Hydrobiological and ichthyological features of the Shirokovsky Reservoir

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Abstract. The characteristic of Shirokovsky Reservoir by communities of phytoplankton, zooplankton, benthic invertebrates, and fish is given. It is the first investigation of the reservoir since the building time of 1948. All levels of the ecosystem are impoverished as species compositions as functional groups. A considerable part of all communities is presented by riverine oxyphilous species. Any invasion species of algae, invertebrates, and fish haven’t registered. The maximal species richness and quantitative parameters of phytoplankton have been registered in the upper riverine part of the reservoir and were determined by Bacillariophyta (primarily centric species). The zooplankton complexes' dominants were Bosmina longirostris, Daphnia galeata, and Mesocyclops leuckarti. Maximal quantity of zooplankton has been shown in the middle part of the waterbody. The species of oligochaetes Limnodrilus hoffmeisteri and chironomids Parakiefferiella coronata were the most important in benthic communities’ structure. Benthofauna species richness and quantity of benthic invertebrates have been maximal in the lower part of the reservoir. The most common fish species at the current period are dace, perch, and Siberian roach. The fish quantity has been the richest in the middle part of the reservoir with lots of shallow areas. Assessing the quantitative values, the Shirokovsky Reservoir was classified as an oligotrophic waterbody at present.

1. Introduction

Reservoirs of the Kama River basin are very interesting due to they are part of Volga cascade reservoirs. Meanwhile, Kama reservoirs are located separately and have many specific biological traits of species richness, invasive species distribution, productivity, etc. For example, the richness of taxonomic groups is decreased from downstream to upstream; some European species are substituted to Siberian ones, biomass comparison of groups in pelagic communities is changed [1–6].

Shirokovsky Reservoir is the third in size range on the Perm Krai territory. It was made at Shirokovsky Township on the Kosva River, 159 km from its mouth. Kosva River was the first order Kama River tribute and it is the Kama Reservoir tribute at present. The reservoir has seasonal regulation and is used in a cascade with Gubakha Reservoir that is placed downstream. The filling process has been lasting from 1946 to 1948. During the first years (July 1948 – July 1950) large
researches of morphology, hydrology, chemical regime, benthic fauna, and fish distribution were done. Recommendations of fauna modification and fishery organization were presented [7, 8]. The next complex researches were provided only after a long period at the summer season of 2012, 2016, and 2017 and partly published [9–11].

The volume of the waterbody is 0.53 km³, length is 25 km, the mean and maximum depth are 12.9 m and 36 m. The drawdown is about 12 m thus the reservoir volume decreases by two-thirds and the lowest level occurs in March. Reservoir’s water masses are cold due to depth and cold-water tributaries. In July the average temperature of surface waters was 11.8°C at the upper part of the reservoir and has increased to 16.1–16.5°C at the middle and downstream parts of the reservoir. Water temperature in gulfs of small tributaries was 8–12°C increasing from their mouths to the main waters of the reservoir. Bottom waters at 20 m depth had a temperature lower than 6°C during the summer periods.

Substrates are varying at the different parts and depths of the reservoir. The silted clays prevail at the upper part of the reservoir, gray silts – at the downstream parts. Substrates on the former river bed of Kosva River are sands and silted sands. There are flooded soils and turfaries at the left bank of the middle part. The substrates on the right bank of the reservoir are cobbles and boulders, stony substrates in the tributary mouths are covered by phytoperiphyton and water moss Fontinalis.

The goal of this work is to show the features of the Shirokovsky Reservoir by plankton, benthos, and fish quantity and its distribution.

2. Materials and methods

Hydrobiological stations were located in 2 transverse sections in the upper part (Site I – 58.9991, 58.0316 and Site II – 58.9613, 58.0084) by 3 on each other; in 1 transverse section on the middle part (Site III – 58.9327, 57.9333) by 5 stations; in 2 transverse sections on the lower part (Site IV – 58.8827, 57.8810 and Site V – 58.8601, 57.7962) by 3 on each other. Gulfs of 3 tributaries were researched: Nyur (58.9425, 57.9121), Verkhnyaya Rassol’naya (58.8796, 57.8276) and Verkhnyaya Mutnaya (58.8678, 57.8710).

Samples of phytoplankton (July 2016, 2017) were taken from 1 m surface waters, the volume of each other was 1 liter. The concentration was carried out by the filtration method. Cells of each species were counted up and measured their average size for the determination of biomass. Zooplankton samples were taken by Judy’s net from the water column to the bottom (shallow depth) or the threefold of Secchi disc transparency depth (photic layer) on deep water areas.

The samples of macrozoobenthos in July 2012, 2016, and 2017 were received. Samples were collected using box dredge with a capture area of 0.01 m² and having 2 portions in each. The samples were washed through a 200–220 μm meshed sieve and fixed with 8% formalin. Immature individuals of non-biting midges have been raised to adults or imago of amphibiotic insects (mayflies, stoneflies, biting midges) have been caught by entomological net to clarify the species composition.

Fish were sampled in July 2012, 2016, and 2017 using a gillnets of 15 classes from 10 to 80 mm meshed and 1 to 5 m high that depended on depth. Also, minnow seine of 10 m length and 4 mm meshed was used.

3. Results

There are 108 infrageneric taxa and 104 species of phytoplankton have been registered in the reservoir. Bacillariophyta was the first in species richness (40%), Chlorophyta was the second (33%), Cyanoprocracyota, Euglenophyta, and Chrysophyta have provided 7-8%, and Dinophyta only 4%. The most important species of phytoplankton were the following species: Asterionella formosa Hass., Aulacoseira spp., Ceratium hirundinella (O.F.M.) Bergh., Cosmarium sp., Euglena spp., Microcystis aeruginosa (Kütz.) Kütz., Sphaerocystis planctonica (Korsh.) Bour., Stauridium tetras (Ehr.) E.Heg., Trachelomonas hispida (Perty) F.Stein, Trachelomonas volvocina (Ehr.) Ehr.

The maximal species richness of phytoplankton has registered in the upper riverine part of Shirokovsky Reservoir and was determined by Bacillariophyta (primarily centric species). Species
richness has been reduced by 2 times in the middle and lower parts of the reservoir, where a large number of species were presented by Chlorophyta. Changes of phytoplankton abundance and biomass were the same. Phytoplankton quantitative parameters have been decreased from the upper part to the lower part of the waterbody. Herewith Bacillariophyta ratio has been reduced and vice versa Cyanoprocrayota ratio. Maximal biomass of green algae has been recorded in the upper part; maximal biomass of Euglenophyta – in the middle part of the reservoir (table 1).

There are 33 species of zooplankton were registered in Shirokovsky Reservoir, 17 species of Rotatoria, 12 Cladocera, 4 Copepoda. The wider distribution has been shown by rotifers Bipalpus hudsoni (Imhof), Kellicottia longispina (Kellicott), Conochilus unicornis Rousselet, cladocerans Bosmina longirostris (Müller), Daphnia galeata Sars, Holopedium giberum Zaddach, Ceriodaphnia quadrangula (Müller), and copepods Mesocyclops leuckarti (Claus).

Zooplankton species richness and quantity have been very low in the upper part of the waterbody. Parameters have been increased to the maximum values in the widest middle part and slightly reduced to the lower part of the reservoir. The proportions of Rotatoria+Copepoda in common abundance and biomass of upstream part zooplankton were 72% and 46%. Its values have been decreasing to 33% and 9% in the downstream part. The dominants were Bosmina longirostris, Daphnia galeata, Mesocyclops leuckarti in all parts of the reservoir. Thus, species list and dominant complexes were formed by usual species for waterbodies of the Kama River basin. The distinguishing features were permanent occurrence and high value in pelagic communities of cladocerans Holopedium giberum and rotifers Bipalpus hudsoni (Imhof), which are very rare species in other Kama River basin waterbodies. Another marker of Shirokovsky Reservoir zooplankton is the predominance of rotifers Asplanchna herricki de Guerne, there is Asplanchna priedonta Gosse in other Kama River reservoirs.

Table 1. The main hydrobiological parameters of Shirokovsky Reservoir in 2016, 2017.

| Parameter | Ecological group | Reservoir part |
|-----------|-----------------|---------------|
|           | Phytoplankton   | Upper | Middle | Lower |
| Species richness | 87 | 35 | 46 | 8 |
| Abundance (ind.·l＜sup>-1</sup>)* | 2.70 | 1.36 | 1.49 |
| Abundance (ind.·m＜sup>3</sup>)** | 0.2×10<sup>-3</sup> | 27.9×10<sup>-3</sup> | 23.9×10<sup>-3</sup> |
| Abundance (ind.·m<sup>2</sup>) | 3566 | 908 | 3318 |
| Abundance (ind.·ha<sup>-1</sup>)*** | 2361 | 863 | 1102 |
| Abundance (mg·l<sup>-1</sup>)* | 2.60 | 0.50 | 1.05 |
| Abundance (mg·m<sup>3</sup>)** | 1.3 | 379.5 | 277.1 |
| Abundance (g·m<sup>2</sup>) | 1.38 | 0.57 | 2.06 |
| Abundance (kg·ha<sup>-1</sup>)*** | 32.25 | 43.34 | 27.35 |

*mean at the 1 m depth surface waters; **mean at the photic layer; ***mean at the gillnets.

There are 17 families and 80 species have been registered in the benthic communities of Shirokovsky Reservoir. The greatest species richness has been provided by chironomid family, which was presented with 48 taxa. There are 18 species of oligochaetes, 4 species of mayflies, 2 species of each bivalve mollusks, gastropods, and stoneflies. Other groups of benthic invertebrates were bugs, caddisflies, beetles, and biting midges were presented by 1 species to each group. The most common species were oligochaetes *Limnodrilus hoffmeisteri* Claparede, *Stylaria lacustris* (Linnaeus), biting midges *Brachypogon vittatus* (Winnertz), chironomids *Harnischia curtalamellata* (Malloch), *Parakiefferiella coronata* (Edwards), *Paralauterborniella nigrohalteralis* (Malloch), *Procladius culiciformis* (Linnaeus).

Benthofauna species richness and quantity of benthic invertebrates were maximal in the lower part of the reservoir. It is due to a more stable level of the reservoir in this part. The species of oligochaetes
Limnodrilus hoffmei steri and chironomids Parakiefferiella coronata were the most important species in benthic communities’ structure of all parts of the waterbody. Also, some species had the high importance on different biotopes such as oligochaetes Aulodrilus limnobius Bretscher, Potamostrix hammoniensis (Michaelsen), Potamostrix moldaviensis Vejdovsky & Mrazek, and chironomids Procladius culiciformis, Procladius imicola Kieffer.

Our ichthyological studies have shown fish composition of 11 species – pike Esox lucius Linnaeus, bream Abramis brama (Linnaeus), Volgian gudgeon Gobio volgensis Vasil’eva et al., ide Leuciscus idus (Linnaeus), Siberian roach Rutilus lacustris (Pallas), common minnow Phoxinus phoxinus (Linnaeus), Siberian spine loach Cobitis melanoleuca Nichols, grayling Thymallus thymallus (Linnaeus), perch Perca fluviatilis Linnaeus, ruffe Gymnocephalus cernuus (Linnaeus), Taimen Hucho taimen (Pallas) and burbot Lota lota (Linnaeus) can be included in the list by an interview with the local fishermen. All captured species are widespread in the reservoir. Volgian gudgeon, common minnow, and Siberian spine loach are the riverine species; they have been concentrated in the gulfs of tributaries and were caught only by minnow seine. In opposite pike was found only in gillnets. Other species including grayling were caught as gillnets as minnow seine.

The most important fish species of the reservoir’s upper part was dace, which has shown high quantity and low mean individual mass (11.3 g). In the middle part, they were perch (127.4 g), roach (57.8 g), and dace (42.5 g). The most numerous species were the same in the lower part of the reservoir, but their mean individual mass has been decreased: dace (27.5 g), perch (22.4 g), and roach (19.3 g).

4. Conclusion

Generally, the species richness of ecological communities of Shirokovsky Reservoir is quite low. Many widespread in the Kama region taxonomic groups and species are absent in the waterbody, these include mollusks of Dreissenidae, Unionidae, Lymnaeidae, Viviparidae, chironomid Chironomus plumosus (Linnaeus), bleak Alburnus alburnus (Linnaeus), silver bream Blicca bjoerkna (Linnaeus), etc. Along with that, we have recorded many oxyphilous, cryophilic species like stoneflies Leuctra digitata Kempny, beetles Elmis maugetii Latreille, chironomids Cricotopus tremulus (Linnaeus), grayling, and others. It is connected with low temperatures of waters during the year and minimal anthropogenic stress (water pollution, fishing activities, and so on). Any invasive species that haven’t registered in the waterbody can be considered as a positive trait.

Assessing the quantitative values, the Shirokovsky Reservoir was classified as an oligotrophic waterbody. Mean biomasses of phytoplankton, zooplankton, zoobenthos, and fish are at the actually low level. There aren’t zooplanktonophagous among the fish species and there are only a few seston-feeders among benthic invertebrates – Chironomus anthracinus Zetterstedt and Chironomus melanescens Keyl. Besides, there is Leptodora kindtii (Focke) in zooplankton composition, which makes trophic pressure influence pelagic communities of invertebrates. The low trophic level is confirmed by stunted fish on juvenile stages. It has been shown for perch which are numerous fish species in the reservoir [11].

Our results show relatively stable conditions of the waterbody in comparison with the investigations of 1948–1950. Species lists of macrozoobenthos are very similar in common sense, but the diversity of mollusks, dragonflies, caddisflies, and beetles are significantly decreased in the present time. In the fish community, the rare species dace has become the most numerous, previously absent species bream and ruffe have shown up.

Thus, Shirokovsky Reservoir is impoverished for all levels of its food web as species compositions as functional groups. It’s typical for the upper reservoirs of the Kama River and their tributaries’ cascades. The key role in the ecosystem is playing by common eurybiontic species.
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