ORIGINAL ARTICLE

Plankton community and the relationship with the environment in saline lakes of Onon-Torey plain, Northeastern Mongolia

Ekaterina Yu. Afonina, Natalya A. Tashlykova *

Institute of Natural Resources, Ecology and Cryology of the Siberian Branch of Russian Academy of Sciences, Laboratory of Aquatic Ecosystems, Chita, Russia

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Abstract The plankton community of sixteen saline lakes located on Onon-Torey plain (Northeastern Mongolia) during the filling phase and the raising of the water level was investigated in July 2011. Thirty-five taxa of phytoplankton and thirty-one species of zooplankton were found. For phytoplankton, blue-green algae (Merismopedia elegans, Anabaenopsis elenkinii, Arthrospora fusiformis, Spirulina major, Lyngbya sp., Oscillatoria sp.) and green algae (Monoraphidium minutum, Tetrastrum komarekii, Ankya ocellata, Oocystis sp.) were dominant. For zooplankton, Filinia longiseta, Brachionus plicatilis, B. variabilis, Hexarthra mira (Rotifera), Daphnia magna, Moina brachiata, M. mongolica (Cladocera), Arctodiaptomus bacillifer, Mixodiaptomus incrassatus, Meta-
diaptomus asiaticus (Copepoda) dominated. Mineralization, active hydrogen ratio, dissolved oxygen and water temperature were the main factors influencing the diversity, structure and distribution of plankton organisms in the steppe lakes during low water level. The RDA analysis for phytoplankton and zooplankton from different lakes was carried out for selected two groups which included lakes and a subset related species. The first group is of oligohaline and mesohaline lakes in which mostly green algae, rotifers and copepods inhabit. The second group is of mesohaline and polyhaline lakes with mainly blue-green algae, some crustaceans and rotifers inhabiting. High abundance and biomass of Spirulina major, Oscillatoria sp. and Brachionus variabilis were observed in lakes with high mineralization, pH and temperature.

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1. Introduction

Naturally mineralized lakes with high pH value are unique ecosystems, they become the objects of many studies. Researches are connected with different aspects of the ecosystem’s structural–functional organization and ecological
changes caused by external influence (Williams, 2002; Balushkina et al., 2007).

There are over 900 natural lake basins in the territory of Eastern Mongolia, 72% of them belong to the Onon, the Uldza and the Khalkhin river basins (Sevastyanov and Tserensodnom, 2014). Semi-arid climate conducive to the evaporative concentration of surface water, and hummocky terrain with many closed depressions favors the formation of saline lakes in this area (Dzyuba and Kulagina, 2005). Most of water-bodies belong to the Eastern Mongolia system of small lakes (Sklyarov et al., 2011). High amplitudes of long-term fluctuations of water level are characteristic of these lakes. These amplitudes result in the variability of morphometrical, hydrochemical and hydrological parameters of lakes. From the scientific point of view, lakes of northeastern Mongolia are natural laboratories for adaptations of saltwater lake organisms to extreme environmental conditions. In this respect studies of plankton communities as one of the most important functional components of lacustrine ecosystems are especially topical. During various periods, the amplitude of fluctuations of depths in small lakes is quite high. Sometimes the lakes dry out fully. Climate change causes changes in water level, area, mineralization, active hydrogen ratio, nutrients and others. Fluctuations in environmental factors lead to changes in species diversity and structure characteristics in communities of aquatic organisms. During low water dry years (2008), when compared to high water 1966 and 1993, the lake depths decreased and water mineralization increased (Itigilova et al., 2014). Information on the changes in the ecological conditions in the lakes is presented in the published papers (Dulmaa, 1966; Sheveleva et al., 2009; Dorofeyuk and Tsesesegna, 2014.). The beginning of the filling in ones lakes and the raising of the water level in others were recorded in 2011. But data from these periods of recovery of ecosystem functioning in the saline lakes of northeastern Mongolia are virtually absent.

Our main goal was to study hydrobiological characteristics (species composition, abundance, biomass of algae and zooplankton) of some saline lakes in the northeastern Mongolia to determine the relationship between plankton community structure and environmental factors during low water level. The main questions were: (1) What environmental factors are main in the saline lakes during the low water level? (2) How do these factors affect the plankton species composition and structure? (3) How do taxonomic groups of phytoplankton and zooplankton respond to changes in environmental factors?

2. Materials and methods

2.1. Description of the study lakes

All studied lakes are located on the territories of steppe Mongolia in the Uldza-Gol and Kerulen rivers basins (Fig. 1).

Almost all lakes are shallow (except Khukh), so waters are stirred by the wind well. Mainly soils are clay, so the water is very turbid. Lakes Sumiyn, Teeliyn and Yakhi were at the stage of flooding with water after full drying in previous years. Its waters were desalinated owing to the new flooding of the lake depressions. The strong smell of hydrogen sulfide was felt from the Lake Khaichiyn Tsaydam.

Dissolved oxygen concentration ranged from 1.2 to 17.5 mg l⁻¹. The pH value ranged 9.2–9.9, describing water as alkaline. The water temperature varied from 19.5 to 35.2°C. In terms of water mineralization, the studied lakes may be divided into three groups: oligohaline lakes having water mineralization of 0.7–4.2 g l⁻¹, mesohaline lakes with water mineralization of 5.0–16.2 g l⁻¹, and polyhaline lakes with mineralization over 20 g l⁻¹ (Itigilova et al., 2014). The dominant cation was sodium, hydrocarbomonate was the dominant anion, chloride was the sub-dominant anion with increasing mineralization (Sklyarov et al., 2011) (Table 1).

In the most deep water Lake Khukh, no clear vertical stratification was found either in temperature (temperature at surface 21.6°C; at bottom, 19.5°C) or in water salinity (2.6–3.8 g l⁻¹). The content of oxygen varied with depth from 12.9 mg l⁻¹ at the surface to 1.2 mg l⁻¹ near the bottom. The values of pH ranged from 9.2 to 9.3. The water transparency varied from 0.5 m to 4.5 m (Itigilova et al., 2014).

2.2. Sampling methods and data collection

Our studies of the plankton community (algae and invertebrates) in 16 saline lakes were carried out in July 2011. Some abiotic environmental parameters (temperature, pH, dissolved oxygen, mineralization) were measured using an AQUAMETER 200TM device (Itigilova et al., 2014). Water transparency was measured by Secchi disk. The viscous clay soils were not allowed to fully carry out the study of lakes. Due to the shallowness of the lakes subsuperficial samples were taken.

For phytoplankton, from each lake (except Khukh), a 1 liter sample was taken. Each sample consisted of subprobe selected in two to four different parts of the lake. Subprobes were mixed, and then one integrated sample of required volume was selected. On Huh Lake a phytoplankton samples were taken from surface, middle and bottom layers by Patalas bathometer (6 l). Thirty-eight of phytoplankton samples fixed in 4% formalin were collected. The sedimentation method was used to concentrate phytoplankton. Cell calculation was made in a counting plate (0.01 ml volume) using the Hansen method. Algae biomass was determined with geometric figures method (Sadchikov, 2003). Taxonomic identification is given by Guides to the Identification of the Freshwater Algae . . . (1962, 1980), Tsarenko (1990); Komárek and Anagnostidis (1986, 1989, 1998, 2005); Genkal and Trifonov (2009); Popovskaya et al. (2011); Guiry and Guiry (2014).

Zooplankton was sampled quantitatively using a Judy net with a filtering cone made of Capron mesh (125 µm) on four lakes (Ikh Dalay, Baga Dalay, Gurmiyn, Khukh). Samples were taken from the whole water column (bottom-to-surface). From other lakes from 10 to 60 l of water was filtered through the net during sampling. These samples were collected using the same principle as for phytoplankton. For qualitative sampling, a hand net was used. A total of 32 quantitative and 18 qualitative samples were collected and processed. The samples were preserved in a 4% formalin solution following standard routine and counted in the Bogorov chamber (Guidelines . . ., 1982). Abundance (ind. m⁻³) and biomass (g m⁻³) were calculated for each species in each sample. The biomass of zooplankton was determined considering the size of zooplankters...
Taxonomic identification was performed according to papers (Kutikova, 1970; Borutskii et al., 1991; Identification Guide ..., 1995).

In every group (phyto-, zooplankton) we considered as dominant species those with abundance and biomass not less than 10% of total abundance and biomass (Fedorov and Gilmanov, 1980).

**Table 1** Natural status of saline lakes in the Northeastern Mongolia (2011)∗.

| Lakes** | Sampling depth, m | Transparency, m | O₂, mg l⁻¹ | pH | T, °C | Mineralization, g l⁻¹ |
|---------|-------------------|-----------------|-------------|----|------|----------------------|
| Teeliyn (1) | 0.4 | – | – | 9.3 | 23.9 | 0.72 |
| Davsan Tsaygan (2) | 0.5/0.8 | – | – | 9.4 | 9.3 | 26.5–26.6 | 1.4 |
| Yakh' (3) | 0.2 | – | – | 7.2 | 9.2 | 19.7 | 1.4 |
| Ikh Dalay (4) | 0.3/2.1 | 2.1 | 10 | 9.5 | 22.1–23 | 3.1 |
| Khukh (5) | 0.5/2.5/2.8/10 | 4.5 | 1.2–12.9 | 9.2–9.3 | 19.5–21.6 | 2.6–3.8 |
| Angirt (6) | 0.4 | – | – | – | 27.6 | 4.1 |
| Sumiyn (7) | 0.1 | – | 7 | 9.3 | 22.2 | 4.1 |
| Guriymi (8) | 0.5/1.5/3.8 | 0.5 | 5.3 | 9.5 | 27–27.6 | 4.2 |
| Baga Dalay (9) | 0.2/1.5 | 1.5 | 6 | 9.4 | 22 | 5.2 |
| Baruun Tsaidam (10) | 0.3 | – | 2.3 | 9.3 | 35.2 | 7.8 |
| Galaut (11) | 0.3 | – | 6.2 | 9.7 | 27.6 | 14.6 |
| Buus (12) | 0.4 | – | 3.7 | 9.4 | 23.2 | 14.7 |
| Delger (13) | 0.2 | – | 17.5 | 9.3 | 26.1 | 14.9 |
| Khaichiyn Tsaydam (14) | 0.1 | – | – | 9.6 | 29.6 | 16.2 |
| Zuuu Tsaydam (15) | 0.3 | – | 6.4 | 9.9 | 30.9 | 21.3 |
| Zeerengiy (16) | 0.2 | – | 4.5 | 9.8 | 28 | 21.4 |

* Itigilova et al. (2014).
** Index number in parentheses; – not measurement.
2.3. Data process

Data analysis of variance was performed using the XLSTAT. Redundancy analysis (RDA) was carried out, based on principal component analysis (PCA), for relationships between the plankton organisms and environmental factors. The statistical software package (Version 12.0) was used for correlation analysis. Values of correlation coefficients are presented for \( p < 0.05 \).

3. Results

3.1. Phytoplankton

The species composition and distribution of phytoplankton are listed in Table 2. Thirty-five taxa of algae were recorded, of them 17 species of Chlorophyta, 6 species of Bacillariophyta, 10 species of Cyanobacteria, 1 species of Dinophyta and 1 species of Euglenophyta.

In high mineralized waters (14.6–16.2 g l\(^{-1}\)) species richness ranged from 2 to 8. Abundance ranged from 6 to 4294.8 \( \times 10^3 \) cell l\(^{-1}\), biomass ranged from 8 to 20,518 mg m\(^{-3}\). The blue-green alga (Arthrospira fusiformis, Spirulina major and Oscillatoria sp.) dominated. In lakes with mineralization 3.8–7.8 g l\(^{-1}\) species richness varied from 4 to 14. Phytoplankton abundance ranged from 41 to 445 \( \times 10^3 \) cell l\(^{-1}\), biomass ranged from 30 to 500 mg m\(^{-3}\). Green, diatoms, blue-green algae (Abaenopsis elektikii, Merisnopedia elegans, Tetrastrum komarecki, Lyngbya sp., Oocystis sp.) were dominants. Most of found species such as Diatoma vulgare, Cocconeis placentula, Navicula oblonga, N. placentula are salt-tolerant freshwater species, euryhaline species or halophile species with a broad adaptation to salinity. Freshwater and brackish species were in low mineralization water. Total abundance and biomass were no more than 3 \( \times 10^3 \) cell l\(^{-1}\) and 0.2 mg m\(^{-3}\), respectively.

The common species richness of phytoplankton ranged from 1 to 13 and tended to decrease with increasing mineralization, but correlation was very low (\( r = -0.40, p = 0.72, n = 20 \)). Biomass ranged from 0 to 20,518 mg m\(^{-3}\) and abundance ranged from 0 to 4455.2 \( \times 10^3 \) cell l\(^{-1}\). Total abundance was not obviously correlated with mineralization and biomass was (\( r = 0.60, p = 0.048, n = 20 \)).

3.2. Zooplankton

Zooplankton species composition and distribution are given in Table 3. Thirty-one species were recorded, represented by 17 species of rotifers, 6 species of cladocerans, and 8 species of copepods. According to the frequency of occurrence, biomass and abundance, the major species were Filinia longiseta, Hexarthra mira, Brachionus plicatilis, B. variabilis (Rotifera); Daphnia magna, Motha brachiatia, M. mongolica (Cladocera); Metadiaptomus bacillifer, Mixodiaptomus incrassatus, Metadiaptomus asiaticus (Copepoda) (Itigilova et al., 2014).

Brackish and freshwater species such as Filinia longiseta, Hexarthra mira, Keratella quadrata and Arctodiaptomus bacillifer were dominants in water with low mineralization (0.72–4.1 g l\(^{-1}\)). The mineralization 5.2 g l\(^{-1}\) was favorable for Mixodiaptomus incrassatus. The typical pond species Daphnia magna dominated in the filling lakes. Halophile species Moina brachiata, M. mongolica, Metadiaptomus asiaticus, Brachionus plicatilis prevailed in lakes with mineralization \( \geq 14 \) g l\(^{-1}\). Brachionus variabilis occurred at highest salinities \( \geq 21 \) g l\(^{-1}\) with huge abundance 11.88 \( \times 10^6 \) ind. m\(^{-3}\).

The species richness ranged from 1 to 13. Correlation with mineralization was low and no obvious (\( r = -0.40, p = 0.72, n = 20 \)). Total biomass ranged from 0.17 to 77.42 gm l\(^{-1}\) and total abundance from 6.2 to 1896 \( \times 10^3 \) ind. m\(^{-3}\). Biomass was not correlated with mineralization and abundance was (\( r = 0.64, p = 0.042, n = 18 \)).

The biomass, abundance and dominant species of phytoplankton and zooplankton are recorded in Table 4.

3.3. Correlation between plankton community and changes of environmental factors

Correlation analysis and multifactorial analysis were performed on the basis of Tables 1, 2 and 3 which allowed us to identify the main factors that determine the differences in the phytoplankton and zooplankton structures of the saline lakes during low water level. The ratio of species and their habitats visualized using RDA analysis are shown in Fig. 2.

Two groups of lakes and a subset of related species are represented in the diagram. The first group is of oligohaline and mesohaline lakes with mineralization \( \leq 5.8 \) g l\(^{-1}\), temperature \( \leq 25^\circ \)C and \( \text{pH} < 9.4 \). The second group is of mesohaline and polyhaline lakes with mineralization \( \geq 7.8 \) g l\(^{-1}\), temperature \( \geq 25^\circ \)C, oxygen \( \leq 6.4 \) mg l\(^{-1}\), and \( \text{pH} > 9.4 \). Two groups of factors acting on the algal and invertebrates’ taxonomic groups in the opposite directions were allocated. The first group of factors included depth and dissolved oxygen, together influenced the green algae, diatoms, rotifers and copepods. The second group of factors were represented by temperature, determined the diversity and abundance of green, blue-green algae and euglenoids.

Pearson correlation coefficient (Table 5) shows that species richness of phytoplankton and zooplankton was increased with growth of the interrelated parameters such as the maximum depth which negatively correlated with water temperature. Mineralization positively correlated with water temperature and pH. The positive correlation is marked for mineralization and abundance and biomass of plankton small-size forms (green algae and rotifers). Biomass and abundance of blue-green algae, copepod and cladocerans had no obvious correlation with mineralization and pH. The pH high positively correlated with abundance of rotifers and green algae and negatively with abundance crustaceans and blue-green algae, though not obviously (\( r = -0.40 \) and \( r = -0.20 \) respectively). The water temperature had positive correlation with abundance and biomass of rotifers and green algae. The dissolved oxygen concentration positively correlated with quantitative characteristics of crustaceans, especially copepods.

The analysis of abiotic factors and quantity indicators of phytoplankton and zooplankton main taxonomic groups helps to reveal main factors influencing on plankton distribution within lake areas. A number of correlatively dependences are revealed, using them the inclusion relations graph is composed (Fig. 3).
| Taxon | Code | Locality |
|------|------|---------|
| Cyanobacteria | | |
| *Merismopedia elegans* A. Braun ex Kützing | Mer el | 5 |
| Gloeocapsa sp. | Gloe | 8 |
| *Anabaenopsis elenkinii* V.V. Miller | Anab elen | 9, 10 |
| *Aphanizomenon flosaquae* var. *klebahnii* Elenkin | Aph flos | 11 |
| Oscillatoria sp. | Osc sp | 9, 10, 11, 14, 15 |
| Oscillatoria sp.¹ | Osc spl | 11 |
| Lyngbya sp. | Lyn sp | 8 |
| *Arthrospira fusiformis* (Voronikhin) J. Komárek & J.W.G. Lund | Arth fus | 11 |
| *Phormidium formosum* (Bory de Saint-Vincent ex Gomont) Anagnostidis & Komárek | Phor for | 12 |
| *Spirulina major* Kützing ex Gomont | Spir maj | 8, 11, 12, 14, 15 |
| Bacillariophyta | | |
| *Cyclotella* sp. | Cyc sp | 5 |
| *Diatoma vulgare* Bory de Saint-Vincent | Dia vul | 5 |
| *Cocconeis placentula* Ehrenberg | Coc pla | 5 |
| *Navicula oblonga* (Kützing) Kützing | Nav obl | 5 |
| *Navicula placentula* (Ehrenberg) Grunow | Nav pl | 5 |
| *Navicula* sp. | Nav sp | 3 |
| Dinophyta | | |
| *Peridinium* sp. | Per sp | 8 |
| Euglenophyta | | |
| *Euglena* sp. | Eug sp | 11, 14 |
| Chlorophyta | | |
| *Ankyra ocellata* (Korshikov) Fott | Ank ocel | 9 |
| *Korshikoviella schoepferai* (Fott) P.C.Silva | Kors sch | 9 |
| *Dictyosphaerium pulchellum* H.C. Wood | Dict pul | 10 |
| *Pediastrum boryanum* (Turpin) Meneghini | Red bor | 8 |
| *Tetraedron minimum* (A. Braun) Hansgirg | Tet min | 8 |
| *Oocystis borgei* J. Snow | Ooc bor | 5 |
| *Oocystis marssonii* Lemmerrmann | Ooc mar | 5 |
| *Oocystis parva* West & G.S. West | Ooc par | 5 |
| *Oocystis* sp. | Ooc sp | 5, 8, 10, 11, 13 |
| *Oocystis* sp.¹ | Ooc spl | 5 |
| *Monoraphidium arcuatum* (Korshikov) Hindák | Mon arc | 2, 10 |
| *Monoraphidium contortum* (Thuret) Komárková-Legnerová | Mon con | 2, 5 |
| *Monoraphidium minutum* (Nägeli) Komárková-Legnerová | Mon min | 2 |
| *Coelastrum microporum* Nägeli | Coc mic | 9 |
| *Tetrastrum komarekii* Hindák | Tet kom | 8 |
| *Scenedesmus obtusus* Meyen | Sc ob | 8 |
| *Closterium cornu* Ehrenberg ex Ralfs | Clos cor | 11 |
| Rotifer | | |
| *Filinia longiseta* (Ehrenberg) | Fil long | 1, 2, 8 |
| *Lecane luna* (Muller) | L luna | 1, 5, 6 |
| *L. flexilis* (Gosse) | L flex | 4 |
| *Euchlanis dillara* Ehrenberg | E dila | 1, 4, 5 |
| *Brachionus urceus* (Linnaeus) | B urce | 6, 8, 9 |
| *B. plicatilis* Muller | B pli | 6 |
| *B. plicatilis asplanchnoides* Charin | Bp aspl | 4, 6, 11, 12 |
| *B. quadridentatus ancyloghathus* Schmarda | B q ancy | 5, 11 |
| *B. variabilis* Hempel | B var | 2, 9, 15 |
| *Keratella quadrata* (Muller) | Ker qad | 1 |
| *Notholca acuminata* (Ehrenberg) | Noth acu | 4 |
| *Hexarthra mira* (Hudson) | H mira | 4, 5, 6, 8, 9, 10 |
| *Asplanchna girodi* Guerne | As giro | 1 |
| *Asplanchnopus hyalinus* Harring | A hyal | 11 |
| *Cephalodella* sp. | Ceph sp | 5 |
| *Polyarthra dolychoptera* Idelson | P doly | 5 |
| *Notonecta* sp. | Not onen | 4, 6 |
| Cladocera | | |
| *Diaphanasoma* sp. | Diap sp | 5 |

(continued on next page)
4. Discussion

The studied saline lakes are small in both area and volume, particularly the beginning of the filling lakes, thus facilitating our investigation. Moreover, they cover a range of mineralization as determined by different water input–outputs and evaporation. Like most other eastern Mongolian saline lakes the pattern of major ionic dominance was almost always magnesium and/or sodium and hydrocarbonate, chloride was rare (Sklyarov et al., 2011). Mineralization in the Mongolian lakes was sufficiently low during the filling stage while other steppe lakes, located on the Russian Federation territory were characterized as hyperhaline during same stage (Gorlacheva et al., 2014).

A variety of environmental factors such as mineralization, dissolved oxygen concentration, pH, hydrological characteristics (water level) may in various combinations or individually, be significant in determining the structure of planktonic community in saline lakes (Geddes et al., 1981; Comin and Alonso, 1988; Doyle, 1990; Stephens, 1990; Seaman et al., 1991; Zotina et al., 1999; Zhao et al., 2005; Gao et al., 2008). Species in ephemeral lakes are adapted to large variability of water chemistry, particularly salinity, temperature and cyclical droughts of varying duration (Hammer and Appleton, 1991; McCulloch et al., 2008). In the steppe Mongolian lakes among

Table 2 (continued)

| Taxon | Code | Locality |
|-------|------|----------|
| Daphnia pulex Leydig | – | 1 |
| D. magna Straus | D magn | 2, 3, 4, 5, 6, 7, 8, 9, 10, 14 |
| Chydorus sphaericus (Müller) | C spha | 1, 2, 5, 11 |
| Moina brachiata (Jurine) | M brac | 4, 6, 7, 9, 10, 11, 12, 15, 16 |
| M. mongolica Daday | M mong | 13, 14 |

Copepoda

| Taxon | Code | Locality |
|-------|------|----------|
| Metadiaptomus asiaticus (Uljanin) | M asia | 10, 12, 13 |
| Hemidiaptomus ignatovi Sars | H igna | 9 |
| Neutrodiaptomus incongruens (Poppe) | – | 1 |

Table 3

| Taxon | Code | Locality |
|-------|------|----------|
| Copepoda | | |
| Metadiaptomus asiaticus (Uljanin) | M asia | 10, 12, 13 |
| Hemidiaptomus ignatovi Sars | H igna | 9 |
| Neutrodiaptomus incongruens (Poppe) | – | 1 |

Rotifera

| Taxon | Code | Locality |
|-------|------|----------|
| Filinia longiseta (Ehrenberg) | Fil | 1, 2, 8 |
| Lecane luna (Muller) | L luna | 1, 5, 6 |
| L. flexilis (Gosse) | – | 4 |
| Euchlanis dilatata Ehrenberg | E dila | 1, 4, 5 |
| Brachionus urceus (Linnaeus) | B urce | 6, 8, 9 |
| B. plicatilis Müller | – | 6 |
| B. plicatilis asplanchnoides Charin | B aspl | 4, 6, 11, 12 |
| B. quadridentatus ancylodagathus | B anc | 5, 11 |
| Schmardia | | |
| B. variabilis Hempel | B vari | 2, 9, 15 |
| Keratella quadrata (Muller) | – | 1 |
| Notholea acuminata (Ehrenberg) | – | 4 |
| Hexarthra mira (Hudson) | H mira | 4, 5, 6, 8, 9, 10 |
| Asplanchna girodi Guerne | – | 1 |
| Asplanchnopus hyalinus Harring | A hyal | 11 |
| Cephalodella sp. | Ceph | 5 |
| Polyarthra dolychoptera Idelson | P doly | 5 |
| Notomnata sp. | – | 4, 6 |

Cladocera

| Taxon | Code | Locality |
|-------|------|----------|
| Diaphanosaoma sp. | Diap | 5 |
| Daphnia pulex Leydig | – | 1 |
| D. magna Straus | D magn | 2, 3, 4, 5, 6, 7, 8, 9, 10, 14 |
| Chydorus sphaericus (Müller) | C spha | 1, 2, 5, 11 |
| Moina brachiata (Jurine) | M brac | 4, 6, 7, 9, 10, 11, 12, 15, 16 |
| M. mongolica Daday | M mong | 13, 14 |

Table 3 (continued)

| Taxon | Code | Locality |
|-------|------|----------|
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| Hemidiaptomus ignatovi Sars | H igna | 9 |
| Neutrodiaptomus incongruens (Poppe) | – | 1 |

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|-------|------|----------|
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| Chydorus sphaericus (Müller) | C spha | 1, 2, 5, 11 |
| Moina brachiata (Jurine) | M brac | 4, 6, 7, 9, 10, 11, 12, 15, 16 |
| M. mongolica Daday | M mong | 13, 14 |

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Table 4  Species numbers, biomass, density and dominant species of plankton.

| Lakes          | Phytoplankton | Zootoplankton |
|----------------|---------------|---------------|
|                | Spp. number  | Abundance ($10^3$) | Biomass (mg$ m^{-3}$) | Dominant species | Spp. number | Abundance ($10^3$) | Biomass (g$ m^{-3}$) | Dominant species |
| Teeliyn        | -             | -              | -                     | -               | 9           | 8000.1            | 11.45                | F. longiseta     |
| Davsan Tsaygan | 3             | 2.9            | 0.2                   | M. contortum    | 6           | 3425.1            | 77.42                | F. longiseta     |
| Yakh'          | 0             | 0              | 0                     | -               | 1           | -                | -                    | D. magna         |
| Ikh Dalay      | -             | -              | -                     | -               | 10          | 74.19–271.1      | 2.78–14              | A. bacillifer     |
| Khukh          | 13            | 0.7–62.7       | 0.03–25.8             | M. elegans, Oocystis sp. | 13          | 20.82–65         | 0.62–4.01            | A. bacillifer     |
| Angirt         | -             | -              | -                     | -               | 10          | 268.9            | 4                    | A. bacillifer     |
| Sumiyn         | -             | -              | -                     | -               | 2           | 6.2              | 0.17                 | M. brachiata      |
| Gurmiyn        | 5             | 4455.2         | 495.1                 | Lyngbya sp., T. komarekii | 9           | 70.97–245.9      | 2–13.30              | H. mira           |
| Baga Dalay     | 5             | 251.5          | 34.7                  | A. elenkinii    | 8           | 25–99.43         | 6.16–17.70           | M. incrassatus    |
| Baruun         | 9             | 41             | 29.4                  | Oocystis sp.    | 4           | -                | -                    | M. asiaticus      |
| Tsaydam        |               |                |                       |                 |             | 150.8            | 1279                 | A. fusiformis, S. major |
| Galuut         |               |                |                       |                 |             | -                | -                    | B. plicatilis     |

(continued on next page)
thirty-five taxa of phytoplankton and thirty-one species of zooplankton were mainly typical brackish or halobiont species. The most species among algae are indifferents. Zooplankton species such as *Lecane luna*, *L. flexilis*, *Keratella quadrata*, *Notholca acuminata*, *Asplanchna girodi*, *Polyarthra dolichoptera*, *Daphnia pulex*, *Neutrodiaptomus incongruens*, *Megalocyclops viridis* are typical freshwater species. The salinity optimum (halopreferendum) of some species (*Metadiaptomus asiaticus*, *Moina brachiata*, *M. mongolica*) corresponds to higher salinity waters (Borutskii et al., 1991; Manuylova, 1964). Rotifers *Brachionus variabilis* is dominant only in hyper-saline waters. These results are in accord with those of other researches (Geddes et al., 1981; Hammer et al., 1983; Zhao and He, 1999; Zotina et al., 1999; Kipriyanova et al., 2007; Gao et al., 2008). In our study cladocerans *Daphnia magna* and diatoma algae *Navicula* sp. dominated in lakes which desalinated owing to the new flooding of the lake depressions;

| Lakes     | Phytoplankton | Zootoplankton* |
|-----------|---------------|-----------------|
|           | Spp. number   | Abundance (10^3 cell l^-1) | Biomass (mg m^-3) | Dominant species | Spp. number | Abundance (10^5 ind. m^-3) | Biomass (g m^-3) | Dominant species |
| Buus      | 2             | 5.8             | 16.02             | *S. major*     | 4           | 80.1             | 2.95              | *M. brachiata*   |
| Delger    | 1             | 18.01           | 8.81              | *Oscycis sp.*  | 2           | 1018.3           | 47.05             | *M. asiaticus*   |
| Khaichyn  | 3             | 58.3            | 243.7             | *S. major*, *Euglena* sp. | 2           | –                | –                 | *M. mongolica*   |
| Tsaydam   | 2             | 4294.8          | 20518             | *Oscillatoria* sp. | 2           | 11896            | 19450.1           | *B. variabilis*  |
| Zuun      | –             | –               | –                 | –              | –           | –                | –                 | –                |
| Tsaydam   | –             | –               | –                 | –              | 2           | –                | –                 | –                |
| Zeerengiy | –             | –               | –                 | –              | –           | –                | –                 | –                |

* Itigilova et al. (2014); – no data.

## Table 5 Pearson correlation coefficient between biological and environmental variables of the saline lakes ecosystem, July 2011.

| Variables | Pearson correlation coefficient | n |
|-----------|--------------------------------|---|
| Oxygen – Abundance of copepods | 0.90*** | 18 |
| Oxygen – Abundance of cladocerans | 0.61** | 17 |
| Oxygen – Biomass of copepods | 0.90*** | 18 |
| Abundance of cladocerans – Abundance of copepods | 0.87** | 12 |
| Biomass of cladocerans – Biomass of copepods | 0.64* | 12 |
| Temperature – Abundance of copepods | 0.83*** | 17 |
| Temperature – Biomass of copepods | 0.80** | 17 |
| Temperature – Temperature | 0.51* | 22 |
| Temperature – Abundance of rotifers | 0.79*** | 18 |
| Temperature – Biomass of rotifers | 0.83*** | 18 |
| Temperature – Temperature | 0.54** | 20 |
| Temperature – Abundance of green algae | 0.56** | 20 |
| Temperature – Biomass of green algae | 0.50* | 22 |
| Mineralization – Abundance of rotifers | 0.66** | 18 |
| Mineralization – Biomass of rotifers | 0.67** | 18 |
| Mineralization – Abundance of green algae | 0.57** | 20 |
| Mineralization – Biomass of green algae | 0.60** | 20 |
| Mineralization – pH | 0.81*** | 22 |
| pH – Abundance of rotifers | 0.94*** | 18 |
| pH – Biomass of rotifers | 0.96** | 18 |
| pH – Abundance of green algae | 0.73*** | 22 |
| pH – Biomass of green algae | 0.76*** | 22 |
| Abundance of rotifers – Abundance of green algae | 0.99*** | 16 |
| Biomass of rotifers – Biomass of green algae | 0.99*** | 16 |
| Depth – Spp. number of zooplankton | 0.76*** | 22 |
| Depth – Spp. number of phytoplankton | 0.70** | 22 |
| Spp. number of zooplankton – Spp. number of phytoplankton | 0.89*** | 20 |

* p < 0.05.
** p < 0.01.
*** p < 0.001.

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Fig. 3 Count relations inclusion of different groups of plankton community and environmental factors. Inclusion measures: 1 – positive, from 75 to 99; 2 – positive, from 51 to 74; 3 – negative, from 50 to 75. T° – temperature, h – depth, Min – mineralization, O₂ – dissolved oxygen, nₕ – species richness of zooplankton, nₚ – species richness of phytoplankton, Gr – abundance and biomass of green algae, Rot – abundance and biomass of rotifers, Clad – abundance and biomass of cladocerans, Cop – abundance and biomass of copepods.

species such as *Lecane luna*, *L. flexilis*, *Keratella quadrata*, *Notholca acuminata*, *Asplanchna girodi*, *Polyarthra dolichoptera*, *Daphnia pulex*, *Neutrodiaptomus incongruens*, *Megalocyclops viridis* are typical freshwater species. The salinity optimum (halopreferendum) of some species (*Metadiaptomus asiaticus*, *Moina brachiata*, *M. mongolica*) corresponds to higher salinity waters (Borutskii et al., 1991; Manuylova, 1964). Rotifers *Brachionus variabilis* is dominant only in hyper-saline waters. These results are in accord with those of other researches (Geddes et al., 1981; Hammer et al., 1983; Zhao and He, 1999; Zotina et al., 1999; Kipriyanova et al., 2007; Gao et al., 2008). In our study cladocerans *Daphnia magna* and diatoma algae *Navicula* sp. dominated in lakes which desalinated owing to the new flooding of the lake depressions;
while, according to Gorlacheva et al. (2014), plankton community consisted halobiontic species during the initial filling phase.

The species richness of cladocerans was low and they occurred rarely, according to Boix et al. (2007) this group is typically of freshwater organisms, and most species do not tolerate high salt concentrations. Thus, even a slight increase in mineralization reduces the abundance and richness of cladocerans. Their disappearance in saline lakes promotes the development of rotifers, in particular euryhaline species of the genera Brachionus (Egborne, 1994; Anton-Pardo and Armengol, 2011). While crustacean species richness and composition can be correlated with salinity over its entire range, categorizing saline lakes according to their flora and fauna in general is difficult because of site specific differences; including those of temperature, oxygen and biological composition (Williams, 1998, 2002). Thus, saline lakes are characterized by the dominance of small organisms (Brucet et al., 2010). In the present study, the main components in polihaline lakes were algae Spirulina major and Oscillatoria sp. and rotifers Brachionus variabilis.

According to our data, water temperature, mineralization and pH are the main factors; they all directly or indirectly determine abiotic and biotic components of Northeastern Mongolia lakes during low water level. It corresponds with Williams (1998) survey papers. Correlation between species richness of phytoplankton and zooplankton and environmental factors was low and not obvious. Other researchers indicate regular decrease of common species richness alongside increase of water mineralization (Comin and Alonso, 1988; Stephens, 1990; Seaman et al., 1991; Campos et al., 1996; Zhao et al., 2005; Balushkina et al., 2007; Kipriyanova et al., 2007; Afonina and Itigilova, 2014). Changes in salinity may directly and indirectly influence plankton abundance, leading to the extinction of some species and the appearance of others. Salinity fluctuations may indirectly cause or contribute to food shortage, thus affecting plankton abundance (Perumal et al., 2009). High mineralization affects not only the structure of plankton community, but also its abundance. In the present study, a significant, positive correlation was observed between abundance and biomass of planktonic community (algae and invertebrates). Massive concentration of algae (above 4.5 \cdot 10^{6} c e l l^{-1}) and small-size zooplankton (above 12 \cdot 10^{6} i n d. m^{-3}) shows a big spatial heterogeneity of plankton quantitative development in the studied lakes. It is mostly connected with its shallowness, by which wind activity fosters plankton accumulation in one of its parts. It has been observed also by Gao et al. (2008), Balushkina et al. (2007), Paturej and Gutkowska (2015).

It should be also noted, that mineralization should be seen as one of the several other factors responsible for the structure of planktonic communities in saline lakes, and as one with perhaps less direct impact than in the past has often been assumed. The reverse situation: positive correlation abundance of crustaceans with mineralization and negative correlation with temperature was observed in Changjiang Estuary (China) (Gao et al., 2008).

The active hydrogen ratio value and water temperature are important in determining the nature of the biological communities (Conte and Geddes, 1988). Thus in our study maximum abundance of halophile species (Spirulina major and Brachionus variabilis) was registered in the lakes with high water temperature and high pH. It was marked in China northern lakes (Zhao and He, 1999; Zhao et al., 2005) and in meromictic salt Lake Shira (Zotina et al., 1999). In inland saline waters of North Hebei (China) species richness, biomass and abundance of zooplankton were no obvious correlation with pH (Zhao and He, 1999). In the Lake Chany (Russia) abundance of algae negatively correlated with pH (Kipriyanova et al., 2007).

5. Conclusions

Our study had shown that the ecosystems in the saline lakes of northeastern Mongolia was characterized by varying degrees of mineralization (from oligohaline to polyhaline) during the initial filling phase and the raising water level. Diversity planktonclosis developed in oligohaline lakes, its abundance and biomass were freshwater and brackish species. Mesohaline lake planktonclosis was mostly composed of halobiontic species. Polyhaline lakes were characterized by having a monodominant community with maximum abundance of small-size hydrobionts from blue-green algae and rotifers. Mineralization, water temperature and pH were an important environment factor determining species composition of the plankton community in saline lakes during low water level.

Authors’ contributions

All authors have contributed to the fieldwork, elaboration of the data, the writing process and the discussion of the results. The authors have no conflict of interest.

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