Assessment of long-term changes in the trophic status of two reservoirs

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Abstract. The studies were carried out with the integrated monitoring of the Ivankovo and Rybinsk reservoirs. The work is devoted to the assessment of long-term changes in the trophic status of water bodies under the influence of natural and anthropogenic influence. The studies combined two traditional methods of analysis. A layer-by-layer study of diatom complexes in bottom sediments and the determination of the taxonomic composition of phytoplankton in reservoirs were carried out. The saprobity index (S) was calculated for diatom complexes from sediments. A comparison was made with similar calculations for the species structure of phytoplankton complexes. Spatial and temporal heterogeneity of saprobization processes in reservoirs was confirmed.

1. Introduction
The problem of forecasting possible negative changes in reservoirs is a top priority in the field of nature management and water quality assessment.

As a result of comprehensive monitoring, a new methodological approach was developed for the ecosystems of the Ivankovo and Rybinsk reservoirs. This approach combines two traditional methods: the analysis of diatom complexes from sediment columns, which is commonly used in paleolimnology, and the analysis of phytoplankton complexes, which is one of the main tools of biomonitoring.

Such combination supposed to provide additional information about the long-term transformations of the trophic status of the studied reservoirs.

2. Materials and methods
The structure and volume of the primary material consists of more than 300 phytoplankton samples taken from the Ivankovo and Rybinsk reservoirs (2017-2019), and 97 samples for diatom analysis from 3 columns of bottom sediments.

Two columns of bottom sediments were collected at the Ivankovo Reservoir: in the area of Peretrusovsky Bay, and between the small islands and the western tip of Grabilovka Island (hereinafter referred to as the Islands). In the water area of the Rybinsk Reservoir, a column of bottom sediments was collected in the Koprino area (figure 1).
Figure 1. Map-scheme of the Rybinsk and Ivankovo reservoirs. Biomonitoring points are marked with lines and circles. The location of the bottom sediment columns collection indicated by capital letters: A-Peretrusovsky Bay; B-Islands; C-Koprino.

The bottom sediment columns were sampled using a shock-closing stratometer and a GOIN column and Nesje Drill [1]. Phytoplankton samples were taken with a "Ruttner" bathometer, from a depth of 1 m. Samples for diatom analysis were taken from bottom sediments columns according to the traditional method [2], with an interval of 1 cm. Sample processing, production of permanent microscope glasses, counting and identification of diatoms were carried out according to standard methods [3; 4; 5].

Processing and analysis of phytoplankton samples was also carried out according to standard methods [6]. The study of permanent preparations was carried out using a light microscope equipped with 100-fold oil-immersion lenses.

The Sladechek saprobity index (S) was calculated for complex monitoring of the reservoir by phytoplankton and diatom complexes from bottom sediments [7]. The work of S. S. Barinova with co-authors [8] was used as the initial information for saprobity numerical values calculation.

3. Results and discussion

Among the indicator species in the Ivankovo Reservoir, diatoms are the most represented ones. In total 136 types of indicators of organic pollution were found. Most of them belong to mesosaprobes. The minimum value of the saprobity index (1.35) was recorded at Ivankovsky Ples (Shevnitsa Island); maximum (2.8) - on the Srednevolzhsky ples (Konakovo).

According to the saprobiological analysis, no significant changes in water quality could be detected. During the observation period, the water quality class in the open parts of the reservoir was equal to II, and in the coastal zone to III.

In the Ivankovsky reservoir, 45 saprobity indicator species (S) were identified in samples from the sediment column collected in the Peretrusovsky Bay. Of these, 4 species are xenosaprobes, 15 species
are oligosaprobes, 20 species are β-mesosaprobes, 3 species are α-mesosaprobes, 2 species are α-β-mesosaprobes, and one species is confined to the oligo-α-mesosaprobe zone.

Based on the obtained numerical values, there is a pronounced saprobization of the reservoir in the bay, which is probably due to the processes of overgrowth, shallowing and accumulation of organic matter. During the analysed time period, the saprobity index increased from 1.575 to 1.725, which corresponds to the β-mesosaprobic zone.

45 saprobity indicator species (S) were identified in samples from the sediment column collected in the Islands region. Of these, 4 species are xenosaprobes, 10 species are oligosaprobes, 22 species are β-mesosaprobes, 4 species are α-mesosaprobes, and 2 species are α-β-mesosaprobes. As a result of the calculations, numerical values of S were obtained along the entire section of the bottom sediment column.

The calculation of the numerical values of S allowed us to establish insignificant changes that are cyclical in nature. The change in the numerical values does not go beyond the error in the calculations and corresponds to the β-mesosaprobic zone.

In the Rybinsk reservoir, 52 saprobity indicator species (S) were identified in samples from the sediment column collected in the Koprino district. Of these, 3 species are xenosaprobes, 20 species are oligosaprobes, 26 species are β-mesosaprobes, and 3 species are α-mesosaprobes.

Based on the obtained numerical values, there is a pronounced saprobization of the reservoir in the bay, which is probably due to the accumulation of organic matter. The rate of saprobization of this section of the Rybinsk reservoir has a non-linear character with a tendency to exceed the beta-mesosaprobic zone.

Similar trends were found for the concentration of $P_2O_5$, which indicates the end of the period of moderate eutrophic status of the Rybinsk reservoir and the next period of eutrophy of the reservoir [9]. The reservoir belongs to the category of low-mineralized reservoirs [10], but at the same time the Rybinsk reservoir is a humified reservoir, and the main ples is considered eutrophic, and in the Sheksninsky and Volzhsky ples the processes of eutrophication are even more pronounced [11].

The trophic status of the reservoir and its long-term changes are largely determined not only by the input of dissolved organic matter, but also by the input of allochthonous one, which is especially important in the formation of bottom sediments [12].

The calculation of the saprobity index (S) allowed us to determine the numerical values of S for all points of sampling of surface sediments: Koprino – 1.98; Mologa – 1.87; Sredny Dvor – 1.77; Navolok – 1.7; Izmailovo – 1.78; Breitovo – 1.9. The results of the calculations indicate that the entire water area of the reservoir belongs to the beta-mesosaprobny zone.

Despite the different configuration, location and hydrological regime, a number of similar, alarming trends were identified for both reservoirs.

A pronounced saprobization and accumulation of organic matter in the coastal zones, both for the Rybinsk and Ivankovo reservoirs, has been established.

4. Conclusion

1. The developed concept of integrated monitoring allows us to obtain new information about the long-term transformations in reservoir ecosystems.

2. In the system of the Ivankovo and Rybinsky reservoirs, there is a pronounced differentiation of trophic indicators in the open central parts and in the coastal shallow water zones.

3. It is established that the calculations of the numerical values spatial distribution of saprobity (S) do not reflect the real level of differentiation.

4. When assessing long-term trophic transformations, the initial methodological errors of the Sladecek calculations (Sládeček, 1973) are less pronounced and fairly reliably reflect changes in the trophic status of the reservoir.
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