www.trjfas.org
ISSN 1303-2712
Turkish Journal of Fisheries and Aquatic Sciences 18: 659-669 (2018) DOI: 10.4194/1303-2712-v18_5_02

RESEARCH PAPER

Structural Indicators of Zooplankton in the Shardara Reservoir (Kazakhstan) and the Main Influencing Factors

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Received 04 April 2017
Accepted 06 September 2017

Abstract

The Shardara reservoir is located in southernmost Kazakhstan, in the zone of intensive farming and industrial development. Zooplankton and basic parameters of the environment have been studied in the summer of 2015. Zooplankton was represented by 60 species. The average abundance of the community amounted to 92.9 thous. specimens m^{-3}, with biomass of 966.0 mg m^{-3}. Copepods and rotifers dominated. The Shannon index values were equal to 2.24 bit specimen^{-1} and 1.23 bit mg^{-1}. The average individual mass of a specimen reached 0.0082 mg. Nonparametric and multivariate analysis of the data showed that macrophytes, nitrates, total nitrogen, organic polyphosphates, and copper favorably influenced Rotifera. Possible reasons for a positive relationship between quantitative indicators of Cladocera and zinc content are discussed. The main negative factors for Copepoda were organic polyphosphates, nitrites, total nitrogen, cadmium, and lead. Decrease in the Shannon index values under the influence of cadmium, ammonium, HCCH isomers is associated with increased dominance of *Acanthocyclops trajani* in the contaminated areas. There was no significant impact of heavy metals and pesticides on most of the structural indicators of zooplankton which can be due to the complex nature of contamination of the reservoir.

Keywords: Zooplankton, structure, heavy metals, Shardara Reservoir, Kazakhstan.

Introduction

Heavy metals and pesticides are listed as the most dangerous pollutants of natural ecosystems. Their influence on aquatic community is multifaceted and unpredictable (Braginsky, 1972; Moore & Ramamoorthy, 1987). One of the major factors for that is the temperature of water. On the one hand, it increases the toxic properties of toxicants for living organisms; on the other hand, it contributes to intensification of self-purification process in reservoirs (VishnuRadhan *et al*., 2015).

Zooplankton serves as a good indicator of the toxic contamination of aquatic ecosystems. Cladocera и Calanoida are the most sensitive to heavy metal contamination (Mangas-Ramı´rez *et al*., 2004; Gutierrez *et al*., 2010; Mano *et al*., 2011; Piscia *et al*., 2015; Ha *et al*., 2017). With escalation of pollution, Cladocera disappears first from the community (Gagneten & Paggi, 2009). Rotifera and Cyclopoida are more adapted to the conditions of polluted water (Offem & Ayotunde, 2008; Xu *et al*., 2014).

The sensitivity of planktonic invertebrates towards heavy metals and pesticides depends on the physic-chemical conditions (Garcı´a-Garcı´ *et al*., 2006), the trophic status of the reservoir (Serra *et al*., 2010), the presence of detergent components (Sobrino-Figueroa, 2016), as well as on relation to the species (Wang *et al*., 2009; Sakamoto *et al*., 2010), their neonatal size (Vesela & Vijverberg, 2007), the number of single-celled algae (Sarma *et al*., 2000) which have mechanisms for heavy metals detoxification (Macfie & Welbourn, 2000).

Along with depressing or stimulating impact on living organisms, chronic toxicity of water pollution causes mutagenic effect. The appearance of deformed specimens in populations of aquatic invertebrates under the influence of heavy metals (Krupa, 1998; Krupa, 2005; De Oliveira Dias, 1999; Grebenjuk & Tomilina, 2014) and pesticides (Kast *et al*., 2001; Alvarado-Flores *et al*., 2015) have been shown experimentally and in field studies.

The Shardara reservoir is located in southernmost Kazakhstan. It is characterized by high water temperatures in summer and the complex nature of the contamination. The study of species diversity, quantitative parameters, composition of dominant groups and species of zooplankton has begun since the formation of the reservoir (Malinovskaya & Ten, 1983; Krupa *et al*., 2009; Balymbetov, 2013).

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The aim of the present work is to provide a statistical analysis of the relationship between the structural parameters of zooplankton and environmental factors – macrophytes, temperature, depth, water transparency, nutrients, organochlorine pesticides and heavy metals in purpose to reveal the major influenced.

Description of Study Site

The Shardara water reservoir is located in one of the most densely populated areas of Kazakhstan with developed agriculture and industry. Its length is up to 80 km at maximum filling, with a maximum width of 25 km. The reservoir is elongated from north-west to south-east (Figure 1). The right bank is leveled, composed of loose sandy clay and clay loam, with steep underwater ledges. The left bank is flat, dissected with bays and coves. The reservoir is fed by the waters of the Syrdarya and Keles rivers. The grounds are dominated by gray silt with sand and clay; close to Syrdarya River, additionally, there is fine detritus. Macrophytes are poorly developed in the reservoir. There are clumps of *Potamogeton natans* L. in the coastal zone, and along the northeastern shore – strips of *Potamogeton malajanus* L.

The reservoir was put in place for irrigation purposes, so this conditions the annual water discharge from spring to autumn. During the level lowering for approximately 1.0-1.2 m at the beginning of June 2015, the depths ranged from 2.8 to 15.0 m. Water transparency reached 0.4-3.2 m, the temperature of the surface layers was 25.6-30.7°C, pH – 8.5-8.6.

Materials and Methods

The research of zooplankton, the content of nutrients, heavy metals and organochlorine pesticides in the water was carried out by means of a grid of 13 stations (Figure 1). The measurements of the temperature and pH values of the surface water layers were taken in the field environment by using Hanna HI 98129 instrument. Water transparency was measured with Secchi disk. Coordinate referencing of the stations was done by Garmin eTrex GPS-navigator. The samples for heavy metals were fixed in the site by adding nitric acid; samples for nutrients were fixed with chloroform. All collected samples were transported to the lab in an icebox. Zooplankton samples were collected by means of the Juday net with inlet diameter of 12 cm, by pulling it through from bottom to surface.

Conventional methods of chemical analysis of water were used (Semenova, 1977; Fomin, 1995). Water samples were analyzed in three – four repetitions. The error of estimate for major ions in the water was 0.5-5%, depending on the analysis type. Heavy metal measuring was performed by mass spectrometry with inductively coupled plasma by using Agilent 7500 A manufactured by Agilent Technologies, USA (National Standard RK ISO 17294-2-2006). The device allows for the detection of the various chemical elements in complex matrices, including those in the sea and grey water and in the biological objects in micro-trace quantities. Abundance Sensitivity of Agilent 7500 A: Low Mass$<5\times10^{-7}$, High Mass$<1\times10^{-7}$. Organochlorine pesticides were measured by gas-liquid and high-performance liquid chromatography (Klisenko *et al*., 1992; Dolzhenko, 2008; Bankina *et al*., 2002). Test-sensitivity is 10^{-5} mcg. The detection threshold is 0.002 mg dm^{-3} of the sample. Data on the content of nutrients, heavy metals and pesticides was compared to the maximum permissible concentrations of substances established for fisheries (MPC) (Kimstach, 1993; Bespamyatnov & Krotov, 1985).

Zooplankton samples were processed by standard methods (Winberg & Lavrenteva, 1984; Balushkina & Winberg, 1979) using guides to the identification (Krupa *et al*., 2016; Kutikova, 1970; Rilov, 1948; Benzie, 2005). In order to characterize the zooplankton structure, we found the total number of species, abundance, biomass of taxonomic groups and that of community, the value of the average individual mass of specimen, the composition and number of dominant species (according to abundance and biomass). Diversity index of Shannon Bi (bit mg^{-1}) and Shannon Ab (bit specimen^{-1}) (Magurran, 1998) were calculated as well as arithmetic difference between the two versions of the index (Δ-Shannon). The latter parameter was introduces by us when studying the plankton communities of the Kolsay mountain lakes (Krupa & Barinova, 2016). The calculation of the index values of Shannon and W-statistic Clarke (Clarke, 1990) was performed using the program Primer 5. Nonparametric correlation analysis and stepwise regression analysis were performed in Statistica 12.0 program.

Hydrochemical and Toxicological Characteristics

Total ions content of water averaged 1055 mg L^{-1}, with minor fluctuations across the water area. Given the total content of dissolved solids (TDS), the water was brackish (Guseva, 2002), with a predominance of sulphate and sodium ions. The content of nutrients (Table 1) did not exceed maximum permissible standards for fisheries (Kimstach, 1993; Bespamyatnov & Krotov, 1985). Among organochlorine pesticides, β-HCCH were present throughout the water area, which is considered unacceptable for fishery water bodies. The content of heavy metals in the water exceeded the MPC for fisheries (Kimstach, 1993).

General Characteristics of Zooplankton

Zooplankton structure was represented by 37

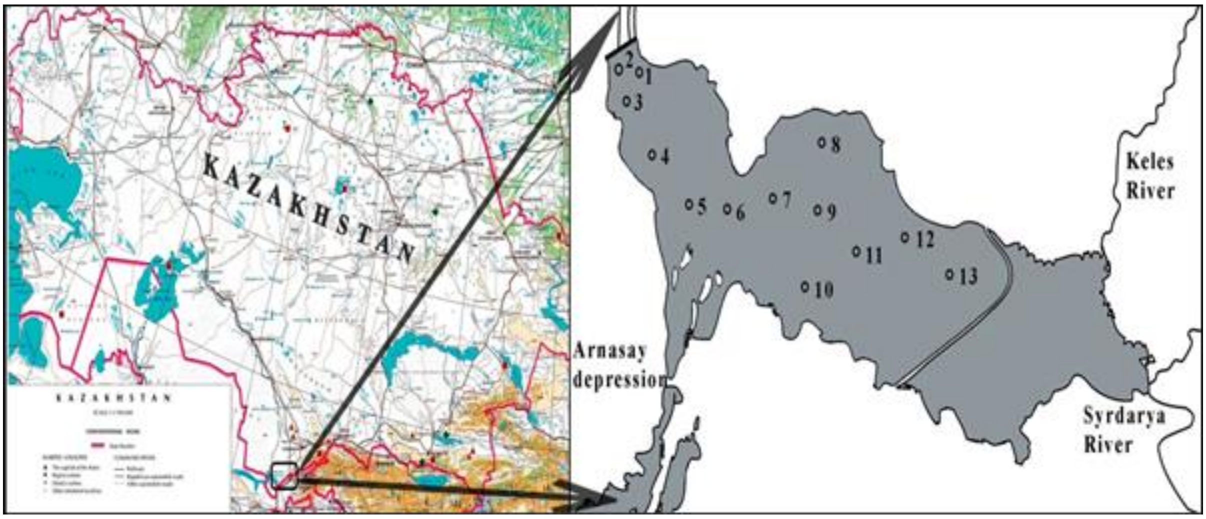

Figure 1. Map of sampling stations in the Shardara Reservoir, summer 2015.
Key: 1-13 are sampling stations. Black line outlines the water level of the reservoir during the sampling period.

Table 1. Hydrophysical, hydrochemical and toxicological characteristics of the Shardara Reservoir, summer 2105

Variable	Units	Mean value with STDEV	Variable	Units	Mean value with STDEV
Temp	°C	27.5±0.5	TDS	mg L^{-1}	1054.7±16.8
Depth	m	7.85±1.15	NH_4	mg L^{-1}	0.115±0.020
Secchi	m	1.47±0.24	NO_3	mg L^{-1}	5.45±0.13
Macrophytes	%	31.2±10.4	NO_2	mg L^{-1}	0.09±0.03
pH		8.54±0.01	P-PO_4	mg L^{-1}	0.040±0.012
Ca	mg L^{-1}	107.9±1.9	Polyphosphate	mg L^{-1}	0.161±0.004
Mg	mg L^{-1}	60.0±0.4	Zn	mg L^{-1}	0.121±0.040
Na+K	mg L^{-1}	120.3±2.7	Cu	mg L^{-1}	0.040±0.006
HCO_3	mg L^{-1}	177.0±1.8	Cd	mg L^{-1}	0.0032±0.0018
SO_4	mg L^{-1}	494.2±11.1	Pb	mg L^{-1}	0.034±0.014
Cl	mg L^{-1}	78.6±0.6	HCCH	mcg L^{-1}	0.0041±0.0008

rotifer species, 11 cladocerans, 6 copepods, 6 taxons of facultative inhabitants. Widespread in the water area were rotifers *Synchaeta stylata* Wierzejski, 1893, *S. vorax* Rousselet, 1902, *Polyarthra* sp., *Keratella cochlearis* (Gosse, 1851), *Pompholyx sulcata* Hudson, 1885, cladocerans *Daphnia galeata* Sars, 1863, *Leptodora kindtii* (Focke, 1844), *Diaphanosoma mongolianum* Ueno, 1938, copepods *Thermocyclops taihokuensis* Harada, 1931, and *Acanthocyclops trajani* Mirabdullayev & Defaye, 2004.

Zooplankton's quantitative parameters were at a moderate level (Table 2). Copepoda and Rotifera dominated in abundance, with the largest contribution made by *A. trajani*, *T. taihokuensis*, *S. stylata*, *Polyarthra* sp. and *P. sulcata*. Biomass was predominantly formed by copepods, with the leading role of cyclops *A. trajani*. The highest concentrations of planktonic invertebrates were observed near the south-western coast, and their minimum abundance was evidenced in the deep zone.

According to abundance, the species were distributed more evenly than according to the biomass, and that was reflected in negative Δ-Shannon values (Table 2). Small-size composition of zooplankton was reflected in the values of the average individual mass of specimen, which is characteristic of eutrophic conditions (Andronikova, 1996). Negative values of W-Clarke evidenced the abundance curve being above the biomass curve.

Statistical Analysis of the Data

Nonparametric correlation analysis (Table 3) showed that warmed shallow areas with macrophytes, with high concentrations of zinc and phosphate, hosted the communities that are more abundant with species. Rotifers *Polyarthra* sp. was noted to be associated to these overgrown areas. Rotifers *Pompholyx sulcata*, on the contrary, preferred open deep parts of the area, with a low content of ammonium ion, zinc, nitrates and phosphates, but with elevated concentrations of copper in the water. The higher abundance of *Phyllodiaptomus blanci* (Guerne & Richard, 1896) (Copepoda, Calanoida)

Table 2. Structural indicators of zooplankton Shardara reservoir, summer 2015

Variable	Mean value with STDEV	Variable	Mean value with STDEV
Rotifera species	8.8±1.1	Rotifera Biomass	22.6±10.9
Cladocera species	3.1±0.3	Cladocera Biomass	72.1±19.4
Copepoda species	2.9±0.2	Copepoda Biomass	864.4±448.3
Others species	0.8±0.4	Others Biomass	6.9±6.9
Total species	15.6±1.6	Total Biomass	966.0±468.0
Rotifera Abundance	44.5±18.5	Shannon Ab	2.24±0.13
Cladocera Abundance	1.0±0.2	Shannon Bi	1.23±0.14
Copepoda Abundance	46.5±16.3	Δ-Shannon	-1.00±0.15
Others Abundance	0.6±0.6	W-Clarke	-0.134±0.013
Total Abundance	92.9±34.0	Average Masse	0.0082±0.0016

Abundance = thous. specimens m^{-3}, Biomass = mg m^{-3}, Average Masse = mg, Shannon Ab = bit specimen $^{-1}$, Shannon Bi = bit mg^{-1}

Table 3. Spearman Rank Order Correlations between the structural parameters of zooplankton in Shardara reservoir and external factors, summer 2015

Paired variables	Spearman Rank Order Correlations	Paired variables	Spearman Rank Order Correlations
Macrophytes – Depth	-0.816	Ab *P. sulcata* – Zn	-0.708
Macrophytes – Temperature	0.718	Ab *P. sulcata* – Cu	0.640
Macrophytes – Secchi	-0.800	Ab *P. sulcata* – Nitrites	-0.740
Macrophytes – Zn	0.558	Ab *P. sulcata* – Phosphate	-0.568
Macrophytes – Phosphate	0.581	Ab *Ph. blanci* – Macrophytes	-0.771
Phosphate – Nitrites	0.919	Ab *Ph. blanci* – Depth	0.627
Nitrites – Zn	0.962	Ab *Ph. blanci* – Secchi	0.743
Total species – Macrophytes	0.567	Ab *Ph. blanci* – Temperature	-0.626
Rotifera species – Macrophytes	0.650	Shannon Bi – Average mass	-0.698
Copepoda species – Cd	-0.650	Shannon Bi – Ab Copepoda	-0.621
Copepoda species – Pb	-0.607	Shannon Bi – Bi Copepoda	-0.753
Ab Rotifera – Ammonia	-0.652	Shannon Bi – Total Biomass	-0.648
Ab Copepoda – β-HCCH	0.580	Shannon Bi – Bi *A. trajani*	-0.692
Bi Copepoda – β-HCCH	0.646	Shannon Bi – Zn	0.555
Bi Total – β-HCCH	0.624	Shannon Bi – β-HCCH	-0.627
Ab *A. trajani* – β-HCCH	0.572	Shannon Bi – Phosphate	0.587
Ab *D. galeata* – Temperature	0.636	Shannon Ab – Cd	-0.633
Ab *D. galeata* – Secchi	-0.601	Shannon Ab – Rotifera species	0.681
Ab *Polyarthra sp.* – Macrophytes	0.556	Shannon Ab – Copepoda species	0.673
Ab *Pompholyx sulcata* – Macrophytes	-0.654	Shannon Ab – Total species	0.666
Ab *P. sulcata* – Temperature	-0.757	Δ-Shannon – Nitrates	0.605
Ab *P. sulcata* – Depth	0.719	Δ-Shannon – pH	-0.660
Ab *P. sulcata* – Secchi	0.793	W-Clarke – Copepoda species	-0.632

was also observed in the deep water. Cadmium and lead have contributed to reducing the number of Copepoda species, whereas the abundance of the group, consisting mainly of cyclopoid *Acanthocyclops trajani*, increased in areas with high concentration of β-HCCH. The abundance of cladocerans *Daphnia galeata* was higher in warmed shallow water areas with low transparency.

The values of Shannon Ab index (bit specimen^{-1}) depended entirely on the total number of species within the community, formed by the diversity of rotifers and copepods. The negative association between Shannon Ab and Cd was due to the fact that cadmium caused a decrease in the copepods diversity, which together with rotifers was the major contributor to the increase in index values (bit specimen^{-1}).

The values of the Shannon Bi index (bit mg^{-1}) declined with an increase in the average mass of specimen in the community in areas with high abundance and biomass of Copepoda and total zooplankton. The main contribution to the rise of zooplankton biomass brought cyclops *Acanthocyclops trajani*, especially in the areas contaminated by HCCH, which, in turn, led to a decrease in the index values of Shannon Bi (bit mg^{-1}). A positive relationship between Δ-Shannon values and nitrates is established, and the negative relationship – with pH values. Multidirectional communication between the

Δ-Shannon and these two parameters are caused by the fact that they, respectively, are negatively correlated with each other. There were no statistically significant relationships between the values W-statistics Clarke and external factors. The indicator's values were decreasing against the backdrop of ascending diversity of copepods.

To determine the main factors controlling the spatial dynamics of the zooplankton structure, we used multivariate regressive step-by-step analysis. As illustrated in Table 4, the species richness of zooplankton, with the main contribution made by rotifers, increased in areas with macrophytes, but decreased under the influence of high water temperatures. The number of species of copepods decreased in areas with high concentration of cadmium in water, but increased within a gradient of HCCH concentrations. The abundance of rotifers was mainly influenced by nitrates, total nitrogen and organic polyphosphates. The change in Cladocera population was determined by phosphates, whereas biomass of the group, including *Daphnia galeata*, grew in shallow overgrown areas with low water transparency and a high content of zinc. Copepoda's quantitative parameters, with the main contribution made by cyclops *A. trajani*, was negatively influenced mostly by nitrates and organic polyphosphates, which further led to a decrease in the abundance and total biomass of zooplankton.

The number of rotifers *Polyarthra* sp. increased in areas where macrophytes developed, but the water temperature and total nitrogen had a negative impact on the population of this species. For rotifers *Pompholyx sulcata*, favorable conditions were in areas with transparent water, high copper content, but low concentrations of cadmium. The distribution of copepod *Phyllodiaptomus blanci* was determined by water transparency only.

Decline of the Shannon Ab index values (bit specimen^{-1}) occurred under the influence of cadmium and ammonium. Index values, that are calculated according to the proportion of species in the total biomass (bit mg^{-1}), increased with rising water temperatures and decreased under the influence of β-HCCH, copper, cadmium, ammonium, total nitrogen, as well as with the enlargement of species within the community. Δ-Shannon values rose with increasing total nitrogen content. The values of W-Clarke negatively correlated with the Shannon Ab values (bit specimen^{-1}).

Discussion

The complex nature of contamination of Shardara reservoir has multidirectional impact on its biota. Our results showed that the abundance of rotifers was controlled by nitrates, total nitrogen and organic polyphosphates. The abundance of one of the dominant species – *Polyarthra* sp., increased in areas where macrophytes developed, but decreased with descending water temperatures and with growth of the total nitrogen content. Total nitrogen, along with transparency, total phosphorus and ammonium nitrogen, were the main factors that determined the species composition and abundance of rotifers in China's lakes (Du *et al*., 2014). For *Pompholyx sulcata*, favorable conditions were formed in areas with transparent water, elevated concentrations of copper and low cadmium content. Depending on the type and conditions of the experiment, the inhibitory effect of copper on the rotifer population appeared at a concentration from 0.03 mg L^{-1} (Gama-Flores *et al*., 2005) to 0.06-0.33 mg L^{-1} (P′erez-Legaspi and Rico-Mart′ınez, 2001). At lower contents of copper in admixture with other heavy metals, it has a stimulating effect on rotifers (Xu *et al*., 2014).

Despite the fact that copper and cadmium are among the most dangerous poisons for living organisms (Moore & Ramamoorthy, 1987), in Shardara reservoir conditions, they did not significantly affect the most sensitive group of aquatic invertebrates – Cladocera. The total abundance of cladocerans and abundance of *Daphnia galeata* were under the positive influence of phosphates and zinc, and the biomass increased in a gradient of concentration of nitrites, zinc, lead and β-HCCH (Table 4). Lower toxicity of zinc, compared to cadmium and copper (Braginsky *et al*., 1987), is associated with its rapid clearance from Cladocera body through molting (Muyssen & Janssen, 2002). The effect of zinc on Cladocera is obviously mediated, and is connected with the distribution of food items – green algae. Between the green algae biomass in the Shardara reservoir and zinc, we found a statistically significant positive relationship (Krupa *et al*., 2017), which may be due to the stimulating effect of low concentrations of zinc on phytoplankton (Cao *et al*., 2015). Lethal concentration of lead to cladocerans are two orders of magnitude higher (more than 3.0 mg L^{-1}) (Garcı′a-Garcı′ *et al*., 2006), and potentially dangerous concentration – one order of magnitude higher (0.19 mg L^{-1}) (Offem & Ayotunde, 2008) than the amount of lead in water of the Shardara reservoir (0.034 mg L^{-1}).

Quantitative parameters of Copepoda, formed mainly by cyclops *Acanthocyclops trajani*, were negatively affected by organic polyphosphates, nitrates and total nitrogen. In Kazakhstan, *A. trajani* often dominates the technical waters with mixed pollution (Krupa, 2012). The reported increase in the population abundance within the gradient of β-HCCH concentrations reaffirms *A. trajani*'s role of an indicator for diagnosing toxic pollution of water bodies. Although Calanoida is more sensitive to the toxic contamination (Gutierrez *et al*., 2010) compared to Cyclopoida, there was no effect of heavy metals and pesticides on diaptomid copepod *Phyllodiaptomus blanci*. This species is a typical

Table 4. Multivariate regression stepwise statistical analysis combined results of environmental and biological variables at the Shardara reservoir, summer 2015

Dependent variable	Step 1	Step 2	Step 3
Total species	-	Macr. b*=0.561	Macr. b*=1.40 Temp. b*=-1.0
Rotifera species	-	Macr. b*= 0.637	Macr. b*=1.35 Temp. b*=-0.87
Copepoda species	Cd b*=-0.63	Cd b*=-0.67 β-HCCH b*=0.517	Cd b*=-0.61 β-HCCH b*=0.555
Ab Rotifera	-	Nitrates b=-0.50 Polyph. b*=-0.64	Nitrates b*=-0.65 Nitrites b=-0.44 Polyph. b*=-0.53 Total nitrogen b*=-0.46
Bi Rotifera	-	Polyph. b*=-0.56	Polyph. b=-0.46 Total nitrogen b=-0.41
Ab Cladocera	Phosph.*=0.615	Phosph. b*= 0.488 Nitrates b=-0.39	Phosph. b*=0.529 Nitrates b=-0.54 Ammon. b=0.350
	-	-	Zn b*=0.617
Bi Cladocera	Zn b*=0.800	Zn b*=0.890 Pb b*=0.556	Zn b*=0.904 Pb b*=0.459
	Pb b*=0.445	β-HCCH b*=0.448	β-HCCH b*=0.417 Cd b=0.165
	Nitrites b*=0.695	Nitrites b*=0.759 Ammon. b=0.282	Nitrites b*=0.666 Ammon. b=0.446 Nitrates b=-0.40
Ab Copepoda	-	Nitrates b=-0.55	Nitrates b*=-0.69 Nitrites b=-0.43
	Polyph. b*=-0.59	Polyph. b*=-0.52 Nitrates b=-0.47	Polyph. b*=-0.56 Nitrates b*=-0.63 Ammon. b=0.366
	Polyph. b*=-0.59	Polyph. b*=-0.52 Nitrates b=-0.47	Polyph. b*=-0.50 Nitrates b=-0.40 β-HCCH b=0.286
Bi Copepoda	-	Polyph. b*=-0.68	Polyph. b*=-0.62 Nitrates b=-0.41
	-	Total nitrogen b=-0.53	Total nitrogen b*=-0.76 Ammon. b=0.418
Total Ab	-	Nitrates b=-0.55 Polyph. b*=-0.65	Nitrates b*=-0.69 Nitrites b=-0.45 Polyph. b*=-0.53 Total nitrogen b*=-0.48
Bi Total	Polyph. b*=-0.67	Polyph. b*=-0.60 Nitrates b=-0.42	Polyph. b*=-0.65 Nitrates b*=-0.59 Ammon. b=0.377
Ab *Polyarthra* sp.	-	Macr. b=0.468 Total nitrogen b*=-0.73	Macr. b*=1.55 T b*=-1.3 Total nitrogen b*=-0.64 Polyph. b*=-0.36
Ab *P. sulcata*	-	-	Secchi b*=0.604
	Cu b*=0.810	Cu b*=0.898 Cd b*=-0.35	Cu b*=0.865 Cd b*=-0.36 β-HCCH b=0.223
Ab *D. galeata*	Secchi b*=-0.59	Secchi b*=-1.0 Macr. b=-0.64	Secchi b*=-1.1 Macr. b=-0.67 pH b=0.257
	-	Zn b*=0.735	Zn b*=0.820 Cd b=0.342
	Zn b*=0.735	Zn b*=0.600 Secchi b=-0.36	Zn b*=0.659 Secchi b*=-0.80 Depth b=0.562
Ab *A.trajani*	-	Cu b=0.442	Cu b=0.395 β-HCCH b=0.292
	Polyph. b*=-0.62	Polyph. b*=-0.56 Nitrates b=-0.43	Polyph. b*=-0.60 Nitrates b*=-0.61 Ammon. b=0.419
Ab *Ph. blanci*	Secchi b*=0.811	Secchi b*=1.18 T b=0.461	Secchi b*=1.11 T b=0.684 Macr. b=-0.34
Shannon Ab	Cd b*=-0.84	Cd b*=-0.96 Pb b=0.220	Cd b*=-0.94 Pb b=0.270 Cu b=-0.20
	-	-	Ammon. b*=-0.65
	Cd b*=-0.84	Cd b*=-0.74 Total species b=0.226	Cd b*=-1.0 Total species b=0.271 Ammon. b=0.321
Shannon Bi	Temp. b=0.882 Secchi b=0.531	Temp. b=0.918 Secchi b=0.959 Depth b=-0.49	Temp. b*=1.58 Secchi b=1.24 Depth b=-1.0 Macr. b=-0.94
	β-HCCH b*=-0.54 Cu b*=-0.51	β-HCCH b*=-0.52 Cu b*=-0.41 Cd b*=-0.40	β-HCCH b*=-0.53 Cu b*=-0.55 Cd b*=-0.43 Zn b=-.27
	Polyph. b=0.439	Polyph. b=0.506 Ammon. b=-0.37	Polyph. b=0.422 Ammon. b*=-0.70 Total nitrogen b*=0.611
	Average Masse b*=-0.73	Average Masse b*=-0.67 Cu b*=-0.52	Average Masse b*=-0.56 Cu b*=-0.47 β-HCCH b*=-0.38
Δ- Shannon	-	Total nitrogen b*=0.648	Total nitrogen b*=0.557 Polyph. b=0.388
	Total nitrogen b*=0.648	Total nitrogen b=0.496 Shannon Bi b=0.474	Total nitrogen b=0.00 Shannon Bi b=0.973 Shannon Ab b=-0.85
W-Clarke	-	Shannon Ab b*=-0.55	Shannon Ab b*=-0.68 Shannon Bi b*=0.336

Bi = Biomass, Ab = Abundance, Macr. = Macrophytes, Temp. = Temperature, Polyph. = Organic polyphosphate, Phosph. = Phosphate, Ammon. = Ammonium, Secchi = water transparency by Secchi disk, β-HCCH = isomers of HCCH, Shannon Ab = bit specimen^{-1}, Shannon Bi = bit mg^{-1}, Average Masse = the average individual masse of specimen, b* = statistically significant coefficient values at $P<0.05$.

inhabitant of shallow water bodies (Saha *et al*., 2016) which in itself speaks of its relative resistance to external conditions. The most significant factor for this species population was reservoir's morphometric parameters.

Diversity of copepods was negatively influenced by cadmium and lead (Table 3), which, according to the results of multivariate analysis (Table 4), led to a decrease in the Shannon index values calculated according to the abundance (bit specimen^{-1}). Along with the toxic pollution, the magnitude of the second version of the Shannon index (bit mg^{-1}) was determined by the internal structure of the community. Namely, it declined with an increase in the average individual mass of a specimen. This nature of the relationship has repeatedly been observed earlier for zooplankton (Krupa, 2012) and phytoplankton (Barinova & Chekryzheva, 2014). Values Δ-Shannon depended on total nitrogen, and the values of W-statistic Clarke decreased with rise of Shannon values (bit specimen^{-1}).

Thus, at relatively high concentrations of toxicants in water Shardara reservoir, their essential impact on the zooplankton has not been identified. This may be due to its trophic status (Serra *et al*., 2010), favorable feed supply (Sarma *et al*., 2000), complex nature of contamination that includes the detergent components (Sobrino-Figueroa, 2016) represented in the Shardara reservoir by organic polyphosphates.

Comparison of the results with the published data (Krupa, 2007) showed that the species richness, quantitative variables, and the composition of dominant species in the zooplankton of the Shardara Reservoir vary significantly, depending on the season and year of research. Thus, the similarity of the species composition of summer zooplankton in 2003 and 2015 (studies were conducted in the first decade of June) was less than 50%. From 2003 to 2015, the number of *Daphnia* species decreased from 3 to 1, of *Asplanchna* – from 4 to 2, of Cyclopoida – from 8 to 3, and of Calanoida – from 2 to 1. In 2003, the quantitative variables of zooplankton were primarily formed by *Synchaeta stylata, Hexarthra fennica, Asplanchna priodonta, Daphnia galeata, D. longispina, D. magna, Acanthocylops trajani*. Of this set of dominant species, only *Synchaeta stylata* and *Acanthocylops trajani* remained in 2015, but other species appeared: *Polyarthra* sp., *Pompholyx sulcata, Thermocyclops taihokuensis.*

Among predatory species that can have a significant impact on zooplankton, *Leptodora kindtii* was constantly present in the summer of 2015, as well as in all seasons of 2003-2005. Its maximum abundance (160 spec. m^{-3}) was observed in the summer of 2004. There was no correlation between the spatial distribution of peaceful zooplankton species and *Leptodora* in 2015, and between the average abundance of *Leptodora kindtii* in 2003-2005 and 2015 and structural variables of zooplankton. The literature data (Pichlová & Brandl, 2003) indicates that *Leptodora* can affect zooplankton only in limited periods of the summer season.

The hydrological regime is one of the essential factors for aquatic animals. In high-water years, nutrients and toxicants entering reservoirs get diluted, while water level recession leads to their increased concentrations (Yang *et al*., 2010).

Due to the irrigation use of Shardara Reservoir, its water area is reduced from spring to autumn by about three times. The artificial reduction of the water level in the Shardara Reservoir is accompanied by specific changes in the zooplankton structure. Analysis of the 2003-2005 data (Krupa, 2007) has shown that when the water level was sufficiently decreased from summer to autumn there was a decrease in species diversity, increase in abundance of zooplankton, sometimes against the background of decrease in biomass, reducing the value of the average individual mass of specimen (Table 5). In summer, rotifers together with copepods dominated in abundance, and cladocerans – in biomass. By the fall, the dominant position of copepods intensified. Seasonal changes in zooplankton structure evidenced an intensification of eutrophication processes from summer to autumn due to lowering of reservoir water level, which was also observed for other aquatic ecosystems (Chuai *et al*., 2012).

Table 5. Long-term comparative characteristics of the zooplankton structure in Shardara Reservoir

Variable	*2003		*2004		*2005		2015
	summer	autumn	summer	autumn	summer	autumn	summer
number of species	77	41	61	46	64	42	60
abundance, thous. specimens m^{-3}	139.2	268.6	109.6	243.1	116.1	117.6	92.9
dominating group	Rotifera	Copepoda	Rotifera, Copepoda	Rotifera, Copepoda	Rotifera	Copepoda	Copepoda, Rotifera
biomass, mg m^{-3}	640	1030	1220	910	1100	635	966
dominating group	Cladocera	Copepoda	Cladocera	Copepoda	Cladocera	Copepoda	Copepoda
average mass of a specimen, mg	0.0224	0.0038	0.0089	0.0036	0.0122	0.0061	0.0082

*according to Krupa, 2007

In June 2015, the values of all the structural indicators of zooplankton occupied an intermediate position between the summer and autumn status, with Copepoda, however, in dominant position as though in autumn. More pronounced signs of eutrophication in the summer of 2015 are associated with the reservoir level reduction for about one-quarter, while in high-water years of 2003-2005 the similar reduction took place at a later date. An indirect sign of interannual changes of the level of water bodies in arid zones is water salinity, which increases in dry years or following the artificial reduction of the level. The value of this indicator in 2015 averaged 1.05 g L^{-1}, which is higher than in the summer of 2003-2005 – 0.82-0.98 g L^{-1}, but lower than in the autumn – 1.18-1.33 g L^{-1} (Amirgaliev, 2007; Krupa, 2012). Therefore, zooplankton structure, including the average individual mass of specimen as an integral index, serves as good indicator of inter-seasonal and interannual changes in the hydrological regime and of the trophic status of aquatic ecosystems.

Comparison with the previous data (Krupa, 2007) suggests that the overall level of toxic contamination of the Shardara reservoir has decreased by 2015. It is indicated by the absence of specimens with morphological abnormalities in copepods populations in 2015, continuously reported earlier (Krupa, 2007). With the content of heavy metals in the water being close to the compared periods (Table 6), the presence of malformed specimens of copepods in 2003-2005 could be considered a response to water being polluted by organochlorine pesticides. In 2015, DDT metabolites were not detected in the water and the concentrations of β-HCCH were one to two orders of magnitude lower than in 2004-2005.

Conclusion

The Shardara reservoir is exposed to organic and toxic pollution that comes from the catchment area, with transit river flow and drainage water. Together with low content of biogenic compounds in the summer of 2015, β-HCCH and heavy metals were present in high concentrations throughout the water area. Shallow well-warmed areas where macrophytes developed, with a high content of zinc, phosphates, were characterized by an increase in zooplankton diversity, mainly due to the rotifers. The stimulating effect on rotifers provided nitrates, total nitrogen, organic polyphosphates, copper and macrophytes, and their abundance decreased within the gradient cadmium concentrations. Cladocerans were more viable in areas with a high content of phosphates, nitrates, zinc, lead and β-HCCH. The content of heavy metals in water of the Shardara reservoir is at a level substantially below the lethal, so their stimulating effect on Cladocera appears to be mediated. For example, the positive effect of zinc on the abundance and biomass of cladocerans may be due to the green algae's growth being stimulated under the influence of zinc. The main factors causing decrease in the abundance of copepods were organic polyphosphates, nitrites and total nitrogen. At the same time, the abundance of cyclops *Acanthocyclops trajani*, that dominated zooplankton, increased in areas contaminated by β-HCCH. Cadmium and lead compromised the richness of copepods. Shannon values reduction under the influence of cadmium, ammonium, β-HCCH is associated with increased dominance of the cyclops *A. trajani* in the contaminated areas. There was no significant effect of toxicants on most of the structural indicators of zooplankton that may be due to the complex nature of the contamination of the reservoir. Compared with the data from the beginning of the 2000-s, in 2015, the overall level of toxic pollution of the Shardara reservoir, with the main contribution of organochlorine pesticides, has decreased, which correlates with the parameters of zooplankton reaction. Therefore, zooplankton characteristics can be used as an indicator of xenobiotic pollution in monitoring of large waterbodies like the Shardara reservoir.

Acknowledgements

The work was carried out under the project № 1846/GF4 G.2015-G2016 for Committee of Science,

Table 6. The content of nutrients, heavy metals and organochlorines pesticides in Shardara reservoir in 2004-2005 and 2015

Indicator	Units	2004 Summer*	2004 Autumn *	2005 Summer*	2005 Autumn*	2015 Summer
NH_4	mg L^{-1}	0.143	0.150	0.264	0.331	0.115
NO_3	mg L^{-1}	9.54	3.69	5.42	4.44	5.45
NO_2	mg L^{-1}	0.071	0.150	0.115	0.090	0.090
P-PO_4	mg L^{-1}	0.0184	0.038	0.045	0.098	0.040
Zn	mg L^{-1}	0.013	0.012	0.076	0.045	0.121
Cu	mg L^{-1}	0.006	0.011	0.014	0.030	0.040
Cd	mg L^{-1}	0.0060	0.0030	0.0020	0.0025	0.0032
Pb	mg L^{-1}	0.022	0.039	0.007	0.008	0.034
HCCH	mcg L^{-1}	0.003-0.150	0.0-0.040	0.282	0.098	0.004
DDT	mcg L^{-1}	0.004-1.360	0.0-0.050	0.119	0.140	0.000

*according to Amirgaliev, 2007; Krupa, *et al.*, 2009

Ministry of Education and Science, Republic of Kazakhstan "Development of the methods for controlling the ecological state of water bodies in Kazakhstan" as well as partly supported by the Israeli Ministry of Absorption.

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