The effect of reproduction of aquatic biological resources of the Volga reservoir on the efficiency of water intake facilities

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Abstract. As a result of a massive outbreak of plankton in the largest recreational Sura reservoir (Penza) which provides 600 thousand people with drinking water in 2019, the intake and supply of water to the water supply network was critical. The comprehensive studies revealed that the main reason was the lack of reproduction of phytophilic fish due to the drainage of spawning grounds in the spawning period. The low water level, the low flow rate and good heating of the reservoir created conditions for stagnant phenomena which, in the absence of reproduced phytophilic fish, were favorable for the mass development of phyto- and zooplankton. The main recommendation for 2020 was to ensure timely watering of spawning grounds. In 2020, spawning grounds were flooded in a timely manner, fish spawning was highly effective, and the abundance of plankton was not observed.

1. Introduction
The Sura reservoir built for recreational purposes - to provide Penza and Zarechny with drinking water (1978) is the largest reservoir in Sura Krai (Penza region and the Republic of Mordovia) with an area of 11 thousand hectares. On a highly productive section, the Sura River lost its significance as the main fishery reservoir [1].

In the 1990s, a big problem arose with the “blooming” of the reservoir. As a result, the intake of drinking water was complicated, and a massive death of juveniles of pike perch (Sander lucioperca (L., 1758)) and perch (Perca fluviatilis (L., 1758)) was observed. To neutralize the “bloom”, the reservoir was algolized with Chlorella vulgaris IGF No. C-111 strain. A small volume of Hypophthalmichthys molitrix (Valenciennes, 1844)) and Hypophthalmichthys nobilis (Richardson, 1845) wwas caught [2]. Such measures were effective, except for the outbreak of phyto-plankton in the abnormally hot summer of 2010; no large-scale “bloom” was observed.

In 2018, an increased amount of plankton appeared in the water treatment facilities of the water supply system Vodokanal LLC; in 2019 its concentration reached a high level, and a threat to water supply arose. A number of assumptions were put forward to explain this phenomenon: pollution of the reservoir with sewage, bank collapse, reservoir clogging, erosion of bottom pollutants. The purpose of this article is to identify the causes of an outbreak of plankton and develop recommendations for its elimination.

2. Materials and methods
Materials on plankton in the Sura reservoir (in treatment facilities of the water supply system and the dam zone) were provided by Gorvodokanal, Penza. Information on water quality was obtained during studies conducted in the fall of 2019. Information on the efficiency of reproduction of aquatic biological
resources was provided by the Federal Agency for Fishery of Penza Region and obtained from our own observations. To assess the ichthyofauna of the reservoir, an analysis of the stock materials of the Privolzhsky Scientific Center of Aquaculture and Aquatic Bioresources of Penza State Agrarian University was carried out [3].

3. Discussion

Plankton abundance. In 2019, the high content of plankton in the water supply treatment facilities was observed from June 10 to November 18. Phytoplankton and zooplankton were observed. Blue-green (Cyanophyta) and green (Chlorophyta) algae prevailed; then until the end of August, *Synedra* sp was dominant. In late August and early September, diatoms were replaced by blue-green algae, and since September 6, *Oscillatoria* sp. were observed. Average indices of the plankton abundance are presented in Figure 1. The maximum indicators were observed in July; on some days, the number was 3.1 million cells / l.

In 2018, plankton was observed from June 26 to 27 September, with a peak in September, and its number was 3-10 times lower than in 2019 (Figure 1). No plankton was observed in 2017 and 2020.

![Figure 1. Phytoplankton abundance (million cells ml) at the water intake of the dam in 2018, 2019](image)

Reproduction conditions. In 2017, fish spawning in the Sura reservoir was satisfactory, in 2018 - ineffective, in 2019 - unsatisfactory, and in 2020 - successful.

An analysis of water samples conducted in October 2019 identified the absence of pollution and a favorable hydrochemical composition of water, both at the confluence of the Sura and Uza rivers, and in the middle and near-dam zones of the reservoir. Silt deposits were insignificant.

As for the hydrological regime of the reservoir, in 2019, starting from the spring spawning period (mainly on April 15 - May 15) and until October, the volume of water in the Sura reservoir was lower than usual by 20% (Figure 2). In terms of pre-flood measures, a significant discharge of water was made; however, the snow density was lower than expected and the inflow of flood waters was much lower than predicted. Accordingly, the shallow areas of the reservoir, where the spawning grounds of phytophilous fish species were located, were not flooded. In April 2019, the areas of the reservoir were at the level of 2018 which was less than the level of 2017 by 22 thousand hectares, and less than the level of 2020 by 10 thousand hectares. In May 2019, it was less than the levels of 2017 and 2018 by 23-30 thousand hectares, and less than the level of 2020 by 12-20 thousand hectares.
Figure 2. Water volume (million m³) in the Sura reservoir in 2018-2020 by month

In 2019, a very low water exchange was observed due to a small inflow of water (Figure 3). After the spring flood from June 1 to November 1, an amount of the average daily inflow and discharge of water was 524 m³/s in 2017, 458 m³/s in 2018, 342 m³/s in 2019, and 447 m³/s in 2020.

The water temperature in May and the first half of June 2019 was 1.4–5.60 °C higher than in the previous year (Figure 4). Thus, the low water level, low accuracy and good heating of the reservoir created conditions for stagnant phenomena, which, in the absence of reproduction of phytophilic fish - consumers of plankton - created favorable conditions for the mass development of phyto- and zooplankton. In 2018, the spawning grounds were not flooded in April; in August, maximum water temperatures and a minimum water exchange were observed.

Figure 3. Water exchange in the Sura reservoir by months in 2018, 2019:
— water inflow, - - water discharge
Figure 4. Water temperature in the Sura reservoir in 2018 - 2020 by month

**Evaluation of the productivity of spawning grounds.** In 2019, the number of fish was calculated based on the average number of the most abundant species of bream (Table 1). Reliable information on the number of generations based on net research catches of bream was observed from the age of 3 years. Therefore, according to the overall mortality rate, the number of bream aged one or two years was calculated. The average number of bream yearlings was 4501 thousand specimens.

### Table 1 Calculation of the average number of one-year old bream in the Sura reservoir

| Age  | Death coefficient, % | Number by years | Average, thousands |
|------|----------------------|-----------------|-------------------|
|      |                      | 2012            | 2013             | 2014             |                  |
| 3 years | 32                   | 621.8           | 607.4            | 499.0            | 576.1            |
| 2 years | 32                   | 1943.1          | 1898.1           | 1559.4           | 1800.2           |
| 1 year  | 40                   | 4857.8          | 4745.3           | 3898.5           | 4500.5           |

In 2015-2019, the average biomass of fish species was as follows: bream - 51.2%; zander - 16.4%; roach - 5.2%; silver bream - 4.0%; crucian carp - 7.2%. The average weight of yearlings of bream, gusters, roach varied from 3 to 5 g. For calculations, we used an average weight of 4 g. Hence, the biomass of bream yearlings was 18.0 tons, and the total biomass of juveniles was 35.4 tons.

Phytophilous fish species that lay eggs on vegetation in the coastal zone of the Sura reservoir are bream, roach, silver bream, crucian carp, and perch. The total biomass of phytophil yearlings was 79.2% or 28 tons.

Thus, in 2019, due to the drainage of spawning grounds, it was impossible to catch 28 tons of juvenile phytophilous fish.

**Estimation of the amount of plankton consumed by juvenile fish.** All juvenile fish in the Sura reservoir consumes zooplankton. Then, some of them consume benthic organisms, some of them become predators or omnivores.

Feed of juvenile fish, which may contain algae is as follows: bream feeds on green, blue-green and diatoms; roach - high-yielding generation, goldfish – algae; silver bream and bleach - algae [4, 5].

Taking into account the analyzed materials, the nutrition of juvenile fish can consist of 50% phytoplankton and 50% zooplankton. The feed coefficient for phitoplanton is 40, for zooplankton – 8;
the phytophilic fish feeding is as follows: zooplankton - 112 tons, phytoplankton - 560 tons; in total - 672 tons or 75 kg / ha.

Thus, in 2019, due to the lack of the 2019 generation, 672 tons of plankton were not consumed which produced new generations and increased its abundance.

A low share of silver carp regularly fished in the reservoir for reclamation purposes could be a cause of the plankton abundance.

4. Conclusion
Due to the drainage of spawning grounds in the spawning period caused by the low water level in 2019 (partly in 2018) and the lack of reproduction, there was no sufficient amount of juvenile phytophilic fish, consumers of phyto- and zooplankton. As a result of the low flow rate and good heating of the reservoir, the occurrence of stagnant phenomena in the reservoir in the absence of pressure from the ichthyofauna, favorable conditions were created for the mass development of plankton. Taking into account this factor, the main recommendations for 2020 were developed: optimal flooding of shallow waters in the spawning period and when stocking with herbivorous fish. Despite the small inflow of flood waters in 2020, spawning grounds were flooded in a timely manner, spawning was highly effective, and plankton was not observed.

Thus, the successful reproduction of aboriginal fish species in the Sura reservoir and in a number of water bodies of the Volga region is one of the main determinants of the ecological state of the water body and durability of water intake treatment facilities. If the optimal watering of natural spawning grounds is not possible, artificial spawning grounds can be used as an additional guarantee.

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