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Hydro-Chemical Characteristic And Peculiarities Primary Production Of Lake Shebety (Zabaikalsky Krai, Russia).

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ABSTRACT

Freshwater reservoirs, without the influence of human production, are one of the most environmentally valuable parts of our planet. Changes in freshwater ecosystems can be assessed by comparing the status of model reservoirs with anthropogenically disturbed ones. The aim of the work is to reveal the ecological state of Lake Shebety as a model reservoir for the mountain taiga zone of North Asia. For water mineralization, Lake Shebety refers to the class of ultra-fresh water bodies with a weakly alkaline reaction medium. The direct thermal stratification and homogeneity of macro- and microelements distribution in depth are noted. Due to the small catchment area (10.5 km^2), significant part of biogenic elements are of autotrophic origin. COD corresponds to 18.8 mg/L, permanganate oxidability of organic matter (PO) – 2.6 mg/L. Gross primary production is the greatest in the surface horizon of the lake deep-water part (0.37 mgO_2/L). The primary production of plankton for the year corresponds to 60.0 g/m^3. As many oligotrophic reservoirs, it has a hydrocarbonate-calcium mineral composition of water. The obtained data are essential in monitoring studies of mountain of mountain freshwater reservoirs to assess the degree of changes occurring under the natural and anthropogenic factors.

Keywords: mountainous territory, freshwater reservoirs, Lake Shebety, hydrochemistry, primary production, oxidizability, organic matter.

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INTRODUCTION

The assessment of the state and prediction of environmental changes is considered one of the most important tasks of environmental research [2, 4, 16, 34, 42].

There are fewer freshwater reservoirs that are subjected to anthropogenic impact. Economic activities covered not only the drainage basins, but also the lakes themselves (artificial change in the water level, discharge of various drains, recreation, fish farming etc.). We know that the anthropogenic impact, during the current global climate change, introduces significant changes in the state of hydrobionts' habitat, determining the conditions for their life activity. Changes in ecosystem cause an increase in the rate of structural and functional rearrangements [3, 28, 32].

The purpose of this work is to show the ecological state of Lake Shebety as a model reservoir for the mountain taiga zone of North Asia. The first studies of hydro-chemical and productional characteristics of Lake Shebety are shown in comparison with other ultra-fresh water reservoirs of the mountain territories (Lakes Baikal, Teletskoye, Bukukun) [38, 11, 12, 24, 27, 35]. The obtained data are necessary in monitoring studies of mountain reservoirs to assess the degree of their changes under the natural and anthropogenic factors pressure.

MATERIALS AND METHODS

The Shebety is a freshwater reservoir located in the territory of the "Chikoy" National Park. The national park is located in the buffer zone of the Baikal natural territory. The lake is located at an absolute altitude of 1567.4 m (Figure 1). The Chikokonsky Range, that surrounds the lake, has absolute altitudes from 1653.5 m – in the north, up to 2252.8 m – in the south. The lake originated 18-20 thousand years ago in the maximum stage of the Sartan glaciation [13]. The lake is flowing, from the south-west the Porokhovoy stream flows, which discharge, at the time of the survey, was 1.3 m^3/s. On the western shore, a stream, without a name, flows of the lake. The area of the lake is 0.87 km^2, the maximum depth is 42.5 m, the average depth is 18 m, and the catchment area is 10.5 km^2.

The material for the hydro chemical analysis was water samples from Lake Shebety, collected during the expeditionary research in July 2002 and 2016. Station 1 – is located at the northern sandy shore of the lake at the depth of 4.5 m. Station 2 is located in the deepwater part of the reservoir. Station 3 (depth 1.8 m) is near the stream mouth. The Porokhovoy characterizes the shallow ecotope with air-water plants. Transparency of water in our studies reached 5 m.

Water samples were taken with Patalas bathometer. To determine the macro-component composition, water was studied with atomic absorption, photometric, gravimetric and titrimetric methods of analysis in accordance with certified methods in the accredited laboratory of the JSC "Laboratory Research Center for the Study of Mineral Raw Materials" (JSC LRCSMRM) (accreditation certificate No. RA.RU.510387, issued on May 27, 2015).

To determine the content of biogenic elements, water samples were fixed and delivered to the Institute laboratory. The water analysis was done using a spectrophotometer SPEKOL-1300. The following methods were used: a method with the addition of Griss reagent for the determination of nitrites, a method of reduction to nitrites with a Griss reagent for determination of nitrates, a method with the addition of Nessler reagent for ammonium ions, a method with a mixed reagent for phosphates, a burning method with potassium per sulphate for total phosphorus.

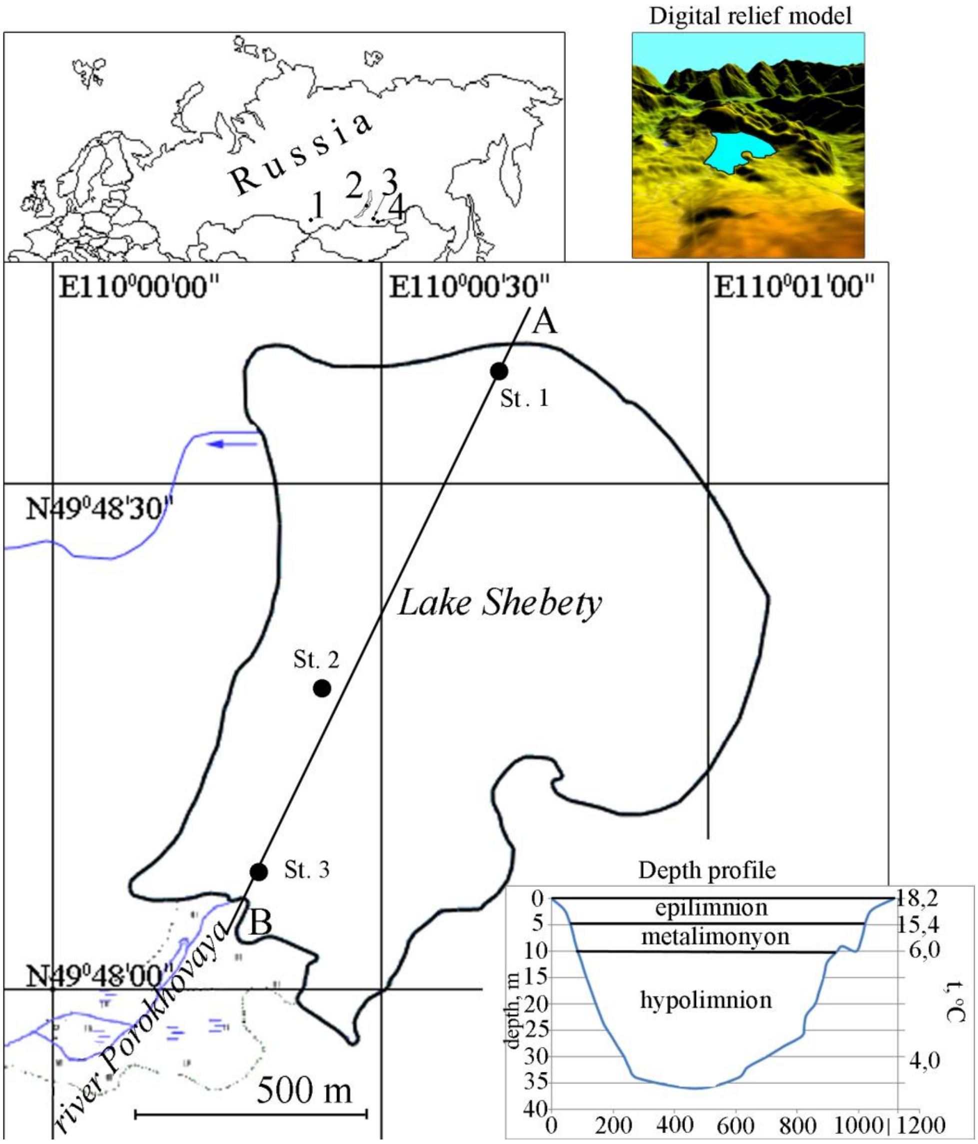

Figure 1: Scheme of location of Lake Shebety (Zabaikalsky Krai): 1 - Lake Teletskoye; 2 - Lake Baikal; 3 - Lake Shebety; 4 - Lake Bukukun

To determine the primary production and destruction of organic matter, the “bottles” method was used «in situ» in the oxygen modification, firstly it was proposed by G.G. Vinberg [39]. Despite the fact that the “bottle” method has a number of vulnerabilities, associated mainly with isolating organisms in a closed volume, it continues to be a common method in the production studies of phytoplankton [9, 22, 23, 25]. The results were obtained with a 24-hour bottles exposure in the water sampling horizons (surface – 0 m, translucence – 2.5 m, transparency – 5.0 m, double transparency – 10.0 m and bottom water layer).

Statistical processing of data was carried out using Microsoft Word Excel software.

RESULTS AND DISCUSSION

Physico-chemical indicators of water. The physical processes, taking place in water bodies, influence the formation of the habitat of hydrobionts and their vital activity. At the end of July, a direct thermal stratification in Lake Shebety is established (Table 1). The thickness of the upper warmed-up horizon of water was 2.5 – 5.0 m. In shallow coastal zones of the lake, the temperature between the surface horizons and the bottom layers of water varies insignificantly (0.1 - 0.2 °C). In the central deep-water part of the lake, the difference between the temperature of the surface and bottom layers is 14 °C. Such direct thermal stratification is a characteristic of deep-water lakes such as Lake Baikal, the lakes of the Finnish lake Plateau, and the lakes of Estonia [4, 35, 38]. Corresponding to the vertical distribution of the temperature gradient of lakes [6, 20] the water layer of Lake Shebety can be divided into epilimnion (up to 5 m), metalimnion (5-10 m), hypolimnion (from 10 m to the bottom).

Table 1: Some physicochemical indicators of the water of the Shebety Lake

Station	Water sampling horizons, m	T, °C	pH	Oxygen, mg/L / % saturation	Color change, grade	Turbidity, mg/L
Station 1	0	18,1	7,09	5,9 / 60,7	17	0,34
	4,5	18,0	8,00	5,7 / 58,5	17	0,34
Station 2	0	18,0	7,22	8,48 / 87,1	17	0,46
	2,5	18,0	7,80	8,48 / 87,1	17	
	5	15,4	7,86	8,48 / 82,7	17	
	10	6,0	7,50	7,63 / 60,7	17	
	26	4,6	7,22	6,95 / 53,4	17	
Station 3	0	18,8	8,26	8,27 / 85,9	19	0,55
	1,8	18,6	8,20	8,48 / 88,1	18	0,42

In the near-bottom horizons of the deep-water part of the lake, due to a decrease in water transparency, we observe oxygen-depletion by a factor of 1.2 in comparison with the surface, and oxygen saturation – by a factor of 1.6. The opposite situation is in Lake Baikal. The high oxygen content in the near-bottom horizons of Lake Baikal is explained with the intrusion into the deep and near-bottom zones of water volumes from the upper layers of the lake with low (below 3.1-3.3 °C) temperature and elevated (more than 10-10.5 mg / L) O_2 concentration [33].

Transparency of water in Lake Shebety is 5.0 m. The reaction of the medium is from neutral to slightly alkaline (Table 1), which is related to the thermal stratification of the lake.

The turbidity of water is the greatest in the shallow part of the lake (station 3) due to the impact of the river water flow, entering the lake. When influence is removed to the opposite shore of the lake, it decreases by a factor of 1.4.

Macro- and microcomponent composition of water In the water of Lake Shebety, as in the compared lakes (Table 2), calcium is dominated in the cationic composition of water.

Table 2: Hydro chemical characteristics of oligotrophic lakes (m ± SD, mg / L)

Indicators	MAC	Lake			
		Shebety	Bukukun	Baikal [12, 14, 17, 33, 35, 38, 40, 41]	Teletskoye [11, 24, 27, 31]
Na	120,0	0,91±0,21	0,86	3,8 - 4,1	1,24 - 4,76
K	50,0	0,48±0,04	0,28	2,0 - 2,1	
Fe	0,1	0,05±0,01	0,06	0,02 - 0,03	0,01 – 0,09
Ca	180,0	4,25±1,50	2,0	15,2 - 15,7	12,9 - 14,4
Mg	40,0	1,05±0,10	1,22	3,0 - 3,1	2,11 - 3,01

Cl^-	300,0	0,97±0,00	0,68	0,6 - 0,7	1,02 - 1,70
SO_4^{2-}	100,0	2,10 - 5,10	<2,00	5,0 - 5,2	4,50 - 7,55
HCO_3^-	-	19,06±1,53	15,25	66,5 - 68,3	53,8 - 59,5
Si	10,0	1,19±0,06	1,00	1,6 - 5,5	2,39 - 2,88
NO^{-3}	40	0,25±0,034	0,78	0,3 - 0,5	0,14 - 0,34
NO^{-2}	0,08	0,01±0,00	0,014	0,040	<0,001
NH_4^+	0,5	0,25±0,032	0,08	0,015	0,022-0,088
PO_4^{3-}	0,05	0,01±0,002	<0,01	0,02-0,06	≤0,01 - 0,07
P_{total}	-	0,014±0,005	-	-	≤0,01 - 0,05
Cu	0,001	0,001	0,002	0,21±0,03	<0,1 - 8,0
Zn	0,01	0,015	0,140	0,003	<0,004
Pb	0,006	0,006	0,0008	<0,00002	<0,002
Mn	0,01	0,018	0,011	0,001 - 0,002	<0,001- 0,009
TDS	-	31,2±0,030	21,2	96,4 - 98,3	78,9 - 88,2
COD, mg O_2/L	-	18,84±3,11	-	-	1,60 - 9,60
PO, mg O_2/L	-	2,57±0,52	-	0,5 - 1,6	2,03 - 2,81

Note. "-" – no data, PO – permanganate oxidability of organic matter, MAC - the maximum permissible concentration in fishery waters (FAF, 2010).

Anionic composition of the waters of these lakes is identical with the predominance of bicarbonate ions. We noted the homogeneity of the ion distribution over depth in Lake Shebety: the surface layers of water do not differ from the bottom horizons. Such homogeneity in the ions distribution over depth, stability in space and time is also the characteristic of Lake Baikal [14]. In the macro-component water composition of Lake Shebety, alkaline earth metals predominate over alkaline metals. The concentration of dissolved silicon averages 1.19 mg / L. Thus, for the water mineralization, Lake Shebety refers to the class of ultra-fresh water reservoirs with a neutral-slightly alkaline reaction medium, characteristic for mountain lakes, such as Lake Baikal (Russia, UNESCO World Heritage Site), Lake Teletskoye (Altai, Russia) and others.

Nitrogen and phosphorus in water Biogenic elements – nitrogen and phosphorus compounds determine the productivity of water bodies. The content of nitrates, nitrites, ammonium and phosphates of Lake Shebety is presented in Table 2. The content of ammonium ions of Lake Shebety exceeds the indications on the Baikal and the Teletskoye. Consequently, in the shallower Lake Shebety, in comparison with the above reservoirs, the processes of biochemical decomposition of complex organic nitrogen-containing compounds are more active.

The content of phosphorus in Lake Shebety is lower than in the Baikal and the Teletskoye lakes. Due to the small catchment area (10.5 km^2), a significant portion of phosphorus, existed in water, is of organic origin. It is established that phosphorus in freshwater hydrobionts is 0.2 - 2% per dry substance. The concentration function of living organisms leads to a decrease in phosphorus, even with relatively small changes in the biomass of hydrobionts [5, 29, 40, 41]. Phosphates are actively consumed by phytoplankton, phytobenthos and higher aquatic plants, and the mineral compounds of nitrogen are mainly by phytoplankton and bacteria. In addition to the connections with organic substances, their deposition in the form of insoluble compounds of calcium, iron and aluminum phosphates can decrease the phosphorus content [10, 15, 17, 26, 30]. In Lake Shebety iron content is low, which is typical for the territory under consideration, much lower than in Lakes Baikal and Teletskoye (Table 2). At high pH values, phosphorus can be co-precipitated as calcium carbonate. Since Lake Shebety pH has a slightly alkaline character, the phosphorus content during the studies is not related to the processes of precipitation and dissolution of iron hydroxide and calcium carbonate, but is connected with in-water processes of its transformation. The regeneration of phosphorus by zooplankton can be considered one of the sources of phosphates. It is found that zooplankton can synthesize from 10 to 20 % of the total phosphorus production in the reservoir [19, 36].

By quality, Lake Shebety water is quite clean, on the content of nitrites (0.01 mg / L) and ammonium ions (0.30 mg/L) belongs to 3a class. According to the content of nitrates (0.25 mg/L), the water of Lake Shebety refers to 2b class (quite clean). By the number of phosphates and total phosphorus – to 2a class (very clean)

Water oxidizability (WO). According to the oxidizability indices, waters of Lake Shebety correspond to the physiographic zonality of natural waters and correspond to the characteristics of mountainous areas with low oxidation (2-5 mg/L). Permangan oxidation of WO in Lake Shebety is small and comparable to the Teletskoye Lake, but higher than the values given for Lake Baikal. Hardly oxidized WO in Lake Shebety is ten times higher than in Lake Teletskoye. The ratio of COD and PO indicates the autochthonous origin of the organic matter (Table 2).

Primary production and destruction of organic matter in Lake Shebety The dominant complex of phytoplankton species in Lake Shebety was mainly represented by diatoms and green algae. The quantitative development of phytoplankton was low. The phytoplankton in the lake area was unevenly distributed. The average phytoplankton abundance in the lake was 54.1 ± 9.7 thousand cells/liter with average biomass of 139.3 ± 72.7 g/m^3

The vertical course of photosynthesis is controlled by the transparency of water and temperature [6, 23]. At the deep-water station of Lake Shebety gross primary production in the surface horizon reached 0.37 mgO_2/L. Starting from a depth of 5 m, it decreased by 5.2 and 9.2 times in comparison with the surface horizon (Table 3, Figure 2). It was noted that the average daily amount of destruction exceeded the gross output in the 0-2.5 m layer by 2-5 times.

Table 3: Production of plankton in the Lake Shebety (July, 2016)

Station	Water sampling horizons, m	T °C	O_2 mg/L	A mg O_2/L	R mg O_2/L
Station 2	0	18,0	8,48	0,37	0,74
	2,5	18,0	8,48	0,10	0,47
	5,0	15,4	8,48	0,07	0,08
	10,0	6,0	7,63	0,06	0,10
	26,0	4,6	6,95	0,04	0,10
Station 3	0	18,8	8,27	0,05	0,42
	1,8	18,6	8,48	0,21	0,42

Note. T – temperature, O_2 – dissolved oxygen in the water, A – gross primary production; R – destruction of organic matter.

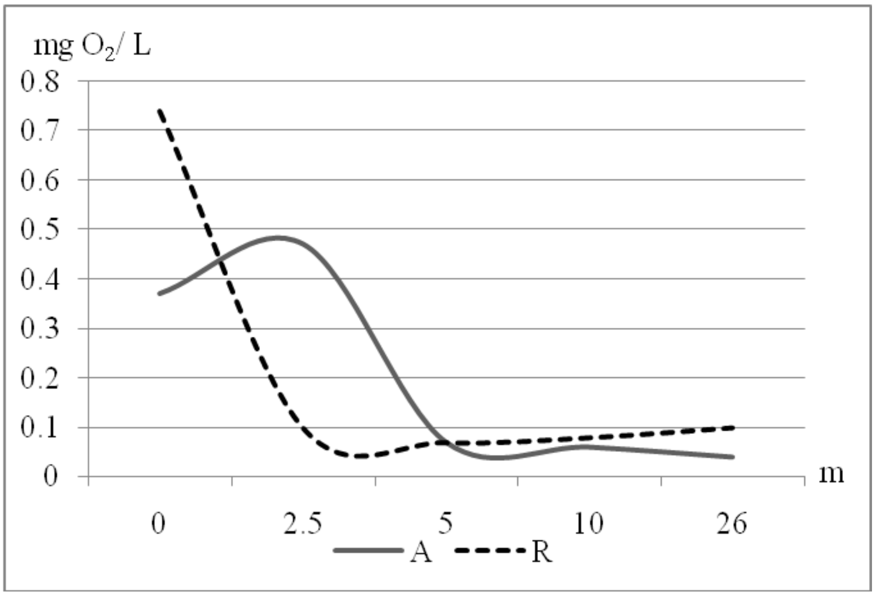

Figure 2: Production of plankton and destruction of organic matter in the deep-water zone of Lake Shebety (July, 2016)

High intensity of destructive processes in the water column, often exceeding the phytoplankton production, can be a source of continuous replenishment of reserves of phosphorus mineral compounds, reintroducing it into the circulation of substances. At the same time, the predominance of the process of destruction over photosynthesis indicates a high ability of the lake to biological self-purification. On the other hand, a constant excess of oxygen consumption can create conditions for oxygen deficiency, as a result of which the ecosystem can be vulnerable to additional anthropogenic loads.

Our investigations were preceded by rainfall, it increased the flow of allochthonous organic matter into the reservoir. In this regard, the destruction exceeds the production in the southwest coast of the lake. This is also indicated by the uniformity of destructive processes in the whole column of water. The water flow from the river Porokhovaya has an impact on gross production. Due to the impact of warm river water, gross production in the surface horizon is four times less than in the bottom (Table 3). A number of authors noted the suppression of photosynthesis in the surface water layer under conditions of shallow depth and increased insolation in the reservoirs of Transbaikal region [22, 25].

The estimated daily production of plankton showed 1.59 mgO_2/m^2, which corresponds to the annual primary production of plankton of 60.0g/m^3. Based on these data, the acceptable fishing catch in the reservoir is 7.33 kg/he. There is only one species of ichthyofauna – an isolated population of Baikal grayling in the lake [37].

Considering that we determined the primary production in the most productive period of the ecosystem, we can state that Lake Shebety corresponds to the parameters of oligotrophic reservoirs [1, 8, 18, 21, 39].

CONCLUSION

Thus, for the first time obtained data on the high-mountain Lake Shebety showed that the reservoir is oligotrophic with signs of mesotrophy. As many reservoirs of oligotrophic nature it has a hydro carbonate-calcium mineral water composition. Specificity of physical and geographical conditions, which determines the ecosystem of reservoir with a low species diversity, determines the productivity of the lake. Organic matter are of autochthonous origin due to the small catchment area (10.5 km^2).

Comparative characteristics of hydro chemical state of Lake Shebety with other oligotrophic reservoirs of the mountain territories [11, 12, 24, 27, 35, 38] show that this reservoir can be considered as a model object in monitoring studies of mountain freshwater ecosystems.

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REFERENCES

[1] Abdurachmanov, G.M., Ivanov, V.P., Sokolskaya, E.A., Pankov, A.G., Vinnikova, V.N., Sokolski, A.Ph. 2007. Primary phytoplankton production and trophic status of the Northern Caspian. Southern Russia: ecology, development. 4, 54-59. https://cyberleninka.ru/article/n/pervichnaya-produktsiya-fitoplanktona-i-troficheskiy-status-severnogo-kaspiya. Date when the reference: 2017.01.21. (in Russian)

[2] Alimov, A.F. 2000. Elements of the theory of the functioning of aquatic ecosystems. SPb.: Science, 147. (in Russian)

[3] Alimov, A.F., Buljon, V.V., Golubkov, S.M. 2009. Resource potential of species, communities and ecosystems of continental reservoirs. Biology Bulletin Reviews. 129. 6, 516-527. https://elibrary.ru/download/elibrary_13607533_35938393.pdf. Date when the reference: 2017.04.12 (in Russian)

[4] Arst, H., Erm A., Herlevi, A., Kutser, T., Leppдranta, M., Reinart, A., Virta, J. 2008. Optical properties of boreal lake waters in Finland and Estonia. Boreal Environment Research. 13, 133-158. http://www.borenv.net/BER/pdfs/ber13/ber13-133.pdf. Date when the reference: 05.03.2017.

[5] Barsdate, R.J., Prentki, R.T., Fenchel, T. 1974. Phosphorus cycle of model ecosystems: Significance for the decomposer food chains and effect of bacterial grazers. Oikos. 25 (3), 239-251. DOI: 10.2307/3543942

[6] Boehrer, B., Schultze, M. 2008. Stratification of lakes. Review Geophysics. 46 (2), 1-27. DOI: 10.1029/2006RG000210.

[7] Brothers, S., Köhler, J., Attermeyer, K., Grossart, H.P., Mehner, T., Meyer, N., Scharnweber, K., Hilt, S. 2014. A feedback loop links brownification and anoxia in a temperate, shallow lake. Limnol. Oceanogr. 59 (4), 1388-1398.

[8] Buljon, V.V. 1994. Patterns of primary production in limnic ecosystems. Proceedings of ZIN RAS. 216, 222. (in Russian)

[9] Buljon, V.V. 2006. Primary production and fish productivity of reservoirs: modeling and prognosis. Inland Waters Biology. 1, 48-56. (in Russian)

[10] Davison, W., Seed, G. 1983. The kinetics of the oxidation of ferrous iron in synthetic and natural waters. Geochimica et Cosmochimica Acta. 47. 1, 67-79. DOI: 10.1016/0016-7037(83)90091-1.

[11] Dolmatova, L.A. 2011. Features of the Hydrochemical Regime of the Teletskoye Lake during the Autumn Cooling Period. World of Science, Culture, Education. 6-2 (31), 418-431. (in Russian)

[12] Domysheva, V.M., Panchenko, M.V., Makirko, M.V., Pestunov, D.A., Belykh, O.I., Popovskaya, G.I., Belan, B.D. 2005. Chemical composition of water and gas exchange by carbon dioxide between the surface of Lake Baikal and the atmosphere, in: Theses of reports of the IV Vereshchaginskaya Baikal Conf., September 26 - October 1, 2005. Irkutsk. 68-69. (in Russian)

[13] Enikeev, F.I., Starishko, V.E. 2009. Glacial morphogenesis and placer formation of the Eastern Transbaikalia. Chita: Chita State University, 370. (in Russian)

[14] Falkner, K.K., Measures, C.I., Herbelin, S.E., Edmond, J.M., Weiss, R.E. 1991. The major and minor element geochemistry of Lake Baikal. Limnol. Oceanogr. 36, 413-423.

[15] Furumai, H., Kondo, T., Ohgaki, S. 1989. Phosphorus exchange kinetics and exchangeable phosphorus forms in sediments. Water Res. 23. 6, 685-691. DOI: 10.1016/0043-1354(89)90200-5.

[16] Golubkov, S.M., Maksimov, A.A., Golubkov, M.S., Litvinchuk, L.F. Functional shift in the ecosystem of the eastern part of the Gulf of Finland under the influence of natural and anthropogenic factors. Doklady Earth Sciences. 2010. 432. 3, 423-425. (in Russian)

[17] Granina, L.Z., Kallender, E. 2007. Elements of iron and manganese cycling in Baikal. Geochemistry. 9, 999-1007. (in Russian)

[18] Grobbelaar, J.U., House, W.A. 1995. Phosphorus as a limiting resource in inland waters: Interaction with nitrogen, in: SCOPE 54 – Phosphorus in the Global Environment. Transfers, Cycles and Management (ed. Tiessen, H.), Wiley, J. and Sons Ltd., Chichester, 255-273.

[19] Gutelmakher, B.L. 1977. Quantitative assessment of the role of zooplankton in the phosphorus cycle in the reservoir. Biology Bulletin Reviews. 38. 6, 914-921. (in Russian)

[20] Kirillin, G., Shatwell, T. 2016. Generalized scaling of seasonal thermal stratification in lakes. Earth-Science Reviews. 161, 179-190. DOI: http://dx.doi.org/10.1016/j.earscirev.2016.08.08.

[21] Kitaev, S.P. 1984. Ecological bases of bioproductivity of lakes of different natural zones. Moscow: Science, 130-133. (in Russian)

[22] Koryakina, E.A. 2006. Primary production of some lakes of the Ivano-Arakhleyskaya system (Transbaikalia), in: Theses of reports of the IX Congress of the HBP RAS. Toliatti: IEIB RAS, 233. (in Russian)

[23] Mineeva, N.M. 2009. Primary production of plankton in the reservoirs of the Volga. Yaroslavl: Printhouse, 279. (in Russian)

[24] Mitrofanova, E.Yu., Tretyakova, E.I. 2013. Teratological forms of diatoms in algal flora of Teletskoye Lake (Russian Altai). Water: chemistry and ecology. 10, 112-119. (in Russian)

[25] Ogly, Z.P. 2009. Indices of phytoplankton productivity in water bodies of Transbaikalian edge. Izvestiya Samara Scientific Center, Russian Academy of Sciences. 11. 1-3, 327-331. (in Russian)

[26] Ostrofsky, M.L. 1987. Phosphorus species in the surficial sediments of lakes of eastern North America. Canad. J. Fish. Aquat. Sci. 44. 5, 960-966. https://dspace.allegheny.edu/bitstream/handle/10456/45405/Ostrofsky_1987_CJFAS_PhosphorusSpecies.pdf?sequence=1. Date when the reference: 2017.01.21.

[27] Robertus, Yu.V., Shevchenko, G.A., Kivatskaya, A.V. 2009. Levels of the presence of microelements in the water of the Teletskoye Lake and its tributaries. Natural Resources of Gorny Altai. 1, 87-90. (in Russian)

[28] Rufova, A.A, Ksenofontova, M.I. 2015. Hydrochemical composition as one of the indicators of current conditions for the formation of lakes (on the example of Yakutsk). Science and Education. 2 (78), 145-151. (in Russian)

[29] Ryzhakov, A.V. 2012. Kinetic characteristics of the transformation of nitrogen-containing compounds in natural water. Ekologicheskaya Khimiya. 21(2), 117-124. (in Russian)

[30] Santana-Casiano, J.M., González-Dávila, M., Rodríguez, M.J., Frank, J.M. 2000. The effect of organic compounds in the oxidation kinetics of Fe (II). Marine Chemistry. 70. 1, 211-222. DOI: http://dx.doi.org/10.1016/S0304-4203(00)00027-X.

[31] Selegei, V., Dehandschutter, B., Klerks, J., Vysotsky, A. 2001. Physical and geological environment of Lake Teletskoye. Ann. Scien. Geolog. 105, 310.

[32] Shatwell, T., Adrian, R., Kirillin, G. 2016. Planktonic events may cause polymictic-dimictic regime shifts in temperate lakes. Sci. Report. 6, 243-261.

[33] Shimaraev, M.N., Granin, N.G., Gnatovskij, R.J., Blinov, V.V. 2015. The Mechanism of Oxygen Aeration of Bottom Waters of Lake Baikal. Doklady Earth Sciences. 461. 2, 379-383. DOI: 10.1134/S1028334X15040078.

[34] Silow, E.A. 2013. The Present State of Human Impact on Lake Baikal. Journal of Siberian Federal University. Biology. 6. 4, 388-404. (in Russian)

[35] Tarasova, E.H., Meshcheryakova, A.I. 1992. The current state of the hydrochemical regime of Lake Baikal. Novosibirsk: Science, 143 p. (in Russian)

[36] Trommer, G., Pondaven, P., Siccha, M., Stibor, H. 2012. Zooplankton-mediated nutrient limitation patterns in marine phytoplankton: an experimental approach with natural communities. Marine Ecology Progress. 449, 83-94.

[37] Tsybekmitova, G.T., Eremeeva, M.I., Gorlacheva, E.P., Afonin, A.V., Mikheev, I.E., Tashlykova, N.A., Afonina, E.Yu., Ivanov, S.S., Butenko, M.N. 2016. Integrated research of Lake Shebety. Modern problems of science and education. 6, 531. (in Russian)

[38] Vetrov, V.A., Kuznetsova, A.I., Sklyarova, O.A. 2013. Basic levels of chemical elements in the water of Lake Baikal. Geography and Natural Resources. 3, 41-51. http://www.izdatgeo.ru/pdf/gipr/2013-3/41.pdf. Date when the reference: 2016.08.09 (in Russian)

[39] Vinberg, G.G. 1960. Primary production of reservoirs. Minsk: Publishing house of the Academy of Sciences of the BSSR, 329. (in Russian)

[40] Votintsev, K.K. 1952. Materials on the dynamics of biogenic elements in the waters of Lake Baikal. Doklady Earth Sciences. 84. 2, 353-355. (in Russian)

[41] Votintsev, K.K. 1961. Hydrochemistry of Lake Baikal. Moscow: Publishing House of the Academy of Sciences of the USSR, 311. (in Russian)

[42] Yu, G., Chen, Z., Zhang, L., Peng, Ch., Chen, J., Piao, Sh., Zhang, Y., Niu, Sh., Wang, Q., Luo, Y., Ciais, Ph., Baldocchi, D.D. 2017. Recognizing the Scientific Mission of Flux Tower Observation Networks – Lay the Solod Scientific Data Foundation for Solving Ecological Issues Related to Global Change. Journal of Resources and Ecology. 8. 2, 116-120. DOI: http://dx.doi.org/10.5814/j.issn.1674-764x.2017.02.001.

[43] Zhang, Y., Wu, Z., Liu, M., He, J., Shi, K., Zhou, Y., Wang, M., Liu, X. 2015. Dissolved oxygen stratification and response to thermal structure and long-term climate change in a large and deep subtropical reservoir (Lake Qiandaohu, China). Water Research. 75, 249-258. DOI: http://dx.doi.org/ 10.1016/j.watres.2015.02.052.

[44] Zverev, V.P. 1993. Hydrogeochemistry of the sedimentary process. Proc. GIN RAS. 477, 176. (in Russian)