Estimation of the ecological status of the Middle Ob floodplain water bodies

V K Popkov*, I O Rozhkova-Timina, S N Kirpotin
Tomsk State University, Laboratory of biodiversity and ecology
*e-mail: hydra@mail.ru

Abstract. A comparative analysis of 4 lakes of the Ob riverbed floodplain was carried out. These lakes differ in the area, depth, overgrowing by higher aquatic vegetation and the flood effects. The assessment of the state of these water bodies was carried out on the basis of the ecological and faunistic analysis of zooplankton, studies of the water chemical composition, including general analyzes and determination of the chemical elements. All studied lakes belong to β-mesosaprobic reservoirs; but they differ in species composition, dominant complex, zooplankton biomass, and they have different stages of succession. The statistically significant associations of zooplankton biomass with concentrations of dissolved CO$_2$ were revealed. The researches demonstrated that the surveyed lakes can be used as model ones in monitoring studies to identify the interannual, cyclic and successional processes.

Introduction
Ob is one of the main Siberian rivers. It is the longest river debouching into the Arctic Ocean; its catchment area (2990000 km$^2$) is the largest in Russia. Ob is formed in the Altai Mountains by the confluence of Biya and Katun rivers and debouches into the Kara Sea, forming the Gulf of Ob. The middle course of the Ob River is characterized by well-developed floodplain, whose width can reach 30 km; it is the second floodplain in the world [1, 2]. The floodplain in the studied area is 15 km wide according to satellite images. Floodplain lakes during the flood are enriched with organic matter and biogenic elements, which leads to the formation of highly productive ecosystems. These processes determine the circulation of water and chemical elements in the oceans [3, 4]. Their importance in the reproduction of the most numerous species of commercial fish and in the formation of fish resources is also known [5, 6]. The condition of floodplain water bodies and their productivity depend on the degree of flood impact (lakes of low, medium and high levels of flooding by hollow waters), on the connection with the river system (drain, flowing, drainage), depth, genesis, stage of development, etc. [7-10]. The floodplain lakes are a favorable environment for the development of phyto- and zooplankton, which serve as food for the inhabitants of flowing waters, and a place for spawning and feeding of fish [11-13]. Nowadays the hydrobiological processes in several lakes in the middle course of the Ob have been sufficiently studied [14]. These lakes have different connection with the river. The goal is to replenish the existing database with research materials of floodplain reservoirs, differing in their condition, to solve the problem of their classification and identification of the interannual, cyclic and successional processes occurring in them.
The purpose of this work is to identify differences in the complex state of floodplain reservoirs and the development of basis for their classification.

Materials and methods
Studies have been conducted on the riverbed left-bank floodplain of the Middle Ob between villages Nikolskoe and Kaibasovo; Tomsk region (N57.246142, E84.181919).

In the study area, the mid-floodplain prevails, rising above the low-water level of the river for 3-5 m. A small part is a high floodplain with heights above the low water of 5-8 m. In these hollows lie lakes, temporary and permanent streams.

The objects of research were two lakes in the basin of the floodplain Kaybasovsky stream, which flows into the River Ob; a partly isolated Malva system, which is part of the Kaybasovsky system during the flood period, and also a drainless lake located on an elevated part of the floodplain (Figure 1).

Figure 1. Study location map. The red line in the small picture is the area covered by the course of the River Ob in Western Siberia; the study sites are shown on the large map of the floodplain.

Sampling of zooplankton was carried out in the open zone of water bodies at the beginning of August (during the period of maximum development of the lake biomass), and at the end of September (at the end of the development period of the summer complex) with a plankton grid of the Jedi type. The determination of the species composition was made using modern determinants.

The quotient of similarity of the species composition of zooplankton between the surveyed lakes was produced according to the formula of P. Jaccard [15]. Evaluation of saprobity produced by the method of Pantle-Bukk in the Sladechek’s modification [16]. Evaluation of the productivity of zooplankton was made according to the classification of S P Kitaev [17].

The methane content was determined on a Bruker GC-456 gas chromatograph (USA) with flame ionization and thermal conductivity. Dissolved organic and inorganic carbon was analyzed using a Shimadzu TOC VSCN carbon analyzer (Japan) with an error less than 3%. The instrument was calibrated to analyze both forms of dissolved carbon in organic-rich and low-inorganic carbon-rich waters [18]. To determine the trace element and anionic composition of the sample was acidified with nitric acid. After
that, inductively coupled plasma mass spectrometry (ICP-MS, Agilent 7500CE, USA) was used using indium and rhenium as internal standards (± 5% accuracy).

Temperature, potentiometric, conductometric and other measurements were also carried out in each lake. Conductivity and pH were measured by data recorders WTW Multi3320 (Germany) with sensors WTW TetraCon 325, pH-Electrode SenTix® 41 and CellOx 325, respectively. The sensors were immersed in water, and the corresponding value appeared on the display. Dissolved CO₂ concentrations were measured by the data recorder GM70 Hand-Held Carbon Dioxide Meter, Vaisala® (Finland) in the same way.

Statistical data processing was carried out using the software package STATISTICA 6.0.

**Results and methods**

The floodplain lakes during their existence have the potential for the subsequent transformation into a producing system of both phytoplankton and macrophyte type [19]. They differ in area, prevailing depths and overgrowth by higher aquatic vegetation (Table 1). The primary production is formed mainly due to macrophytes. Their abundance, obviously, determines the succession status of each of the examined reservoirs. The influence of floods in the sewage lakes decreases with distance from the channel of the Ob River and high-altitude location (in the direction of Abat - Karasevoye - Malva). Lake Inkino is flooded by hollow waters only in the years of high water content.

**Table 1. General characteristics of studied lakes.**

| Lake     | Area, ha | Prevailing depths, m | High aquatic vegetation coverage, % |
|----------|----------|----------------------|-------------------------------------|
| Abat     | 15       | 2.0-2.5              | 25                                  |
| Karasevoye | 9       | 0.7-1.2              | 65                                  |
| Malva    | 3        | 1.8-2.0              | 30                                  |
| Inkino   | 7        | 2.5-3.5              | 15                                  |

In all studied lakes, the environment was slightly alkaline, close to neutral. Both lake water and river water is mostly calcium-sodium. The values of electrical conductivity and the concentration of dissolved CO₂ in these lakes might be different (Table 2). A positive correlation of the CO₂ content with the development of higher aquatic vegetation is observed. The neutral environment (pH about 7) is regulated by the presence of carbon and carbonic acids, and it is also characteristic of most natural waters [8, 20-22]. Carbon dioxide is formed due to oxidation of organic matter in water or bottom sediments, respiration of aquatic organisms, fermentation of decaying organic residues, geochemical processes in sedimentary rocks [20, 23].

**Table 2. Physical parameters and elements’ concentrations in studied lakes.**

| Lake     | CO₂, ppm | CH₄, μmol/l | pH  | Cond, μSm/cm | Ca, μg/l | Na, μg/l | Mg, μg/l | Si, μg/l | K, μg/l | P, μg/l | Al, μg/l |
|----------|----------|-------------|-----|--------------|----------|----------|----------|----------|---------|---------|----------|
| Abat     | 10000    | 89.6        | 7.3 | 328          | 37800    | 17180    | 9297     | 5514     | 1643    | 31.25   | 1,361    |
| Karasevoye | 13500   | 137.16      | 7.2 | 223          | 32210    | 4457     | 8046     | 6146     | 805.2   | 50.31   | 2,688    |
| Malva*   | 6920     | 22.4        | 7.3 | 189          | -        | -        | -        | -        | -       | -       | -        |
| Malva**  | 1690     | 1.34        | 7.9 | 232          | 34710    | 7032     | 5249     | 1581     | 18.91   | 7,522   | -        |
| Inkino*  | 4780     | 9.95        | 7.3 | 137          | 18110    | 4180     | 4985     | 1066     | 804     | 9,453   | 2,721    |
| Inkino** | 1320     | 0.2         | 7.9 | 141          | 18590    | 6511     | 4467     | 896      | 963.3   | 6,095   | 2.96     |
Lake СО₂, ppm CH₄, μmol/l pH Cond, μSm/cm Ca, μg/l Na, μg/l Mg, μg/l Si, μg/l K, μg/l P, μg/l Al, μg/l

“-” absent, * - sampled in July, ** - sampled in September

As a result of the study, the following values and indicators of the status of the examined reservoirs were obtained:

21 species of zooplankton have been identified in floodplain lakes (Table 3). The lake Abat has extremely low species composition. This lake has average depths (for surveyed water bodies) and quantity of high aquatic vegetation (4 species in total). The largest number of species were identified in the shallow macrophyte lake Karasevoye that, obviously, is caused by a variety of habitat. These two lakes are characterized by the highest biomass of zooplankton in summer. The Cladocera group is the most abandoned in the total biomass of zooplankton in these bodies. This group is filter feeders according to the feeding method (Table 4). This group is also part of the summer dominant complex of two other lakes (Malva and Inkino). But Copepoda and its juveniles are more than half of the total biomass of zooplankton in a drainless relatively deep-water lake Inkino. In the autumn their proportion in this reservoir increases up to 94%. At the same time, the total biomass of zooplankton in this lake at the end of the developmental cycle of the Cladocera does not decrease, as it usually happens, but increases. In the shallow lake Malva in autumn Cladocera were not found in the samples, and the total biomass decreases very sharply (by a factor of 36).

Table 3. Species composition and biomass (mg / m³) of zooplankton in studied lakes.

| Zooplankton groups and species | Abat | Karasevoye | Malva* | Malva** | Inkino* | Inkino** |
|-------------------------------|------|------------|--------|---------|---------|---------|
| **Rotatoria**                 |      |            |        |         |         |         |
| Synchaeta oblonga Ehrenberg, 1831 | -    | -          | r      | r       | -       | -       |
| Polyarthra longiremis Carlin, 1943 | 4    | 24         | r      | r       | 1       | -       |
| P. vulgaris Carlin, 1943       | -    | -          | r      | 2       | 6       | -       |
| Asplanchna priodonta Gosse, 1850 | -    | 248        | 3      | 3       | -       | -       |
| Euchlanis dilatata unisetata Leydig, 1854 | -    | 3          | -      | -       | -       | -       |
| Platyias patulus patulus (Mueller, 1786) | -    | 3          | r      | r       | -       | -       |
| Keratella cochlearis (Gosse, 1851) | 1    | 1          | r      | r       | -       | -       |
| K. quadrata (Muller, 1786)     | -    | r          | -      | -       | -       | -       |
| Hexarthra mira (Hudson, 1871)  | -    | -          | 10     | 10      | -       | -       |
| **Total Rotatoria**            | 5    | 279        | 15     | 15      | 7       | 0       |
| **Cladocera**                 |      |            |        |         |         |         |
| Diaphanosoma brachiurum (Lievin, 1848) | -    | 223        | -      | -       | -       | -       |
| Daphnia longispina (O.F. Muller, 1785) | 6101 | r          | 778    | -       | 1       | 30      |
| D. cucullata (Sars, 1862)      | -    | -          | -      | -       | 144     | -       |
Zooplankton groups and species | Abat | Karasevoye | Malva* | Malva** | Inkino* | Inkino**
--- | --- | --- | --- | --- | --- | ---
*Simocephalus vetulus* (O.F. Muller, 1776) | - | r | - | - | - | -
*Ceriodaphnia pulchella* Sars, 1862 | - | 46 | - | - | - | -
*Chydorus sphaericus* (O.F. Muller, 1785) | - | - | - | - | 1 | -
*Alona affinis* Leydig, 1860 | - | - | - | 1 | - | -
*A. guttata* Sars, 1862 | - | 2 | - | - | - | -
*Bosmina longirostris* (O.F. Muller, 1785) | - | 990 | - | - | - | 1
**Total Cladocera** | 6101 | 1261 | 778 | 146 | 32 | **Total Copepoda**

*Heterocope saliens* (Liljeborg, 1863) | - | - | - | - | 101 | 360
*Thermocyclops crassus* (Fischer, 1853) | - | 20 | - | - | 9 | -
*Cyclops sp.* | 11 | - | - | - | - | 148
*Nauplii* | 20 | 135 | 3 | 3 | 7 | x
*Copepodita* | - | 794 | 4 | 4 | 50 | x
**Total Copepoda** | 31 | 949 | 7 | 7 | 167 | 508
**Total** | 6137 | 2521 | 800 | 22 | 320 | 540

r – rare species, - - absent, * - sampled in July, ** - sampled in September

In general, the biomass value shows the positive correlation with the concentration of dissolved CO₂. Spearman’s correlation coefficient is 0.8, with p = 0.05. The species composition and the dominant zooplankton complex in each of the surveyed lakes are quite specific. The coefficients of similarity of the species composition of zooplankton between the lakes range from 21 to 60 (Table 4). Differences between lakes on this indicator mainly depend on the differences between lakes in depth and overgrowth, and the total biomass in the summer period is directly related to the length of the flood, decreasing as it is remote from the riverbed of the Ob and high-altitude location of the lake. These indicators can be the basis for developing a classification of lakes located in the floodplain of the Middle Ob.

Zooplankton biomass in the lakes Malva and Inkino is estimated as low, in the lake Karasevoye as medium, in the lake Abat as high.

Table 4. Similarity coefficients of species composition of zooplankton between studied lakes.

|       | Abat | Karasevoye | Malva | Inkino |
|-------|------|------------|-------|--------|
| Abat  | -    | 30         | 50    | 60     |
| Karasevoye | 30   | -          | 45    | 21     |
| Malva | 50   | 45         | -     | 38     |
| Inkino| 60   | 21         | 38    | -      |

Talking about saprobic species, the most common Rotifers in the studied lakes are *Asplanchna priodonta*, the most common Cladocera - *Diaphanosoma brachiurum, Ceriodaphnia pulchella, Bosmina longirostris, Chydorus sphaericus*, who belong to β- and o- β-mesosaprobies. The juvenile copepods are
very common; adults are absent or few. The exception is lake Inkino, where in the summer and, especially, in the autumn, a significant proportion of the total biomass of zooplankton is *Heterocope saliens* (Copepoda).

According to the saprobity indices, all lakes belong to the 3rd class (β – mesosaprobic zone). Within the limits of this class, in the summer period, the Karasevoe and Inkino lakes are characterized by the smallest values of the saprobity index, the Abat and the Malva have the largest saprobity index (Table 5). The dependence of the index values on the impact of high water, depth and overgrowth of water bodies was not identified.

| Lakes      | Number of species | Biomass, mg/m³ | Dominant complex (% of total biomass)          | Iₛ |
|------------|------------------|----------------|-----------------------------------------------|----|
| Abat       | 4                | 6137           | *Daphnia longispina* (99%), *Asplanchna priodonta* (10%), *Diaphanosoma brachiurum* (9%), *Bosmina longirostris* (39%), *Copepoda juveniles* (32%) | 2,10 |
| Karasevoye | 14               | 2521           | *Copepoda juveniles* (32%)                      | 1,62 |
| Malva*     | 8                | 800            | *Daphnia longispina* (97%)                      | 2,09 |
| Malva**    | 7                | 22             | *Hexarthra mira* (68%), *молодь копепод* (30%)    | 1,77 |
| Inkino*    | 7                | 320            | *D. cucullata* (45%), *Heterocope saliens* (32%), *молодь копепод* (18%) | 1,73 |
| Inkino**   | 6                | 540            | *Heterocope saliens* (67%), *Cyclops sp* (27%)  | 2,07 |

* - sampled in July, ** - sampled in September, Iₛ – saprobic index

**Conclusion**

Judging by the current state, the shallow lake Karasevoye is the most aged among the examined lakes. The lake Inkino, which is the most remote from the river Ob, is at a relatively early stage of succession, and the lakes Abat and Malva have an intermediate position in the succession line.

The studies convincingly showed that the differences between the lakes in hydrological, chemical and environmental indicators are quite large, which makes it possible to use these bodies of water as a model when conducting monitoring studies to identify the interannual, cyclic and successive processes occurring in them.

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**References**

[1] Petrov I B 1979 *The Ob-Irtysh Floodplain. Typification and Quality Evaluation* (Novosibirsk: Nauka, Siberian Branch Publ.) 136 (In Russian)

[2] Viers J, Barroux G, Pinelli M, Seyler P, Oliva P, Dupre B and Resende Boaventura G 2005 *Science of the Total Environment* **339** 219–32
[3] McClelland J W et al 2016 *Global biogeochemical cycles* **30** 629–43

[4] Kwon M J, Heimann M, Kolle O, Luus K A, Schuur E A, Zimov N, Zimov S A and Göckede M 2016 *Biogeosciences* **13** 4219-35

[5] Fatschevskiy B V 2007 *Scientific notes of the Russian State Hydrometeorological University* **5** 118-29 (In Russian)

[6] Popkov V K and Popkova L A 2010 *The current state of aquatic biological resources*, ed E W Pitschenko and I W Moruzi (Novosibirsk: Novosibirsk State Agricultural University) 156-60 (In Russian)

[7] Bustillo V, Victoria R L, De Moura J M S, Victoria D De and Colicchio E 2011 *Earth Interactions* **15** 1–28

[8] Bayanov N G and Krivdina T V 2013 *Regional Research of Russia* **2** 52–67 (In Russian)

[9] Seidel M, Dittmar T, Ward N D, Krusche A V, Richey J E, Yager P L and Medeiros P M 2016 *Biogeochemistry* **131** 281–302

[10] Havlikova P, Chuman T, Jansky B 2017 *Environmental Monitoring and Assessment* **189** (12) 639

[11] Ivanov A I and Dudkin E A 2014 *Models, systems, networks in economics, technology, nature and society* **4** (12) 200–7 (In Russian)

[12] Alimova G S, Tokareva A Yu, Popova E I, Zemtsova E S and Chemagin A A 2015 *Recent problems of science and education* **5** 670. (In Russian)

[13] Bianchini I-Jr and da Cunha-Santino M B 2016 *Wetlands* **36** 557–64

[14] Popkov V K, Popkova L A, Ruzanova A I and Golubykh O S 1996 *Biological resources of the Middle Ob floodplain: dynamics and forecast*, ed A M Adam (Tomsk: AO «Izd-vo NTL») 140-81 (In Russian)

[15] Jaccard P 1901 *Bulletin de la Société vaudoise des sciences naturelles* **37**(140) 241-72

[16] Temporary guidelines for hydrobiological analysis of water quality in small rivers 1994 (Moscow: Nauka) 106 (In Russian)

[17] Kitaev S P 1984 *Ecological basis of bioproductivity of lakes of different natural zones* (Moscow: Nauka) 207 (In Russian)

[18] Prokushkin A S, Pokrovsky O S, Shirokova L S, Korets M A, Viers J, Prokushkin S G, Amon R M W, Guggenberger G and McDowell W H 2011 *Environmental Research Letters* **6** (4) 045212

[19] Pokrovskaya T N, Mironova N Ya and Shilkrot G S 1983 *Macrophyte lakes and their eutrophication* (Moscow: Nauka) 153 (In Russian)

[20] Alekin O A 1953 *Basic Concepts of Hydrochemistry* (Leningrad: Gidrometeorologicheskiye Publ.) 296 (In Russian)

[21] Hutchinson G E 1969 *A Treatise on Limnology: Geography, Physics, and Chemistry* (Moscow: Progress Publ.) 591 (In Russian)

[22] Shirokova V I, Chubinskaya K M, Orekhova K T, Lanskoy V F, Millitsin N P 2015 Proceedings of the Mordovia State Nature Reserve **13** (13) 233-99 (In Russian)

[23] Amaral J H F et al 2018 *Science of the Total Environment* **630** 1381–93