Biodiversity of the Ingoda River ecosystem

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Abstract. The results of a study of the biodiversity of hydrobionts in the Ingoda River are presented. In phytoplankton sixty six taxa of algae with a rank below the genus have been identified. The zooplankton contains 21 species. The species composition of the macrophytobenthos includes 5 taxa. In the flora of hydrophytes, 15 plant species have been identified. The zoobenthos contains 40 species. Our researches have been showed that widespread species prevail in the flora and fauna of hydrobionts in the Ingoda River. Two alien species (Elodea canadensis and Gmelinoides fasciatus) have been recorded in the Kenon Lake. A very rare East Siberian species of mayfly Acanthametropus nikolskyi has been recorded in the Ingoda River zoobenthos.

1. Introduction
The Ingoda River (left tributary of the Shilka River, Amur River basin) originates from the northern slopes of the Khentei ridge, below the city of Chita, and cuts through the Chersky ridge and a number of low mountain ranges of the Trans-Baikal Territory. The length of the Ingoda River is 708 km and its catchment area is 37200 km² [1].

Of all the rivers of the Trans-Baikal Territory, the Ingoda River is experiencing the greatest anthropogenic load. Here, water intake represents 232 million m³, or 74.9% of the total volume of water withdrawn. Wastewater discharge is increasing annually. At the same time, the river is used for recreation by the townspeople and is a breeding and feeding area for valuable fish populations (Hucho taimen Pallas, Brachymystax lenok Pallas, Thymallus arcticus grubei Dybowskii) [2].

However, the poor hydrobiological knowledge of the river does not allow making well-grounded economic decisions that would reduce the negative load on water bodies and improve water quality [1]. Therefore, the purpose of the work is to assess the biodiversity of water bodies in the zone of influence of effluents from the treatment facilities of the airport settlement. The assessment of biodiversity was carried out for the ecosystems of the Ingoda River, the water supply canal, and the section of the Ingoda River water flow into Lake Kenon.

2. Materials and Methods
The studies were carried out on July 7, 2020 in the Ingoda River (sites 1 and 2), the water intake canal (sites 3 and 4), and in Lake Kenon (site 5) at the location where the injected water is discharged (figure 1). The studies were carried out during the summer dry season.

Transparency was determined with a Secchi disk. The physical and chemical parameters of water (pH, salinity, oxygen, water temperature) were also measured in water sampling spots. For
phytoplankton, one litre samples were obtained from each lake using a Patalas bathometer. Phytoplankton samples were collected and fixed in 4% formalin. The sedimentation method was used to concentrate the phytoplankton. Cell calculations were made in a counting plate (0.01 ml volume) using the Hansen method. The algal biomass was determined using the geometric figures method [3]. Taxonomic identification was given by M D Guiry and G M Guiry [4].

Figure 1. Map-scheme of the site location. Here and below in tables 1–5: 1 – Ingoda River 0.5 km above the discharge; 2 – Ingoda River 0.5 km below the discharge; 3 – the mouth of the water supply channel; 4 – water supply canal 0.3 km above the mouth; 5 – Kenon Lake in the place of discharge of waters pumped from the Ingoda River.

Zooplankton were sampled quantitatively using a Judy net with a filtering cone made of Capron mesh no 55 (125 μm) and using a hydrobiological hand net. Ten to 60 L of water was filtered through the latter during sampling. The samples were preserved in a 4% formalin solution following standard procedure and counted in the Bogorov chamber [5]. The biomass of zooplankton was determined considering the size of the zooplankters [6, 7].

The samples of zoobenthos were collected with a Levanidovs benthometer (S=0.064 m²) [8]. Research on macroalgae and aquatic plants were conducted using conventional methods and techniques [9, 10].

3. Results

3.1. Physical and chemical parameters

Physical and chemical parameters are presented in table 1.

Table 1. Physical and chemical parameters of the Ingoda River.

| Sites | GPS             | Temperature °C | Redox potential mV | pH  | Electro-conductivity µs cm⁻¹ | Total dissolved solids ppm | Salinity ppt | Turbidity ntu |
|-------|-----------------|----------------|-------------------|-----|-----------------------------|---------------------------|--------------|---------------|
| 1     | 51°59.9632' N 113°21.5097' E | 21.6          | 183                | 7.13 | 94                          | 61                        | 0.04         | 41.3          |
| 2     | 52°00.3084' N 113°21.9677' E | 20.8          | 181                | 8.01 | 92                          | 59                        | 0.04         | 44.8          |
| 3     | 52°00.3731' N 113°22.2424' E | 21.3          | 175                | 8.37 | 84                          | 55                        | 0.04         | 43.8          |
| 4     | 52°00.5168' N 113°22.1799' E | 23.9          | 188                | 8.01 | 96                          | 62                        | 0.04         | 45.7          |
| 5     | 52°01.3378' N 113°21.7231' E | 22.2          | 233                | 7.79 | 471                         | 303                       | 0.22         | 41.3          |
3.2. Biodiversity of aquatic organisms

The phytoplankton of the surveyed sites included 66 taxa of algae with a rank below the genus (52 species, varieties, and forms), which belonged to seven divisions, 11 classes, 26 orders, 34 families, and 52 genera. The greatest species richness was inherent in diatoms and green algae, together accounting for 78.8% of the identified taxa. A noticeable share of the species richness was made up of Chrysophyta (7.6% of the total number of taxa), Charophyta (4.5%), and Dinophyta (4.5%). Other divisions of algae (Cyanobacteria and Euglenophyta) played a significantly smaller role in the taxonomic composition of phytoplankton and accounted for 4.5% of the total. According to the taxonomic composition, the phytoplankton of the surveyed sites were characterised as diatomaceous.

The proportion of diatoms varied from 50–89% of the total number of taxa. A significant participation in the taxonomic composition of green algae (up to 35% of the total number of taxa) was noted for the sites of Lake Kenon (site 5).

The distribution of the species richness of phytoplankton, estimated by the values of the specific species richness (the number of species in the sample), showed that the waters of the surveyed sites are not very taxonomically diverse (28±9 species in the sample). The fluctuation limit was 19–44. The smallest number of taxa – 19 – was recorded in the Ingoda River at site 2, the largest – 44 – in Lake Kenon. The dominant phytoplankton complex of the surveyed sites was represented mainly by Bacillariophyta – *Melosira varians* C. Agardh, *Lindavia comta* (Kützing) Nakov, Gullory, Julius, Theriot & Alverson, *Ulnaria ulna* (Nitzsch) Compère, and *Hannaea arcus* (Ehrenberg) R M Patrick in R M Patrick Reimer. At the sites of Lake Kenon, the dominant species included Chlorophyta (*Nephrocytium agardhianum* Nägeli, *Pandorina morum* (O.F. Müller) Bory, *Elakatothrix genevensis* (Reverdin) Hindák) and Dinophyta (*Gymnodinium* sp., and *Ceratium hirundinella* (O. F. Müller) Dujardin).

The abundance of algae varied from 75.7 to 168.9 ×10³ cells L⁻¹. The biomass value ranged from 99.2 to 385.37 mg m⁻³. The maximum abundance and biomass were recorded at site 3, the minimum – in Lake Kenon (site 5) (table 2).

### Table 2. Abundance, biomass and composition of the dominant phytoplankton complex of the surveyed sites.

| Sites | Abundance (×10³ cells L⁻¹) | Dominant species (% of the abundance) | Biomass (mg·m⁻³) | Dominant species (% of the biomass) |
|-------|---------------------------|--------------------------------------|------------------|-------------------------------------|
| 1     | 87.36                     | *U. ulna* (15); *M. varians* (15)    | 200.27           | *U. ulna* (14); *H. arcus* (16); *M. varians* (41) |
| 2     | 94.47                     | *M. varians* (11); *U. ulna* (29)    | 165.66           | *M. varians* (28); *U. ulna* (33) |
| 3     | 168.92                    | *M. varians* (13); *U. ulna* (36)    | 385.37           | *Gymnodinium* sp. (16); *U. ulna* (32); *M. varians* (32) |
| 4     | 96                        | *U. ulna* (35)                       | 126.21           | *U. ulna* (53) |
| 5     | 75.72                     | *U. ulna* (11); *E. genevensis* (26) | 99.22            | *U. ulna* (16); *C. hirundinella* (20) |

As a percentage, Bacillariophyta prevailed among the phytoplankton of the surveyed sites, accounting for 49–98% of the total abundance and 38-98% of the total biomass. At the sites of Lake Kenon,
Kenon (site 5), the share of Chlorophyta in plankton reached 30% of the total number and total biomass, and that of Dinophyta up to 40% of the total biomass.

The composition of the algoflora, as in previous studies (1967–1970 [9], 2015, 2017 [11–13]), during the period of work in 2020 was characterized by the poverty of a high-quality composition and a diatom-chlorophyte character. Previously obtained data on the quantitative development of summer phytoplankton are scarce [9]. For the summer phytoplankton 1967–1968, blossoming of the blue-green alga *Microcystis aeruginosa* was noted when the biomass reached 12.7 g m\(^{-3}\). For 1970, on the contrary, the scarcity and underdevelopment of plankton algae was noted and associated with prolonged floods. The abundance of phytoplankton during this period did not exceed 6.8×10\(^3\) cells L\(^{-1}\). In general, the nature of the phytoplankton of the Ingoda River is similar to that of other mountain rivers [14–18].

The zooplankton consisted of 21 species of plankton invertebrates, including nine species of Rotifera (43% of the total number of species), seven of Cladocera (33%), and five of Copepoda (24%). The total number of taxa at the sampling sites varied from one (site 3) to ten (site 5). In zoogeographic terms, most of the noted zooplankton species were attributed to cosmopolitan species (50%); in terms of biotopic confinement, most species were littoral (38%) and eurybiontic (33%).

The values of the total abundance and biomass of zooplankton varied from 0.02–0.03 to 72.54×10\(^3\) ind. m\(^{-3}\), and the total biomass from 0.15-0.17 to 213.08 mg m\(^{-3}\). The highest concentration of zooplankters was noted in the Lake Kenon (at the site of discharge of river waters), and the smallest at sites 2 and 3 (in the zone of influence of waste waters) (table 3).

**Table 3.** Distribution of the total abundance (N, ×10\(^3\) ind. m\(^{-3}\)) and total biomass (B, mg m\(^{-3}\)) of zooplankton in the studied water bodies.

| Sites  | 1   | 2   | 3   | 4   | 5   |
|--------|-----|-----|-----|-----|-----|
| N      |     |     |     |     |     |
| Rotifera | 0.06 | 0.02 | 0   | 0.04 | 36.40 |
| Copepoda | 0.03 | 0.01 | 0   | 0.02 | 13.69 |
| Cladocera | 0.01 | 0   | 0.02 | 0.01 | 22.46 |
| Total  | 0.10 | 0.03 | 0.02 | 0.07 | 72.54 |
| Rotifera | 0.11 | 0.02 | 0   | 0.06 | 11.40 |
| Copepoda | 0.12 | 0.24 | 0   | 0.03 | 38.66 |
| Cladocera | 0.02 | 0   | 0.15 | 0.08 | 60.42 |
| Total  | 0.25 | 0.26 | 0.15 | 0.17 | 213.08 |

The composition of invertebrates in plankton varies within the framework of previous studies, in which from 2-7 to 49 taxa were recorded. Crustaceans at the sites of sampling were very poorly represented and only by the naupliar and copepodite stages Cyclopoida and *Chydorus sphaericus* (O.F. Müller). The rotifers were dominated by widespread and eurybiontic species: *Euchlanis dilatata* (Gosse), *Proales theodora* Ehrenberg, *Notommata*, and *Bdelloidea* spp.

In the species composition of the macrophytobenthos of the studied water bodies, five taxa were identified, including *Stigeoclonium tenue* var. *tenue* and *Cladophora fracta* (table 4). The accumulations of Cyanobacteria found at site 2 did not belong to macrophytobenthos in size, and therefore, they were not considered in our study. In general, the species found were cosmopolitan. The greatest diversity was observed at the site upstream of the wastewater discharge. According to M.I. Kachaeva [9], the composition of species at site 1, with the exception of *Cl. fracta*, was typical of the Ingoda River near the City of Chita. The abundance of *Cladophora* indicated changes in the composition of the river flora and in areas upstream of the study site. The absence of significant accumulations of macroscopic algae in the water supply channel was due both to the change of rhoeophilic conditions to limnophilic ones, with a higher abundance of aquatic vegetation, and to the pollution of the Ingoda River by waste waters.
Table 4. Species composition, abundance and phytomass (abundance/phytomass (wet-dry), mg m$^{-2}$) of macroscopic algae.

| Taxon                                | Sites          | 1        | 2        | 3        | 4        | 5        |
|--------------------------------------|----------------|----------|----------|----------|----------|----------|
| Cyanobacterial mats                  | Cyanobacteria  | -/a      | 6/7.1–2.9| -        | -        | -        |
|                                      | Chlorophyta    | -/a      | -        | -        | -        | -        |
| Stigeoclonium tenue var. tenue (C. Agardh) Kützing | 1/-            | 1/-      | -        | -        | -        | -        |
| Chaetophora elegans (Roth) C. Agardh | 1/-            | -        | -        | -        | -        | -        |
| Draparnaldia glomerata (Vaucher) C. Agardh | 2/-            | -        | -        | -        | -        | -        |
| Cladophora fracta (O.F. Müller ex Vahl) Kützing | 6/189.6–12.8   | -        | -        | -        | 3/5.0–1.2| -        |
| Charophyta                           | Charophyta     | -        | -        | -        | -        | 6/245.0–59.9|

*a No data

Earlier [19], it was indicated that Ulothrix zonata var. zonata Kütz. did not reach mass development; individual filaments were recorded along the coastal strip in the zone of distribution of incoming waters. In later studies, species of the genus Spirogyra were observed to have dominated in the areas of development of U. zonata. One of the factors preventing the dispersal of these species of macroalgae in Kenon Lake was the sandy littoral of the reservoir. The rise in the water level in the reservoir and the formation in recent years of the belt of aerial-aquatic plants from Phragmites australis (Cav.) Trin. Ex Steud. radically changed the conditions for the development of macroalgae within free windows in the thickets of Ph. australis, Cl. fracta.

In the flora of hydrophytes, 15 plant species have been identified in this study; the identified species are widespread, eurytopic species (table 5).

Table 5. Phytomass (dry weight) g m$^{-2}$ of the dominant hydrophytes of the surveyed sites.

| Species                                                 | Sites          | 1        | 2        | 3        | 4        | 5        |
|---------------------------------------------------------|----------------|----------|----------|----------|----------|----------|
| Potamogeton perfoliatus Linnaeus                       | 28.83          | 18.74    | 11.16    | 26.04    | -/a      | -        |
| Potamogeton compressus Linnaeus                        | 1.1            | -        | -        | 0.5      | -        | -        |
| Stuckenia vaginata (Turcz.) Holub                      | 2.79           | -        | -        | 3.72     | 11.16    | -        |
| Phragmites australis (Cav.) Trin. ex Steud.            | -              | -        | -        | -        | 104.16   | -        |
| Chara tomentosa Linnaeus                               | -              | -        | -        | -        | 7.44     | -        |
| Elodea canadensis Michaus                              | -              | -        | -        | -        | 0.2      | -        |
| Potamogeton crispus Linnaeus                           | -              | -        | -        | -        | 0.2      | -        |
| Myriophyllum sibiricum Kom.                             | -              | -        | -        | -        | -        | 1.86     |

*a No data

In the Ingoda River section, upstream of the wastewater discharge area, specimens of E. canadensis, an invader species in the water bodies of the Trans-Baikal Territory, were found. The most overgrown was the channel of the Ingoda River at site 1. Here, communities of aerial-aquatic plants were developed, represented by the Scirpus radicans Schkuhr strip interspersed with Butomus umbellatus L. In the water column, a wide strip at depths from 0.3-1.0 m was formed by communities of P. perfoliatus, with interspersals of P. vaginatus. At sites 2 and 3, the vegetation was represented by an intermittent band of P. perfoliatus (table 5). A strip of P. perfoliatus stretched along the coast of the water intake canal at depths of 0.2-0.4 m. Differences in the diversity of hydrophytes at the survey sites were largely due to the structure of the river channel.
Forty species of zoobenthos were found in the studied area. Chironomids (20 species), mayflies (eight species), and oligochaetes (five species) comprised the main part of the taxonomic diversity of zoobenthos. The composition of zoobenthos consisted of rheophilic and limnophilic taxa. The largest number of zoobenthos taxa in the sample was observed in the Ingoda River (Table 6). Larvae of *Pothamantis luteus* (L.) mayflies were found at all research sites with the exception of Lake Kenon. Mayflies *Ephemerella* (Torleya) sp., oligochaetes *Limnodrilus hoffmeisteri* Claparède and *Tubifex tubifex* (O.F. Müller), as well as the gastropod *Cinclus (S.) confusa* (Westerlund) were found in 60% of the samples. The occurrence of other representatives of zoobenthos was less than 40%. Mayflies *Ephemerella* (*T.*) sp. and *P. luteus*, and larvae of the chironomid *Polypedilum* sp. (chironominae genuinae No. 3 Lipina) were constant species in the Ingoda River; oligochaetes *L. hoffmeisteri* and *T. tubifex*, mayfly *P. luteus*, and snail *C. (S.) confusa* were commonly identified in the water intake channel. An amphipod *Gmelinoides fasciatus* (Stebbing) was found at the site of water discharge into Lake Kenon. The mayfly *Acanthometopus nikolskyi* Tshernova was found at a background site above the discharge zone from the treatment facilities.

Quantitative indicators of zoobenthos were low (Table 6). Larvae of chironomids *Stictochironomus* gr. *crassisforceps*, *Chironomus* gr. *nigrifrons*, *Polypedilum* sp., and *Cladotanytarsus* gr. A. and oligochaetes *L. hoffmeisteri* and *T. tubifex* were the most abundant zoobenthos of the Ingoda River and the intake channel; the chironomids *Cladotanytarsus* gr. *mancus* were those of Kenon Lake. Larvae of mayflies *P. luteus*, *Ephemerla shengmi* Hu, *A. nikolskyi*, mollusks *Boreoelona contortrix* (Lindholm) and *Pisidium annicium* (Müller), and larvae of chironomids *Polypedilum* sp. prevailed in the total biomass of the zoobenthos of the Ingoda River and the intake channel. The amphipod *Gm. fasciatus* dominated the biomass of zoobenthos at the site of water discharge into Lake Kenon.

**Table 6.** Composition, abundance (N, ind. m⁻²) and biomass (B, g m⁻³) of zoobenthos.

| Taxa         | Sites |
|--------------|-------|
|              | 1     | 2     | 3     | 4     | 5     |
|              | N     | B     | N     | B     | N     | B     | N     | B     |
| Oligochaeta  | 49    | 0.30  | 78    | 0.17  | 1272  | 1.44 | 466   | 0.74  | 31    | 0.03  |
| Bivalvia     | "a"  | -     | -     | -     | 248   | 1.92 | -     | -     | -     | -     |
| Gastropoda   | 78    | 3.66  | -     | -     | 31    | 1.10 | 32    | 0.11  | -     | -     |
| Amphipoda    | -     | -     | -     | -     | -     | -    | -     | 248   | 0.48  | |
| Ephemeropera | 79    | 2.21  | 157   | 0.8   | 63    | 1.95 | 141   | 1.83  | -     | -     |
| Heteroptera  | 31    | 0.08  | 31    | 0.25  | -     | -    | 16    | 0.03  | -     | -     |
| Chironomidae | 437   | 0.82  | 995   | 0.66  | 32    | 0.04 | -     | -     | 1473  | 0.45  |
| Total        | 713   | 7.04  | 1256  | 1.84  | 1643  | 6.45 | 636   | 2.67  | 1752  | 0.96  |
| Taxa abundance in sample | 16 | 16 | 9 | 9 | 5 |

*No data

Comparison of quantitative data with the results of previous studies is difficult due to the small number of data. The biomass of zoobenthos reached 1.4 g m⁻² at the end of June 1946, and mayfly larvae were one of the dominant ones in its structure [20]. The biomass of zoobenthos in July 2020 was at this level or higher, and the contribution of mayfly larvae is still high in its structure.

4. Conclusion

As a result of the study of the biodiversity of hydrobionts of the Ingoda River, 66 taxa of algae with a rank lower than the genus were identified. The greatest species richness was inherent in diatoms and green algae. The maximum quantitative indicators were noted at the beginning of the water intake channel (site 3), and the minimum in Lake Kenon (site 5).

The zooplankton contained 21 species of invertebrates. In zoogeographic terms, most of the noted zooplankton species were attributed to cosmopolitan species; in terms of biotopic confinement, most of the species were littoral and eurybionic. Quantitative indicators were highest in the Kenon Lake,
and lowest in the Ingoda River downstream of the wastewater discharge from the airport settlement and upstream of the water intake channel.

In the species composition of the macrophytobenthos of the studied water bodies, five taxa were identified, including *St. tenue* and *Cl. fracta*. In the flora of hydrophytes, 15 plant species were identified. In the species composition of the macrophytobenthos of the studied water bodies, five taxa were identified, including *St. tenue* and *Cl. fracta*. In the flora of hydrophytes, 15 plant species were identified. The flora of the river was represented by cosmopolitan species. Their development was largely due to the morphometric features of the river channel, hydrological conditions, and the nature of bottom sediments. The absence of significant accumulations of macroscopic algae in the water supply channel was due both to the change of rheophilic conditions to limnophilic ones, with an abundance of higher aquatic vegetation, and to the pollution of the Ingoda River by waste waters.

Forty species were found among the zoobenthos of the studied area. A rare East Siberian species of mayfly *A. nikolsky* was also registered. Rheophilic and limnophilic taxa were found in the composition of zoobenthos. The largest number of zoobenthos taxa was found at the sites in the Ingoda River. The quantitative indicators of zoobenthos were low. Chironomid larvae created the main abundance of zoobenthos in the Ingoda River and the intake channel. Mayfly larvae predominated the total biomass of the zoobenthos of the Ingoda River and the intake channel. The amphipoda *Gm. fasciatus* dominated the biomass of zoobenthos at the site of water discharge into Lake Kenon.

In general, the results of this study showed that the flora and fauna of hydrobionts of the Ingoda River in the surveyed area were represented by cosmopolitan species. The benthos communities contained an alien plant species, *E. canadensis*, and the zoobenthos of Lake Kenon, the amphipod *Gm. fasciatus*.

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