degree of contamination.

Sites	Saprobity	Number of species	Shannon index	Dominant species	Water quality assessment
Average in relatively clean sites of open littoral	1.63 – 1.88	20 – 33	2.64 – 3.37	*Eurytemora affinis, Podonevadne trigona*	Quite clean
Discharge of urban sewage at the Festival pier	2.57 – 2.80	3 – 11	0.87 – 1.21	*Rotaria rotatoria, Euchlanis dilatata*	Moderately dirty
Petrovsky plant sewage	2.42 – 2.63	7 – 9	1.06 – 1.76	*Rotaria rotatoria, Bosmina longirostris*	Moderately dirty
100 m downstream discharge of urban sewage	2.07 – 2.41	10 – 14	2.08 – 2.22	*Asplanchna priodonta, Brachionus calyciflorus*	Weakly dirty
100 m downstream Petrovsky plant sewage	1.93 – 2.29	10 – 18	1.86 – 2.67	*Rotaria rotatoria, Asplanchna priodonta*	Weakly dirty

The largest index of saprophytics as well as smallest number of species and species diversity were noted at the sites ‘Discharge of urban sewage at the Festival pier’and ‘Petrovsky plant sewage’. These sites were classified as ‘Moderately dirty’ by degree of water quality. The sites 100 m downstream of sewage discharges were classified as ‘Weakly dirty’, and the rest sites of open littoral were classified as ‘Quite clean’.

In the following diagram for the sake of greater visibility the degree of of the factors influencing zooplankton in the percentage ratio is shown. (Fig. 3.1.7).

Taking into account the values of rainfall, temperature, biomass of phytoplankton, etc. in the long-term dynamics a model that evaluates the factors influencing the biomass of pelagic zooplankton of the Zaporizke Reservoir in summer was developed. Standardized coefficients of correlation of biomass of zooplankton with the factors influencing it were used to assess the degree of influence. The most influential factors turned out the temperature and precipitation. There was also great percentage of fish-planktophages being as an indicator of the development of zooplankton.

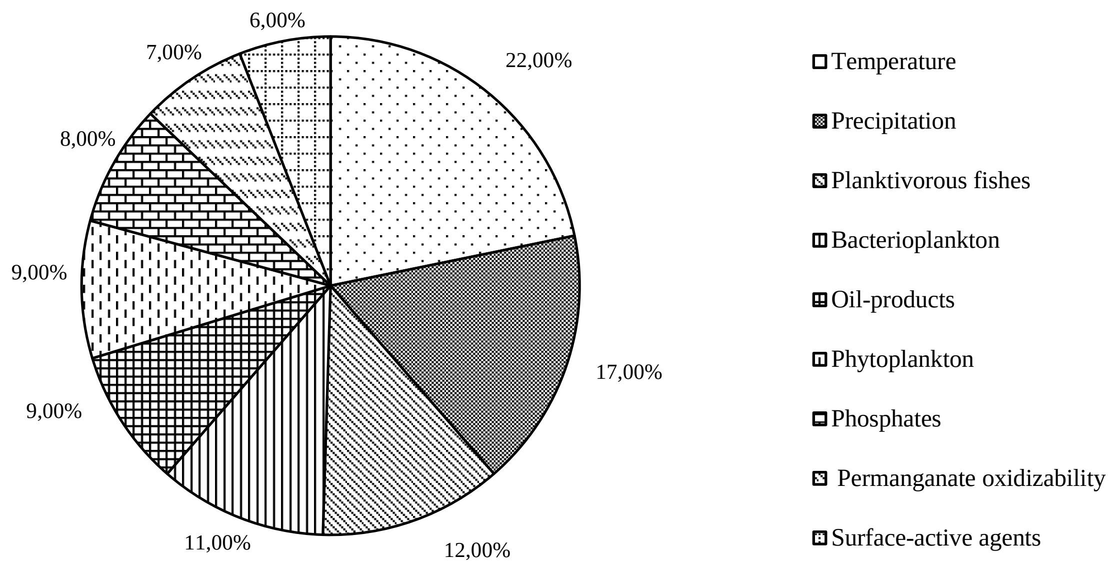


Figure 3.1.7. The factors influencing zooplankton of the Zaporizke Reservoir.

During the study period in Samara Bay 97 species of zooplankton has been identified including 57 rotifers, 11 copepods, 28 cladocerans and 1 molluscs (veliger stage of Dreissena). In summer among the studied biotopes the percent of rotifers was highest in open littoral zone and the percent of crustaceans was highest in the beds of potamogeton plant. The beds of potamogeton had the highest species diversity of phytophilous crustaceans due to variety of habitat in this biotope. These crustaceans play the biggest role in the development of zooplankton. Abundance of zooplankton turned out the highest in pelagic zone while biomass of zooplankton was maximal in potamogeton beds (Fig. 3.1.8).

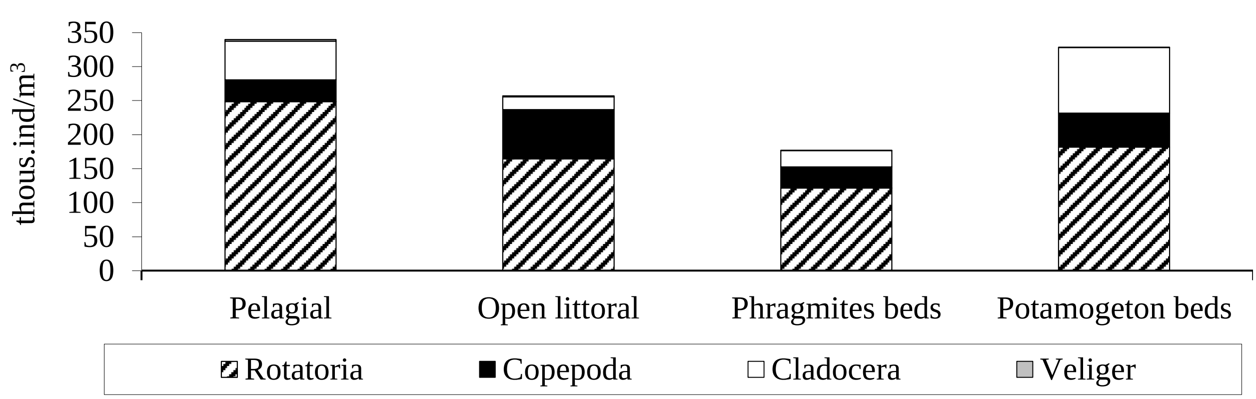


Figure 3.1.8. Abundance of zooplankton of littoral biotopes of Samara bay in summer.

In the pelagial zone the rotifers of the genus *Asplanchna, Brachionus, Ascomorpha, Filinia* intensively multiplied that is characteristic for conditions of high concentration of organic matter [36]. Biomass of zooplankton of Samara bay varied from 675.9 to 1379 mg/m^3, in average – 988,3 mg/m^3 (Fig. 3.1.9).

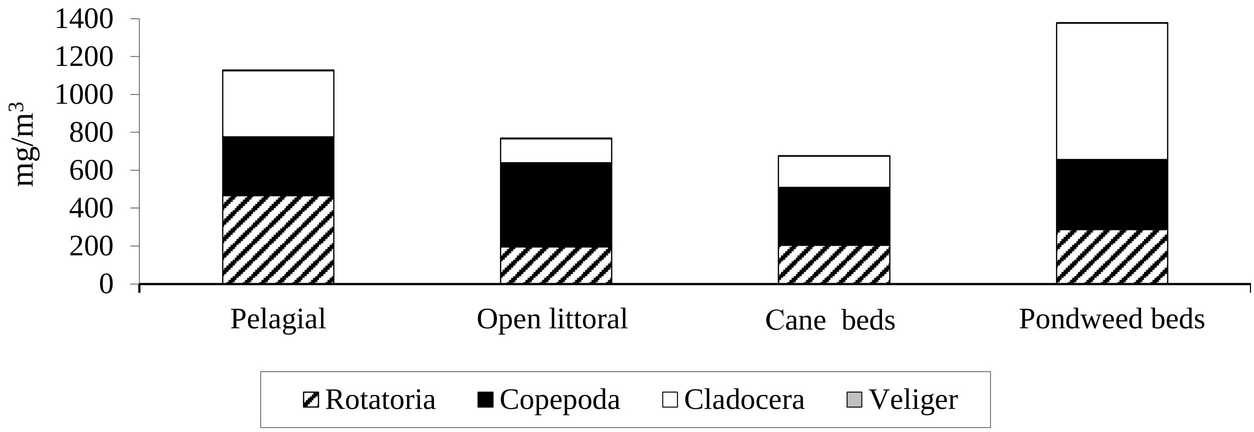


Figure 3.1.9. Biomass of zooplankton of biotopes of Samara bay in summer.

Biomass of zooplankton in pelagic zone and in pondweed beds was similar. While in pelagic zone this biomass was formed mainly by numerous rotifers, then in pondweed beds by more massive crustaceans. The smallest biomass of the zooplankton was found in the beds of cane – 675,9 mg/m^3, that is probably caused by allelopathic oppression of zooplankton in conditions of dense cane beds. Biomass of zooplankton on all biotopes in the lower part of Samara Bay was 5% higher than on the biotopes of the upper part of the bay, that is due to the inhibition of zooplankton in conditions of very dense cane beds and waterlogging of the upper part of Samara Bay.

According to the index of saprobity open littoral happened to be the most polluted biotope (S = 2.41), in the pelagic zone this index was somewhat lower. It was in these biotopes that there Right in these biotopes the saprobions *Asplanchna priodonta*, *Filinia longiseta*, *Brachionus calyciflorus*, *Br. diversicornis* were the most numerous. Saprobiontic species was also found both in pondweed and cane beds but their percentage was smaller. On average saprobity index by zooplankton was 2.04 ±0.14, that is corresponding to the grade of water quality “Weakly dirty”.

Despite the considerable pollution of Samara bay, this water boby is of great importance in the creation of fish stocks due to lake-like conditions as well as to a large area of macrophyte beds and water column saturated with organic matter. All of these conditions are favourable for intensive reproduction of limnophilous zooplankton [37].

The state of food supply development in small reservoirs had its own peculiarities. In Pivdenne reservoir have been found 17 species of zooplankton including Rotatoria (8 species), Copepoda (3 species) and Cladocers (6 species). On biomass rotifers dominated and their share reached 84 %. The dominant rotifer species were *Asplanchna priodonta*, *Keratella cochlearis*, *Brachionus calyciflorus*, *Br*, *quadridentatus*, *Br. urceus*. Cladocerans had less biomass and they were represented mainly by the species *Daphnia longispsna*, *Bosmina longirostris*, *Diaphanosoma brachiurum*, which percentage amounted 12 % of total zooplankton biomass. Copepods were represented mainly by nauplial and copepodic forms. Among adult copepods the species *Acanthocyclops americanus and Cyclops strenuus* dominated. The percentage of copepods percentage amounted 4 % of total zooplankton biomass. At different sites the total zooplankton biomass varied from 0.34 to 0.92 g/m^3, and averaged 0.66 g/m^3 (Fig. 3.1.10). On the basis of biomass of zooplankton Pivdenne reservoir according to the fishery classification is evaluated as water body of low nutrient status (III fish-farming class).

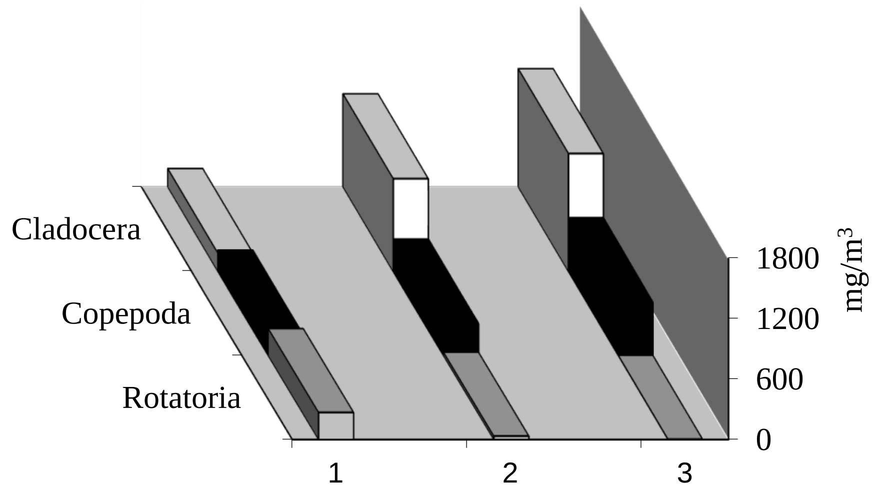


Figure 3.1.10. Biomass of zooplankton of some reservoirs of the Dnieper region.
Note: 1– Pivdenne reservoir, 2 – Khrystoforivs’ke reservoir, 3 –Kam’yans’ke reservoir.

Species composition of zooplankton of Khrystoforivs’ke reservoir included widespread species and cosmopolites of limnetic or sluggish river origin, freshwater and moderate halophilic species as well as eurythermal inhabitants of mainly eutrophic reservoirs. A total number of 22 zooplankton species have been identified. Species composition of Rotatoria (7 species) and Copepoda (8 species) was the most diverse whereas there was only 4 species of Cladocera.

In ecological aspect zooplankton was rather monotonous both in pelagials and in littoral zones. This is due to the morphometry of the reservoir (small depths in most of the water body). Slightly increased intake of organic compounds caused zooplankton biomass increasing in the sites near domestic sewages intake. The total zooplankton abundance varied from 19.6 to 27.4 thous. ind/m^3. Copepods dominated in abundance of zooplankters. Crustaceans primarily juveniles of copepods (*Cyclops visinus*), and cladocerans (*Diaphanosoma brachiurum*, *Daphnia cucullata*) had a share from 80% to 90% of total abundance and biomass of zooplankton. The total zooplankton biomass varied from 827.7 to 1730.4 mg/m^3 on the average 1275.2 mg/m^3. On the basis of zooplankton biomass Khrystoforivs’ke reservoir according to the fishery classification is evaluated as water body of middle nutrient status (I-II fish-farming class) and the reservoir has significant fishing potential.

In Kam’yans’ke reservoir the total zooplankton biomass varied from 655.8 to 2456.7 mg/m^3 on the average 1275.2 mg/m^3. Among zooplankton gropes cladocerans dominated (68.5% of total biomass) and to a lesser extent copepods (31.4% of total biomass). The share of rotifers was very insignificant. The most numerous were the species *Ceriodaphnia affinis*, *C. pulchella*, *Daphnia cucullata*, *Thermocyclops oithonoides*, *Eurytemora affinis* as well as juvenile copepod and cladocerans stages. On the basis of zooplankton biomass Kam'yans'ke reservoir according to the fishery classification is evaluated as water body of middle nutrient status (I-II fish-farming class) and the reservoir has significant fishing potential.

In 2010 few individuals of jellyfish *Craspedacusta sowerbii* were found in the Zaporizke Reservoir. Afteryears abundance of jellyfish increased that had an impact on zooplankton being a food for jellyfish. The jellyfish is an invasive species which has spread across continents with ships ballast water in the second half of the twentieth century [38]. In Ukraine the jellyfish was discovered in Chernobyl NPP cooling pond, in the site of Trypillian hydroelectric station warm waters discharge in Kanev reservoir as well as in the cooling pond of Khmelnitsky NPP (Nuclear Power Plant) and in other water bodies [39,40]. Thus seasonal dynamics of littoral zooplankton have been styding in connection with seasonal dynamics of jellyfish. In 2015 studying of seasonal dynamics of jellyfish showed that numbers of jellyfish was correlated with bell diameter, the correlation coefficient was r = 0,88 (Fig. 3.1.11).

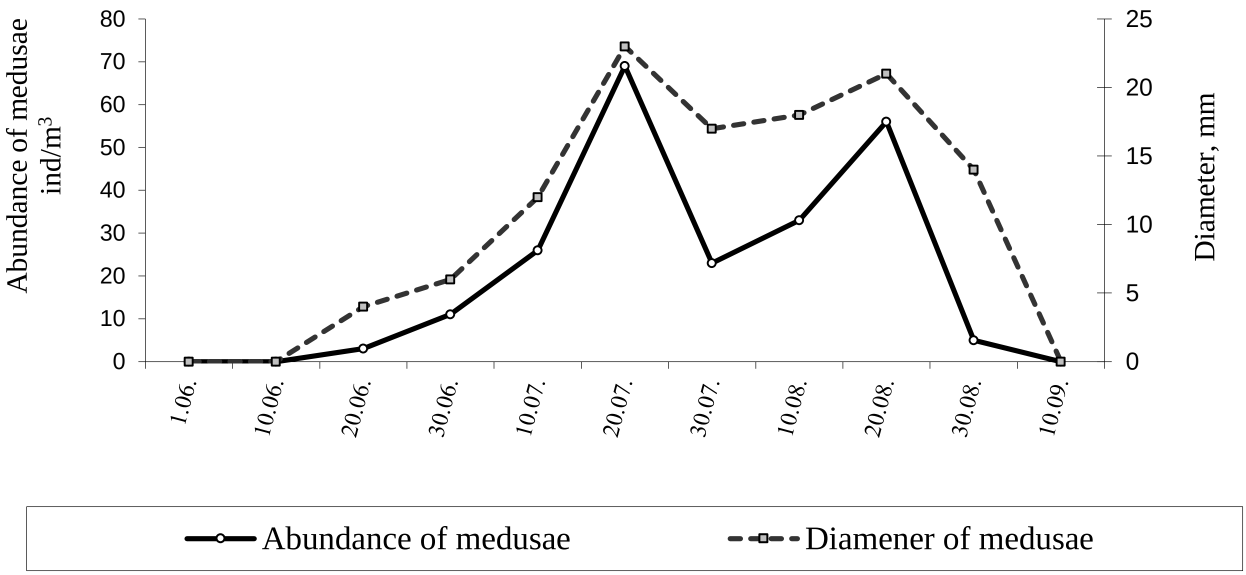


Figure 3.1.11. Seasonal dynamics of abundance and size of jellyfish *Craspedacusta sowerbii* in the rowing channel of the Zaporizke Reservoir.

Synchronicity of numbers as well as bell jellyfish diameter increase caused by dependence of both parameters on water temperature. Jellyfish and zooplankton abundance increased in palallel in the rowing channel but rotifers clearly dominated among zooplankton with share of 80-90% by abundance (Fig. 3.1.12).

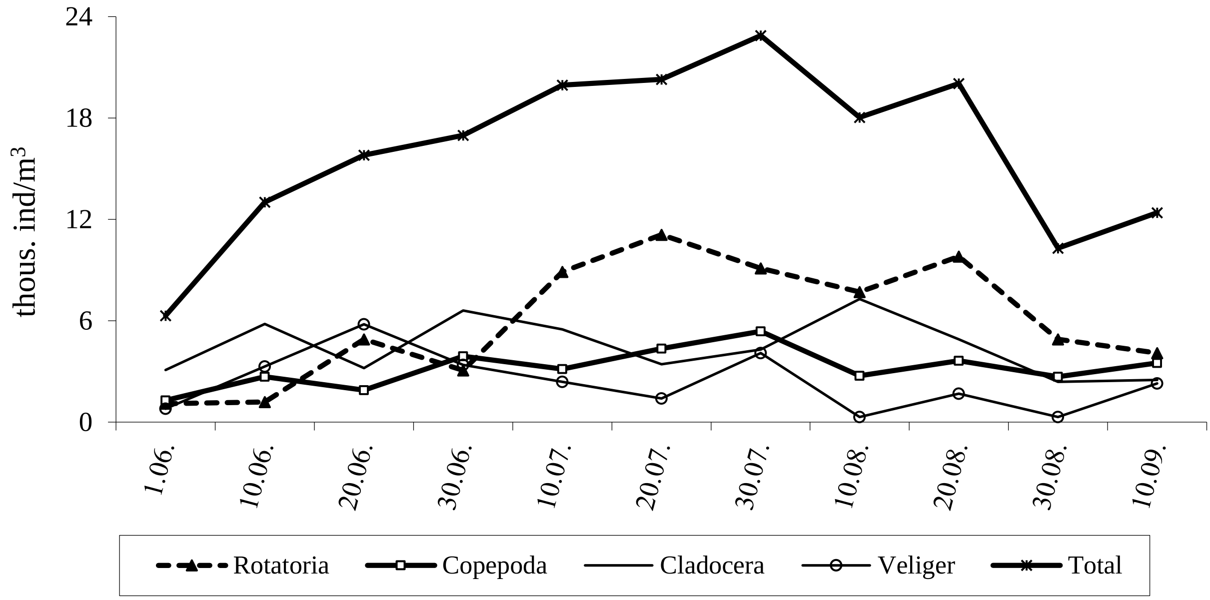


Figure 3.1.12. Seasonal dynamics of zooplankton abundance in the rowing channel of the Zaporizke Reservoir.

Highest numbers of jellyfish and rotifers were recorded at 20 July and 20 August. This synchronicity was caused by jellyfish predation on primarily large zooplankton. Predation press of jellyfish affected in greatest extent the species *Bosmina longirostris* as well as juvenile stages of copepods (Fig. 3.1.13).

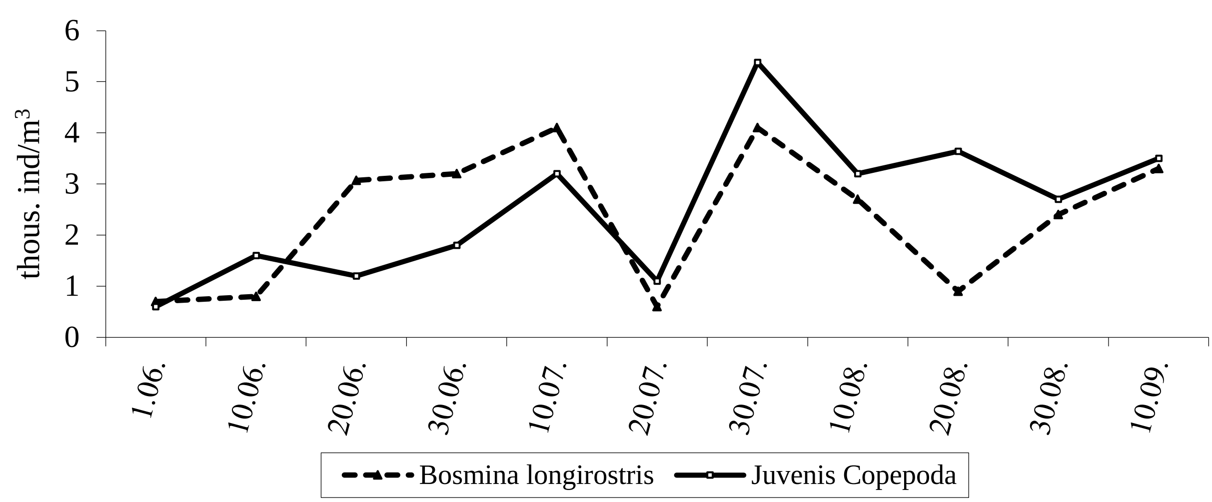


Figure 3.1.13. Seasonal dynamics of abundance of *Bosmina longirostris* and juvenile stages of copepods in the rowing channel of the Zaporizke Reservoir.

Numbers of these zooplankton groups decreased significantly on 20 July and after reduction of jellyfish numbers because of their dying increased immediately. Grazing of

Bosmina longirostris and copepods juvenile stages by jellyfish was most intensive probably due to the fact that these species were most numerous among large zooplankton organisms. This phenomenon was noted by Jankowski [41]. Near Monastyrsky average zooplankton abundance was lower compared to the rowing channel due to small number of rotifers (Fig. 3.1.14).

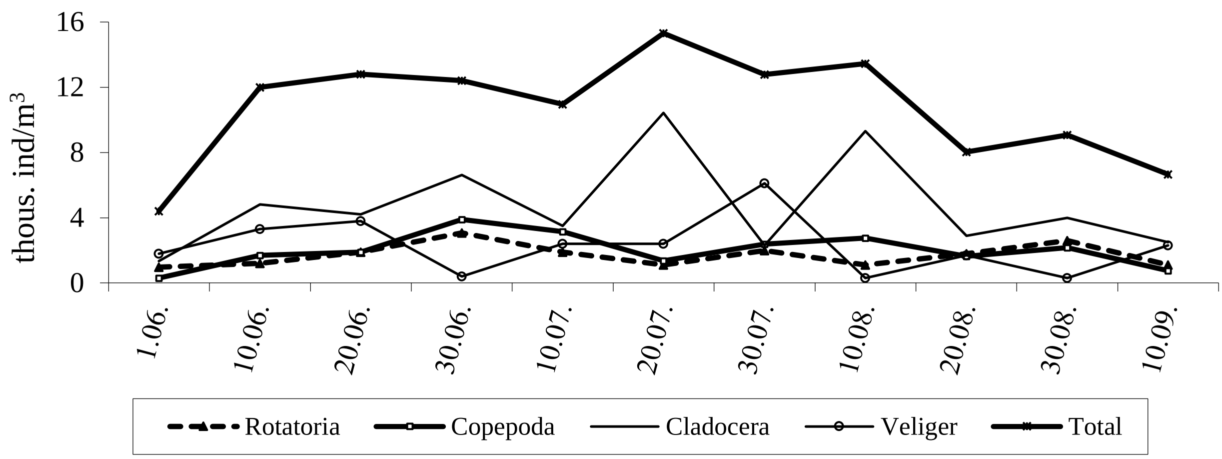


Figure 3.1.14. Seasonal dynamics of zooplankton abundance near Monastyrsky island of the Zaporizke Reservoir.

In contrast to the rowing channel, near Monastyrsky island jellyfish number didn't exceed 12 ind/m^3 and had only one peak in July that was caused by less jellyfish grazing on zooplankton compared with the rowing channel. As a result average seasonal biomass of zooplankton near Monastyrsky island was higher compared to the rowing channel. Seasonal dynamics of zooplankton varied to a greater extent in the rowing channel due to consumption of large species which percentage of the total zooplankton biomass was significant. Biomass of zooplankton near Monastyrsky island was maximal in July with dominance of cladocerans whereas in the rowing channel maximal zooplankton biomass was shifted to August. Thus, the analysis of revealed fenomenon shows varying of jellyfish impact on zooplankton in the sites of the Zaporizke Reservoir depending on its shallowness.

The triburaties of the reservoir are saturated with toxic and organic matter due their shallowness and eutrophication. Ecological problems concerning small rivers are noted in numerous works of scientists [42]. Mokra Sura river is one of Zaporizke reservoir tributaries and this river receives a significant number of domestic and industrial sewages. Eutrophication is the main ecological problem of Mokra Sura river because of agricultural and domestic wastewaters as well as aeration plant sewage emergency discharge into the river. High concentration of organic matter and shore erosion together with macrophytes overgrowing and slime accumulation in Mokra Sura river lead to shallowing and ending of the river. Industrial sewage of tyre and tube-rolling plants also flow into the river. Toxic compounds such as heavy metals, oil products and surface-active compounds flowing into the river inhibit hydrobionts reproduction. Sewage impact together with slime accumulation causes transformation of the river hydrobiocenosis. Thus an urgent task is to estimate the current ecological state and water quality of Mokra Sura sites that's why studying of such a sensitive component as zooplankton supported by the results of biotesting is very important to improve ecology of the river [43]. For the first time zooplankton of Mokra Sura river was described in the 30s of the twentieth century as more productive compared with reservoir zooplankton [44]. Later domestic and industrial wastewater impact caused zooplankton species reduction in Mokra Sura river and rotifers became the dominant grope in zooplankton community of the river [45].

During the investigated period among the sites of Mokra Sura river the lowest number of species has been registered at the upper sites of near the tire plant and near the Dnipro – Zaporizhzhya highway (Fig. 3.1.15). At these sites the rotifers *Rotaria rotatoria, R. neptunia, Adineta gracillis, Philodina roseola, Harbotrocha* sp. classified as Bdelloidea class dominated.

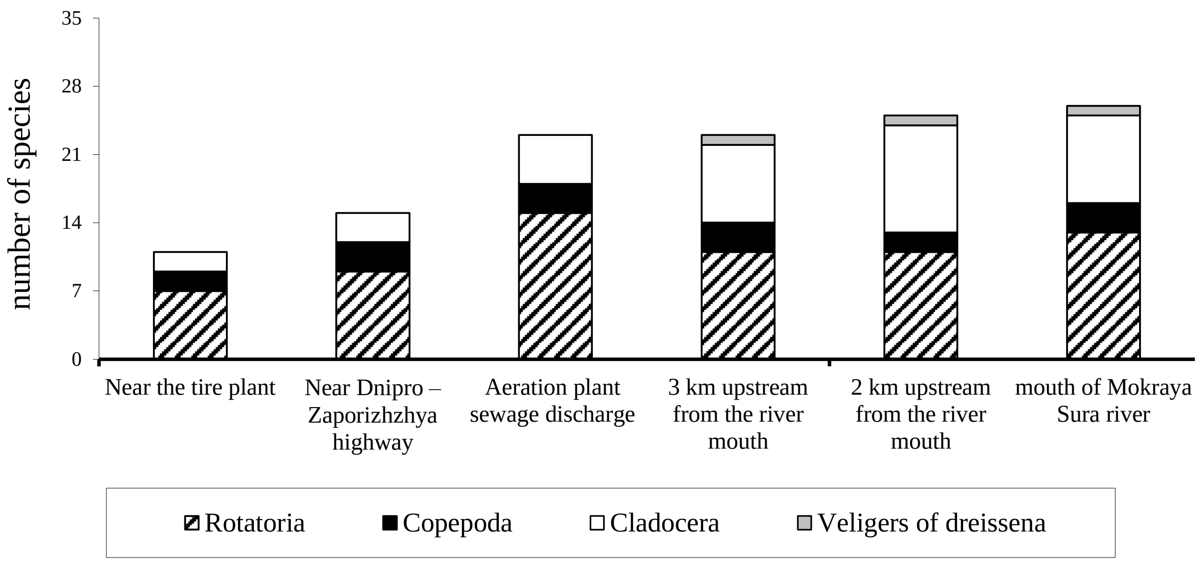


Figure 3.1.15. Number of zooplankton species at the sites of Mokra Sura river in autumn and spring (aggregate).

Proportion of these species of total zooplankton species was 61% in autumn and 63% in spring. Species number of demersal bdelloid rotifers was numerous while filter-feeding crustaceans were absent in water column. Dominance of bdelloid rotifers was caused by slime accumulation at the upper sites of the river. Depth of the river at these sites was no more than 0.5 m. Bdelloid rotifers are resistant not only to suspended solids but they can also withstand impact of heavy metals and other toxic agents of river industrial sewage [46]. Filter-feeding crustaceans usually die under such conditions as their filtration apparatus quickly becomes clogged and in addition these crustaceans are sensitive to toxic agents.

At the site of aeration plant sewage discharge the number of bdelloid rotifers species decreased greatly to 12% of the total species number in comparison with the upper sites of the river. On the other hand an increasing of species diversity of such planktonic saprobiotic rotifers as *Brachionus calyciflorus, Br. diversicornis, Br. quadridentatus, Asplanchna priodonta, A. brightwelli, Synchaeta pectinata, Anuraeopsis fissa, Filinia longiseta, F. mayor* has been registered. At this site emergency discharge of aeration plant sewage occur that leads to increasing of species diversity of planktonic saprobiotic rotifers being an indicator of river water pollution with organic matter.

At the sites 3 km and 2 km upstream from the river mouth the total species number reduced but species diversity of filter-feeding crustaceans was highest compared with other investigated sites. At the river mouth species diversity of planktonic rotifers increased slightly. Outlet of the tube with purifed wastewaters from aeration plant is situated here that causing reproduction of planktonic rotifers species. Mixing of reservoir and river waters also caused increasing of zooplankton total species number.

In autumn abundance and biomass of zooplankton reached the highest values near aeration plant sewage discharge and in the river mouth while these figures were the lowest at the upper sites where bdelloid rotifers percentage of total zooplankton abundance reached 97%. At the site of aeration plant sewage discharge abundance increased to 136.4 thous. ind / m^3, due to planktonic rotifers reproduction. Eutrofication effect due aeration plant sewage emergency discharge caused reproduction of rotifers – saprobionts near the pontoon bridge. Thus planktonic species dominated at the sites where abundance of zooplankton was maximal while bottom species dominated at the upper sites where abundance of zooplankton was minimal. Significant numbers of dreissena veligers entering from the reservoir is a specific feature of Mokra Sura mouth where river and reservoir waters are mixed.

Among the investigated sites biomass of zooplankton varied to a greater extent compared with zooplankton abundance (Fig. 3.1.16). Rotifers dominated at the upper sites while abundance of crustaceans increased at the sites situated not far from the river mouth. Low zooplankton abundance together with low individual mass of rotifers caused the smallest biomass of zooplankton at the upper sites of Mokra Sura river. At the sites 3 km and 2km upstream from the river mouth such cladocerans species as *Chydorus sphaericus, Bosmina longirostris, Podonevadne trigona* dominated especially by biomass of zooplankton. At these sites situated not far from the river mouth percentage of filter-feeding crustaceans abundance as well and biomass was highest compared with other investigated sites at 5% significance level. Large figures of Cladocera development indicates improvement of water quality at these sites.

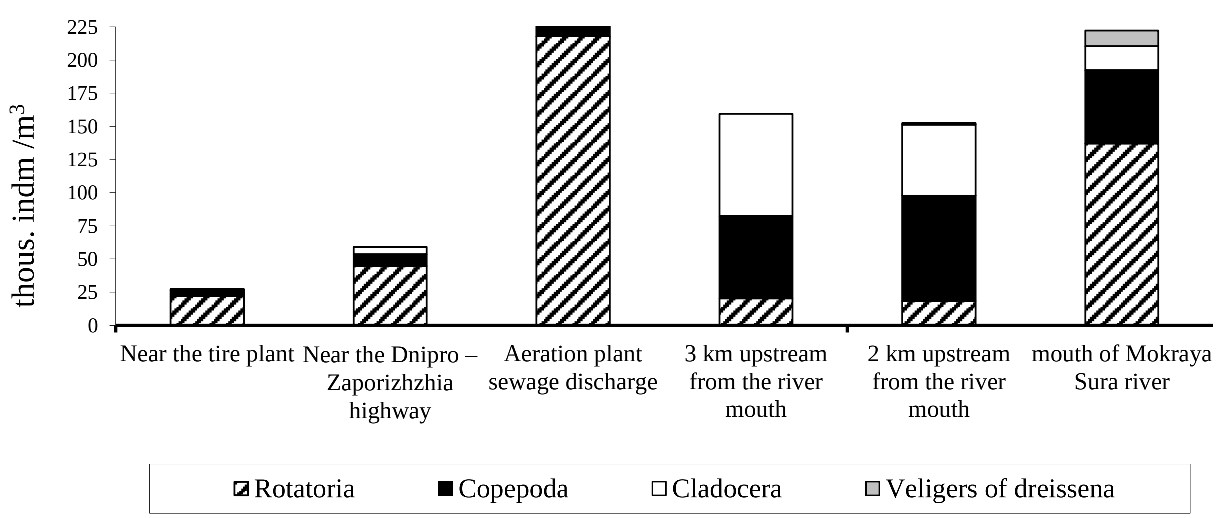


Figure 3.1.16. Biomass of zooplankton at the sites of Mokra Sura river in autumn.

In spring abundance and biomass of zooplankton varied slightly compared with autumn at all river sites except the site near aeration plant sewage discharge and at the river mouth. Under low temperature crustaceans abundance was minimal and rotifers dominated (Fig. 3.1.17).

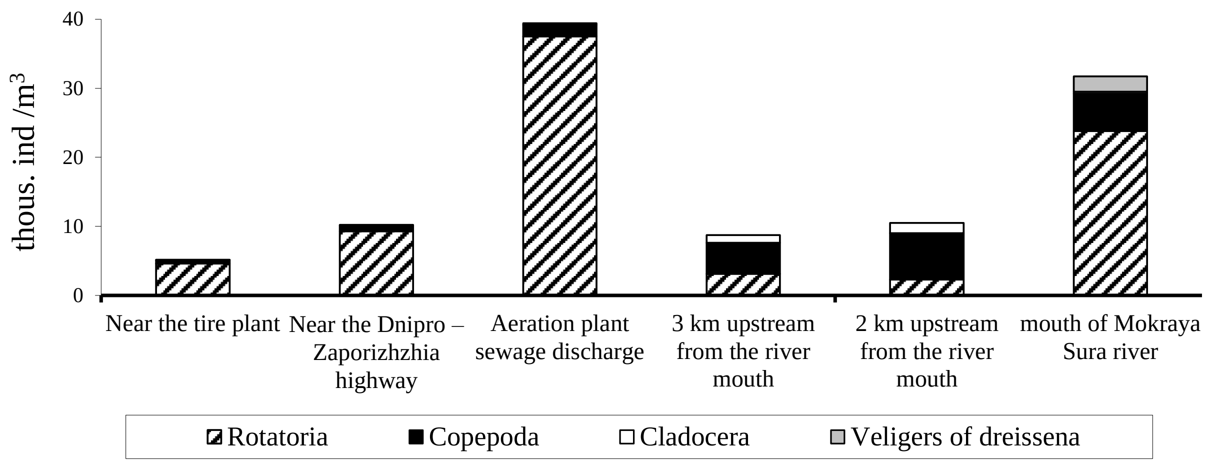
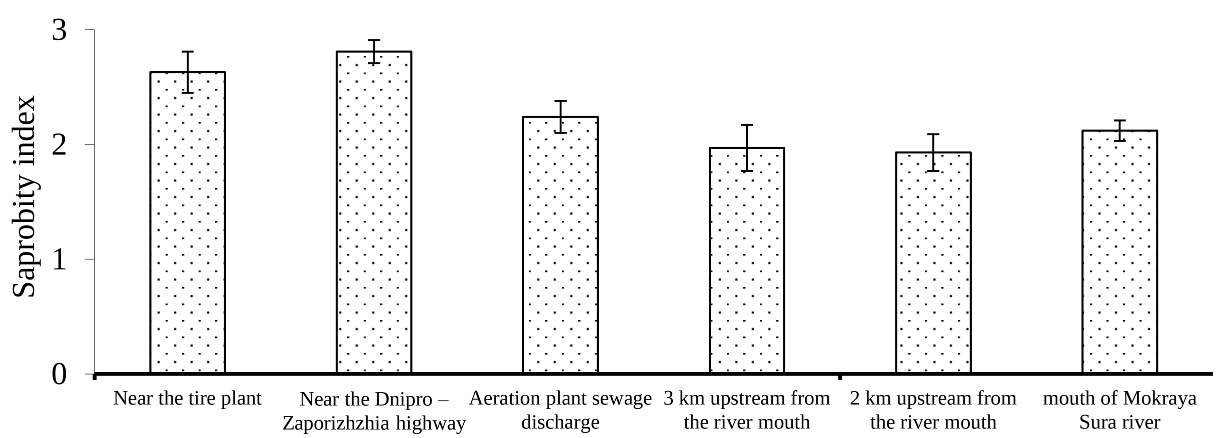
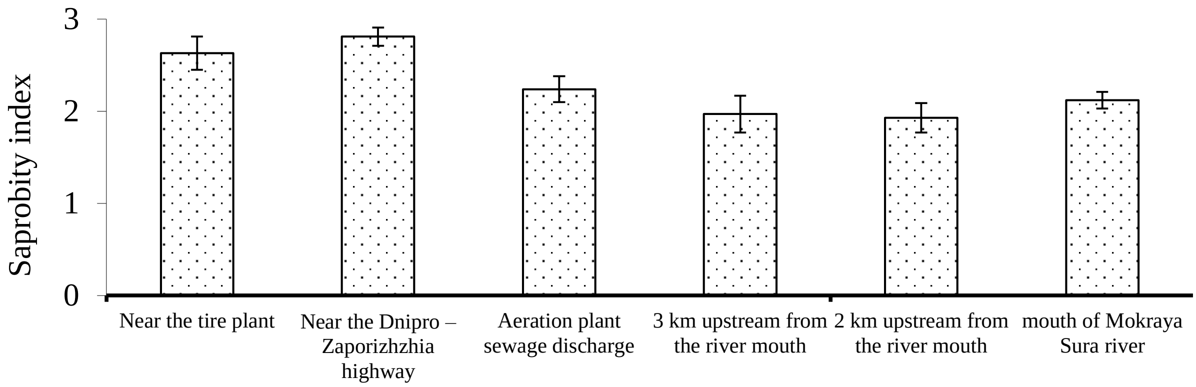


Figure 3.1.17. Abundance of zooplankton at the sites of Mokra Sura river in spring.

Near the Dnipro – Zaporizhzhia highway abundance of zooplankton was even higher in comparison with the sites 3 km and 2 km upstream from the river mouth. Highest figures of zooplankton abundance and biomass near aeration plant sewage discharge was caused due to sewage discharge and high concentration of organic matter stimulates reproduction of planktonic rotifers – saprobionts in spite of spring low temperature (from 10 to 12 °C). Near the tire plant abundance of zooplankton was the lowest due to simultaneous impact of slime accumulation and industrial sewage pollution. At the upper sites "Near the tire plant" and "Near the Dnipro – Zaporizhzhia highway" saprobity index was maximal especially in spring – up to 2.84 (Fig. 3.1.18), that corresponds to the category of water quality "Dirty" according to the classification.



A



B

Figure 3.1.18. Saprobity index of zooplankton at the sites of Mokra Sura river in autumn (A) and in spring (B).

High value of the index was caused by benthic species of bdelloid rotifers. Near the pontoon bridge where aeration plant sewage discharges into the river saprobity index value corresponded to water quality class ‘Polluted’ due to large number of planktonic rotifers – saprobionts species and their high abundance. In the river mouth with outlet of the tube from aeration plant saprobity index value decreased compared with the site of sewage emergency discharge and water corresponded to quality class ‘Contaminated’. Water quality corresponded to the category ‘Moderately polluted’. Decreasing of the index in the river mouth is caused by two reasons: 1) Sewage from aeration plant arising out of the tube is purified, 2) Water arising out of the tube is diluted with not only river but also with reservoir water. The lowest values of saprobity index was recorded at the sites 3 km and 2 km upstream from the river mouth, where the water quality corresponded to the category ‘Relatively clean’.

The results of biotesting showed the maximum toxicity of water in the river at the site of aeration plant sewage discharge. Percantage of cladocerans *Daphnia magna* Strauss who died within 4 days in water from this site averaged 53.7% (Fig. 3.1.19). This percentage corresponds to the category of quality ‘Polluted’, that confirms the data of zooplankton samples.

At the sites Near the tire plant and Near the Dnipro – Zaporizhzhia highway percentage of daphnia who died within 4 days (toxicity index) in water from this site averaged 25.1 – 27.5% that corresponds to the category of quality ‘Moderately polluted’ quality. Taking into account high saprobity index water quality of this site should be characterized as ‘Polluted’. Thus biotesting results don’t correspond with zooplankton samples which indicated the upper sites as the most contaminated. This may be due to deposition of toxic agents into slime under low depth at the upper sites of the river. Water quality of other sites estimated on biotesting and zooplankton samples results corresponded. Thus in the river mouth 12.4% of daphnia died that corresponded to the water quality ‘Moderately polluted’. In water from the sites 3 km and 2 km upstream from the river mouth almost all daphnia survived within 4 days that allows to estimate water quality of these sites as ‘Clean’.

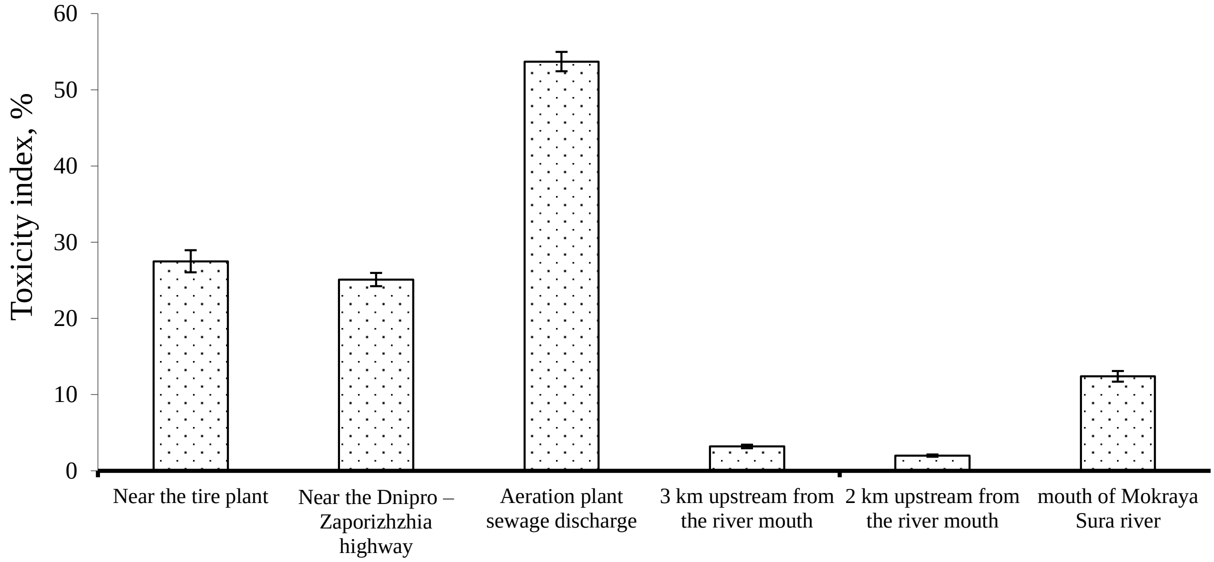


Figure 3.1.19. Toxicity index of zooplankton at the sites of Mokra Sura river in spring.

3.2. Zoobenthos

During the investigated period 130 species of zoobenthos has been identified at the sites of the Zaporizke Reservoir and its tributaries (Table 3.2.1).

Table 3.2.1. Species composition of zoobenthos of the Zaporizke Reservoir and its tributaries.

Species and taxons	Occu-rence	Species and taxons	Occu-rence
Phylum Porifera		**Phylum Arthropoda**	
Classis Demospongiae		**Classis Arachnida**	
Ordo Haplosclerida		**Ordo Aranei**	
Familia Spongillidae		**Familia Cybaeidae**	
Spongilla lacustris L.	+	*Argyroneta aquatica Clerck*	+
Phylum Cnidaria		**Classis Malacostraca**	
Classis Hydrosoa		**Ordo Amphipoda**	
Ordo Anthoathecata		**Familia Gammaridae**	

Familia Hydridae		*Chaetogammarus tenellus Sars.*	+++
Hydra vulgaris Pall.	++	*Ch. ischus Stebb.*	+
Pelmatohydra oligactis Pall.	Sporadic	*Ch. warpachowski Sars.*	++
Phylum Bryosoa		*Dikerogammarus haemobaphes Eich.*	+++
Classis Phylactolaemata		*D. villosus Sow.*	++++
Ordo Plumatellida		*Pontogammarus crassus Sars.*	+
Familia Plumatellidae		*Synurella ambulans Mull.*	Sporadic
Plumatella fungosa Pall.	+	**Familia Corophiidae**	
Phylum Mollusca		*Corophium curvispinum Sars.*	+
Classis Gastropoda		**Ordo Mysida**	
Ordo Lymnaeiformers		**Familia Mysidae**	
Familia Planorbidae		*Limnomysis benedeni Czern.*	++
Planorbis planorbis L.	++	*Mesomysis kowalewskii Czern.*	+
Ordo Rissoiformes		*Paramysis intermedia Czern.*	+
Familia Bithyniidae		**Ordo Cumacea**	
Bithynia tentaculata L.	+	**Familia Pseudocumidae**	
B. leachi Shep.	++	*Schizorhynchus eudorelloides Sars.*	+
Familia Bulinidae		*Pseudocuma cercaroides Sars.*	++
Planorbarius corneus L.	++	*Pterocuma pectinata Sow.*	+
Familia Physidae		**Ordo Isopoda**	
Physa acuta Drap.	+	**Familia Asellidae**	
Familia Lithoglyphidae		*Asellus aquaticus L.*	+++
Lithoglyphus naticoides Pfeiff.	+	**Ordo Decapoda**	
Familia Lymnaeidae		**Familia Astacidae**	

Lymnaea stagnalis L.	++	*Pontastacus leptodactilus Eschscholtz*	+
L. auriculata L.	+++	**Classis Insecta**	
Amphipeplea glutinosa Mull.	Sporadic	**Ordo Odonatoptera**	
Ordo Vivipariformers		**Familia Lestidae**	
Familia Viviparidae	+	*Sympecma paedisca Brauer*	+
Viviparus viviparus L.	++++	**Familia Coenagrionidae**	
Familia Valvatidae		*Enallagma cyathigerum Charp.*	+
Valvata piscinalis Mull.	++	*Erythromma najas Hans.*	+
Ordo Cerithiiformes		*Coenagrion puella L.*	++
Familia Melanopsinae		**Familia Libellulidae**	
Fagotia esperi Feruss.	Sporadic	*Libellula quadrimaculata L.*	+
Ordo Neritopsiformes		**Ordo Diptera**	
Familia Neritidae		**Familia Chironomidae**	
Theodoxus fluviatilus L.	++++	*Tanytarsus lauterborni Kieff.*	++
Classis Bivalvia		*T. lobatifrons Kieff.*	+
Ordo Unioniformers		*T. mancus Wulp.*	++++
Familia Unionidae		*T. exiguus Joh.*	+++
Unio pictorum L.	+	*Allochironomus sp.*	Sporadic
Ordo Cardiiformers		*Corynoneura sp.*	++
Familia Dreissenidae		*Clinotanypus nervosus Mg.*	+
Dreissena bugensis Andr.	++++	*Tendipedini macrophtalma*	+
Dr. polymorpha Pall.	++	*Syndiamesa nivosa*	Sporadic
Familia Cardiidae		*Prodiamesa sp.*	Sporadic
Monodacna colorata Eichw.	Sporadic	*Diamesa prolongata Kieff.*	+

Phylum Annelida		*Einfeldia carbonata Mg.*	++++
Classis Oligochaeta		*E. pagana Mg.*	++
Ordo Haplotaxida		*Endochironomus dispar Mg.*	+++
Familia Aeolosomatidae		*E. tendens F.*	+
Aeolosoma variegatum Vejd.	+	*Glyptotendipes gripecoveni Kieff.*	+++
Familia Naididae		*G. polytomus Kieff.*	+
Stylaria lacustris L.	++++	*Limnochoronomus nervosus St.*	++++
Dero dorsalis Ferr.	++	*L. tritomus Kieff.*	+
Nais barbata Mull.	++++	*Micropsectra praecox Mg.*	+
N. behningi Mich.	+	*Pentapedilum exsectum K.*	+++
N. communis Pig.	+++	*Polypedilum convictum Walk.*	++++
N. elinguis Mull.	++	*P. nubeculosum Mg.*	+++
N. pardalis Pig.	++	*P. scalaenum Schr.*	+
N. pseudobtusa Pig.	+++	*Sergentia longiventris Kieff.*	+++
N. simplex Pig.	Sporadic	*Chironomus plumosus L.*	++++
Paranais littoralis Mull.	+	*Chironomus thummi Kieffer*	+++
Pristina bilobata Bretsch.	++	*Chironomus semireductus Lenz.*	+
P. aequiseta Bourn.	Sporadic	*Trichocladius lucidus Staeg.*	Sporadic
Chaetogaster crystallinus Vejd.	+	*Cricotopus algarum Kieff.*	++
Ch. diaphanus Gruith.	+++	*C. silvestris F.*	++++
Uncinais uncinata Levin	+	*Cryptochironomus anomalus Kieff.*	++
Ophidonais serpentina Mull.	++	*C. conjugens Kieff.*	+
Familia Tubificidae		*C. pararostratus Lenz.*	+
Iiyodrilus bedoti Pig.	Sporadic	*C. viridulus F.*	+++

I. hammoniensis Mich.	+++	*C. defectus Kief.*	+
Limnodrilus claparedeanus Ratz.	++	*Psectrocladius psilopterus Kieff*	+++
L. hoffmeisteri Clap.	++++	*Tanypus villipennis Kieff.*	++
L. michaelseni Last.	+	*Psectrotanupus varius Fabricius*	+
L. udekemianus Clap.	++	*Procladius ferrugineus Scuze.*	++++
L. newaensis Mich.	+	*Demeijerea rufipes L.*	+
Tubifex tubifex Mull.	++++	**Familia Ceratopogonidae**	
Classis Hirudinea		*Culcoides punctatus Meig.*	
Ordo Arhynhchobdellea		**Familia Chaoboridae**	
Familia Erpobdellidae		*Chaoborus crystallinus De Geer*	++
Erpobdella nigricollis (Brand.	+	**Familia Syrphidae**	
E. octoculata L.	+	*Eristalis tenax L.*	+
Familia Hirudinidae		**Familia Psychodidae**	
Haemopis sanguisuga L.	+	*Psychoda sp.*	+
Ordo Rhynchobdellea		**Ordo Ephemeroptera**	
Familia Glossiphoniidae		**Familia Baetidae**	
Glossiphonia complanata L.	++	*Cloëon dipterum L.*	++++
Glossiphonia heteroclita L.	++	**Ordo Trichoptera**	
Helobdella stagnalis L.	+++	**Familia Polycentropodidae**	
Protoclepsis tessulata Mull.	+	*Neureclipsis bimaculata L.*	+
Classis Polychaeta		*Holocentropus picicornis Steph.*	++
Ordo Canalipalpata		**Familia Limnephilidae**	
Familia Ampharetidae		*Limnephilus flavicornis Fabr.*	+
Hypania invalida Grube		**Ordo Coleoptera**	

Hypaniola kowalewskii Grimm	+++	**Familia Hydrophilidae**	
	+	*Enochrus sp.*	+
		Familia Haliplidae	
		Haliplus sp.	+
		Familia Dytiscidae	
		Ilybius sp.	+
		Ordo Hemiptera	
		Familia Naucoridae	
		Naucoris cimicoides L.	+

Note: (Sporadic) – occasional finds, (+) – low occurence, (++) – medium occurence, (+++) – high abundance, (++++) – dominant species.

During the current study zoobenthos of the Zaporizke Reservoir was represented by bottom invertebrates of 6 phylum 11 classis 24 ordo and 45 family. The phylum Arthropoda was the most represented consisting of 70 species. The phylum Annelida consisted of 34 species inside of which the classis Oligochaeta was the most rich. The phylum Mollusca consisted of 17 species. Richness of species diversity of the classis Insecta was caused by the familia Chironomidae (larvaes) consisting of 41 species and Malacostraca consisting of 16 species. Not typical species for water-bodies of Eurasia *Shizorhynchus eudorelloides* (240 ind/m^2) and *Synurella ambulans* (320 ind/m^2) were found respectively in Orel river and in Samara bay. Species composition of zoobenthos of the Zaporizke Reservoir was typical for Dnipro reservoirs with dominatation of freshwater species originating from northern and temperate latitudes [47]. Species of the Ponto-Caspian complex dominated in aggregations of *Dreissena* mussels and at biotops of reservoir upper part. Number of zoobenthos species varied from 6 to 27 among the sites with the lowest figures in profundal slimes and with the largest figures in littoral beds. In trophic structure detritophagous and seston-feeders invertebrates dominated and predators had a secondary place that indicates high trofic level of the reservoir [48].

Benthic invertebrates inhabite five substrates in the Zaporizke Reservoir such as sand, muddy sand, slime, aggregations of *Dreissena* mussel, macrophyte beds. Abundance of zoobenthos is determined mainly by the substrate of intertebrates dwelling. The substrates listed above were associated with four bottom types: muddy sand of profundal, slime of profundal, muddy sand of littoral and slime of littoral. Intensive hydrodynamics and sediment erosion in littiral and partly in profundal of the Zaporizke Reservoir upper part caused that the trophic structure of zoobenthos was diverse including such trophic types of invertebrates as collectors as well as euryphagous phytophagous and detritophagous invertebrates.

Concortium of *Dreissena* mussel (*Dreissena bugensis*, *Dr. polymorpha*) has been formed in muddy sand of profundal of reservoir upper part.

Bottom layer of the Zaporizke Reservoir water column is slightly affected by climatic factors due to slow stream that's why seasonal changes of zoobenthos are insignificant in these layers. Abundance of zoobenthos in winter often was maximal compared to other seasons. Thus in December and in early spring in profindal of reservoir upper part near Monastyrsky island abundance of "soft" zoobenthos averaged 4.6 thous. ind./m^2 varying from 3 to 7 thous. ind/m^2 and biomass of "soft" zoobenthos averaged 27.2 g/m^2 varying from 10 to 40 g/m^2.

Biomass of *Dreissena* mussels averaged 3.2 kg/m^2 and biomass of zoobenthos in favorable conditions of *Dreissena* aggregations was high: abundance of gammarids averaged 20.2 g/m^2, polychaetes – 3.9 g/m^2, oligochaetes – 2.5 g/m^2 (Table 3.2.2).

Table 3.2.2. Seasonal dynamics of zoobenthos in profundal muddy sand of the Zaporizke Reservoir.

Month	'Soft' zoo benthos	Oligo chaetes	Chiro nomids	Crusta ceans	Poly chaetes	Others gropes	Molluscs
1	2	3	4	5	6	7	8
January	2580 10,8	1800 5,46	340 0,41	380 4,3	40 0,6	0 0	3300 2400
February	3060 23,4	300 1,7	300 0,56	1840 19,5	100 1,66	0 0	8100 4720
March	1816 19,5	408 0,65	248 0,31	866 15,1	136 3,4	8 0,006	4216 2314
April	5260 50,5	2100 3,81	360 0,13	2040 41,2	760 5,3	0 0	8600 5060
May	2393 38,1	653 1,35	247 0,22	1160 26,3	40 0,55	40 0,02	10213 5603
June	1730 6,66	330 0,8	1160 2,7	160 3,1	0 0	80 0,06	2520 1860
July	1360 4,04	200 0,44	920 1,64	80 1,8	0 0	160 0,16	920 770
August	1240 4,88	800 2,12	280 0,38	40 0,92	80 1,4	40 0,06	840 1000
September	800 3,4	480 1,6	320 0,4	80 1,4	0 0	0 0	1960 1360
October	1960 7,04	1200 2,7	280 0,38	160 3,5	0 0	320 0,46	3400 2800
November	740 4,36	400 0,68	120 0,18	40 0,04	120 2,2	60 0,36	1780 1120
December	5400 35.5	1860 2.96	360 0.94	3100 30.4	60 1	20 0.24	6580 3620

Note: Over the line – abundance, ind./m^2; under the line – biomass, g/m^2

In *Dreissena* aggregations the next species dominated: *Limnochironomus nervosus, Tanytarsus exiguus, Limnodrilus hoffmeisteri, Dikerogammarus villosus, D. haemobaphes, Hypania invalida*. Influence of spring flood washing away the layer of slime accumulated during summer and autumn doesn't cause the decreasung of zoobenthos abundance in conditions of *Dreissena* aggregations. Biomass of "soft" zoobenthos was high during spring varying from 19.5 to 50,5 g/m^2 with gammarids domination. High abundance of zoobenthos in winter and early spring was caused by lack of fish feeding during this period. In summer and autumn biomass of zoobenthos was significantly lower varying from 4.04 to7.04 g/m^2 compared with winter and spring with similar percentage of oligochaetes, chironomids and crustaceans. On solid substrates (beams, rocks) biomass of *Dreissena* mussels and gammarids reached the highest values (Table 3.2.3). Species *Holocentropus picicornis* and *Neureclipsis bimaculata* together with high abundance of the species of Ponto-Caspian origin indicates good ecological conditions in profundal muddy sand [49].

Table 3.2.3. Seasonal dynamics of zoobenthos in profundal slime and solid substrates of the Zaporizke Reservoir.

Month	Biotop	'Soft' zoo benthos	Oligo chaetes	Chiro nomids	Crusta ceans	Polyc haetes	Others gropes	Molluscs
March	Slime	6400 / 23.1	2000 / 2.8	40 / 0.06	120 / 0.64	4240 / 19.6	0 / 0	280 / 100
	Solid substrates	5920 / 118	0 / 0	0 / 0	5500 / 110	140 / 2.4	280 / 6.0	21760 / 11900
February	Slime	3640 / 6.9	1200 / 1.4	40 / 0.06	80 / 0.16	2320 / 5.24	0 / 0	80 / 30

Over the line – abundance, ind./m^2; under the line – biomass, g/m^2

It's obvious that filtration capacity of mussel *Dreissena* is a main factor of self-cleaning in profundal muddy sand. In March abundance of zoobenthos decreased because of spring flood washing away accumulated slime in biotop of profundal slime in contrast to profundal muddy sand. High abundance of polychaetes (*Hypania invalida, Hypaniola kowalewskyi*) and oligocaetes (*Limnodrilus hoffmeisteri, Tubifex tubifex*) was typical in profundal slime.

In littoral muddy sand of reservoir upper part species *Dikerogammarus villosus, Chaetogammarus ischnus, Procladius ferrugineus, Polypedilum convictum, P. nubeculosum, Psectrocladius psilopterus, Glyptotendipes gripecoveni, Limnodrilus hoffmeisteri, Viviparus viviparus* dominated. During winter and spring until the spring flood in littoral muddy sand boomass of zoobenthos was high and averaged 26.4 g/m^2 with maximum 55.4 g/m^2 (Table 3.2.4).

Favourable oxygen conditions together with organic matter of slime and accumulation of leaves caused high abundance of gammarids and chironomids. Decreasing of benthos abundance from 24.5 to 5.2 g/m^2 primarily due to Gammaridae reduction was caused by spring flood washing away the layer of accumulated slime. At the same time increase of chironomids and oligochaets abundance took place. Ponto-Caspian species *Pontogammarus maeoticus Pterocuma pectinata* which are indicators of good ecological state were found in this biotope. During summer and autumn biomass of zoobentos in littoral muddy sand varied from 3.0 g/m^2 to 7.4 g/m^2. In littoral slime abundance of chironomids and oligochaetes was higher compared to littoral muddy sand. Species *Limnodrilus hoffmeisteri*, *Tubifex tubifex*, *Ilyodrilus hammoniensis*, *Polypedilum convictum*, *P. nubeculosum Cryptochironomus defectus*, *Dikerogammarus villosus* dominated in littoral slime. Despite high number of species significant dominance of *Tubifex tubifex* and *Limnodrilus hoffmeisteri* was the cause of Shannon index low value.

Table 3.2.4. Seasonal dynamics of zoobenthos in littoral muddy sand of the Zaporizke Reservoir

Month	'Soft' zoo benthos	Oligo chaetes	Chiro Nomids	Crusta ceans	Poly chaetes	Other gropes	Molluscs
1	2	3	4	5	6	7	8
January	2320 9.24	1360 4.66	560 1.55	280 2.86	0 0	120 0.17	40 68
February	5580 29.2	3300 12	1180 2.6	1080 14.6	0 0	20 0.01	0 0
March	2920 10.86	1320 2.55	1253 2.85	273 5.1	7 0.007	87 0.35	47 57
April	3042 55.4	2000 6.5	1680 3.5	3600 45.1	0 0	320 0.3	80 160
May	1441 5.2	1151 3.9	453 0.85	13 0.45	0 0	0 0	13,3 118
June	4052 4.76	2000 1.76	1960 1.84	300 0.3	0 0	460 0.73	160 201
July	1657 3.92	667 1.46	743 1.35	120 0.79	6,7 0.01	93 0.07	107 102
August	1130 3.0	900 2.4	40 0.08	80 0.2	20 0.02	20 0.3	150 205
September	3080 4.86	2500 3.7	400 0.59	40 0,21	0 0	140 0.36	260 247
October	1087 2.35	690 1.53	200 0.24	53 0.23	0 0	120 0.21	280 200
November	740 1.62	520 1.06	90 0.15	70 0.28	20 0.03	40 0.1	127 75
December	2460 7.41	1520 4.74	800 2.05	100 0.56	0 0	40 0.06	330 240

Over the line – abundance, ind./m^2; under the line – biomass, g/m^2

Distribution of zoobentos along the Zaporizke Reservoir and its tributaries had been studing in spring 2015. Based on index CISC of zoobentos ecological state of the Zaporizke Reservoir sites was estimated. Species composition as well as proportion between gropes of benthic invertebrates varied greatly between the sites (Table 3.2.5). Profundal muddy sand of reservoir upper part (near Monastyrsky island) characterized by the best ecological state according to index CISC and *Dreissena bugensis* was an edificator in this biotop. *Dreissena* mussel is well known to evaluate invertebrate densities [50]. In this biotope aggregations of species *Dreissena bugensis* and to a lesser extent zebra mussel (*Dreissena polymorpha)* formes consortia where gammarids as well as chironomids and polychaetes refuge from predation and find food [51]. *Dreissena* are filter feeders capable of filtering large quantities of water in a relatively short period of time [52]. They circulate water for respiration and feeding and remove particles from the water [53]. Importation of organic material through pseudofeces deposition provides food for inhabitats of aggregations of *Dreissena* mussel [54]. Filtration capacity of *Dreissena* together with flowage cause high level of oxygen in this biotope. All of the above factors provide high species diversity of zoobenthos in profundal muddy sand. Abundance of *Dreissena bugensis* exceeds greatly abundance of other species that why Shennon index turned out to be low. On the other hand high biomass of zoobenthos and low saprobity index caused the best ecological state of profundal muddy sand by index CISC. In profundal slime of reservoir upper part near Monastyrsky island density of *Dreissena* was significantly less compared to profundal muddy sand and abundance of saproboints belonging to the classis Oligochaeta and Polychaeta increased therefore CISC rank of this biotope was much lower (5th). In Samara bay *Spongilla lacustris* formed the consortium where species *Demeijerea rufipes Viviparus viviparus* and *Asellus aquaticus* were abundant.

Table 3.2.5. Structure and function characterization of zoobenthos in the Zaporizke Reservoir the Zaporizke Reservoir sites.

Sites	Type of bottom	Biotope	N	B	S	POI	H	AS	CISC	R	P	Dominant species
Orel river	muddy sand	Profundal	5.4	4.7	20	19	2.3	2.5	4.0	3	2.2	P.c., I.n., Ch. w.
near Kodaki water draw-off	muddy sand	Littoral	1.6	6.5	12	38	1.9	2.9	6.3	6	1,6	L. h., I. n., P.c.
near Solnechny residental district	muddy sand	Littoral	0.32	0.2	5	0	1.0	2.0	6.69	7	0.06	Cr.s., L.h.
near discharge of urban sewage	slime	Littoral	0.6	1.2	3	27	1.4	3.7	9.3	11	0,27	E. t., L.h.
near Monastyrsky island	muddy sand	Profundal	10	31.6	10	2	1.67	2.0	2.94	1	17.2	Dr.b., D.v., D. h.
	slime	Profundal	14	39.5	16	22	2,.47	2.47	5.5	5	18.7	Dr.b., D.v., L.h. H.i.
	muddy sand	Littoral	3.8	10.1	8	63	2.12	2.93	5.3	4	8.6	Dr.b., Dr.p., L. h.
	slime	Littoral	8.0	11.5	15	8	1.92	2.5	8.3	10	15.1	L.h., T. tu.,
Samara bay	muddy sand	Profundal	10.4	44.2	9	0	1.3	2.3	3.38	2	26.8	D.r., V.v., A. aq.
near the stream of Tonelna beam	slime	Littoral	2.7	8.3	7	37	2.2	3.5	7.13	9	1.3	Ch. t., L.h., E. c.
near Viys'kove villiage	slime	Profundal	5.0	20.8	9	84	1.78	3.5	7.12	8	5.2	L.h., T. tu., T. th.

N – abundance of benthos, thous. ind./m^2; B – biomass, g/m^2; S – number of species; OIП – Parele oligohaetes index, %; H – Shennon index of species diversity, bit/ind. ; AS – average saprobity; CISC – combined index of the state of communities; R – rank of the site according to CISC;P – productivity during the spring, г/м^2. CISC = (2 AS + 1,5 POI + 1,5 B + N + H + S) / 8. This formula contains not absolute values of variables but their ranks. Species: L. h. – *Limnodrilus hoffmeisteri*; L. n. – *Limnodrilus newaensis*; T. tu. – *Tubifex tubifex*; H. i. – *Hypania invalida*; Dr. b. – *Dreissena bugensis*; Dr. p.- *D. polymorpha*; Pr. f. – *Procladius ferrugineus*; P. c. – *Polypedilum convictum*; Cr. s. – *Cricotopus silvestris*; Ch. t. – *Chironomus thummi*; D. r. – *Demeijerea rufipes*; E. c. – *Einfeldia carbonata*; D. v. – *Dikerogammarus villosus*; D. h. – *D. haemobaphes*; Ch. w. – *Chaetogammarus warpachouski*; P. c. – *Pseudocuma cercaroides*; A. aq. – *Asellus aquaticus*; V. v. – *Viviparus viviparus*; E. t. – *Eristlis tenax*.

High biomass of 'soft' zoobenthos and high species diversity were typical for this site and index CISC had the rank 2 that corresponds to "good" ecological state. High abundance of the species *Pseudocuma cercaroides* in muddy sand of Orel river that indicates good ecological state. In litoral muddy sand near Monastyrsky island Parele oligohetes index increased but many species of bottom invertebrates (gammarids and chironomids together with larvae of classis Odonata, Ephemeroptera and Trichoptera) caused that index CISC was equal to 4 that corresponds to 'satisfactory' ecological state. The site near Kodaki water draw-off was characterized by high Parele oligohetes index and medium biomass of zoobenthos and this site corresponded to 'satisfactory' ecological state by index CISC. Despite the fact that the site near Kodaki water draw-off is situated in contaminated upper part of the Zaporizke Reservoir the main discharges are located below this site. Self-cleaning capacity of hydrobionts is very important for water quality of the site near Kodaki water draw-off because water intake for the city Dnipropetrovsk is carried out at this site. Species *Limnodrilus hoffmeisteri* and *Tubifex tubifex* are the most resistant to pollution but under flowage in reservoir upper part abundance of these species was low. Organic matter inflow caused high saprobity and Parele oligohetes index at the site near the stream of Tonelna beam. In the reservoir lower part near Viys'kove villiage slime accumulation together with low current speed and great depth (33 meters) caused domination of saprobionts *Limnodrilus hoffmeisteri* and *Tendipes plumosus* and as a result the index CISC equaled 8 that corresponds to "bad" ecological state. Near discharge of urban sewage low biomass of zoobenthos took place and such saprobionts as *Psectrotanypus varius* and larvae of *Eristalis tenax* dominated and as a result the index CISC had the rank 11 that corresponds to 'bad' ecological state.

In the benthofauna of the Pivdenniy reservoir 11 species of zoobenthos have been indefined. On the biomass mollusks *Dreissena bugensis* та *D. polimorpha* dominated, composing 91.5% of total zoobenthos bimass (2034 g/m^2). Crustaceans *Chaetogammarus tenellus Sars. Ch. ischus Stebb. Dikerogammarus haemobaphes Eich. D. villosus Sow. Corophium curvispinum Sars.* were found in great abundance in mollusks aggregations and they composed the most part of 'soft' zoobenthos biomass. Percentages of oligochaenes and chironomids larvae were much lesser compared to crustaceans. Middle biomass of 'soft' zoobenthos was 5.36 g/m^2 On the basis of biomass of zoobenthos Pivdenne reservoir according to the fishery classification is evaluated as water body of middle nutrient status (II fish-farming class). Thus, according to zoobenthos indicators, the reservoir can be effectively used only for roach and bream being an active consumer of *Dreissena* mussel. Abundance of other species of benthivorous fishes should be regulated by adjusting of introduced invertebtates.

In the benthofauna of the Christophorivske Reservoir 11 species of zoobenthos relating to 7 sysmematic gropes have been indefined. Oligochaetes with chironomids larvae and to a lesser extent crustaceans from gammarids and corophiides dominated in 'soft' zoobenthos biomass. mollusks *Dreissena bugensis* and *D. polimorpha* were edificatory species and promoted cructaceans development. Other groups were registered in single numbers. *Pontastacus leptodactilus Esch* was also found in bentic community. The presense of species of Dreissenidae familia being filtrators is a factor of reservoir self-purification.

On the other hand dominance of Tubificidae familia among oligochaetes as well as *Cryptochironomus* genus among chironomids larvae indicates eutrophication of the reservoir.

The average abundance of oligochaetes was 1120 ind./m^2 and its biomass is 3.76 g/m^2. The average abundance of chironomids larvae was 1920 ind./m^2 and its biomass is 2.46 g/m^2.

Thus average 'soft' zoobenthos biomass (8.08 г/м) indicates good fishing potential of the reservoir. The reservoir according to the fishery classification is evaluated as water body of middle or high nutrient status (I – II fish-farming class). In the future the reservoir can be effectively used for growing fishes consuming macrozoobenthos, but it is necessary to carry out stocking with bentivorous fishes such as common carp or wels catfish to use effectively rich resourses of 'soft' zoobenthos.

3.3. Phytoplankton

In the Zaporizke Reservoir being under anthropogenic pressure domestic and industrial sewage impact with ineffective system of sewage treatment cause transformation of algae biocenosis and may cause blue-green algae bloom. In the Zaporizke Reservoir during the period of being within cascade of Dnipro reservoirs blue-green algae bloom was observed every year in July-September with average abundance 34 mln.cells/dm^3 and biomass 9.3 mg/dm^3 [55]. Blue-green algae of genus *Microcystis* and *Anabaena* were the agents of bloom similarly in all Dnipro reservoirs [56]. Retrospective studies of the the Zaporizke Reservoir phytoplankton showed that under sewage and eutrophication process at the sites of sewage impact abundance of saprobiontic populations increased while total biomass of phytoplankton especially green algae biomass decreased and some species from the group Chrysophyta disappeared [55]. A tendency of saprobity increasing has been observed in retrospective analysis [57]. While saprobiontic species indicating ɑ-mesosaprobic conditions were not met in 30 years of 20th century then sporadic forms were observed in 60 years and in 90 years their percentage in total number of indicating saprobic species reached 14%. The problem of algae bloom in response to eutrophication is also a matter of great importance. Toxic compounds such as heavy metals, oil products and surface-active compounds flowing into the river inhibit reproduction of sensitive algae [58,59]. Nowadays despite decreasing of industrial sewage volume in the Zaporizke Reservoir the concentration of toxic compound is growing due to accumulation by soil and subsequent raising to water column [35]. Species composition and abundance of phytoplankton are sensitive indicators of water pollution and eutrophication. Since the primary task is to assess the ecological status of the reservoir then investigation of such a sensitive component as phytoplankton is crucial to prevent irreversible changes in state of the reservoir hydrobiocenosis and to restore its steady state. First of all, it is important to study the transformations taking place in phytoplankton community at the sites of direct sewage discharge.

During the study period 74 species and intraspecific taxons has been recorded in species composition of phytoplankton of the Zaporizke Reservoir. The percentage of species between algal groups was as follows *Chlorophyta* (33%), *Bacillariophyta* (34%), *Cyanoprocaryota* (24%), *Euglenophyta* (6%), *Pyrrophyta* (3%).

The dominant species were *Cyclotella meneghiniana Kützing, 1844, Stephanodiscus hantzschii Grunow, 1880, Melosira islandica O.Müller, 1906, M. granulate (Ehrenberg) Ralfs, 1861, M. g. v. angustissima Müller*, 1899, *Pediastrum duplex Meyen 1829, Coelastrum microporum Nägeli in A. Braun, 1855, Dictyosphaerium pulchellum H.C. Wood, 1873, Ankistrodesmus angustus C.Bernard, 1908, Microcystis aeruginosa (Kützing) Kützing 1846, Aphanizomenon flos-aquae (L.) Ralf ex Bornet et Flahault, 1886, Anabaena flos-aquae Ralfs ex Bornet & Flahault 1886, Oscillatoria planctonica Woloszynska 1912*. Thus dominating species are typical for phytoplankton of the Dnipro cascade and these algae creating the mean part of food supply of upper trophic level [56].

Most of the species has been found under investigation seasonal dynamics of phytoplankton at a stationary site at Monastyrsky island. Number of species at the sites varied from 3 to 21 and averaged 11.7 (Table 3.3.1). However, number of phytoplankton species beyond sewages equaled 14.3 and in the sewages equaled 4. The lowest number of species was recorded in discharge of urban sewage at the festival pier. This was due to pollution impact that suppressed life-sustaining activity of algae and decreased species diversity of phytoplankton.

Table 3.3.1. Number of phytoplankton species in the Zaporizke reservoir in September, 2016.

Phytoplankton gropes	1	2	3	4	5	6	7	8	Average
Cyanophyta	5	2	4	3	1	3	4	3	3.1
Bacillariophyta	8	1	3	6	0	3	7	4	4.0
Chlorophyta	6	1	1	4	0	2	5	4	2.9
Euglenophyta	0	1	1	1	2	2	1	1	1.1
Pyrrophyta	2	0	1	0	0	0	1	1	0.6
Total	21	5	10	14	3	10	18	13	11.7

1 – near Kodaki water draw-off, 2 – Petrovsky plant sewage, 3 – 100m downstream Petrovsky plant sewage, 4 – river port of Dnipro sity, 5 – discharge of urban sewage at the festival pier, 6 – 100 m downstream discharge of urban sewage, 7 –Monastyrsky island, 8 – near Viys'kove villiage.

Blue-green algae were domination group over a large part of the vegetation period that is consistent with the data of the scientists who studied phytoplankton development in reservoirs of Dnipro cascade. Scientists explain the dominance of blue-green algae due to high percentage of phosphate compared to nitrate (concentration ratio of N to P is less than 29:1) [60]. It should be noted that in spring 2016 seasonal dynamics of phytoplankton was characterized by increased and prolonged (about a month) compared to the 2015 diatoms bloom of the species *Melosira islandica* and to a lesser degree *Melosira granulata* which biomass reached 23 mg/dm^3. Bloom of diatoms ended in early April. The association of diatom bloom with low temperatures was also marked by other authors [55,61]. Upon studying of native algae samples during the spring bloom many ciliates, rotifers and filamentous fungi were met among abundance of *Melosira* filaments. This indicates the presence of significant amount of water dissolved organic matter excreted by *Melosira* during its vegetation.

In late June 2016 bloom of blue-green algae began. At the beginning of the bloom the values marked varied from 0.1 to 3.7 mg/ dm^3 and a month later vegetation rate of the species *Microcystis aeruginosa* began to increase and algae *Microcystis aeruginosa* became the dominant species in mid-August. Maximal average biomass (31.5 mg/ dm^3) was observed in late August. Bloom of blue-green algae continued until early October. Upon studying of native algae samples at the beginning of summer bloom crustaceans from Chydoridae actively nourished *Microcystis* cells were frequent. This confirms the importance of blue-green algae as food for zooplankton that was noted by other authors [62].

The data according vertical distribution of phytoplankton showed its non-uniformity in water column during algae bloom in spring and during the summer-autumn period. At the beginning of bloom in spring high values of algae concentration were characteristic for bottom water and upon bloom development maximal algae concentration moved to surface layer of water column (Fig. 3.3.1). In summer distribution pattern of phytoplankton in bottom and surface layers changed considerably. Blue-green algae dominating in summer accumulated in surface layer whether at the beginning or at the end of its bloom. With the accumulation of phytoplankton biomass, the difference in concentration of blue-green alga between surface and bottom layers increased. In autumn phytoplankton biomass in bottom layer increased compared to the surface layer because the cooling of the bottom layer is slower that’s why algae in bottom layer aren’t subjected to depression usual for phytoplankton in surface layer. In 2015 bloom of diatoms algae was less intensive compared to 2016 due to long period of low temperature in March and further rapid increase of temperature. Bloom of *Melosira islandica* began March 19 and lasted for only a few days (Fig. 3.3.2). During *Melosira islandica* bloom biomass of diatoms in bottom layer amounted up to 18.5 mg / dm3 and exceeded diatoms biomass in surface layer. This is due to the fact that in winter resting spores and partly vegetative cells of diatoms and blue-green algae remain on the bottom and upon favorable conditions phytoplankton vegetation begins from the bottom [56,63]. *Melosira islandica* is a stenothermic algae which vegetation takes place in the temperature range from 4 °C to 8 °C. In addition, reaching of water temperature 4 °C promotes mixing of water column and raising algae from the bottom to the surface. Therefore, at the beginning of Melosira bloom maximum biomass was concentrated in the bottom layer but with rising of temperature up to 6 °C mixing of water column took place that caused elevation of algae to the surface layer. Further depression of phytoplankton took place. After depression of phytoplankton a new growth of algae biomass lasted about a week.

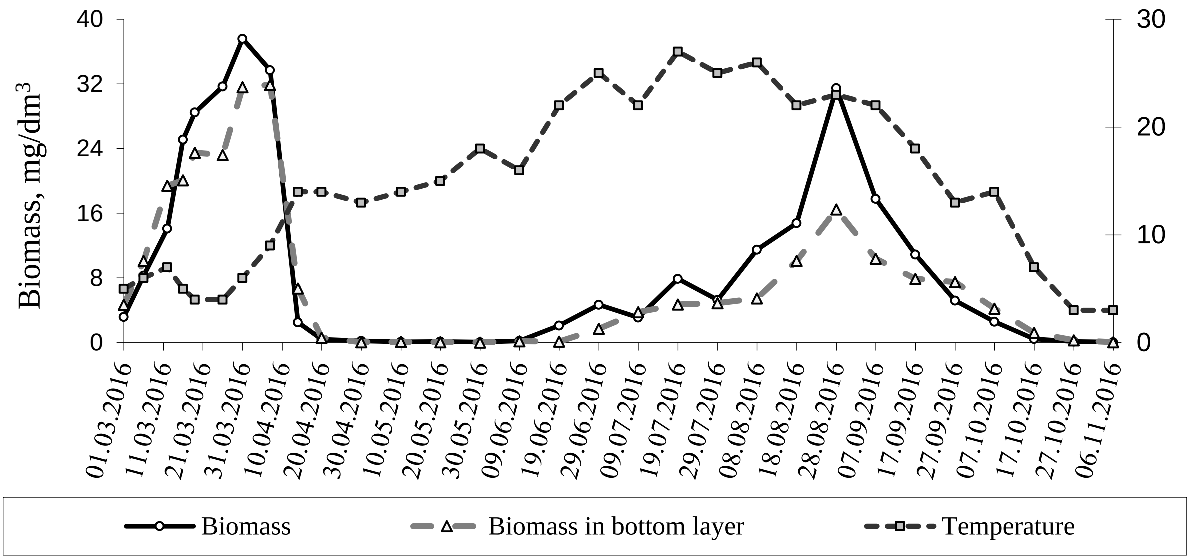


Figure 3.3.1. Seasonal dynamics of phytoplankton biomass of the Zaporizke Reservoir in 2016

This phytoplankton vegetation was characterized by less intensive growth compared with *Melosira* bloom and was caused by large diversity of the species *Melosira granulata, Navicula gracilis, Stephanodiscus hantzschii, Chroomonas pulex, Pediastrum duplex, Chlamydomonas monadina, Dictyosphaerium pulchellum, Ankistrodesmus angustus, Scenedesmus acuminatus.* Therefore, it was polydominant community with great species diversity, similar biomass of the species as well as with frequent changes of dominants and small degree of dominance.

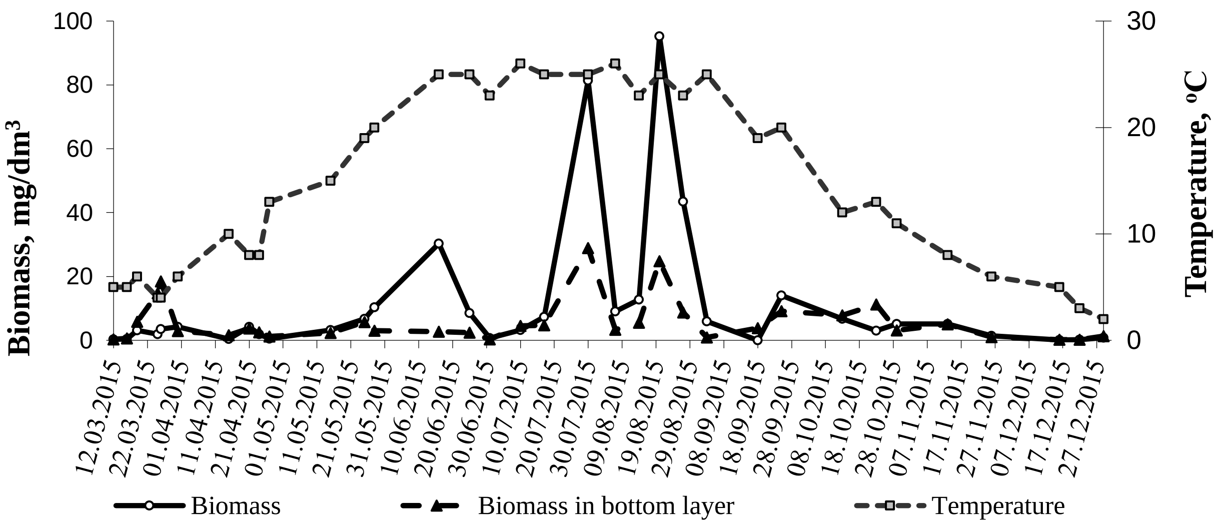


Figure 3.3.2. Seasonal dynamics of phytoplankton biomass of the Zaporizke Reservoir in 2015

During this period the vertical distribution of algae was uniform. In spring total biomass of phytoplankton in the surface layer of the reservoir varied from 0.28 to 10.35 mg / dm^3 and averaged 3.13 mg/dm^3. At the beginning of June, the species *Aphanizomenon* flos-aquae became a dominant and biomass of phytoplankton reached 30.3 mg/dm^3. Vertical distribution of phytoplankton was not uniform with concentration of algae in the surface layer. This phenomenon is typical for blue-green algae domination due to gas vacuole presence.

Blue-green algae *Oscillatoria limnetica* and *Anabaena flos –aquae* together with *Aphanizomenon flos – aquae* were dominating species in spring.

In 2015 development of the species *Microcystis aeruginosa* began in July. During the period from 10.07.15 to 30.07.15 biomass of phytoplankton increased from 3.24 to 81.4 mg/dm^3 of which 97% was created by *Microcystis aeruginosa*. Maximum of phytoplankton biomass – 95.2 mg/dm^3 was observed at the end of August. Bloom of blue-green algae lasted until the middle of October. In autumn due to gradual die-away of blue-green algae proportion of Bacillariophyta species from genus *Nitzchia, Stephanodiscus, Cyclotella, Navicula* etc. was growing in phytoplankton species composition. The number of phytoplankton varied widely – from 1.99 to 34.0 mln. cells/dm^3 in the surface layer and from 0.55 to 8.0 mln. cells/dm^3 mln. cells/dm^3 in the bottom layer. Since the end of September until the end of October phytoplankton biomass in the bottom layer increased in comparison with the surface layer and this difference was especially apparent in December. Higher level of phytoplankton biomass in the bottom layer in comparison with the surface was caused probably by less temperature fluctuations in the bottom layer in comparison with the surface layer in the cooling period of the reservoir. High stability of temperature in the bottom layer which seldom drops below 4 °C, is the reason that algae are found in the bottom layer from where phytoplankton vegetation begins with warming in spring. In summer and in September the total biomass of algae in the reservoir varied from 2.05 to 520 mg/dm^3, and averaged 87.3 mg/dm^3 in surface layer and 4.22 mg/dm^3 in bottom layer. Diatoms and blue-green algae were dominating groups occupying 19 – 34 %, and 36 – 84.0 % of total algal biomass, respectively while green algae 12-25 % and algal groups occupied 6 – 10 % of the total phytoplankton biomass. In winter phytoplankton was represented mainly by cold-water or eurythermic diatoms. During this period the biomass of phytoplankton had the lowest annual values and varied from 0.07 to 0.9 mg/dm^3 in the surface layer and from 0.2 to 1.32 mg/dm^3 in the bottom layer and averaged 0.47 mg/dm^3. On September 7, 2016 samples of phytoplankton were collected at different sites of the reservoir in order to study the distribution of phytoplankton in the reservoir and the impact of wastewater on the level and ratio of phytoplankton groups development as well as for ranking of the reservoir sites by contamination. Abundance of phytoplankton varied from 11.4 to 687.2 mln.cells /dm^3 and averaged 192.4 mln.cells/dm^3 (Table 3.3.2).

In the sampling period blue-green algae clearly dominated among phytoplankton groups that reflected on their percentage of total phytoplankton abundance at the different sites – from 86.5 to 99.3%, in average 95.7%. In early September 2016 at relatively clean station 'Near Kodaki water draw-off' served as the site for comparison abundance of phytoplankton was 141.97 mln.cells/dm^3 and biomass was 8.77 mg/dm^3. Species diversity and uniformity of phytoplankton groups was highest at the site 'Near Kodaki water draw-off' compared to other sites studied. The maximal abundance and biomass was observed at the site 'Near Voyskovoe village' while minimal abundance and biomass were reported at the sites 'Petrovsky plant sewage' and 'discharge of urban sewage at the Festival pier'. Degree of phytoplankton development increased at the sites 100 m downstream discharges but in different manner.

While level of phytoplankton biomass increased slightly at the site ‘100 m downstream Petrovsky plant sewage’ then at the site ‘100 m downstream discharge of urban sewage’ biomass of phytoplankton rised sharply from 2.93 to 16.28 mg/dm^3 (Table 3.3.3).

Table 3.3.2. Abundance of phytoplankton groups (mln.cells/dm^3) at littoral sites of the Zaporizke Reservoir in September 2016

	1	2	3	4	5	6	7	8
Bacillariophyceae	1.71	013	0.25	0.63	0.07	0.21	1.15	1.6
Cyanophyceae	139.3	10.5	32.91	73.47	33.4	310.9	231.1	682.3
Clorophyceae	0.96	0.28	0.44	0.36	0	1.92	1.48	3.08
Euglenophyceae	0	0.52	1.34	0	5.12	3	0.72	0.25

Note: 1 – near Kodaki water draw-off, 2 – Petrovsky plant sewage, 3 – 100m downstream Petrovsky plant sewage, 4 – river port of Dnipro city, 5 – discharge of urban sewage at the Festival pier, 6 – 100 m downstream discharge of urban sewage, 7 – near Monastyrsky island, 8 – near village ‘Viyskove’.

Table 3.3.3. Biomass of phytoplankton groups (mg/dm^3) at the sites of open littoral of the Zaporizke Reservoir in September 2016

	1	2	3	4	5	6	7	8
Bacillariophyceae	2.1	0.16	0.3	0.75	0.08	0.25	1.33	1.86
Cyanophyceae	6.43	0.5	1.55	3.47	1.57	14.8	11.1	32.4
Clorophyceae	0.24	0.07	0.11	0.09	0	0.48	0.37	0.77
Euglenophyceae	0	0.12	0.34	0	1.28	0.75	0.18	0.05

Note: 1 – near Kodaki water draw-off, 2 – Petrovsky plant sewage, 3 – 100m downstream Petrovsky plant sewage, 4 – river port of Dnipro city, 5 – discharge of urban sewage at the Festival pier, 6 – 100 m downstream discharge of urban sewage, 7 – near Monastyrsky island, 8 – near village ‘Viyskove’.

It is obvious that decreasing in phytoplankton biomass at the sites of sewages discharge was caused by toxic effect of sewages compounds on degree of phytoplankton development. Thus despite tolerance of blue-green algae to the effects of sewages toxic compounds blue-green vegetation is inhibited in conditions of the Zaporizke Reservoir.

A significant increase in phytoplankton biomass at the site ‘100m downstream discharge of urban sewage’ was caused by specifics of the sewage in which proportion of nutrients and organic matter was much higher compared to the site '100 m downstream Petrovsky plant sewage' due to high concentration of such compounds as heavy metals and oil products at the last site which inhibit phytoplankton vegetation. Organic matter of the site 'discharge of urban sewage at the Festival pier' while nutrients decomposition stimulates primarily blue-green algae reproduction and as a result blue-green algae bloom had the greatest rates at the site '100 m downstream discharge of urban sewage' compared to other sites in reservoir upper part.

Decrease in degree of phytoplankton development at the site 'river port of Dnipro city' was apparently caused by high oil product concentration that inhibits reproduction and growth of algae. At the site 'near Monastyrsky island' at relatively high biomass species diversity and uniformity of phytoplankton groups increased compared to upstream sites. The greatest abundance and biomass of phytoplankton in lower part of the reservoir at the site 'near Voyskovoe village' were explained on the one hand by farness of the site from the nearest major sewage and on the other hand by retardation of current speed that lead to the development and accumulation of phytoplankton. Under analyzing of water quality formation features and self-purification processes in the Zaporizke Reservoir it was found out that much part of phytoplankton species are indicators of water organic pollution as their percent of total phytoplankton species in this part of reservoir equaled 54%. Massive development of such β-mesosaprobiontic species as *Euglena acus, E. viridis, Trachelomonas hispida*, *Stephanodiscus hantzschii* at the areas of sewages impact indicates water quality impairment due to organic matter pollution especially in the upper part of the reservoir under the influence of Dnipro city sewages. At the investigated sites of the Zaporizke Reservoir saprobity index indicating organic pollution varied from 1.91 to 2.0 and averaged 2.26. Saprobity index had maximal value at the site 'discharge of urban sewage at the festival pier' while at the site 'Petrovsky plant sewage'. Saprobity index little decreased and the sites 100 m downstream both studied sewages ranged in similar order (Table 3.3.4).

Table 3.3.4. Saprobity index by phytoplankton at the sites of open littoral of the Zaporizke Reservoir in September 2016

The site of open littoral	Shannon index	Saprobity index
Near Kodaki water draw-off	1.9	1.91
Petrovsky plant sewage	0.85	2.55
100 m downstream Petrovsky plant sewage	1.13	2.26
River port of Dnipro city	1.57	2.20
Discharge of urban sewage at the Festival pier	0.43	2.74
100 m downstream discharge of urban sewage	0.62	2.33
Near Monastyrsky island	1.69	2,1
Near Viyskove village	0.97	2.0

At the sites ut of sewage influence β-mesosaprobic algae species with average saprobity index 2.05. The smallest saprobity index corresponding to the lowest level of organic pollution of the sites investigated was observed at the site 'near Kodaki water draw-off' that is caused on one hand by situation of this site upstream of the main sewages and on the other hand by the most stream speed among studies sites as saprobiontic species are inhibited in conditions of high stream speed.

Shannon index by phytoplankton reflecting its species diversity at the sites investigated showed decreasing of species diversity at the sites of both sewages investigated. Shannon index low values were observed both at the sites of sewages and at the sites downstream sewages that is explained by not only low species numbers but also by unevenness of species development under absolute domination of *Microcystis aeruginosa*. The highest value of Shannon index was observed at the site 'near Kodaki water draw-off' where uniformity of phytoplankton groups and species was maximal. In addition at this site high species diversity of diatoms was registered that is an indicator of water quality improving [64].

Under analyzing of the data obtained of phytoplankton development as well as analyzing of saprobity and Shannon indexes by phytoplankton according to the water quality classification [49] the site 'discharge of urban sewage at the festival pier' qualified as the 7 category 'heavily polluted', the site 'Petrovsky plant sewage' qualified as the 6 category 'polluted', both sites 100m downstream the studied sewages as the 5 category 'moderately polluted', the sites 'near Monastyrsky island' and 'near Voyskovoe village' as the 4 category 'weakly polluted' and the site 'near Kodaki water draw-off' as the 3 category 'clean enough'.

Species composition of phytoplankton of Pivdenne reservoir was quite diverse and represented by 28 species of algae including 13 species (46%) of Chlorophyta, 4 species (14%) of Cyanophyta, 10 species (36%) of Bacillariophyta), 1 species (4%) of Euglenophyta. Biomass of phytoplankton varied from 8.2 to 26.0 g / m^3 at different sites (on average 16.2 g / m^3). According to the fishery classification Pivdenne reservoir belongs to the 2 class (Sherman et al., 1992). Phytoplankton biomass was created mostly by blue-green algae *Microcystis auregenosa*, *Anabaena flos-aquae*, *Aphanizomenon flos-aquae*. In the second half of the summer, in the sites of blue-green algae concentration phytoplankton biomass reached 32 g / m^3. Among Chlorophyta fillum the genus *Volvox*, *Pandorina*, *Scenedesmus* dominated while among Bacillariophyta fillum the genus *Navicula*, *Pinnularia*, *Sinedra*, *Gomphonema* were more frequent. The analysis of the results of samples processing shows that the species composition of phytoplankton of Khrystoforivs'ke reservoir in the investigated period was represented by algae from five systematic divisions: Cyanophyta, Euglenophyta, Pyrrophyta, Chlorophyta, Bacillariophyta. In terms of biodiversity, the euglenic and diatoms had the greatest species richness were - from 50% to 70% of species.

But most of phytoplankton biomass was created by the Cyanophyta and Euglenophyta species *Euglena viridis*, *E. acus*, *E. proxima*, *Trachelomonas verrucosa*, *Scenedesmus quadricauda*, *Scenedesmu saccuminatus*, *Anmstrodesmus aciciularis*, *Pediastrum duplex*, *Coelastrum microporum*, *Tetraedron incus*, *Anabaenaflos-aquae*, *Oscillatoria tenuis*.

Quantative and species composition of littiral and pelagic phytoplankton were similar. Great share of Euglenophyta in phytoplankton of of Khrystoforivs'ke reservoir is indicates of organic contamination influx. Biomass of phytoplankton of Khrystoforivs'ke reservoir was 64,1 g / m^3 that according to the fishery classification corresponds to parameters of water bodies of high nutrient status (I - II fish-farming class). Thus, the reservoir should be stocked with phytoplanktivorous fishes for its further use with fishery purposes.

4. BIOLOGICAL CHARACTERISTICS OF INDUSTRIAL FISH FAUNA AND EVALUATION OF FISH RESOURCES IN FISHERY OBJECTS

The formation of industrial ichthyofauna has a certain dynamics, which grounds predicting future catches. But in the complex reservoirs, influenced by anthropogenic load, ecosystem destabilizes, causing unforeseen ichthyological successions, which lead to a decrease in industrial fish stocks. One way to control the state number of industrial populations is the long-term seasonal ichthyological monitoring that underlies the biological justification of fishing in the internal waters of the country.

Currently, due to uncontrolled human activities (excessive selective fishing of older age groups of fish, non-observance of the rules of industrial and amateur fishing, etc.), as well as regulation of river flow and global warming (increased water temperature, increased mineralization, increased area of shallow water with high sedimentation and overgrown aquatic vegetation) in the Zaporizke Reservoir there is a steady trend to the increase of low-value short-cycle fish species and loss of the diversity of industrial species. This is also contributed by the decreased number of predators; the level of their populations' reproduction is low.

Environmental management in the internal waters, which is realized through industrial fish capture, should have a rational ground, including measures to preserve and increase the industrial stocks of fish in the Zaporizke Reservoir by forecasting and limiting the capture of certain fish species.

The modern existence of continental reservoirs is characterized by increased pressures on components of aquatic ecosystems. Water pollution by flows of technogenic and service-utility origin, which contain mineral and organic substances, pesticides, oil products and radionuclides, change the habitat of aquatic lives, which is reflected in their species composition and dynamics of quantitative indicators.

In turn, this leads to the transformation of the species composition of fish fauna, and it reduces the number of valuable fish species (Pike *Exos luceus* Linnaeus, 1758; Russian sturgeon *Acipenser gueldenstaedtii* Brandt et Ratzeburg, 1833; Sterlet Acipencer ruthenus Linnaeus, 1758; Pikeperch Sander lucioperca Linnaeus, 1758) and the number eurybiontic short-cycle of fish (Black Sea sprat *Clupeonella cultriventris* Nordmann, 1840; European bitterling *Rhodeus amarus* Bloch, 1782; Pseudorasbora *Pseudorasbora parva* Temminck et Schlegel, 1846; gobies Gobiidae Fleming, 1822) grows up. Also this is contributed by deterioration of the main species reproduction conditions.

Everyone knows that the volume of commercial reserve and the level of the reproduction of certain fish species are determined by the efficiency of their breeding. This means that the number of fish populations in natural waters is limited mainly by breeding conditions. Many regulated reservoirs have significant stress factors for natural reproduction of native fish species – violation of level regime in the spring, the adverse condition of spawning grounds, illegal fishing during the spawning season, etc [65,66].

Table 4.1. Ichthyofauna of the Zaporizke Reservoir.

№	Taxonomic category	Stages of formation of ichthyofauna			
		until 1931	1932 – 1960	1961 – 2010	2010 – 2017
1	2	3	4	5	6
	Petromyzontidae Bonaparte, 1831				
1	*Eudontomyzon mariae* (Berg, 1931)	+	–	–	+ *
	Acipenseridae Bonaparte, 1831				
2	*Acipenser gueldenstaedtii* (Brandt & Ratzeburg, 1833)	+	–	–	–
3	*Acipenser ruthenus* (Linnaeus, 1758)	+	+	+	+
4	*Acipenser stellatus* (Pallas, 1771)	+	–	–	–
5	*Huso huso* (Linnaeus, 1758)	+	–	–	–
	Anguillidae Rafinesque, 1815				
6	*Anguilla anguilla* (Linnaeus, 1758)	+	–	+ *	+ *
	Clupeidae Cuvier, 1816				
7	*Alosa pontica* (Eichwald, 1838)	+	–	+ *	+ *
8	*Clupeonella cultriventris* (Nordmann, 1840)	–	+	+	+
	Cyprinidae Fleming, 1822				
9	*Abramis brama* (Linnaeus, 1758)	+	+	+	+
10	*Alburnoides bipunctatus* (Bloch, 1782)	+	–	–	+ *
11	*Alburnus alburnus* (Linnaeus, 1758)	+	+	+	+
12	*Aristichthys nobilis* (Richardson, 1845)	–	–	+	+
13	*Aspius aspius* (Linnaeus, 1758)	+	+	+	+
14	*Ballerus ballerus* (Linnaeus, 1758)	+	+	+ *	+ *
15	*Ballerus sapa* (Pallas, 1814)	+	+	+ *	+ *

16	*Barbus borysthenicus* (Dybowski, 1862)	+	+	–	–
17	*Blicca bjoerkna* (Linnaeus, 1758)	+	+	+	+
18	*Carassius gibelio* (Bloch, 1782)	–	–	+	+
19	*Carassius carassius* (Linnaeus, 1758)	+	+	+	+
20	*Chondrostoma nasus* (Linnaeus, 1758)	+	+	+ *	+ *
21	*Ctenopharyngodon idella* (Valenciennes, 1844)	–	–	+	+
22	*Cyprinus carpio* (Linnaeus, 1758)	+	+	+	+
23	*Gobio gobio* (Linnaeus, 1758)	+	+	+	+
24	*Hypophthalmichthys molitrix* (Valenciennes, 1844)	–	–	+	+
25	*Idus idus* (Linnaeus, 1758)	+	+	+ *	+ *
26	*Leucaspius delineatus* (Heckel, 1843)	+	+	+ *	+
27	*Pelecus cultratus* (Linnaeus, 1758)	+	+	+	+
28	*Petroleuciscus borysthenicus* (Kessler, 1859)	–	–	+	+
29	*Pseudorasbora parva* (Temminck et Schlegel, 1846)	–	–	+	+
30	*Rhodeus amarus* (Bloch, 1782)	+	+	+	+
31	*Rutilus frisii* (Nordmann, 1840)	+	–	–	–
32	*Rutilus rutilus* (Linnaeus, 1758)	+	+	+	+
33	*Scardinius erythrophthalmus* (Linnaeus, 1758)	+	+	+	+
34	*Squalius cephalus* (Linnaeus, 1758)	+	+	+	+
35	*Tinca tinca* (Linnaeus, 1758)	+	+	+	+
36	*Vimba vimba* (Linnaeus, 1758)	+	+	+ *	+ *
	Cobitidae Swainson, 1839				
37	*Cobitis taenia* Linnaeus, 1758	+	+	+	+
38	*Misgurnus fossilis* (Linnaeus, 1758)	+	+	+	+
	Balitoridae Swainson, 1839				
39	*Barbatula barbatula* (Linnaeus, 1758)	+	+	+	+ *
	Siluridae Cuvier, 1816				

40	*Silurus glanis* (Linnaeus, 1758)	+	+	+	+
	Ictaluridae Gill, 1861				
41	*Ictalurus punctatus* (Rafinesque, 1818)	–	–	+ *	+ *
	Esocidae Cuvier, 1816				
42	*Esox luceus* (Linnaeus, 1758)	+	+	+	+
	Lotidae Bonaparte, 1837				
43	*Lota lota* (Linnaeus, 1758)	+	+	+	+ *
	Atherinidae Risso, 1827				
44	*Atherina pontica* (Eichwald, 1831)	–	–	+	+
	Gasterosteidae Bonaparte, 1831				
45	*Gasterosteus aculeatus* (Linnaeus, 1758)	–	–	+	+
46	*Pungitius platygaster* (Kessler, 1859)	+	+	+	+
	Syngnathidae Bonaparte, 1831				
47	*Syngnathus nigrolineatus* (Eichwald, 1831)	+	+	+	+
	Centrarchidae Bleeker, 1759				
48	*Lepomis gibbosus* (Linnaeus, 1758)	–	+ *	+ *	+
	Percidae Cuvier, 1816				
49	*Gymnocephalus acerinus* (Guldenstadt, 1774)	+	+	–	+ *
50	*Gymnocephalus cernuus* (Linnaeus, 1758)	+	+	+	+
51	*Perca fluviatilis* (Linnaeus, 1758)	+	+	+	+
52	*Sander lucioperca* (Linnaeus, 1758)	+	+	+	+
53	*Sander volgensis* (Gmelin, 1789)	+	+	+	+ *
	Gobiidae Fleming, 1822				
54	*Benthophilus stellatus* (Sauvage, 1874)	+	+	+ *	+ *
55	*Mesogobius batrachocephalus* (Pallas, 1814)	–	–	+	+
56	*Neogobius fluviatilis* (Pallas, 1814)	+	+	+	+
57	*Neogobius gymnotrachelus* (Kessler, 1857)	–	–	+	+

58	*Neogobius kessleri* (Gunther, 1861)	+	+	+	+
59	*Neogobius melanostomus* (Pallas, 1814)	+	+	+	+
60	*Proterorhinus marmoratus* (Pallas, 1814)	+	+	+	+
	Cottidae Bonaparte, 1831				
61	*Cottus gobio* (Linnaeus, 1758)	+	–	–	–

Note: '+' – the presence of species, '–'– absence of species, '*' – occasional find.

The new conditions for fish existence emerged as a result of over-regulation of the Dnieper River runoff and creating cascade of reservoirs; they have caused the significant restructuring of qualitative and quantitative ichthyofaunal content. The number of migratory and reophilic fish species (European asp *Aspius aspius* Linnaeus, 1758; Common vimba *Vimba vimba* Linnaeus, 1758; Common barbel *Barbus barbus* Linnaeus, 1758; Pontic-Azov shad *Alosa pontica* Eichwald, 1838; Russian sturgeon *Acipenser gueldenstaedtii* Brandt et Ratzeburg, 1833) gradually decreased, while the number of limnophilic fish (Prussian carp *Carassius gibelio* Bloch, 1782; Silver bream *Blicca bjoerkna* Linnaeus, 1758; Common tench *Tinca tinca* Linnaeus, 1758; Common rudd *Scardinius erythrophthalmus* Linnaeus, 1758; European perch *Perca fluviatilis* Linnaeus, 1758; Common bream *Abramis brama* Linnaeus, 1758; Common carp *Cyprinus carpio* Linnaeus, 1758) respectively increased. The latter takes the leading position in fish catches. The runoff over-regulation regime which acts in the reservoir waters over the past 80 years has led to siltation, overgrowth of natural spawning grounds with aquatic vegetation, shoaling shallow coastal areas. As a result, throughout the reservoir water area, rather tense situation with natural reproduction of resource fish species has been formed, and the overall environmental situation of the basin has worsened on the background of intense human impact.

4.1. Characteristics of industrial fish populations of Zaporizke Reservoir

The analysis of catches from fishing gears at the rate of 100 netting days of the control for certain species is stable, fluctuating within the limits of indicators for 2014–2016 years, and corresponds to a multi-yearly average.

The species composition of the ichthyofauna was typical for the reservoir. The analysis of age groups and dimensional and weight series does not give grounds for reducing the size of industrial stocks.

The results of the studies allowed increasing the limits for the catches of zander and white breamin 2018.

According to the State Agency of Fisheries in Dnipropetrovsk region, in 2016, 803.1 tons of fish were captured in the Zaporizke Reservoir. The highest percentage fell on Prussian carp and amounted to 43.19 %. The next place in industrial catch had the roach – 20.55 %, then the bream and white bream – 8 %. Fifth one, in the ranking of industrial catches was a white carp (Fig. 4.1.1).

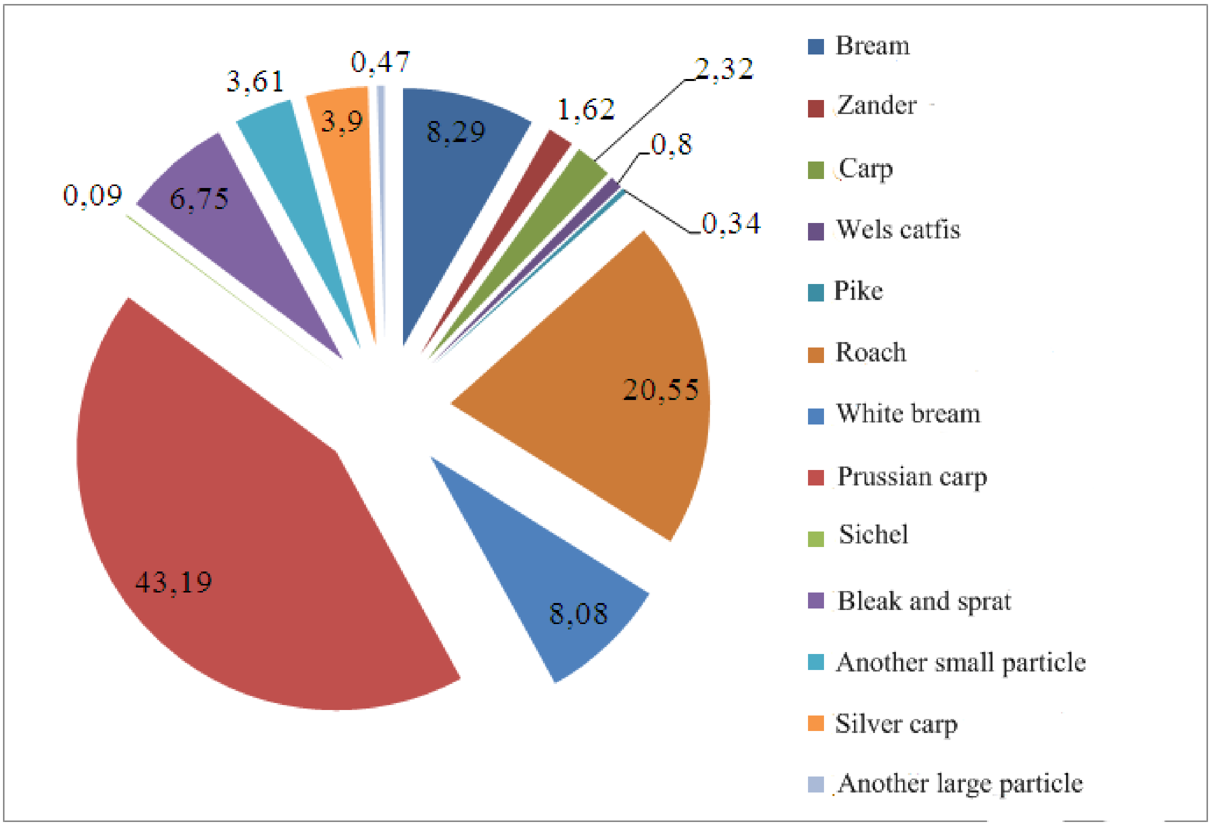


Figure 4.1.1. Percentage of industrial fish species in catches of the Zaporizke Reservoir in 2016, %.

The roach *Rutilus rutilus* (Linnaeus, 1758). The average annual catch of roach from 2006 to 2016 reached 144.34 tons. For the last 10 years, the minimum catch of 118 tons was in 2013; the maximum one was in 2009 and reached 167.9 tons. The roach capture in 2016 amounted to 165.03 tons (table 4.1).

The age structure of the population of roach had 11 age groups, from 3 (0.95%) to 12 years (0.95%). By gender, age groups were distributed as follows: females of 3–12 years old, males of 3–11 years old. The core of the roach population was 4–6 years old individuals with a proportion of 80.9%. The average industrial length of roach individuals was kept at the level of 2015–2016 and amounted to 21.8±0.6 cm, the weight was 222.9±12.9 g, and in females the linear and weighted indices were higher respectively by 9% and 24%. As in previous years, it is noted that the individuals caught in the Samara Bay of the Zaporizke Reservoir were significantly slower in the growth and were significantly stunted due to the tense ecological state of the bay.

The reproductive core of the roach population was individuals of 4–6 years. The females of 5–6 years old and males of 4–5 years old dominated in the spawning population.

The Fulton fattening factor was 2.11±0.04, that is, the roach fattening was practically the same as in previous years. The fattening and fatness ratio (3–4 points) indicates favorable feeding conditions for this species of fish.

Figure 4.1.2. *Rutilus rutilus* (Linnaeus, 1758).

In 2017, in comparison with 2015, the number of roach in catches of control nets in the Zaporizke Reservoir increased by almost 19% and amounted to 10846 individuals (2419 kg) per 100 netting days. In 2016, there were 7788 individuals. (1659 kg) per 100 netting days of control gear, which is less by 15% than biomass in 2015.

In 2018, we can expect a slight increase in the size of the population of roach, since the 2011 generation was quite productive in comparison with the previous two years, the number of yearlings reached 196 ind./100 m^2. In 2012, the number of yearlings in the coastal areas was 125.85 ind./100 m^2. In 2013, the number of roach yearlings in the littoral of reservoir reached 50.68 ind./100 m^2, and the number of two-year-olds was 177.39 ind./100 m^2. In 2014, the number of roach yearlings in the littoral of reservoir reached 42.15 ind./100 m^2, and the number of two-year-olds was 84.11 ind./100 m^2. Thus, basing on the results of the analysis of the control of the fish stacks and the results of small-scale fishing, it can be assumed the moderate catch of older age groups on the background of sufficient replenishment, which compensates for the industrial withdrawal of this species.

As in previous years, the main catch of roach was observed for nets with a mesh size of 36–40 mm and amounted to 74% of the total volume. In the large-mesh net, the roach hit one-on-one – 1.2 %. According to the indicators of age and size and weight structure of the industrial roach population, the magnitude of industrial replenishment, it can be assumed that the state of the industrial roach population is at a fairly stable level.

Taking into account the natural coefficient (0.26) and total mortality (43.8%), the magnitude of replenishment and industrial activity, the roach stock in the Zaporizke Reservoir for 2018 was estimated at 1050 tons. The assimilation of the limits in previous years was at the level of 72–82%. With an optimal catch of about 25 %, we recommend setting a roach catch limit of 210 tons (Table 4.1.2).

Bream *Abramis brama (*Linnaeus, 1758). The analysis of the dynamics of industrial catches shows that during 2006–2016 the catch of the bream is fairly stable and remains at the level of 50–67 tons. In 2015, the industrial harvesting of the bream reached 66.58 tons, which is 78.3% of the established limit (Table 4.1, 4.1.2).

The age structure of the bream is represented by 14 classes; the maximum age in catches was 16 years (0.4%). The number of age classes in the fishery is at level 12. The core of the population of the bream was individuals aged from 5 to 10 years (92.3% in the fishery). The static series of the bream had the appearance of a curve with a sufficiently broad vertex for individuals aged 5–7 years and a smooth recession (from 8 to 11 years) with a subsequent gradual decrease in the number of individuals of older age groups. Taking into account the dynamics of catching the bream at 100 net days of the control order, this distribution shows an increase in the number of modal senior age groups, which are under the main industrial load.

The minimum age groups involved in spawning were in females, 4 years old with a proportion of 12.4%, in males 3 years old with a proportion of 2.3%. The reproductive core of the population was 4–8 years old fish and reached 82 %.

The industrial length of individuals according to the data of research fishing was 34.44±0.98 cm; the average weight was 1043.28±86.56 g, which is almost equal to the figures for 2014–2016. The fluctuation of the minimum and maximum values by weight in the bream was between 260 and 3730 g.

Figure 4.1.3. *Abramis brama (*Linnaeus, 1758).

Average values of the Fulton fattening factor over the last ten years are characterized by stability and amount to 2.4±0.05 units.

On average, in 2017, a catch per the 100 net days of control orders amounted to 961 ind. (1002.5 kg), in 2016 – 859 ind. (1003 kg), in 2015 – 994.5 ind. (962.9 kg), in 2014 this indicator was 1008.3 (1050.6 kg). The last five years there is a slight variation of this indicator in the range of 30–50 kg, which indicates a fairly stable state of the industrial bream population.

Approximately 52% by number (and 64% by biomass) of catches of bream was in nets with a mesh size of 75–80 mm. During the last seven years, there is a clear tendency to reducing the catches by small-mesh nets with a step a = 30–40 mm, which accounted for 13.2% of the total catch. Catching bream by nets with a step a = 55–70 mm, that is, those generations that will form the basis of fishing in 2018 reached 37%, indicating that the industrial core is sufficiently replenished.

In 2018, the bream stock will be formed by generations of 2011, 2012, 2013, 2014, which were marked as unproductive – 7.7, 2.38, 0.75 and 4.32 per 100 m^2, respectively.

The catch limit for catching the bream in recent years is kept at the level of 70–90%, in 2015 it was 76.3%, in 2016 it was 78.3%. Taking into account the coefficient of natural mortality (0.19), catch rate (0.26), the number of individuals of older age groups, the stock of bream is estimated at 440 tons today. Because of the low youth replenishment rates, it is advisable to set the catch limit for the bream in 2018 not higher than 25 % of the total stock, 110 tons. (Table 4.1.2)

Zander *Sander lucioperca* (Linnaeus, 1758). The natural range of the zander covers all the large river and lake basins of the Baltic (Elba, Oder, Vistula, Neman, West Dvina, Neva, the rivers of the Bothnichna and the Finnish bays) and the Black Sea (Maritsa, Danube, Dniester, Dnipro, Don, Kuban). After the construction of numerous channels and reservoirs and acclimatization works, the area of zander has considerably expanded. In Europe, it was acclimatized in England (Thames River), France (Rhône), Germany (Rhine River), Southern Sweden (Lake Venern), in the White Sea basin, Crimea.

In the reservoirs of the Dnipropetrovsk region, the zander is widespread, not numerous species. It is found everywhere in all reservoirs of the region, in some lakes and ponds, in river tributaries it is less common. It is valuable object of fishing.

In recent years, the population of zander in the Zaporizke Reservoir had such tendency as low rates of replenishment, reduced reproductive indicators and ‘rejuvenation’ of the spawning stock, and a decrease in the linear and weighted indices of the industrial population.

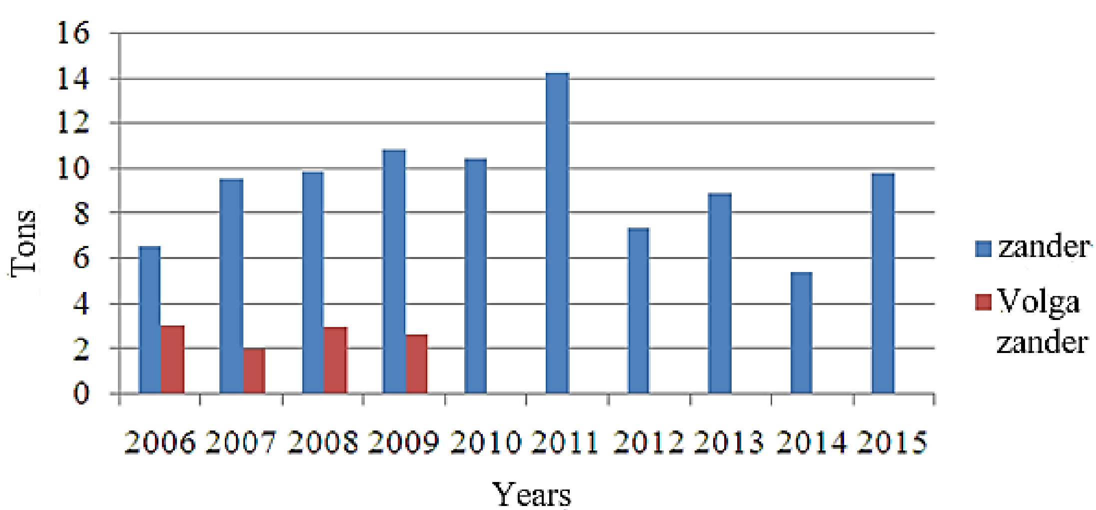


Figure 4.1.4. The actual catch of zander and Volga zander in the Zaporizke Reservoir.

The industrial catches of zander in the Zaporizke Reservoir during 2006–2016 are considerably instable and rather low. The catches of this species range from 5.4 tons (2014) to 13.0 tons (2016), which is the result of an over catch in 2002, after which its catches dropped sharply. The dynamics of industrial catches of zander during the last two years indicates a positive trend and stable development, 81% of the limit (Table 4.1.2). Today, the proportion of zander in general catches in the Zaporizke Reservoir is no higher than 2%; annual average catches are kept at the level of 9.25 tons (Fig. 4.1.4), and the commercial exploitation of the *Volga zander* in 2010 is generally prohibited by law.

The age range of zander in control catches had 13 classes (3–14 years old). The core of the industrial population consisted of 4–7 year old individuals (88.4%). The share of elderly fish in the main was represented by 8–14-year-olds and was 4.9%. In the population of zander there is an increase in the proportion of 3-year-old individuals, indicating its rejuvenation. The curve of the static series has a peak in four-year-olds, then in fewer five-year periods, and a gradual decline in curvature since the six-year period was observed. In the current year, the tendency to significant rejuvenation of the zander is also observed, which is caused by the reduction of the right wing of the static series due to the low number of senior-age individuals in catches. Although there is a slight increase in the average age of fish, in 2017 this figure reached 5.04, in 2016 – 4.4 years, and in 2015 it was 3.85 years. Thus, it is possible to note the decisive influence of natural replenishment on structural indicators of the zander population covered by the fishery (Fig. 4.1.5).

The industrial length of individuals from control nets ranged from 19 to 87 cm, and the average length of industrial length reached 39.99±1.43 cm. The minimum mass of individuals found in fishing gear ranged from 200 g at three years old fish, maximum at 14 years old fish reached 5.38 kg. The average weight of zander was 1053.6±130.9 g. The Fulton fattening factor was at the level of previous years and was 1.9±0.25.

Figure 4.1.5. *Sander lucioperca* (Linnaeus, 1758).

In 2015, on 100 net days of the control order, zander on average in the Zaporizke Reservoir was 287.5 kg, which is 37 kg higher than in 2014. In 2016, catches on 100 net days of control orders amounted to 239 kg (364 ind.), which is 16.8 % less than last year. In the spring of 2017, catches per 100 net days of control orders amounted to 708.5 kg (672 ind.), which is the highest figure in the last 10 years.

Catches of zander in current year by number and biomass is based on nets with a mesh a = 40–50 mm, reaching 61 %. In the nets, with the mesh a = 30–36 mm in 2017, the percentage decreased from 34.8% (2016) to 30.4% (2017). In the Samara Bay, on a net with a mesh of 30–32 mm there are about 38 % of the total catch of zander, which is caused by sufficient stiffness of individuals caused by the hydroecological conditions of the bay and anthropogenic loading.

The current stock of zander is provided by generations 2012, 2013 and 2014. The number of yearlings in this period was respectively 0.44, 0.54 and 1.23 ind./100 m^2. The low number of zander was observed in 2010 and 2011 and amounted to 0.10-0.11 ind./100 m^2 for each year; in 2012 and 2013, the number of two-year-olds in shallow waters of the Zaporizke Reservoir reached 1.22 and 1.5 ind./100 m^2. In 2014, the number of two-year-old zander in the littoral reached 0.98 ind./100 m^2.

Thus, taking into account the coefficient of natural mortality (0.26), the catch rate (0.27), the increase in the indicator of industrial activity, the stock of zander in the Zaporizke Reservoir can be estimated at 124 tons. The recommended limit for catching pike perch in 2018 should not exceed 20 t (Table 4.1.2).

As in previous years, there is a significant negative impact on the zander population on the part of fishermen who catch under-sized individuals in large quantities.

Volga zander *Sander volgensis* (Gmelin, 1789). In the Dnipro reservoirs of the Dnipro region, the Volga zander has a limited distribution. This is a not numerous species, since it meets mosaically throughout the water area of Kakhovske, Zaporizke and Kam'yans'ke Reservoirs, in large tributaries (Samara Bay, Samara Dniprovska River, the entries of Mokra Sura and Kilchen rivers). In the Zaporizke Reservoir the Volga zander forms local populations, the morphotype of which differs from the morphotypes of the Don and Volga representatives of the species. The species is protected in accordance with the provisions of Annex 3 of the Berne Convention, entered in the International Red Data Book of IUCN, in the Red Data Book of Ukraine.

In the Zaporizke Reservoir, the main places of existence of the Volga zander are located on plots with sufficient flow, rich oxygen regime, and rocky, sandy and sandy-rocky bottom, depth fluctuations, adjacent to the shallow, flooded riverbeds of the river. The most numerous populations of the Volga zander are such from the middle (from the Dnipro to the Petrov-Svistunovo village) and the lower (from the village Petrov-Svistunov to the dam of Zaporizhzhya hydro power station) deep-water sections of the Zaporizke reservoir.

The Volga zander population in the Zaporizke Reservoir is in critical state, the species is classified as vulnerable and endangered, and its number is limited and is characterized by localization.

The age range of the Volga zander has 8 classes (2–9 years). The population core consisted of 3–5-year-old individuals (78%). The share of elderly fish in the main was represented by 7–9-year-olds and amounted to 7% (Table 4.1.1).

Table 4.1.1. Biological indicators of the Volga zander

Indicators		max	min	M±m
Length L, cm	♀	61.00	23.00	39.10±1.74
	♂	62.00	21.00	35.29±1.45
Length l, cm	♀	52.00	19.00	34.14±1.55
	♂	51.00	17.00	31.18±1.23
Weight, g	♀	2400.0	180.00	620.15±108.10
	♂	1200.0	170.00	510.23±56.16
FC (by Fult.)	♀	2.13	1.16	1.46±0.05
	♂	2.40	1.10	1.35±0.04
Age, years	♀	8.00	2.00	4.36±0.25
	%	1.5	3.3	-
	♂	9.00	2.00	4.54±0.37
	%	2.5	1.5	-
Fertility, thous. eggs.		138.75	31.3	91.72±32.84

Note: max is maximum value, min is minimum value, M±m – is arithmetic mean and error, σ – is mean square deviation, V – is quadratic coefficient of variation, ♀ – females, ♂ – males.

The length of the individuals of the Volga zander was: 35 cm in females, 32 cm in males; the weight of females varied in the range from 180 g to 2.4 kg, an average of 620 g, males – from 170.0 g to 1.2 kg, an average of 510 g.

The Volga zander population shows an increase in the proportion of 2-year-olds and 3-year-olds, indicating its rejuvenation. Rejuvenation of the population is a negative consequence, which indicates excessive catching of the individuals of the population, first of all, poaching fishing, catching inferior individuals and the catch of this species by fishermen.

The average weighed Fulton fatting coefficient of the Volga zander was at the level of fatting of the zander and was 1.4 units. The feeding conditions of the Volga zander in the Zaporizke Reservoir can be considered as good, and its forage base is formed by many numerical representatives of cmall short-cycle species (bleak, kilka, gobies, and aterina), which, according to the fishery classification, are low-value and non-industrial.

The tempo of the linear and weight growth of the Volga zander in this reservoir is stable high, that is, the conditions of feeding is not a limiting factor in the formation of its ichthyomass.

Figure 4.1.6. *Sander volgensis* (Gmelin, 1789).

White bream *Blicca bjoerkna* (Linnaeus, 1758). For the last 10 years, the volume of its extraction is kept at the level of 40–64 tons (up to 10 % in total catches). In 2016, the development of the quota was 86.5 %. White bream catches are based mainly on individuals aged 4–5 years. In control catches, white bream is represented by 9 industrial groups, from 3 (0.7 %) to 11 (0.7 %) years. The static series of age indices of white bream has the appearance of a not symmetric curve with a peak on 4year-old specimens, as well as a displacement of a row in the right wing due to the catch of 7–11 year old individuals. The increase in catches in the number of individuals of older age groups created conditions for increasing the average age of industrial individuals from 4.7 years (2016) to 5.15 (2017).

The average linear and weight indicators were: industrial length was 17.93±0.50 cm, weight was 157.96±16.84 g. The value of linear and weight indicators almost remained at the level of the past years. The average linear and weight indicators of industrial individuals for almost 10 years are kept almost equal. Females were oppressed in the growth of males by 21 %. In the Samara Bay, individuals of the silver bream were significantly stunted, so it is recommended to remove them with fine-meshed stacked nets.

The fattening factor was quite high and reached 2.20±0.17. Stable linear and weight indicators and fattening factors indicate favorable feeding conditions for this species of fish.

The research quota for catching white bream in 2017 was determined as 96.7 %. In 2017, catches of white bream per 100 net days of the control order of stack nets reached 1332 ind. (210.5 kg), which is 60 % higher than last year’s figures. In 2016, catches of white bream per 100 net days were 653 ind. (126.8 kg), which is 3 % by number and 9.5 % by biomass lower than in 2015, 670 ind. (140.1 kg). The main catch, as in the previous year, fell on the net with mesh size a=30–40 mm (78 % by number and 65.4 % by biomass).

The core of the industrial flock of white bream was the generation of individuals of 2013 and 2014. The number of yearlings of these years was low and was at the level of 0.3 and 1.52 ind./100 m^2.

Figure 4.1.7. *Blicca bjoerkna* (Linnaeus, 1758).

Table 4.1.2. Development of capture limits for fish in the Zaporizke Reservoir over the past 10 years and the establishment of catch limits for 2018

Years	Zander			Bream			Roach			White bream		
	limit, t	fish catch data, t	%	limit, t	fish catch data, t	%	limit, t	fish catch data, t	%	limit, t	fish catch data, t	%
2007	14.0	9.5	68.2	70.0	53.0	75.5	220.0	161.0	73.0	70.0	41.0	59.0
2008	14.0	9.8	70.2	75.0	55.1	73.4	220.0	144.0	65.4	70.0	40.0	57.3
2009	17.0	10.81	63.6	80.0	56.8	71.0	225.0	167.9	74.6	75.0	49.0	65.3
2010	12.0	10.40	86.7	75.0	58.8	78.4	210.0	144.57	68.8	70.0	45.75	65.4
2011	20.0	14.21	71.1	75.0	62.41	83.2	180.0	143.21	79.6	80.0	52.27	65.3
2012	18.0	7.35	40.8	75.0	65.57	87.4	200.0	141.53	70.8	75.0	56.45	75.3
2013	9.5 P	8.69	91.47	70.0 P	67.1	95.95	180.0 P	118.09	65.61	63.0 P	52.63	83.53

2014	10.0 L	5.39	53.9	75.0 L	50.7	67.6	190.0 L	122.04	64.23	58.0 L	38.8	66.9
2015	12.0 L	9.74	81.19	80.0 L	61.0	76.26	187.0 L	133.5	71.41	58.0 L	42.63	73.5
2016	16.0 L	13.0	81.25	85.0 L	66.58	78.33	200.0 L	165.03	82.51	75.0 L	64.87	86.49
Fish catch limit, t												
2017	14.0 L			88.0 L			190.0 L			70.0 L		
2018	20.0 L			110.0 L			210.0 L			90.0 L		

Note: P – catch forecast, L – catch of the species is within the established limit.

Taking into account the natural coefficient (0.23) and total mortality (44.6 %), the white bream stock is estimated at 360 tons, taking into account optimal fishing (25 % of the stock), and given the significant increase in the catches of the species by 100 net days of the control order, we recommend to set the limit for the catch of white bream in 2018 in the amount of 90 tons (Table 4.1.2).

Some specialists note the mandatory limitation of catches of certain resource species, which is related to the degree of industrial use and the dynamics of stocks. Thus, in all reservoirs of the Dnieper, bream, zander, roach and white bream are subjected to mandatory capture limitation.

Carp *Cyprinus carpio* (Linnaeus, 1758). One of the most important species of Zaporizke reservoir is carp. The actual catches of carp in the reservoir stayed at the level of 10–18 tons from 2009 to 2013, during the period 2014–2015, industrial catches of carp decreased to 9.2–9.9 tons. In 2016, the catch of this species reached 18.65 t. The relative share of carp in catches does not exceed 1.5–2 %, which may be caused by an increase of its direct food competitor, Prussian carp by a factor of 15.5 (from 22.3 tons in 2001 to 346.85 tons in 2016).

The age range of carp is represented by 20 classes (3–22 year-olds). The core of the industrial population of carp is 5–10 years old individuals (72.02 %). The share of elder age groups over the age of 11 reached 14.9 %, indicating the presence of older age groups in the population. The variation series has the form of a non-symmetric curve with a peak on 5 years old individuals and displacement of the variation row to the right due to the accumulation of older age groups.

A small number of younger age groups indicates insufficient natural replenishment of the population. This is confirmed by the rather low indicators of the number of young coastal populations in recent years (5,04 ind./100 m^2 in 2009; 0,07 ind./100 m^2 in 2010; 0,86 ind./100 m^2 in 2011; 8.97 ind./100 m^2 in 2012; 5.56 ind./100 m^2 in 2013; 4.26 ind./100 m^2 in 2014).

The average figures of the population were as follows: industrial length – 41.04 ± 1.45 cm, weight – 2752.15±941.35 g. Compared with 2016 and 2015, the average linear and weight indicators of individuals decreased, due to an increase of four years and five years old individuals in the proportion. Fulton's fattening factor remained at a stable level of 2.5.

Figure 4.1.8. *Cyprinus carpio* (Linnaeus, 1758).

Studies in 2017 showed that there were 1270.5 kg per 100 netting days of the control order; 65 kg belonged to small-mesh nets. In 2016, the catch of carp per 100 netting days of the control order amounted to 1,175.8 kg, 48 kg of which fell on the small-net net. In 2015, the catch of carp by 100 netting days of the control order amounted to 1650 kg, of which 52 kg fell on the small-net nets, and 1598 on the net with a large mesh. In 2014, this figure amounted to 1150 kg, of which 50 kg fell on small-net nets, and 1100 kg on the small-net nets. The index for 2013 was 908 kg, of which 41 kg fell on small-net nets, and 867 kg on the net with a large mesh. In the last 5 years, this indicator is stable.

The main capturein the control order, both in number (63.7% of the total) and mass (72.4%) was provided by nets with mesh size of 80-100 mm. Thus, the stock available for rational fishing in 2018 can be estimated as normal, but due to the low natural reproduction rates of carp, there is no basis for its substantial stock replenishment. In addition, during the period from 2003 to 2009, the replenishment of a carp with young fish was not carried out. In recent years, the volumes of stocking were only 1–2% of the recommended amount.

Taking into account the coefficient of natural mortality (0.21) and the coefficient of total mortality (0.35), the stock of carp in the Zaporizke Reservoir can be estimated at 112 tons. Including rather low rates of use of quotas in 2012–2015 (at the level of 30–50%), as well as the use of the quota in 2016 at 88.8%, the forecast of allowable capture of carp in 2018 will be 25 tons (Table 4.1.2).

The presence of older aged individuals weighting more than 10 kg complicates the industrial capture of the carpwith stacked nets with mesh size of 120 mm, since these fishing gear do not catch large fish. In order to remove elderly individuals, it is recommended to use nets with the mesh size higher than 120 mm and catch individuals with a large-mesh nets with a mesh size a = 100 mm separately.

Prussian carp *Carassius gibelio* (Bloch, 1782). It is a leading industrial species in the Zaporizke reservoir. Over the past 15 years, the industrial catch of carp has increased from 30 tons per year to 350 tons per year, which indicates an increase in the number of this species (Fig. 4.1.9), indicating an increase in the number of this species. It is also an important object of amateur and sport fishing. This suggests that the volume of Prussian carp capture from the reservoir is much larger.

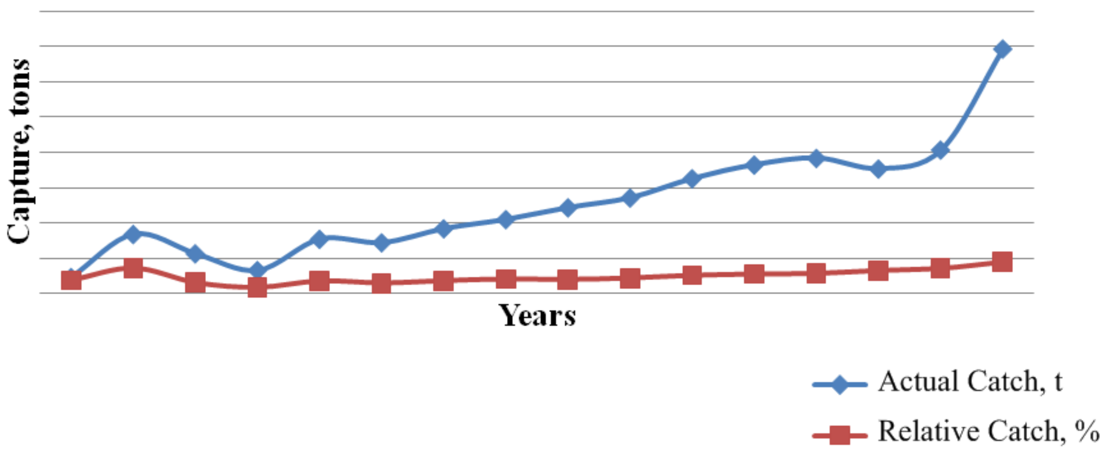


Figure 4.1.9. Dynamics of industrial catches of Prussian carp in the Zaporizke Reservoir during 2001–2016.

In 2016 proportion of Prussian carp was almost 43 % of net capture, and became a leader in the fishery. In our opinion, this indicator is rather low, since this species formed sufficient stock in the reservoir, which due to the low cost and seasonal nature of industrial development is not fully used by fishermen.

The species is numerous in all biotopes of the reservoir and in some of its tributaries, including high-transformed ones (Samara Bay, Samara River, Mokra Sura River). Approximately 60% of the capture of Prussian carp accrues to the Samara Bay of the Zaporizke Reservoir, where hydroecological (low flow, considerable sedimentation, overgrown, large amount of shallow water) and hydrobiological conditions (high feed base) are optimal conditions for increasing the Prussian carp number and biomass. Due to the significant number and biomass, as well as the influence of anthropogenic factors of the bay, individuals of this species are stunted, in comparison with other parts of the reservoir, which requires the development of special measures for its industrial development, namely the use of small-scale stacks in places of its mass localization.

The situation with small-mesh nets is the most complicated and dynamic. According to the Rules of Industrial Fisheries (paragraph 19.1), the minimum allowable size of the mesh in stacked nets allowed for use in the water area of Dnipro reservoirs is 30 mm. At the same time, many years of research on the water area of the Zaporizke Reservoir indicate the need to use nets with a larger mesh size (34 mm and more). At the same time, the general fish industry situation in the Samara Bay is different from the situation in the reservoir, in the area of the bay there are clusters of fish that are stunted and have reduced linear and weight indicators. Therefore, we recommend to use a set of small-mesh nets with a mesh size a = 30–34 mm in the fishery industry in the Samara Bay.

The age structure of the population of Prussian carp in catches has 11 classes (from 3 to 13 years old). The basis of the fishery use was individuals aged 5–8 years (82.8%). The share of older age groups (8 years and older) was 15.1, despite 8.4% in 2016, 7.8% in 2015, and 5 % in 2014. The core of the spawning population of the Prussian carp was 4-8 years old fish (91.7%). Species of older age groups are steadily presented in the population of Prussian carp, indicating an insufficient industrial load on the formed fish stock of middle and senior age groups.

Indicators of industrial length of fish were kept at the level of the past years and reached 22.64±0.49 cm. Indicators of mass of Prussian carp ranged from 90 to 2500 g and averaged 378.98±28.44 g. In single-age groups, males lagged behind at the rate of growth from females by 22%. The average values of the fattening coefficient of Prussian carp in the last 10 years are quite high and reach 3.2±0.17. The fattening and fatness ratio (3–4 points) indicates favorable feeding conditions for this species of fish, which increased its number in bay and shallow water reservoirs.

Figure 4.1.10. *Carassius gibelio* (Bloch, 1782).

In 2017, the total capture of Prussian carp in the reservoir was 5846 ind. (2221.5 kg) per 100 netting days. In 2016, this figure was 4800 ind. (1376.5 kg); in 2015 it reached 4629 ind. (1673.4 kg). Unlike 2016, the main proportion (64.2%) was captured by the net with a mesh size a = 36–50 mm, whereas by weight the largest proportion (60.9%) accrued on the net with the mesh size a = 50–60 mm Thus, the replenishment of the most productive size-age groups of Prussian carp, which will be based on fishing in current 2017 and the next 2018, may be characterized as excellent.

The replenishment of the Prussian carp population in 2018 will be mainly by means of the generations of 2013 and 2014. In 2013, the number of these yearlings of Prussian carp in the Zaporizke Reservoir was 6.6 ind./100 m^2, and 40.2 ind./100 m^2 in the Samara Bay. In 2014, the number of yearlings of Prussian carp in the middle of the Zaporizke Reservoir reached 22.11 ind./100 m^2, which indicates a good natural replenishment of this species.

Taking into account the coefficient of natural (0.21) and total (42.7%) mortality, the rate of replenishment due to the lack of carp capture in the Zaporizke Reservoir (the development of quotas during 2009–2015 was 63–85 %), the accumulation of older age groups, the state of the natural replenishment, the industrial stocks of Prussian carp can be estimated at 1680 tons. The forecast of the permissible catch of silver carp in 2018 should be raised to 420 tons (Table 4.1.2).

Taking into account the dynamics of industrial fish capture, indicators of natural replenishment, biological features of Prussian carp in the Zaporizke Reservoir, we can conclude that the population of this species is progressing, which in turn causes the need for intensification of its industrial exploitation. Despite the calculation of the forecasted capture of Prussian carp, industrial fishing of this species in 2018 should be carried out without limits and forecasts, that is, "not limiting".

Perch *Perca fluviatilis* (Linnaeus, 1758). The annual catch of the perch is consistently stays at the level of 10–12 tons, which corresponds to the average annual multi-year indicator for the last 10 years,which amounts to10.9 tons. The annual development of the quota is within 60–80 %. In 2017, the capture of perch per 100 netting days of the control order was 210 kg. In 2016 and 2015, itamounted 320.0 kg per 100 netting days and 178.2 kg respectively.

The populations of the perch in the Zaporizke Reservoir today have a stable age and size-weight structure and reproductive parameters, therefore gradually increasing its size. In an industrial herd, perch is dominated by individuals of 4–6 years old (85.1 %).

Average indices of industrial length of perch are 20.81±0.83 cm, the mass was 226.56±35.38 g, which is almost the same as in previous years. In the conditions of the Zaporizke Reservoir, two types of perch can be clearly distinguished: coastal and deep water type, which differ in size and morphometric indices and the power spectrum. In the Samara bay the perch has a lag in growth.

The age range of industrial catches is represented by 7 classes (from 3-year-old individuals – 9.1 %, up to 9-year-old individuals – 0.8 %). The average age of perch was 4.8 years, from 3 to 9 years in females and from 3 to 8 years in males. Limits of age groups were 0.8 %. The average age of individuals in 2017 rose from 3.75 (2016) to 4.88 years.

Figure 4.1.11. *Perca fluviatilis* (Linnaeus, 1758).

The basis of industrial stocks was individuals of fairly productive generation of 2013 and 2014. The number of yearlings for that period was 49.36 and 21.21 ind./100 m^2 respectively, indicating a positive replenishment of the perch.

The main catch of the perch in 2017 accrued on a net with a mesh size of 36–40 mm (60.1 % by number and 69.4 % by biomass). In the Samara bay, the perch is captured by nets with a mesh size a=30–36 mm with a predominance of catches by the nets with mesh size of 30 mm, since perch is slow-growing in the bay because of anthropogenic factors.

Consequently, by 2018, there is a sufficient supply of effective perch capture. The perch stock in the Zaporizke reservoir is estimated at 154 tons. Taking into account the natural mortality rate (0.27) and the percentage of the 2016 limit use (80.4 %), the estimated permissible catch of perch in 2018 may be 30 tons.

Common rudd *Scardinius erythrophthalmus* (Linnaeus, 1758). The average annual capture of common rudd in the last ten years is kept at 3 tons per year. The main fishery is based on 6 industrial groups (3–8 years). In 2017, the catch amounted to 120.6 individuals (27.75 kg) per 100 netting days of control orders, compared to 89.5 ind. (20.4 kg) in 2016 and 120.5 ind. (28.2 kg) in 2015, but is almost equalto the figures of 2013–2014. The structural parameters of the common rudd in catches of 2017 were almost the same as in 2016; the main volume of catch of the common rudd was formed by the nets with mesh size a = 36–40 mm, which caught the average age groups of this species of fish.

Average weight and linear indicators were next: the industrial length of females was 20.49±0.69 cm, the weight was 230.12±20.21 g, which is almost the same as in the years 2015–2016.

Figure 4.1.12. *Scardinius erythrophthalmus* (Linnaeus, 1758).

In the coastal areas of Zaporizke Reservoir the common rudd is a fairly common species, which is actively exploited by amateur fishermen. The number of yearlings in 2013 and 2014 was 4.79 and 3.87 ind./100m^2, respectively.

The natural mortality rate of the common rudd is 0.25, the mortality rate reaches 43.4 %, the industry absorbs about 50–70 % of the quota. Thus, the stock of the common rudd in the Zaporizke Reservoir can be estimated at 40 tons. With a rational capture of common rudd, the forecast of the permissible catch of this species can be kept at the level of 10 tons.

Pike *Esox luceus* (Linnaeus, 1758). During the last ten years, the average annual pike capture has been kept at 5.4 tons (0.4 % of total net catches). Pike was caught separately in the lower section of the reservoir during fishing. It was noted in the upper section of the reservoir and in the rivers of Samara, Mokra Sura, Oril, where in spring it came to spawn.

During surveys in the Zaporizke Reservoir, the most common were individuals weighing from 850 to 3400 g. The average weight of individuals is 1120.6±122.2 g. Sexually mature individuals were found at the age of 3–5 years. In 2017, 28.75 kg was captured per 100 netting days of the control order, instead of 24.5 kg in 2016.

The main factors causing the decline in the size of the industrial population of the pike are the following: the absence of a ban on fishing during the period of spawning of this species of fish (March), poaching and uncontrolled amateur fishing, the operation of the level regime of the reservoir, which causes drying of spawning grounds, siltation of spawning grounds, shortage of spawning substrate. Unless appropriate measures are taken to protect and replenish pike stocks in the reservoir, there is no reason to expect them to be replenished.

The stock of pike in the Zaporizke Reservoir is estimated at 20 tons. The forecast of the permissible catch of the pike in 2018 is 5 tons.

Figure 4.1.13. *Esox luceus* (Linnaeus, 1758).

Wels catfish *Silurus glanis* (Linnaeus, 1758). The analysis of the dynamics of the industrial capture of the catfish from 2006 to 2016 showed that the average annual capture of this species over the past 10 years has reached 3.07 tons. The catches of the catfish in the reservoir range from 1.7 to 6.4 tons. In 2016 the development of the quota for catching catfish reached the level of 42.7%.

Catfish is weakly exploited by the main fishery because of the low efficiency of fishing gear (gill nets, sometimes creel are often used). Currently, catfish are mostly caught by amateur fishermen (mostly underwater hunting), which catch fish of limit age groups. The potential number of the catfish in the reservoir can be large, but, due to the problems with its catch, it is not possible to evaluate it. For rational catfish catch creel should be used.

The average weight of catfish species is 3320.1±540.2 g, and ranges from 1.3 kg to 19.9 kg. The industrial length of individuals varies from 61.0 to 9135.0 cm, and averaged 87.21±3.57 cm.

Analysis of the fishing gear showed that in 2017, that there were 94.6 ind. (314.2 kg) per 100 netting days, the indicator for 2016 is111.4 ind. (459.2 kg). Forecast of the allowable catch of the catfish in 2018 can be estimated in the amount of 15 tons.

Figure 4.1.13. *Silurus glanis* (Linnaeus, 1758).

Another large particle. This category includes asp, chub and ide. During the last 5 years, the capture of fish species of another large particle varied from 1.3 tons (2013) to 3.79 tons (2016). Average annual multi-year catch of particle species reached 2.3 t/year. The development of the quota for catching species of the category of 'another large particle' in 2016 amounted to 84.22 %. Forecast for allowable fishing for this species in 2018 is 10 tones.

Asp *Aspius aspius* (Linnaeus, 1758). The average annual catch of asp is 0.87 (from 0.3 to 1.27 t). In 2015, the development of the quota of asp was 27.8 %. In 2014, the development of the quota of asp was 19.5 %. In 2013, the development of the limit was 30.5% (in 2012 – 54 %, in 2010 – 50.8 %).

In 2017, in 100 netting days, the catch of asp in the reservoir can be estimated in the amount of 13.6 ind. (34.1 kg). In 2016 this figure was 17.9 ind. (30.5 kg). In 2015, it was 12 ind. (9.2 kg). Compared to last year, this indicator has increased, but there is no reason to make optimistic forecasts about the general state of the population.

The level of natural reproduction of this species remains low. The number of asp yearlings in the shallow waters of the Zaporizke Reservoir in 2011–2012 was 1.04 and 0.21 ind./100 m^2 respectively. In 2013, this figure slightly increased to 3.42 ind./100 m^2, in 2014 it was 2.48 ind./100 m^2.

The results of control capture in 2017 showed that the age of fish is 4–9 years. Limiting linear and weight indices of asp are following: industrial length is 30–60 cm, weight ranges from 820 to 3340 g. The average weight was 2640.0±454.6 g.

Figure 4.1.14. *Aspius aspius* (Linnaeus, 1758).

Due to the low level of the limit use, as well as consistently low rates of reproduction of asp, the forecast for permissible catch of asp in 2018 is 3 tons.

Chub *Squalius cephalus* (Linnaeus, 1758). The species belongs to the category "Other large particles". Industrial catches of this species are at the level of 0.8-1.6 tons. There is a weak tendency of increasing catches from 1.7 t (2013) to 1.6 t (2015). In 2015, the development of the quota on the chub was 80.1 %. In 2014, this indicator amounted to only 58.5 % (34.5 % in 2013, 71.5 % in 2012, 62.5 % in 2011). Average annual catches are kept at 1.08 tons.

Chub is mostly caught with nets with the mesh size a=36–48 mm (up to 60 %). Industrial catches of the chub consist of 4–9 years old individuals. The spawning population was dominated by 6–7 year old fish. Linear and weight indices were: length – 21–42 cm, weight – 280–2550 g.

The chub stock is formed by generations of 2012, 2011 and 2014. In 2012, the number of yearlings was at the level of 1.28 ind./100 m^2. In 2013, this indicator reached 0.74 ind./100 m^2. The number of yearlings in reservoirs in 2014 was on average 3.13 per 100 m^2. The species is widespread in coastal areas. Youth of chub is under considerable pressure of amateur fishing.

Taking into account the level of development of the limit, as well as the indexes of the chub, the forecast of the permissible catch of the species in 2018 may amount to 4 tons.

Other particle species. The industrial capture of other particle species such as blue bream, white-eye bream, common nase, tench, and sichel in recent years are at a steadily low level, which is primarily caused by their low number in the reservoir. The analysis of their capture with control fishing gear does not reveal any tendency indicating the accidental occurrence of their falling into the fishing gear, therefore they can be considered as by-catches in the catch of particle fish species.

The development of the quota for fish species of the category "other small particles" in the last 5 years has a tendency to increase from 2012 to 2016, the development of the quota has increased from 57.9 % to 82.8 %, and the average annual catch reaches 16.6 tons/year. The forecast for catching fish from the category ‘other small particles’ in 2018 is 42 tons.

Pumpkinseed *Lepomis gibbosus* (Linnaeus, 1758). The number of pumpkinseed increases. It is often caught in industrial fishing gear, recorded during scientific research and caught by amateur fishermen. If in 2011, pumpkinseed was caught rarely, in 2012–2013, its local habitats were found in the Zaporizke Reservoir and its tributaries, and the number of this species fingerlings reached 0.03 ind./100 m^2 in the Samara Bay and ind./100 m in the Zaporizke Reservoir [67].

Figure 4.1.15. *Lepomis gibbosus* (Linnaeus, 1758).

The number of two-year-olds has increased respectively, and in 2016 in the Zaporizke (Dnipro) Reservoir number of two-year-olds per m^2 of shallow water areas was almost twice higher than in 2012 and amounted to 0.93 ind./100 m^2. The total biomass of young pumpkinseed (fingerlings + two-year-olds) in 2013 in the littoral areas of the Zaporizke Reservoir reached 8.74 g/100 m^2, which is almost 63.3 % more than this indicator in 2012.

In 2014, the number of pumpkinseed fingerlings at the research stations reached 1.8 ind./100 m^2 in Samara Bay and 1.5 ind./100 m^2 in the reservoir. In 2015 in the Samara Bay there was a significant increase in the number of pumpkinseed pumpkinseed, up to 2.7 ind./100 m^2.

The age composition of the stock of pumpkinseed males from the control gear of the catch (the seine and the stack nets) consisted of 5 age classes represented by individuals aged from 3 to 7 years, which was 20 % and 6.6 % respectively. The core of the population was individuals of five years of age and amounted up to 32 %.

The age structure of the female population consisted of 4 age classes. The captures of the pumpkinseed are represented by individuals aged 3 to 6 years, which was 15 % and 10 %

respectively. The reproductive core of the pumpkinseed population was females at the age of 5 years and amounted to 40 %. The analysis of the age structure of the population of the pumpkinseed indicates an increase in the number of age classes in the population of the pumpkinseed of the Zaporizke Reservoir, which may indicate a further increase in the population of this species.

Currently, it is quite difficult to predict the number of pumpkinseed in Zaporizke Reservoir, but judging from the fact that this species is well adapted to the environment of the region and acclimates quickly the reservoirs of Dnipro region, its number increases. The increase in the number can be explained by the fact that during monitoring catches in May 2012 in the Samara Bay near the Odynkivka village, pumpkinseed, was rarely caught in such fishing gear as gill nets with a mesh size of 30-32 mm. And in 2016, during the works at the monitoring point in the waters of the Samara Bay in the Novoselivka village from June 10, 2016 till June 30, 2016 during the analysis of industrial catches from stack nets with a mesh size a = 30 mm 20-200 kg of pumpkinseed was removed daily (Fig. 4.1.16).

Figure 4.1.16. Pumpkinseed catches in 2016.

A similar trend persisted for 2017. Its largest catches were in the period from 15 to 30 June, during the massive spawning of the pumpkinseed.

It was also found that pumpkinseed is a component of food spectrum of European perch *Perca fluviatilis* (Fig. 4.1.17).

Figure 4.1.17. Pumpkinseed in a food spectrum of European perch

Thus, in 2018, it is recommended to allow the capture of pumpkinseed without limitation and forecasting.

Phytovorous species. The most important resource species of the Zaporizke Reservoir is the silver carp. The species is extremely useful biomeliorator of Dnipro reservoirs, which transforms low-calorie phytoplankton (which is practically not used by other species of fish), to high-quality fish products.

In 2016, in the Zaporizke Reservoir, 31.3 tons of silver carp were captured, which is 3.9 % of the total number of captured fish. The average annual capture of silver carp in the last 10 years is kept at 53.9 t/year. The minimum catch of species was in 2014 and amounted to 30.6 tons, maximum catch was 82.1 tons in 2009. From 2011 to 2016 there is a gradual decrease in industrial capture of silver carp, caused primarily by a decrease in its catch, redistribution quotas between users and organizational difficulties during its capture, since it is desirable to catch large individuals with active fishing gear such as stacked nets with a 100 mm or more mesh size, and the bed of the Zaporizke Reservoir is not adapted for seines.

The age range of silver carp is represented by 17 classes (3–18 year-olds). The core of the industrial population of silver carp is 4–10 year-olds (70.7 %). The share of elderly fish over the age of 10 reached 25.6 %, indicating the accumulation of older age groups in the population. The variation series has the form of a non-symmetric curve with peak on individuals of 7 years and displacement of the variation row to the right due to the accumulation of older age groups. Reducing of abundance of younger age groups indicates insufficient stocking of reservoir with this species.

The average indices of the population were following: industrial length was 56.50±2.35 cm, weight was 3120.1±430.2 g. The Fulton fattening factor remained at a stable level and reached 2.5.

The presence of older individuals with weight over 10 kg makes it difficult for the industrial development of the species with stacks with mesh size less than120 mm, since these fishing gear do not catch large fish. In order to remove elderly individuals, it is recommended to use nets with the mesh size larger than 120 mm and to conduct selective capture of individuals with a large-meshed nest in places of its concentration.

Under the conditions of Zaporizke Reservoir the species does not spawn, replenishment of the population occurs only by annual stocking the reservoir with the youth. The volumes of capture vary from year to year and depend on the funding and activity of users of aquatic bioresources. From 2002 to 2015, 2.7 million individuals of silver carp and 1.04 million individuals of hybrids of silver carp and bighead were stocked.

Since the species does not spawn in the reservoir, and serves as the object of pasture fish farming in 2018, it is recommended to continue the capture of herbivorous fish (silver carp and bighead, their hybrids, grass carp) without limitation and forecasting.

Sprat, bleak, belica, bitterling. These species of fish are zooplankton-feeders, which serve as food competitors for fish fry. The stock of sprat over the last two years was used on average by 60–70 %. The basis of the population of the sprat and bleak is 1–2 year-olds. The average weight of the sprat was 1.6 g, the length was 4.8 cm, the fat content was 1–2 points. The fattening factor of sprat was 1.20±0.05; the dry matter content was 21.8±1.8 %.

The capture of the sprat and bleak is characterized by a certain specificity of the fishery organization; therefore, in 2016 their catch was kept at the level of 54.2 tons, which is almost twice less than the index of 2015, which was 123.9 tons.

The catches of short-cycle fish species in 2018 should not be limited and should not be less than 200 tons (Table 4.1.3). In addition, it is recommended to strengthen the control over the realization of the reclamation capture of short-cycle fishes (sprat, bleak, belica, bitterling).

Table 4.1.3. Limits and forecasts of admissible special use of water bioresources of national value in the Zaporizke (Dnipro) Reservoir in 2018 (tons)

№	Objects of special use	Volume of admissible special use
1	Bream	110.0 L
2	Zander	20.0 L
3	Carp	25.0 P
4	Pike	5.0 P
5	Wels catfish	15.0 P
6	Roach	210.0 L
7	White bream	90.0 L

8	Blue bream	1.0 P
9	Prussian carp	Not limited
10	Sichel	2.0 P
11	Bleak and sprat	Not limited
12	Phytovorous fish $^{-1}$	Not limited
13	Another large particle $^{-2}$	10.0 P
14	Another small particle $^{-3}$	42.0 P
15	Gobies	0.0
16	Pumpkinseed	Not limited
17	Crayfish	1.0 P

Note: –[1]Silver carp, bighead, their hybrid, grass carp, –[2]Chub, asp, ide, –[3]Perch, tench, common rudd, white-eye bream, common nase, vimba, ruffe. P – catch forecast, L – catch of the species is within the established limit.

Crayfish. Today, river crayfish is caught as an additional capture, targeted fishing for crayfish is almost absent, crayfish traps are practically not used. However, crayfish are promising objects of aquaculture and fish farming. Over the past 10 years, the average annual catch of crayfish from the Zaporizke Reservoir reached 0.218 tons.

On average, the length of the captured crayfish ranged from 8.5 cm to 16.1 cm. The industrial length of the crayfish was 10.3±0.9 cm. The females of the crayfish caught from the Samara bay had lower linear and weight indices, caused by anthropogenic loading on this site. The fertility of the crayfish ranged from 80 eggs to 326 eggs and averaged 236.3±24.1 eggs.

From 2011 to 2015, there was a low level of development of the quota (16.4 % in 2015, 16 % in 2014, 1 % in 2013, 20 % in 2012 and 26 % in 2011). In 2016, the crayfish capture quota was developed at 29 %. Forecast of crayfish catches by 2018 should be set at 1.0 ton.

4.2. Species composition of fish populations of coastal habitats of the Zaporizke Reservoir and its environmental assessment

Throughout the period of study (2010–2014) the species composition of young fish of the littoral areas of the Zaporizke Reservoir totaled 35 fish species belonging to 11 families, including: Cyprinidae – 16 species, Gobiidae – 7, Percidae – 3, Gasterosteidae – 2, Syngnathidae – 1, Cobitidae – 1, Esocidae – 1, Clupeidae – 1, Atherinidae – 1, Centrarchidae – 1, Siluridae – 1 species. The caught species were related to 7 faunistic complexes: the tertiary plain freshwater complex – 3, the Ponto-Caspian freshwater complex – 10, the Ponto-Caspian sea complex – 11, the boreal plaincomplex – 8, the Chinese plain complex – 1, the American complex – 1, the boreal piedmont complex – 1 species. The basis of coastal ichthyocenosis of Zaporizke reservoir was compounded by the fish species of the tertiary plain freshwater (54.7 %), the boreal plain (19.5 %) and Ponto-Caspian freshwater (14.5 %) faunal complexes.

In coastal areas of the Zaporizke Reservoir the growth of species diversity index is related both to the increase in the species number within the fish communities and to the decrease of the index of relative organization (Foerster index), which points to reducing the dominance degree of certain species in different years of research (Table 4.2.1). As a result, the relative contributions of different species to the total fish biodiversity were aligned.

Table 4.2.1. Environmental assessment of coastal populations of fish fry, 2010–2014.

Environmental index	Years				
	2010	2011	2012	2013	2014
Shannon index (*H*)	0.99	2.13	2.29	1.75	1.83
System complexity index (H_m)	4.75	4.91	4.86	4.95	4.90
Foerster index of relative organization (*R*)	0.79	0.53	0.56	0.65	0.75

The dominant species of coastal ichthyocenosis of the Zaporizke Reservoir were singled out with help of Mordukhay-Boltovskoy's index of coenotic value (ICV), which takes into account the number of each species and its contribution to the total biomass. For the Zaporizke Reservoir imbalances in the structure of the coastal populations of fish fry are marked; that is expressed through availability of the dominant species with high ICV values ranging from 218.35 to 2031.51. These fish species include the following ones: European bitterling *Rhodeus amarus* (Bloch, 1782), Roach *R. rutilus*, Bleak *Alburnus alburnus* (Linnaeus, 1758), Monkey goby *Neogobius fluviatilis* (Pallas, 1814). Following dominant species, the gradual aligned decrease in the index of coenotic value for the fish groups with ICV values ranging from 5 to 30, is observed; they are: prussian carp *Carassius gibelio* (Bloch, 1831), Black Sea sand smelt *Atherina pontica* (Eichwald, 1810), belica *Leucaspius delineates* (Heckel, 1843), round goby *Neogobius melanostomus* (Pallas, 1814), pseudorasbora *Pseudorasbora parva* (Temminck et Schlegel, 1846), bream *A. brama*, European perch *Perca fluviatilis* (Linnaeus, 1758), Common rudd *Scardinius erythrophthalmus* (Linnaeus, 1758) and Spined loach *Cobitis taenia* (Linnaeus, 1758). The ICV value for such species as European asp *Aspius aspius* (Linnaeus, 1758), European chubs *Squalius cephalus* (Linnaeus, 1758), common carp *C. carpio*, common zander *Sander lucioperca* (Linnaeus, 1758) were in the range of 0.04 to 5.22 – this indicates poor reproduction of these species and irregularities in the ichthyocenosis structure likely caused by anthropogenic factors.

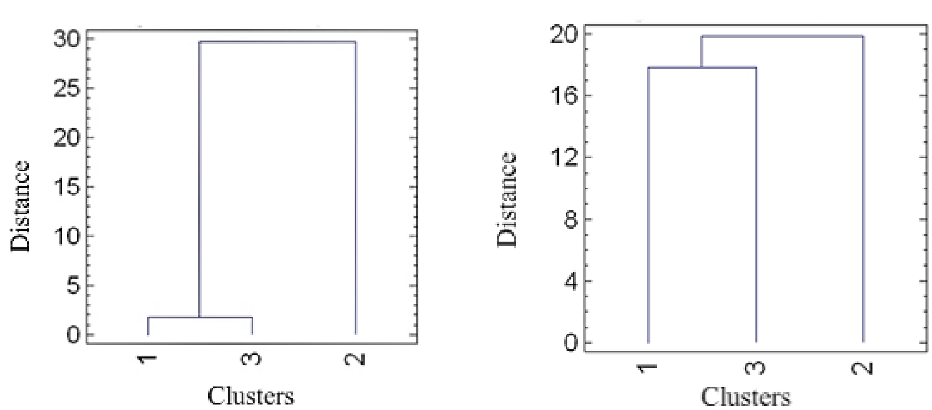
In general, the overall situation concerning the fish fauna biodiversity of the Zaporizke Reservoir sites at the structure disturbances of fish communities caused by man-made factors. Among representatives of commercial ichthyofauna, the roach young fish is the most common in shallow waters of the Dnieper cascade reservoirs.

It occurred to catch at all points of observation. Over the research period the roach fingerling number observed in 2012 was 24.58 ind./100 m^2 with the highest one in 2010 – 99.0 ind./100 m^2, while the young roach biomass reached 37.36 g/100 m^2 and 198.5 g/100 m^2, respectively. Thus, natural reproduction of the roach in the Zaporizke Reservoir can be characterized as satisfactory.

The bream fingerlings were quite common and occurred in all parts of basins. The greater number of the bream inhabited the lower part of the Zaporizke Reservoir. The bream population replenishment with new generations occurred every year, but not to the same extent, the fish yield in coastal areas of the Zaporizke Reservoir declined from 6.50 ind./100 m^2 (2010) to 2.38 ind./100 m^2 (2012) and 0.75 ind./100 m^2 (2013). Biomass, which is created with the bream fingerlings in the intertidal zone of the reservoir, also varies in a wide range from 2.39 g/100 m^2 to 46.80 g/10 m^2. Thus the bream reproduction in the Zaporizke Reservoir is at an unsatisfactory level.

Young fish of the common carp occurred only in certain parts of the reservoir and preferably at the beginning of the growing season. It was noted in sufficiently large quantities in the lower part of the Zaporizke Reservoir, within Viys'kove village and in Vorona, Krupskaya and Zvonetskaya cloughs – in this part the common carp fingerling abundance reached 2.45 ind./100 m^2 on the average. In Samara Bay the common carp fry occurred in biotopes of reed beds, thickets of flowering rush and pond grass that grew both on the muddy bottom and on the sandy one. In the total reservoir, the common carp fingerling abundanceranged from 0.07 ind./100 m^2 (2010 index) to 0.86 ind./100 m^2 (2011 index). For the last two years the common carp fingerling abundance is within the range of 0.4 to 0.5 ind./100 m^2. Over the research period the biomass that was created in the intertidal zone of the Zaporizke Reservoir by the common carp fingerling, ranged from 3.36 to 14.41 g/100 m^2. Thus, the common carp reproduction in the Zaporizke Reservoir is at the unsatisfactory level.

Influence of anthropogenic factors on fish communities of different areas of the Zaporizke Reservoir. The results of cluster analysis of morphometric parameters of one-year-old and two-year-old fish showed that the young fish caught in the lower part of the Zaporizke Reservoir (near the Viyskove village) was different from the young fish caught near the Monastyrsky island and in Samara Bay, where the fish morphometric parameters were smaller (Fig. 4.2.1). This phenomenon is likely caused by anthropogenic impact on aquatic ecosystems of the studied areas.



0+ 1+

Figure 4.2.1. The results of cluster analysis of morphological parameters of one-year-old (0+) and two-year-old (1+) fish from different parts of the reservoir: Monastyrskiy island (1), v. Viyskove (2), Samara Bay (3)

So technogenic loading due to industrial and communal enterprises of Dnipro City as well as environmental conditions of Samara Bay affects not only the diversity of fish species, but also the development of young fish, reducing the performance of its morphological characteristics. Therefore, the morphological indices of young fish might be used to assess the degree of anthropogenic impact on the aquatic ecosystem.

4.3. Current industrial fish fauna of small water bodies

The current fish fauna of the **Southern reservoir** consists of 26 species of fish. It was formed on the basis of aboriginal species, auto naturalized species and ones, which were introduced into the reservoir. In the aboriginal complex and auto naturalized species there are 23 species, among them industrial species are roach, common rudd, bleak, carp, Prussian carp, pike, perch, sprat, bream, white bream, catfish, zander and 3 species of gobies. There are also 3 introduced species: silver carp, bighead, and grass carp. The population of carp is formed both by the aboriginal (outgoing) form, as well as by the stocking the ponds with the cultural form of the species (carp).

By power type, the ichthyocomplex consists of benthophages (35 %), predatory fish (19 %), zooplankton-eaters (31 %) and herbivorous fish (15 %).

Fishing is based mainly on herbivorous fish (90–95 %). In the dynamics of the last five years, there is a steady proclivity for reducing capture of gobies from 62 to 22 tons. Total fish productivity also decreased from 67 to 19 kg/ha.

The roach dominates among aboriginal species. The capture of this species is represented mainly by 5–6 year-olds. The age range is rather short and consists of 5 classes. The pace of growth is high. As an active molluscivorous species, roach practically does not have feeding competitors. The fattening factor of roach is high and reaches 2.8–3.3, which indicates favorable conditions for feeding this species of fish. However, there is no positive trend towards increasing the population of gossip. It is mainly caused by the low level of its reproduction due to the unstable hydrological regime in the reservoir and the lack of sufficient shallow area necessary for effective spawning of fish and feeding the fries.

The proportion of Prussian carp is in the total capture is 0.2 %. There are 2–7 years old individuals in the capture, but the core of the industrial population is 5–6 year old individuals. The Fulton fattening factor has reached 4.8±0.44. The average length is 18.6 cm and weight is 0.31 kg. Thus, the indicators of fattening and the physiological state of Prussian carp indicate a favorable feeding conditions for this species of fish.

Bream is a valuable industrial species of large particle. For the last 5 years, its capture has been reduced to 10–14 % of the planned volume. It is mainly caused by its low level of reproduction in the reservoir, as well as by the disruptions in the organization of fishing. The basis of the industrial population of the bream consists of 3–4 years old individuals. The average linear and weight indices are following: length is 35.6±4.1 cm, weight is 918.8±14.7 g. The average value of the Fulton fattening coefficient is 2.55–3.2. Thus, the morphometric and physiological indices of industrial individuals indicate favorable conditions for feeding of this species of fish.

The most industrially valuable predators are pike, zander and perch. All these species are extremely limited in the capture. The capture of perch does not exceed 10 % of the planned amount; and pike and zander are practically absent in recent years. In the total ichthyomass, the share of predatory fish is about 4 %.

This is a very low figure, given the large number of low-value fish in the reservoir. The low pressure of predatory fish naturally leads to the simplification and degradation of the industrial ichthyotcoenosis structure, as well as the deterioration of the epizootic situation in the reservoir. Since the level of natural reproduction of these species in the Southern Reservoir is not able to ensure sufficient replenishment of their industrial stocks, it is advisable to solve this problem by introduction and artificial reproduction.

The share of carp in the general fish capture is kept at the level of 0.5–1.5 % for the last five years. Over the past 5 years, the actual carp capture has decreased from 87 to 2 % compared to the planned capture, wherein the reservoir is systematically stocked by the carp yearlings in the planned amounts. In catches, the age range is represented mainly by 4-6 year-olds. The length of the individuals varies from 24.0 to 65.0 cm; the mass varies from 1.2 to 5.5 kg. The fattening factor is 3.0±0.23. Indicators of fattening and physiological state are satisfactory and indicate a sufficient supply of food.

Silver carp and bighead form the basis of fishing in the Southern Reservoir. Their share in fish capture is kept at 90–95 %, although the actual capture volumes have decreased almost threefold (from 56 to 21 tons) in the last five years. Silver carp and bighead are annually introduced into the reservoir in the planned quantity. Silver carp is an active consumer of phytoplankton and biomeliorator during the ‘blooming’ of water; it reduces the biomass of phytoplankton by 30–40 %. The modern herd of the silver carp is represented by two-seven-year-old fish with linear parameters of 24–86 cm and a weight of 0.37–10.8 kg. The average length is 62.5 cm; the average weight is 5.8 kg.

Bighead prefers zooplankton as a feed. With a sufficient supply of food, bighead opposes the rate of growth of the silver carp, but under the conditions of the Southern reservoir, at a low concentration of food zooplankton, the growth rate of the bighead is lower: the average length is 59.3 cm; the average weight is 4.9 kg.

Grass carp is another valuable species of the phytophilic group. Its share in capture ranged from 5 to 0.1 % for the last 5 years. The industrial herd of the grass carp in 2012 was formed by 3–4 years old fish, which replenished the stock due to the full stocking of 2009–2010.

Low valuable short-cycle species of fish in the reservoir are represented by a bleak, sprat, stone moroko and bitterling. They are food competitors for young fish of valuable zooplankton-eaters species, so their quantity in fishery waters should be limited and regulated by reclamation.

The current fish fauna of **Khristoforivske reservoir** has 16 species of fish. It was formed by the aboriginal species living in this water area and in the Bokovenka river and by introduced species. The aboriginal complex includes 12 species. The main species of local fish fauna, which currently live in Khristoforivske reservoir, are roach, common rudd, Prussian carp, pike, ruff, perch, zander. The introduced species are carp, silver carp, bighead (hybrid form). Structurally, an aboriginal ichthyocomplex consists of benthophages, euriphages, predators and plankthophages with proportions of 42 %, 30 %, 21 %, 7.0 %, respectively.

The basis of the roach population is 3–5 years old fish. Fish over 6 years old are not observed. In a five year (4+) age roach has 17–18 cm in length and mass of 0.09–0.12 kg, which corresponds to the average parameters of this species. These figures are closer to Azov roach than to aboriginal roach. The industrial roach stock in the reservoir is 0.368 tons.

The structure of the Prussian carp population and its individual parameters indicates that the living conditions in the reservoir are favorable for this species. There is no stunted form of Prussian carp in the reservoir. The average length is 18.7 cm and weigh is 0.13 kg. The Prussian carp is definitely promising industrial species. Actual fish productivity of Prussian carp in the reservoir is 47.9 kg/ha.

A trophic group of predators is represented in the fishery by zander, perch and pike. Linear and weight parameters of zander correspond to the standard for reservoirs of the region reach 33–42 cm with a body weight of 0.55–0.98 kg in 3–4-year-olds. Individuals over 6 years of age were not found. The average weight of individuals, which have reached an industrial size was 0.7 kg.

Perch is a typical species for this reservoir. At the age of four years, it reaches 16–20 cm and weights up to 0.12–0.2 kg. The average weight of fish, which have reached the industrial size, is 0.14 kg. There is no stunted form of this species in the reservoir.

The total age range of pike populations in the reservoir is shortened and consists of 3 age classes. The reproductive part of the population is represented by 4-year-olds. Individual length and weight parameters of the pike are following: length is 32.0–35.0 cm, weight is 0.2–0.3 kg. The average weight of individuals that have reached the industrial size is 0.3 kg. The number of pike in the reservoir is sufficient for the partial reclamation function of this species, as a predator. But, since the pike is also actively consuming and young introduced species, its additional stocking is not appropriate. The use of pike as an object of amateur fishing is also promising.

The state of the population of low-value industrial short-cycle species (ruff, bleak) requires annual melioration measures. Taking into account high reproductive capacity of the ruff, its potential threat as a trophic competitor and destroyer of eggs of industrial species of fish, it is necessary to remove the ruff annually using catching gear with small mesh (minnow seine).

The introduction of a grass carp into the reservoir was not systematic and its volumes were below planned ones. Therefore, in the control capture the grass carp is represented separately. Linear and weighted indices of 3-year-old fish are rather high (45–47 cm, 2.6–2.8 kg, respectively). Taking into account the volumes of preliminary stocking and biological parameters (average weight is 0.35 kg), stock of grass carp is 0.735 tons.

Currently the population of carp in Khristoforivske reservoir is formed by the introduced cultural form of carp. The basis of the population is fish, stocked in 2009 and 2010. The investigated fish have averaged parameters inherent in carp and sazan. Average weight of carp is 1.3 kg.

Thus, the total fishery productivity of the Khristoforivske reservoir is 299.5 kg/ha, the actual industrial one is 90 kg/ha.

The species composition of the native fish fauna of **the ponds of the Novomoskovsk region** is poorer, its formation took place both spontaneously and through the introduction. The native species of fish are following: Prussian carp, perch, bleak, roach, pike. Alien fish are represented by four species: silver carp, grass carp, carp and zander.

The basis of the industrial fish fauna of both ponds, according to control catches, is carp. Its share in the total ichthyomass ranges from 48 to 55 %. In fish capture, this species was represented by two and four-year-olds with lengths of 19.0–35 cm and weight of 0.3–2.3 kg. The fattening factor is 2.8±0.44. Such indicators, as well as high values of fattening, indicate favorable conditions for carp on growing in these reservoirs. High potentials of forage benthos make this species promising for grazing aquaculture.

The proportion of silver carp in the total ichthyomass of two ponds is 21.3–22.4 %. The basis of the herd is formed by 4–5 year old individuals weighing between 1.6–3.6 kg with a body length from 45 to 60 cm. The total stock of silver carp can be estimated at 0.161 tons and 0.455 tons or 10 kg/ha, which corresponds to the average fish productivity.

Grass carp is another valuable species of the phytophilic group. Its share in fish capture is insignificant and reaches about 2 %. The basis of an industrial herd of grass carp is 3–5-years old fish weighing from 0.84 to 3.5 kg. The amount of higher aquatic vegetation indicates the possibility of annual stocking ponds by this species of fish and its more intensive exploitation.

The dominant by ichthyomass representative of the aboriginal fish fauna of the reservoir was Prussian carp (13.2 %). Three-six years old Prussian carps with length of 15–25.3 cm and weighing 0.16–0.37 kg are presented in capture. The core of the industrial population is the 4 years old fish with length of 16–21 cm and weight of 150–230 g. Indices of fattening and the physiological state of Prussian carp indicate favorable feeding conditions for this species of fish.

It should be noted that in the implementation of pasture aquaculture, Prussian carp low-valuable species, which can become competitor for valuable cultivating objects. In this regard, it is necessary to maintain the population of the silver carp in a low level. The main measure should be the capture of its clusters with a floating seine with mesh size not more than 50 mm.

The perch is a predatory species of aboriginal fish fauna in the ponds. Its share in capture varies from 1 to 1.5 %. Perch is presented in catches by two-seven years old fish 13–28 cm in length and weighing 60–470 g. Perch is a threat to young fish, including valuable species. Therefore, in order to ensure a high industrial return from yearlings, the minimum weight of planting material should be set at a level not less than 25 g.

The basis of the native ichthyofauna of **the ponds of Verkhnedneprovsky regionis** 11 species of fish, among them, 80 % are representatives of the boreal-plain faunal complex, the rest are fish of the Ponto-Caspian freshwater faunal complex. Aboriginal fish species include Prussian carp, perch, bleak, common rudd, white bream, bitterling, roach, common ruff, round gobie, gudgeon, Black Sea sprat. There are five alien fish species, such as silver carp, grass carp, carp, bream, common pike, common European catfish.

The basis of industrial fish fauna of ponds, according to control capture, is carp. Its share in the total ichthyomasis reaches 42.6 %. In capture, this species was represented by two-sixth years old fish 19.0–52.2 cm in length and weighing 0.3–4.3 kg. The fattening factor was 2.8±0.44. Such indicators, as well as high values of fatness, indicate favorable conditions for feeding carp in researched waters, as well as the prospect of implementing its pasture aquaculture.

Bream, like carp, belongs to a group of benthic fish fed by invertebrate benthic organisms. In catches, the bream is found predominantly at the age of 3-5 years, weighing from 0.3 to 0.7 kg with a body length of 27.5 to 32.2 cm. The proportion of silver carp and their hybrids in the total ichthyomas is 18.6 %. The basis of the herd is formed by 4–5 year old individuals with a weight of 1.6–3.6 kg with a body length of 45 to 60 cm. Grass carp is another valuable form of the phythophilic group. In catches its share is insignificant and reaches about 2 %. The basis of an industrial herd of grass carp is 3–5-year-old fish weighing from 0.84 to 3.5 kg.

Pike is a high-value food fish, as well as a valuable object of industrial and amateur fishing. Being a fry, it starts a predatory way of feeding, and at the end of the first year becomes a typical predator. It is characterized by high power intensity and growth rate. At an increment of 1 kg of body weight it uses about 3–3.5 kg of forage fish. The common catfish is another introduced predator. Catfish has high nutritional qualities and is characterized by a rapid growth rate. In the second year of his life it reaches a mass of 1.2 kg, in the third year its weight is up to 3.5 kg. At an older age, the catfish is a typical predator and consumes mostly fish, frogs, tadpoles, sometimes small mollusks, worms. According to the tenant of the reservoir, the average weight of the catfish in industrial capture is about 2 kg.

The dominant by ichthyomass species of the aboriginal fish fauna of the reservoir was Prussian carp (17.4 %). In catches Prussian carp is represented by three-six years old fish with length of 15–25.3 cm and weighing 0.16–0.37 kg. The core of the industrial population is the 4-year-oldswith length of 16–21 cm and weight of 150–230 g. Indices of fattening and the physiological state of Prussian carp indicate a favorable feeding conditions for this species of fish.

The share of roach and bleak is 10 %. Age groups of industrial individuals range from 3 to 6 years. The average mass of roach is 220±18.4 g, and bleak`s is 175,59,5 g. Perch is the predatory species of aboriginal fish in the ponds. Its share in catches varies from 4 to 7 %. Perch is presented in catches by two-seven years old fish with length of 13-28 cm and weighing 60–470 g.

5. ECO-TOXICOLOGICAL AND BIOCHEMICAL INDICATION OF ICHTHYOFAUNA IN THE PRYDNIPROV'IA RESERVOIRS

5.1. Eco-toxicological indication of ichthyofauna in the Dnipropetrovsk region reservoirs

Among the most common high-toxic substances in fresh water, the heavy metals occupy one of the leading places. Their ions characteristic feature is not collapsing in the natural environment, but changing the form of localization, gradually accumulating in an ecosystem different components. That is why, the research of these toxicants accumulation with hydrobionts and the influence of their ions on the fish metabolism is very imporant [68]. The latter, as is known, are higher, often end-of-the-line links of trophic chains in aquatic ecosystems, and therefore a significant accumulation of heavy metal ions in their organs and tissues should be expected [69]. Given that fish are a common food product, there is a high probability of the specified metalsgetting into a human body.

A significant increase in the heavy metals content in water leads to numerous biochemical, physiological and morphological changes in the body. Since the normal livelihoods of fish are determined by the coordinated work of all functional systems and biochemical processes on their basis, the deviation from the norm in one of them, caused by a toxicant, can lead to a disruption of the whole organism vital functions. This leads to a reduction in the aquatic ecosystems species diversity, in which the species resistant to heavy metals are dominant, that causes changes in the structure of populations and ecosystems in general.

Since hydrobionts, by their external parts and by such important organs as gills are completely immersed in water, the action of dissolved substances on the membrane permeability is an indicator of the substances action initial degree. there are soluble non-toxic substances In addition to toxicants in natural waters that can reduce or increase the toxicity of other substances by changing the membrane permeability.

The main amount of ions that get to the fish body, gets through gills (up to 70%), somewhat less through the skin (up to 20%), and the rest - through the digestive system [70].

While heavy metals getting in the organism hydrobionts can be identified at two stages. On the first, it takes a fairly fast (from several minutes to several hours, depending on the systematic affinity of the hydrobiont) the element absorption from the aqueous medium as a result of sorption processes or ion exchange and chemical interactions with surface structures. The nature, speed and physical and chemical characteristics of the heavy metals receipt first stage have not been researched sufficiently. However, in all cases it can be confirmed that it is determined by the capacity of surface structures, that is, the specific hydrobionte absorption surface of the organism, the number and chemical groups activity which can bind metal. With the saturation of this capacity, the accumulation process begins to be limited by other factors, such as the metal getting through the membrane structures, the metabolism of the substances in the body itself, the excretion rate, and others, that determine the second stage. At a certain concentration of metal in the body, there is a dynamic equilibrium between intake and withdrawal.

In the fish organism, in the first place accumulate the metals that are actively involved in metabolic processes. More actively accumulate the metals that are capable of reacting with protein or other body groups that are easily and quickly absorbed by water organisms from water or food and are included in metabolic processes [71].

As for the content of heavy metals in the hydrobionts body, the organ-tissue and subcellular specificity of the accumulation of heavy metals is well known. High variability of the heavy metals content in hydrobionts is due to the hydrochemical conditions, the forms of finding the elements in the environment, nutritional conditions, seasonal factors, pollution, animal sizes, metabolic needs, nutritional conditions, the metabolism intensity and a number of other factors [72].

The level of metal in the body greatly depends on the way of life and the hydrobionts feeding nature. In M.Y. Yevtushenko and co-authors researches [73] show that in comparison with predators, more active metals accumulate in benthops, which is explained by the type of feed. This feature qualitatively distinguishes heavy metals from organic toxicants, which is characterized by a tendency of accumulation in the food chain.

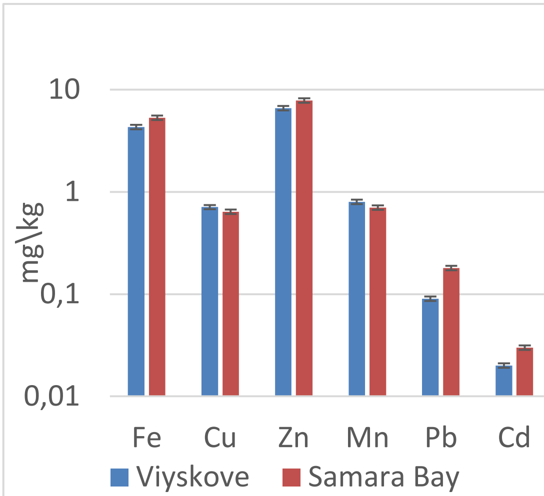
If we consider the heavy metals tissue and organ distribution in the hydrobionts organism in general, then one can find a series of regularities. Aquatic organisms are characterized by more active heavy metals accumulation in organs and tissues that are in contact with the aquatic environment, organs involved in the binding and elimination of most harmful substances in the body (liver and kidney), as well as in a number of other internal organs with a high level metabolism. The most significant accumulation of heavy metals, as a rule, occurs in superficial tissues. [74,75]. Some authors have shown that rather actively heavy metals are accumulated in gonads, which is explained by the active accumulation of protein and lipid reserves in them, while the processes of excretion in them are slowed down [76,77].

It can be noted that in reservoirs, which are under strong anthropogenic press, there are serious changes in density, diversity, and group structure of the ichthyofauna species composition. The result of reservoirs chronic contamination is the impoverishment of their ichthyofauna, reduced catches and proportion of particularly valuable species.

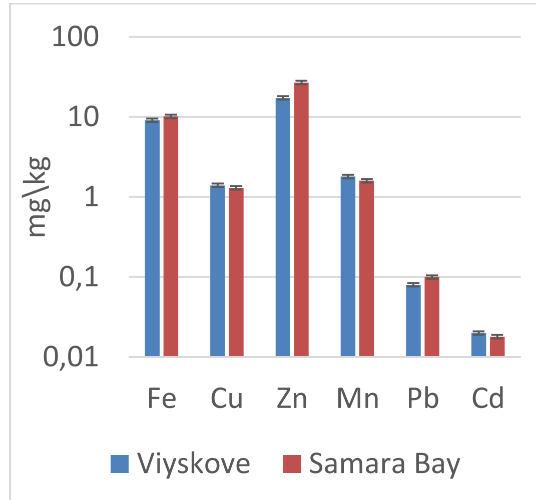
The research of toxicological indicators allows not only to assess and predict the environmental impacts of violations of the aquatic environment quality, but also to develop methods for optimizing fish products in water bodies. heavy metals Bioaccumulation in living organisms and the organs and tissues distribution describes the processes and ways of transferring pollutants from one trophic level to another. Different species of fish are appropriate to be used as hydroecological systems pollution bioindicators with heavy metals [78,79].

The research of heavy metal content in the fish body is an interest in both the ecological and the hygienic aspect. Particularly valuable is the information on the bioaccumulation of heavy metals by age-old fish living in the same ecological conditions.

The analysis of the heavy metals content in the roach body showed that their concentration did not exceed the MAC for fish as a food (Fig. 5.1.1). In the four-year-old specimens (mature) of ordinary roach, taken from the reservoir different parts, there are statistically significant differences between the certain metals content. Thus, zinc concentration is lower in fish from the reservoir lower part by 63%, lead by 50%, and cadmium by 33% compared to the monolithic individuals from the Samara Bay ($p < 0,05$).



A



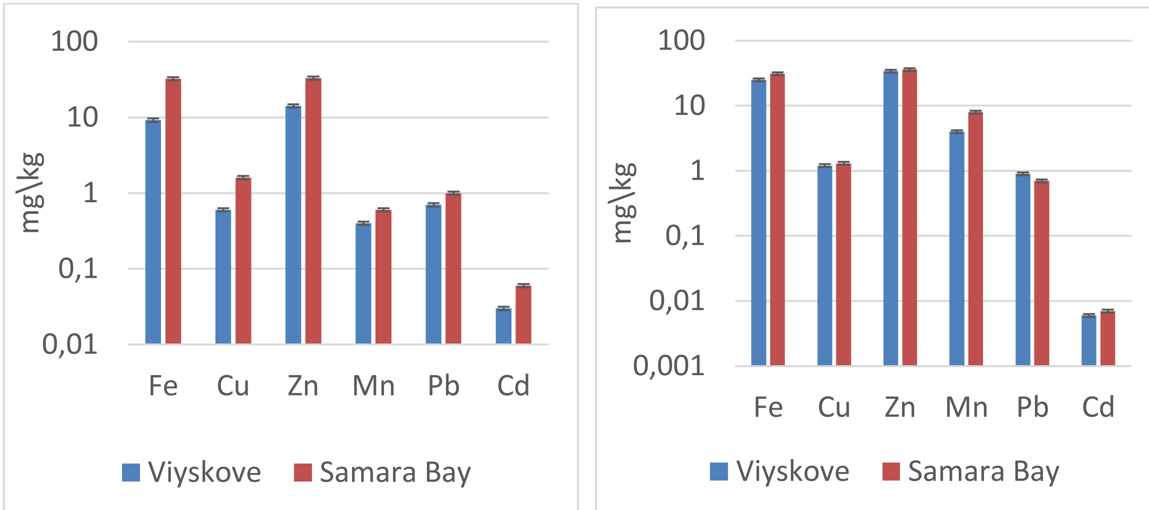
B

Figure 5.1.1. The heavy metals content in the roach from the Zaporizke Reservoir: A – grown-up individuals; B – young fish

In non-adult fish from the reservoir different parts, no probable differences in the heavy metals content were detected. In the body of young fish actively accumulated essential elements - iron, copper, zinc and manganese. Their content in the two-year roach was higher compared to four-years by 48-53%; 49-50%; 34-62% and 55-56% respectively ($p < 0{,}05$). The dynamics of trace elements in the fish ontogenesis is explained by the close relationship between their content in the main ecosystems components, that is, the reservoirs biogeochemical regime and food composition, the nutrition intensity and, as a consequence, the intensification of the metabolism processes [80]. Young roach is fed by algae, soft higher aquatic vegetation, zooplankton and small zoobenthos, and in the diet of older age groupspredominate molluscs.

In the adult specimens of the prussian carp from the Zaporizke Reservoir, no excess heavy metals concentration for fish as a food product was detected. Statistically significant differences in the content of all investigated heavy metals in the four-year-old specimens organism of crucian carp that were inhabited in various reservoir areas under anthropogenic loading were established. Thus, the lead content was lower by 30%, manganese and cadmium - by 33%, zinc by 57%, copper by 63%, and iron by 75% from copper from the reservoir lower part (v. Viyskove) compared to the Samara Bay ($p < 0.05$).

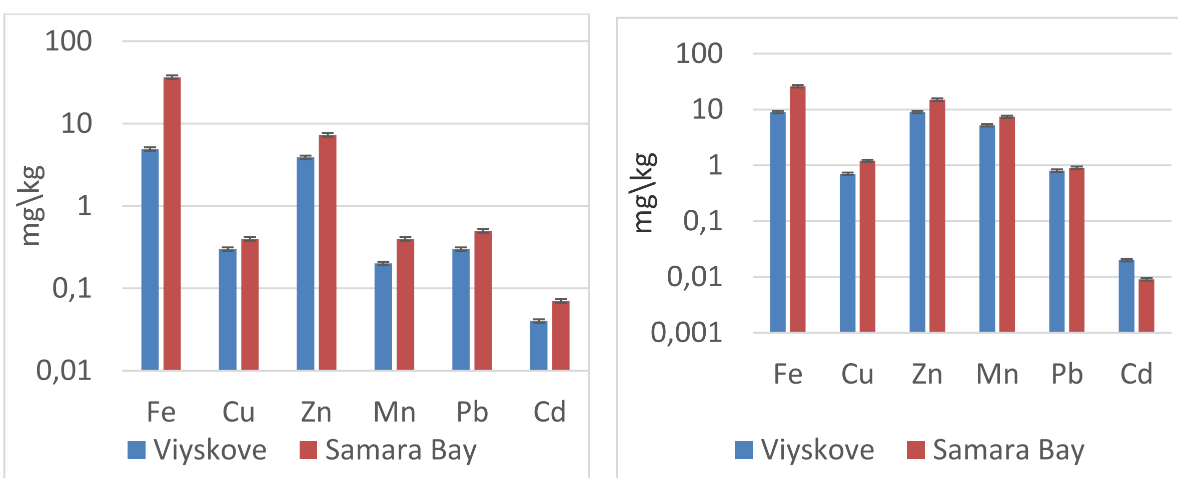
In the young prussian carpbody, MAC excess of manganese in the Samara Bay and the Zaporizke Reservoir lower part the was recorded in 4 and 2 times respectively. The probable difference between the content of lead and manganese in fish from the Zaporizke reservoir different parts is established. The concentration of lead exceeded its content by 72% in the prussian carpfrom Samara Bay and by 50% in manganese compared with the fish in the Zaporizke Reservoir lower part ($p < 0{,}05$) (Fig. 5.1.2).



A B

Figure 5.1.2. The heavy metals content in the prussian carp body from the Zaporizke Reservoir: A – grown-up individuals; B – young fish

There was a higher concentration of zinc in the young prussian carp from the reservoir lower part in 2.7 times, copper - 2 times, zinc - 2.4 times compared with the fish of older age groups. The manganese concentration in adult fish from both researched sections of the reservoir was lower compared to those for 99 and 93% of fish in the lower section and Samara Bay, respectively. The cadmium accumulation of in the prussian carpbody with age is revealed. Thus, its concentration in the older age groups was higher in 5 - 8,6 times ($p < 0,05$).



A B

Figure 5.1.3. The heavy metals content in the european perch body from the Zaporizke Reservoir: A – grown-up individuals; B – young fish

In the four-year-old (adult) european perchindividuals from the Zaporizke Reservoir, the heavy metals content did not exceed the MAC for fish as a food. The toxicants concentration was significantly higher in Samara Bay fishes in the range of 1.3–7.4 times ($p < 0.05$) (Fig. 5.1.3).

High manganese concentrations were detected in young european perch carcass: 3.7 MAC in the Samara Bay and 2.6 MACs in the. The concentrations of zinc, copper, iron in the Samara Bay fish exceeded their content comparing to the fish from the Zaporizke Reservoir lower sectionby 74%, 81% and 65% respectively ($p < 0,05$)

The content of iron in the young perch from the Zaporizke Reservoir lower section exceeded 1.8 times in comparison with the adult individuals. The concentration of other essential elements in the four-year-olds was lower compared with underyearlingat 51 - 96%. There was alsocadmium accumulation with the fish age, the content of which was higher in the adult individuals in 2 and 7.7 times compared with the young fish from the reservoir lower part and Samara Bay, respectively.

Thus, in the young fish body from the reservoir ‘clean area’ (the v. Viyskove district) revealed a greater number of essential elements, compared with the same year individuals from the Samara Bay. It is believed that aquatic animals effectively accumulate an excess of metal from the contaminated environment and experimentally, which makes the metal content in the tissues an adequate biomarker of contamination with certain active metals. At the same time, in the world scientific literature, a database begins to be created, which testifies to the dependence of metals accumulation in an organism not only on the level of these metals in the environment, but also on the physiological needs and influence of the other environmentalcomponents, including numerous organic pollutants - persistent organic substances and pesticides, etc., which presence can modulate the organisms metal-accumulation ability. In particular, essential elements are lost and accumulated pollutants and potentially toxic [81].

A statistically significant difference between essential elements bioequivalence (zinc, manganese, iron and copper) is established in different-age fishes. In all fish species there were quite high accumulation coefficients of zinc, iron and manganese. Moreover, the value of this coefficient for zinc dominated and averaged 8619. It is known that in the first place in the body, the elements that are essential for its vital activity, actively participating in the physiological processes, are intensively accumulated. During the fish growth, the need is increased not only in macroelements, but also in trace elements, particularly, in zinc. It is needed in large quantities to form a bone skeleton, swimmers, scales. As an alkaline phosphatase activator, it is necessary for the synthesis and activation of enzymes containing zinc, which provides tissue respiration processes, that during the period of fish early ontogenesis is carried out enough intensively. That is what determines the high cumulative capacity of the fish organism the in the growth early stages (larvae, fry).

At present, the foundation Kam’yanske reservoirs fishery up four- and five-year individuals of common carp (*Carassius gibelio,* Bloch 1782), European perch (*Perca fluviatilis,* Linnaeus 1758), pike-perch (*Sander lucioperca*, Linnaeus 1758) and silver carp (*Hypophthalmichthys molitrix*, Valenciennes 1844). Toxicological researches have shown that the concentration of all investigated metals in fish muscle is relevant to health standards (GSTU 2284: 2010, 2012). In researched fish muscles, the content of zinc and iron was observed to be higher than other heavy metals. Perhaps this is due to the fact that they are physiologically active metals participating in the life-sustaining activity of aquatic organisms

(Fig. 5.1.4). Fishes are able to absorb iron directly from water through gills, but the main source of it in the organism is the food. The iron content in the muscles of fish depends on the species and sex characteristics and season. The highest iron content was observed in the muscles of common carp (17.54 mg/kg) and was higher compared to the pike-perch muscle by 22% and European perch and silver carp muscle by 47% ($p \leq 0.05$). Zinc enters the organism via water and fish food, and the first way is more important for the high zinc content in the water. The content of zinc in the muscles of common carp (41.16 mg/kg) was higher compared to other researched fish muscle by 70% ($p \leq 0.05$).

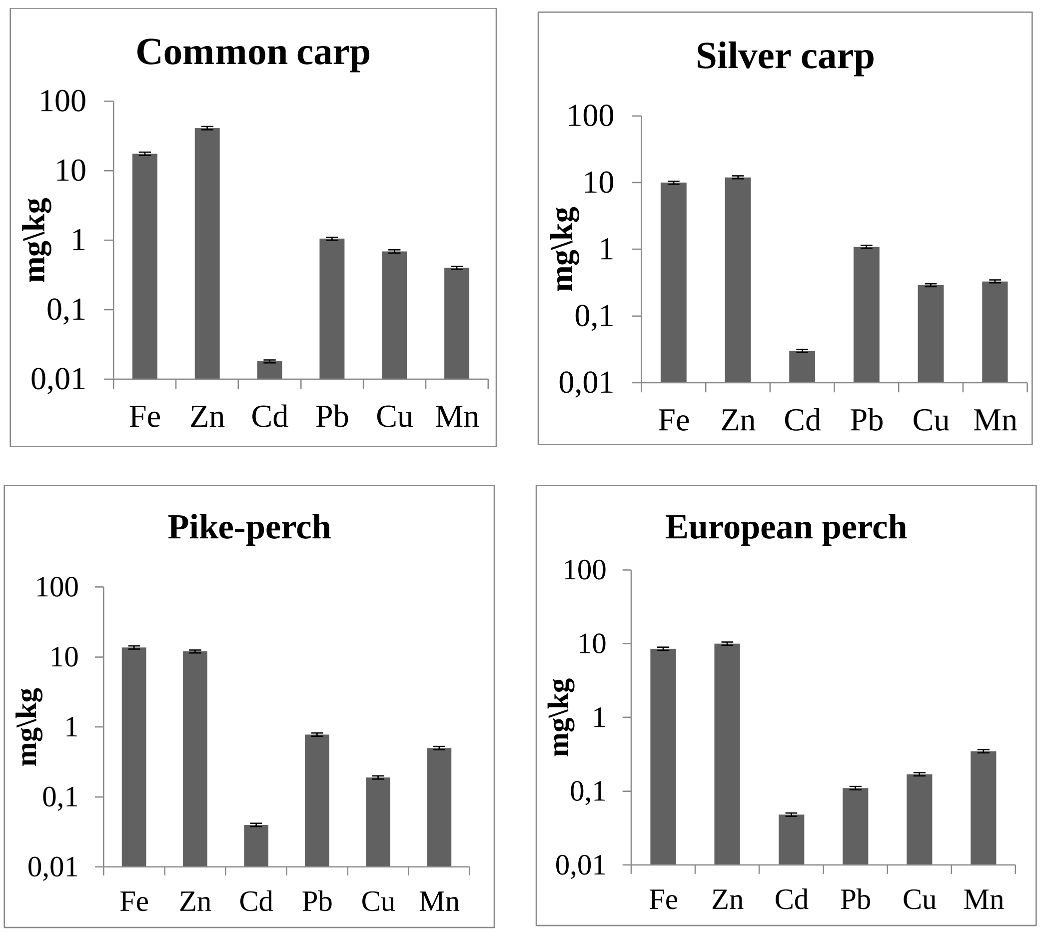


Figure 5.1.4. The contents of heavy metals in fish muscles in Kam’yanske Reservoir, mg/kg wet weight, M ± m, n = 5.

That is connected with the both nutrition and habitat types of common carp, which constantly contacts with the bottom sediments. The physiological role of cadmium is poorly researched, because, despite its salts are highly toxic, it is necessary for the fish. Cadmium does not belong to the organism’s vital elements. However, it could be claimed that its low concentrations stimulate cell division. Amongst the most researched fish, the cadmium concentration was observed in the European perch (0.048 mg/kg). Its content in European perch muscles is higher than that in pikeperch for 17%, in silver carp for 38% and in common carp for 63% ($p \leq 0.05$). The toxicity of lead is slightly lower than cadmium. It belongs to one of the most dangerous pollutants because it has a lengthy action. Lead, judging by various biological indicators, is a strong inhibitor of cellular metabolism and might increase the toxicity of other metals. It is known that prolonged exposure to fish that are on top of the food chain, even small concentrations of lead could increase toxic effects but not adapting to it. In Kam'yanske reservoir, silver carp muscle has the largest lead content than other fish species (1.09 mg/kg), and it was higher compared to the levels of pike-perch muscle by 28% ($p \leq 0.05$). Also the lead content in the muscles of silver carp was higher than that in European perch and common carp muscle, on an average, by 91% ($p \leq 0.05$). Copper is present in all organisms and one of the trace elements necessary for their normal growth. Copper is very important for increasing the immune, biological and harmful effects resistance from the environmental factors in the growth process. Compared with other types of fish, the concentration of copper is the highest in the common carp, 0.69 mg/kg wetweight and higher compared to the levels of silver carp muscle by 58% ($p \leq 0.05$).

This littleamount of metal content is possibly related to the fact that its metabolic antagonists are ironand zinc, which are accumulated in high concentrations in the muscles of fishes researchedin Kam'yanske reservoir. Compared to other fish species, the metal content observed in common carp muscle more than that in pike-perch and European perch by 72 and 75% ($p \leq 0.05$), respectively. Thus, the level of fish organism supply depends on following factors: biochemical features habitats, climatic and hydrochemical factors and physiological state of zinc and iron in the body of the fish. Aquatic organisms get manganese from water and food objects. There is a selective ability of aquatic organisms' individual taxonomic groups to its accumulation. In manganese exchange, there are species features. It is considered that the levelof manganese absorption from the water is high enough. Biological activity of manganese inaquatic ecosystems depends on the pH, the presence of organic and other complexing agents, the concentration of suspended components and oxidation-restorative properties of water.

Therefore, the role of manganese in water bodies could only be considered by these factors. The highest concentration of manganese in comparison with other fish species in the reservoir is observed in pike-perch (0.496 mg/kg) and is larger compared to the levels of the bodyother researched fishes by 28% ($p \leq 0.05$). Perhaps this is due to the fact that pike-perch hasmore predatory lifestyle and feeds on small fish, which in turn can be a source of manganese for them. Comparative analysis of the heavy metals accumulation factors in the muscle of different fish species in Kam'yanske reservoir showed its value in a wide range, which is primarily due to the eating habits and their habitat. Some kinds of fish have relatively high rates of accumulation of zinc and iron. First of all, the essential elements were accumulated – zinc and iron. Some species distinguished relatively high rates of accumulation: zinc in the common carp and iron in European perch, pike-perch and silver carp ($201 < AR < 1000$). Also, there is a moderate rate of accumulation of zinc in fishes such as European perch, pike-perch and silver carp ($51 < AR < 200$). It is also important that common carp had extremely high rates of iron accumulation ($AR < 1000$).

In the Prydniprovia reservoirs the heavy metals content in the edible part of industrial fish did not exceed the permissible concentrations for fish as a food product.

The total contents of heavy metals were maximal in prussian carp and common carp compared to other fish. According to the heavy metals total content in the researched fishes organisms from the Zaporizke Reservoir, one can construct a series of: prussian carp>common carp> other fish species >european perch, which is explained by their type of nutrition and biotope.

5.2. Biochemical indication of ichthyofauna in the Zaporizke Reservoir

Fish is an important commercial product that represents the nutritional value for humans, therefore the biochemical indication of fish material provides the criteria for assessing the quality of fish stocks and their agricultural significance. At the expense of quality fish products, it is possible to solve the problem of protein deficiency that most people are fronted [82–84]. As a part of biochemical composition of the fish tissues, they have total protein components and amino acids that are necessary for normal human life. The main biochemical indicators of the general state of fish are the content of proteins, fats and carbohydrates in its tissues. Analysis of these parameters allows estimate the state of fish stocks in natural reservoirs in conditions of transformation as a result of anthropogenic impact on aquatic ecosystems [85–87].

Under the conditions of total pollution of surface waters, the issue of physiological and biochemical monitoring of natural fish populations becomes more and more relevant. In the system ecological and biological testing of fish in the conditions of technogenic transformation of aquatic ecosystems, regularities of plastic and energy metabolism are important, reflecting the physiological and biochemical status of the organism during the annual life cycle [88, 89].

The objects of the studies of biochemical composition of fish tissues were pike-perch (*Sander lucioperca*, Linnaeus, 1758), european perch (*Perca fluviatis*, Linnaeus, 1758), freshwater bream (*Abramis brama*, Linnaeus, 1758), and roach (*Rutilus rutilus*, Linnaeus, 1758),

The results of studies on the determination of protein contents in industrial fish tissues of the Zaporizke Reservoir are presented in the Table 5.2.1.

Table 5.2.1. The protein contents in the tissues of industrial fish in the Zaporizke Reservoir (g/100g of dry weight), M ± m, n = 6

Type of fish	The lower section			The Samara Bay		
	Muscles	Gills	Liver	Muscles	Gills	Liver
European perch	92.7±3.1	55.2±2.2	51.3±3.1	86.6±0.54	42.3±1.09*	36.14±1.2*
Pike-perch	93.6±4.4	51.7±1.8	47.0±1.6	85.0±4.50	45.3±0.54*	34.3±0.54*
Freshwater bream	91.6±1.5	46.0±3.9	46.0±0.8	80.6±0.95*	41.3±2.1	33.2±1.1*
Roach	76.6±3.13	37.0±0,4	61.0±3.3	72.4±1.3	35.6±1.3	40.4±1.2*

*significant difference between the paired values of the Student's coefficient at $p \leq 0.05$.

From the results obtained, it can be seen that the muscle tissue contains the highest amount of protein in comparison with the liver and gills. If we compare fishes that have a carnivorous and peaceful way of life, we see that in biological tissues of predators the protein content is higher. This is due to the fact that predators consume protein foods and need more nutrients and energy, as they drive a more mobile way of life.

Based on the averaged data of other authors [84,90], we can note that the protein content of most fish from the Zaporizke Reservoir is somewhat lower than the level corresponding to this season. This may indicate a weakening of metabolic processes in fish, reduced physiological and functional capabilities, which can lead to a decrease in immunity, and as a consequence, to an increase in the incidence and susceptibility to various types of infections.

In the Samara Bay of the Zaporizke Reservoir, the protein content was decreased in the muscles of the studied species, but the signsficant deviation of 14% was only in bream.

In gills, significant decreases in protein contents were observed in predatory fishes – 24% in perch and 13% in pike-perch.

In the liver, the protein contents were significantly lower in all species of fish, perch – by 30%, in pike-perch – by 27%, in bream – by 30%, in roach – by 34%.

The muscle tissue forms the basis of the fish body and is the most valuable in terms of food, both for humans and for other mammals. Fish gills take on the first ‘impact’ caused by chemical changes in the aquatic environment, which often affects the biochemical parameters in this organ. Muscles can also serve as indicators of contamination, but to a lesser extent than gills, kidneys and liver.

By comparing the results obtained from two sections of the Zaporizke Reservoir, we can concluded that the protein content in fish tissues from the lower part of the reservoir is higher in almost all indicators than in the Samara Bay fishes. The content of protein in fish tissues depends on many factors, but primarily determined by the level of development of the feed base. The Samara Bay is a contaminated section of a water reservoir with a large amount of shallow water and a well-developed natural forage base for fish. However, since the bay has a significant anthropogenic impact and the state of the environment is unfavorable due to toxic pollution, the protein content in industrial fish tissues is lowered compared to the lower section of the Zaporizke Reservoir.

Fat in the body of fish is a very labile substance in both quantitative and qualitative terms. It is the main energy source, therefore its amount varies depending on age, season of the year, changes in nutrition, as well as in connection with starvation, long migrations of fish, etc [7,91,92]. Fat is deposited in certain places of the body of fish, typical for this species. Fish fat consists predominantly of triglycerides and fatty acids, unsaturated (84%) and saturated (about 16%).

As can be seen from the results of the study, more common lipids are found in muscle tissue and liver of peaceful industrial fish such as bream, roach (Table 5.2.2).

Significant trophic ductility and rapid adaptation in the diet of carp fishes allow them to accumulate lipids in the liver, which can be used both for energy and for plastic needs. The total lipid content indicates the activity of anabolic processes and the mobilization of lipids as sources of energy, or their use in adaptive reorganization of metabolism and structural components of the cell. The nature of the distribution of lipids in tissues and organs of various types and ecological groups depends on the environment, motor activity, age, and the like. The predators with a mobile existing way, spend more energy.

It should be noted that the catch took place in the autumn period, after a summer takeover before wintering, when fishes accumulate the largest amount of fat.

Judging by the results on the content of total lipids, we can conclude that their highest content was determined in the liver, and in less degree lipids are deposited in the muscles. Gills are characterized by low levels of total fat and weak lipid metabolism as non-specific tissue for their storage.

Table 5.2.2. The lipid contents in the tissues of industrial fish in the Zaporizke Reservoir (g/100g of dry weight), M ± m, n = 6

Type of fish	The lower section			The Samara Bay		
	Muscles	Gills	Liver	Muscles	Gills	Liver
European perch	22.3±0.6	14.1±1.2	48.3±1.2	29.3±0.06*	17.25±0.53	46.2±1.1
Pike-perch	21.6±0.02	13.8±0.9	42.2±0.3	38.0±0,03*	16.4±1.06	44.5±0.7
Freshwater bream	29.9±0.2	14.2±0.7	66.1±2.4	49.9± 0.3*	15.7±1.8	54.1±0.99*
Roach	45.85±0,3	13.7±1.3	59.1±1.1	49.1±0.4*	16.2±0.8	52.2±2.1*

*significant difference between the paired values of the Student's coefficient at $p \leq 0.05$.

The fish from the Samara Bay showed a significant increase in the content of total lipids in the muscles: roach – by 70%, freshwater bream – by 67%, perch – by 31% and pike-perch – by 75%. Increased lipid content in the muscle tissue of the Samara Bay may indicate a metabolic abnormality due to adverse conditions that have arisen in the area.

In the liver of fish, lower fat content was determined, reliable deviations were found in peaceful fish, in bream – by 18%, in roach – by 12%.

Significant decrease in the total fat content in the liver of investigated fish selected in the Samara Bay indicates a general lipid metabolism and accumulation of spare lipids.

A necessary condition for the use of fat in energy metabolism is good oxygen supply to the body. In the Samara Bay here is water with low oxygen content, which is likely to slow down the process of lipid accumulation. Also, the negative impact of numerous industrial wastes disrupts the lipid metabolism in the organisms of hydrobionts, resulting in a fish poorly tolerates wintering.

In any living organism, including fish, substances that are easily mobilized for the production of energy are carbohydrates, and primarily glucose and a spare carbohydrate – glycogen. Glycogen is a reserve form of carbohydrates and is found in virtually all cells in different quantities.

The results of our studies have shown that the content of glycogen is the highest in the liver of fish, where its specific storage occurs (Table 5.2.3). In muscle tissue, the level of glycogen is higher than in gills, especially in predatory fish, which are characterized by high mobility. This can be explained by intense carbohydrate metabolism in the muscles, a significant need for glycogen for rapid movements, compared with gill epithelium.

Table 5.2.3. The glycogen contents in the tissues of industrial fish in the Zaporizke Reservoir (g/100g of dry weight), M ± m, n = 6

Type of fish	The lower section			The Samara Bay		
	Muscles	Gills	Liver	Muscles	Gills	Liver
European perch	0.78±0.03	0.10±0,01	3.80±0.05	0.62±0.01*	0.14±0.01	2.50±0.02*
Pike-perch	0.93±0.008	0.17±0.05	2.80±0.01	0.66±0.05*	0.15±0.02	1.80±0.06*
Freshwater bream	0.74±0.006	0.15±0.03	2.20±0.001	0.81±0.016	0.20±0.01	2.10±0.08
Roach	0.70±0.03	0.21±0.016	2.18±0.001	0.78±0.03	0.23±0.04	1.76±0.06*

*significant difference between the paired values of the Student's coefficient at $p \leq 0.05$.

Indicators of glycogen content in the liver of predatory fish appeared to be higher compared to peaceful ones. In the liver tissue of roach and bream, these values were 2.2 g/100 g of dry weight, and in european perch and pike-perch, they were significantly higher – by 72 and 27% respectively.

The industrial fish species caught in the Samara Bay of the Zaporizke Reservoir showed a predominant decrease in the glycogen contents in investigated tissues and organs. Thus, in the perch muscles, glycogen level was decreased by 20%, in pike-perch muscles – by 29%. In the liver of the perch, the glycogen content has been decreased by 35%, in the liver of pike-perch – by 36%, in roach – by 20%.

From the results obtained during the researches, it can conclude that the anthropogenic pollution of the Samara Bay influences the metabolic processes of the ichthyofauna, and especially the carbohydrate metabolism, because in all the tissues and organs of the fish investigated we found a decrease in the glycogen content. Consequently, the carbohydrate metabolism is most sensitive to changes in the environment.

The objects of the juvenile fish biochemical studies were some species as followed: european perch (*Perca fluviatis*, Linnaeus, 1758), freshwater bream (*Abramis brama*, Linnaeus, 1758), roach (*Rutilus rutilus*, Linnaeus, 1758), prussian carp (*Carassius gibelio*, Bloch, 1782), Monkey goby *(Neogobius fluviatilis*, Pallas, 1814*)*, bleak (*Alburnus alburnus*, Linnaeus, 1758). Ichtyological sumples were picked up in the summer and autumn in the lower part of the Zaporizke Reservoir near the Viys'kove village.

The results of studies have shown that protein content in the body of fish was dependent on the diet. For example, predators (perch) who feed on animal food had the highest protein content (78 g% in dry weight), whereas the bleak, whose diets dominated plants food (phytoplankton), contained the smallest amount of protein – 57 g %. The results of the study are presented in the Table 5.2.4.

In the autumn, the amount of protein in most fish species increased. This is due to the seasonal accumulation of nutrients before long-term wintering. In fish, as in many animals, when eating more fat, which is differed by structure from their own ones, some of them are directly deposited in the depots. The fattiness of the fish varies considerably during the season, depending on the factors of the environment and the age of the fish.

Table 5.2.4. The protein contents in the tissues of juvenile fish in the Zaporizke Reservoir (g/100g of dry weight), M ± m, n = 6

Types of fish	Summer sample	Autumn sample
European perch	78,0 ± 0,22	72,7 ± 0,22*
Freshwater bream	70,2 ±0,53	73,4 ± 0,36*
Roach	60,4 ± 0,51	75,3 ± 0,44*
Prussian carp	67, 9 ± 0,93	73,6 ±0,35*
Monkey goby	63,2 ± 0,84	66,1 ± 0,63
Bleak	57,6 ± 0,23	64,4 ± 0,63*

*significant difference between the paired values of the Student's coefficient at $p \leq 0.05$.

For the first time, fry are able to consume only the protozoa and algae, but gradually their diet is becoming more diverse, in it there are animal organisms. The juveniles are beginning to move more, due to which the contents of lipids in their tissues increased. The results of studies indicate that in the body of fish in the autumn, the fat content is likely to increase (table 5.2.5). The largest differences between summer and autumn samples were in roach, prussian carp, perch and bleak.

Table 5.2.5. The lipid contents in the tissues of juvenile fish in the Zaporizke Reservoir (g/100g of dry weight), M ± m, n = 6.

Types of fish	Summer sample	Autumn sample
European perch	22,3 ± 0,83	30,1 ± 0,62*
Freshwater bream	29,9 ± 0,72	32,2 ± 0,68
Roach	20,7 ± 0,26	29,0 ± 0,96*
Prussian carp	20,1 ± 0,57	28,7 ± 0,27*
Monkey goby	35,1 ± 0,45	36,8 ± 0,27
Bleak	32,2 ±0,65	36,5 ±0,62*

*significant difference between the paired values of the Student's coefficient at $p \leq 0.05$.

Based on the results of the study, we can note that the fat content in the pelagic fish species that drive the mobile way (roach, perch) is lower compared to bottom fish (monkey goby), which have a calm way of existence. The difference between the levels of lipid accumulation in them reached 43 %.

Glycogen occurs in factually all cells in different quantities. It was found that glycogen is the main energy substance in fish in the embryonic period. In the postembryonic period, the main supplier of endogenous nutrition is fat, whose reserves are 2–3 times higher than that of glycogen. Our results confirm this conclusion (table 5.2.6).

Table 5.2.6. The glycogen contents in the tissues of juvenile fish in the Zaporizke Reservoir (mg/100g of dry weight), M ± m, n = 6.

Types of fish	Summer sample	Autumn sample
European perch	322,0 ± 0,74	263,0 ± 0,45*
Freshwater bream	197,1 ± 0,57	130,1 ± 0,34*
Roach	219,6 ± 0,36	176,1 ± 0,62*
Prussian carp	170,2 ± 0,35	98,1 ± 0,35*
Monkey goby	73,2 ± 0,38	70,6 ± 0,37*
Bleak	101,5 ± 0,32	75,2 ± 0,91*

*significant difference between the paired values of the Student's coefficient at $p \leq 0.05$.

The content of glycogen in different species of fish significantly varied. Thus, in sedentary bottom fish, it was the lowest and equaled 73.18 mg % in the summer. It was lower at 28–77 % compared to more mobile fish.

In the autumn, the activity of fish nutrition is significantly reduced and, accordingly, there is a fall in the content of glycogen in the body of fish. In addition, with decreasing water temperature, the intensity of fish movement decreased, therefore the body's needs in carbohydrates are reduced as a source of energy. The main reserve depot of carbohydrates during wintering in fish is the liver.

Thus, the content of protein in the body of juvenile fish increased in the autumn compared to the elderly and depended on the way of feeding of fish, in predatory fish the level of protein was higher compared to peaceful fish. The content of lipids in the tissues of the young-of-the-year fish increased with the approach of autumn, and the content of glycogen, on the contrary, declined. In the body of juveniles, inactive bottom fishes, there was a greater amount of fat and less glycogen compared to mobile pelagic fish.

For the purpose of forecasting possible changes in ichthyofauna, dynamics of abundance and stocks of economically significant fish species, scientific substantiation of fishery management activities, it had been studied the physiological condition and quality of eggs and juvenile fish based on their biochemical composition in the fishing areas of the Zaporizke Reservoir with different anthropogenic contamination levels [89,93,94].

The biochemical composition indexes of roe and biological tissues of juvenile fish were determined in eight samples of fish species: pike-perch (*Sander lucioperca*, Linnaeus, 1758), european perch (*Perca fluviatis*, Linnaeus, 1758) , common carp (*Cyprinus carpio*, Linnaeus, 1758), freshwater bream (*Abramis brama*, Linnaeus, 1758), roach (*Rutilus rutilus*, Linnaeus, 1758), prussian carp (*Carassius gibelio*, Bloch, 1782), white bream (*Blicca bjoerkna*, Linnaeus, 1758) and rudd (*Scardinius erythrophthalmus*, Linnaeus, 1758), which are the most common catches in the Zaporizke Reservoir. The studies were conducted in two fishing areas, which differ in their ecological conditions: the lower section of the Zaporizke Reservoir near the village of Viys'kove and in the Samara Bay. Lower 'conditionally clean' part of the reservoir is located in a farmhouse-agricultural zone and not influenced by industrial wastes; Samara Bay is characterized by a weak strength, the extensive area of shallow water, and by the results of many years research, it is considered to be ecologically critical area [12, 95]. Because emissions of coal industry and municipal wastewater into Samara river at the cities of Novomoskovsk and Pavlograd, the hydrochemical regime of Samara Bay is characterized by a high content of mineral substances, pesticides, nitrates, ammonium nitrogen, and at certain periods – deficiency of dissolved oxygen, which negatively affects the physiological state of the fish.

The studies showed that the protein contents in fish eggs at lower section of the Zaporizke reservoir was (g/100g of dry weight) in pike-perch – 80.06±4.01, european perch – 67.04±3.35, common carp – 83.01±4.15, freshwater bream – 78.1±3.9, roach – 75.8±3.79, prussian carp – 87,.01±4.35, white bream – 57.92±2.89 and rudd 53.42±2.67 (Fig. 5.2.1).

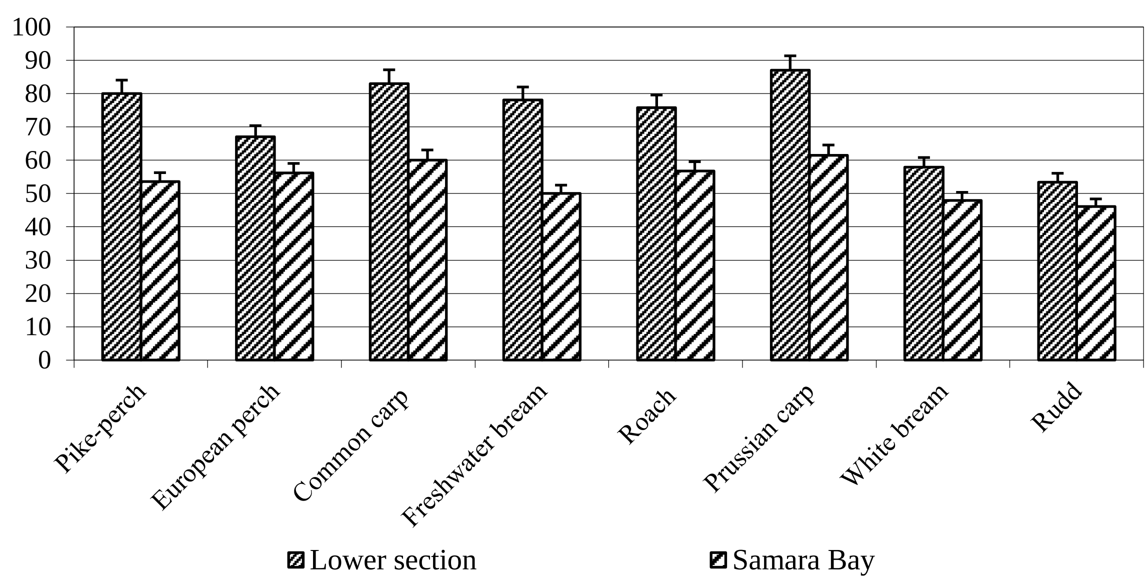


Figure 5.2.1. The protein contents in fish eggs in the Zaporizke Reservoir (g/100g of dry weight, M ± m, n = 6).

Thus, the protein content was higher in eggs of the commercially valuable fish species. Also, a high level of protein was measured in prussian carp eggs, which is characterized by high plasticity and adaptability to environmental conditions.

Determination of protein content in eggs of fish from the Samara Bay showed that the values of all indexes were somewhat reduced as compared to the lower section of the Zaporizke Reservoir. The protein content in eggs of freshwater bream was reduced by 35.95%, pike-perch – by 33.1%, common carp – 27.63%, prussian carp – 29.32%, roach – 25.16%, white bream – 17.2%, european perch – by 16.13%, and rudd – 13.75%. The greatest loss of protein was observed in the eggs of valuable food fish – pike-perch and freshwater bream; the smallest decline of protein level was in low-value species, as white bream, european perch, rudd, with high adaptive capacity.

The results of the protein level determination in the tissues of juvenile fish from the lower section of the Zaporizke reservoir showed that it was (g/100g of dry weight) in a pike perch 59.56±2.97, prussian carp – 68.12±3.40, common carp – 65.94±3.29, freshwater bream – 51.47±2.57, european perch – 56.26±2.8, roach – 45.71±2.28, white bream – 43.02±2.15, rudd – 45.85±2.29 (Fig. 5.2.2).

Thus, the highest protein content in tissues was observed in juvenile prussian carp and common carp, which indicates the strong development of fodder for these fish species. Exceed the protein content in predatory fish species as compared to the peaceful ones is, probably, due to the type of existence and power features.

Analyzing the protein levels in tissues of juvenile fish from the Samara bay, we found no significant differences when compared with the data obtained in the studied of fish species from the lower part of the reservoir. The protein content in tissues is quite stable indicator resistant to various impacts. Our results are in accordance with the average data to other authors, presented in the scientific literature [84,90].

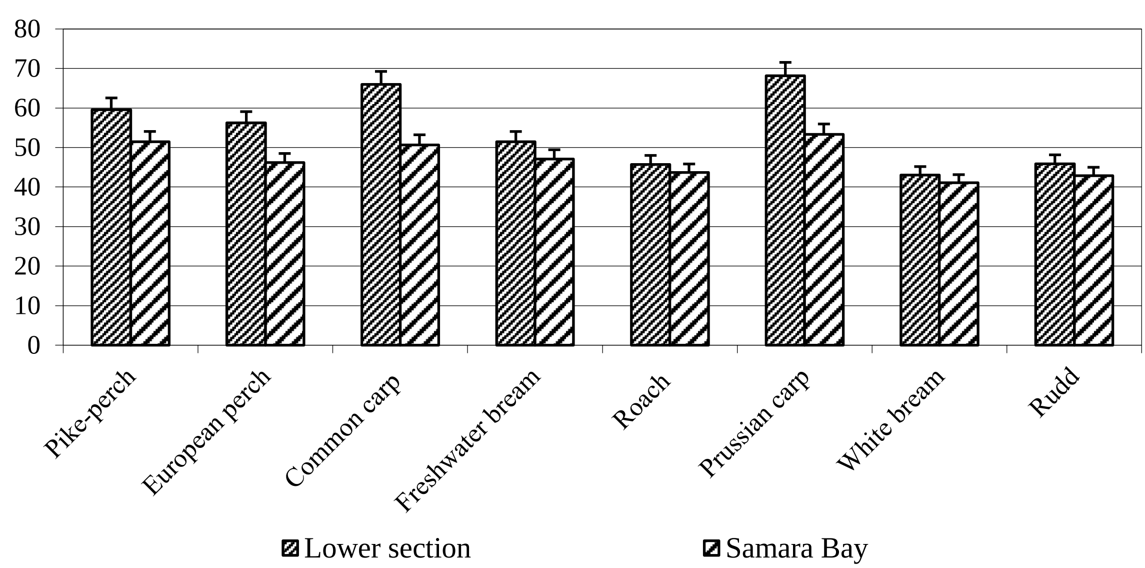


Figure 5.2.2. The protein contents in the tissues of juvenile fish (0+) from the Zaporizke Reservoir (g/100g of dry weight, M ± m, n = 6).

According to the results of our research the contents of total lipids in the studied samples of fish roe from the lower section of the Zaporizke Reservoir were (g/100g of dry weight) in pike-perch – 26.8±1.34, european perch – 32.96±1.64, common carp – 26.8±1.34, freshwater bream – 25.91±1.29, roach – 29.8±1.49, prussian carp – 25.6±1.28, white bream – 39.4±1.97, rudd –42.3±2.11 (Fig. 5.2.3). The smallest amounts of lipids were contained in the roe of predatory species, which belong to the 'lean fishes'.

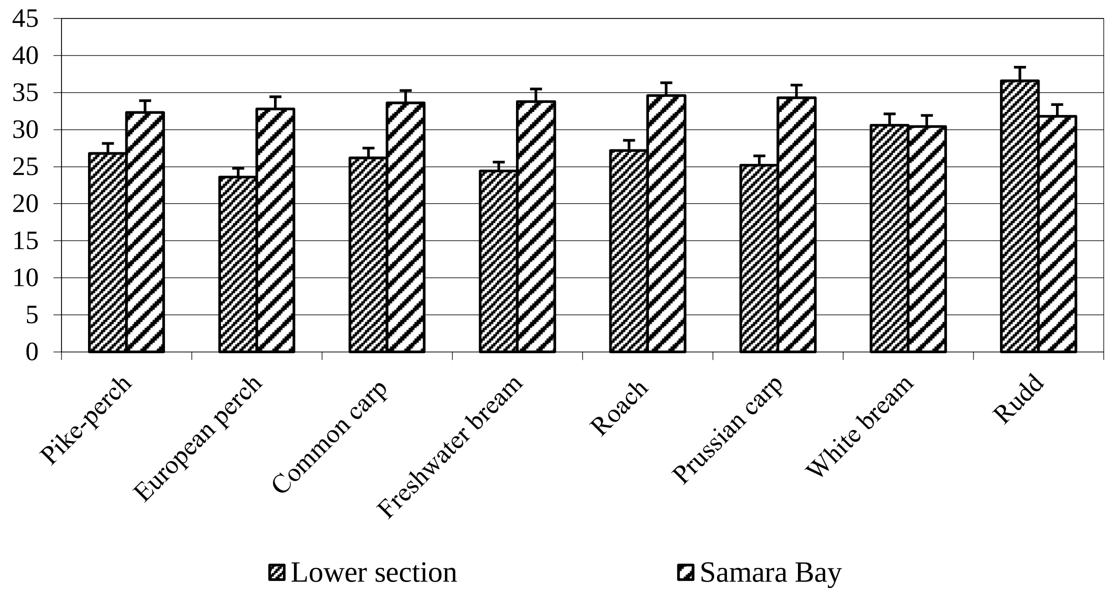


Figure 5.2.3. The contents of total lipids in fish roe from the Zaporizke Reservoir (g/100g of dry weight, M ± m, n = 6).

Research of the total lipids level in the roe of studied fish species in Samara Bay have resulted in a significant excess of the indicator values compared to conventionally clean area. Thus, the pike-perch eggs contained lipids of 34.6 ± 1.73 g/100g of dry weight, which exceeded the net area by 29.1%, the eggs of european perch – 39.3±1.96 (exceeding by 19.2%), common carp – 40.6±2.03 (exceeding by 51.5%), freshwater bream – 38.2±1.91 (47.4 %), roach – 35.6±1.78 (19.5 %), prussian carp – 40.8±2.04 (59.3%), white bream and rudd – respectively 40.8±2.04 and 43.8±2.19 (exceeding by 3.5% at both cases). Thus, in the Samara Bay greater lipid amounts were contained in the roe of predatory fish species and commercially valuable peaceful fishes, compared to the relatively clean area. Elevated level of fats in the roe of predatory and peaceful commercially valuable fishes were in accordance with reduced protein content.

Fat accumulation is a negative factor, which satisfy to disorders of lipid metabolism in fish and points to spawning adaptation to extreme conditions, exceptional to anthropogenic pollution of Samara Bay in this case.

The results of the total lipid level determination in juvenile fish tissues of the lower section of the Zaporizke Reservoir showed that it was (g/100g of dry weight) in a pike perch – 22.9±1.14, european perch – 23.6±1.18, common carp – 26.2±1.31, freshwater bream – 24.4±1.22, roach – 27.2±1.36, prussian carp – 25.2±1.26, white bream – 30.6±1.51, rudd – 36.6±1.83 (Fig. 5.2.4).

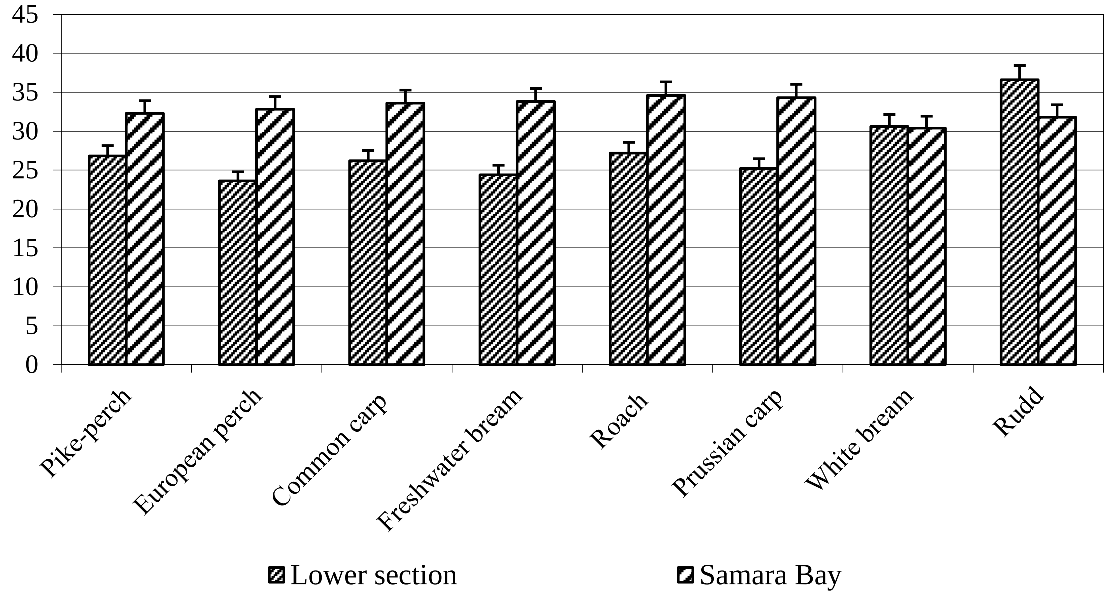


Figure 5.2.4. The contents of total lipids in the tissues of juvenile fish (0+) from the Zaporizke Reservoir (g %/dry weight, M ± m, n = 6).

Among the species of peaceful fish the lower fat contents were found in the tissues of commercial fish juveniles: common carp, freshwater bream; the high fat contents – in low-value species (white bream and rudd). Perhaps this is due to the later transition to exogenous feeding.

According to the content of total lipids in the tissues of juvenile fish of studied species from the Samara Bay it was found excess on 27–41% of the means data obtained in relatively clean zone.

Thus, the level of total lipids was (g/100g of dry weight) in pike perch – 32.3±1.61 (exceeding by 41.0%), european perch – 32.8±1.64 (39.0%), common carp – 33.6±1.68 (28.2%), freshwater bream – 33.8±1.69 (33.5 %), roach – 34.6±1.73 (27.2%), prussian carp – 34.3±1.71 (36,1%). In the juvenile white bream the lipid content in tissue did not different from the relatively clean area and was 30.4±1.52 g/100g of dry weight, in rudd it was 31.8±1.59 g/100g of dry weight, which was 13.2% lower than in the conventionally clean area. Thus, in the Samara Bay greater amounts of lipids in the tissues were found in juvenile fish of predator and valuable food species as compared to peaceful and low-value ones. It can be assumed violation of their rate of energy exchange processes, which may adversely affect the course of the life cycle (cause stunted growth, delay in feeding intensity, decline). However, the low value fish in terms of the lipid levels in the tissues are more resistant to extreme conditions.

Protein content of the commercial fish roe was lower in samples taken from Samara Bay, compared with the lower section of the Zaporizke Reservoir, probably due to the less favorable environmental conditions in the area. Comparing data on the protein content in tissues of juvenile fish from different areas of the Zaporizke Reservoir, it have not find significant differences, as the protein level was quite stable indicator. It was revealed that in the Samara Bay the roe of predatory and valuable food fish contained high amounts of lipids and fat-like substances in comparison with the conventionally clean area.

The accumulation of lipids is a negative factor, which indicates the spawning adaptation to extreme conditions, in particular to anthropogenic pollution of Samara Bay.

Comparing the data on the total lipid content in the tissues of juvenile fishes from different parts of the Zaporizke Reservoir, we can conclude that the indicators of lipid contents in tissues of juvenile from Samara Bay were higher than those from the lower section of the reservoir.

According to the results of biochemical assays, the content of protein in the body of juvenile fish increased in the autumn compared to the elderly and depended on the way of feeding of fish, in predatory fish the level of protein was higher compared to peaceful fish. The content of lipids in the tissues of the young-of-the-year fish increased with the approach of autumn, and the content of glycogen, on the contrary, declined. In the body of juveniles, inactive bottom fishes, there was a greater amount of fat and less glycogen compared to mobile pelagic fish.

The juvenile fish from the Samara Bay had been characterized with the biochemical composition of worst performers in comparison with the juvenile fish of the lower section of the Zaporizke Reservoir, which was in accordance with the quality of fish eggs in that region. It should be noted that in the samples taken from the Samara Bay, the amount of protein was significantly decreased, and the amount of lipids was increased, indicating a violation of protein-lipid ratio, when the deficit of plastic matters is compensated by the energy substances under the conditions of anthropogenic transformation of the Zaporizke Reservoir.

6. EPIZOOTIC CONDITION OF DNIPROPETROVSK REGION FISHERY PONDS

Large reservoir ecosystem that includes the Zaporizke Reservoir is characterized by a stable inter-populational relationship, including relations of the parasite type – the owner. Violation of their stability indicates serious changes in biocenotic balance, which can lead to irreversible phenomena.

According to parasitological researches, 26 parasites species were found in pike-perchfrom the ZaporizkeReservoir. The most diverse species were miksosporidias, ciliary infrusorias and monogenetic flukes, but the intensity of invasion by these parasites, in average, was low (Table 6.1). The Trematoda class was represented primarily by the larval stages of the Diplostomum. Diplostomas were localized in the eyes of fish with an invasion intensity up to 920 parasites per fish (Samara Bay). In this case, the infection of fish in the population was 100%. Representatives of other classes were found on fishes rarely and in single copies.

Table 6.1. Indicators of the main industrial fishes of the Zaporizke Reservoir contamination by parasites

Parasites, class	Roach		Silver bream		Cruciancarp		Pike-perch		Perch	
	EI	II	EI	II	EI	II	EI	II	EI	II
Myxosporea	12	6±2.3	8	4±2.4	14	7±4.0	6	2±0.8	7	3±0.9
Peritricha	4	2±0.5	6	2±0.6	4	3±0.9	9	1±0.2	4	1±0.6
Monogenea	47	4±1.1	39	3±0.9	41	4±0.8	30	5±1.6	17	3±0.9
Trematoda	100	262±24	94	180±19	-	-	24	6±1.8	26	8±1.2
Cestoda	3	1±0.5	6	1±0.4	4	2±0.8	-	-	4	1±0.6
Nematoda	3	1±0.2	-	-	2	1±0.3	4	1±0.5	60	17 ± 1.5
Hirudinea	6	2±1.0	5	2±0.4	8	2±1.1	-	-	-	-
Crustacea	9	2±1.1	7	1±0.3	6	2±0.3	15	3±1.4	8	2±1.2

19 species of parasites were found in the Silver bream, among which the most diverse were infusoria and monogenesis. According to the infection indicators of the epizootic significance was acquired only by the diplomostats family larvae. Their number in individual fish was more than 1000 samples. The affected fish had clear clinical signs of parasitic cataracts.

The crucian carp parasitic fauna consisted of 21 species. Unlike other fish species, the representatives of the trematodes class were not found in the crucian carp, but monogenetic flukes were quite diverse – 6 species, among which the Dactylogirus and the Diplozoon were dominant. Crustaceans were submitted by two species – Argulus foliaceus and Lernea cyprinacea L. All types of parasites were in a few amount and did not have mass distribution.

The pike-perch and perch predators had a less diverse species of parasitic fauna – 15 and 14 species, respectively. In pike perch per number predominated trematodes. Often, the maritas of Phyllodistomum and Bucephalus families were more likely to be found. In helminthofauna nematodes in pike perch dominated by kamalanids. Among the crustaceans, the families Ergasilus and Achtheres dominated.

In the past three years, the perch has begun to gain heightened attention both from researchers and from users in connection with the noticeable (in several times) increase in the infection of the parasitic nematode *Eustrongylides excisus*. In the scientific literature of the period 70–80'-years of the last century there is no data on the detection of estorhidides in the fish from the Zaporizke Reservoir, and also located above the cascade the Kam'yanske Reservoir. In the next twenty years parasitological fish reseachesfrom the Zaporizke Reservoir have apparently not been conducted, as we did not receive information about the status of fish parasitoofauna during this period.

For the first time, *Eustrongylides excises* Jagersklold, 1909, we found in the summer of 2008 in the perch from the lower part of the the Zaporizke Reservoir. The larvae had a filamentous shape, red in color and 35–55 cm length.

At the head end, there are 12 papillas, located in 2 circles of 6 in each. Papillas of the outer circle is smaller than the papillae of the inner circle. The tail end is asymmetric in male larvae and symmetrical, rounded – in larvae-females.

Parasites localized in the body cavity on the surface of the liver, gonads and intestines, as well as in the muscles. The larvae were predominantly in the third stage of development, in the free state. Indicators of fish contamination were: EI – 8%, II – 1.2 ± 0.06 sample/fish.

In case of high infection with parasites, some perch specimens in the pre-nest period had underdeveloped sexual products (Fig. 6.1.). In the catfish parasites were found in one instance from the two examined from the II 24 samples/fish. Thus, over the past five years, the population of parasite nematodes in the Eustrongylides has increased its size and rates of fish invasiveness by almost 10 times. In addition, the number of species infected by this parasite has increased.

In 2011, the perch infection by eustorgilidesam increased to 18%, and the second – 2.6 ± 0.08 sample/fish. In the same year, the parasites were found in a bull – in 6 samples of 8 researched, with II – 4–8 samples/fish. In 2012, an increase in the number of nematodes and the range of their owners expansion of was noted. In the perch the EI was 37%, and the II increased to 5.5 ± 0.11 samples / fish. For other fish species, eustorgilides were found in pike-perch, but the infection rates were lower – EI – 11%, II – 2.6 ± 0.08 samples/fish. In the spring 2013, parasites are noticed in the perch and catfish. Infection of various local perch populations ranged from 20 to 67%, and the second – 17.2 ± 1.53 (2–68) samples/fish. The larvae of the parasite were localized in the body cavity (17–50%), in the internal organs – the liver, gonads (9–12%), muscles (up to 50%) and were in the free state (stage III), both in the connective tissue capsule (IV stage). Sometimes there were 2 parasites in the capsule.

It is known that in the cycle of estorhidides development fish perform as a second intermediate and paratenic (reservoir) host. The first intermediate host is small-worm worms - oligochaetes. Adult nematodes parasitize in the gastric mucosa of cormorants. For the development of E. excisus, the most important are predatory fishes, especially the perch, which is paratenchy host.

The ways of the parasite pervasionin the Zaporizke Reservoir may be different, but the most probable is the flight of invasive cormorants. The places of potential birds infestation with nematodes can be Dnieper estuaries and gulfs, where there are cells of fish (bulls)high invasion of estorhilides [96,97]. Once in the reservoir, the parasite quickly adapts and increases its size, as there are favorable conditions for its development – a fairly high biomass of oligochaetes (up to 20 g/m^2) and a large population of tight-frosted coastal perch forms in which the dietary diet is dominated by benthic invertebrates, including oligochaetes.

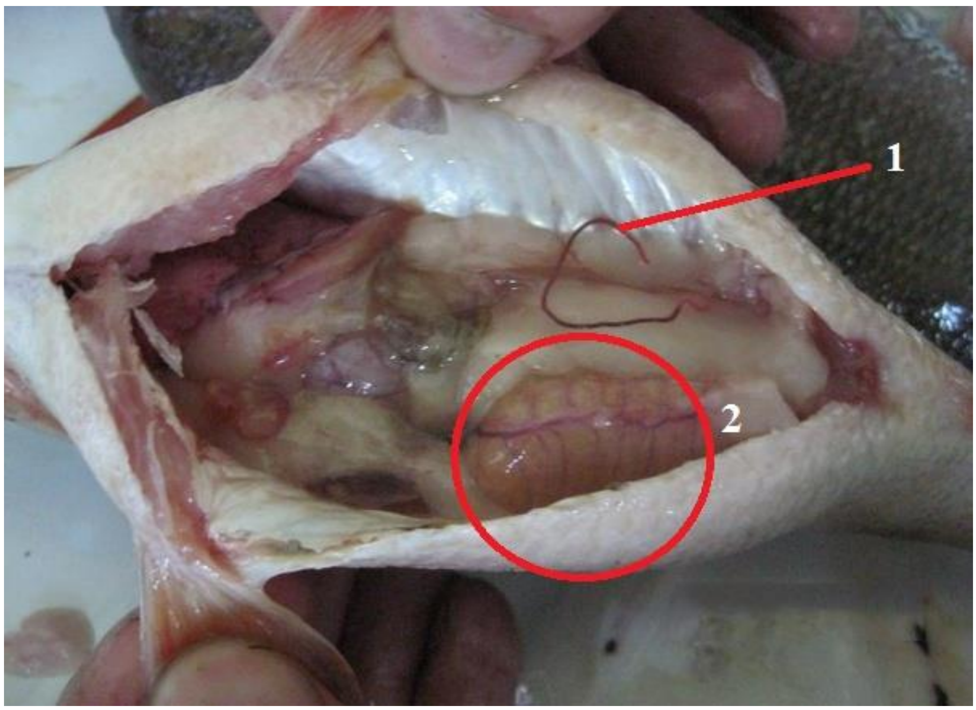


Figure 6.1. Infection of the perch with the larvae Eustrongylides excisus:
1 - parasite, 2 - underdeveloped gonads.

We investigated the effect of larvae *E.excisus* on the fish tissues microstructure, in which the parasite localization occurs. On histological preparations of the perch liver, large areas of necrosis are observed on the path of migration of the parasite larvae (Fig. 6.2.). When the larvae passes throughthe blood vessels walls, resulting in uniform blood elements released into the tissue. Deformation of hepatocyte nuclei around the cysts with larvae of the parasite is also noted.

It should be noted that the pathological effect of esturilides on fish is still not sufficiently studied. There are cases of the perch parasitic castration, gastrointestinal hyperemia in catfish, purulent inflammation of kidneys in sturgeon [98]. There remains the controversial issue of the parasite pathogenic effects on mammals and humans. Since E.excisus belongs to the dioctophytic family, which also includes Dioctophyme renale – a pathogens of a dangerous dioctomyoma disease in humans, many attribute estrogenidides to potentially dangerous parasites. In addition, high fish tissues invasion by parasites can lead to a decrease in the nutritional quality of fish as a food product.

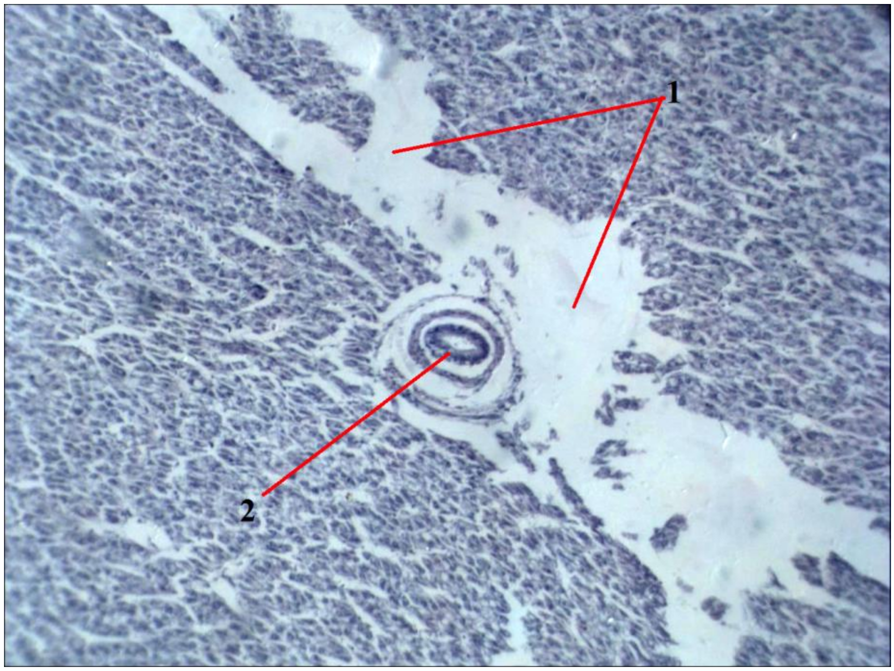


Figure 6.2. Cutting of the perch liver affected by the nematode E.exisus:
1 - a cavity formed in a tissue on the path of the larvae of E.exisusmigration;
2 - a cyst from E. exisus.

Due to the fact that infection of fish with Eustrongylides excisus in the Zaporizke Reservoir acquires the epizootics nature, the research of the distribution range and pathogenic properties of this parasite requires careful attention from both science and veterinary control services.

Figure 6.3. Bream infected with Ligula intestinalis

During the young fish reseachfrom the coastal populations of the Zaporizke Reservoir, a foalslithe of was discovered in bivalves of carp fish – crucian carp, bream and roach. The parasite was in the fish abdominal cavity in the amount of 1 to 2 samples. The length of the helminth varied from 17 to 33 cm (Fig. 6.3.)

Fish infection by *Ligula intestinalis* was observed in the area of Samara Bay. It was here where the optimal conditions for the cycle of the parasite development were: a fairly high concentration of pterygopharyngeal crustaceans – the first intermediate hosts of the parasite, and the nesting birds accumulation – the final hosts of the parasite.

Indicators of young fish infection with Ligula intestinalis are presented in Figure 6.4. The largest indicators of the invasion intensity were in the crucian carp – 38%, somewhat smaller in the bream – 32% and roach – 25%.

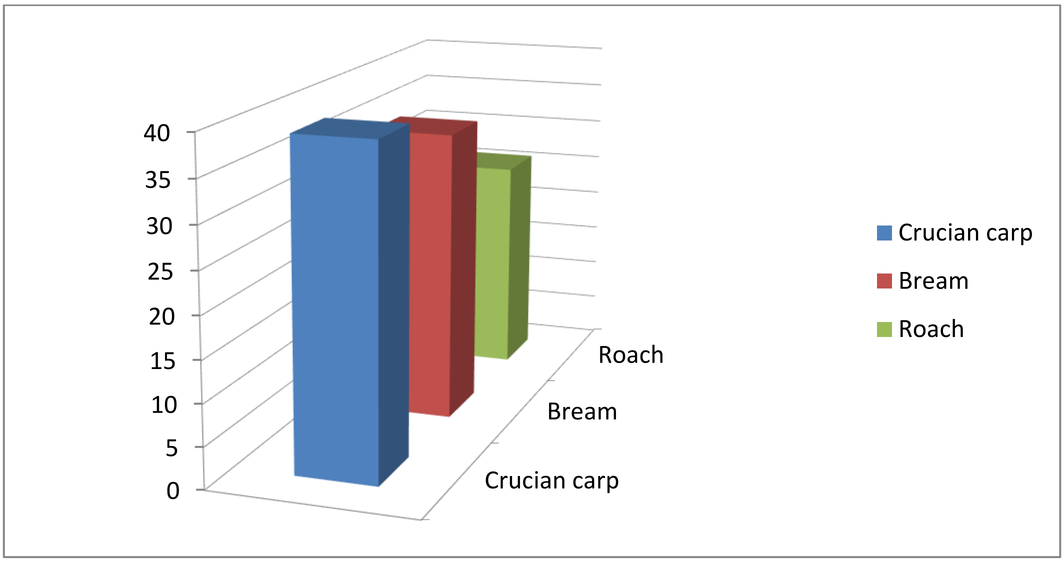


Figure 6.4. Invasion extensiveness by *Ligula intestinalis* in the Samara Bay, %

We investigated the effect of the Ligula on fish morphological physiological parameters (Table 6.2.). It was found that young bream, affected by the parasite, lagged behind in growth by 10–15% of healthy fish.

Table 6.2. Morpho-physiological parameters of two-year-old bream, damaged and not affected by *Ligula intestinalis*

Indexes	Affected fish	Not Affected fish
Average weight, g	124±10.16	146±14.52
Length, cm	15.7±2.11	14.0±1.2
Fulton coefficient of fattening	3.2±0.08*	4.8±0.08

Liver index, %	1.8±0.03*	4.5±0.04
Heart index, %	0.6±0.08*	1.0±0.02
Spleen index, %	0.3±0.01*	1.0±0.05

* - the difference between the indicators is probable ($p \leq 0,05$)

The parasite has a particularly negative influence on the state of the fish internal organs and fatness. Thus, in affected fish the Fulton fattening factor decreased by 33%. The relative weight of the liver has decreased by 60%, which indicates a dystrophic phenomenon in the body and a decrease in its functional activity. There was also noticeable decrease in the relative weight of the heart (by 40%) and the spleen (by 70%).

It is known that the pathological action of the Liguli on fish is explained not only by mechanical damage but also by toxication of the organism with the parasite metabolism product (99).

During an epizootic examination of the sections of the Zaporizke Reservoir fish were found to have tumors. The first information on the researches results of neoplasms in the fish in the Dnipro reservoirs appeared in 2000 [100]. In the pike Esox lucius L., 1758 of the Kyivske Reservoir (upper in the Dnipro cascade), tumors up to 10 cm in size were described as oval, flat pink-gray formations protruding on the surface of the skin. Tumors were localized on the lateral part of the body and were diagnosed as lymphosarcoma with histology. The affected fish comprised between 7 and 30% of the catch.

Later, lymphosarcomatosis was described in pike and pikeperch from other reservoirs in the Dnipro cascade – Kanivske, Kremenchutske and Kakhovske.

As a result of electron microscopic studies, a retrovirus was isolated from fish tumor cells, which turned out to be phylogenetically similar to the TH4 virus isolated earlier in Ireland in pikes affected by lymphosarcoma [101]. Thus, the viral nature of lymphosarcomatosis in the fish from the Dnipro reservoirs has been confirmed.

In the Kyivske and Kanivke Reservoirs, other types of tumors were detected in fish: dermatofibrosarcoma – in pikeperch and tench, and carcinoma in bream. The extent of the fish lesion was 6–10% [102]. We did not find Data on the neoplasms research in the fish from the Zaporizke Reservoir.

While researching the fish from the Zaporizke Reservoir (16 species), new formations were found only in mature pikes that lived in the mouth of the rivers Samara (Samara Bay) and Mokra Sura. The relative number of fish affected with tumors was in the Samara Bay – 4%, in the river Mokra Sura – 18%. The intensity of the lesion ranged from 1 to 3 tumors per fish (2 on average).

Tumors were localized in the region of the back and anal fin. They had a rounded shape, irregular edges and a tuberous surface. Their diameter was 20–50 mm. There were tumors in the initial stage of formation, as well as in the stage of decay and ulceration (Fig. 6.5). Color varied from light pink to dark red, the tumor was covered with a thick layer of mucus above.

Figure 6.5. Clinical picture of tumor in pike.

Dirung histological analysis of muscle tissue selected in the area bordering the tumor, no visible pathological changes were detected (Fig. 6.6).

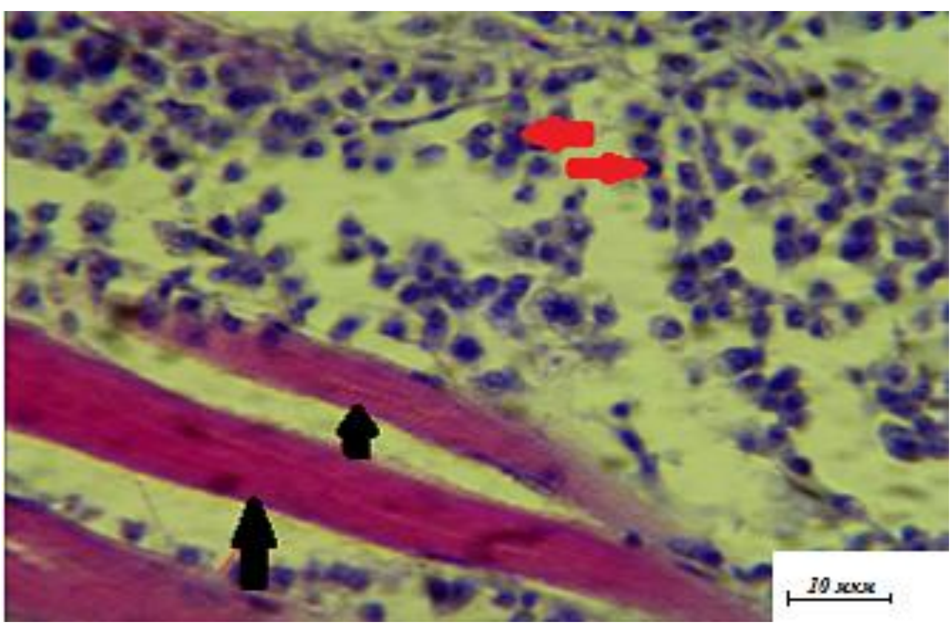


Figure 6.6. Histopathological picture on the border of the tumor and muscle tissue (red arrows – lymphocytes, black arrows – muscle fibers), hematoxylin-eosin, × 400.

Muscle fibers are clearly expressed, retain their structural orientation, the cell walls are integral, and the cytoplasm is intensely colored, which indicates a high functional activity of the cells. The blood vessels are intact. At the border between the muscle tissue and the tumor, the initial stages of collagen fiber destruction are visible. Muscle tissue becomes looser, fibers are disoriented. The cytoplasm of individual cells is pale. There is an active process of lymphoid infiltration and necrotic changes. Metastasis of tumor cells in other tissues and organs was not revealed. In the tumor central zone, the fibers completely replace the tumor cells. Muscle tissue changes into connective tissue, completely losing its functional properties. There are no blood vessels. Lymphoid cells are located singly or in groups. Cells are large enough and have lobed nuclei. There are multinucleated plasma cells. The medicals show extensive areas of necrosis.

Cytometric researches showed that at the border with the tumor, the width of muscle fibers increased from 5.82 ± 0.32 to 7.62 ± 0.94 mkm and the distance between them was reduced from 9.02 ± 0.82 to 7.44 ± 0.94 mkm. As we approach the tumor center, the surface area of tumor cells increases from 11.80 ± 4.43 to 13.20 ± 6.07 μm, while the surface area of the nuclei, on the contrary, decreases from 9.83 ± 0.54 to 8.11 ± 1.34 μm. At the same time, the nuclear-cytoplasmic ratio in mature tumor cells decreases by 27% (from 0.83 to 0.61) as compared to young cells, which indicates a nuclear fusion gradual extinction and a decrease in the tumor cells ability to divide.

An analysis of the tumor histological structure revealed in the pike from the Zaporizke Reservoir basin gives grounds to diagnose it as benign lymphoma. Tumor growth occurs due to infiltration of lymphoid elements represented by atypical lymphocytes and plasma cells, against the background of muscle tissue structures complete disappearance, and is accompanied by inflammatory processes. Metastases to internal organs and muscle tissue were not detected. A similar histological picture is described for some forms of benign human lymphomas.

The etiology of lymphomatosis in the pike from the Zaporizke Reservoir requires special researches. The exact causes of lymphocytes uncontrolled reproduction and their migration into the skin remain poorly understood. Provocative role in the lymphomas formation is assigned to viral infections and carcinogenic chemicals [103], although the virus has not always been able to isolate the pike from lesion with lymphoma [104]. The favor of the viral infection involvement in the disease development is indirectly evidenced by the fact that it is in the near-mouth areas from the rivers Samara and Mokra Sura the pike forms dense spawning congestions, which creates favorable conditions for infecting fish with viruses. Provoke the development of the disease can also reduce immunity in fish due to the adverse ecological state of these rivers.

Thus, according to parasitological researches in Zaporizke Reservoir fish, it is possible to state the center of diplostomous among roach and silver bream populations. Its formation is facilitated by the features of the bayhydrobiocenosis – the presence of large areas with aquatic vegetation thickets, where concentrates mollusks and fish species – intermediate and definitions hosts of diplostomiasis. And also the hearth of eustongillosis among the local populations of the perch, the proliferation of which causes an increase in the oligochaetes number – the intermediate hosts of the parasite, which is thereservoirs indicator ofpollution with organic substances. In the young bream, spot-tail pinfish and roach, there were registered outbreaks of liculus, which were spotted locally in the reservoir gulf, where favorable conditions for the parasite development were.

The epizootic state of the researched small reservoirs, in general, can be characterized as satisfactory. The parasitofauna of fishes of the such small reservoirs as Pivdenne, Khristoforovs’ke and Kam’yanske depended on the nature of the reservoirs supply and the young fish infection degree, which annually pour these reservoirs.

The largest variety of parasites was observed in the fishes of the Pivdenne Reservoir - 17 species, in the Khristoforovs’ke Reservoir - 12 species of parasites, in the Kam’yanske

Reservoir - 9 species. The number of parasites species was dominated by the simplest, among them the most frequent representatives were the genera *Trichodina*, *Ichthyophthirius*, *Apiosoma*. Parasitic worms, which were represented by monogeneses *Dactylogyrus*, *Diplozoon*, by trematodes *Diplostomum spathaceum*, *Posthodiplostomum cuticola*, by cestodes *Ligila intestinalis* and by parasite crustaceans *Argulus foliaceus*, *Lernea cyprinacea* were quite common. But in quantitative terms the intensity of infection was not high and is represented basically by individual instances of parasites.

In the ponds, the species composition of the parasitic fauna was limited, but the quantitative infection indices were quite high, and the distribution of some parasites species reached epizootic value (Table 6.3).

Table 6.3. Species composition of parasitic fauna and indicators of fish contamination insome ponds in Novomoskovsk and Verkhnedneprovsk regions.

Fish-owner	Parasite class	Novomoskovsk region		Verkhnedneprovsk region	
		EI, %	II, sample/fish	EI, %	II, sample/fish
Bream	*Diplostomum spathaceum*	40	2 ± 0.3	-	-
	Ligila intestinalis	30	1.5 ± 0.7	-	-
Crucian carp	*Argulus foliaceus*	88	1.5 ± 0.05	-	-
	Mucophilus cyprini	100	Massively	-	-
	Dactylogyrus vastator	22	3 ± 0.2	18	2 ± 0.3
Silver bream	*Argulus foliaceus*	35	4 ± 0.8	-	-
Roach	*Ichthyophthirius multifilius*	42	4 ± 0.5	-	-
	Mucophilus (Epiteliocystis) cyprini	100	Massively	-	-
Carp	*Ichthyophthirius multifilius*	24	2 ± 0.4	10	3 ± 0.4
	Diplostomum spathaceum	-	-	63	3 ± 0.8
	Myxosporidioses piscearium	-	-	75	14 ± 0.2
	Dactylogyrus vastator	12	2 ± 0.6	50	2 ± 0.1
	Lernea cyprinacea	18	3 ± 0.8		

Silver carp	*Trichodina reticulata*			56	19 ± 0.3
	Sinergasilus lieni			21	8 ± 0.5
	Posthodiplostomum cuticola			36	26 ± 0.7
Grass carp	*Ligila intestinalis*	-	-	15	2 ± 0.3

The most dangerous parasites in the Novomoskovsk ponds were: *Argulus foliaceus* (the invasion extensiveness of crucian carp has reached 88%), Ichthyophthirius multifilius and Lernea cyprinacea. All parasites with a direct development cycle and a wide range of hosts. In conditions of fish high densities of planting in ponds there are favorable conditions for the rapid parasites transition from one species to another. The parasitic diseases proliferation is also caused by the lack of water exchange in ponds and full-fledgedfish feeding.

Low culture of fishing and uncontrolled fish transportation of have led to outbreaks of dangerous helminthic diseases in pond fish [105].

According to our observations, recent years in pond fish, diseases such as ligulosis and post-dysplastic disease progress. Contaminated fish are significantly lagging behind in growth, losing their nutritional qualities and appearance. The main reason for the spread of helminthiasis is the unsatisfactory ecological state of the reservoirs, namely the excessive organic matter accumulation and the overgrown of shallow water with aquatic vegetation. As a result, in the reservoirs there are favorable conditions for increasing the number of molluscs and breeding nesting birds, which serve respectively as parasitic wormsintermediate and final masters.

The epizootic state deterioration of the might also be triggered by the ichthyofaunaunbalanced composition as a result of illiterate waterlogging. Most often, the formation of artificial ichthyotsenozy ignores the predatory fish role as sanitarians-biomeliorators.

Another feature of the modern small reservoirs epizootic state in Ukrainian south-eastern region is a high level of carp fish infection with mucophilosis (epitheliocistosis). This agent affecti by the fishgills, which become pale, anemic and genuinely covered with mucus. And although the death of fish from this disease was not noted, but there were signs of anxiety, sluggishness, lack of appetite. The main reason for the spread of this disease, in our opinion, is the reservoirspollution of with organic substances.

Thus, various types of fishing reservoirs in the Dnipropetrovsk region ichthyopathological and parasitological analysis results indicate the progressive spread of fish dangerous helminthic diseases caused by the lack of proper veterinary control over waterlogging, an fish farming unsatisfactory sanitary state and extremely low cultere.

7. FISH BREEDING AND RECLAMATION RECOMMENDATIONS

7.1. Recommendations on the fish stocking

Calculation of fish stock amount. In Zaporizke Reservoir, certain reserves of the forage base have been formed, that allows stoking large number of young fish of industrial species. At the same time, an important aspect of these works is the use of planting material for optimal weight, which will depend on such important indicators as survival and industrial return. The experience of artificial reproduction of the ichthyofauna on the Dnieper reservoirs shows that the optimal age group for planting material is two-year-olds with a weight of at least 100 g.

The calculations of the Zaporizke Reservoir fish stocking for 2018 are presented in Table 7.1.1. For the calculation of actual fish productivity for individual species of fish, the average indicators of their actual catch for the last 5 years was used.

Silver carp:

- average production of phytoplankton in the reservoir is 28100 kg/ha;
- potential increase of ichtyomass due to phytoplankton is 168.6 kg/ha;
- total loss of ichthyomass from natural mortality is 33.7 kg/ha;
- growth of ichthyomas of silver carp in the growing season, taking into account natural mortality is 135 kg/ha;
- the possible industrial catch of silver carp is 30 % of the growth gane, is 40.5 kg/ha;
- the difference between the potential and the actual catch of the silver carp = 40.5–2.5 = 38.0 kg/ha;
- the density of planting of the silver carp at an average seasonal growth gane of 0.7 kg is 38.0: 0.7 = 54.3 ind./ha.

Bighead carp:

- average production of phytoplankton in the reservoir is 432 kg/ha;
- potential increase of ichtyomass due to zooplankton is 57.6 kg/ha;
- total loss of ichthyomass from natural mortality is 11.5 kg/ha;
- growth of ichthyomas of silver carp in the growing season, taking into account natural mortality and the competition of other fish-planktophages is 23 kg/ha;
- the possible industrial catch of bighead carp is 30 % of the growth gane, is 7 kg/ha;
- the difference between the potential and the actual catch of the big head carp = 7–0 = 7 kg/ha;
- the density of planting of the bighead carp at an average seasonal growth gane of 0.5 kg is 7: 0.5 = 14.0 ind./ha.

Carp:

- average production of zoobenthos in the reservoir is 702 kg/ha;
- potential increase of ichtyomass due to zoobenthos is 98.3 kg/ha;
- total loss of ichthyomass from natural mortality is 19.7 kg/ha;
- growth of ichthyomas of carp in the growing season, taking into account natural mortality and the competition of other fish-benthophages is 34.7 kg/ha;
- the possible industrial catch of carp is 30 % of the growth gane, is 10.4 kg/ha;
- the difference between the potential and the actual catch of the carp: 10.4–0.5 = 9.9 kg/ha;
- the density of planting of the carp at an average seasonal growth gane of 0.5 kg is 9.9: 0.5 = 19.8 ind./ha.

Grass carp:

- average production of macrophytes in the reservoiris 223502 tons;
- it is planned to provide an increase in grass carp due to 10 % biomass of macrophytes – 22350 tons;
- potential increase of ichtyomass due to macrophytesat $K_к$ = 50 is 745 tons;
- total loss of ichthyomass from natural mortality is 223.5 tons;
- growth of ichthyomas of grass carp in the growing season, taking into account natural mortality is 521.5 tons;
- the possible industrial catch of grass carp is 30% of the growth gane, is 156 tons;
- the difference between the potential and the actual catch of the grass carp = 156–2.1 = 154 tons;
- the total number of two-year-old grass carps with an average seasonal gain of 0.7 kg is 220 thous. ind (Table 7.1.1).

Table 7.1.1. The recommended fish stocking rates for the Zaporizke Reservoir in 2018

Fish species/age	Samle, g	Number, thous. ind.			Total weight, tons		
		Dnipro reg.	Zaporizhzhya reg.	All	Dnipro reg.	Zaporizhzhya reg.	All
Carp, 1+	100–130	400	170	570	40–52	17–22	57–74
Silver carp, 1+	100–130	910	650	1560	91–118	65–84	156–203
Bighead carp, 1+	100–130	280	120	400	28–36	12–16	40–52
Grass carp, 1+	100–130	148	72	220	15–19	7–9	22–28

Fish stocking needs to be carried out at different parts of the reservoir in order to reduce mortality rates and increase industrial return. In the zone of operation of the Dnipropetrovsk State Fish Inspection, the following ratio is recommended:

- Upper area – 30 %;
- Middle area – 40 %;
- Samara Bay – 30 % of the total volume of stock.

Taking into account the critical state of the pike and tench populations in the Zaporizke Reservoir, it is recommended the introduction of these types of fish into the reservoir in following quantities:

- tench – age group 0+, weight 10–20 g, total amount – 135 thous. ind., total weight – 1.4–2.7 tons;
- pike – age group 0+, weight 100 g, total amount – 83 thous. ind., the total weight – 8.3 tons;
- Zander – the age group 1+, weight 100 g, the total number – 83 thous. ind., the total weight – 8.3 tons.

For productive use of stocks of zooplankton and their release on the growth of ichtyomass of valuable species of fish-planktophages, it is necessary to organize reclamation of low-value species (Bleak and sprat) in the autumn-winter period by finely-small-scale trawl or small-breed nest and bring the catches of these fish species up to 200 tons per year.

7.2. Fish farming and melioration measures

Hydromelioration measures:

1. Works on clearing and restoration of natural spawning grounds in the bays and gullies of the Zaporizke Reservoir.

2. Works on the restoration and creation of wintering pits for aboriginal and acclimatized species of fish on the territory of Samara Bay and the upper part of the reservoir.

3. Works on optimizing the hydroecological state of the Samara Bay by clearing the old bed of the Samara River, implementation of biological measures against overgrown of higher aquatic vegetation and the massive growth of blue-green algae by stocking herbivorous fish (grass carp and silver carp), as well as molluscivorous fish such as black carp into the Samara Bay to improve the epizootic situation.

Installation of artificial nests. Research of efficiency of artificial spawning grounds using in the waters of Zaporizke Reservoir was carried out. The artificial spawning nest represented the net webbing from nylon material with 12–16 mm mesh fixed on a metal hoop (Fig. 7.2.1) [106].

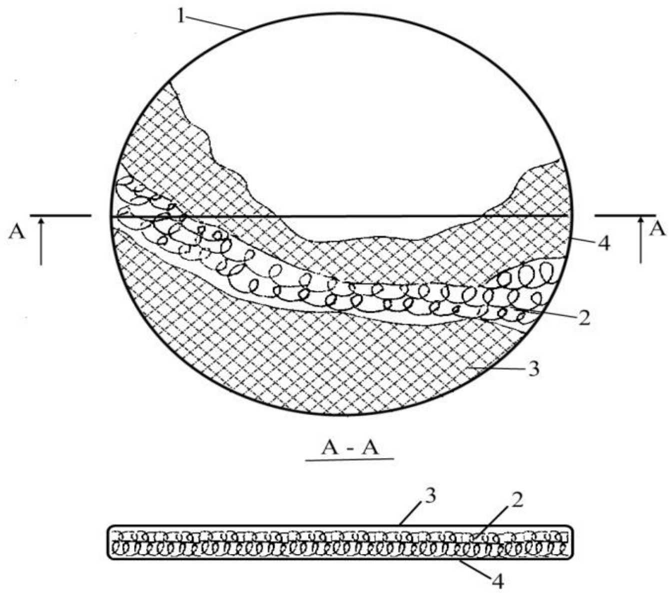


Figure 7.2.1. Scheme of artificial spawning ground, a top view and a sectional view along A-A: 1 – a metal frame 2 – spawning substrate 3–4 – upper and lower layers of the network fabric

4000 units of artificial spawning grounds were installed in the lower part of the Zaporizke Reservoir. They effectively protected the egg laying from acute changes of the water level in the reservoir. It was estimated that phytophilous fish deposited their eggs in 3000 spawning grounds. On the average, spawning fish deposited about 72 g of fish roe per 1 spawning grounds. Each gram of the fish roe contains about 320 eggs. The percentage of larvae release from eggs reached 82 % (Table 7.2.1).

Table 7.2.1. Spawning of fish on artificial spawning grounds.

Place of installation	Krupska dell, Zaporizke Reservoir
Amount of spawning nests, pcs.	4000
Date of installation	12.04 (2000 pcs.) 18.04 (2000 pcs.)
Beginning of spawning of phytophilous fish	24.04 (9 °C) (roach) 20.05 (16 °C) (bream, carp)
Amount of nests with spawn	3000
Average batche of spawn it a nest, g;	72
Number of eggs in 1 g.	320

Larvae output	82 %
Obtained larvae, mln. pcs.	56,68

Thus, as a result of these experiments, use of the spawning nests gives the possibility to get about 56.68 million fish larvae. So the artificial spawning grounds positively influence on the reproduction of the carp fish in the Zaporizke Reservoir.

It was noted that sires of phytophilous fish approach spawning grounds not simultaneously but in multiple parties (approaches). Since the nests were put up at the same time, they were almost fully used by first group of sires (Fig. 7.2.2). Also, because nests were put quite early (at a temperature of 5 °C) and were washed rarely, some of them got silted, so they were not used for spawning.

For the rational use of artificial spawning grounds it is recommended to exhibit spawning nests gradually, according to the water heating and approach of sires fish to spawning grounds (or purposefully put nests before every approach of sires).

Figure 7.2.2. Spawn of carp fish laid on artificial spawning substrate.

The best time for installation of spawning grounds is before spawning, when temperature is on 2–3 °C below spawning temperature. This optimizes the use of additional spawning areas. If the spawning substrate is filled with eggs by 75 %, and spawning of fish still continues, it is recommended to install additional spawning nests. To prevent silting of spawning substrates spawning nests should be washed at least 1 time in two days. During the washing it is recommended to remove foreign objects from spawning modules [106].

Efficiency of artificial spawning grounds using. Taking into account the area of the Zaporizke reservoir and the number of fish breeders, in 2018 the number of artificial spawning grounds in the reservoir should be at least 40 thousand units:

– on the territory of Dnipro region it should be 27 thousand units: 5 thousand units in Samara Bay, 2 thousand units it the entry of Shiyanka river, 10 thousand units in entry of the Mokra Sura river; 10 thousand units near the Kizlevy island and Krupskaya (Tyaginka) gully.

– on the territory of the Zaporizhzhya region it should be 13 thousand units:5 thousand units in Ploska Osokorivka bay, 5 thousand units in entry of the river Vilnyanka, 3 thousand unitsin Gadiycha bay.

To improve the reproduction conditions for fish resources it is necessary to gradually increase the annual number of spawning grounds up to their optimal number – 120 thousand units including the annual supplement: in 2018 – 40 thousand units; in 2019 – 20 thousand units; in 2020 – 30 thousand units; in 2021 – 30 thousand units. Use of artificial spawning nests will allow optimizing the natural reproduction and reconditioning 20000 m^2 of effective spawning grounds by 2021.

Works with spawning nests should be conducted by users of aquatic biological resources, fish-producing organizations, and state authorities, but under the control of fish protection authorities, as well as with the support of research organizations.

The ecological, economic and social effects of the implementation of measures to restore spawning grounds. Installation of artificial spawning grounds has both short-term prospects and long-term.

Short-term results: in the first year of installation of artificial spawning grounds in the waters of ZaporizkeReservoir there were improved conditions for fish spawning. It is possible to obtain a large amount of larvae and juvenile fish (about 57 million ind.), that joined the natural populations of fish and preserved biodiversity of aquatic ecosystems.

Long-term results:

– environmental effect is improvement of natural reproduction, preservation of biodiversity, restoration of spawning grounds, raising the biological productivity of water;

– economic impact is that in terms of industrial fish catch from inland waters of Ukraine, installation of spawning nests will help to increase the supply of fish and therefore increase fishing as a strategic natural renewable resource;

– social impact is that increase of fish productivity helps to provide jobs for population (especially in rural areas) and retains existing jobs in terms of the economic crisis.

The introduction of the practice of setting artificial spawning grounds and artificial reefs affects the development of recreational fishing, eco-tourism and recreation areas on reservoirs of complex appointment [106].

Practical guidelines for restoring reproduction conditions. In many regulated reservoirs, the natural reproduction of aboriginal fishes is subject to such significant stress factors as violation of the level regime in the spring, unsatisfactory spawning grounds, poaching fishing during spawning, etc. It is possible to fix the situation with shortage of spawning grounds with the help of integrated fish farming and reclamation measures, which are quite labor-intensive and expensive (creation of stationary spawning grounds, waterlogging, cleaning spawning grounds, dredging), or by using artificial spawning nests for the period of spawning that can improve the environment for spawning of fish in natural waters without significant investment in environmental measures.

The reproductive potential of zander and Volga zander under conditions of the Zaporizke Reservoir is being implemented today by no more than 30 % due to the degradation of natural spawning grounds and their low efficiency. In addition to improving the recreation zones of fish through restoration of water due to hydromechanized works, the most effective is the creation of artificial spawning grounds in the coastal areas of the Zaporizke Reservoir, which traces the shortage of shallow water and bays (especially the upper and middle sections). Currently, due to the considerable sedimentation of small rivers and lake sites, lithophils have lost some of the spawning areas of water reservoirs that can be offset by the creation of special spawning nests.

Lithophilic fish, such as zander, lay eggs in nests built on a sandy or muddy bottom of the pond. They clean the bottom from dirt, sludge and plant residues, and create a small saucer-like deepening's on a sandy bottom. Spawning of zander takes place in April – early May at a temperature of 11–15 °C. Eggs of zander may be laid on the rhizome of typha, willow, vines, sometimes on a rock or on a solid bottom, and also on artificial spawning grounds, which are installed in reservoirs. A male is near a nest and protects eggs. Caviar, which fish lay in such a nest, is better protected from predators.

As spawning nests for zander, artificial disk spawning nests of polyvinylchloride can be used (Fig. 7.2.3). The nest has the form of a concave disc with a diameter of about 0.5 m, which is attached to a tripod in height 10–15 cm. The nest is characterized by strength and has a solid surface.

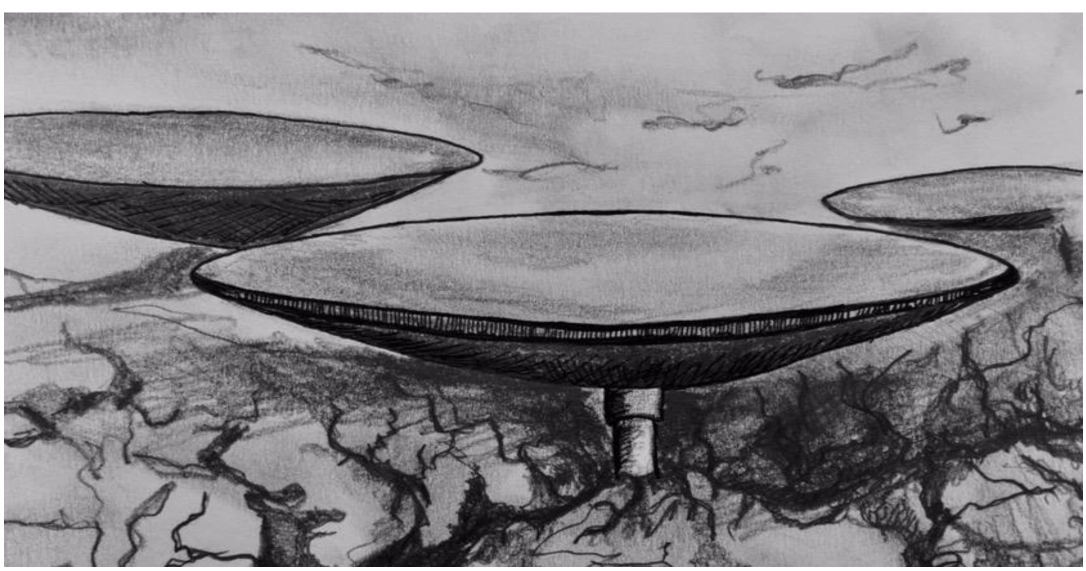


Figure 7.2.3. The construction of artificial spawning nest for lithophilic fish.

The spawning nest is installed at the bottom of the reservoir in places of zander`s spawning. During spawning, the zander lays eggs into the nest and protects them. In addition, at the edges of the nest, small periphytonic organisms can develop, which can serve as an initial feed for fish larvae.

Similar spawning nests are characterized by ease of use and versatility, as they are not destroyed under the influence of aggressive water environments. It is recommended to install 50 such disks per 1 hectare of water. Artificial spawning disk for lithophils should be grouped in 3–5 pcs.

We have identified local populations of the Volga zander in the lower reaches of the Zaporizke reservoir, where it inhabits, breeds and feeds (Figure 7.2.4).

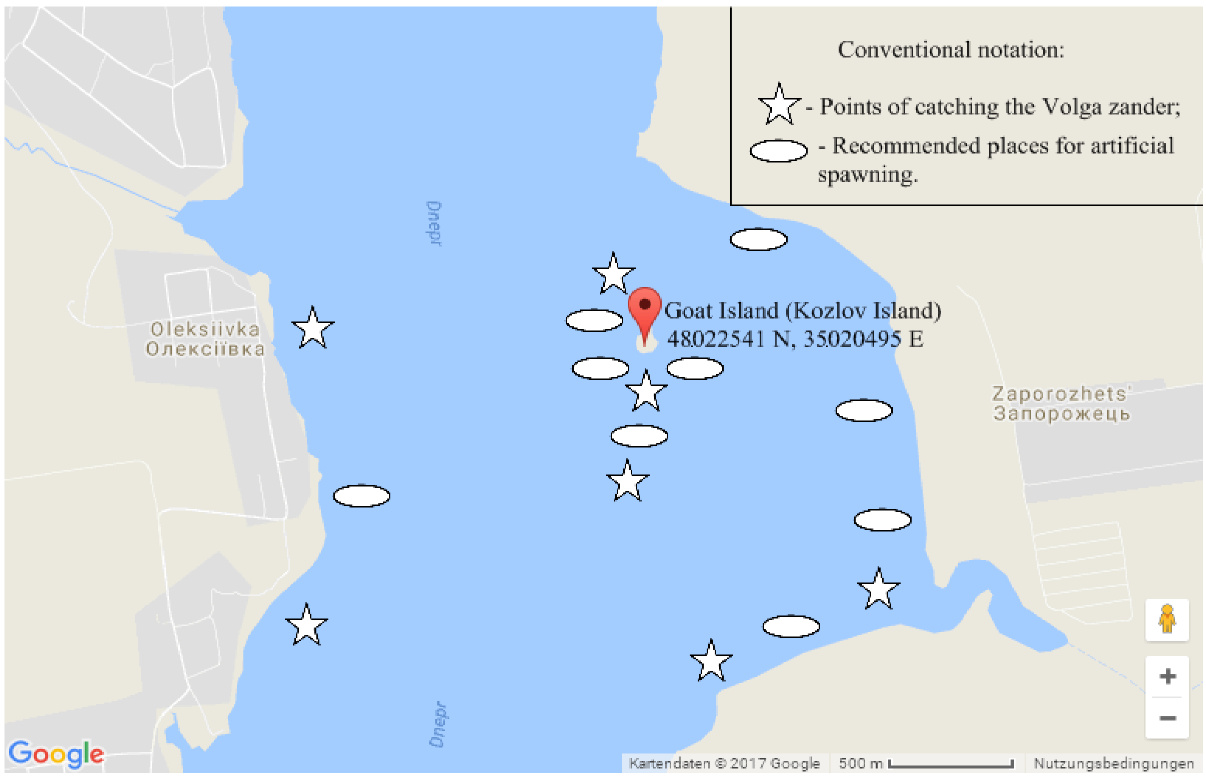


Figure 7.2.4. Local Areas of the Volga zander and its Places of Spawning.

Volga zander, like the zander, builds nests, which it protects after spawning. In shallow waters near of the Kozlov Island (Goat Island) 48°22541 N, 35°20495 E, separate birch nests of Volga zander were located on spawning grounds of the zander, which is why these species can compete with each other in the places of joint spawning.

In order to improve the conditions for the reproduction of the Volga zander we designed artificial spawning nests, and identified the locations of their installation and the scheme of the points where the main spawning grounds of the Volga zander are located and where there is a lack of spawning substrate due to rubbing and silting the banks of the river. The construction of an artificial spawning nest for lithophilic fish (zander and Volga zander) is also proposed.

The number of artificial spawning grounds should correspond to the reproductive potential of aboriginal fish in the process of their use. In addition, it is possible to significantly optimize the process of restoring valuable fish species due to the construction (on the basis of scientific and biological justifications) of natural-artificial spawning grounds such as stone ridges and nets, which will also serve as spawning ground, shelter for young fish and, accordingly, increase in the number of fish from fry to industrial sizes. The installation of artificial spawning nests is one of the ecological and economic ways to improve the conditions for the reproduction of fish in natural waters.

The installation and exploitation of artificial spawning grounds were discussed and formed the basis of the 'Fisheries Development Program of the Dnipropetrovsk Region for 2010–2015' (http://www.magd-rn.dp.gov.ua/OBLADM/Obldp.nsf/(docweb)/AF393D2B7553 4B89C2257776006BBC1B?OpenDocument&PrintForm), but in fact during 2010–2015 this direction was not implemented.

The restoration of spawning grounds for industrial fish species is provided by legislative acts approved by the Cabinet of Ministers of Ukraine: 'On Approval of the Concept of the National Program for the Conservation of Biodiversity for 2005–2025' (Order No. 675-r of September 22, 2004 http://zakon2.rada.gov.ua/laws/show/675-2004-%D1%80), 'On Approval of the State Target Economic Program Development of the Fisheries for 2012–2016' (Resolution dated November 23, 2011, No. 1245 http://zakon3.rada.gov.ua/laws/show/1245-2011-%D0%BF).

The number of artificial spawning nests for zander is determined from a preliminary estimation of the reproductive core of the population, taking into account that for one spawning group, which can consist of one female and two males, the required area is 20 m^2. The number of spawning nests should be corresponded to the number of females that will use them.

Installed artificial nests should be inspected daily for the presence of eggs, and in its absence they should be washed, gradually shaking it in the water column. In the case of detection of eggs in the spawning modules, the nest is noticed by a float with a tag, which marks the date of spawning.

To restore the population of the Volga zander and preserve the number of the zander, we have made calculations on the amount of artificial spawning that must be installed annually in the reservoir. It is recommended on a permanent basis to introduce artificial spawning nests within the lower reaches of the Zaporizke Reservoir during the spring period. It is necessary to gradually increase annually the number of spawning nests for zander and Volga zander to their optimum amount, which is 10 thousand pcs. including annually supplement: 5 thousand pieces in 2018 and 5 thousand pieces in 2019.

CONCLUSIONS

According to the environmental assessment, the water of the Zaporizke Reservoir belongs to 3 classes of quality, 4 categories (satisfactory), eutrophic, α-β mezosaprobic. According to the fishery characteristics, the hydrochemical parameters, in general, corresponded to the MAC. The water of the investigated small reservoirs and ponds of Dnipropetrovsk region meets the requirements related to fish farming facilities and is suitable for growing the main objects of aquaculture in Ukraine. By the integrated environmental assessment using chemical water quality indexes of fishing reservoirs in Dnipropetrovsk region, they was characterised as 'satisfactory' and 'slightly polluted'.

The maximum difference between pelagic zooplankton biomass between the parts of the reservoir occurred in July and August, when the development of copepods and cladocerans was intensive. In summer middle biomass of pelagic zooplankton in reservoie was 147.8 mg/m^3 and 758.4 mg/m^3 in the upper and in the lower part of the reservoir respectively. In the littoral biotops the following zooplankton biomass were recorded: in the biotope of spatterdock beds – 554,3 mg/m^3, in open littoral biotope – 769.3 mg/m^3, in the biotope of cane beds – 675.9 mg/m^3, in the biotope of pondweed beds – 2278.9 mg/m^3.

Biomass of zooplankton of Samara bay varied from 675.9 to 1379 mg/m^3, in average – 988.3 mg/m^3 Despite the considerable pollution of Samara bay, this water boby is of great importance in the creation of fish stocks due to lake-like conditions as well as to a large area of macrophyte beds and water column saturated with organic matter. All of these conditions are favourable for intensive reproduction of limnophilous zooplankton.

Medusa *Craspedacusta sowerbii* numbers in the Zaporizke Reservoir have a tendency to increase that caused by increasing of temperature in water column. Jellyfish abundance was maximal in in shallow sites of the reservoir with slow current, where as a result of medusa predation zooplankton biomass reduced with rotifers percentage increasing. Such species as *Bosmina longirostris* and juvenile stage of copepod were mostly undergone to medusa consumption because of to their relatively large size compared to other zooplankters.

Lowest abundance and biomass of zooplankton was at the upper sites of Mokra Sura river due to joint effect of slime accumulation eutrophication and industrial sewage. Bdelloid rotifers dominance lead to high saprobity index and indicates eutrophication effect here. At other sites of the river planktonic rotifers - saprobionts indicates the eutrophication effect which was maximal at the site of aeration plant sewage emergency discharge. Degree of planktonic rotifers dominance corresponded to degree of zooplankton abundance while bottom rotifers dominated at the sites where abundance of zooplankton was minimal. Large figures of filter-seeding crustaceans as well as low saprobity index indicate improvement in water quality at the sites 3 km and 2 km upstream from the river mouth. The results of zooplankton samples and biotesting corresponded except the upper sites of the river where toxicity was lower in comparison with the site of aeration plant that may be due to deposition of toxic agents into slime under low depth.

Species composition of zoobenthos was typical for Dnieper cascade reservoirsirs and included bottom invertebrates of 6 phylum 11 classis 24 ordo and 45 families. The best ecological state according to the index CISC was marked at the site of littoral muddy sand near Monastyrsky island due to filtration capacity of *Dreissena* together with flowage causing high level of oxygen. Simplification of benthic invertebrates trophic structure and significant decrease of zoobenthos abundance under dominance of insect larvae and oligochaetes indicated the worst ecological state near discharge of urban sewage and in slime of the Zaporizke Reservoir lower part and it was caused by slime and toxic agents accumulation.

In phytoplankton seasonal dynamics of the Zaporizke Reservoir 2 peaks of algae vegetation were determined. Diatom bloom was observed in March and early April and algae biomass was higher in the bottom layer with a gradual decrease in the direction of the surface layer. During the period of spring bloom abundance of phytoplankton averaged 34.0 mln. cells/dm^3 and biomass 37.0 mg/dm^3 respectively. From July to October the apparent dominance of blue-green algae took place with a clear concentration in the surface layer in July. During the whole vegetative season from March to November biomass of phytoplankton were 11.8 mg/dm^3 in average. Decreasing of phytoplankton growth at the areas of sewages influence was caused by toxic substances of sewages. With distance enlarging from the sewages, degree of phytoplankton development increased and to a greater extent in the case of domestic sewage.

On the basis of biomass of zooplankton, phytoplankton and zoobenthos Pivdenne, Khristophorivske and Kam’yanske reservoirs according to the fishery classification is evaluated as water bodies of mainly middle nutrient status (II fish-farming class) and the reservoirs has significant fishing potential.

According to the results of the studies, the fish productivity in the small reservoirs of the Dnipro region has a rather wide range of fluctuations, from 53 to 299 kg/ha. The main factors that cause low productivity of water bodies are ecological and organizational ones. Today, native fish ofauna is not able to provide high fish productivity in small reservoirs and ponds as a result of the lack of conditions for full reproduction. In addition, low professional fishing practices lead to inappropriate use of biological resources of ponds.

The dominant species of fish in the modern industrial fish fauna of the Zaporizke Reservoir are roach and Prussian carp (30 % and 20 % in catches respectively).The most ecologically adapted species is Prussian carp, which productivity in the reservoir has grown more than 5 times over the past 10 years.

The status of industrially valuable zander is considered as depressive, as evidenced by a significant predominance of younger age group sin the age structure, which causes low average values of its linear and weight growth. The state of populations of bream and roach can be characterized as stable.

The general conditions for the reproduction of fish resources in the Zaporizke Reservoir are not satisfactory. Insufficient press of predators promotes the rapid growth of non-industrial species of fish, serving as food rivals for youth of valuable fish species.

Fish productivity of small reservoirs of Dnipro region has a rather wide range of fluctuations, from 53 to 299 kg/ha. The main factors that cause low productivity of water bodies are ecological and organizational.

To improve the reproduction conditions for fish resources it is necessary to gradually increase the annual number of spawning grounds up to their optimal number – 120 thousand units including the annual supplement: in 2018 – 40 thousand units; in 2019 – 20 thousand units; in 2020 – 30 thousand units; in 2021 – 30 thousand units. Use of artificial spawning nests will allow optimizing the natural reproduction and reconditioning 20000 m^2 of effective spawning grounds by 2021.

From the results obtained during the biochemical researches, it can conclude that the anthropogenic pollution of the Samara Bay influences the metabolic processes of the ichthyofauna, and especially the carbohydrate metabolism, because in all the tissues and organs of the fish investigated we found a decrease in the glycogen content. Consequently, the carbohydrate metabolism is most sensitive to changes in the environment.

The juvenile fish from the Samara Bay had been characterized with the biochemical composition of worst performers in comparison with the juvenile fish of the lower section of the Zaporizke Reservoir, which was in accordance with the quality of fish eggs in that region. It should be noted that in the samples taken from the Samara Bay, the amount of protein was significantly decreased, and the amount of lipids was increased, indicating a violation of protein-lipid ratio, when the deficit of plastic matters is compensated by the energy substances under the conditions of anthropogenic transformation of the Zaporizke Reservoir.

Various types of fishing reservoirs in the Dnipropetrovsk region ichthyopathological and parasitological analysis results indicate the progressive spread of fish dangerous helminthic diseases caused by the lack of proper veterinary control over waterlogging, a fish farming unsatisfactory sanitary state and extremely low culture.

To improve the fish productivity of water bodies in Dnipropetrovsk region the hydromelioration measures are necessary, as follow: clearing and restoration of natural spawning grounds in the bays and gullies of the Zaporizke reservoir; restoration and creation of wintering pits for aboriginal and acclimatized species of fish on the territory of Samara Bay and the upper part of the reservoir; optimizing the hydroecological state of the Samara Bay by clearing the old bed of the Samara River, implementation of biological measures against overgrown of higher aquatic vegetation and the massive growth of blue-green algae by stocking herbivorous fish (grass carp and silver carp), as well as molluscivorous fish such as black carp into the Samara Bay to improve the epizootic situation.

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