ISSN 1995-0829, Inland Water Biology, 2008, Vol. 1, No. 2, pp. 150–157. © Pleiades Publishing, Ltd., 2008.
Original Russian Text © E.G. Krupa, T.S. Stuge, T.Ya. Lopareva, D.S. Shaukharbaeva, 2008, published in Biologiya Vnutrennikh Vod, No. 2, 2008, pp. 49–56.

ZOOPLANKTON, ZOOBENTHOS AND ZOOPERIPHYTON

Distribution of Planktonic Crustaceans in Lake Balkhash in Relation to Environmental Factors

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Received September 12, 2006

Abstract—The quantitative development of planktonic crustaceans in Lake Balkhash has been studied in relation to water transparency, pH, mineralization, ion concentrations, ion ratios, content of easily oxidizable organic matter, nutrients, and heavy metals. It is shown that the decrease in the abundance of animals in a brackish part of the lake area is caused by a high concentration of K^+ at a relatively low amount of Ca^{2+} and Na^+ ions. The dependence of quantitative development of planktonic crustaceans on the content of nutrients, mineralization, concentrations of the main ions (except for alkali metals) and their ratio is not manifested for all species. Pollution of the lake by heavy metals has caused either a sharp decrease or an increase in the range of variations of the abundance of crustaceans.

DOI: 10.1134/S1995082908020077

INTRODUCTION

Lake Balkhash (the Balkhash–Alakol lake system) is located in an arid zone of Central Asia in southeastern Kazakhstan between 45°00′ and 46°50′ N and 73°20′ and 79°30′ E. Due to its morphological features, the lake is subdivided into two parts—a shallow and wide western part (western Balkhash) and a deeper and narrow eastern part (eastern Balkhash). The Ili, Karatal, Aksu, and Lepsy rivers empty into the lake.

A distinctive feature of the lake is a gradual increase of water mineralization from 0.5–0.9 g/dm^3 in the utmost point of western Balkhash to 5.6–6.5 g/dm^3 in eastern Balkhash. The lake is subdivided into eight hydrochemical regions according to the level of water mineralization [25]. The total content of salts in the lake water varies from year to year as well. During the recent high water period, the average mineralization decreased from 3.08 g/dm^3 in 1998 [22] to 2.20 g/dm^3 in 2004.

The location of Lake Balkhash in a region of complex ore deposits determines the high natural (background) content of such heavy metals as Zn, Pb, Cu, Cr, and Co in different components of the ecosystem. Wastewaters from the Balkhash copper smelting and the lead–zinc industrial complex, anf from coal- and complex ore-pit mining cause technogenic pollution of the lake [15].

The above-mentioned properties of Lake Balkhash (nonuniformity of mineralization coupled with a changing level of pollution by heavy metals) are of great interest because of their effect on aquatic animals, in particular, on planktonic crustaceans.

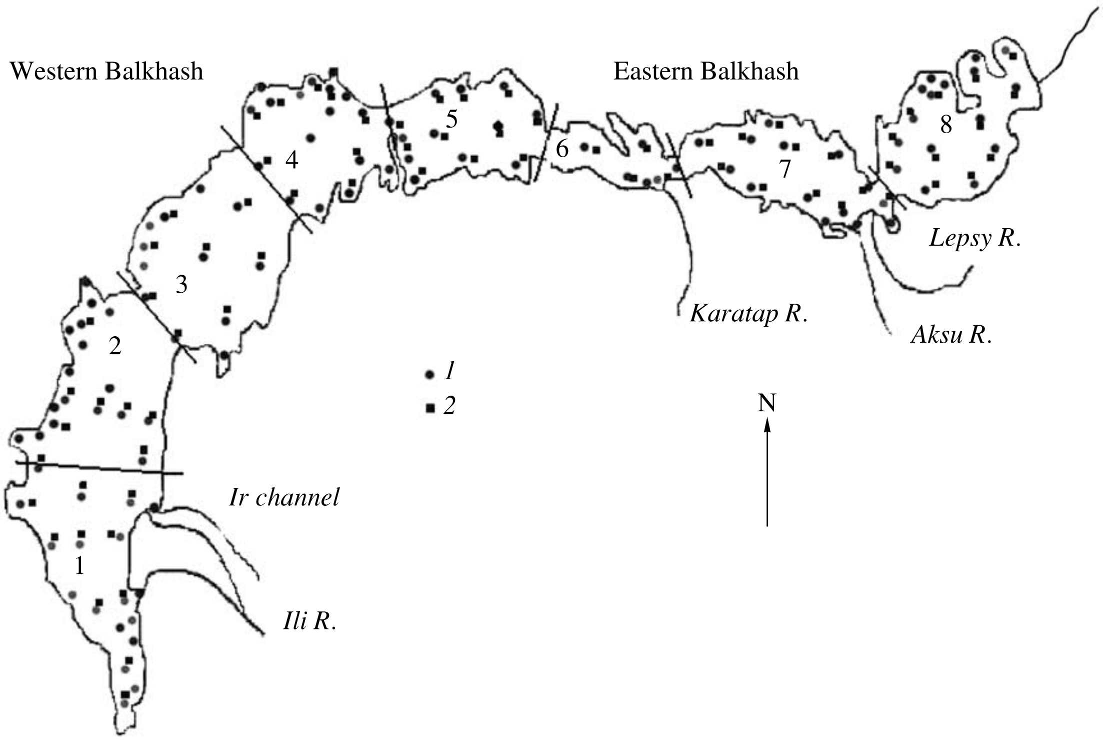
The zooplankton in the lake have been studied continually since 1929. The main attention has been paid to the study of taxonomical diversity and dynamics of quantitative indices of planktonic invertebrates [1, 8, 21, 24]. Two studies devoted to the effect of mineralization on crustaceans in Lake Balkhash are known [18, 23]. There exist certain evidence on the relationship between quantitative development of zooplankton and the level of toxic pollution of the lake [29].

The goal of the present work is to study the dependence of quantitative development of the dominant species of planktonic crustaceans in Lake Balkhash on the physical and chemical parameters of the water.

MATERIALS AND METHODS

Zooplankton were collected in July 2003 and 2004 using a Juday net on a standard and constant network of stations covering all hydrochemical regions of the lake (see figure). In 2003 in western Balkhash, 56 samples were collected; in eastern Balkhash, 48 samples; in 2004, 33 and 38 samples, respectively. At all stations, the depth and transparency were measured and water samples were collected for determination of pH; analysis of the ion and salt composition; the concentrations of nutrients, organic matter, dissolved gases (160 samples), and heavy metal (110 samples).

The zooplankton samples were processed using standard methods [2, 11]. A chemical analysis was con-



Scheme of the location of stations for zooplankton sampling in hydrochemical regions (1–8) of Lake Balkhash in 2003 (*1*) and 2004 (*2*).

ducted according to standard techniques [17]. Determination of K^+ and Na^+ was performed separately by plasma photometry using a PLAPHFO-4 photometer. The heavy metal content in water samples was determined with the help of an AAS-1N spectrophotometer (Germany).

The correlation coefficients between logarithms of the abundance of planktonic crustaceans and environmental factors (transparency, pH, mineralization, absolute ion content and their ratio, the content of easily oxidized organic matter, nutrients, and heavy metals concentrations in water) were calculated using STATISTICA 6.0. The results are presented as mean values with errors ($x \pm SE$). The statistical significance of values of the correlation coefficient and differences in mean values were estimated using Student's test at a significance level $p < 0.05$ [5].

RESULTS

In July of 2003 and 2004, the temperature of the surface water layer was 23.7–26.2°C. The water transparency increased from 0.53 m in the utmost point of western Balkhash up to 4.40 m in eastern Balkhash; pH values increased from 8.0–8.4 up to 9.06–9.40; and values of permanganate oxidation increased from 7.7–7.9 up to 10.5–12.1 mg O/dm^3. The concentrations of nutrients were as follows: NH_4^+, 0.03–0.21 mg/dm^3; NO_2^-, 0.002–0.067 mg/dm^3; NO_3^-, 0.12–0.49 mg/dm^3; and P_{total}, 0.004–0.034 mg/dm^3.

The water mineralization increased gradually from 460 mg/dm^3 in the first hydrochemical region up to 4928–5940 mg/dm^3 in the eighth (Table 1). With an increase in mineralization, the concentrations of all ions increased significantly except for Ca, which decreased. The mean values of mineralization and concentrations of all ions (except for Ca) in eastern Balkhash were statistically significantly higher during both years of investigations, and concentrations of Ca ions were significantly lower than in western Balkhash. With a decrease in the water mineralization from 2003 to 2004, the content of Mg decreased all over the lake, and the content of Na and K ($p < 0.05$) decreased in eastern Balkhash.

All over the lake area, Cd, Cu, Zn, and Pb were detected. In 2003, the pollution of eastern Balkhash with heavy metals was higher than that of western Balkhash (Table 2). In 2004, the concentrations of Zn and Cu were higher in the western part of the lake and concentrations of Cd and Pb were higher in the eastern part. In 2004 as compared to 2003, the concentrations of Pb in the eastern part and the concentrations of all heavy metals in the western part of the lake increased 1.5–2.2 times; concentrations of Zn, Cu, and Cd in the eastern part decreased 1.5 to 2.9 times. Annual variations in the mean concentrations of all heavy metals in

Table 1. Mineralization (M) and chemical composition (mg/dm^3) of water in Lake Balkhash in 2003 and 2004

Year	Number of samples	M	K^+	Na^+	Ca^{2+}	Mg^{2+}	HCO_3^-	SO_4^{2-}	Cl^-
		Western Balkhash							
2003	26	1150 ± 86 / 460–2385	16 ± 1 / 5–31	183 ± 16 / 54–368	45 ± 1 / 40–54	63 ± 5 / 34–98	267 ± 9 / 207–388	361 ± 34 / 87–576	188 ± 18 / 51–443
2004	21	1146 ± 93 / 460–1982	10 ± 1 / 5–20	213 ± 23 / 41–361	43 ± 1 / 32–53	33 ± 2 / 20–49	268 ± 10 / 195–376	374 ± 36 / 196–710	188 ± 19 / 36–376
		Eastern Balkhash							
2003	25	4230 ± 258 / 2800–5940	73 ± 5 / 41–100	945 ± 67 / 448–1506	33 ± 2 / 24–53	227 ± 13 / 138–299	613 ± 31 / 407–778	1503 ± 92 / 1028–2083	833 ± 49 / 437–1188
2004	20	3805 ± 216 / 2306–4928	56 ± 4 / 31–82	760 ± 47 / 430–1049	32 ± 1 / 24–45	108 ± 6 / 62–135	616 ± 30 / 432–869	1403 ± 89 / 823–1816	868 ± 54 / 482–1195

Note: Here and in Tables 2 and 3: above the line—mean values with an error; under the line, the range of variations.

Table 2. Content of heavy metals (μg/dm^3) in the water of Lake Balkhash in 2003 and 2004

Year	Number of samples	Zn	Cu	Cd	Pb
		Western Balkhash			
2003	30	19.7 ± 3.1 / 5.6–99.3	14.2 ± 1.8 / 2.4–36.4	3.3 ± 0.2 / 1.1–5.7	9.6 ± 1.1 / 4.4–24.7
2004	20	42.4 ± 15.3 / 13.0–264.0	21.5 ± 0.4 / 5.4–66.3	2.9 ± 0.01 / 0.9–3.8	21.3 ± 0.1 / 13.3–36.2
		Eastern Balkhash			
2003	21	23.1 ± 3.5 / 4.4–52.5	21.3 ± 2.0 / 4.1–42.3	11.6 ± 2.3 / 4.2–56.0	23.3 ± 2.5 / 3.5–45.6
2004	20	15.0 ± 0.1 / 6.1–24.2	12.0 ± 0.2 / 4.0–27.2	4.0 ± 0.03 / 0.9–6.8	41.0 ± 0.4 / 6.9–74.3
MPC_{fishwb} [10, 19]		10.0	1.0–5.0	0.5–5.0	10.0

eastern Balkhash, and Cu and Pb in western Balkhash, were statistically significant ($p < 0.05$).

In the structure of zooplankton, 70 taxa of crustaceans were identified: Cladocera, 39; Cyclopoida, 19; Calanoida, 2; Harpacticoida, 6; Copepoda parasitica, 2; Ostracoda, 1; Anostraca, 1.

Four species were spread all over the lake: *Arctodiaptomus salinus* (Daday), *Thermocyclops crassus* (Fischer), *Mesocyclops leuckarti* (Claus), and *Diaphanosoma lacustris* Korinek. In the pelagiac zone of eastern Balkhash, the above-mentioned species were added to *Daphnia galeata* Sars, *Leptodora kindtii* (Focke), *Ceriodaphnia reticulata* (Jurine), and *Polyphemus pediculus* (Linne), but the last three species were rare. In bays and premouth parts of rivers, the diversity of crustaceans increased up to 9–20 taxa, mainly due to small numbers of species of the families Chydoridae and Macrothricidae, and the genera *Eucyclops*, *Microcyclops*, and *Macrocyclops*.

In 2003, the abundance of planktonic crustaceans in western Balkhash averaged 34.7×10^3 ind./m^3; in 2004, 59.6×10^3 ind./m^3; and in eastern Balkhash, 50.8×10^3 and 62.9×10^3 ind./m^3, respectively. Over the entire lake area, *Arctodiaptomus salinus*, *Thermocyclops crassus*, *Mesocyclops leuckarti*, and *Diaphanosoma lacustris* dominated. In eastern Balhkash, *Daphnia galeata* was also a part of the dominant complex.

The mean values of the abundance of *Arctodiaptomus*, *Diaphanosoma*, and *Cyclops* in the western and eastern parts of the lake statistically did not significantly differ. During both of the study years, the abundance of daphnia was reliably higher in eastern Balkhash as compared to western Balkhash (Table 3). A positive correlation between the abundance of animals and the water chemical composition was found for *Arctodiaptomus* in 2003 and for daphnia in both years (Table 4). The distribution of *Diaphanosoma* and *Cyclops* in the lake area did not depend on variations in mineralization or the concentrations of certain ions.

Table 3. The number of crustaceans (thous ind./m^3) in Lake Balkhash in 2003 and 2004

Part of Lake Balkhash	Year	*Arctodiaptomus salinus*	*Diaphanosoma lacustris*	*Mesocyclops leuckarti*	*Thermocyclops crassus*	*Daphnia galeata*
western	2003	14.5 ± 4.5 / 0.5–44.9	4.7 ± 1.6 / 0.01–14.7	9.8 ± 1.8 / 1.5–73.4	4.3 ± 0.7 / 0.6–14.5	0.01 ± 0.06 / 0.0–0.3
eastern	2003	23.3 ± 3.9 / 0.8–67.7	6.7 ± 1.7 / 0.2–60.9	7.1–0.9 / 0.01–15.7	3.5 ± 0.5 / 0.06–11.4	2.8 ± 0.6 / 0.04–8.3
western	2004	23.3 ± 3.5 / 0.3–52.3	17.5 ± 4.3 / 0.3–35.5	8.8 ± 1.2 / 1.3–29.4	8.2 ± 1.1 / 0.4–22.2	0.02 ± 0.06 / 0.0–0.01
eastern	2004	21.7 ± 3.7 / 2.5–87.7	15.2 ± 3.0 / 0.2–7.8	11.5 ± 1.7 / 2.5–33.7	8.6 ± 1.9 / 0.7–36.9	2.4 ± 0.4 / 0.2–7.8

Table 4. Correlation coefficients for the logarithm of the number of crustaceans in Lake Balkhash and the absolute content of ions and water mineralization (mg/dm^3)

Species	Year	Mg^{2+}	Na^+	K^+	Cl^-	HCO_3^-	SO_4^{2-}	Mineralization
Arctodiaptomus salinus	2003	0.50	0.51	0.49	0.47	0.47	0.47	0.47
Daphnia galeata	2003	0.67	0.69	0.68	0.71	0.67	0.68	0.69
	2004	0.63	0.44	0.50	0.46	0.44	0.54	0.52

Note: $p < 0.05$.

The dependences between the abundance of crustaceans and the ratio of ions were observed only in eastern Balkhash. A statistically significant decline in the abundance of all considered species occurred with an increase in the K^+/Na^+ ratio (Table 5). A decrease in the abundance of *Mesocyclops*, *Thermocyclops*, *Arctodiaptomus*, and *Diaphanosoma* started in the range of K^+/Na^+ ratio 0.071–0.080; in the abundance of *Daphnia*, 0.067–0.078. In 2004, such a dependence was not observed for *Arctodiaptomus*; however, like in 2003, a decrease in the abundance of crustaceans started at a K^+/Na^+ ratio of ~0.08.

During both years of the study, a significant positive correlation was recorded between the abundance of daphnia and ratios of Mg^{2+}/Ca^{2+} and K^+/Ca^{2+} (Table 5). In 2004, the abundance of *Arctodiaptomus* depended in a positive manner on the Mg^{2+}/Ca^{2+} ratio, and the abundance of *Thermocyclops*, *Mesocyclops*, and *Diaphanosoma* statistically showed a significant decrease with an increase in the K^+/Ca^{2+} ratio.

A statistically significant negative correlation was observed between the abundance of daphnia and the Ca^{2+}/Cl^- and HCO_3^-/Cl^- ratios in both years. For *Arctodiaptomus*, the dependence on Ca^{2+}/Cl^-, HCO_3^-/Cl^-, and Mg^{2+}/Cl^- ratios was found only in 2003. A negative correlation between the abundance of *Diaphanosoma* and Mg^{2+}/Cl^- ratio was obtained in 2003, and a positive correlation in the both years was observed for *Cyclops*.

A negative correlation with hydrocarbonate and sulfate ions (HCO_3^-/SO_4^{2-}) was found only for daphnia (Table 5).

Correlations between concentrations of nutrients and the abundance of crustaceans was traced in some years: 2003 between the abundance of *Arctodiaptomus* and the content of ammonium ($r = -0.64$, $p < 0.05$); in 2004, between the abundance of *Mesocyclops* and the content of ammonium ($r = -0.52$, $p < 0.05$); and between the abundance of *Arctodiaptomus* and the concentration of nitrates ($r = -0.52$, $p < 0.05$).

In desalinated water of the western part, the correlation between the abundance of crustaceans and ion ratios was statistically insignificant during both years. On the whole, during both years no significant correlations were observed in the lake between the abundance of crustaceans and the Na^+/Ca^{2+}, Na^+/Cl^-, K^+/Cl^-, and SO_4^{2-}/Cl^- ratios, nor between such environmental factors as transparency, pH value, and the content of easily oxidized organic matter.

The pollution of Lake Balkhash by heavy metals has exerted a definite effect on the quantitative development of planktonic animals. In 2003, the decrease in the number of thermocyclops in eastern Balkhash correlates with the high content of Cd ($r = -0.69$, $p < 0.05$). The abundance of *Cyclops* declined from 0.3×10^3–20.0×10^3 ind./m^3 (on average, 5.6×10^3 ind./m^3) in moderately polluted zones (Cd < 10–11 μg/dm^3) to 0.06–5.0×10^3 ind./m^3 (on average, 2.6×10^3 ind./m^3)

Table 5. Correlation coefficients for the logarithm of the abundance of crustaceans in eastern Balkhash and certain ion ratios

Ion ratios	Values of ratios	*Arctodiaptomus salinus*	*Daphnia galeata*	*Diaphanosoma lacustris*	*Mesocyclops leuckarti*	*Thermocyclops crassus*
K^+/Na^+	0.065–0.095 / 0.062–0.093	–0.54 / –	–0.40 / –0.76	–0.50 / –0.75	–0.66 / –0.73	–0.61 / –0.45
Mg^{2+}/Ca^{2+}	0.43–12.2 / 0.65–5.93	– / 0.45	0.64 / 0.51	–	–	–
K^+/Ca^{2+}	0.79–3.91 / 0.72–3.49	–	0.64 / 0.33	– / –0.35	– / –0.45	– / –0.52
Ca^{2+}/Cl^-	0.02–0.12 / 0.02–0.09	–0.60 / –	–0.53 / –0.77	–	–	–
HCO_3^-/Cl^-	0.57–0.95 / 0.66–0.94	–0.56 / –	–0.50 / –0.76	–	–	–
Mg^{2+}/Cl^-	0.21–0.32 / 0.09–0.21	–0.47 / –	–	–0.36 / –	0.50 / 0.56	0.38 / 0.53
HCO_3^-/SO_4^{2-}	0.38–2.52 / 0.27–0.72	–	–0.41 / –0.76	–	–	–

Note: Above the line—2003; under the line—2004; "–"—the absence of a statisctically significant correlation, $p < 0.05$.

under heavy pollution (Cd = 15–56 μg/dm^3). Lower values of the correlation coefficient were obtained for an abundance *Cyclops* and the total content of Cd and Cu ($r = –0.46$, $p < 0.05$). An insignicant negative correlation with Cd in the eastern part of the lake area was also recorded for *Diaphanosoma* ($r = –0.24$) and daphnia ($r = –0.34$).

In 2004, a negative correlation was recorded between the abundance of arctodiaptomus in western Balkhash and concentrations of Zn ($r = –0.76$, $p < 0.05$). At concentrations of Zn < 20 μg/dm^3, the average abundance of arctodiaptomus attained 22.1×10^3 ind./m^3, decreasing to 1.1×10^3 ind./m^3 in heavily polluted parts (80–264 μg/dm^3). Under the effect of high Zn concentrations, a decline in abundance of other crustacean species was also recorded, but the correlations were statistically insignificant. It should be noted that dramatic changes in the abundance of animals were manifested at Zn concentrations >20.0 μg/dm^3. A significant correlation was recorded when a decrease in abundance of her simultaneously with an increase in Zn concentrations as, for instance, for *Arctodiaptomus*. For other species, a sharp increase in the range of abundance variations was noted without a significant correlation.

In 2004, water pollution by Zn in eastern Balkhash was less expressed as compared to its western part (Table 2) and did not exert any sufficient effect on the abundance of crustaceans. During both years of the study, no correlation was reported between the abundance of animal and Cu and Pb concentrations, nor with the total concentration of metals in the water.

DISCUSSION

Lake Balkhash is a unique natural model with a pronounced gradient of mineralization along the longitudinal axis of the lake. In the western part of the lake, at average total salt concentrations of up to 1.5 g/dm^3, no correlation was found between the abundance of crustaceans and concentrations of certain ions and their ratios. The correlation between the quantitative development of crustaceans and the chemical composition of the water (at an average mineralization of 3.8–4.3 g/dm^3) was recorded only in eastern Balkhash.

Analysis of the distribution of the most common and typical species of crustaceans has shown that their correlations with chemical environmental factors were similar for *Thermocyclops*, *Mesocyclops*, and apparently for *Diaphanosoma* (a negative correlation with the K^+/Ca^{2+} ratio, and an absence of correlations with the absolute content of the main ions and mineralization). In contrast to the three species, there were the changes in the abundance of daphnia and *Arctodiaptomus* (a dependence on the absolute contents of certain ions and mineralization, a positive correlation with Mg^{2+}/Ca^{2+} and for daphnia with K^+/Ca^{2+}, and a negative correlation with ratios of certain cations and anions to Cl). A significant negative correlation with K^+/Na^+ was found for all species under consideration.

The most important among mineral substances are Na and K ions responsible for the osmotic pressure of an internal medium of aquatic organisms [27]. As is known, K is toxic to living organisms [7, 26]. Its threshold concentration for some zooplankton species is 60 mg/dm^3 [12]. Calcium reduces the toxicity of potassium [7, 12, 26]. As was demonstrated in experiments on *Pontogammarus robustoides* (Grimm), the optimal K^+/Ca^{2+} ratio is 0.15–0.20 (at K and Ca concentrations expressed in mg-equiv/dm^3) [28] or to 0.29–0.39 (at K and Ca concentrations expressed in mg/dm^3). In 2003–2004 in the eastern part of the lake, values of the K^+/Ca^{2+} ratio exceeded the optimal values by a factor of 2–10. A statistically significant negative correlation between the K^+/Ca^{2+} ratio and the abundance of *Cyclops* and *Diaphanosoma* recorded in 2004 probably testifies to a K^+/Ca^{2+} ratio unfavorable for these crustaceans in eastern Balkhash, as was earlier shown for Ponto-Caspian gammarids and corophеids [4, 28]. A significant positive correlation recorded in both years between the abundance of daphnia and the K^+/Ca^{2+} ratio and an absolute content of K testifies to higher stability of daphnia to high concentrations of K as compared to *Cyclops* and *Diaphanosoma*.

The experiments have shown that the presence of Na also reduces the toxic effect of potassium on aquatic animals [7, 16, 28]. Negative correlations found between the abundance of all studied species and the K^+/Na^+ ratio are evidence that, considering the specific chemical composition of the water in eastern Balkhash, an available amount of Na is not sufficient for reduction of potassium toxicity.

Analysis of changes in the number of copepods *Mesocyclops leuckarti* (Claus) and *Thermocyclops oithonoides* (Sars) under the effect of potassium pollution in Lake Poppalijarvi (Karelia) leads us to the same conclusion. The average abundance of crustaceans in the lake for many years declined from 12.8×10^3 ind./m^3 at a potassium concentration of 20–22 mg/dm^3 to 1.5×10^3 ind./m^3 at a potassium concentration of 42.4–60.0 mg/dm^3 [12, 14]. Values of the K^+/Ca^{2+} ratio in the water of Lake Poppalijarvi during that period was 0.98–4.3 (calculated according to [13]), and they were comparable to values reported in eastern Balkhash (0.7–3.9) at a more favorable Mg^{2+}/Ca^{2+} ratio in Lake Poppalijarvi than in Balkhash water. However, at extremely low concentrations of Na (K^+/Na^+ = 2.6–10.0 [13]) the abundance of *Cyclops* in Lake Poppalijarvi after the onset of potassium pollution was 7–14 times less than in Lake Balkhash at similar concentrations of K and the K^+/Ca^{2+} ratio.

Of interest is a positive significant correlation found between quantitative development of daphnia and the Mg^{2+}/Ca^{2+} ratio. Many cladoceran species are very sensitive to excess Mg salts. Polyphemidae are exceptions. Their survival is reduced when, during experiments, Ca salts are added to Mg salts [3]. The water in the eastern part of Balkhash is characterized by a rather high content of Mg and low content of Ca. The development of *Daphnia galeata* in a mineralized area of Lake Balkhash and a positive correlation with Mg^{2+}/Ca^{2+} ratio and with Mg content allow us to refer daphnia to the group of cladocerans resistant to an excess of this metal in the environment.

In 2003–2004, the pollution of a large area of Lake Balkhash by heavy metals sufficiently exceeded the maximum permissible concentrations for fishery waterbodies (Table 2). According to the data published in [6, 26] in terms of their toxicities to aquatic species, heavy metal ions may be ranked in the following order: $Cd^{2+} > Cu^{2+} > Zn^{2+} > Pb^{2+}$. An acute toxicity of Cd for different aquatic species is within the range of concentrations from 3 to 500 μg/dm^3 [20]. Before 2001, only negligible amounts of Cd were recorded in some parts of Lake Balkhash, but in the subsequent years concentrations of it have significantly increased [22]. In 2003–2004, a significant decline in abundance under the impact of Cd was recorded only for *Thermocyclops* at metal concentrations of 4.2–56.0 μg/dm^3. The reason for the lower values of the correlation coefficient between the abundance of *Cyclops* and the Cd and Cu concentrations may be related to antagonism between the effects of these metals [20].

The LC_{50} values for copper, depending on the environmental conditions and durations of exposure for aquatic animals, range from 6 to 2250 μg/dm^3 [20]. The average long-term content of Cu in western Balkhash is 32.0 μg/dm^3, and in eastern Balkhash, 34.7 μg/dm^3 [22]. In 2003 and 2004, at concentrations of waterborne Cu equal to the average long-term values, no significant correlation was recorded between the abundance of crustaceans and the metal content.

Zinc and lead are considered less toxic to aquatic species than Cd and Cu. Acute toxicity of Pb lies within the range of concentrations from 2 to 6700 μg/dm^3 [20]. Average long-term concentration of Pb in western Balkhash water attains 21.5 μg/dm^3, and in eastern Balkhash, 28.4 μg/dm^3 [22]. In 2003 and 2004, no significant correlations were found between the abundance of planktonic crustaceans and Pb concentrations even at its maximal content (74.3 μg/dm^3).

LC_{50} values of zinc for different aquatic species vary from 500 to 5000 μg/dm^3. Some animal species, such as *Daphnia hyaline* Leydig, are very sensitive to Zn [20]. For *Daphnia magna* Straus, LC_{50} values of zinc vary from 5 to 1695 μg/dm^3 depending on the age of animals, duration of exposure, and temperature [6]. Lake Balkhash and especially its western part are characterized by a constantly high level of zinc pollution (on average, 37.0–40.9 μg/dm^3) [22]. In 2004, a significant decline in the abundance of *Arctodiaptomus* was recorded under the impact of Zn concentrations from 13.0 up to 264.0 μg/dm^3. An observed increase in the range of variations in the abundance of *Cyclops* and *Diaphanosoma* at Zn concentrations >20.0 μg/dm^3 can be caused by the toxic effect of the metal. An increase in variations already at heavy metal concentrations as low as 0.1 of the maximum permissible content was observed during experiments on different aquatic species, while the average values of the indices did not differ from the control [9].

The toxicity of heavy metals depends mainly on their form in water. The share of the most toxic ionized forms of heavy metals in their total concentration depends on certain physical and chemical environmental factors such as total water hardness, mineralization, pH value, presence of organic substances, amount of Ca, and temperature [20]. At toxic metal concentrations below LC_{50} but higher than the maximum permissible content for waterbodies used for commercial fishing (MPC_{fishwb}) [10], important factors that decrease heavy metal toxicity for aquatic species in Lake Balkhash are alkaline reaction and high water mineralization. Nevertheless, a negative correlation between the abundance of crustaceans and metal concentrations testifies to the insufficient buffer capacity of Lake Balkhash in certain cases. It should be taken into account that a permanent presence of heavy metals in concentrations of ≥15–20 μg/dm^3 can lead to the appearance of malformations in crustacean populations when they are in great abundance. This was repeatedly observed in polluted waterbodies of Kazakhstan [30], including Lake Balkhash, in 2003.

CONCLUSIONS

The effect of the water chemical composition on the abundance of the most common (typical) crustacean species was reported only in an eastern part of Balkhash at an average mineralization of 3.8–4.3 g/m^3. A decline in the abundance of animals is caused primarily by high concentrations of K with a low amount of Ca^{2+} and Na^+. The correlations with other factors (content of nutrients, mineralization, absolute and relative content of ions) were not reported for all species. A positive correlation between the abundance of *Daphnia galeata* and the Mg^{2+}/Ca^{2+}, K^+/Ca^{2+} ratios and an absolute content of Mg^{2+} and K^+ allow us to refer daphnia to a group of cladoceran species with high resistance to Mg and K salts in the environment. An increased total mineralization and alkaline reaction of water in the Balkhash in some cases do not reduce the toxicity of heavy metals, which is evidenced by the negative correlations between the abundance crustaceans and the content of certain metals in the water.

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