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Biological substantiation of works on artificial reproduction (stocking) of aquatic bioresources in the lower reaches of the Zaporozhian (Dnipro) Reservoir for the period 2021-2025

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ABSTRACT

The main purpose is developing effective measures for stocking the Zaporozhian (Dnipro) Reservoir with valuable fish species by studying the biological and fishery aspects of the formation and exploitation of their commercial stocks. During the work, we used the generalized results of integrated hydrobiological studies performed in 2021. Materials were collected in the Zaporozhian (Dnipro) Reservoir using standard fishing gears for fish sampling. Collection and processing of phyto-, zooplankton and zoobenthos samples were carried out using conventional hydrobiological methods. Calculation of fish seed amounts was carried out using classical fishery and ichthyological methods. The status of fish feed supply of the Zaporozhian (Dnipro) Reservoir and its production potential was determined. Based on the obtained data, we calculated the potential productivity of the reservoir. It was found that the reservoir had certain feed supply reserves allowing large scale stocking with the juveniles of commercial fish species. The recommended amounts of reservoir stocking in 2021 were calculated as follows: 570 thousand 1+ Common carp; 1560 thousand 1+ Silver carp; 400 thousand 1+ Bighead carp; 220 thousand 1+ Grass carp. The presented results of the study of the state of fish feed supply in the reservoir allow stocking with the calculated amounts creating the bases of the rational use of aquatic bioresources with the preservation of the productive potential of commercial fish species exploited by commercial fishery in the Zaporozhian (Dnipro) Reservoir. Stocking the reservoir with fish allows

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improving the overall ecological status of the reservoir and increasing fish productivity under the conditions of commercial fishery exploitation.

***Keywords*:** fish, Zaporozhian (Dnipro) Reservoir, stocking, feed supply, carp, silver carp, bighead carp, phytoplankton, zooplankton

1. INTRODUCTION

Artificial introduction of aquatic bioresources into reservoirs is one of the main measures of biological reclamation, which is not only improves the ecological condition of the reservoir and preserves biodiversity, but also has a positive effect on increasing fish productivity [1–7]. There is a positive impact of stocking on the reservoirs of Ukraine, so it is advisable to continue the practice of settling aquatic bioresources in the Zaporozhian (Dnipro) Reservoir [8–10].

2. MATERIALS AND METHODS

Hydrobiological research methods. Sampling and processing of samples of phyto-, zooplankton, microphytobenthos, zoobenthos and macrophytes was carried out by traditional methods in hydrobiology.

Phytoplankton. Algologic water samples were taken with a Molchanov bathometer and an Apstein net. Species identification was performed according to classical methods. Biomass was determined by cell volume, taking the specific weight of algae equal to one. The dominance was assessed by biomass. The number of dominants included species which total biomass was at least 80 % of the total biomass of phytoplankton.

Zooplankton. Zooplankton samples were taken according to the generally accepted method – filtering through the Apstein plankton net (gas № 71) 100 dm^3 of water, followed by fixation with 4 % formaldehyde solution [11]. Qualitative composition and quantitative development of zooplankton were determined. Quantitative processing of samples was performed by counting in Bogorov's chamber taking into account the number of organisms of different size and age groups. Biomass was calculated by the formula of mass dependence on body length:

$$w = ql^3, \quad (1)$$

where w – biomass, q – coefficient of proportionality, l – length of the body.

Zoobenthos. Zoobenthos samples were taken with an Ekman-Bergi grab (with a capture area of 0.004 m^2) and hydrobiological scraper nets (diameter of the scraper net hoop – 20-25 cm), which are much more convenient to take samples in shallow areas of the reservoir at a depth of 1.0–5.0 m. At each station, three samples were taken with a grab and one sample with a hydrobiological net-scraper according to the standard method.

Bottom invertebrates were fixed in 4 % formalin solution. The soil was washed through a mesh of fine mill gas. Weighing was performed on torsion scales in groups. Determination of

species composition was performed using microscopes "MICROmed" XS-2610 and "Carl Zeiss Jenamed 2". In the study of macrozoobenthos groups, the average numbers and biomass were calculated, which were determined as arithmetic mean, where this species occurred during the study period. For each species, species occurrence was determined (as a percentage), expressed as the ratio of the samples where the species was detected to the total number of samples taken during the entire study period at a particular station. This figure was calculated by the formula:

$$P = (m / n) 100\%, \quad (2)$$

where m – number of samples (stations) on which the species was found, n –total number of samples (stations).

Ichthyofauna. Fish were caught with a Shutter nets for fishing with a mesh size of a = 30-120 mm during research fishing in the spring and summer of 2021 near the village Vilnoandriyivka (Fig. 1) in accordance with the permit for special use of aquatic bioresources №000006/2021 dated 09.04.2021, biological analysis of fish was performed in accordance with generally accepted methods.

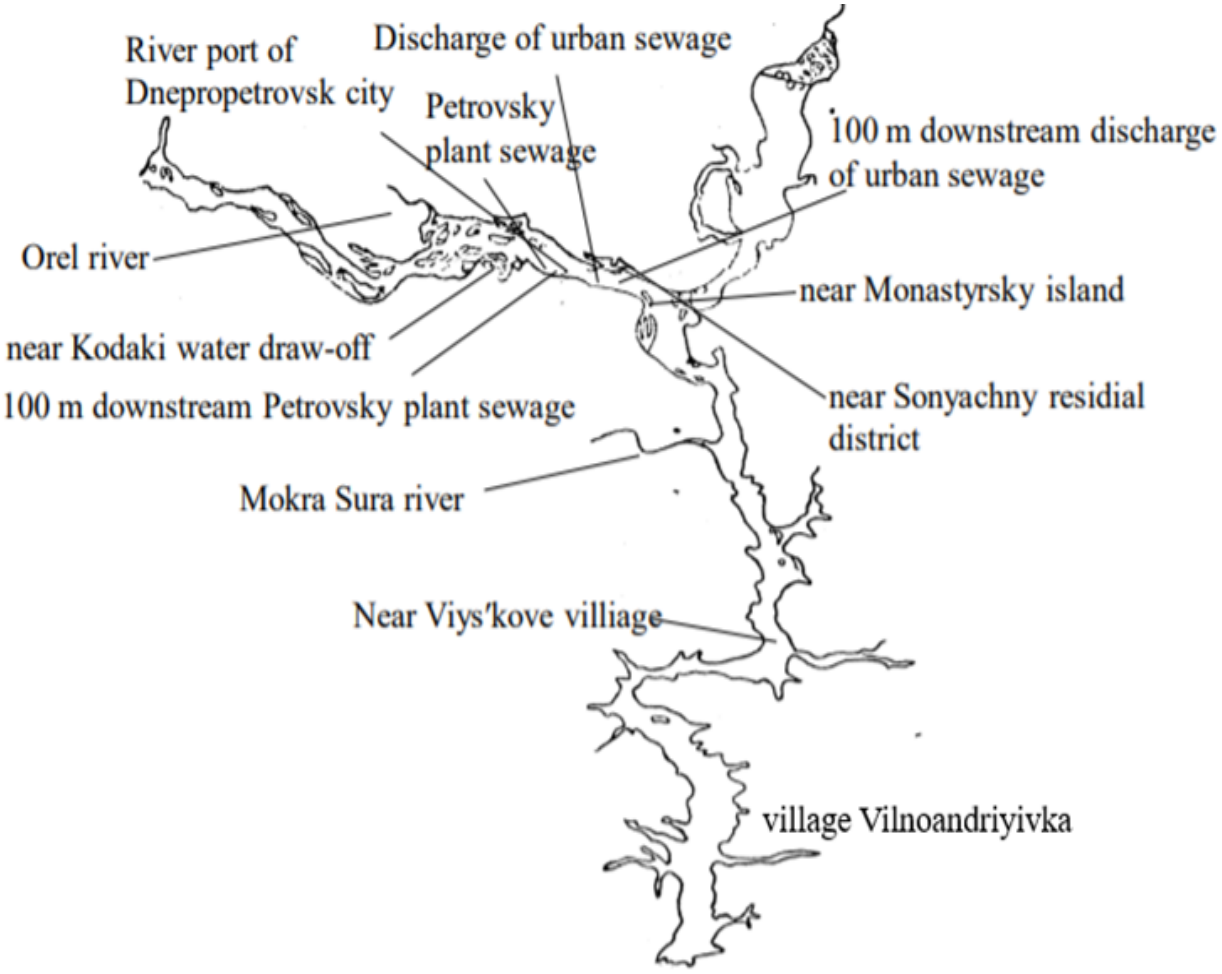

Figure 1. The sites of sampling along the Zaporozhian (Dnipro) Reservoir and its tributaries (47 57′36″N, 35 06′52″E).

3. FEED BASE OF THE ZAPOROZHIAN (DNIPRO) RESERVOIR

Long-term data of the Department of General Biology and Aquatic Bioresources and the Scientific Research Laboratory of Ichthyology, Hydrobiology and Radiobiology of DNU were used for stocking calculations.

3. 1. Phytoplankton

In phytoplankton samples, diatoms were 38 % by number of species, chlorophytes – 33 %, blue-green algae – 16 %, Euglena algae – 9 %, others – 4 %. The biomass in the Zaporozhian (Dnipro) Reservoir was dominated by blue-green algae – 90 %. The average phytoplankton biomass in the reservoir was: in the spring – 3.7 g / m^3, in the summer – 17.6 g / m^3, in the autumn – 6.2 g / m^3.

The spring maximum of phytomass biomass is determined by the development of diatoms: *Melosira italica*, *Melosira granulata*, *Cyclotella meneghiniana*, *Diatoma vulgare* and others. Summer flowering of water is due to the development of blue-green algae: *Microcystis aeruginosa*, *Oscillatoria limnetica*, *Anabaena flos-aquae* and others. In autumn, the share of diatoms of the genuses Stephanodiscus, Nitzchia, Cyclotella, Navicula and others in phytoplankton samples increases due to the gradual extinction of blue-green algae.

It is estimated that the average production of phytoplankton in the reservoir is 45 000 kg / ha. The potential increase in ichthyomas due to phytoplankton is 450 kg / ha. The increase in ichthyomas of silver carp during the growing season, taking into account the natural mortality, may be 340 kg / ha. The state of development of phytoplankton in the Zaporozhian (Dnipro) Reservoir allows us to note the presence of a significant reserve to increase its fish productivity due to the introduction of fish-phytoplankthophages – Silver carp [12, 13].

3. 2. Zooplankton

In the zooplankton community of the Dnieper (Zaporizhzhya) reservoir 120 species were recorded, of which: 65 Rotifers, 17 Copepoda, 37 Cladocera, and veliger of Dreisen – 1 species.

The dominant species of zooplankton were the following species: *Eurytemora velox*, *Heterocope caspia*, *Bosmina longirostris*, *Euchlanis dilatata*, *Asplanchna priodonta*, *Thermocyclops oithonoides*, *Chydorus sphaericus*.

To calculate the potential fish productivity created in the Zaporozhian (Dnipro) Reservoirdue to zooplankton, we used the average biomass of zooplankton during the growing season (from April to October) – 230 mg / m^3. This value of biomass corresponds to low-water reservoirs. Taking into account the average depth of the reservoir of 8 m and the P/B coefficient for zooplankton – 20, the production of zooplankton in the Zaporozhian (Dnipro) Reservoiris 412.4 kg / ha, which corresponds to 54.7 kg / ha of potential fish products.

3. 3. Zoobenthos

102 species of zoobenthos belonging to 12 groups were found in the zoobenthos of the Zaporozhian (Dnipro) Reservoir. Recorded: among the larvae of chironomids – 35 species, oligochaetes – 23 species, mollusks – 16 species, crustaceans – 10, leeches – 4, other groups – 20. The species composition of the benthic fauna of the reservoir is characteristic of the reservoirs of the Dnieper cascade. Representatives of the Ponto-Caspian complex dominated the Dreisen overgrowth and the biotopes of the middle part of the reservoir. The number of

species varied at stations from 5 to 25, the smallest number of species was observed – on the muds of the profundal and in the contaminated areas of the littoral, the largest – in the thickets of the littoral zone [14].

Biocenoses of two species *of Dreissena bugensis*, *Dr. polymorpha*, which are to some extent consumed by roach, were observed on weakly silted sand [14]. In the middle part of the reservoir, in winter the biomass of soft zoobenthos averaged 20.0 g / m^2, and in summer and autumn it decreased to 3.8–6.2 g / m^2, which is due to the active nutrition of fish.

The average biomass of zoobenthos in the profundal of the middle part of the reservoir in summer was 2.6 g / m^2, which was almost 4.5 times lower than the biomass of zoobenthos in the lower part, where the biomass of zoobenthos reached 11.7 g / m^2. In autumn, the average biomass of zoobenthos decreased in the profundal of the middle part of the reservoir to 1.4 g / m^2, in the lower part to 11.2 g / m^2.

The average biomass of soft zoobenthos of the Zaporozhian (Dnipro) Reservoir reached 12.4 g / m^2, taking into account the indicators of zoobenthos development in the littoral. This corresponds to high-water reservoirs. Based on the P/B coefficient of zoobenthos equal to 6, we find that the production of zoobenthos of the Zaporozhian (Dnipro) Reservoir is 780 kg / ha, which corresponds to 53.1 kg / ha of potential fish productivity of benthophage fish (Carp, Freshwater bream, Prussian carp, Roach and etc.).

4. ASSESSMENT OF THE STATE OF FISH RESOURCES

Fish productivity of the Zaporozhian (Dnipro) Reservoir in 2020 was 28.45 kg / ha. According to the statistics of the State Agency of Land Reclamation and Fisheries of Ukraine in Dnipropetrovsk region in 2020 in the Zaporozhian (Dnipro) Reservoir 1166.62 tons of aquatic bioresources were removed, which is at the level of catch in 2018, and 3 tons higher than in 2019. Among it, the largest percentage fell on Prussian carp – 55.06 % (which is 3.2 % higher than in 2019). The next in industrial catches was dominated by Roach – 15.62 %, Freshwater bream – 6.17, White bream – 6.07%, herbivorous – 4.61%. Compared to the structure of industrial catch in 2018–2019, the percentage of industrial groups has not changed significantly, and the main fishery is based on members of the carp family.

Roach. Over the last 10 years, the minimum catch in the amount of 118 tons was in 2013, the maximum in 2020 – 182.23 tons (Table 1) [9, 15]. In the age structure of the roach population there were 13 age groups – from 3 (0.57 %) to 15 years (0.24 %). According to the sex, age groups were distributed as follows: females – 3–15-years-old individuals, males – 3–14-years-old. The core of the roach population was 4–6-years-old individuals (75.4 %). The average industrial length and the weighted average weight of Roach individuals remained at the level of 2017–2020 years and amounted to 21.4 ± 0.31 cm and 211.49 ± 11.72 g for males, 24.15 ± 0.44 cm, and 345.39 ± 23.03 g for females respectively. There is a steady trend of negative impact of the hydroecological condition of certain areas of the reservoir on local populations. It is noted that the individuals caught from the Samara Bay and from the estuary of the Mokra Sura River (near the village of Voloske) of the Zaporozhian (Dnipro) Reservoir lagged in growth due to the tense ecological condition of the area and their linear-weight parameters were 9.5–12.4 % lower than the fish caught from the main stream pool of the reservoir.

The reproductive nucleus of the Roach population was individuals 4–6 years old (75.4 %). In the spawning population, 5–8-years-old individuals predominated among females, and 4–7-years-old individuals predominated among males.

Conditions for feeding Roach in the reservoir are quite favourable [16], as the reservoir has a sufficient forage base for this species of fish. The fatness of roach according to Fulton during the last 5 years is kept at the level of 2.2 ± 0.14 units. The coefficient of fatness and fat content (3–4 points) indicate favourable feeding conditions.

Freshwater bream. The analysis of the dynamics of industrial catches shows that during 2010–2020 the catch of Bream is quite stable and remains at the level of 60–80 tons. In 2020, the industrial withdrawal of Bream reached 71.98 tons, which is 77.4 % of the established limit (Table 1).

Table 1. Development of fishing limits in Zaporozhian (Dnipro) Reservoir for the last 10 years.

Years	Pike perch			Freshwater bream			Roach			White bream		
	Limit, t	Catche, t	%	Limit, t	Catche, t	%	Limit, t	Catches, t	%	Limit, t	Catches, t	%
2011	20	14.21	71.1	75	62.41	83.2	180	143.21	79.60	80	52.27	65.30
2012	18	7.35	40.8	75	65.57	87.4	200	141.53	70.80	75	56.45	75.30
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	66.90
2015	12.0 L	9.743	81.19	80.0 L	61	76.26	187.0 L	133.5	71.41	58.0 L	42.63	73.50
2016	16 L	13.0	81.25	85 L	66.58	78.33	200 L	165.03	82.52	75 L	64.87	86.49
2017	14.0 L	10.85	77.5	88.0 L	69.58	79.1	190.0 L	159.56	84.00	70.0 L	55.96	79.90
2018	20.0 L	13.73	68.7	110.0 L	83.64	76	210.0 L	173.42	82.60	90.0 L	69.55	77.30
2019	22.0 L	16.54	75.2	100 L	80.77	80.78	200.0 L	175.16	87.58	85.0 L	68.45	80.53
2020	21.0 L	15.45	73.6	93.0 L	71.989	77.4	220.0 L	182.23	82.80	92.0 L	70.79	76.90

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

The age composition of bream is represented by 17 classes, the maximum age in catches was 19 years (0.01 %). The core of the Bream population were individuals aged 5–9 years (79.2 %).

In 2021, a variation in the age classes of bream from industrial fishing gear had the form of a curve with a wide top, which accounted for individuals 5–7 years old. A gradual decline in the variation curve was observed in 8-year-old individuals with a subsequent gradual decrease in the percentage of individuals in older age groups. This distribution is due to an increase in the number of modal older age groups, which account for the main industrial load.

The minimum age groups found in fishing were 5-year-old females – 5.8 %, 3-year-old males – 1.2 %. The reproductive nucleus of the population consisted of individuals aged 5-9 years – 79.2 %.

The industrial length of male bream according to control catches was 34.64 ± 0.89 cm; average weight – 870.23 ± 61.67 g, biological indicators of females, respectively were: 35.08 ± 1.11 cm and 1047.92 ± 99.69 g. The biological indicators of Bream fluctuate within the statistical values of 2019 and 2020. Fluctuations in the minimum and maximum weight of bream ranged from 200 g to 2750 g

The Zaporozhian (Dnipro) Reservoir has a sufficient forage base for Bream feeding, the feeding peak is in August-September. The average-age values of the Fulton fattening coefficient over the last 10 years are characterized by stability 2.3 ± 0.08 units.

Pike-perch. The last 5 years, catches of this species range from 13.0 tons (2016) to 16.54 tons (2019), its industrial development reaches 70–75 % of the established limit (Table 1).

The age range of Pike-perch in the control catches of 2021 was 14 classes (3-16 years). The core of the industrial population consisted of 4–9-year-old individuals (83.12 %). The share of fish of older age groups is mainly represented by 10-15-year-old individuals and was 1.2 %. The curve of the variation series had a peak on 5-year-old individuals, then 6-year-old flow in smaller numbers and there is a gradual decrease in curvature from 7-year-olds.

In 2021, the average industrial length of males of pike perch reached 35.30 ± 0.93 cm, and the average weight reached 658.4 ± 58.71 g, biological indicators of females reached, respectively: 37.76 ± 1.04 cm and 852.94 ± 96.64 g. The coefficient of fatness according to Fulton was at the level of previous years and amounted to 2.32 ± 0.34 units.

To ensure the stability of the species, it is recommended to introduce bio-ameliorative measures, namely the introduction of artificial spawning grounds and stocking of the reservoir with pike perch fry.

White bream. In the last 10 years, the volume of its withdrawal has remained at the level of 40-79 tons. In 2020, the development of the limit amounted to 76.9 %. The main fishing for white bream is based mainly on individuals aged 4-5 years.

In control catches, White breams' populations are represented by 12 age groups – from 3 (1.22 %) to 14 (0.32 %) years. The variation series of age indicators of the bream has the form of an asymmetric curve with a vertex on 6-year-old individuals, there is also a shift of the series in the right side due to the catch of individuals older than 7 years.

The average linear weights indicators of males were industrial length – 19.8 ± 1.63 cm, weight – 240.5 ± 24.52 g of females, respectively – 20.46 ± 1.81 cm and 241.22 ± 36.18 d. The average linear weight indicators of industrial individuals in recent years have remained stable. In the conditions of the Samara Bay, individuals of White bream are characterized by stunted growth, so it is advisable to carry out the main fishing with the use of small-mesh nets.

In 2021, the coefficient of fattening of fish was quite high and amounted to 2.2 ± 0.21 units. Stable linear weights parameters and fattening coefficient indicate favourable feeding conditions for this species in the reservoir.

Common carp. One of the valuable resource species of the Zaporozhian (Dnipro) Reservoir is a Carp. Actual catches of Carp in the reservoir from 2008 to 2019 were kept at the level of 9–22 tons. In 2020, catches of Carp reached 13.38 tons, which is 23.9 % of the forecast of its development. The relative share of Carp in catches does not exceed 1.15 %, which may be due to an increase volume of almost 30 times (from 22.30 tons in 2001 to 642.29 tons in 2020) of its direct food competitor – Silver carp.

In 2021, the age range of Carp is represented by 16 classes (3–18 years-old). The core of the industrial population were 6-9 years-old (62.4%). The share of older age groups older than 10 years reached 10.1 %. The variation series has the form of an asymmetric curve with a peak on 8-years-old individuals and a shift of the variation series to the right. This peak of the variation series is explained by the increase in the share of 6-years-old in 2018, which is probably the result of last year's stocking of the reservoir.

The average population indicators amount: males' industrial length – 49.05 ± 2.09 cm, weight – 2591.89 ± 268.37 g, females', respectively, 56.08 ± 2.26 cm and 4019.55 ± 482.47 g

It is recommended to maintain the Carp population at a stable level by stocking young animals with the reservoir every year.

Prussian carp. In 2020, Prussian carp catch reached maximum values – 642.29 tons, which is 55.06 % of total catches in the reservoir. In 2019, in the Zaporozhian (Dnipro) Reservoir, the catch of Prussian carp reached almost 52 % (602.9 tons) of the total net catches of fish. Over the past 20 years, the industrial catch of Prussian carp has increased almost 30 times. Prussian carp is also a popular object of amateur and sport fishing, which gives reason to believe that the actual extraction of Prussian carp from the reservoir is much higher [17].

Indicators of industrial length of Prussian carp kept at the level of previous years – the length of males 20.22 ± 0.47 cm, the length of females – 21.46 ± 0.52 cm Indicators of Prussian carp ranged from 100 g to 1010 g and averaged were 287.54 ± 21.26 g – males, and 345.95 ± 19.44 g – females.

Northern pike. Valuable bio-ameliorator – a predator. Prefers slow-flowing watercourses. It grows quite quickly, especially in the first years of life before puberty. The most common individuals weighing from 560 to 4200 g. The average weight of individuals – 1980 ± 240.1 g. Mature individuals met at the age of 4–5 years. In 2021, 100 grids of the control order accounted for 21.46 kg, in 2020 – 25.41 kg, despite 22.16 kg in 2019.

The number of Pike is quite low, due to a few significant limiting factors: the lack of a ban on fishing during the spawning season of this species (March), poaching and uncontrolled amateur fishing, spring operation of the reservoir level, which causes desiccation and silting substrate, diseases caused by the appearance of fibrosarcoma on the body of fish. Without the implementation of measures to protect and restore Pike stocks in the reservoir, there is no reason to expect a significant replenishment. It is also recommended to introduce artificial stocking of pike juveniles.

Wels catfish. According to official statistics, Catfish catches reached 6.5 tons in 2020. In 2019, the catch of Catfish in the Zaporozhian (Dnipro) Reservoir reached 9.82 tons. The low Catfish catch can be explained by inefficient fishing gear, as catfish are poorly assimilated by gill nets. To date, Catfish are largely caught by amateur fishermen (mainly through spearfishing). Passive traps should be used for targeted catfish fishing.

The last 5 years there has been a positive trend towards its catch. In 2018 and in 2019 the development of Catfish catch quotas reached the level of 61-65 %, in 2020 – only 40 %.

The average weight of Catfish individuals reaches 3385.4 ± 560.8 g and ranged from 0.9 kg to 25.4 kg. The industrial length of individuals averaged 80.3 ± 25.2 cm.

It is recommended to introduce into the practice of stocking the reservoir with juveniles' Catfish, as it is a valuable bio-ameliorator.

Sichel. Sichel is a valuable industrial species. The species is constantly observed in industrial catches, but the withdrawal rate is low – in 2020 only 414 kg were caught. At present, small but stable Sichels' populations have formed in the Zaporozhian (Dnipro) Reservoir. The reservoir in 2002 achieved the highest production rate in recent decades – 9.3 tons, but in subsequent years, its catch has decreased significantly and did not exceed 2.95 tons, in 2019 was caught 39.9 kg, which is 39.9 % of the forecast for its catch in 2019. Object of amateur fishing. It is difficult to accurately assess the state of replenishment of the population due to the absence of its individuals in the last five years in fry samples. Its reduction is due to unsatisfactory conditions for incubation of pelagic caviar in polluted waters of the Dnieper.

Other large particle (Asp, Chub and Ide). It is noted that the catch of large particles is at a low level, and fish fall into the fishing gear rarely. Over the last 10 years, the catch of fish species of "other large particle" ranges from 1.3 tons (2013) to 7.5 tons (2020). Development of species of the category "other large particle" in 2020 reached 62.6 % of the forecast.

Asp. The average long-term catch of Asp is 0.85 tons (from 0.3 to 1.27 tons). In 2015, the development of the asp quota was 27.8 %. In 2014, the development of the Asp quota was 19.5 %. In 2013, the development of the limit was at the level of 30.5 % (in 2012 – 54 %, in 2010 – 50.8 %).

According to the results of control catches in 2021, it was determined that the age of fish in the industrial population is 5–6 years-old. Marginal linear-weight indicators of Asp: industrial length – 32–66 cm, weight from 890 g to 1640 g. The weighted average weight made 920.0 ± 176.4 g.

Chub. The species is widespread in the littoral of the reservoir, due to which the juveniles of chubs is under considerable pressure from amateur fishermen. The Chub falls into the nets with a = 36–48 mm (up to 70 % of the total catches of the species). In industrial catches, the chub is represented by individuals aged 4-9 years. Linear weight indicators amount: length – 22–46 cm, weight – 210–1840 g.

Industrial catches of this species are at the level of 0.8–1.5 tons. There is a weak tendency to increase head catches from 0.7 tons (2013) to 1.6 tons (2015). In 2015, the development of the quota for the chub was 80.1 %. During 2014, this figure was only 58.5% (in 2013 – 34.5 %, in 2012 – 71.5 %). The average annual long-term catch is kept at 1.08 tons.

Other partial species (European perch, Tench, Rudd, White-eye bream, Common nase, Vimba bream, Ruffe, Pumpkinseed). Industrial catches of other particle species during the last 10 years, are at a consistently low level, the analysis of their catch by control gear shows that they fall into the gear accidentally, so they can be considered as by-catch in commercial catch of particle species.

The development of the quota of fish species of the category "other small particles" of the last 5 years is kept at the level of 80.89 %. Industrial development of fish of another small particle in 2019 amounted to 33.34 tons, which was 74.1 % of the forecast. In 2020, this figure reached 32.09 tons (64.2 %).

European perch. As of 2021, the Perch population in the Zaporozhian (Dnipro) Reservoir has a stable age, size, and weight structure and due to indifference to the spawning substrate – high reproductive rates, so it is constantly replenishing its number. The industrial Perch herd is dominated by individuals aged 4–10 years (85.4 %).

The average industrial length of perch: males – 20.66 ± 0.37 cm, females – 24.70 ± 0.85 cm. The average weight of individuals: males – 185.33 ± 9.59 g, females – 347.08 ± 38.16 g, which is almost no different from previous years. In the Samara Bay, Perch lag in growth by 9.5–12.1 %.

The age range of industrial catches is represented by 10 classes (from 3-years-old individuals – 6.5 %, to 12-years-old individuals – 0.1 %), which is one class more than in 2020. The average age of the perch on which the fishery is based was 5 years.

Zope. Occurs singly in the upper part (including in the reservoirs of the Zaporozhian (Dnipro) Reservoir, in the Samara Bay, at the estuary of the Mokra Sura River). The Zope population in the reservoir has been in a critical state for the last two decades, and the analysis of herd replenishment is complicated by the absence of juveniles of Zope in the control catches. Factors that limit the number of species: low water temperatures during spawning and industrial discharges, as well as the sensitivity of fish to changes in oxygen regime.

The average linear weights indicators of males: industrial length – 18.6 ± 1.42 cm, weight – 236.2 ± 22.16 g, females, respectively: 19.88 ± 1.46 cm and 239.16 ± 24.21 g.

Tench. The industrial species, which is found in the catches of amateur fishermen near the reeds and potamogetons thickets, accidentally fall in the industrial fishing gears. The average length of Tench was 24.28 ± 1.20 cm, weight – 320.00 ± 28.12 g, age – 5 years. As Tench is a small aboriginal species, it is recommended to stock the reservoir with Tench fry.

Rudd. In all parts of the reservoir Rudd quite common species [18]. The biological indicators of Rudd in the catches of 2021 were almost like 2019–2020: the main catch of Rudd was formed due to nets with a mesh step a = 38–40 mm, which caught the middle age groups of this species of fish. The average linear weights were equal to length – 20.4 ± 1.52 cm, weight – 192.4 ± 24.2 g. The ratio of males and females in the herd is defined as 1 : 1.

Pumpkinseed. One of the potentials economically dangerous species of animals for the industrial ichthyofauna of Ukraine [19, 20]. The species realizes its dangerous potential in omnivorousness (it eats plankton, small nekton and even caviar of other fishes), rapid population growth, as well as in endurance to anthropogenic factors that are present in the hydrobiocenosis of the Zaporozhian (Dnipro) Reservoir. The species is relatively aggressive and is well established as a separate ecological niche in the biocenosis, including in the Samara Bay. Today, during the spawning period (from the third decade of May to August) in the Samara Bay catch from 10 kg to 200 kg of Pumpkinseed per day. The results of many years of research on the invasion of this species formed the basis of regulatory documents on the order of commercial fishing in the Zaporozhian (Dnipro) Reservoir in 2017.

Herbivorous (Silver carp, Bighead carp, their hybrid, Grass carp). One of the most important resource species of the Zaporozhian (Dnipro) Reservoir is the Silver carp. The species is an extremely useful bio-ameliorator of the Dnieper reservoirs, which converts low-calorie phytoplankton (which is practically not used by other species of fish) into high-quality fish products.

In 2020, 53.79 tons of herbivorous fish were removed, which is a rather low figure. For example, in 2019, 106.43 tons of herbivorous fish were removed in the Zaporozhian (Dnipro) Reservoir, which is almost 22 tons more than in 2018.

The age range of the Silver carp is represented by 15 classes (3–17 rivers). The core of the industrial population of carp was 5–8 years-old individuals (60.2 %). The share of older age groups older than 10 years reached 12.6 %. The variation series has the form of an asymmetric curve with a peak on 6-year-old individuals and a shift of the variation series to the right due to the accumulation of older age groups. The reduction in the number of younger age groups indicates insufficient stocking of the reservoir, which has a sufficient forage base.

The average indicators of individuals of Silver carp: industrial length – 62.97 ± 3.10 cm, weight – 5081.48 ± 520.89 g. The coefficient of fatness according to Fulton remained at a stable level – 2.3 ± 0.2 units. The average biological parameters of Grass carp: industrial length – 72.52 ± 4.18 cm, weight – 5240.52 ± 610.18 g

In the conditions of the Zaporozhian (Dnipro) Reservoir the species does not reproduce, the population is replenished only due to the annual stocking of the reservoir with juveniles. From 2002 to 2015, 2.7 million specimens of Silver carp were introduced, and 1.04 million – hybrids of Silver carp and Bighead carp. As the species is not capable of self-reproduction in the reservoir but is the object of pasture fish farming in 2021–2025, it is recommended to continue the breeding of herbivorous fish (Silver carp, Bighead carp, their hybrids, Grass carp) to optimize the structure of ichthyofauna.

Black and Caspian Sea sprat and Common bleak. These fish species are zooplankthophages, which are direct food competitors of juveniles of industrial fish species. The industrial stock of Sprat in the reservoir is almost undeveloped. These are short-cycle species, so the basis of the population of Sprat and Bleak are 1–2 yers-old. The average weight of Sprat individuals was 1.5–0.17 g, at a length of 4.4 ± 0.15 cm, and fat reserves were 1–2 points. The fattening factor of Sprat was 1.25 ± 0.04 units; dry matter content – 23.2 ± 1.7 %.

The catch of Sprat and Bleak is characterized by a certain specificity of the organization of the fishery, so in 2020 65.95 tons were seized, in 2019 – 34.69 tons, in 2018 – 53.17 tons.

5. RECOMMENDED VOLUME OF STOCKING OF RESERVOIR

Calculations of stocking of the Zaporozhian (Dnipro) Reservoir for 2021 are presented in Table 2.

Table 2. Recommended stocks of the Zaporozhian (Dnipro) Reservoir in 2021.

Species, age of fish	Weight, g	Number of copies, thousand			Total weight, t		
		Dnipropetrovsk Oblast	Zaporizhzhia Oblast	Total	Dnipropetrovsk Oblast	Zaporizhzhia Oblast	Total
Common 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

Note: Age of fish 1 + – two-years-old.

To calculate the actual fish productivity for individual species of fish the average indicators of their actual catch for the last 5 years were used.

Silver carp:

Average phytoplankton production in the reservoir – 28100 kg / ha;

Potential increase in ichthyomas due to phytoplankton – 168.6 kg / ha;

Total losses of ichthyomas from natural mortality – 33.7 kg / ha;

Increase in ichthyomass of silver carp during the growing season, taking into account natural mortality – 135 kg / ha;

Possible commercial catch of silver carp is 30 % of the increase, is – 40.5 kg / ha;

The difference between the potential and actual catch of Silver carp 40.5 – 2.5 = 38.0 kg / ha;

Planting density of Silver carp with an average seasonal increase of 0.7 kg is 38.0:0.7 = 54.3 specimens / ha.

Bighead carp:

Average production of zooplankton in the reservoir – 432 kg / ha;

Potential increase in ichthyomas due to zooplankton – 57.6 kg / ha;

Total losses of ichthyomas from natural mortality – 11.5 kg / ha;

Increase in ichthyomas during the growing season, taking into account the natural mortality and competition of other planktophagous fish – 23 kg / ha;

Possible industrial catch of Bighead carp is 30 % of the increase, is – 7 kg / ha;

The difference between the potential and actual catch of bighead carp 7–0 = 7 kg / ha;

Planting density of Bighead carp with an average seasonal increase of 0.5 kg is – 7:0.5 = 14.0 specimens / ha.

Common carp:

Average production of zoobenthos in the reservoir – 702 kg / ha;

Potential increase in ichthyomas due to zoobenthos – 98.3 kg / ha;

Total losses of ichthyomas from natural mortality – 19.7 kg / ha;

Increase in carp ichthyomas during the growing season, taking into account the natural mortality and competition of other benthic fish – 34.7 kg / ha;

Possible commercial catch of Carp is 30 % of the increase, is – 10.4 kg / ha;

The difference between potential and actual Carp catch: 10.4 – 0.5 = 9.9 kg / ha;

Planting density of Carp with an average seasonal increase of 0.5 kg is – 9.9:0.5 = 19.8 specimens / ha.

Grass carp:

Total production of macrophytes in the reservoir – 223502 tons;

It is planned to provide an increase in Grass carp at the expense of 10 % of macrophyte biomass – 22350 tons;

The potential increase in ichthyomas due to macrophytes at kk = 30 is – 745 tons;

Total losses of ichthyomas from natural mortality – 223.5 tons;

Increase in ichthyomass of Grass carp during the growing season, taking into account natural mortality – 521.5 tons;

Possible commercial catch of Grass carp is 30% of the increase, is – 156 tons;

The difference between the potential and actual catch of Grass carp = 156 – 2.1 = 154 tons;

The total number of two-years-old Grass carp with an average seasonal increase of 0.7 kg is – 220 thousand specimens.

In the case of stocking with a sample less than 100 g, taking into account the natural mortality of this year – 60 %, the amount of stocking of this-year 0+ is given in table. 3

Table 3. Recommended volumes of stocking of Zaporozhian (Dnipro) Reservoir by this year in 2021.

Species, age of fish	Weight, g	Number of specimens, thousand			Total weight, t		
		Dnipropetrovsk Oblast	Zaporizhzhia Oblast	Total	Dnipropetrovsk Oblast	Zaporizhzhia Oblast	Total
Common carp, 0+	25-30	640	272	912	16.0–19.2	6.8–8.16	22.8–27.36
Silver carp, 0+	25-30	1456	1040	2496	36.4–43.7	26.0–31.2	62.4–74.9
Bighead carp, 0+	25-30	448	192	640	11.2–13.4	4.8–5.8	16.0–19.2
Grass carp, 0+	25-30	236.8	115.2	352	5.9–7.1	2.9–3.5	8.5–10.6

Note: Age of fish – 0 + – this-years.

In the case of stocking with fish larvae should consider the high natural mortality. In many fish out of 1000 larvae born, only 1 adult (0.001%) will be fished. There is a percentage of industrial return, which shows the percentage between the amount of source material and the adults caught.

Stocking should be carried out in different parts of the reservoir to reduce mortality and increase industrial return.

Given the crisis of Pike perch, Pike, Tench and Catfish populations in the Zaporozhian (Dnipro) Reservoir, it is recommended to introduce the fry of these fish species into the reservoir in the amount of:

Tench – age group 0+, weight 10–20 g, total number – 135 thousand specimens, total stock weight – 1.4–2.7 t. Stocking by tench can be carried out annually;

Pike – age group 1+, weight 100 g, total number – 83 thousand specimens, total weight of stock – 8.3 tons; age group 0+, weighing less than 100 g – 132.8 thousand pecimens. Pike stocking can be done annually;

Pike perch – age group 1+, weight 100 g, total number – 83 thousand specimens, total stock weight – 8.3 tons; age group 0+, weighing less than 100 g – 132.8 thousand specimens; larvae – 264 thousand pecimens. Stocking with Pike perch can be carried out annually;

European catfish – age group 1+, weight 100 g, total number – 40 thousand specimens, total weight of stock – 4.0 tons; age group 0+, weighing less than 100 g – 65.5 thousand pecimens; larvae – 131.0 thousand pecimens. Catfish stocking can be done annually.

The recommended volumes of stocking in the lower reaches of the Zaporozhian (Dnipro) Reservoir within the Zaporizhzhya region for the period 2021–2025 are given in Table 4.

Table 4. Recommended volumes of stocking of the lower reaches of Zaporozhian (Dnipro) Reservoir in the period 2021–2025.

Species, age of fish	Weight, g	2021		2022		2023-2025	
		Number of specimens, thousand	Total weight, t	Number of specimens, thousand	Total weight, t	Number of copies, thousand	Total weight, t
Common carp, 1+	100–130	170.0	17–22	170.0	17–22	85.0	8.5–11
Silver carp, 1+	100–130	650.0	65–84	650.0	65–84	325.0	32.5–42
Bighead carp, 1+	100–130	120.0	12–16	120.0	12–16	60.0	8.5–11
Grass carp, 1+	100–130	72.0	7–9	72.0	7–9	36.0	3.5–4.5
Common carp, 0+	25–30	272.0	6.8–8.16	272.0	6.8–8.16	136.0	3.4–4.08
Silver carp, 0+	25–30	1040.0	26.0–31.2	1040.0	26.0–31.2	520.0	13.0–15.6
Bighead carp, 0+	25–30	192.0	4.8–5.8	192.0	4.8–5.8	96.0	2.4–2.9
Grass carp, 0+	25–30	115.2	2.9–3.5	115.2	2.9–3.5	57.6	1.45–1.75

The biological substantiation can be revised (updated or supplemented) if necessary, at the request of the Office of the State Agency for Land Reclamation and Fisheries in Zaporizhzhia region.

6. CONCLUSIONS

A) In phytoplankton samples, diatoms were 38 % by number of species, chlorophytes – 33 %, blue-green algae – 16 %, Euglena algae – 9 %, others – 4 %. The biomass in the Zaporozhian (Dnipro) Reservoir was dominated by blue-green algae – 90 %. The average phytoplankton biomass in the reservoir was: in the spring – 3.7 g / m^3, in the summer – 17.6 g / m^3, in the autumn – 6.2 g / m^3. It is estimated that the average production of phytoplankton in the reservoir is 45 000 kg / ha. The potential increase in ichthyomas due to phytoplankton is 450 kg / ha. The increase in ichthyomas of Silver carp during the growing season, taking into account the natural mortality, may be 340 kg / ha.

B) In the zooplankton community of the Dnieper (Zaporizhzhya) reservoir 120 species were recorded, of which: 65 Rotifers, 17 Copepoda, 37 Cladocera, and veliger of Dreisen – 1 species. The production of zooplankton in the Zaporozhian (Dnipro) Reservoiris 412.4 kg / ha, which corresponds to 54.7 kg / ha of potential fish products.

C) 102 species of zoobenthos belonging to 12 groups were found in the zoobenthos of the Zaporozhian (Dnipro) Reservoir. Recorded: among the larvae of chironomids – 35 species, oligochaetes – 23 species, mollusks – 16 species, crustaceans – 10, leeches – 4, other groups – 20. The production of zoobenthos of the Zaporozhian (Dnipro) Reservoir is 780 kg / ha, which corresponds to 53.1 kg / ha of potential fish productivity of benthophage fish (Carp, Freshwater bream, Prussian carp, Roach and etc.).

D) Fish productivity of the Zaporozhian (Dnipro) Reservoir in 2020 was 28.45 kg / ha. In 2020 in the Zaporozhian (Dnipro) Reservoir 1166.62 tons of aquatic bioresources were removed, which is at the level of catch in 2018, and 3 tons higher than in 2019. Among it, the largest percentage fell on Prussian carp – 55.06 % (which is 3.2 % higher than in 2019). The next in industrial catches was dominated by Roach – 15.62 %, Freshwater bream – 6.17, White bream – 6.07%, herbivorous – 4.61%. Compared to the structure of industrial catch in 2018–2019, the percentage of industrial groups has not changed significantly, and the main fishery is based on members of the carp family.

E) The recommended amounts of reservoir stocking in 2021 were calculated as follows: 570 thousand 1+ common carp; 1560 thousand 1+ silver carp; 400 thousand 1+ bighead carp; 400 thousand 1+ bighead carp; 220 thousand 1+ grass carp.

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