Diversity of littoral zoobenthos in Lake Arakhley (Transbaikalia) during the arid phase

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Abstract. There is little data available on the zoobenthos of the Baikal region’s eastern periphery water bodies in low-water years. The taxonomic diversity of zoobenthos of the littoral zone of a deep lake (Arakhley, Transbaikalia) was studied in an extremely low-water year, 2017. The zoobenthos of the lake littoral zone was represented by 44 taxa. Chironomids accounted for 41% of the zoobenthos taxonomic diversity, 14% each – gastropods and leeches. The taxonomic diversity of the littoral zoobenthos in different parts of the lake varied from 19 to 24 taxa and averaged 22.3 ± 1.97 taxa. The relationship between taxonomic diversity and depth in Lake Arakhley is described by polynomial dependence. Deviations from the relationship identified at the periphery of vegetation thickets were due to the ecotone effect. Obtained data shows the state of zoobenthos taxonomic diversity under conditions of climate aridization and the reduction of littoral sandy habitats.

1. Introduction
The effect of water level fluctuations on lakes’ ecosystems has been studied relatively well [1, 2]. However, in deep lakes, irreversible and undesirable changes can occur suddenly, due to the spatial complexity of their ecosystems and the asynchronous response of littoral and pelagic communities to changing environment factors [3, 4]. These phenomena determine the need for monitoring the littoral zone of deep lakes [4].

Transbaikalia is located at the junction of natural zones in mountainous conditions; it has an ultra-continental climate and significant cyclical long-term fluctuations in the moisture content of the territory. Natural conditions and the ancient complex history of ecosystem formation determined the diversity of aquatic ecosystems. Data on the state of taxonomic diversity of zoobenthos in the aquatic ecosystems of Transbaikalia in dry years are limited and obtained only at shallow steppe lakes [5-7].

Lake Arakhley is one of the largest reservoirs in Transbaikalia. It is a deep, thermally stratified lake of the Ivano-Arakhley lakes’ system, located in the forest-steppe zone on the eastern periphery of the Baikal region near the junction of the Amur, Lena, and Yenisei river basins. Since the 1960s, Lake Arakhley has been studied as the model ecosystem in hydrobiological research in Transbaikalia [8]. The purpose of complex studies on the lake is to identify the regularity of long-term changes in the structural and functional organization of regional aquatic ecosystems.

There is a problem of method differences when comparing the long-term monitoring data of lake ecosystems [1]. An analysis of long-term data on Lake Arakhley [9, 6] reveals various volumes of hardly comparable and scattered data on the lake zoobenthos’ taxonomic composition and diversity. The reason is the laboriousness of the research, the lack of a unified research program, and the irregularity of monitoring.
The detailed studies were carried out in the 1960s [9]. Later, studies were carried out at a limited number of monitoring stations and mainly during periods of high water levels [6]. There is no data on the composition and diversity of species of the zoobenthos of the Ivano-Arakhley lakes’ system in dry years. This lack of data limits the ability to study the zoobenthos response to habitat and climate changes in the Baikal region. Besides, it hampers the development of programs for the protection of biodiversity and the use of resources of aquatic ecosystems.

This study aimed to identify the species diversity of zoobenthos in the littoral zone of Lake Arakhley and its spatial distribution in the extremely low-water period of 2017.

2. Methods
Detailed information about the lake characteristics and research methods was presented earlier [10, 11]. The area of Lake Arakhley is 58 km², its length is 11 km, and its depth is 16.7 m. An aridization of climate has led to a decrease in the water level of Lake Arakhley to extremely low values over a 60-year observation period. It was found that the littoral zone was limited to a depth of 4.5 m, up to which macrophytes were found, represented here by the *Potamogeton praelongus*. Only parts of plants removed from the littoral zone were observed deeper than 4.5 m.

In 2017 monitoring stations were laid in the western (west), northern (north) and southern (south) parts of Lake Arakhley in the depth ranged from 0 to 4.5 m. In June, samples were taken in the western littoral with a depth interval of 0.5 m; in August, samples were taken in the western and southern littoral with a depth interval of one meter; in October, samples were taken in the western and northern littoral with a depth interval of one meter. The coordinates of the western station “depth 4.5 m” is 52.16959° N and 112.84344° E, coordinates of the southern station “depth 4.5 m” is 52.16959° N and 112.84344° E, and the coordinates of the northern station “depth 4.4 m” is 52.24719° N and 112.91512° E. At every depth, one sample was taken with a Petersen bottom grab, with a sampling area of 0.025 m². Totally, 30 samples were taken.

3. Results and discussion
Forty-four zoobenthos taxa were found in the littoral zone of Lake Arakhley (table 1); 40 of them were found on the western profile. Chironomids accounted for 41% of the taxonomic diversity of zoobenthos, 14% each – gastropods and leeches.

The number of taxa in the sample reached 15 (table 2). The taxonomic diversity of the zoobenthos was in a relatively narrow range from 19 to 24 taxa and amounted to 22.3 ± 1.97 (Mean ± SD) taxa in five samples from the zone of depths from 0 to 4.5 m. Differences between profiles and seasonal fluctuations of the indicator in the western littoral were within this range. The taxonomic diversity evenly increased to a depth of 4 m, then it decreased. In the depth range of 0–6 m, the relationship between taxonomic diversity and depth in Lake Arakhley was described by the polynomial dependence:

\[ y = -1.2707x^2 + 8.6573x + 4.2967 (R^2 = 0.75) \]  

(1)

The high values of taxonomic abundance and taxonomic diversity found at depths of 1.5 and 4.0 indicated the ecotone effect on the periphery of macrophytes thickets.

Comparison of our data with the results of previous studies [6, 9] is difficult due to the discrepancies in research methods and the use of an irreproducible research program in high-water years. A list of species of the littoral zoobenthos of Lake Arakhley, according to I M Shapovalova [9], includes 110 taxa. Such studies provide the most complete data on the taxonomic diversity of the zoobenthos of Lake Arakhley, but in practice, the terms of these studies are difficult to reproduce. Despite the frequent scheme of monitoring stations in 2017, no caddisflies, *Lymnaea* spp., and a number of Oligochaeta and Chironomidae species were found in the zoobenthos of the littoral zone.
Table 1. Taxonomic composition of the littoral zoobenthos of Lake Arakhly in 2017.

| Taxa                                      | Inhabited depths, m | Occurrence, % | Density, ind. m² |
|-------------------------------------------|---------------------|---------------|------------------|
| Porifera                                  | 2 – 4.5             | 33.3          | 14³ (40 – 240)⁶  |
| Oligochaeta                               |                     |               |                  |
| Uncinais uncinata (Orsted, 1842)          | 1 – 2.5             | 10.6          | 22 (40 – 1,240)  |
| Limnodrilus hoffmeisteriae Claparede,1862 | 1.5 – 4.5           | 16.7          | 41 (80 – 360)    |
| Tubifex tubifex (O.F. Müller, 1773)       | 0.5 – 6.0           | 33.3          | 14 (40 – 53)     |
| Rhyacodrilus sibiricus Semernoy, 1971     | 1.5 – 2.5           | 13.3          | 26 (40 – 1,040)  |
| Lumbriculus sp.                           | 4.5 – 5.0           | 3.3           | 1 (40)           |
| Hirudinea                                 |                     |               |                  |
| Albuglossiphonia heteroclitica (L., 1761) | 3.0 – 4.5           | 16.7          | 5 (80 – 80)      |
| Erpobdella lineata (O.F. Müller, 1774)    | 1.5 – 5.5           | 13.3          | 3 (40 – 40)      |
| Glossiphonia complanata (L., 1758)       | 1.5 – 5.0           | 33.3          | 15 (40 – 280)    |
| Helobdella stagnalis (L., 1758)          | 2.0 – 6.0           | 33.3          | 15 (40 – 320)    |
| Hemiclepsis marginata (O.F. Müller, 1774) | 2.0 – 4.0           | 16.7          | 4 (40 – 80)      |
| Psectrocladius gr. appendiculata          | 1.0 – 1.5           | 3.3           | 1 (40)           |
| Stictichironomus gr. totendi              | 1.5 – 2.5           | 13.3          | 2 (40 – 80)      |
| Procladius gr. pedellus                   | 3.5 – 6.0           | 3.3           | 3 (160)          |
| Psectrocladius (P.) zetterstedti Brundin, 1949 | 0.5             | 3.3           | 3 (200)          |
| Polypedilum (T.) bicrenatum Kieffer, 1921 | 1.5 – 2.5           | 16.7          | 11 (40 – 480)    |
| Chironomus gr. phosphus sp.1              | 3.0 – 5.0           | 16.7          | 11 (40 – 240)    |
| Ch. gr. phosphus sp.2                     | 1.5 – 4.0           | 23.3          | 6 (40 – 120)     |
| Cryptochironomus gr. defectus             | 1.0 – 5.5           | 26.7          | 25 (40 – 560)    |
| Endochironomus albipennis (Meigen, 1830)  | 1.5 – 4.5           | 20.0          | 54 (40 – 1,560)  |
| Glyptotendipes barbipes (Staeger, 1839)   | 3.0 – 4.0           | 6.7           | 1 (40)           |
| Gl. caudaticola (Kieffer, 1913)           | 2.0 – 4.0           | 6.7           | 2 (40 – 80)      |
| Microtendipes gr. pedellus                | 3.5 – 6.0           | 3.3           | 3 (160)          |
| Stictichironomus gr. crassiforceps        | 0.0 – 2.5           | 23.3          | 77 (80 – 2,000)  |
| St. gr. histrio                           | 0.5 – 1.5           | 10.0          | 9 (40 – 360)     |

* mean in the 0–4.5 m depth zone

⁶(min – max) in the habitats
Along with the difference in the research program, the absence of some of the zoobenthos taxa in Lake Arakhley in 2017 could be due to the extremely low water level and the associated drainage of shallow sandy-pebble and sandy biotopes. As in Lake Zun-Torey [12], the water level decreasing by two meters in Lake Arakhley led to a reduction in the habitats of the littoral zoobenthos and a shift in the ratio towards the prevalence of biotopes of deep zones formed in Lake Arakhley on silty sediments. Sandy and pebble bottom sediments are widespread to a depth of three meters and more in high-water years [9]. In 2017, only silty bottom sediments were found in the western littoral of the lake deeper than two meters. This is also indicated by the moisture content of bottom sediments in 2017, which in the zone of depths up to 1.5 m, inclusive, varied from 25 to 30%, and at a depth of two meters and deeper, was not lower than 90%, which corresponds to silts. The littoral zone is a zone of high zoobenthos diversity; therefore, the reduction in littoral sandy habitats could be a factor in the decrease in the occurrence of psammophilic zoobenthos and the decrease in taxonomic diversity of lake zoobenthos in general.

Compared with the zoobenthos of the larger shallow steppe lake, Zun-Torey [7], the taxonomic diversity of zoobenthos in Lake Arakhley is much higher in the extremely dry period. 14 taxa were found in Lake Zun-Torey, and the taxonomic abundance of its zoobenthos did not exceed seven. In both cases, in extremely dry years, there was a reduction in the zoobenthos habitats formed on sandy and pebble-sandy bottom sediments.

The data obtained in 2017 characterized the taxonomic diversity of zoobenthos on the eastern periphery of the Baikal region during an extremely dry period. We anticipate that sandy biotopes and psammophilic communities of zoobenthos will occupy an insignificant part of the littoral if the level of Lake Arakhley decrease by one meter. An increase in Lake Arakhley’s water level should lead to an increase in the maximum depth of the littoral zone, restoration of drained sandy habitats, and an increase in the taxonomic diversity of zoobenthos.

### 4. Conclusion

Our results revealed the need to develop a program for long-term monitoring of the taxonomic diversity of the Ivano-Arakhley lake’s zoobenthos. We propose to sample zoobenthos using the net of monitoring stations established during this research plus to determine the number of samples on the monitoring profile in dependence on the depth of the littoral zone. Such a scheme allows to identify trends in changes in the taxonomic diversity of littoral zoobenthos under the influence of changes in the water level and climate. Perhaps, the data obtained in 2017 on Lake Arakhley will be useful when comparing the taxonomic diversity of zoobenthos in different types of lakes of the Baikal region.

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**Table 2. Taxonomic abundance and diversity of littoral zoobenthos in Lake Arakhley in 2017.**

| Depth (m) | Taxonomic abundance (taxa 0.025 m⁻²) on the profiles | Taxonomic diversity (number of taxa) |
|-----------|------------------------------------------------------|-------------------------------------|
|           | June west | August west | August south | October west | October north | Mean |
| 0         | 3         | 4           | 3            | 2            | 3.0           | 5    |
| 0.5       | 3         | 9           | 4            |              | 5.7           | 11   |
| 1.0       | 4         | 9           | 4            |              | 7.7           | 12   |
| 1.5       | 8         | 6           | 14           |              | 9.3           | 20   |
| 2.0       | 9         | 9           | 5            | 8            | 7.7           | 12   |
| 2.5       | 7         | 10          | 8            |              | 9.3           | 12   |
| 3.0       | 7         | 13          | 8            | 8            | 9.3           | 20   |
| 3.5       | 9         | 10          | 8            |              | 9.3           | 20   |
| 4.0       | 12        | 12          | 15           | 10           | 9.3           | 23   |
| 4.5       | 11        | 7           | 7            |              | 9.3           | 16   |
| 5.0       | 7         | 9           | 6            |              | 7.3           | 15   |
| Taxonomic diversity (number of taxa) | 23 | 21 | 24 | 24 | 19 | 23 | 44 |

* in the littoral
Acknowledgments
This study was supported by the Program for Basic Research of the Siberian Branch of the Russian Academy of Sciences, project No. FUFR-2021-0006.

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