

# The changes in the profundal benthos during the extremely low water level in the deep lake Arakhley (Siberia)

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**Abstract.** Data on the impact of long-term water level fluctuations on benthic invertebrate communities of the deep lakes in Siberia are scarce due to the rarity of such events and the short history of observations. The studies of the dynamics of zoobenthos and the *Chironomus anthracinus* population in the central part of the profundal zone of the deep Lake Arakhley (Transbaikalia region, Russia) were carried out in December 2020-2023. The lake level was extremely low in 2020-2023. Zoobenthos biomass increased by 10.9 times from 6.6 g to 71.8 g/m<sup>2</sup> from 2020 to 2023. The increase in zoobenthos abundance is due to increases in the number and biomass of oligochaetes *Tubifex tubifex* and chironomids *Chironomus anthracinus*. In December 2022, the *Chironomus anthracinus* population was dominated by second-instar larvae with a size of 8.7±0.08 mm, in 2023 - third-instar larvae with a size of 13.2±0.10 mm. The growth rate of *Chironomus anthracinus* corresponded to a three-year life cycle. Annual production of *Chironomus anthracinus* in 2022 was 16 g/m<sup>2</sup>, in 2023 – 22.8 g/m<sup>2</sup>. The results of the study revealed significant fluctuations in the structure, abundance and production of zoobenthos in the profundal zone of Lake Arakhley during the extremely low-water period.

## 1 Introduction

There is little information on the ecological effects of natural water level fluctuations in lakes. This applies to lakes in general and deep stratified lakes in particular. The reasons are economic regulation of the water level of many lakes, the rarity of long-term fluctuations, and in the case of deep stratified lakes, their relative scarcity. There are few publications on Russia and Siberia, as well as on invertebrates. Long-term monitoring research in Siberia is carried out on the ancient Lake Baikal. Long-term fluctuations in the water level regime are provoked by climate change, are characterized by significant amplitude and can therefore be triggers for important changes in the state of aquatic ecosystems. In shallow lakes, a decrease in the water level causes extreme living conditions for organisms and a pronounced change in communities even in their central part. Deep, stratified lakes are characterized by spatial complexity and asynchronous response of coastal and deep zone communities to changes in factors. The significance of water level fluctuations in such lakes is better expressed in the

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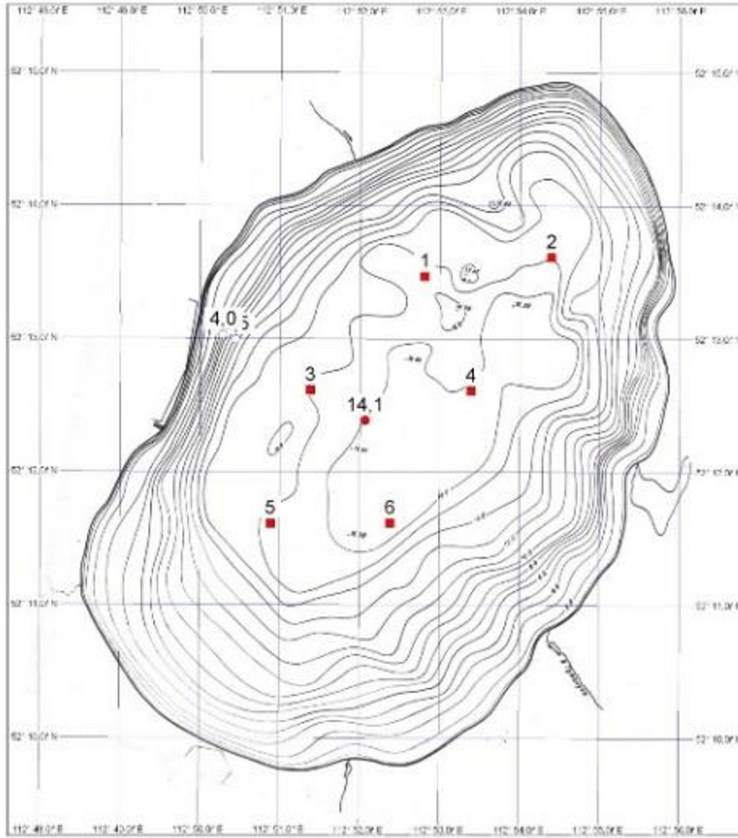
coastal zone, while in the deep zone they are unclear. The beginning of the 21st century turned out to be extremely dry in Siberia, which allows us to expand our understanding of the response of benthic communities and ecosystems of deep lakes to water level fluctuations and related factors.

Benthic invertebrates are one of the main components of benthic communities in the profundal zone of lakes, so they are used to identify patterns in the dynamics and evolution of profundal and hypolimnion communities in deep lakes under the influence of natural and anthropogenic factors. Continuous data series from long-term studies are especially necessary because they allow us to identify long-term trends. Comprehensive hydrobiological studies have been conducted on Lake Arakhley since the 1960s, but information on the state of the zoobenthos of this lake relates mainly to medium- and high-water years. Information on the zoobenthos of Lake Arakhley during the low-water phase is very scarce. There is only an assumption that the water level and the abundance of zoobenthos are in antiphase. The aim of the study was to assess the state of the zoobenthos in the profundal zone of deep Lake Arakhley in extremely low-water years [1-17].

## 2 Materials and methods

The studies of the zoobenthos of Lake Arakhley were carried out from December 16 to 23, 2020-2023 at the monitoring station «14.1» in the central part of the lake (52.2059°N, 112.8673°E) (Fig. 1). Lake Arakhley is the largest, deepest, stratified reservoir in the forest-steppe zone of southern Siberia. The climate of the territory is moderate, sharply continental with long-term cyclic changes in moisture. The previous low water level in the lake was in the 1980s. From 1996 to 2018, the water level in the lake decreased again to extremely low levels over a 70-year period. Then the water level began to rise. From 2020 to 2022, the lake depth in the central part increased from 13.83 m to 14.1 m, in 2023 it decreased to 13.87 m. Over a 70-year period, the amplitude of lake level fluctuations was about 2.3 m. The lake area is about 56 km<sup>2</sup>. The lake is freshwater. Ice cover forms on the lake from October to May. The bottom water temperature in the central part of the lake in early August 2020-2023 was in the range of 11-12.3°C. The surface temperature of silt sediments at the monitoring station in December 2020-2023 varied in the range of 3.5-4°C. Stratification of water masses and the appearance of a thermocline at a depth of 10-11 m in the summer in high-water years are noted in the lake. Littoral zone was 12%, the sublittoral zone was 32%, and the profundal zone was 56% of the benthic area in the western part of the lake during the research period. Thus, the profundal zone occupies most of the lake benthic. It corresponds to the hypolimnion layer and is limited from above by the thermocline layer.

Sampling was performed using a Petersen bottom grab (DCH-0.025) with a capture area of 0.025 m<sup>2</sup>. Samples were washed through a sieve with a mesh size of 0.30 mm. Weight of the organisms was determined after they were dried until the water disappeared from the surface of their body. 218 larvae of 2022 and 172 larvae of 2023 were measured to study the size structure of the *Ch. anthracinus* population. Standard errors were calculated for the average values. The estimated production rates of *Chironomus* were calculated using the method of Boysen-Jensen. The elimination of biomass *Tubifex* was not taken into account.



**Fig. 1.** Scheme of monitoring stations for long-term monitoring of zoobenthos in the profundal zone of Lake Arakhley. Red punch and numbers 1-14.1 are the numbers of monitoring stations.

### 3 Results

Zoobenthos at the monitoring station in the central part of Lake Arakhley in 2020–2023 was represented by the oligochaetes *Tubifex tubifex* and *Limnodrilus profundicola*, chironomids *Chironomus anthracinus* and *Tanytarsus pseudolestagei* Shilova, 1976. Oligochaetes *T. tubifex* were found throughout the entire study period, while *Limnodrilus profundicola* were found from 2020 to 2022, *T. pseudolestagei* – in 2022, and *Ch. anthracinus* were found in 2022 and 2023 (Table 1).

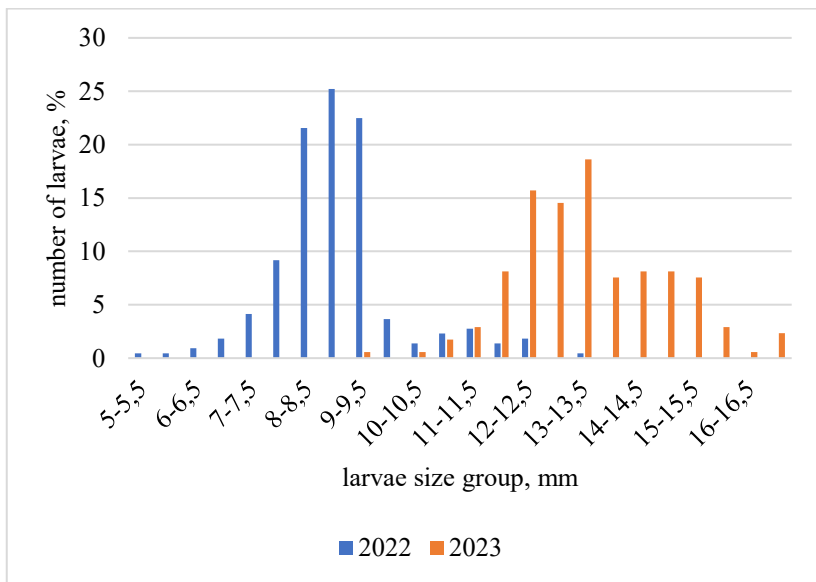
Abundance of zoobenthos on the monitoring station in the central part of Lake Arakhley varied by 9 times, and biomass by 10.9 times (Table 1). In 2020–2021, zoobenthos was represented only by oligochaetes and was characterized by low abundance. In 2022–2023, there was an outbreak of chironomids, which led to an increase in the abundance of zoobenthos and the complexity of its structure. Zoobenthos production also varied widely - from 8 g / m<sup>2</sup> to 44 g / m<sup>2</sup>. The main changes of zoobenthos abundance occurred in 2022, when biomass increased fourfold. This was influenced by a steady increase in the abundance of *T. tubifex*, and the appearance of juvenile *Ch. anthracinus*. Together, these species accounted of zoobenthos production in 2022. In 2023, the increase in zoobenthos biomass was due to *Ch. anthracinus* (Table 1), while the biomass of other zoobenthos representatives decreased. The abundance of oligochaetes *L. profundicola* steady decreased throughout the

entire study period. Thus, the larvae of the chironomid *Ch. anthracinus* have become one of the main zoobenthos components by the end of the study period. A slight decrease in the abundance of *Ch. anthracinus* during 2023 from 8720 ind./m<sup>2</sup> to 6840 ind./m<sup>2</sup> corresponds to the formation of a new zoobenthos structure with the dominance of the chironomid *Ch. anthracinus*.

**Table 1.** Changes in biomass and zoobenthos production in the central part of Lake Arakhley

Taxa	Biomass, g / m <sup>2</sup>				Production, g / m <sup>2</sup>		
	2020	2021	2022	2023	2021	2022	2023
<i>L. profundicola</i>	4.6	2.7	2.2	–	-1.9	-0.6	-2.2
<i>T. tubifex</i>	2.0	12.0	40.6	33.0	10	28.6	-7.6
<i>Ch. anthracinus</i>	–	–	16.0	38.8	–	16.0	29.9
<i>T. pseudolestagei</i>	–	–	0.04	–	–	0.04	-0.04
Total	6.6	14.7	58.8	71.8	8,1	44.1	20.1

The growth rate of *Ch. anthracinus* larvae in Lake Arakhley was low. In December 2022, the larval sizes ranged from 5 to 13.4 mm ( $8.7 \pm 0.08$  mm,  $M \pm SE$ ), with the 8–9.5 mm size group predominating (69.3%) (Fig. 2). By December 2023, the size of *Ch. anthracinus* larvae increased and ranged from 9.0 to 17 mm ( $13.2 \pm 0.10$  mm), with the 12–13.5 mm (48.8%) and 13.5–15.5 mm (31.4%) size groups predominating (Fig. 2). The individual weight of the larvae increased from 1.83 mg to 5.67 mg. Thus, in December 2022, most of the larvae corresponded to the second instar and the 2022 generation, and in December 2023 – to the third instar. By the end of larval development, the *Ch. anthracinus* larvae should reach the size of the fourth instar and about 18 mm in length, which suggests the emergence of adults of the 2022 generation in June 2025. Thus, the analysis of the size structure of the *Ch. anthracinus* population shows a three-year life cycle of *Ch. anthracinus* in the profundal of Lake Arakhley in 2022-2023.



**Fig. 2.** Size structure of the *Ch. anthracinus* population at the monitoring station in the central part of Lake Arakhley in December 2022 and 2023.

Larvae of the genus *Tanytarsus* were rare during the study period – 80 ind./m<sup>2</sup>. Their sizes ranged from 3 to 6.3 mm.

## 4 Discussion

Identifying the contribution of natural and anthropogenic factors that determine the dynamics of communities is a difficult task. Long-term data series of monitoring studies make it possible to identify trends in benthic communities and their relationship with anthropogenic influence, and to analyze the ecological aspects of climate change. Such studies are demanding in terms of the volume and continuity of the data array, but data series are not always long and continuous. In addition, identifying trends in changes in communities and ecosystems under the influence of various factors is complicated by changes in research goals and methods, and sampling schemes. A review of studies of the zoobenthos of the profundal zone of Lake Arakhley revealed the above-mentioned problems in relation to the analysis of long-term data series of zoobenthos for the entire lake. One of the main problems is the lack of data for low-water years. The studies carried out in 2020-2023 at the station in the central part of the lake fill this gap to some extent. Significant changes in zoobenthos from 2020 to 2023 do not agree with the assumption that the main changes in the abundance and functional indicators of zoobenthos in Lake Arakhley are determined exclusively by the dynamics of the water level in the lake. Fluctuations in the abundance, structure and production of zoobenthos were quite significant even in adjacent years with changes in the level of only 0.27 m, which is about 2% of the lake depth in these years. The reasons for changes in benthos may be anthropogenic eutrophication, introduction alien species, deuterotrophication and etc. Significant changes in lake Arakhley could have been caused by the life cycle and ecology of the dominant taxa - oligochaetes and chironomids.

A peculiarity of the research period is the absence of *Chironomus* larvae in the zoobenthos in 2020-2021, although they were always present in previous years. The colonization of the territory by *Ch. anthracinus* at the research station in 2022 could have occurred from refugium habitats. The high abundance of the 2022 generation led to high increases in larval biomass in 2023, despite the low growth rates of larvae. Very low growth rates of larvae in Lake Arakhley are mainly due to the low temperature of the bottom water layers, which in early August 2020-2023 was only 10-12 °C. It is known that animal growth rates depend on temperature and decrease with decreasing temperature. In addition, the growth of *Ch. anthracinus* in Lake Arakhley stops during the ice period due to a decrease in the silt temperature to 3.5-4°C.

Chironomids larvae of the genus *Chironomus* are one of the main food items for benthophagous fish in lakes, which affects the temporal dynamics of the population. Unexpectedly, a slight decline in the abundance of larvae in Lake Arakhley in 2023 at a high their density apparently is due to low perch consumption, one of the main consumers of larvae of the genus *Chironomus* in the lake. This, in turn, may be due to the large number of fish-eating birds *Phalacrocorax carbo* on the Ivano-Arakhley lakes, the appearance of which is associated with a significant decrease in the abundance of perch in the lake during the research period.

Higher settlement density and intrapopulation competition for space and trophic resources may have a greater impact on the dynamics of *Ch. anthracinus* larval abundance in the profundal of Lake Arakhley in the future, rather than interspecific relationships. The importance of density in intrapopulation regulation of the abundance of chironomids of the genus *Chironomus* is known. Climate changes may affect the abundance of chironomids (including the genus *Chironomus*) by the mechanism of density dependence. The absence of younger *Ch. anthracinus* larvae in Lake Arakhley in 2023 may be due to the influence of intrapopulation competition for territory. The intestines of the larvae in December 2022 were

filled in most of the larvae, and in 2023 they were empty, which may also be a consequence of increased intrapopulation competition for trophic resources as the larvae grow under conditions of their high density. A further decrease in the number of larvae of the 2022 generation is possible due to increased intrapopulation competition and limited trophic resources necessary for larval growth.

There are studies that oligochaetes Tubificidae and chironomids genus *Chironomus* larvae are competitors and their abundance dynamics are in antiphase. Indeed, there are opposite dynamics of their abundance in the profundal of Lake Arakhley in 2020-2023. Nevertheless, a number of features of the biology of *T. tubifex* indicate its adaptation to competition with *Ch. anthracinus* larvae. Unlike chironomids, *T. tubifex* showed high activity during the under-ice period of 2020-2023. Thus, in December, it had a large number of breeding individuals, cocoons or juveniles. In 2020, the number of oligochaetes cocoons was 360 cocoons/m<sup>2</sup>, and in 2022 it reached 2920 cocoons/m<sup>2</sup>. In December 2023, no cocoons were found, but young oligochaetes were abundant. The feeding habits of *T. tubifex* also apparently allow it to avoid competition with *Chironomus* larvae. *T. tubifex* feeds in deep layers of bottom sediments, while *Ch. anthracinus* larvae are surface collectors of bottom sediments. The fullness of the gut indicates that *T. tubifex* actively feeds in December, unlike *Ch. anthracinus*.

Since zoobenthos indicators depend on the state of bottom sediments and bottom water layers, changes in zoobenthos from 2020 to 2023 may also reflect changes in the hydrophysical parameters of the habitat of zoobenthos organisms, as well as the functioning of pelagic communities and the lake ecosystem. In the years preceding the study, a significant transformation of the pelagic zooplankton of Lake Arakhley occurred. Thus, changes in the zoobenthos during the low-water period of 2020-2023 could be caused the state ecosystem of Lake Arakhley or in its plankton community.

## 5 Conclusion

Significant changes in the abundance, structure and production of zoobenthos at the monitoring station in the central part of the lake of Lake Arakhley were revealed in the extremely low-water years of 2020-2023. The reasons for these changes are not related to the dynamics of the water level and are apparently determined primarily by the ecology of the chironomid larvae and oligochaete that dominate the benthos. The level of quantitative development of zoobenthos is high, its functional indicators were determined mainly by *Ch. anthracinus* and *T. tubifex*. By consuming oxygen or undulating, chironomids and oligochaetes change the oxidation-reduction potential of bottom sediments and other physicochemical parameters of the benthic and bottom layers of water. They participate in destruction of organic matter and migration of chemical elements in bottom sediments and the removal of elements from aquatic ecosystems. Significant changes in density, biomass and production suggest significant changes the role of zoobenthos in the fluxes of matter and energy at the water-bottom sediment boundary at the monitoring station in the central part of Lake Arakhley in extremely low-water years. Probably, under certain conditions this role can be very high.

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