Quantitative characteristics of zooplankton in the rivers of the Upper Amur Basin, exposed to the effects of placer gold mining

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Abstract. Research conducted in June and September 2020 showed that the species composition of rotifers and lower crustaceans in 17 water courses of the Upper Amur Basin, exposed to the effects of placer gold mining, included 43 species. Most of the water courses were researched for the first time. Based on the environmental and geographic assessment, the prevalent species were widespread and eurytopic. Most parts of the rivers were characterised by low quantitative characteristics (0.01–3.77 × 10³ ind. m⁻³ and 0.06–54.64 mg m⁻³), which was explained by the hygrological conditions and long-term effects of mining in the river beds. A better productivity (up to 39 × 10³ ind. m⁻³ and 228 mg m⁻³) was registered in the areas of former excavations in the river beds, with slower water exchange and better conditions for the development of zooplankton.

Placer gold mining is a source of negative impacts on the Amur basin’s water bodies. The impact of placer gold mining on the local river valleys consists of the elimination of the biotic parts of the biocenosis and geomorphological transformation of the river beds, bottoms and valley slopes. The impact on the river network is mainly downstream from the mining sites. Erosion of the disturbed area results in the relocation of large masses of fine sand and silt downstream, thus impacting the light permeability of water and the formation of river bed ecosystems.

The aim of the research was to identify species composition and establish the structural and quantitative characteristics of zooplankton in the water courses in the territory of placer gold mining in the Zabaikalye Territory.

The research was carried out at 17 water bodies (24 research stations) in June and September 2020 (figure 1); the names of the stations are given in table 1 and 2. The researched water courses are I–V order tributaries of the Amur River and their length ranges from 8 to 200 km [1]. The largest are the Amazar and Cherny Uryum, their average depth ranges from 0.3 to 1.0 m and the average velocity is from 0.5 to 1.0 ms⁻¹, reaching 3 ms⁻¹ during river floods. These water bodies and their tributaries are the areas where placer gold mining was carried out by dredging and hydraulic mining giants. The stream beds are heavily disturbed as a result of long term mining.

The researched area comprises typical medium-altitude mountains, with dissected topography and absolute elevations of 600–800 m (maximum elevations are 900–1400 m within mountain ranges). The climate of the area is sharply continental with high amplitude daily and yearly temperature
Variations (up to 90°C); it is characterised by a sub-zero average yearly temperature and low precipitation, with most of it falling during the warm season. Permafrost is pervasive. Rivers freeze up in October and freeze to the bottom. They are mainly fed by summer precipitation, spring thawing and the thawing of the active layer of permafrost [2, 3].

The quantitative and qualitative samples were collected and treated according to the standard hydrobiological methods. Quantitative samples of zooplankton were collected by filtering 100 l of surface water through the Apstein network (mesh size 0.064 mm). Qualitative samples were collected with a plankton net (mesh size 0.064 mm) from mid-water, from aquatic vegetation, and from the ground surface in various areas of the water course. All samples were preserved in 96% alcohol, in such a way that the concentration of alcohol in the sample was no less than 70%. Laboratory treatment of the samples was carried out according to the standard quantitative and weighing method [4]. Due to the poor number of river plankton found, the total amount of water was counted using a Bogorov counting chamber. The biomass was identified with the use of regressive equations for individual body mass – body length estimation [5, 6].

Figure 1. Schematic map of the research area with sample collecting stations.

Species composition of the zooplankton in the researched water courses of the Upper Amur Basin in 2020 comprised 43 species, of which Rotifera accounted for 23, Copepoda – 13, and Cladocera – 7. In addition, there were specimens of Bdelloidea Hudson, 1884 gen. sp., Harpacticoida Sars, 1903, Calanoida Sars, 1903, which species we were unable to identify.
With regards to the geographic distribution, widespread species prevailed in the species list. In terms of habitat, eurytopic species and representatives of the littoral phyto philous complex were present.

Table 1. Quantitative characteristics of zooplankton in the researched water courses of the Upper Amur Basin in June 2020.

| Water object                        | Station No | Length of water course, km | Number of species | Rotifera N/B b | Cladocera N/B | Copepoda N/B | Total N/B |
|-------------------------------------|------------|---------------------------|------------------|----------------|---------------|--------------|-----------|
| Amazar River                        | 1          | 200                       | 3                | 0.007          | 0             | 0.010        | 0.017     |
|                                     | 2          | 32                        | 2                | 0.007          | 0             | 0.010        | 0.017     |
|                                     | 3          | 31                        | 2                | 0.007          | 0             | 0.360        | 0.367     |
|                                     | 4          | 28                        | 5                | 0.010          | 0             | 0.030        | 0.040     |
|                                     | 5          | 6                         | 6                | 0.010          | 1.440         | 1.450        |           |
|                                     | 6          | 48                        | 4                | 0.003          | 0             | 0.170        | 0.173     |
|                                     | 7          | 14                        | 14               | 2.857          | 0.013         | 0.897        | 3.767     |
|                                     | 8          | 25                        | 10               | 20.907         | 0.053         | 17.913       | 38.873    |
|                                     | 9          | 16                        | 16               | 2.713          | 0.037         | 2.490        | 5.240     |
|                                     | 10         | 36                        | 14               | 0.243          | 0.110         | 1.640        | 2.740     |
|                                     | 11         | 36                        | 8                | 0.040          | 0.010         | 0.013        | 0.063     |
|                                     | 12         | 37                        | 2                | 0.030          | 0.080         | 0.330        | 0.440     |
|                                     | 13         | 25                        | 5                | 0.070          | 0.027         | 0.103        | 0.200     |
|                                     | 14         | 60                        | 4                | 0.007          | 0.047         | 1.480        | 1.537     |
|                                     | 15         | 30                        | 2                | 0.057          | 0.053         | 0.203        | 0.313     |
|                                     | 16         | 136                       | 6                | 0.070          | 0             | 0.110        | 0.180     |
|                                     | 17         | 91                        | 6                | 0.010          | 0.007         | 0.067        | 0.084     |
|                                     | 18         | 8                         | 8                | 0.017          | 0.013         | 0.100        | 0.130     |
|                                     | 19         | 17                        | 4                | 0.003          | 0.170         | 1.960        | 2.143     |
|                                     | 20         | 8                         | 2                | 0.004          | 0.100         | 1.100        | 1.104     |
|                                     | 21         | 8                         | 2                | 0.004          | 0.100         | 0.620        | 0.620     |

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| 2          | 32                         | 2                | 0.007          | 0             | 0.010        | 0.017     |
| 3          | 31                         | 2                | 0.007          | 0             | 0.360        | 0.367     |
| 4          | 28                         | 5                | 0.010          | 0             | 0.030        | 0.040     |
| 5          | 6                          | 6                | 0.023          | 0.003         | 0.037        | 0.063     |
| 6          | 48                         | 4                | 0.003          | 0             | 0.170        | 0.173     |
| 7          | 14                         | 14               | 2.857          | 0.013         | 0.897        | 3.767     |
| 8          | 25                         | 10               | 20.907         | 0.053         | 17.913       | 38.873    |
| 9          | 16                         | 16               | 2.713          | 0.037         | 2.490        | 5.240     |
| 10         | 36                         | 14               | 0.243          | 0.010         | 0.313        | 0.566     |
| 11         | 36                         | 8                | 0.040          | 0.010         | 0.013        | 0.063     |
| 12         | 37                         | 2                | 0.030          | 0.080         | 0.330        | 0.440     |
| 13         | 25                         | 5                | 0.070          | 0.027         | 0.103        | 0.200     |
| 14         | 60                         | 4                | 0.007          | 0.047         | 1.480        | 1.537     |
| 15         | 30                         | 2                | 0.057          | 0.053         | 0.203        | 0.313     |
| 16         | 136                        | 6                | 0.070          | 0             | 0.110        | 0.180     |
| 17         | 91                         | 6                | 0.010          | 0.007         | 0.067        | 0.084     |
| 18         | 8                          | 8                | 0.017          | 0.013         | 0.100        | 0.130     |
| 19         | 17                         | 4                | 0.003          | 0.170         | 1.960        | 2.143     |
| 20         | 8                          | 2                | 0.004          | 0.010         | 0.620        | 0.620     |

a abundance, × 10^3 ind. m^2.
b biomass, mg m^2.

In the River Amazar and its tributaries (Amazarkan, Bolshoy Amazar, Maly Amazar) in early June, there were 2 to 6 species of small, armourless Rotifera (*Bdelloidea* spp., *Polyarthra dolichoptera* Idelson, 1925), Cyclops of the gen *Cyclops, Diacyclops, Eucyclops*, and juvenile stages of Cyclopoidea and Calanoida. The abundance and biomass of zooplankton were low: 0.017–0.063 × 10^3 ind. m^2 and 0.367–1.450 mg m^2, respectively (table 1). The prevailing groups in the water courses were Copepoda.
(forming 53–83 % of the total abundance and 63–99 % of the biomass), followed by Rotifera (17–40% of the abundance and 1–31% of the biomass); a single species of Cladocera was found in one water body. In September, the most dominant were juvenile stages and male Cyclopoida. The biomass grew due to adult females Acantocyclops venustus Norman & Scott, 1906, Eucyclops arcanus Alekseev, 1990, see table 2. The quantitative values for the upper part of the River Amazar, obtained in 2020, are comparable with the data for the middle and lower courses in 2011 and 2018 [7, 8]. During the research periods in 2011 and 2018, very low levels of the development of planktonic invertebrates was registered: the number of species varied from 1 to 7, the population varied from 0.01 to 0.22 × 10^3 ind. m^-3, and the biomass did not expand beyond 0.96 mg m^-3.

**Table 2.** The quantitative characteristics of zooplankton in the researched water courses of the Upper Amur Basin in September 2020.

| Water object | Station No | Number of species | Rotifera N/B | Cladocera N/B | Copepoda N/B | Total N/B |
|--------------|------------|-------------------|--------------|---------------|--------------|-----------|
| Bolshoy Amazar River | 2 | 5 | 0.007 | 0.003 | 0.040 | 0.050 |
| Amazarkan River, conditionally background | 4 | 5 | 0.007 | 0.003 | 0.020 | 0.030 |
| Kudechi River, downstream from the drainage reservoir | 9 | 12 | 0.063 | 0.040 | 0.146 | 0.249 |
| Kara River | 12 | 7 | 0.040 | 0.380 | 3.130 | 3.550 |
| Luzhanki River | 13 | 3 | 0.300 | 0.170 | 0.130 | 0.600 |
| Cherny Uryum River, upstream from the dredger 164 | 18 | 2 | 0.005 | 0.020 | 0.023 | 0.043 |
| Cherny Uryum River, downstream from the dredger 164 | 19 | 5 | 0.007 | 0.030 | 1.100 | 1.106 |
| Alekseyevsky Stream | 23 | 0 | 0 | 0 | 1.680 | 1.680 |
| Bezymyanka Stream | 24 | 2 | 0.005 | 0.085 | 2.380 | 2.430 |

* abundance, × 10^3 ind. m^-3.
* biomass, mg m^-3.
* zooplankton organisms were not found.

In the rivers Kara, Bogocha, Gorbitsa, and Dyuyumsha (first order tributaries of the River Shilka) the number of species in June varied from 2 to 5, the abundance changed from 0.047 to 0.313 × 10^3 ind. m^-3, and the biomass ranged from 0.063 to 3.730 mg m^-3 (table 1). The basis of the river zoocenosis was formed by young generations of Cyclopoida and Calanoida (36–79% of the abundance and 40–96% of the biomass). Among the adult specimens, Microcyclops varicans Sars G.O., 1863 was identified as a species, rotifers of Bdelloida order had also developed (32–64% of the abundance) as well as Bosmina longirostris O.F. Müller, 1776 (up to 13% of the abundance and 10% of the biomass). In September, in the rivers Luzhanki and Kara 3–7 species were identified. The abundance was 0.043–0.087 × 10^3 ind. m^-3, and the biomass was 0.60–1.73 mg m^-3 (table 2). In the River Kara, species diversity grew compared to June, due to a growing number of Rotifera species.

In the River Zheltuga and its tributary rivers (Kudechi, Davenda, and Boguziyav), the largest number of species (4–16) were identified in June, due to the development of zooplankton organisms in the former drainage reservoirs in the river beds (table 1). At these parts of the rivers (the former drainage reservoir at the River Kudechi) the maximum number (38.873 × 10^3 ind. m^-3) and biomass (228.07 mg m^-3) were recorded. The burst of abundance was mainly due to rotifers P. dolichoptera Idelson, 1925 and the basis of the biomass were juvenile species of Cyclopoida and Calanoida, rotifers Asplanchna priodonta Gosse, 1850 and Asplanchna girodi de Guerne, 1888. In September, the
quantitative characteristics \((0.249 \times 10^3 \text{ ind. m}^{-3} \text{ and } 3.55 \text{ mg m}^{-3})\) in the River Kudechi were substantially lower than in June, but they were the maximum values for all the researched water courses (table 2). We compared the obtained characteristics for the river Boguzya in 2020 and literature values from 2013 [9] and identified a similarity in the number of species, species composition, dominating groups, and quantitative characteristics in the beginning of the vegetation period.

In the River Cherny Uryum and its tributaries (the Itaka, Alekseyevsky and Bezymyanka) the number of species varied from 2–8 in June (table 1) and 0–5 in September (table 2). The abundance and biomass were low \((0.01–0.18 \times 10^3 \text{ ind. m}^{-3} \text{ and } 0.62–4.33 \text{ mg m}^{-3} \text{ in June and } 0–0.09 \times 10^3 \text{ ind. m}^{-3} \text{ and } 0–1.68 \text{ mg m}^{-3} \text{ in September})\). The core of the zoocenosis was made of copepods Harpacticoida and *Diacyclops crassicaudis* Sars, 1863, (together with juvenile species, they formed 76–100% of the abundance and 91–100% of the biomass). In September, zooplankton organisms were not found in the Alekseyevsky stream.

The characteristic features for zooplanktocenosis of the rivers located in this area can be identified. In the water courses of this type, zooplankton are poor and represented by the species which are most adaptable to such factors as low water temperature, a short vegetation period, high water velocity (especially during floods), and increased content of suspended particles due to gold mining in the river beds. Typical filter feeding organisms (such as Cladocera) were occasionally found as a single species, which is explained by the unfavourable conditions for their development, e.g. the heavy ‘muddiness’ of the water. Near the actual, dredged mining sites, zooplankton is non-existent. It was found that, to a certain degree, recovery of the zooplankton communities is due to the availability of abandoned, flooded excavations and open pits, where more favourable conditions for the development of organisms are created, such as lower water exchange, better ability of the water to warm up (especially at the shore), and better trophic conditions.

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