Plankton communities in various parts of the water area of the Volzhsko-Kamsky Reserve Sarali cluster (Kuibyshev Reservoir)

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Abstract. The article presents the results of monitoring of hydrochemical composition and structure of plankton communities in the water area of the Saralinsky part of the Volzhsko-Kamsky Reserve. The maximum indicators of the species richness, abundance, and biomass of algae, as well as zooplankton biomass, are noted in the ducts. A reliable relationship between the indicators of the quantitative development of phyto- and zooplankton and the content of dissolved oxygen is established. The statistic relationship between phyto- and zooplankton biomass is shown. In phytoplankton the massive development of Planktothrix agardii Gomont is noticed. This fact shows the changes in the complex of the dominant species of blue-green algae in the Kuibyshev reservoir.

1. Introduction

One of the main tasks assigned to National Nature Reserves is to protect the nature areas in order to preserve biological diversity and maintain the natural state of protected nature complexes and objects. Regular monitoring on their territories is necessary to fulfill this task.

The Volzhsko-Kamsky Reserve is located on the territory of the Tatarstan Republic and consists of two separate parts: Raifsky (Zelenodolsky district) and Saralinsky (Laishevsky district). The total area of the Saralinsky cluster is 5480 ha; 1,5 ha is the water area located in the lower part of the Volzhsko-Kamsky Reserve of the Kuibyshev reservoir. The area of our study is a heterogeneous area located in the Volga and Kama spurs of the reservoir, directly in the bays and channels.

The most important component of the biota of any water body is plankton. Plankton is a complex of microorganisms passively carried by the water stream. It consists of both single-celled algae which are the primary producers of organic matter and oxygen in a pond, and first-order consumers, so called zooplankton. These organisms sensitively react on the changes in environmental conditions and so they are indicators of their state. Analysis of the species richness and indicators of the quantitative development of this group of organisms makes an additional contribution to the assessment of the biological diversity of the protected area, and makes it possible to assess the quality of water by the level of their development.
The aim of this work is to identify the current state of phyto- and zooplankton in the water area of the Saralinsky part of the Volzhsko-Kamsky Reserve, to fulfill a comparative analysis of the development of planktonic organisms in various areas, and to assess the quality of water by physical, chemical and hydrobiological indicators.

2. Materials and methods
Phyto- and zooplankton were sampled in the summer 2018 at permanent stations in different streams: in the Volga spur (conventionally referred to as the “Volga river” region); in the Kamsky spur (“Kama river” region), in the zone of mixing of waters, in the gulf and in the channels of the Atabayevsky shelter (figure 1).

To study the phytoplankton, we used the data of averaged samples obtained by draining water taken from different horizons (from the surface to the bottom) in 1 m increments. Samples of zooplankton were taken by pulling the Jedi network (with gas No. 70) from the surface to the bottom. Material processing was carried out according to the standard hydrobiological methods [1, 11, 12].

![Figure 1. Layout of sampling stations in the waters of the Saralinsky section of the reserve.](image)

At the same time the hydrochemical samples at the control stations were taken and analyzed. The analysis was performed for the content of 24 ingredients according to the standard methods adopted in the environmental analysis. The assessment of water quality according to physico-chemical parameters is calculated according to the ecological and sanitary classification of surface land waters [13] and according to the water pollution index (IZV6). The assessment of the ecological status of the reservoir according to the indicators of the development of planktonic organisms was carried out according to the rank index EX, the trophic index of zooplankton (E) and phytoplankton biomass. Since the number of samples taken at different sites was not the same, average values of abundance and biomass were used for comparative analysis.
The ensemble of ecological parameters of zooplankton was calculated using the FW-Zooplankton module [2]. Those species whose abundance and biomass was ≥10% of the total are considered as the dominant species.

The determinants of L A Kutikova (1970; 2005), N N Smirnov (1976; 1996), M Y Orlova-Bienkowskaja (2001) were used in determination of taxonomic identification of zooplankton [9, 10, 14, 16, 17] and phytoplankton determinants from the “Süßwasserflora von Mitteleuropa” series [3-7]. In the constructed diagrams the general equation and the magnitude of the approximation reliability (R2), as well as the linear trend parameter are shown.

3. Results and discussion
The results of the long-term monitoring of the physicochemical parameters of water of the Saralinsky part are published by the authors in [20]. The hydrological conditions and hydrochemical regime of the watercourses during the investigations differed. The transparency of the water ranged from 0.6 to 1.0 m on the rivers and 0.3-0.45 m in the channel, the color of water was green and greenish-yellow. Due to mixing the temperature regime corresponded to the regime of rivers. The surface and bottom layers had approximately the same (with a difference of 0.2-1.0 °C) temperature of water.

Water was attributed to the bicarbonate class of the calcium group with medium and increased mineralization (according to the O A Alekin scale). The value of total mineralization from one station to another varied from 168.7 to 207.0 mg/dm³. The maximum values were observed at the stations of the “Volga river” region. The hydrogen index corresponded to a weak alkaline environment and varied from 8.0 to 8.7 units. The pH high values have always been observed in the shallow channels, which is associated with the period of “blooming of water”. The total hardness corresponded to the category “soft water” or “moderately hard water” and varied from 2.2 to 3.5 mmol/dm³. The minimum values of this indicator were noted in the area of the channel, the maximum - in the “Volga river” region.

The gas regime was characterized by normal saturation 8.3-10.6 mg/dm³ of dissolved oxygen in the surface layer at stations located in the coastal zone of the rivers, and oversaturation (up to 112% saturation) in the channel 10.8-12.8 mg / dm³. The value of BOD₅ was 1.24–5.51 mgO₂/dm³ (up to 2.8 PDKᵦᵦ), the COD value was 19.3–27.8 mgO/dm³. Excess of PDKᵦᵦ in nutrients were not recorded. The content of ammonium ions was 0.31-0.44 mg/ m³, nitrites - 0.02-0.04 mg/dm³, nitrates - 0.1 mg/dm³, phosphates - 0.05-0.14 mg/dm³. The value of ASPAV varied from station to station from 0.042 to 0.128 mg/dm³.

The content of heavy metals by stations and years was changed as follows: lead – less than 0.002 mg/dm³, zinc - 0.001-0.0154 mg/dm³, nickel - less than 0.005- 0.069 mg/dm³, manganese - 0.0024-0.0154 mg/dm³, copper - less than 0.001-0.002 mg/dm³, iron - 0.26-0.42 mg/dm³. Exceeding the permissible concentrations was noted only for copper (1.5 PDKᵦᵦ) and total iron (2.6-2.9 PDKᵦᵦ).

The water quality, estimated by the ESC ranking indicator, was 2.6-3.8 points and corresponded to the quality of “quiet and sufficiently clean water”. Quality assessment in the area of “Volga river” and “Kama river” regions was lower scores. In the channel, the quality corresponded to the category “sufficiently clean water”. The IZVₖ corresponded to the class "clean" ("Kama river" region) and "moderately polluted water" ("Volga river" region and channels).

In the phytoplankton of the Saralinsky part of the Volzhsko-Kamsky Reserve, 161 taxa of algae of lower genus type were identified. The division of green algae had the greatest species diversity in which 46% of the total species richness of algal flora was concentrated. After them, diatoms and blue-green algae followed. The numbers of species from these divisions were close, and their shares in the formation of the total number of algae species and forms were around 17%. Studies were carried out in the summer period (in August), when “blooming” of water by blue-green algae is observed, therefore the species richness of the representatives of this division was quite high.

The maximum number of algae species, varieties and forms – 98 was registered in the channel, the minimum number was registered in the waters of the rivers Volga and Kama (the average specific numbers of species were 39 and 45, respectively).
A distinctive feature of phytoplankton that develops in the duct is a fairly high proportion of algae that are capable of mixotrophic type of nutrition (representatives of the cryptophyte, dinofyhte, and euglenic algae divisions). In total, their part was 33% of the total species diversity. Representatives of these divisions are known to be able to feed on organic matter, consuming it both in osmotrophic and halozoic manners [1, 15].

The number of phytoplankton varied within fairly wide limits: from 11 million cells/l ("Volga river" region) to 135 million cells/l (stations located in the channels). The main role in the formation of the total number of phytoplankton was played by blue-green algae. Ordinary species that regularly cause water to "bloom" are Aphanizomenon flos-aquae (L.) Ralfs and Microcystis aeruginosa (Kütz.) Kütz. They dominate in the "Volga river" region, while the Planktothrix agardhii Gomont presented in the large quantities in the "Kama river" region and in the duct.

The massive development of these species deserves special attention. As it is known, the change of the dominant complex of species in the reservoir is a long process. The change in the dominant species of blue-green algae in the course of the reservoir eutrophication proceeds according to the scheme: Anabaena - Microcystis, Aphanizomenon - Oscillatoria. In the Kuibyshev reservoir, Planktothrix agardhii Gomont, previously attributed to Oscillatoria agardhii Gom., has been consistently included in the rank of dominant species since the anomalously hot 2010, especially in the coastal zone [18]. Developing in the littoral, and entering a large body of water, subjected to a change in its trophic status, this species gets massive development in the latter.

The Ponto-Caspian invaders in the Volga reservoir, namely Actinocyclus variabilis (Makar.) Makar, were also present in the plankton community of organisms, and Skeletonema subsalsum (Cl.-Euler) Bethge. Indicators of quantitative development of the latter species are particularly high in the Volga river waters.

The phytoplankton biomass changed from 2.0 to 6.0 g/m$^3$. The main role in its formation was played by diatoms and blue-green algae. The minimum indicators were recorded in the Volga river waters, the maximum were recorded in the channel. The development of large-cell forms of dinofyhte and euglenic algae is noted in the duct. Representatives of these particular divisions played a decisive role in the formation of the total phytoplankton biomass. As it is known, the biomass is an indicator that determines the trophic status of a reservoir [19]. In accordance with its indicators, the level of organic pollution of the channel can be assessed as eutrophic, the remaining sections of the reserve can be assessed as mesotrophic.

In the composition of zooplankton, 73 species of were identified. Namely: Rotifera — 33 (45% of the total number of species), Cladocera — 26 (36%), Cyclopoida — 10 (14%), Calanoida — 4 (5%). The amount of zooplankton was quite high and averaged over 400 thousand species per m$^3$ the biomass is 0.87 g/m$^3$, respectively. The maximum indicators of the zooplankton abundance were noted in the area of the "Volga river" region, the minimum indicators were noted in the "Kama river" region. The maximum biomass was registered in the channel, and the cladocera was actively developing at this site.

A statistically significant linear relationship was established ($r = 0.48, F = 41.01, p = 0.0510$) between the values of the total population ($r = 0.44, F = 21.17, p = 0.0510$) and biomass ($r = 0.63, F = 5.2, p = 0.0318$) of the phytoplankton, and an indicator of zooplankton biomass and dissolved oxygen saturation (Fig. 2 a). The relationship of this indicator with zooplankton biomass was not obvious ($r = -0.08, F = 1.2, p = 0.0118$). A statistically significant linear relationship between the indices of the total biomass of zoo- and phytoplankton was also established (Fig. 2b) (correlation coefficient $r = 0.58$, Fisher dispersion ratio $F = 57.08, p = 0.0315$). The relationship between the numbers of organisms in zoo- and phytoplankton is not obvious ($r = 0.09, F = 3.2, p = 0.0211$). However, it should be noted that with increasing of the number of Cladocera, decreasing of the number of phytoplankton is observed (Fig. 2 a). A statistically significant linear relationship ($r = 0.68, F = 47.08, p = 0.0401$) was also established between the values of the total biomass of zooplankton and the biomass of Planktothrix agardhii.
This type of algae is probably the main food for non-selective primary filter feeders such as Cladocera. This assumption confirms the fact of a reliable statistical relationship between the amounts of Planktothrix agardii and Cladocera \((r = 0.46, F = 25.15, p = 0.0214)\). Representatives of Cladocera, like algae, are capable to rapid reproduction in the presence of abundant food sources [8].

In terms of the quantitative development of zooplankton, the trophic status of waters in certain areas of the Saralinsky section of the Volga-Kama Reserve can be estimated as mesotrophic.

![Graph](image)

**Figure 2.** The ratio of the main groups of zooplankton and the total resulting phytoplankton in terms of abundance \((a, \text{ind.}/\text{m}^3)\), biomass \((b, \text{mg} / \text{m}^3)\) in different parts of the Saralinsky part of the Volzhsko-Kamsky Reserve (Kuibyshev reservoir). Here \(N_r\) means the number of rotifers, \(N_c\) means the number of cladocerans, \(N_{cop}\) means the number of copepods, \(N_{fito}\) means the total number of phytoplankton, \(B_r\) means the biomass of rotifers, \(B_c\) means the biomass of Cladoceran, \(B_{cop}\) means the biomass of copepods, \(B_{fito}\) means the total biomass of phytoplankton; abscissa – station.
4. Conclusion
The ecological state of the waters of the Kuibyshev reservoir in the area of the Volzhsko-Kamsky Reserve, characterized by physical and chemical indicators as “fairly clean waters”, has been in a stable position for the past few years. There was no excess of MPC / x for nutrients, the content of organic substances (BOD5 and COD) was within the normal range. The content of heavy metals, except copper and iron, corresponded to the background content in the waters of Tatarstan Republic. This special protected area can be characterized (by physico-chemical parameters) as a reference for the Kuibyshev reservoir within the republic.

The Saralinsky part of the Volzhsko-Kamsky Reserve, depending on the hydrological and hydrochemical conditions, is a heterogeneous area. Depending on the conditions, communities of planktonic organisms (phyto- and zooplankton) are formed in its different parts, differing from each other in their qualitative composition and quantitative development. A reliable statistical relationship has been established between the abundance and biomass of phyto- and zooplankton and the oxygen content in water and the biomass of plankton organisms. According to the phytoplankton biomass, the level of organic pollution in the reservoir is in the zone of meso-eutrophic water. In terms of zooplankton it is in the zone of mesotrophic water.

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