Influence of meromixia on the distribution of zoobenthos and zooplankton in the salt soda lake Doroninskoe

P V Matafonov
Institute of Natural Resources, Ecology and Cryology Siberian Branch of RAS, 16a, Nedorezova Street, Chita, 672014, Russian Federation
E-mail: benthos@yandex.ru

Abstract. Meromictic soda lakes are considered models of reservoirs of the Early Proterozoic. Lake Doroninskoe belongs to a rare type of moderately salty alkaline soda lake with a carbonate type of salinity and pronounced meromixia. Studies and publications on the zoobenthos of the lake are rare. In 2005–2007, studies of zoobenthos and zooplankton of the lake were carried out. Meromixia of the water column caused the stable presence of zooplankton only in a layer up to 4 m. The distribution of the taxonomic abundance, quantitative development and structure of zoobenthos in the lake corresponds to the stratification of the water column into mixolimnion, chemocline and monimolimnion. Bottom biotopes and water column layers deeper than 4 m were uninhabited, which is probably due to the lack of oxygen and high hydrogen sulphide content in the bottom water layers due to meromixia. A similar distribution of zooplankton in Lake Doroninskoe and its mesocosm model was revealed.

1. Introduction
Soda lakes are considered models of the conditions that existed on Earth in the Early Proterozoic [1]. Such lakes have a number of unique characteristics: the dominance of cyanobacteria, insignificant abundance of aquatic vegetation, pronounced features of the water’s chemical composition, pronounced stratification of the water column, etc.

Lake Doroninskoe belongs to a rare type of moderately salty alkaline soda lake with a carbonate type of salinity and pronounced meromixia – only a few soda meromictic lakes are known in the world. It is believed that Lake Doroninskoe is the only soda meromictic reservoir in Siberia [2]. Studies of hydrochemical, hydrophysical, microbiological and geochemical characteristics showed the uniqueness of the lake's meromixia [3–5]. Information on the zoobenthos and zooplankton in the lake is rare [6, 7]. This limits the understanding of the role of biota in the function of the lake’s ecosystem. In addition, studies of the zoobenthos and zooplankton of Lake Doroninskoe are necessary to determine the possibility of using mesocosms for modelling the ecosystems of meromictic lakes. The prospects of using mesocosms to understand the ecosystems of meromictic lakes were revealed previously when modelling the hydrochemical and microbiological components of the Doroninskoe Lake ecosystem in the mesocosm [8].

The aim of this study was to identify the influence of meromixia on the distribution of zoobenthos and zooplankton in Lake Doroninskoe.
2. Methods
Lake Doroninskoe (51.235819°N, 112.236149°E) is located in the Amur River basin in the forest-steppe zone. The area of the lake is about 5 km², and the depth reaches 6 m in high-water years. The lake is meromictic with a pronounced gradient of hydrochemical and hydrophysical characteristics in the water column [3–5]. Bottom sediments up to a depth of 3 m are represented by sand, silted sand and clay, bottom sediments with colonies of cyanobacteria, and in the central part oily black silts with an odour of hydrogen sulphide.

Zoobenthos samples were collected from December 2005 to September 2007 using a Petersen dredger with a capture area of 0.025 m². To identify the effect of meromixia, zoobenthos samples were taken at a depth interval of 0.5 m. Sampling was performed on the profile of the north-west coast at the deep center in September 2007. One sample was taken at each depth. The samples were washed through a sieve with a mesh of 0.3 mm. The samples were preserved in a 4% formalin solution. The taxonomic abundance was estimated by the number of taxa in the sample in an area of 0.025 m².
In December 2005 and October 2006, zooplankton samples were collected using a bathometer. The samples were fixed with 4% formalin solution. The weight of the organisms in the sample was determined by a calculated method based on the relationship between the mass and body length of the organisms.

3. Results and Discussion
Only six species of zoobenthos were found in Lake Doroninskoe in 2005–2007: chironomids Procladius (Psilotanykus) sp. and Cryptotendipes sp.; ceratopogonidae Palpomyia (G.) tuvae Remm, 1972 and Palpomyia (P.) gr. rufipes; and beetles Hygrotus (C.) enneagrammus (Ahrens, 1833) and Berosus sp.

The taxonomic abundance of zoobenthos in Lake Doroninskoe was low. In 2007, in the depths zone up to 1.5 m, its values did not exceed 4 species in 0.025 m² (figure 1). Zoobenthos was represented here by all the identified species. In the depth range of 2–4 m, Procladius (P.) sp. larvae and, occasionally, H. enneagrammus beetles were found. Zoobenthos were not found deeper than 4 m.

![Figure 1. Distribution of taxonomic abundance and biomass of zoobenthos in Lake Doroninskoe in September 2007.](image-url)
In 2007, the highest abundance and biomass of zoobenthos were at depths of 1.5 and 2 m (figure 1). The abundance of zoobenthos here reached 14,280 ind. m$^{-2}$, and the recorded biomass was 57.5 g m$^{-2}$. Beetles accounted for most of the biomass of zoobenthos to a depth of 1.0 m. The larvae of Procladius sp. comprised up to 99% of the abundance and biomass of zoobenthos were created in the depth zone from 2.0 m. Average (M±SE) the values of the abundance and biomass of zoobenthos were 2363±1279 ind. m$^{-2}$ and 9.84±5.1 g m$^{-2}$, respectively, on the examined profile. Procladius sp. (67.3%) and Hygrotus sp. (21.5%) dominated the biomass of zoobenthos. The larvae of Cryptotendipes sp. were assigned to the meiozoobenthos, their abundance exceeded 2000 ind. m$^{-2}$ at a depth of 0.3 m, and at a depth of 2 m, it was 40 ind. m$^{-2}$, with no larvae were found deeper than 4 m.

From 2005–2006, the distribution of zoobenthos in the lake (table 1) corresponded, in general, to the results of 2007. The taxonomic abundance in shallow water did not exceed four taxa in the sample. Larvae and imago of H. enneagrammus and Berosus sp. comprised most of the zoobenthos’ biomass in shallow water. The larvae of Procladius sp. caused a high abundance of zoobenthos in the depth zone of 2.5–3 m (table 1). Single individuals found in the zone of depths from 4.8 m, apparently, were brought here by water currents.

**Table 1.** Abundance (A, ind. m$^{-2}$), biomass (B, g m$^{-2}$) and taxonomic abundance (TA, taxa 0.025 m$^{-2}$) of zoobenthos in Lake Doroninskoe from 2005–2006.

| Date       | Depth, m | Indicator | Procladius sp. | P. (G.) tuvae | H. (C.) enneagrammus | Berosus sp. | Total | TA |
|------------|----------|-----------|----------------|---------------|---------------------|-------------|-------|----|
| 10.12.2005 | 0.7      | A         | 2920           | 4080          | 2000                | 1720        | 10720 | 4  |
|            | B        | 1.72      | 1.20           | 13.60         | 5.76                | 22.28       |       |
|            | A        | 16340     | 320            | –             | –                   | 16660       | 2     |
|            | B        | 64.12     | 0.02           | –             | –                   | 64.16       |       |
| 02.08.2006 | 2        | A         | 4340           | 180           | 80                  | 460         | 5060  | 4  |
|            | B        | 2.82      | 0.22           | 0.54          | 2.56                | 6.14        |       |
|            | A        | 5640      | –              | 180           | –                   | 5820        | 2     |
|            | B        | 20.52     | –              | 0.88          | –                   | 21.4        |       |
| 10.2006    | 4.8      | A         | 40             | –             | –                   | 40          | 1     |
|            | B        | 0.06      | –              | –             | –                   | 0.06        |       |
|            | A        | –         | –              | 20            | –                   | 20          | 1     |
|            | B        | –         | –              | 0.02          | –                   | 0.02        |       |
| 2.4        | A        | 10600     | 40             | 80            | –                   | 10720       | 3     |
|            | B        | 25.76     | 0.04           | 0.48          | –                   | 26.28       |       |
| 10.2006    | 6.2      | A         | –              | –             | –                   | –           |       |
|            | B        | –         | –              | –             | –                   | –           |       |
|            | A        | –         | –              | –             | –                   | –           |       |
|            | B        | –         | –              | –             | –                   | –           |       |

* absence of organisms.

The copepod *Metadiaptomus asiaticus* (Uljanin, 1875) was found in the zooplankton of Lake Doroninskoe. In December 2005, its distribution in the water column was not regular: its low abundance was noted in a layer at 4 m (table 2). In October 2006, studies revealed that stable zooplankton communities exist in a layer of up to 4 m. Copepods were not found at the surface or
deeper than 4 m; they were most abundant at the surface to a depth of 1 m. In the depth range after than 1 m, copepod density decreased with depth according to logarithmic dependence 

\[ y = -26.395 \ln(x) + 43.943 \quad (R^2 = 0.99) \]

**Table 2.** Abundance (A, \( \times 10^5 \) ind. m\(^{-3} \)) and biomass (B, g m\(^{-3} \)) of *M. asiaticus* in Lake Doroninskoye.

| Depth, m | December, 2005 | | October, 2006 | |
|---------|----------------|---|----------------|---|
|         | A   | B   | A      | B   |
| 0       | –    | –    | 0      | 0    |
| 1       | 10.8 | 0.631 | 45.0   | 2.649 |
| 2       | 16.0 | 0.980 | 25.0   | 1.472 |
| 3       | 12.0 | 0.653 | 15.0   | 0.883 |
| 4       | 0.4  | 0.022 | 5.0    | 0.294 |
| 5       | 14.2 | 0.869 | 0      | 0    |
| 6       | –    | –    | 0      | 0    |
| Total   | 53.4 | 3.2  | 90.0   | 5.3  |

\( ^a \) no samples.

Studies in 2005–2007 showed a pronounced effect of meromixia on zoobenthos and zooplankton in Lake Doroninskoe. Stable communities of zoobenthos and zooplankton in the lake were found only up to a depth of 4 m. A depth of 4 m was critical for zoobenthos; organisms found deeper than 4 m were only observed accidentally.

Changes in zooplankton at a specific depth corresponded to the stratification of the water column into mixolimnion, chemocline, and monimolimnion. A complex of hydrochemical and hydrophysical factors caused changes in zooplankton with depth. The lack of oxygen in the zone of maximum depths [3] is probably the main reason for the absence of organisms deeper than 4 m. In addition, a significant decrease in the redox potential and a high content of hydrogen sulphide in water layers deeper than 4 m [3] could limit the spread of zooplankton in the monimolimnion.

The main features of changes in the taxonomic abundance and abundance of zoobenthos corresponded to the distribution of bottom sediments and stratification of the water column. The zone up to 4 m inhabited by zoobenthos corresponded to the mixolimnion; the uninhabited zone was the monimolimnion, and the intermediate zone corresponded to the chemocline. In the coastal zone, the change in the structure of zoobenthos at a depth of 1.5 allows to distinguished littoral subzones.

The revealed features of the spatial distribution of zoobenthos and zooplankton are necessary to verify the correspondence of ecosystems of real reservoirs and their models mesocosms. Thus, the vertical distribution of *M. asiaticus* in Lake Doroninskoe corresponded to the vertical distribution of rotifers in the water column of the mesocosm of Lake Doroninskoe [8, 9]. In both cases, zooplankton organisms inhabit the upper layers of the water column above the chemocline.

Zoobenthos and zooplankton of the lake were represented by the species inhabiting salt and brackish lakes with extreme environments. *M. asiaticus* is a widespread in salty reservoirs. *P. tuvae*, *Berosus sp.*, and the larvae of *Procladius sp.* are the main components of the benthos in drying steppe brackish lakes, such as the Zun-Torey Lake [10]. *H. enneaphragma* are also inhabitants of brackish lakes. Larvae of the genus *Procladius* are predominantly predators, but in Lake Doroninskoe, detritus and cyanobacteria are probably the main food sources for *Procladius* sp. Colonies of cyanobacteria formed the upper layer of bottom sediments in larval habitats and comprised the majority of the larvae gut content. This feeding system likely allowed the species to achieve high abundance in relatively extreme environment caused by meromixia.

**Acknowledgments**

This study was supported by the Program for Basic Research of the Siberian Branch of the Russian Academy of Sciences, № 121032200070-2.
References

[1] Zavarzin G A and Zhilina T N 2000 *Nature* **2** 45–55
[2] Gorlenko V M, Buryukhaev S P, Matyugina E B, Borzenko S V, Namsaraev Z B, Bryantseva I A, Boldyрева Е N, Sorokin D Yu and Namsaraev B B 2010 *Microbiology* **79** 410–21
[3] Zamana L V and Borzenko S V 2007 *Reports of the Academy of Sciences* **417** 232–5
[4] Borzenko S V, Zamana L V and Noskova E V 2015 *Advances In Current Natural Sciences* **1** 420–5
[5] Bordonskiy G S, Gurulev A A, Lukyanov P Yu, Orlov A O and Tsyrenzhapov S V 2015 *Scientific notes of Transbaikal State University* **62** 17–25
[6] Itigilova M Ts 2010 Daily migration of zooplankton in soda lake Doroninskoe (Transbaikalia) *Proc. of the Conf. Ecology of aquatic invertebrates* (Borok: IBIW) pp 119–22
[7] Matafonov P V 2009 Zoobenthos of the soda-salt lake Doroninskoe *Proc. of the 10th Congress of the Hydrobiological Society at the Russian Academy of Sciences* (Vladivostok: Dal'nauka) p 260
[8] Matyugina E B, Borzenko S V, Matafonov P V and Belkova N L 2014 *Current Res. Microbiol. Biotech.* **2** 398–401
[9] Matafonov P 2014 *Advances In Current Natural Sci.* **11** 137–8
[10] Matafonov P and Bazarova B 2018 *Res. J. Pharm. Biol. Chem. Sci.* **9** 120–8