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Macroinvertebrates of fluctuating lakes in Mongolia

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The dynamics of the water budget of Orog Nuur and Taatsiin Tsagaan Nuur fluctuating lakes in the Valley of the Lakes (Western Mongolia) in the period 2010–2018 is studied. It is shown that Orog Nuur Lake has passed to the wet phase in its long-term cycle, while Taatsiin Tsagaan Nuur Lake is currently in a transitional phase, which in previous cycles lasted 2–4 years. The composition and long-term changes in the species composition and quantitative characteristics of macrozoobenthos and macrozooophytos of Orog Nuur Lake, and macrozoobenthos and nekton of Taatsiin Tsagaan Nuur Lake is studied. A total of 27 species of macroinvertebrates is recorded for Orog Nuur Lake and 23 species for Taatsiin Tsagaan Nuur Lake. During the study period, Orog Nuur Lake showed an increase in the diversity and abundance of benthic communities that exhibit multi-annual fluctuations due to changes in water level. The macroinvertebrate communities of Taatsiin Tsagaan Nuur Lake are typical of a temporary water body, in each year of research, being dependent on the area of the lake and water budget, which in turn depends on changing patterns of its filling. Based on data from 2014, when Taatsiin Tsagaan Nuur Lake was first filled with water after a dry phase, we calculated sex ratios and average individual body mass for each sex group of three syntopic species of Spinicaudata that experienced a sharp increase in abundance.

Keywords: fluctuating lakes, water level, lake area, Western Mongolia, macrozoobenthos, nekton, number of species, abundance, biomass, Spinicaudata.

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Introduction

The Valley of the Lakes in Western Mongolia is an intermontane depression in Central Asia, which separates the Khangai and Gobi Altai Mountains, four lakes (Böön Tsagaan Nuur, Orog Nuur, Taatsiin Tsagaan Nuur, and Ulan Nuur) are the ultimate water receptacles. The first of them does not dry out, the rest are fluctuating, that is, they are characterized by periodic changes in the groundwater and surface water levels observed in fluctuating of their budget. Based on long-term observations, dry (3–6 years), transitional (2–4 years) and wet (10–30 years) phases were recognized. During the dry period, the lakes completely dried out. During the transitional phase, they were filled only for a short summer period, drying by autumn. During the wet phase, the lakes were consistently filled with water (Dgebuadze, 1995; Dgebuadze et al., 2014).

For lakes and some other ecosystems, the existence of several, at least two, states that are stable and relatively stable has been described (van Nes et al., 2007; Scheffer et al., 2001 and others). For shallow lakes, it was found that the trigger mechanism, which provides the transition from a turbid to a clear state, is a sharp draw-down of water levels in dry summers (van Geest et al., 2007; Scheffer and Jeppesen, 2007). For floodplain lakes, it is shown that the flood phase determines the quantitative characteristics of macrozoobenthos communities (Prokin and Seleznev, 2018). In hypersaline lakes, the salinity changes associated with the water content of the year are responsible for one or another alternative state of the ecosystem, including those at the level of general species richness (Shadrin, 2013). Thus, the level regime dynamics can change not only the features of individual communities of hydrobionts, but also the general direction of ecological succession of the ecosystem according to the mechanism of hysteresis, or "demutational shifts" (term: Razumovsky, 1981).

In this regard, the study of the hydrobiological regime of fluctuating lakes, which are characterized by perennial cyclical changes in water levels, is of considerable interest, especially during climate change and anthropogenic transformation of ecosystems, which is very clearly manifested in the arid conditions of Central Asia. The aim of our work was to describe the formation of macroinvertebrate communities and to analyze the long-term dynamics of these communities due to changes in the characteristics of Orog Nuur and Taatsiin Tsagaan Nuur lakes.

Material and methods

Meteo-information was obtained from the server http://www.meteomanz.com/ for the city of Bayanhongor (Observación ..., 2019), weather station code 44287. The total precipitation is calculated from April to August, mm (*Prec.*, mm), average daily average air temperature April to August (*Tav*, °C), the number of days with precipitation > 1 mm from April to August (*Days prec. > 1 mm*), the maximum monthly precipitation amount dropped from April to August, mm (*Prec. max*, mm). The data were obtained as raw SYNOP / BUFR arrays from the NOAA server and were calculated using the GFS 0.5º prediction model.

Orog Nuur Lake was surveyed in 2010 and in 2013–2018, and Taatsiin Tsagaan Nuur Lake in 2014–2018.

The lake areas on the study date were calculated using the Landsat 4–5 TM C-1 Level 2, Landsat 8 OLI / TIRS C1 Level 1, 2 satellite images (Earth Explorer, 2019). For all selected images, atmospheric correction was performed using the SCP module of the Quantum GIS program. For Landsat 8 images, pan-sharpening was performed to increase the resolution of images. All channels were grouped into one. To facilitate visualization of the water surface, the pseudo-color images obtained were further processed by changing the order of the channels – 2–4–1. The areas of the lakes were calculated manually. Based on the analysis of satellite images for Taatsiin Tsagaan Nuur Lake a period during which the lake was filled with water by the date of sampling was calculated for each year of research.

The physical and chemical characteristics of the water were measured using a YSI-85 portable probe. Water temperature (*Tw*, ºC), electrical conductivity (*EC*, μS/cm) and pH were analyzed.

Quantitative samples of macrozoobenthos were collected at the end of July and the beginning of September using a Petersen scoop grab with a capture area of 0.025 m^2 (2010, 2016), a box-shaped bottom grab DAK-100 (2013–2015) and a Ekman – Burge grab (2017, 2018), with an area of 0.01 m^2, two liftings per sample. Samples of nekton in Taatsiin Tsagaan Nuur Lake in 2014, 2016–2018 were collected using a Balfour-Browne net (10 pulls), with an area of 0.25 m^2, at a distance of 4 m on two strings, one of which was attached to the bottom of the frame, and the second was attached to the handle. In the two studied lakes, the open littoral was examined outside macrophyte thickets at depths of 0.2–0.5 m in different years, reed beds were sampled in the littoral (depths of 0.3–0.7 m), pelagial / profundal in the central part of the lakes, where the depth was 0.5–1.5 m. In Orog Lake macrozoophytos was studied in 2014, 2016 and 2018 in thickets of *Stuckenia* sp., and and in 2014 also in filamentous algae.

In total, 36 samples of macrozoobenthos were sampled and processed, 12 samples of nekton and 4 of macrozoophytos. In addition, qualitative sampling of aquatic macroinvertebrates was carried out in the lakes using a Balfour-Browne water-net.

The abundance was calculated (*N*, specimens/m^2 for macrozoobenthos, specimens/m^3 for nekton, specimens/kg of wet weight of the plant for macrozoophytos), biomass (*B*, g/m^2 for macrozoobenthos, g/m^3 for nekton, g/kg of wet weight of the plant – for macrozoophytos), number of species (*n*).

The power analysis for linear models was performed using a significance level of 0.05, a test power of 90%, and a coefficient of determination $R^2 = 0.15$. The size of the effect (Cohen, 1988) was calculated as $R^2/(1-R^2)$ and amounted to 0.18. The required sample size was 60 measurements.

Since the available material is insufficient, the dependence of the quantitative characteristics of hydrobionts on the parameters of the medium was determined by an exact permutational regression analysis. The Pearson correlation coefficient was also used, the significance level of which was determined by a permutation test. The correlation coefficients between the lakes were compared using a Fisher Z-transformation. All calculations were made

Table 1. Meteorological data for the catchbasin of Orog Nuur Lake and Taatsiin Tsagaan Nuur Lake (Bayankhongor).

Indicator	Year						
	2010	2013	2014	2015	2016	2017	2018
Prec., mm	149.5	134.4	164.5	144.6	398.6	83.7	192.8
Tav, °C	12.20	12.54	12.66	12.68	12.60	14.60	14.08
Days prec. > 1 mm	28	23	33	23	37	21	24
Prec. max, mm	43.5	46.5	66.3	78.7	170.7	34.5	116.2

in the R 3.5 statistical analysis environment using the "pwr", "ImPerm" and "RVAideMemoire" packages. Initial data are available at the link: www.ibiw.ru/upload/staff/267/mongol_lakes.zip.

Results

According to the amount of precipitation in the series of the years studied, high-water 2016 and low-water 2017 years were recognized (Table 1), which is most likely explained by the maximum of precipitation than by the number of days with precipitation (Table 1). Average temperatures increased compared to previous years in 2017–2018 (Table 1).

During the period of our research (2010, 2013–2018) Orog Lake was first filled with water after drying in 2010, but by the autumn it was dry. In subsequent years, the filling process continued, and the lake was no longer dry, that is, from 2011 a wet period continued. During the study period, the lake area increased from 28.5 to 85 km^2 (Table 2).

During the research period (2014–2018), Taatsiin Tsagaan Nuur Lake was filled annually, but in some years it dried out in summer and/or autumn, which indicates an increase in the duration of the transition period compared to previous studies (Dgebuadze, 1995). Given the winter freezing to the bottom, Taatsiin Tsagaan Nuur Lake during the study period can be considered a temporary water body.

The following picture of seasonal dynamics was typical for this lake during the period under study. After thaw, the first glacier waters come from the nearby Mayangan Yamaat Range and the lake's basin begins to fill with water beginning from its southwestern part, which usually happends in the first ten days of April (Fig. 1B). Further, depending on the development of the meteorological scenario, water may either come from the catchment area of the Taatsiin Gol River or the lake dries out by the beginning or middle of May (Fig. 1C, D), turning into a soda brine with some water present (2011, 2012, 2014, 2016, 2018). Such a state may persist until the second or third ten days of July. It is at this time that heavy rains begin, and the lake is quickly filled with water (Fig. 1E, F). At the same time, in the mouth of the Taatsiin River and directly in the delta, thickets of reeds (*Phragmites australis* (Cav.) Trin. ex Steud., 1840) develop, which stand out on satellite images as bright green spots (Fig. 1E, F). The lake is filled to its usual borders within a short time, within ten days, and by the time of the study (second – third ten days of August) we find it filled with water. For example, in the last year studied (2018), due to abundant precipitation, the lake filled quickly from a total absence of water to an area of 8.43 km^2 (Fig. 1G), because 118 mm of precipitation fell in 18 days, from the end of July–mid-August. In such a state, it can go into freezing (Fig. 1H), and provided that there is an insufficiently large amount of precipitation in the subsequent period, it can again be transformed into brine (Fig. 1A) or completely dry out (2011, 2013, 2015, 2017). The freezing period

Table 2. Some characteristics of the Orog Nuur and Taatsiin Tsagaan Nuur lakes. "–" – the lake was not examined.

Year	Area in August–September, km^2		The duration of the water presence in Taatsiin Tsagaan Nuur Lake to the date of sampling, days
	Orog Nuur	Taatsiin Tsagaan Nuur	
2010	28.55	–	–
2013	87.62	–	–
2014	73.31	10.37	36
2015	64.85	8.17	132
2016	79.54	9.13	20
2017	85.14	7.66	114
2018	85.00	8.43	48

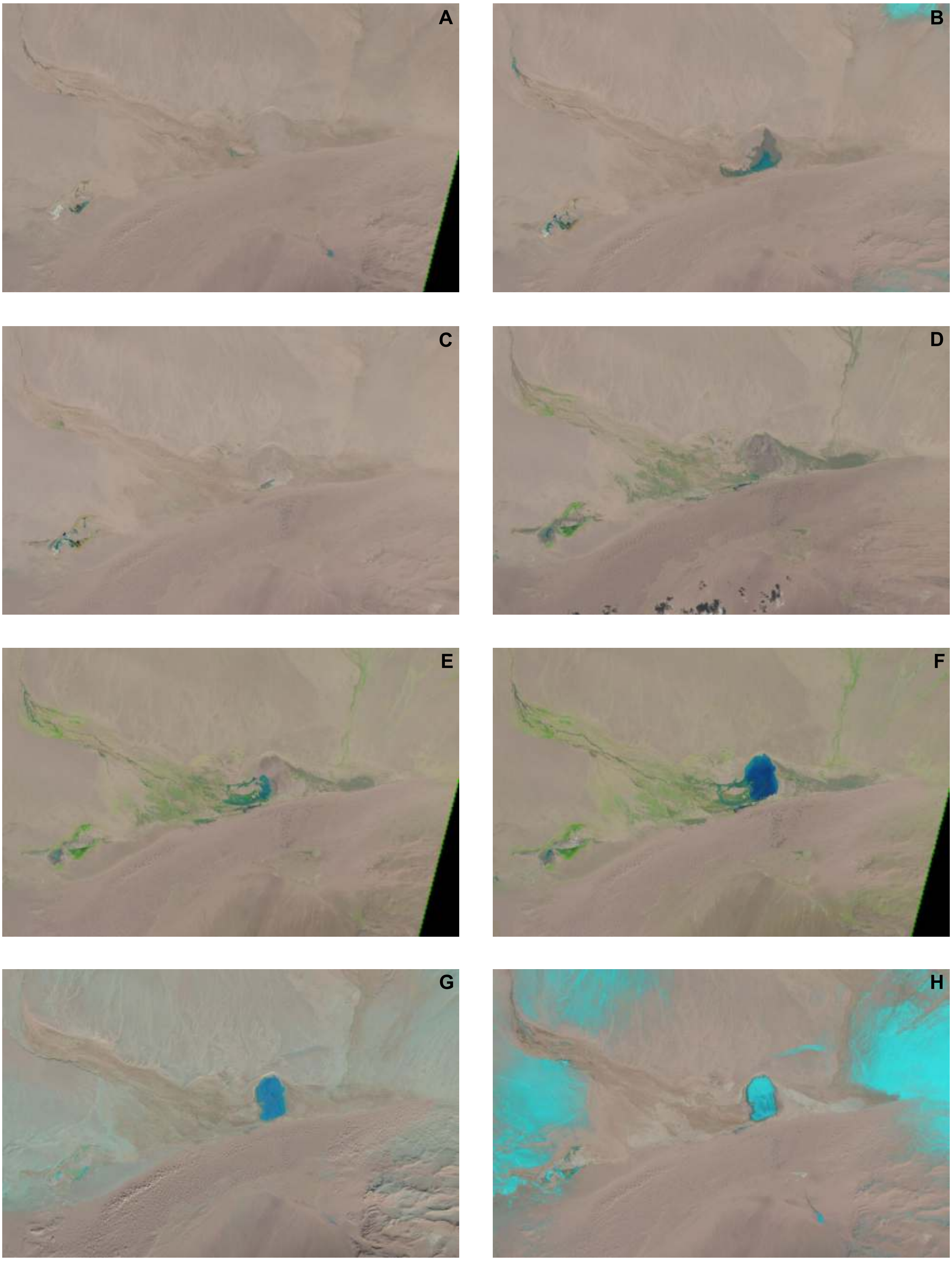

Fig. 1. Dynamics of filling of Taatsiin Tsagaan Nuur Lake in 2018–2019 according to SENTINEL satellite imagery: **A** – 20.03.2018, **B** – 06.04.2018, **C** – 01.05.2018, **D** – 15.07.2018, **E** – 07.08.2018, **F** – 17.08.2018, **G** – 12.12.2018, **H** – 17.03.2019.

lasts from late November to mid-March. A very interesting pattern can be observed when a high-water year is followed by a low water year. For instance, in 2016 on the catchment of the Taatsiin Gol River, the largest amount of precipitation during the study period fell, as a result of which the lake did not dry up in the fall and went into freezing. In 2017, despite record-breaking low rainfall, the lake remained filled during the growing season, drying up only by autumn. At the end of the second ten days of March 2018, the lake was filled with glacial water (Fig. 1A), remaining from March 22 to May 1. Then the lake dried up and began to reappear on June 25th. From that time until March 2019 the lake was filled with water.

In most cases, water temperatures in the pelagial (center of the lake) were lower than in the open littoral and reed thickets. Interannual changes in water temperatures are more noticeable in the shallow Taatsiin Tsagaan Nuur Lake (Table 3), where they increased significantly in the period 2017–2018, when the lake was characterized by a minimum area (Table 2) and depth.

The electrical conductivity, as well as the temperature, mainly decreased from the littoral to pelagic zone (Table 3). In the Orog Nuur Lake, against a background of a small decrease in the lake area (Table 2, 3), the electrical conductivity doubled in 2015 compared with the previous year, and in Lake Taatsiin Tsagaan Nuur in 2017, it increased by more than four-fold compared to 2016, which can be explained by a decrease in the lake area due to a decrease in precipitation and an increase in air temperature during this period (Table 1, 2, 3). In general, Orog Nuur Lake showed a more stable mode of electrical conductivity with a maximum disparity over the period of research of three times. At the same time, interannual differences in Taatsiin Tsagaan Nuur Lake can reach 12.7 times (2017 and 2018), including the whole range of interannual differences of Orog Nuur Lake and significantly going beyond it in the direction of maximum values. In 2014, 2015, 2016 and 2018 large values of electrical conductivity was observed in Orog Nuur Lake, and in 2017 Taatsiin Tsagaan Nuur Lake.

The hydrogen index changed minimally in the series of the studied biotopes and was characterized by greater long-term stability (Table 3) than other water properties of the lakes. The pH values of the lake were very close, although some differences were noticeable in some years. For instance, in 2014, 2016 and 2018, higher values were observed in Orog Nuur, and in 2015 and 2017 in Taatsiin Tsagaan Nuur.

Table 3. Physical and chemical characteristics of the water of the studied biotopes of the Orog Nuur and Taatsiin Tsagaan Nuur lakes. o. lit. – open littoral; reed – reed thickets in the littoral; pel. – pelagial; "–" – the lake was not examined.

Parameter	Year	Lake					
		Orog Nuur			Taatsiin Tsagaan Nuur		
		o. lit.	reed	pel.	o. lit.	reed	pel.
Tw, ºC	2010	23.2	–	–	–	–	–
	2013	21.9	–	18.8	–	–	–
	2014	22.1	21.1	21.0	18.2	18.9	18.2
	2015	17.9	18.1	18.8	14.7	14.5	14.4
	2016	21.5	21.2	20.3	21.2	20.5	19.6
	2017	21.9	21.9	21.0	28.4	28.4	28.2
	2018	27.7	26.4	24.7	29.2	29.5	29.6
EC, µS/cm	2010	1900	–	–	–	–	–
	2013	1924	–	1861	–	–	–
	2014	2503	2383	2314	1613	1614	1592
	2015	5500	5550	5880	1710	1686	1735
	2016	3700	3710	3550	3270	2840	2850
	2017	2097	3000	2095	15006	15000	15000
	2018	4340	4080	4050	1439	1415	1180
pH	2010	9.00	–	–	–	–	–
	2013	8.94	8.92	8.94	–	–	–
	2014	8.92	8.9	8.94	8.82	8.85	8.85
	2015	8.96	8.96	8.96	9.01	9.01	9.01
	2016	8.64	8.64	8.64	8.44	8.40	8.42
	2017	8.46	8.46	8.46	8.87	8.87	8.87
	2018	8.86	8.88	8.90	8.68	8.70	8.80

Interestingly, in 2015 Orog Nuur Lake showed a higher electrical conductivity of water, but at the same time lower pH values than Taatsiin Tsagaan Nuur Lake. Perhaps this is due to an excess amount of organic matter received by Orog Nuur Lake from the catchment area, for example, faeces of small cattle or plant debris from shore where hay is being harvested for winter feeding of animals. Indirectly, our assumption is confirmed by the fact that its was previously shown for zooplankton of Orog Nuur Lake that the trophicity coefficient can depends on how close the pastures are to the water's edge (Krylov et al., 2011).

In the study period the fauna of macroinvertebrates of Orog Nuur Lake included 27 species, including Chironomidae – 8, other Diptera – 3, Gastropoda – 4, Coleoptera – 5, and also one species each of Bryozoa, Oligochaeta, Hirudinida, Crustacea, Odonata, Heteroptera, and Trichoptera. Six species were recorded only by qualitative sampling (Table 4).

In 2010, in the first year of filling of the lake after complete drying, macrozoobenthos communities were probably not yet formed. On clay soils of the littoral, only single specimens of chironomid larvae were found (Table 4). In reed thickets, with dominance of *Procladius ferrugineus* (94.7% *N*, 89.7% *B*), diptera larvae of the family Dolichopodidae were found (Prokin, 2014).

In 2013, bottom dwelling invertebrates were not found in the reed-free littoral zone, and in the deeper area and in the reed thickets macrozoobenthos was represented only by the chironomid species, *Chironomus anthracinus*, which reached its maximum abundance in the thickets (Table 5).

In 2014, the species richness of macrozoobenthos increased (*n* = 14), the total number and biomass of communities (Table 5). In the open littoral zone, quantitative parameters were based on the chironomids *Tanypus punctipennis* (66.7% *N*, 29.3% *B*) and *C. anthracinus* (26.7% *N*, 68% *B*). In the reed thickets, chironomids dominated in numbers due to *Dicrotendipes nervosus* (69.2% *N*), but had less biomass than the bryozoan *F. sultana* (87% *B*), forming colonies on living and dying reed shoots. At the deepest part, the abundance of benthos decreased – as in 2013, it numbered the only species of *C. anthracinus*, represented only by occasional specimens (Prokin and Zhavoronkova, 2015).

In 2015, the only macroinvertebrates in littoral communities were the bryozoans *F. sultana*, and in the deepest part *C. anthracinus* (83.3% *N*, 90.9% *B*) dominated, along with the oligochaetes *Limnodrilus* sp. (Table 5).

In 2016, in all biotopes, macrozoobenthos was represented by a single species *C. anthracinus*, with the highest abundance in the profundal area (Table 5).

In 2017, 3 species were registered in the lake macrozoobenthos, 1 in each biotope, with minimal abundances (Table 5). Oligochaetes of *Limnodrilus* sp. were found in the open littoral, the chironomid *Dicrotendipes nervosus* were found in the reed thickets, and the chironomid *Cryptochironomus* gr. *defectus* was recorded in the profundal.

In 2018, in the composition of macrozoobenthos, 12 species were identified with the maximum total abundance and biomass in reed beds (Table 5) and the minimum abundance in the open littoral zone. This season, *Tanypus punctipennis* (73.7% *N*, 80.2% *B*) dominated in reed thickets (*n* = 9), *T. punctipennis* (38.5% *N*, 42.9% *B*) and *C. anthracinus* (46.1% *N*, 42.9% *B*); only two species were found in the open littoral zone (*Dicrotendipes nervosus*, Dolichopodidae sp.) represented by a few specimens.

In 2014 we studied phytophilic macroinvertebrate communities developing in the thickets of the pondweed *Stuckenia* sp. and in surface-floating mats of filamentous algae. Five species were identified in the community of macrozooophytos of pond weed, the total number was 1083.6 specimens/kg of wet weight of plants with the chironomid *Dicrotendipes nervosus* dominating (51.2% *N*); total biomass was 3.01 g/kg wet weight of plants with the dominance of *F. sultana* (72.1% *B*). In the community of the green hair algae (*n* = 4), the total number of macroinvertebrates was 91.77 specimens/kg of wet mass of plants with the greatest participation of *Enochrus* sp. (36.8% *N*), *Cricotopus* gr. *sylvestris* (31.6% *N*), and *Gammarus lacustris* (26.3% *N*). The total biomass was 0.36 g/kg wet weight of plants, with *Enochrus* sp. (55.5% *B*) and *Gammarus lacustris* (36.1% *B*) (Prokin and Zhavoronkova, 2015).

In 2017, in the thickets of *Stuckenia* sp., four macrozooophytos species were noted with a total population of 353.5 specimens/kg, biomass 4 g/kg, dominated by the number of chironomid *Cricotopus* gr. *sylvestris* (66.7% *N*), by biomass – bryozoan *F. sultana* (96% *B*).

In the same thickets in 2018, three species were recorded with a total abundance of 882 specimens/kg, biomass of 0.93 g/kg, with the dominance of chironomid *Tanypus punctipennis* (71.1% *N*) and the damselfly *Ischnura elegans* (65.6% *B*).

In the Taatsiin Tsagaan Nuur Lake, 23 macroinvertebrate species were found in total, of which 10 were Coleoptera, Crustacea and Heteroptera four each, Hydracarina and Odonata two each, and Chironomidae – one. 5 species were only recorded from the qualitative samples (Table 4). In common with Orog Nuur Lake were the beetles *Nebrioporus hostilis* (Dytiscidae), the damselfly *Ischnura elegans* (Coenagrionidae) and larvae of the Diptera family Dolichopodidae.

According to the 2014 quantitative samples, macrozoobenthos was absent in the gravel-clayey littoral at a depth of 0.3 m, and the only species of *Leptesteria dahalacensis* was found on the same soils in the reed thickets at a depth of 0.7 m, the abundance was 100 specimens/m^2 and the biomass was 6.55 g/m^2.

Table 4. Taxonomic composition of the population of macroinvertebrate of Orog Nuur and Taatsiin Tsagaan Nuur lakes. * – species found only by qualitative sampling.

Taxon	Lake: Orog	Lake: Taatsiin Tsagaan
Bryozoa		
Fredericella sultana (Blumenbach, 1779)	+	–
Oligochaeta		
Limnodrilus sp. (juv.)	+	–
Hirudinida		
Piscicola geometra (Linnaeus, 1761)	+	–
Gastropoda		
Radix parapsilia Vinarski et Glöer, 2009*	+	–
R. auricularia (Linnaeus, 1758)*	+	–
Gyraulus stelmachoetius (Bourguignat, 1860)	+	–
G. chinensis (Dunker, 1848)	+	–
Crustacaea		
Eocyzicus orientalis Daday, 1913	–	+
Caenesteria davidi (Simon, 1886)	–	+
Leptesteria dahalacensis (Ruppell, 1837)	–	+
Triops granarius (Lucas, 1864)	–	+
Gammarus lacustris Sars, 1843	+	–
Hydracarina		
Eylais extendens Müller, 1776	–	+
E. triarcuata Piersig, 1899	–	+
Insecta		
Odonata		
Ischnura elegans (van der Linden, 1820)	+	+
Coenagrion vernale Hagen, 1839	–	+
Heteroptera		
Paracorixa concinna (Fieber, 1848)	–	+
Sigara lateralis (Leach, 1817)	–	+
S sibirica Jaczewski, 1963	–	+
S. seistanensis (Distant,1920)*	+	–
Corixidae spp. (nymphae)	–	+
Trichoptera		
Triaenodes sp.	+	–
Coleoptera		
Nebrioporus hostilis (Sharp, 1884)*	+	+
Hygrotus confluens (Fabricius, 1787)	–	+
H. enneagrammus (Ahrens, 1833)	–	+
H. flaviventris (Motschulsky, 1860)*	–	+
H. parallellogrammus (Ahrens, 1812)*	–	+
Hygrotus spp. (larvae)*	–	+
Helophorus parajacutus Angus, 1970*	–	+
Enochrus quadripunctatus (Herbst, 1797)*	+	–
Enochrus spp. (larvae)	+	–
Berosus fulvus Kuwert, 1888	–	+
Berosus spp. (larvae)	–	+
Ochthebius subaeneus Janssens, 1967	+	–
O. perdurus Reitter, 1899*	+	–
Macroplea mutica (Fabricius, 1792)	–	+
Chironomidae		
Tanypus punctipennis Meigen, 1818	+	–
Procladius ferrugineus Kieffer, 1919	+	–
Cricotopus gr. *sylvestris*	+	–
Cryptochironomus gr. *defectus*	+	–
Cladopelma sp.	+	–
Dicrotendipes nervosus (Staeger, 1839)	+	–
Glyptotendipes paripes (Edwards, 1929)	+	–
Chironomus anthracinus (Zetterstedt, 1860)	+	–
Other Diptera		
Bezzia aff. *kuhetiensis* Remm, 1967	+	–
Ephydridae sp.	+	–
Dolichopodidae spp.	+	+
Total	**27**	**23**

Table 5. Species richness and quantitative characteristics of the macrozoobenthos of Orog Nuur and Taatsiin Tsagaan Nuur lakes. o. lit. – open littoral; reed – reed thickets in the littoral; prof. – profundal; "–" – the lake was not examined.

Parameter	Year	Lake					
		Orog Nuur			Taatsiin Tsagaan Nuur		
		o. lit.	reed	prof.	o. lit.	reed	prof.
n	2010	1	2	1	–	–	–
	2013	0	1	1	–	–	–
	2014	3	8	1	0	1	1
	2015	1	1	2	0	1	1
	2016	1	1	1	1	2	0
	2017	1	1	1	0	1	0
	2018	2	9	4	0	0	0
N, spec./m^2	2010	40	380	120	–	–	–
	2013	0	850	250	–	–	–
	2014	750	1300	50	0	100	100
	2015	50	50	300	0	150	200
	2016	20	40	300	50	850	0
	2017	50	100	50	0	50	0
	2018	100	3800	650	0	0	0
B, g/m^2	2010	0.10	0.78	0.16	–	–	–
	2013	0	6.80	2.70	–	–	–
	2014	3.75	17.30	0.25	0	6.55	9.85
	2015	1.60	0.30	0.55	0	1.65	1.80
	2016	1.04	0.84	3.54	0.55	23.55	0
	2017	0.10	0.20	0.15	0	0.35	0
	2018	0.15	4.80	0.70	0	0	0

In the deepest area without reed thickets, the species *Caenesteria davidi,* with 100 specimens/m^2 and biomass of 9.85 g/m^2 was found (Prokin and Zhavoronkova, 2015).

Quantitative samples of nekton showed a more objective picture of the distribution of macroinvertebrates in various lake biotopes. The total abundance of Spinicaudata in shallow waters was 11.5±5.7 specimens/m^3, in uncharted areas of great depths – 2.5±1.9 specimens/m^3, reed thickets – 15.2±5.4 specimens/m^3. The distribution of nekton biomass in 2014 is shown in Fig. 2.

Thus, the abundance of Spinicaudata, a mass group of lake nekton, in 2014, was significantly higher in reed thickets and in more heated areas of the shallow littoral than at greater depths outside the thickets. The survey data show that for Spinicaudata, the traditional assessment of the abundance of macroinvertebrates using bottom sampling may give incorrect results, either overestimating (on the pelagial) or underestimating (on the open littoral) their true abundance (Prokin and Zhavoronkova, 2015).

The collected material provided preliminary data on the ratio of the sexes of two of the three syntopic Spinicaudata species occurring, and on their average individual mass (Table 6). According to the total number of collected specimens, *Leptesteria dahalacensis, Eocyzicus orientalis* and *Caenesteria davidi* were represented in a ratio of 1:8:26.7. For *E. orientalis*, the sex ratio was close to 1:1 with a greater average weight of males. The ratio of males and females of *C. davidi* was 1:2, also with a greater average weight of males. Probably, the higher individual mass of Spinicaudata males is explained by the fact that females spend a significant part of their energy on producing eggs (Prokin and Zhavoronkova, 2015).

In 2015, the lake macrozoobenthos was represented by a single chironomid species *Chironomus anthracinus* in the profundal and reed thickets. No benthic macroinvertebrates were found in the open littoral zone (Table 5).

In 2016, macrozoobenthos was represented by two species of crustaceans in the open littoral and reed thickets, in the profundal no benthic invertebrates were found. In the thickets where the maximum abundances were recorded (Table 5), both species were found, with the species *Caenesteria davidi* dominating in numbers (88.2% *N*), and *Triops*

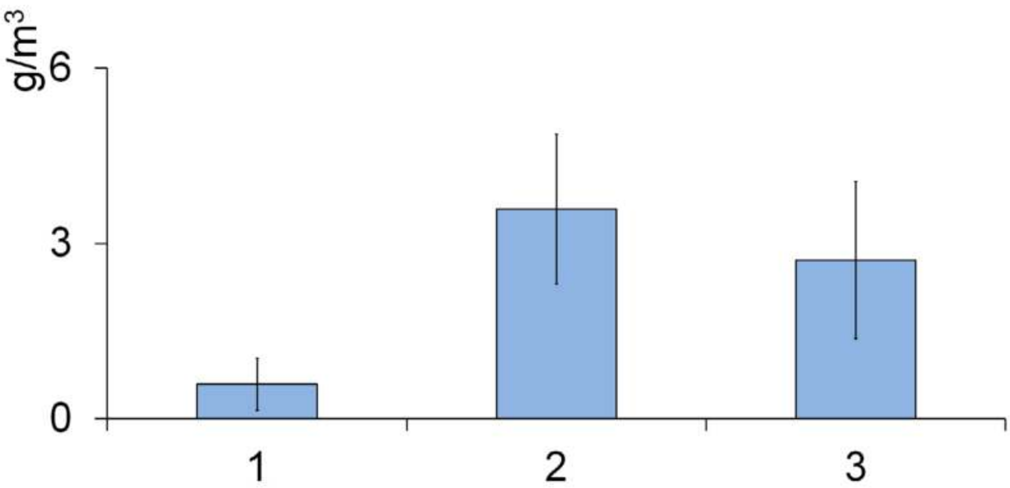

Fig. 2. Biotopic distribution of the biomass of Spinicaudata of Taatsiin Tsagaan Nuur Lake in 2014: 1 – pelagial at a depth of 0.7 m; 2 – reed thickets at a depth of 0.7 m; 3 – littoral at a depth of 0.3 m.

granarius in biomass (63.7% *B*). In the open littoral, only *C. davidi*, represented by single specimens, was encountered.

In nekton in that year two species were also found (*C. davidi* and *Paracorixa concinna*) in the same biotopes, but here the pelagial differed in the maximum abundance of organisms due to the development of a single species *C. davidi* (Table 7). In thickets ($n = 2$), the quantitative development of nekton was significantly lower (Table 7), with *C. davidi* dominating (88.9% *N*, 85.7% *B*).

As part of the lake macrozoobenthos in 2017, only larvae of the family Dolichopodidae were found, represented by single specimens in reed thickets. In the 2017 nekton, 11 species of insects were found with the maximum species richness and abundance in reed beds (Table 7), dominated by bugs, i.e., nymphs of Corixidae (54.6% *N*, 41.5% *B*) and the adult *Paracorixa concinna* (30.8% *N*, 45.3% *B*). In the open littoral, five species of nekton were found dominated by *P. concinna* (46.4% *N*, 78.3% *B*), in the pelagic zone, 7 species dominated by the nymphs of Corixidae (46.4% *N*, 30% *B*), *Sigara sibirica* (26.4% *B*), and *S. lateralis* (20.9% *B*). The total abundance and biomass of nekton in the open littoral and pelagial were similar (Table 7).

In 2018, no macrozoobenthos was found in any of the examined biotopes, and 3 species of heterotopic insects were found in the nekton, found only in reed beds (Table 7), dominated by *P. concinna* bugs (40% *N*, 47.4% *B*) and water beetles *Berosus fulvus* (40% *N*, 31.6% *B*).

Discussion

Along with filling and silting of Orog Nuur Lake in 2010–2014, species richness and macrozoobenthos abundance increased in littoral communities, then in 2015–2017 species diversity and abundance declined, having increased again in 2018 (Table 5). In addition to chironomids, bryozoans, leeches, mollusks, caddisflies and beetles were recorded in the macrozoobenthos during the study period. At the greatest depths of the profundal, monospecific groups of *Chironomus anthracinus* were formed, and then the chironomids *Cryptochironomus* gr. *defectus*, *T. punctipennis* and the oligochaetes *Limnodrilus* sp. were recorded. Bryozoans, crustaceans *Gammarus lacustris*, damselfly *Ischnura elegans*, larvae of wa-

Table 6. The number of specimens and the average individual mass of Spinicaudata in Taatsiin Tsagaan Nuur Lake in 2014.

Species	Sex	specimens	g/specimen
Eocyzicus orientalis	♂♂	38	0.047
	♀♀	34	0.032
Caenesteria davidi	♂♂	80	0.052
	♀♀	160	0.033
Leptesteria dahalacensis	♂♂	7	0.045
	♀♀	2	0.019

Table 7. Species richness and quantitative characteristics of the nekton communities of Lake Taatsiin Tsagaan Nuur. o. lit. – open littoral; reed – reed thickets in the littoral; pel. – pelagial.

Parameter	Year	Biotope		
		o. lit	reed	pel.
n	2014	3	3	3
	2016	1	0	2
	2017	5	9	7
	2018	0	3	0
N, spec./m^3	2014	46	60.8	10
	2016	19.6	0	3.6
	2017	2.8	54.2	2.8
	2018	0	0.5	0
B, g/m^3	2014	2.79	3.58	0.59
	2016	0.14	0	0.04
	2017	0.01	0.49	0.01
	2018	0	<	0

ter beetles of the genus *Enochrus* and Diptera of the families Chironomidae, Ceratopogonidae and Ephydridae participated in the formation of phytophilic communities. Thickets of *Stuckenia* sp. showed higher macroinvertebrate abundances compared to floating mats of filamentous algae.

Low macrozoobenthos abundances are probably characteristic of Orog Nuur Lake, since in 1991 only chironomids were noted here, with low abundance rates (Dulmaa et al., 1994), and in August 2004 beetles, chironomids and biting midges (6 species in total) were found with fluctuations in the total number of communities from 200 to 400 specimens/m^2 and biomass – from 0.6 to 2.36 g/m^2 (Shcherbina and Ayuushsuren, 2007). The decrease in the species richness and quantitative characteristics of the lake macrozoobenthos, which began in 2015, may be due to an increase in electrical conductivity (in 2014, average EC for the lake = 2400 µS/cm, in 2015 – EC = 5643 µS/cm), although in 2018, with a high average electrical conductivity (EC = 4156 µS/cm), a high species richness was recorded in the lake, the maximum average abundance and high biomass of communities (Table 3).

Significant interannual changes in the composition and quantitative characteristics of the macrozoobenthic and nekton communities of Taatsiin Tsagaan Nuur Lake are due to its functioning as a temporary basin in the study period. Macrozoobenthos is not usually developed by the time of sampling, or is represented by nektonic and pelagobenthic crustacean species characteristic of temporary basins (*Triops granarius*, Spinicaudata). The only year (2015) when chironomids were encountered in the benthos was characterized by the maximum period of lake filled with water by the time of sampling (132 days). At the same time, in 2018, when the water-filled period was only 48 days, no macrozoobenthos was detected at all, and nekton was represented by a small number of heterotopic species with low abundance in a single biotope. Necton in 2014 and 2016 was represented mainly by crustaceans and in 2017–2018 by insects, mostly heterotopic beetles and bugs. The reasons for such a restructuring of nekton communities can be associated with the intensive consumption of crustaceans by aquatic birds, as well as with some non-obvious factors that adversely affected the production and preservation of Spinicaudata eggs. In particular, in 2017, amid a decrease in precipitation, there was a more than four-fold increase in the electrical conductivity of lake water (up to 15000 µS/cm) (Table 3), which apparently had an adverse effect on the development of crustaceans. In these conditions, heterotopic insects have advantages in settling in the lake as they are more resistant to this factor.

Comparison of the quantitative characteristics of hydrobionts with the properties of water for each biotope showed a significant inverse relationship between the abundance and biomass of nekton in the open littoral zone of Taatsiin Tsagaan Nuur Lake on water temperature (regression coefficient $b = -3.73$, significance level $p = 0.042$, coefficient of determination $R^2 = 0.91$ and $b = -0.197$, $p = 0.042$, $R^2 = 0.6$). The inverse dependence of nekton biomass on water temperature in the Taatsiin Tsagaan Nuur Lake, without reference to biotopes, also turned out to be significant ($b = -0.135$, $p = 0.024$, $R^2 = 0.31$). This is due to too intensive warming of water (up to 29.6 °C) at shallow depths, which causes macroinvertebrates to concentrate in the least heated biotopes, in particular, reed thickets, which also provide additional microbiotopes to avoid predators and food resources in the form of plant detritus. Analysis of quantitative characteristics for all biotopes showed a significant positive dependence of the number of nekton species in Taatsiin Tsagaan Nuur Lake from the electrical conductivity of water (b = 0.0004, p = 0.002, R^2 = 0.7) and acidity (b = 8.97, p = 0.033, R^2 = 0.36). Correlation analysis confirms these dependencies: there is a correlation between the number of nekton species and electrical conductivity (r = 0.84, p = 0.004); the number of species and acidity (r = 0.6, p = 0.018); biomass and water temperature (r = −0.56, p = 0.026). The observed patterns are explained by the large species richness and lesser biomass of heterotopic insects found here in recent years compared to crustaceans.

Among the quantitative indices of hydrobionts averaged over various biotopes, a significant relationship was found between the benthos biomass in Taatsiin Tsagaan Nuur Lake and the number of days with precipitation > 1 mm (b = 0.5, p = 0.033, R^2 = 0.96). It should be noted that all three humidity characteristics studied (the amount of precipitation for April–August, the number of days with precipitation > 1 mm and the maximum precipitation) were significantly positively correlated with each other. Also, due to the impoverished species composition of the communities, all quantitative indicators of benthos in lakes are correlated. Since the quantitative parameters of benthos in Taatsiin Tsagaan Nuur Lake showed no reliable correlation with other humidity characteristics, we tend to consider the above correlation as random.

Using Fisher's Z-transformation, we compared the correlation coefficients between the quantitative characteristics of macrozoobenthos and the characteristics of the environment in two lakes. Significant differences in biotopes showed the dependence of abundance on water temperature (r_1 = 0.45 and r_2 = –0.26 for Orog Nuur Lake and Taatsiin Tsagaan Nuur Lake, respectively, the significance of the differences p = 0.044) and the dependence of the number of species on water temperature (r_1 = 0.43, r_2 = –0.4, p = 0.018). The mean values also differ according to the number of species as a function of water temperature (r_1 = 0.66, r_2 = –0.76, p = 0.039), and the dependence of biomass on the number of days with precipitation > 1 mm (r_1 = 0.41, r_2 = 0.98, p = 0.032). The statistically insignificant, but rather high degree of difference was shown by correlations of water abundance and temperature (r_1 = 0.75, r_2 = −0.51, p = 0.076), as well as the total number of species and water temperature (0.68, r_2 = –0.59, p = 0.082). These results are of a non-strict nature, since no multiple testing corrections was applied to them. Due to the small number of samples, the significance level of all correlation coefficients is low, and even relatively mild multiple testing correction (Holm's and Hommel's methos) lead to a significance level of differences equal to one for almost all comparisons.

Thus, a comparison of the correlation coefficients shows that the quantitative indicators of macrozoobenthos in the two lakes depend on the characteristics of the environment in different ways. In particular, macrozoobenthos of Orog Nuur Lake benefits from more heated biotopes, and in Taatsiin Tsagaan Nuur Lake, characterized by considerable warming of the water column, it is the other way around.

The taxonomic composition of the macroinvertebrates of the studied lakes varies considerably. In a drying Taatsiin Tsagaan Nuur Lake in contrast to Orog Nuur Lake, homotopic hydrobionts from the Bryozoa, Oligochaeta, Hirudinida and Gastropoda groups are not found, and a tenth of the number of chironomid species were recorded. At the same time, completely different groups of crustaceans were found here compared to those in Orog Nuur Lake; water mites, and species richness of heterotopic insects from the orders Heteroptera and Coleoptera is significantly higher, 4 and 2 times, respectively (Table 4).

A comparison of the macrozoobenthos of Orog Nuur and Taatsiin Tsagaan Nuur lakes in the first year of filling the basin (2010 and 2014, respectively) shows fundamentally different mechanisms for the formation of the macroinvertebrate fauna. In Orog Nuur Lake communities are formed by chironomids, and only later in the composition of macrozoobenthos and phytophilic communities do other taxonomic groups appear, represented by the most widespread species in the region. Probably, the settlement of this lake, in addition to by imagos of amphibiotic and aquatic insects capable of migrating through the air, is due to the invertebrates from the Tuin Gol River, which flows into the lake, as well as from the helocrens common in the vicinity (Prokin and Zhavoronkova, 2015).

In the formation of the population of macroinvertebrates of Taatsiin Tsagaan Nuur Lake in the first year of its existence (2014), a leading role was played by species capable of surviving in a dry period as resting eggs (Spinicaudata, *Triops granarius*). As a rule, no more than two species of "Conchostraca" live in one reservoir (Thiery, 1991), and *Eocyzicus orientalis* often occurs in fish ponds and paddy fields together with *Leptesteria dahalacensis* (Dobrynina, 2003). The recorded syntopic habitat of these species with *Caenesteria davidi*, was not previously indicated and is of undoubted interest (Prokin and Zhavoronkova, 2015). Univoltine and bivoltine species of water mites of the genus *Eylais* (Eylaidae) are typical inhabitants of temporary and drying-out basins, where they enter the stages of the larva settling on imagoes of aquatic insects (Heteroptera, Coleoptera). Mature mites and deutonymphs are predators that feed on planktonic crustaceans (Cook, 1974; Wiggins et al., 1980). Hence, in the first year of the filling phase of the basin, species are present that can spread through the air (adults of *Nebrioporus hostilis*; larvae of water mites, which are phoretic or parasitic on insects). This means of introduction also explains the presence of larvae of the genus *Hygrotus* (Coleoptera, Dytiscidae), which avoid development in flowing water, and, therefore, are not migrants from the river (Prokin and Zhavoronkova, 2015). Later, the macroinvertebrate fauna of the lake becomes enriched with heterotopic bugs and bugs against a background of the extinction of crustaceans, which, we assume, is due to a sharp increase in water conductivity in 2017. Chironomids can inhabit the lake during the maximum stable water level during the 2015 season, but do not withstand its further drying or freezing to the bottom. Thus, during the period of research, the fauna of this lake reflects its state as a temporary basin.

An increase in the duration of the transition period revealed in the water cycle of Taatsiin Tsagaan Nuur Lake compared to data from previous publications (Dgebuadze, 1995), probably indicates a serious climate change in the region and requires further monitoring studies.

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