Biodiversity of a small water body during the initial filling phase (the Amazar River of the Amur River Basin, Russia)

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Abstract. In 2017, for the purposes of the Pulp and Saw Mill (PSM) “Polyarnaya”, the spillover dam was constructed on the Amazar River, a left tributary of the Amur River. Upon completion of the dam construction, the waters of the river formed a small river reservoir PSM “Polyarnaya”. This work covers findings on components and quantities of the newly formed reservoir at its initial stage and the data on biodiversity of its feeding flows. At this stage, the species composition of the flora and fauna in the reservoir falls in between the lacustrine and the riverine ones. The riverine conditions are observed in the upstream area of the reservoir; the middle area bears an intermediate status; while the limnetic zone near the dam features transformation of the river system into a lake-like running-water ecosystem. Seasonally, in the period from spring to autumn, phytoplankton showed a decreasing trend of the quantitative values; whereas the total abundance and biomass of zooplankton were increasing; zoobenthos featured lack of trends; macrophytes contents were different from season to season being abundant in the Amazar River near the urban settlement in spring and in the Amazar River downstream from the dam in autumn. Consequently, the initial stage of the formation of the reservoir is rather similar to original watercourses in the physical and chemical parameters and in the composition of flora and fauna as well.

1. Introduction

The Amur is the major river in the Russian Far East that drains the border areas of the Russian Federation and China. The Amur basin features 37 reservoirs with the total storage capacity of 68,676 mln m³. Particular small rivers are also engaged forming 29 small reservoirs with the total storage capacity from 1 to 10 mln m³ (overall reservoir capacity being equal to 70.9 mln m³) and 5 reservoirs with the total storage capacity from 100 to 1,000 mln m³ (overall reservoir capacity being 186.2 mln m³) [1]. In 2017, within 137 km of the Amazar River, the 11 m high and 600 m long spillover dam was built to form a reservoir [2] for the purposes of the Pulp and Saw Mill (PSM) “Polyarnaya” (Figure 1). Currently, the reservoir is not listed in the Water Register and the construction financing of the PSM “Polyarnaya” is cut off. The reservoir is bound to affect the ecosystem of the Amazar River bringing significant changes to the river regime downstream of the dam and interfering with habitat conditions for fishes and other water organisms, namely, hydrobionts [3].

The article aims to display the first findings on hydrobiont biodiversity in the newly built reservoir at the Amazar River.
2. Materials and methods
The Amazar River is the first major left tributary of the Amur River and has a high degree of fishery sensitivity. The river has a length of 290 km and the water catchment area of 11,100 km$^2$. The average annual volume of runoff in the mouth is 1.96 km$^3$ [4]. The dam of the hydrotechnical construction has a stepped-pool fish ladder similar to the one installed on Nizhne-Tulomskaya Hydroelectric Power Station [5].

The research and observations were performed at 10 stations: 1 – the Amazar River near the urban settlement of Amazar; 2 – the Bolshaya Chichatka River near the urban settlement of the Amazar; reservoir: 3 – run-of-river area, 4 – limnetic zone of transition; 5 – upstream; 6 – fish-way; 7 – downstream; 8 – the mouth of the Krestovaya River; 9 – the Amazar River downstream from the dam; 10 – the Krestovaya River upstream from the site of the Pulp and Saw Mill “Polyarnaya” (Figure). Sampling was conducted in spring (May) and autumn (October) in 2018–2019, and in summer (August) in 2018. Samples were analyzed in accordance with standard hydrobiological techniques.

![Sketch map of the reservoir at the PSM “Polyarnaya”](image)

3. Results

3.1. The reservoir
The reservoir (N 53.802519°, E 120.939566°) is located 8 km far from the urban settlement of Amazar. Its length equals to 7.5 km and surface area is 1.46 km$^2$. The full reservoir level is 429.60 m with full static volume of 4.73 m$^3$. The reservoir is filled during the spring flood (from April to May). It was constructed to supply the Pulp and Saw Mill “Polyarnaya”. As per the classification [6], according to its surface area, storage capacity, river bed morphology, design, and water course regulation, the reservoir is referred to as a small-scale shallow-water run of the river reservoir of a simple long linear form with seasonal regulation of the watercourse.

Bathymetric survey has revealed 3 zones of the reservoir: a run-of-water shoal, a limnetic zone of transition, and a limnetic zone (Figure 2). The width of the run-of-water zone ranges within 120 m, an average depth of water equals up to 2.0 m. The limnetic zone of transition has a width up to 150 m and a depth to 6.0 m. The limnetic zone features a combination of shoals (260 m long) and deep-water areas within the river bed (up to 9.8 m). Shoals appear as a drowned bushy valley lying along the banks and covered in wood felling residues and branches remained after bed clearing.

Bathymetric map has shown that areas with a depth from 0 to 3 m have the largest surface and represent 53% of the total bottom surface. Areas from 3.5 to 7.5 m deep take up 37% of the total bottom
surface, while areas with a depth from 7.5 to 11 m comprise 10% of the reservoir. That is why lowered water levels during winter months in terms of freezing will have a sizable effect on benthic biocenoses.

3.2. Biodiversity of aquatic organisms

Phytoplankton species of the selected water bodies and watercourses features 90 algal taxa with a rank lower than genus belonging to 6 divisions (Cyanobacteria – 6 taxa, Bacillariophyta – 45, Chrysophyta – 8, Dinophyta – 1, Charophyta – 8, Chlorophyta – 19 and Euglenophyta – 2). The taxonomic composition of plankton algae was diatom during the entire studied period. Species Fragilaria radians, Ulnaria ulna, Hannaea arcus, Achnanthes lanceolate, Tabularia fasciculate, Meridion circulare, Tabellaria fenestrata, Gomphonema olivaceum, Gomphonema coronatum, Euglena gracilis, and Closterium leibleinii were common for the water bodies studied. The algal flora of the Amazar reservoir was largely composed of the algae of the Amazar River. The dominant complexes of the reservoir were similar to those of the selected watercourses. The Sørensen index of similarity varied from 42% to 77%.

The abundance and biomass of phytoplankton were low and did not exceed $250.9 \times 10^3$ cells/l and $151.38 \text{ mg/m}^3$, respectively. Seasonally, in the period from spring to autumn, phytoplankton showed a decreasing trend of the quantitative values. Diatom algae were dominant.

There were detected 28 species, forms and types of macroalgae falling into 5 systematic sections: Cyanophyta (4 species), Ochrophyta (4 species), Rhodophyta (2 species), Chlorophyta (11 species), and Charophyta (7 species). The species composition of the basin features the following predominant taxa: in Cyanophyta – Nostocales (3 species), and in Chlorophyta – Chaetophorales (3 species). It was found that the phytomass of the macroalgae communities varies in a wide range (Table 1).

| Study area | Taxa | Phytomass, mg/m² |
|------------|------|------------------|
|            |      | air wet weight   | air dry weight |
| The Amazar River in an urban-type settlement Amazar | Mougeotia sp2. ster. | 11,447 | 3,395 |
| The Amazar River below the dam | Mougeotia sp2. ster. | 5,152 | 1,515 |
|            | Achnanthes lanceolate | 5,965 | 2,281 |
|            | Draparnaldia mutabilis | 1,132 | 0,226 |
|            | Achnanthes lanceolate | 0,660 | 0,198 |
| The Amazar River (lower reaches) | Total | 1,792 | 0,425 |
|            | Mougeotia sp2. ster. | 125,122 | 48,780 |
|            | Calothrix gypsophila f. orsiniana | 9,512 | 3,659 |
|            | Total | 134,634 | 52,439 |

The meiofauna of the Amazar River basin features 59 taxa with a rank below genus including 32 species of Rorifera, 18 – Cladocera, and 8 – Copepoda. Bdelloid rotifers and crustacean (Harpacticoida, Cyclopoida and Calanoida) juveniles were also detected. The total taxa number varied from 5 (Bolshaya Chichatka River) to 34–36 taxa (Amazar River and reservoir). The ubiquitous species Chydlorus sphaericus, bdelloid rotifers, and juvenile stages of cyclops were found in all studied water bodies. Species Proales sp., Trichocerca longiseta, Euchlanis dilatata, Ch. sphaericus, Graftoleberis testudinaria, and Eucyclops serrulatus occurred more often than others. The degree of similarity determined with the Chekanovsky-Sørensen index of similarity [7] has revealed differences in the meiofauna between separate water objects. The index varied from 10 to 40%. The pair of the Amazar River and the reservoir showed the highest degree of similarity. The zooplankton abundance and biomass were very low and did not exceed $0.94 \times 10^3$ ind./m³ and 22.38 mg/m³, respectively. The highest
concentration of aquatic organisms was noted in the reservoir, the lowest in the Bolshaya Chichatka and Krestovaya rivers. Rotifers and copepod juveniles formed the basis of zoocenoses.

Zoochenthos of the selected watercourses and reservoir featured 14 taxonomic groups including Nematoda, Oligochaeta, Hirudinea, Plecoptera, Ephemeroptera, Trichoptera, Odonata, Megaloptera, Simuliidae, Tabanidae, Ceratopogonidae, Chironomidae, Gastropoda, and Bivalvia. The number of taxa in samples varied from 1 to 7. Typical zoochenthos was represented by chironomids that occurred in 100 % of the samples, oligochaetes accounted for 67 %, while trichopterans and ephemeropterans – 57 %, gastropods – 52 %, and plecopterans – 33 %. (Table 2).

Table 2. Abundance (N, ind./m²) and biomass (B, g/m²) of zoochenthos in May, 2019.

| Water object | Reservoir | Krestovaya River | Bolshaya Chichatka River | Amazar River |
|--------------|-----------|------------------|--------------------------|--------------|
| No. of monitoring station | 8 | 6 | 2 | 5 | 1 | 4 |
| Depth, m | 6 | 1.9 | 3.5 | 0.3 | 0.3 | 0.5 |
| Oligochaeta | N | B | N | B | N | B | N | B | N | B | N | B |
| Hirudinea | 0.24 | – | – | 1480 | 4.24 | 50 | 0.40 | – | – | 67 | 0.15 |
| Gastropoda | 1.12 | 27 | 11.54 | 120 | 1.2 | – | – | – | – | 33 | 0.67 |
| Plecoptera | – | – | 13 | 2,16 | – | – | – | – | – | – | – |
| Ephemeroptera | 320 | 3.32 | 27 | 0.03 | 440 | 2.76 | 67 | 0.48 | – | – | 67 | 0.15 |
| Trichoptera | – | – | 107 | 0.09 | 40 | 0.08 | 885 | 9.59 | – | – | 67 | 0.05 |
| Megaloptera | – | – | 13 | 0.01 | – | – | – | – | – | – | – | – |
| Tabanidae | – | – | – | – | – | – | 17 | 0.12 | – | – | – | – |
| Simuliidae | – | – | – | – | – | – | 50 | 0.03 | – | – | – | – |
| Ceratopogonidae | 80 | 0.04 | – | – | – | – | – | – | – | – | – | – |
| Chironomidae | 880 | 2.8 | 536 | 0.24 | 720 | 0.6 | 2739 | 1.82 | 985 | 0.43 | 1470 | 1.15 |
| Total | 1400 | 7.52 | 724 | 14.07 | 2840 | 9.0 | 3874 | 12.74 | 985 | 0.43 | 1737 | 2.25 |
| Taxonomic abundance | 5 | 6 | 6 | 7 | 1 | 6 |

4. Discussions

Hydrobiological monitoring on run-of-water reservoirs of Russia has revealed the main trends and the stages of their formation. The findings showed that during the initial stages of the reservoir development, its flora and fauna have insignificant differences from the original watercourse with hydriobionts changing gradually and acquiring their specific nature mainly based on the geographic location of the water body [8–12].

In the investigated water objects of the Amazar River basin, low diversity of hydriobionts was detected including 85 phytoplankton species, 28 macroalgae taxa, 56 zooplankton taxa, 14 zoochenthos groups. The composition of the dominant species in phyto- and zooplankton as well as macrophytes flora is represented by cosmopolitan, widely distributed organisms typical for the area under study.

The algal flora of the reservoir is based on the algae of the Amazar River. The dominant complex of the reservoir is similar to that of the river with high values of the Sørensen index. In both watercourses and the reservoir, low values of abundance and biomass are registered. At the moment of exploration, the phytoplankton of the Amazar reservoir showed low biodiversity. The similar conditions were observed at the Pavlovskoye [13], the Bureyskoye [14], the Yumaguzinskoye [15] and other run-of-water reservoirs. Plankton algae of the reservoir did not show rapid growth of cyanobacteria in the first years of its formation [16–19]. On the contrary, over the whole vegetation cycle, diatoms predominate in the reservoir which is characteristic for the reservoirs of this type [13–15].

Zooplankton of the Amazar reservoir is mainly formed by the meiofauna of the Amazar River. Taxonomic composition of the crustaceans of the reservoir and the river features a relatively high value
of the Chekanovsky-Sørensen index of similarity. In the river and in the reservoir, low values of hydrobiomia abundance were registered. Peak values of abundance and biomass were detected in the limnetic zone of the reservoir generally formed by copepod crustaceans. The fauna of rotifers and crustaceans of the Amazar reservoir in 2018–2019 showed poor species diversity which was also observed at the run-of-water reservoirs on the Yenisey River [20, 21], the Irtysh River [22], and the Zavkhan River [23]. The low content of plankton fauna of the Amazar reservoir recorded in the first years is caused by low diversity of the river plankton, the absence of floodplain water bodies nearby, the lack of the littoral zone, and the high content of mineral particles inflowing with the Amazar water and affecting zooplankton.

The transformation of the limnetic zooplanktocoenoses occurs over a long period and tends to be dominated by limnophilic complexes [24, 25]. The formation of any reservoir is considered to be complete only after its predominant species composition ceases to rapidly transform and remains more stable in its ratios [9]. If the reservoir has been being filled for several years, its zooplankton formation takes longer time as well [26]. Zooplanktocoenoses of the reservoirs built on the mountainous and semi-mountainous rivers feature a relatively high development rate during warm months at the surface levels of the pelagic zone and in the littoral zone (on the shallow well-warmed areas with a minimal impact on biotopes from wind and wave currents and discharge currents) [27–29].

In the reservoir, zoobenthos values of taxonomic biodiversity and biomass are high. Taxonomic composition of the limnetic zone of the reservoir is mixed with occurring rheophiles (ephermeropetans, trichopterans) and limnophiles (hirudines, gastropods and oligochaetes). Zoobenthos biomass increased as compared to 2004 [30]. Low values of diversity and abundance of zoobenthos downstream from the dam were observed during the course of the study in 2018–2019. It was observed that, in October 2004, before the reservoir construction, chironomid larvae were predominant in the area of the planned flooding (25.190 units ind./m²) and relatively high values of zoobenthos biomass were registered (3.6 g/m²) [30]. Currently, zoobenthos conditions are affected by mechanical pressure of the waters falling from the dam. Acquiring the lacustrine quality of zoobenthos in the reservoir is influenced by continuous overflow of the reservoir and the flood probability that inhibits sludge buildup. Based on the previous forecast [30], the process of reaching a stable condition for benthos will depend on the rate of stable bottom formation.

At this stage, the species composition of the flora and fauna in the reservoir falls in between the lacustrine and the riverine ones. The riverine conditions are observed in the upstream area of the reservoir; the middle area bears an intermediate status; while the limnetic zone near the dam features the transformation of the river system into a lake-like running-water ecosystem. Seasonally, in the period from spring to autumn, phytoplankton showed a decreasing trend of the quantitative values, whereas the total abundance and biomass of zooplankton were increasing; zoobenthos featured the lack of trends; macrophytes contents were different from season to season being abundant in the Amazar River near the urban settlement in spring and in the Amazar River downstream from the dam in autumn. Consequently, the initial stage of the reservoir formation is rather similar to the original watercourses in the physical and chemical parameters and in the composition of the flora and fauna as well.

Ichthyofauna is mainly formed by rough fish species. The highest diversity of fishes is detected in the Amazar River in the downstream currents. It was observed that spawning migration through the fishway passage extends from the early-May up to the early-June. At the beginning of the migration the adult specimens of Brachymystax lenok and Thymallus grubii predominate; while at the end Cyprinidae and immature Brachymystax lenok and Thymallus grubii are mainly detected.

As it was previously thought [4], hydroelectric complexes and reservoirs on the rivers of the Amur basin would have a favorable effect on fishery and create an opportunities for the development of the fishing industry. Yet the data review proves that new reservoirs are mainly inhabited by coarse fishes while troubles in the fish migration to the spawning areas of Thymallidae and Salmonidae destroy the existing ichthyocenoses [31–34].
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