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The dynamics of biogenic elements in the ecosystem of Lake Arakhley (Eastern Transbaikalian Region)

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Abstract. This study presents the interannual dynamics of biogenic elements (nitrogen and phosphorus) in Lake Arakhley and compares functioning values of the water ecosystem within different types of intra-annual (seasonal) dynamics of the content of biogenic elements and organic matter in low water years and high water years. The research shows tendencies of increasing and decreasing contents of nitrogen and phosphorus. In low water years, organic matter is autochthonous, whereas in high water years its origin is allochthonous. The concentrations of biogenic elements do not exceed the values of maximum permissible concentration in fishery waters which means that eutrophication has not started. It was found that the dynamics of the content of nitrogen and phosphorus is determined by change in abiotic conditions and rate of biochemical and biological processes. The findings provide better understanding how mesotrophic lakes function.

1. Introduction

Lake Arakhley is located in Eastern Siberia in the watershed of the Vitim and the Selenga Rivers. The area of the lake belongs to the Vitim taiga highland province of Baikal and Jugur mountain taiga region. The altitude of the lake bottom is 944-965 m above sea level. The Arakhley valley is surrounded by the Osinovy Ridge in the north and northeast and by the Yablonovy Ridge in the southeast [1]. The catchment area of the lake is 256 km², the surface area – 54 km², the maximum depth – 14 m, the average depth – 10.2 m. Lake Arakhley is important for recreation and fishery industry of Transbaikalian Region.

The quality of water ecosystems is significantly influenced by climatic changes of the southeast of Transbaikalian Region, described by V A Obyazov [2]. Climatic cycles registered annually over a long period of time contribute to water content of the lake. In those climatic cycles, high water years were in 1988, and in the period from 1996 to 1999, whereas low water years were observed from 2008 to 2017. According to the findings by V A Obyazov et al. [3], the duration of a complete climatic cycle is equal to 10-14 years. During our observations, the level of the lake changed within the range from 2.0 to 2.2 m.

Cyclic climatic fluctuations influence the ecosystem functions of water bodies. The dynamics of nitrogen and phosphorus concentration depends on the rate of biochemical and biological processes that in their turn indicate changes in water bodies. Organic matter content is the key factor that determines not only the quality of water but also the living conditions for hydrobionts, and, indirectly, general biological productivity of water bodies [4, 5].



2. Materials and Methods

The materials presented in this research are based on the findings of hydrochemical research (1988, 1996-1998; 2008-2009) on Lake Arakhley performed by the water ecosystems laboratory of the Institute of Natural Resources, Ecology and Cryology of the Siberian Branch of the Russian Academy of Sciences.

Throughout the study period, we carried out more than 30 expeditions in different seasons of the year. For hydrochemical analysis, we used water samples taken by Patalas bathometer. The biogenic elements content was measured by standard techniques: nitrites were determined using the Griess reagent; nitrates – by recovery to nitrites with the Griess reagent; the Nessler's reagent was used for determination of ammonia ions; the mixed reagent was used for phosphates; and the determination of total phosphorus was conducted by digestion with potassium persulphate. The permanganate oxidizability values (PO) were determined by the Kubel method, the chemical oxygen demand values (COD) were obtained by oxidizing organic compounds by potassium dichromate in a sulphuric acid solution. The optical densities of the solutions were measured using spectrophotometer SPEKOL-1300 [6].

3. Results and Discussion

The interannual dynamics of biogens in the lake is complicated and depends on the effects of the previous year, high-water season, hydrological processes, etc. As it was stated above, high water period lasted up to 2000, while the period from 2008 to 2017 was marked as arid with small amount of annual rainfall. It was found that in terms of water budget of Lake Arakhley, the precipitation inputs on the lake surface slightly prevail over inflow contribution (precipitation – 17.8 million m³/year, inflow – 16.1 million m³/year); while evaporation outputs are significant in contrast to outflow (evaporation – 27.1 million m³/year, outflow – 6.8 million m³/year [3, p 24].

Low content values of nitrites (0.002-0.007 mg/l) and nitrates (0.011-0.014 mg/l) registered in 1988, 1997, 1988 are due to the high rate of nitrification caused by significant water oxygenation (85-125 %). The research has shown that in 1988, 1996-1998 the minimal concentrations of nitrates were observed in the surface of the water column in the summer, whereas the maximal values were registered throughout the whole water column in the winter. In 2008-2009, the content of nitrates increased and remained in the range of 0.025-0.029 mg/l (Figure 1).

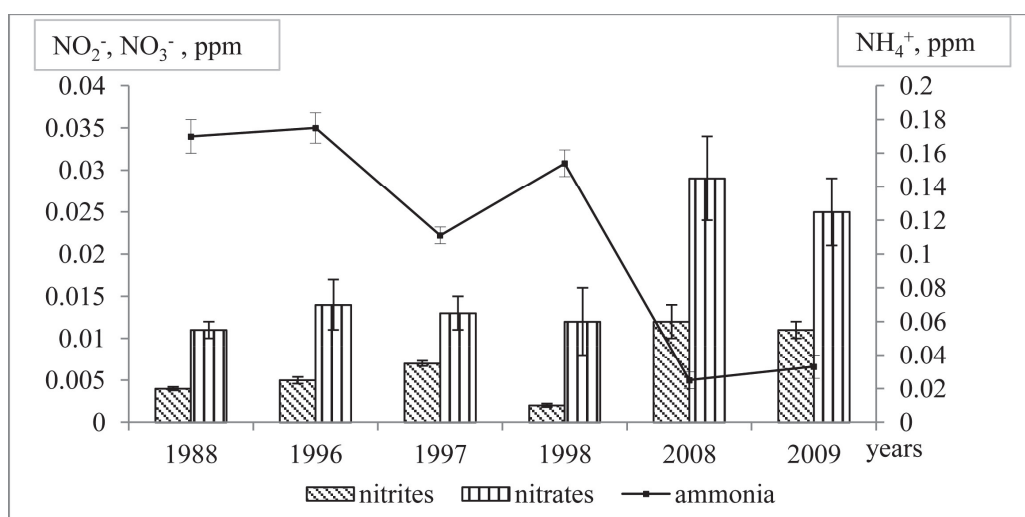


Figure 1. The content of ammonia nitrogen, nitrates and nitrites in Lake Arakhley.

The content of mineral nitrogen and its interannual dynamics in low water years were generally determined by the reserves of nitrate nitrogen. The source of uninterrupted replenishment of mineral phosphorus compounds including them into the cycle of matter can be explained by high rate of the

destruction processes in the column of water predominant over the phytoplankton production [7]. Besides, phosphates are produced as a result of the zooplankton regeneration. It was observed that from 10 to 20 % of the overall water body production is supplied by the phosphorus released by the zooplankton [8].

Low values of organic phosphorus (0.003-0.015 mg/l) were noted in high water years (1998, 1996-1998) while its concentration increased in 2008-2009 (0.029-0.044 mg/l) (Figure 2).

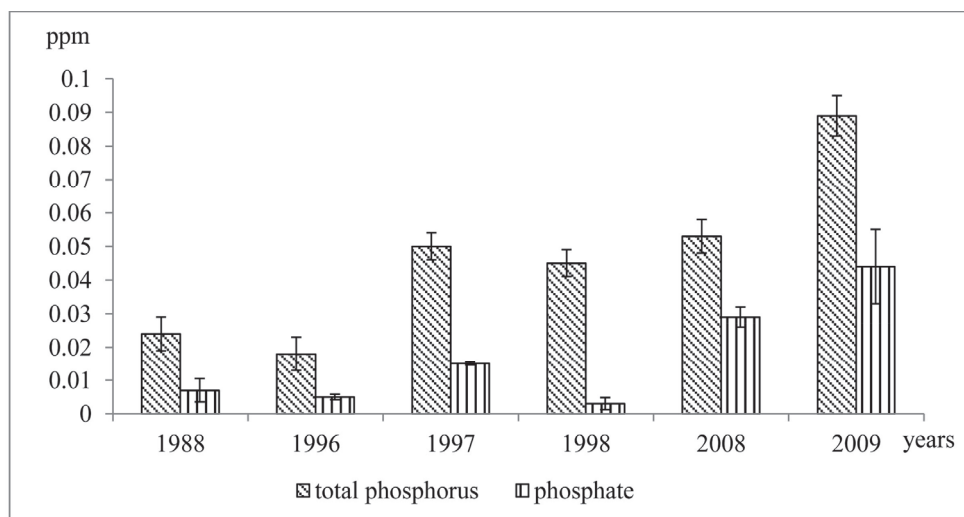


Figure 2. The dynamics of the content of phosphorus in Lake Arakhley.

Low phosphorus concentration in the lake during high water years can be due to iron that precipitates phosphorus to the bottom sediments as insoluble compounds. According to research [9], the average content of total iron in Lake Arakhley changes from 0.10 to 0.35 mg/l with extreme values of 0.96 mg/l.

Increased phosphorus content results from growing inner phosphorus load during low water years. Seasonal and long-term changes in phosphate content are caused by the phytoplankton development and intense destruction of organic matter in the lake [10,11].

In 1996-1998, the average ratio of $P_{\min}/P_{\text{total}}$ was 0.22 (predominant organic phosphorus), whereas, in 2008-2009, it was 0.52 (practical correlation between mineral and organic forms of phosphorus). This goes to show intense biochemical processes in the ecosystem leading to production of nutrients and decomposition of organic wastes which ensures the normal course of life in the lake. The water of the lake is diluted with rainfall in high water years that changes the content of biogenic elements as it was found in the research [11, 12]. Table 1 shows the findings on biogenic elements for the recent years the content of ammonia and nitrite nitrogen as well as phosphate phosphorus tend to decrease (Table 1). It was found that short-term recurring cycles of drying and wetting contribute to high rates of phosphate mineralization compared to high water period [13].

Table 1. Interannual dynamics of biogenic elements (nitrogen and phosphorus) in Lake Arakhley (mg/l).

Year	NO_2^- (N=26)	<i>p</i>	NO_3^- (N=26)	<i>p</i>	NH_4^+ (N=26)	<i>p</i>	PO_4^{3-} (N=26)	<i>p</i>	P_{total} (N=26)	<i>p</i>
2017	0.005	0.0001	0.25	0.06	0.004	0.0003	0.009	0.0006	0.075	0.024
2018	0.035	0.0009	0.74	0.12	0.002	0.0002	0.014	0.0008	0.035	0.007
MAC ^a	3.30		40.0		1.50		1.14		3.50	

^aMAC - the maximum allowable concentration in fishery waters [14].

In 2017-2018 low water years, nitrates and total phosphorus content continues to increase not exceeding the values of maximum permissible ratio (MPR) for the fishery water bodies. Meanwhile, according to the findings of 2017-2018, the ratio of PO/COD is less than 50 % which is typical for low water years (Table 2).

Table 2. Interannual dynamics of the content of organic matter in Lake Arakhley (mg/l).

Year	PO (N=26)	<i>p</i>	COD (N=26)	<i>p</i>
2017	4.9	0.9	10.3	3.2
2018	6.1	1.2	12.1	4.1
MAC	12.0		30.0	

Consequently, the formation of organic matter is generally determined by inner production and destruction processes.

4. Conclusion

Cyclic climatic changes of the rainfall amount lead to the fluctuation of water content of lakes. The dynamics of the content of nitrogen and phosphorus is determined by change in abiotic conditions and rate of biochemical and biological processes as well as concentration of organic matter brought from the water catchment area.

The research on changes in the nitrogen and phosphorus concentrations and composition of organic compounds proved that nitrates and total phosphorus content increases in low water years while the content of ammonia and nitrite nitrogen and phosphate phosphorus decreases. In low water years, organic matter is autochthonous, whereas in high water years its origin is allochthonous. The recent findings on the content of biogenic elements for 2017-2018 indicate lower values compared to MAC. Thus, inner processes of the lake observed in low water years indicate mesotrophic trophicity. The relevance of the study is derived from an increasing tendency of recreational impact and commercial fishing pressure on the lake.

Acknowledgments

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