Macrozoobenthos communities in the Kuybyshev reservoir
Priplotinnyi Reach: long-term dynamics

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Abstract. The authors analyzed the dynamics of benthic communities in the Kuybyshev Reservoir Priplotinnyi Reach, over a long-term observation period 1958-2020. The authors note a certain frequency of changes in the ratio of macrozoobenthos coenoses and biomass of benthic communities at the stations of the former Volga channel and the Priplotinnyi Reach floodplain. During the research period in 2005, 2020 there was a decrease in the biomass of benthos. The stage of destabilization of the Kuybyshev reservoir ecosystem, noted since the mid-1980s, against the background of anthropogenic eutrophication processes, is accompanied by a sharp decrease in the biomass of benthos and structural changes in benthic communities. In 2020, the benthos biomass, compared to 1985, decreased in deep-water areas and in the Priplotinnyi Reach coastal zone by about 8 times and amounted to 2.0 g / m², which is due to a decrease in the proportion of pelophilic coenosia of oligochaetes Tubifex tubifex and Limnodrilus hoffmeisteri. The biomass of forage benthos in the coastal zone decreased from 5.48 g / m² to 2.94-1.75 g / m² due to anthropogenic impact. The authors revealed similar processes of development of the chironomid coenosis on the former channel and the flooded floodplain. During the autumn survey, 9 species were recorded in shallow waters, the proportion of which is 19.5%. There was found a low biomass of Procladius ferrugineus larvae - 0.05-0.08 g / m². The authors discuss the data of hydrobiological monitoring at the stations of the former channel and the flooded floodplain of the Priplotinnyi Reach, including the change in the coenosis of chironomids (Diptera, Chironomidae) as an object of indication of the ecological state of the reservoir.

1. Introduction
The Kuybyshev reservoir is the largest reservoir of the Volga cascade, widely used in the national economy for the needs of energy, shipping, seasonal water supply regulation, agricultural irrigation and fish farming. The Reservoir is a powerful accumulator of surface runoff from a large area and, in particular, a receiver of contaminated wastewater of anthropogenic origin. An increase in the penetration of the number of alien species was noted in the period 1980-1990. This is due to both the natural processes of species dispersal and human economic activity: the development of navigation and the artificial introduction of Caspian aquatic organisms in order to increase the productivity of water bodies [1].

Analysis of long-term data from surveys of benthos in the reservoir in 1958 - 1985 and subsequent studies of individual reaches of the reservoir revealed changes in the productivity of zoobenthos over the years of the existence of the Kuybyshev reservoir. A certain frequency of changes in the biomass...
of benthos was identified for all areas of the reservoirs. There were noted the periods (1958-1966, 1967-1973, 1975-1985) of an increase in the biomass of benthos in the Kuybyshev reservoir, associated with an increase in the trophicity of the reservoir. In the 60s, the biomass of benthos increased \((5.81 \pm 0.34 \text{ g/m}^2)\) due to the involvement of organic matter in the circulation during the erosion of the primary soils of the reservoir bed. In the 70s, the increase in the biomass of benthos \((12.95 \pm 0.63 \text{ g/m}^2)\) was due to an increase in the input of natural organic matter into the water on account of industrial and agricultural wastewater from the catchment area of the flooded floodplain. In the 1980s, the substantial biomass of benthos \((28.24 \pm 1.15 \text{ g/m}^2)\), excluding large mollusks) was caused by an increase in the nutrient load out of the regulation of the Volga and Kama runoff by the dams of the Cheboksary and Nizhnekamsk hydroelectric power stations [2-4].

In macrozoobenthos communities, oligochaetes accounted for 54.4%, chironomid larvae - 25.6%, mollusks - 14%, crustaceans - 3.2% of the total biomass of benthic organisms. Since the 90s, researchers have noted structural changes in the composition of benthic communities, changes in the species and trophic structure in the composition of the chironomid coenosis. This made it possible to use benthic communities to test the state of the reservoir and its individual areas. Earlier [5, 6], the authors discussed the identified mechanisms of the formation of the structure of zoobenthos communities under the long-term processes of eutrophication of the reservoir. The authors carried out a statistical analysis of benthic communities based on the results of mathematical processing of monitoring data on the Kuybyshev reservoir, and analyzed in detail the correlations between the distribution of chironomid communities and the hydrochemical characteristics of water masses [7].

The aim of the research is a comparative assessment of changes in the long-term structure of benthic communities in the Kuybyshev reservoir Priplotinnyi Reach.

2. Materials and Methods

Hydrobiological monitoring of the state of ecosystems of the Kuybyshev reservoir was carried out from the moment of its creation at permanent stations of the former channel and flooded floodplain [2-5, 8, 9].

We provide the results of soil sampling in the Kuybyshev reservoir Priplotinnyi Reach from 1957 to 1985, then, after a break, in 2005 and in 2020. Earlier, physicochemical indicators of water quality were measured annually in the Kuybyshev reservoir; hydrochemical and hydrobiological analysis of the state of water and bottom sediments was carried out. The population composition of macrozoobenthos was studied in soil samples. In recent years, monitoring studies were carried out in certain years. But in 2020 we launched an expedition to collect soil samples at 7 coastal stations \((H 3-4 \text{ m})\) and deep-water stations \((H 12-21 \text{ m})\) of the Priplotinnyi Reach in September -October (number of samples \(N = 14\)). The Priplotinnyi Reach is our choice for long-term data analysis due to long-term taxonomic and structural studies of benthic communities as well as the proximity to the location of the reservoir and the possibility of reconnaissance studies (figure 1).

We took quantitative samples of benthos using Ekman-type grab (surface area 20 cm\(^2\), 2 lifts at the station. When assessing the biomass of benthos, we took into account “soft” benthos, without large mollusks (Unio, Anodonta, Dreissena). We used standard hydrobiological methods to collect and process the samples [10, 11].

For a comparative assessment of benthic communities in the Priplotinnyi Reach, we used the results of our own research and archival data from the Institute of Ecology of the Volga River Basin of the Russian Academy of Sciences.

3. Results and Discussion

A number of articles and monographs summarize the studies of the formation of bottom fauna and its spatial distribution during the period of long-term observations [2-6, 8, 12-14]. In the Dam Reach, hydrometeorological conditions determine the interannual and seasonal variability of the chlorophyll \(a\) content. The average content of chlorophyll \(a\) suggests that the reservoir is a eutrophic water body. The content of the main biogenic elements of nitrogen \((N_{\text{min}})\) and phosphorus \((P_{\text{min}})\) in the Priplotinnyi
Reach, suggests that the reservoir corresponds to the meso- and eutrophic type of waters. Some researchers note a late autumn increase in the content of chlorophyll $a$.[15, 16].

Monitoring studies identified 152 species and taxa in the Kuybyshev reservoir (1958 - 1985), of which 43 are oligochaetes, 50 - chironomid larvae, 47 - mollusks, and 13 are crustaceans. Other taxa that are rare include polychaetes, leeches, larvae of mayflies, caddis flies, ceratopogonids, beetles, etc. 110 species and taxa of benthos were registered: 37 species - Chironomidae, 24 - Oligochaeta, 23 - Mollusca, 13 - Crustacea, 4 - Hirudinea, 2 - Polychaeta, 10 - other taxa (Trichoptera, Ephemeroptera, etc.). The frequency of occurrence of more than 50% is characteristic of oligochaetes Potamothrix moldaviensis Vejdovsky et Mrázek, 1902, Limnodrilus hoffmeisteri Claparede, 1862, Isochaetides michaelseni (Lastočkin, 1936), polychaetes Hypania invalida (Grube, 1860), larvae of chironomids Procladius ferrugineus Kieffer, 1919, mollusks Dreissena bugensis (Andrusov, 1897)[17]. The composition of the macrozoobenthos fauna changed in different years in certain areas of the reservoir, which is associated with both hydrometeorological conditions, anthropogenic impact, the habitat of hydrobionts in different biotopes, the degree of influence of alien species on the native fauna, and long-term natural coenotic fluctuations. The stage of destabilization of the Kuybyshev reservoir ecosystem, noted since the mid-1980s, is accompanied by structural changes in benthic communities against the background of changes in the trophic status of the reservoir[5].

The Priplotinnyi Reach, is a trailing lacustrine extension of the reservoir with an area of 397 km$^2$ and a volume of water masses of 6.8 km$^3$. This is a small deep-water reach of the reservoir; its maximum depth reaches 40 m. The features of the reach include the significant backwater, temporary reverse currents caused by hydroelectric power station; intensive accumulation of bottom sediments and a significant number of pollutants.[18].

During the research period from 1958 to 2005, 68 species and taxa were recorded in the area of the dam at the monitoring stations of the former channel, of which 26 species were represented by mollusks, 22 by oligochaetes, 14 by chironomids; at the stations of the flooded floodplain, of 58
species, oligochaetes accounted for 25 species, mollusks for 18, chironomids for 10, and crustaceans for 6 species.

A certain detailing of benthic communities can be carried out by analyzing the data of routine observations and studying the benthic biocenoses of the two main biotopes: the former channel and the flooded land over the period of long-term development of the benthofauna. We’ve recorded the trend towards a decrease in the average biomass of “soft” forage benthos in almost all reaches of the reservoir since 2005 [1].

Tables 1 and Table 2 demonstrate the long-term changes in the structure of benthic communities and biomass of benthos at different sites of the Priplotinnyi Reach in certain periods of research.

**Table 1.** Long-term dynamics of biomass of the main taxa of macrozoobenthos (%) in the former channel of the Kuybyshev Reservoir Priplotinnyi Reach

| Taxa       | 1958-1960 | 1961-1966 | 1968-1973 | 1975-1985 | 2005   | 2020   |
|------------|-----------|-----------|-----------|-----------|--------|--------|
| Oligochaetes | 95.7      | 94        | 94.3      | 80.3      | 46.7   | 48.9   |
| Chironomids | 3.9       | 5.4       | 4.4       | 13.5      | 15.2   | 16.7   |
| Molluscs    | 0.3       | 0         | 0         | 3.4       | 0      | 0      |
| Varia \(^a\) | 0.1       | 0.6       | 1.3       | 2.8       | 38.1   | 34.4   |
| Average biomass, g / m\(^2\) (without *Dreissena* mollusks) | **10.43** | **4.67** | **8.48** | **27.36** | **1.00** | **2.55** |

\(^a\) insect larvae, polychaetes, crustaceans

Let us mention that in the former channel of the Priplotinnyi Reach, oligochaetes constituted the bulk of the benthos biomass during the entire observation period. Their share was approximately 80-96% until 1975-1985. This period is characterized by the accumulation of silt deposits in all lake-like reaches of the reservoir, when the oligochaete fauna acquired a tubificid character with the dominance of the pelophiles *Limnodrilus hoffmeisteri* Claparede, 1862 and *Tubifex tubifex* (Müller, 1773). A significant decrease in the biomass of oligochaetes on silted soils of deep-water areas of the Reach has been recorded since the 1990s (table 1). The share of chironomids in the former bed of the long-term dynamics of biomass of the main taxa of macrozoobenthos (%) in the former channel of the Kuybyshev Reservoir Reach increased from 4.4-13.5% to 15.2-16.7% during this period. Among other aquatic organisms, the share of polychaetes was more than 30%, with a sharp general decrease in the biomass of benthos to 1.0–2.55 g / m\(^2\) (table 1). An increase in the proportion of “alien” species of polychaetes *Hypania invalida* (Grube, 1860) and leeches *Archaeobdella esmonti* Grimm, 1876 in the composition of other aquatic organisms does not affect the increase in the total biomass of benthos in the autumn sampling period, due to their low occurrence [8].

As the anthropogenic impact on the ecosystem of the Kuybyshev reservoir Priplotinnyi Reach increases by 2005 on the shallow flooded floodplain (table 2), we also record a decrease in the total biomass of benthos from 5.48 g / m\(^2\) to 2.94-1.75 g / m\(^2\).

Seven species were recorded as part of oligochaetes in the coastal zone, of which the pelophilous *L. hoffmeisteri* and *T. tubifex* dominated. Oligochaetes in 2005-2020 accounted for 35.1-43.7% of the total benthos biomass. In the coastal zone, among others, authors occasionally note leeches *Glossiphonia complanata* (Linnaeus, 1758), polychaetes *Hypania invalida* (Grube, 1860) and crustaceans *Dikerogammarus haemobaphes* (Eichwald, 1841) and *Gammarus (Chaetogammarus) ischnus* Stebbing, 1898. We record accumulations of alien mollusks *Dreissena bugensis* (Andrusov, 1897) and *Dreissena polymorpha* (Pallas, 1771) in the coastal zone in druses with a biomass of 326 g / m\(^2\). The biomass of mollusks was 1.4 kg / m\(^2\) at a depth of 14 m (st. 7).
Table 2. Long-term dynamics of biomass of the main taxa of macrozoobenthos (%) in the flooded floodplain of the Priplotinnyi Reach (sampling in September-October)

| Taxa               | 1958-1960 | 1961-1966 | 1968-1973 | 1975-1985 | 2005   | 2020   |
|--------------------|-----------|-----------|-----------|-----------|--------|--------|
| Oligochaetes       | 52.1      | 58.0      | 86.0      | 75.7      | 35.1   | 43.7   |
| Chironomids        | 46.6      | 42.0      | 13.6      | 15.3      | 11.2   | 19.5   |
| Molluscs           | 0         | 0         | 0.4       | 6.0       | 37.4   | 0      |
| Varia a            | 1.3       | 0         | 0         | 3.0       | 16.3   | 36.8   |
| Average biomass, g/m² (without \textit{p. Dreissena} mollusks) | 0.73 | 0.72 | 2.20 | 5.48 | 2.94 | 1.75 |

\textit{a} insect larvae, polychaetes, crustaceans

As for chironomids, when analyzing changes in the community of aquatic organisms in individual reaches for different time periods, we reveal relatively similar processes of development of communities of chironomids in different reaches in the former channel and the flooded floodplain [7]. During the autumn survey in shallow waters, we recorded 9 species, the proportion of which was 19.5% in the absence of pelophilous \textit{Chironomus plumosus} larvae and low biomass of \textit{Procladius ferrugineus} at some stations of the floodplain (H-3-14 m) up to 0.05-0.08 g/m². We observe a relative similarity of the structure of the chiromid coenoses in 1975-1875 and some specificity of the species composition during the research period in 2005-2020. Here there is an increase in the role of small species of \textit{Microchironomus tener} (Kieffer, 1918) \textit{Polypedilum (Tripodura) bicrenatum} Hirvenoja, 1962, \textit{P. nubeculosum} (Meigen, 1804) \textit{Polypedilum (Tripodura) scalaenum} (Schrank, 1803), etc.

Table 3 shows the average values of the biomass of macrozoobenthos in the Priplotinnyi Reach (without large mollusks and mollusks of the genus \textit{Dreissena}) in certain periods of the formation of its water masses, changes in trophic status, hydrological characteristics and anthropogenic impact. A trend towards a decrease in the long-term biomass of benthic aquatic organisms is evident for the benthos of deep-water and shallow-water areas of the Priplotinnyi Reach in 2005-2020. The number of forage benthos in macrozoobenthos communities is currently 2469 ind./m², with an average biomass in October of 2.06 g/m² in the coastal area and at the stations of the flooded floodplain (table 3).

Table 3. Macrozoobenthos biomass (g/m²) in the Priplotinnyi Reach in different time periods

| Time periods | 1958-1966 | 1967-1973 | 1975-1985 | 2005-2020 |
|--------------|-----------|-----------|-----------|-----------|
| Priplotinnyi Reach | 62 | 3.46±0.37 | 71 | 6.17±0.51 | 103 | 16.06±0.98 | 38 \textit{b} | 2.06±0.97 |

\textit{a} n is the number of samples for the growing season;
\textit{b} number of samples during the expedition

Thus, the analysis of long-term changes in benthic communities (the Priplotinnyi Reach example) showed that previously the average long-term biomass of macrozoobenthos in the former channel of the reservoir significantly exceeded that in the flooded floodplain [1]. However, under anthropogenic eutrophication, climatic fluctuations, and the spatial heterogeneity of the distribution of biogenic load fluxes on the reservoir [19], we note the leveling of the quantitative values of benthos at almost all stations.
4. Conclusions
The results of many years of research give an idea of the main regularities in the development of the Kuybyshev reservoir forage benthos, which is necessary for assessing the productivity of the reservoir. We note the role of oligochaetes and chironomids as indicator groups necessary for biotic assessment of long-term changes in the ecological state of the reservoir. We also point to the comparative instability of the species composition of the bottom communities of the reservoir, the insufficient degree of knowledge of various regions, especially its shallow waters, bays and estuarine sections of rivers flowing in under modern conditions of climatic and anthropogenic changes. The beginning period of the successional formation of the reservoir ecosystem makes it possible to analyze the spatiotemporal dynamics of the distribution of bottom communities and a quantitative comparison of structural changes in each reach of the reservoir [7].

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