

Influence of Environmental Factors on the Zoobenthos in the Shallow Brackish Lake Zun-Torey, Russia

P.V. Matafonov¹ and M.Ts. Itgilova²

¹Laboratory of aquatic ecosystems
Institute of Natural Resources, Ecology and Cryology SB RAS,
Nedorezova st., 16a, 672014, Chita (Russian Federation);
Email : benthos@yandex.ru

²Laboratory of aquatic ecosystems
Institute of Natural Resources, Ecology and Cryology SB RAS,
Nedorezova st., 16a, 672014, Chita (Russian Federation);
Email : imts49@mail.ru

ABSTRACT

The ecosystems of brackish lakes are highly variable in time, so the actual task of limnology is to identify their discrete states that are necessary for the environmental monitoring of such lakes. The influence of environmental factors on the zoobenthos in the shallow brackish lake Zun-Torey was researched in 2014. The extremely low water level determined a high level of mineralization, high water temperatures and a low diversity of sediments in the lake Zun-Torey in 2014. The first two RDA axes correlated with depth, sediments, TDS and ORP and collectively explained 83% of zoobenthos and environmental variables variation. Temperature, TDS, SSG influenced the zoobenthos biomass and species abundance in the lake. Water transparency was a decisive factor determining the zoobenthos communities spatial distribution in the lake Zun-Torey. Extreme habitat conditions of zoobenthos and continuous spatial shifts of the euphotic littoral communities induced by water level fluctuations should be taken into account in the environmental monitoring of lake Zun-Torey ecosystem.

Keywords: Brackish lakes, zoobenthos, environmental factors, littoral, global ecoregion, Zun-Torey lake.

Mathematics Subject Classification: 92D40

Journal of Economic Literature (JEL) Classification : Q51, Q57

1. INTRODUCTION

The ecosystems of saline lakes are highly variable in time, so the actual task of limnology is to identify their discrete states based on concept of multiplicity of ecosystem alternative stable states that are necessary for the environmental monitoring of such lakes (Shadrin, 2014; Shadrin, 2018). Lake Zun-Torey is an example of a large shallow brackish lake located in Russia near the China, Mongolia and Russia borders junction. The lake is one of the most important objects of the international Chinese-Mongolian-Russian protected area in the «Daurian steppe» – one of the global 200 ecoregions for priority conservation (Olson, Dinerstein, 2002). Hydrobiological studies on the lake Zun-Torey have

been carried out since 1982 (Lokot et al, 1991; Kuklin et al, 2013; Bazarova et al 2019). At the same time, studies of the lake zoobenthos with coupling with environmental factors are few (Klishko, 2001; Matafonov, 2015; Matafonov, 2018)). To date, there are no special researches of the influence of environmental factors on the Zun-Torey lake zoobenthos. Formerly the detailed research of zoobenthos spatial distribution carried out in the lake Zun-Torey in extremely low-water year (Matafonov P, Bazarova, 2018). The aim of this research was to investigate influence of environmental factors on the zoobenthos in the shallow brackish lake Zun-Torey in the extremely low-water phase of the hydrological cycle.

2. MATERIAL AND METHODS

2.1. Study area

Lake Zun-Torey (50.076063° N, 115.800986° E) located in the steppe zone of the Transbaikalian region, Russia, and belongs to the wetland ecosystems. In wet years, the lake area reaches 300 km² (Lokot et al, 1991), in the drought 2015 year its area decreased to 193 km² (Bazarova et al, 2019).

2.2. Macroinvertebrate sampling and measurement of environmental parameters

Zoobenthos of lake Zun-Torey was sampled on 23–24 July 2014, according to the layout of the sampling sites uniformly spread over the entire lake (Matafonov, Bazarova, 2018). Other parameters of the lake Zun-Torey and a detailed description of zoobenthos research methods have been published (Matafonov, Bazarova, 2018).

The study of environmental parameters was performed *in situ* together with zoobenthos sampling. Hydrophysical parameters: temperature, turbidity, pH, oxidation-reduction potential, electrolytic conductivity, resistance, total dissolved solids, salinity, and seawater specific gravity were measured using Aquaprobe multiparameter water quality testing instrument. Particle size of sediments was categorized according to the accepted scale (Manual ..., 1983). Sediments were assigned values from 0 (clay) to 5 (sand, sand with gruss).

2.3. Data analysis

The data were statistically processed with XLStat and Microsoft Excel®. Sampling sites were clustered based on a sampling sites similarity matrix calculated by zoobenthos density with use of Chekanovsky-Serensen index. Redundancy analysis (RDA) was carried out based on the zoobenthos and environmental parameters. The data were pre-normalised by the Hellinger transformation method to analyse the redundancy. Seawater specific gravity was excluded from RDA due of data insufficiency on three sampling sites.

3. RESULTS

3.1. Spatial distribution of zoobenthos

Three main clusters of sampling sites and zoobenthos communities are identified (Fig. 2) at the level of dissimilarity 2,2. All species of zoobenthos were found in a narrow depths range up to 0,34 m. The wide depths zone more than 0,8 m was inhabited only by chironomidae *Procladius* gr. *ferrugineus* and ceratopogonidae *Palpomyia* (Gluhovia) *tuva* Remm, 1972.

3.2. Spatial variation of environmental parameters

Environmental parameters in the lake Zun-Torey are presented in Tab. 1. Hydrophysical parameters varied in a narrow range. The differences between the clusters discriminated by zoobenthos are not

pronounced in these parameters. Only Cluster 1 was differ relatively high pH values. At the same time, the discriminated clusters have obvious differences in the sediments composition.

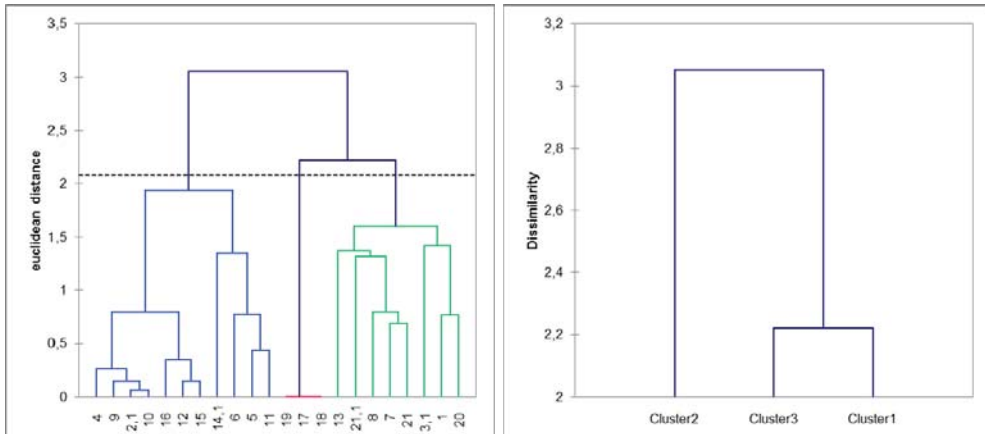


Figure 1. Dendrogram for hierarchical clustering of the 22 sampling sites according to the composition and density of zoobenthos. 1 – 21.1 – sampling sites numbers.

Table 1. Comparison of environmental variables among the three groups (Mean±SD (min-max)).

Parameter	Cluster 1	Cluster 2	Cluster 3	In the lake
Depth, m	0.20	1.3	1.1	0.9
T, °C	23.6	21.8	22.4	22.5
Turbidity (NTU)	69.5±40.9	69.0±35.5	105±58.6	74.3±40.4 (24.9-164)
pH	10.0±0.04	9.9±0.02	9.9±0.04	9.9±0.03 (9.87-10.0)
ORP (Redox)	71.5±15.3	71.5±19.6	60.1±10.9	70.5±17.0 (48.3-117)
EC (uS/cm @20°C)	22418±708	22386±580	22053±364	22367±597 (21366-23638)
Res (Ohms.cm)	41.3±2.76	42.8±1.40	43.0±2.00	42.3±2.20 (38-46)
TDS (mg/L)	14571±460	14550±358	14334±237	14539±385 (13887-15364)
Sal (ppt)	11.2±0.35	11.2±0.27	11.0±0.18	11.2±0.30 (10.7 – 11.8)
SSG (st)	9.8±0.74	9.4±0.45	9.1±0.15	9.5±0.52 (8.6 – 10.5)
Sediment	mostly sand	clay	sand clay	

T – temperature; ORP – oxidation-reduction potential; EC – electrolytic conductivity; Res – resistance; TDS – total dissolved solids; Sal – salinity; SSG – seawater specific gravity.

3.3. Association zoobenthos with environmental factors

The first two RDA axes collectively explained 83% of zoobenthos and environmental variables variation (Fig. 2). The first axis accounts for 58%. Relative to this axis zoobenthos of the first and second clusters divided into different planes. The first cluster zoobenthos parameters, sediments and pH positively correlate with the first axis. The second cluster zoobenthos parameters and depth negatively correlate with this axis.

Relative to the second axis zoobenthos divided by biomass into different planes. Zoobenthos biomass, TDS and ORP positively correlated with second axis, temperature correlated negatively. Relative to the RDA axes the species abundance of zoobenthos was positively correlated with pH and mineralisation and negatively with the depth.

The correlation analysis showed the species abundance decrease with depth increase ($r_s = -0.44$, $p = 0.04$). Maximum species abundance value in samples on depth dependence has form $y = 2.301x - 0.51$ ($R^2 = 0.97$, $n = 9$). The species abundance increased with pH ($r_s = 0.50$, $p = 0.02$). Zoobenthos biomass positively correlated with TDS ($r_s = 0.44$, $p = 0.04$).

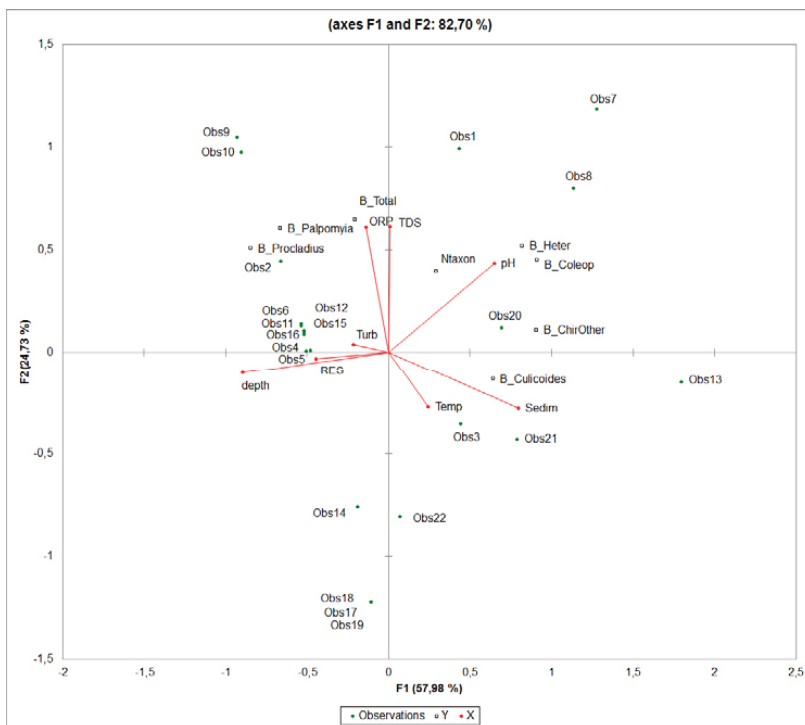


Figure 2. RDA map showing macroinvertebrate communities in relation to environmental variables.

Obs1 - Obs22 – numbers of sampling sites, Sedim – sediments, B_Procladius – biomass of *P. gr. ferrugineus*, B_Palpomyia – biomass of *P. (G.) tuvae.*, B_Total – biomass of zoobenthos, B_Heter – biomass of Heteroptera, B_Coleop – biomass of Coleoptera, B_ChirOther – biomass other chironomids, B_Culicoides – biomass of *C. riethi*, Ntaxon – species abundance (species in a sample).

4. DISCUSSION

The salt lakes research reveal the influence of mineralization, water level fluctuations, substrate, vegetation and other environmental factors on the ecosystems of this lakes (Williams, 1998; Sheffer, 2004; Leira, Cantonati, 2008; Bazarova et al, 2019). The Torey lakes zoobenthos studies have focused on the influence of the water level fluctuations, waters mineralization and chemical composition (Lokot et al, 2001; Klishko, 2001).

Effect of mineralisation

The influence water mineralization on the zoobenthos species abundance in the lake Zun-Torey was low ($r_s=0.32$, $p=0.14$) in the 2014. Only a negative ratio the maximum species abundance with the water mineralization was found in the nearshore zone (Fig. 3). Perennially mineralisation in the Zun-Torey Lake varies in the wide range from 2 g/l in the high-water level 1999 year (Matafonov, Bazarova, 2018) to 25 g/l in winter of the low water-level years (Lokot et al., 1991). In the shalowest water level 2014, the composition of the lake Zun-Torey zoobenthos did not have such homotopic animals as molluscs, oligochaete, and amphipoda observed in the 1980s and in the high water level 2003 (Lokot et al., 1991; Matafonov, 2015). This is comply with the regularity of zoobenthos diversity decreasing and the share of halotolerant heterotopic species increasing with the water mineralisation increasing (Williams, 1998). Obviously, as in other saline lakes (Hammer et al., 1990; Williams, 1998; Alimov, 2008) mineralisation is one of the most important factors influence the perennially fluctuations of the lake Zun-Torey zoobenthos composition and diversity.

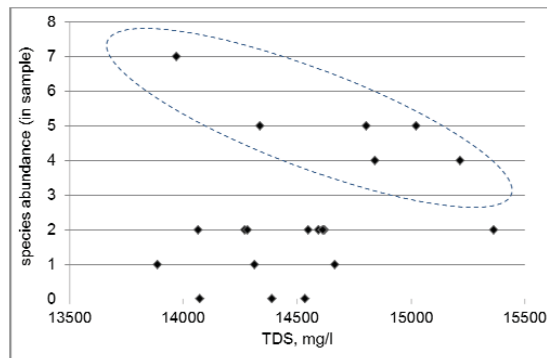


Figure 3. The ratio of species abundance and water mineralization (TDS) in the lake Zun-Torey in 2014. Delineated the maximum species abundance values trend.

Effect of high water temperature

Aquatic biological communities growth requires optimal water temperatures (Banerjee, 2019). Until recently, the influence of high water temperatures on the Torey lakes zoobenthos has not been given attention. The water temperature in the lake Zun-Torey was at a relatively high level for hydrobionts and caused low the lake zoobenthos biomass (Fig. 4) in 2014. Besides high water temperature limited the possibility of lake Zun-Torey settlement by species with low upper level of thermal tolerance, causing the overall low species diversity of the lake littoral zoobenthos (Matafonov, 2018).

Influence of water density

The influence of SSG on the Torey lakes zoobenthos has not been previously studied. Salinity and water temperature determine the water density. Spatial differences in water density may also be due to water currents. The zoobenthos biomass of the second and third clusters were found to be positively related to seawater specific gravity ($r_s=0.88$, $p<0.001$). A positive relationship of biomass *Procladius* gr. *ferrugineus* with SSG was revealed in the more 0.8 m depths zone (Fig. 5). *Procladius* larvae are able to swim and they can be displaced by water currents

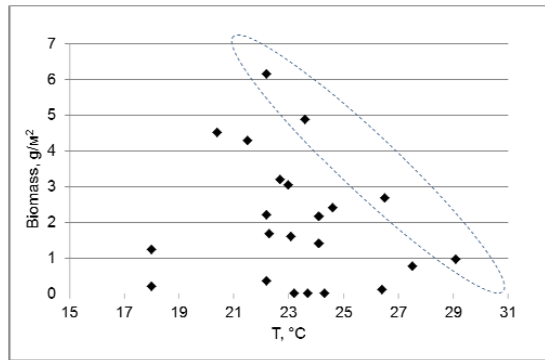


Figure 4. The ratio of zoobenthos biomass and temperature (T, °C) in the lake Zun-Torey in 2014. Delineated the maximum biomass values trend.

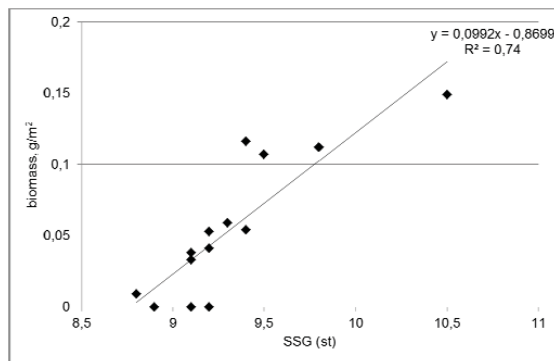


Figure 5. The ratio of the *Procladius* gr. *ferrugineus* biomass and seawater specific gravity in the lake Zun-Torey.

Influence of sediments

Sediments are of great importance as a habitat for zoobenthos in saline lakes (Herbst et al., 2013). Until recently, there was an opinion about the sediments of the nearshore and central zones similarity in lake Zun-Torey (Lokot et al., 1991). A very low similarity zoobenthos in the first clusters (Matafonov, Bazarova, 2018) in 2014 caused by the large habitats diversity for species with different sediment preferences. The predominance of sand clay sediments and absence of zoobenthos at the sampling sites of the third cluster indicates the probability of erosion of sediments by water currents. Insignificant deposits of organic silt could limits the settlement pelophilic species in the lake Zun-Torey from nearby water bodies.

Influence of water turbidity

Although the effect of water turbidity on zoobenthos is low in RDA, it is an important regulatory factor in the ecosystems of shallow lakes (Scheffer, 2004), since it determines the water transparency and abundance of primary producers. In the lake Zun-Torey, water turbidity increases in the ice-free period (Lokot et al., 1991). One of the reason of this is the erosion and resuspension of dominant clay sediments in the lake. This may explains the separation of turbidity and sand sediment in different RDA planes.

In addition, It is possible that high turbidity limits the settling of the Zun-Torey lake with bivalve as in the Mongolian steppe lakes (Prokin, 2013) due a large amount of mineral particles in water can have a direct negative effect on filter feeding organisms (Alimov, 1981).

Influence of water transparency

Until recently, the influence of water transparency on the Torey lakes zoobenthos communities has not been given attention. Although, in the 2014 the main changes of zoobenthos composition and structure are occurred in the depths zone 0.2 – 0.4 m (Matafonov, Bazarova, 2018), the most of the previously reviewed environmental parameters had no a significant gradient in this depth range. For example, pH gradient here was 0.02 – 0.04 only. Thus, the main differences between the zoobenthos of the first and the second clusters were due sampling sites location in the different photic layers (Matafonov, Bazarova, 2018). The zoobenthos of the first cluster corresponds to the euphotic littoral type by its spatial distribution, species composition and diversity.

Influence the littoral spatial shift

Until recently, the influence of littoral spatial shift on the Torey lakes zoobenthos has not been given special attention. In 2014 the lake Zun-Torey had a width of about 17.5 km and depth up to 1.48 m but the width of the photic zone varied only from 30 to 500 m depending on the bottom slope. In this regard, the distribution of littoral zoobenthos was limited to a very small depth range of the euphotic (littoral) zone close to the coastline. At the sloping slope this zone can shift during one year by tens or more meters. The east coast has retreated by 5 km since 1999 to 2015 (Bazarova et al., 2019). During the water level decrease in Zun-Torey Lake, the littoral zoobenthos expand onto the biotopes earlier occupied by the aphotic zone, during the water level rise expand onto the flooded terrestrial biotopes. Obviously, in areas with a sloping slope, the littoral zoobenthos following the littoral zone continuously colonize new habitat. Littoral spatial shifts was a causes the eggs death of chironomidae *Procladius ferrugineus* in the lake Barun-Torey (Lokot et al., 1991) located near the lake Zun-Torey. Thus, continuous littoral spatial shifts limits the settlement of the lake Zun-Torey by sessile organisms and their abundance in the lake.

In addition to a direct influence on zoobenthos, the spatial shift of the littoral zone is one of the reasons of small abundant of the macrophyte. In this regard, the littoral zoobenthos of Zun-Torey Lake is limited by low diversity and an abundance of trophic resources and plant refuge. Due the absence of bottom macrophyte, the littoral species, e.g. *Gammarus lacustris*, forcedly inhabit the stone downside near the coastline (Matafonov, 2015).

Thus, the spatial shift of the littoral zone of lake Zun-Torey to be important factor of low diversity and quantitative development of zoobenthos in the lake.

Influence the water level fluctuations

To date, there is no clear understanding of water level fluctuations influence on the zoobenthos of Torey lakes. As in other shallow lakes (Leira, Cantonati, 2008) the large perennial water level fluctuations is one of the most significant factors determined environmental factors and community parameters Torey lakes (Kuklin et al., 2013; Bazarova et al., 2019). Apparently water level fluctuations determine habitat conditions and the spatial distribution of zoobenthos in the lake Zun-Torey.

The depth of the Zun-Torey lake decreased from 5.5 m in 1999 (Matafonov, Bazarova, 2018) to 1.48 m in July 2014. The water level decreasing led to the drying out of the shallow areas and stony

sediment habitats occupied by the littoral zoobenthos. Apparently, in extremely droughty years, the habitats of zoobenthos in the lake Zun-Torey are represented by clay only. Along with water level decreasing and drying of sediments, transparency decreases, salinity of the lake waters increase more than 10 times, increases the water temperature temporal fluctuations.

In winter low-water years freezing of nearshore zone has a negative effect on the quantitative development of zoobenthos, this was found in the studies of zoobenthos shallow zone other Torey lakes in 1983 – 1986 (Lokot et al., 1991). Thus, water level decrease determine extremal environment conditions and a low zoobenthos diversity in the most part of the Zun-Torey lake in drought years.

The water level increase is accompanied by an increase in the transparency of water up to 0.5 m (Bazarova et al, 2019), the expansion of the littoral zone, the appearance of stony and sandy biotopes, a decreasing salinity and temperature variations. All this leads to an increase in habitats and trophic resources of zoobenthos and an increase in its diversity.

5. CONCLUSION

Although all the revised factors (TDS, SSG, ORP, pH, depth, and other) had an influence on the species abundance and biomass of zoobenthos, however, water transparency was a decisive factor determined the main zoobenthos communities features in the lake Zun-Torey. The spatial distribution of the main discriminated zoobenthos communities was caused by the very low water transparency. So far, the littoral communities of zoobenthos in lake Zun Torey, their spatial and temporal shift displacements have not received special attention. The results of this study show that extreme habitat conditions and continual euphotic littoral communities spatial shifts induced by water level fluctuations should be taken into account in the environmental monitoring of lake Zun-Torey zoobenthos and ecosystem. Besides, wetland ecosystems are typical habitats of water birds (Boukrouma, 2018), so regular monitoring of littoral zoobenthos is necessary as part of water birds habitat and trophic resources changes monitoring in the " Daurian step " global ecoregion

Acknowledgements

This research was supported by the Project IX.137.1.1. «Biodiversity of natural and natural-technogenic ecosystems of the Trans-Baikal Territory (Central Asia) as an indicator of the dynamics of regional climate change». We thank Dmytrii V. Matafonov for his help in statistical data processing.

6. REFERENCES

- Alimov, A.F., 1981, *Functional ecology of freshwater bivalves*, Science, Leningrad, 248 p. (in Russian)
- Alimov, A.F., 2008, Relations between biological diversity in continental waterbodies and their morphometry and water mineralization. *Inland Water. Biol.*, **1**, 3–8. <https://doi.org/10.1007/s12212-008-1001-6>
- Banerjee, S., Banerjee, A., Palit, D., 2019 Seasonal and diurnal variation of zooplankton in relation to physicochemical parameters of two freshwater pond ecosystem: a case study. *Int. J.Ecol. Dev.*, **1**, 61-74
- Boukrouma, N., Lalaibia, L., Djelloul, F., 2018 Diversity and seasonal variation of water birds in Tiffech Lake (Souk Ahras, Northeastern Algeria). *Int. J. Ecol.Dev.*, **4**. 103–111.

Bazarova, B.B., Tashlykova, N.A., Afonina, E.Yu., Kuklin, A.P., Matafonov, P.V., Tsybekmitova, G.Ts., Gorlacheva, E.P., Itigilova, M.Ts., Afonin, A.V., Butenko, M.N., 2019, Long-term fluctuations of the aquatic ecosystems in the Onon-Torey plain (Russia). *Acta Ecol. Sinica*, **39**, 157–165.

Hammer, U.T., Sheard, J.S., Kranabetter, J., 1990, Distribution and abundance of littoral benthic fauna in Canadian prairie saline lakes. *Hydrobiologia*, **197**, 173–192. <https://doi.org/10.1007/BF00026949>

Herbst, D.B., Medhurst, R.B., Roberts, S.W., Jellison, R., 2013, Substratum associations and depth distribution of benthic invertebrates in saline Walker Lake, Nevada, USA. *Hydrobiologia*, **700**, 61–72.

Klishko, O.K., 2001, *Zoobenthos of the lakes of Transbaikalia*, Publishing house of the BSC SB RAS, Ulan-Ude, 208 p. (in Russian)

Kuklin, A.P., Tsybekmitova, G.T., Gorlacheva, E.P., 2013, State of lake ecosystems in Onon-Torei plain in 1983–2011 (Eastern Transbaikalia). *Arid Ecosyst.*, **3**, 122–130. <https://doi.org/10.1134/S2079096113030062>

Leira, M., Cantonati, M., 2008, Effects of water-level fluctuations on lakes: an annotated bibliography. *Hydrobiologia*, **613**, 171–184.

Lokot, L.I., Strizhova, T.A., Gorlacheva, E.P., Shamsutdinov, V.Kh., Chechel, A.P., Topolov, A.A., Itigilova, M.T., Klishko, O.K., Ogly, Z.P., Balushkina, E.V., Serebryakova, M.S., Orlik, L.A., Afonin, A.V., 1991, *Soda Lakes of Transbaikalia: Ecology and Productivity*, Publishing House "Science" SB RAS, Novosibirsk, 216 p. (in Russian)

Manual on methods for hydrobiological analysis of surface waters and bottom sediments, 1983, Gidrometeoizdat, Leningrad, 240 p. (in Russian)

Matafonov, D.V., 2015, The structure of macrozoobenthos communities in the lakes of the Onon-Torey plain in the initial period of the shallow-water phase of the hydrological cycle. *Bull. BGSHA*, **39**, 58–65. (in Russian)

Matafonov P.V., 2018 Influence of water high temperatures on zoobenthos of the shallow salt lake Zun-Torey in the small-water period *Int. J. Appl. Fundam. Res.*, **11**, 99 – 102 (in Russian)

Matafonov, P.V., Bazarova, B.B., 2018, Spatial distribution of zoobenthos in the shallow saline lake Zun-Torey in the low-water phase. *Res. J.Pharm., Biol. Chem. Sci.*, **9**, 6, 120-128.

Olson, D.M., Dinerstein, E., 2002, The Global 200: Priority ecoregions for global conservation. *Annals of the MO. Bot. Gard.*, **89**, 199–224. DOI: 10.2307/3298564

Prokin, A.A., 2013, Macrozoobenthos at the beginning of the XXI century. *Limnology and paleolimnology of Mongolia*, Moscow, 170 – 185 (in Russian)

Scheffer, M., 2004, *Ecology of shallow lakes*, Springer, Netherlands, 357 p. DOI: 10.1007/978-1-4020-3154-0

Shadrin, N.V., 2018, The alternative saline lake ecosystem states and adaptive environmental management. *J. Oceanol. and Limnol.*, **36**, 6, 2010-2017, <https://doi.org/10.1007/s00343-018-7307-2>

Williams, W.D., 1998, Salinity as a determinant of the structure of biological communities in salt lakes. *Hydrobiologia*, **381**, 191-201.