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Original Research Article

The usage of zooplankton distribution maps for assessment of ecological status of the Shardara reservoir (Southern Kazakhstan)

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ABSTRACT

The spatial distribution of biological indicators of zooplankton in Shardara reservoir (southern Kazakhstan) was investigated in summer 2015. The development of macrophytes in the water area significantly affected the species diversity of zooplankton. Copepoda avoided places with high concentrations of polyphosphates from detergents, but gained a competitive advantage on water areas polluted by β-HCCH. The most favorable conditions for Cladocera, represented mostly by *Daphnia galeata*, were formed on parts of the reservoir with high content of phosphates, nitrites, zinc and accumulation of green algae. Cladocera avoided waters with a high content of lead, copper and cadmium. Statistical maps of distribution of Δ-Shannon, Clarke's *W*-statistics and average individual mass did not reveal any certain relations with environmental variables, which we attribute to the complex nature of the Shardara reservoir's pollution. A strong relationship between the Δ-Shannon and Clarke's *W*-statistics parameters was found. It was found that Δ-Shannon is easy calculated and can be used for the zooplankton community structure description.

1. Introduction

Aquatic invertebrates are good indicators of the ecological status of the water bodies. The diversity, composition and number of dominant species, the proportion of Rotifera, Cladocera, Calanoida and Cyclopoida in the total quantitative parameters of zooplankton are indicative (Andronikova, 1996; Jeppesen et al., 2011; Ochocka and Pasztaleniec, 2016). Rotifera are the most diverse in the eutrophic water bodies, crustaceans – in the mesotrophic ponds of Poland (Kuczyńska-Kippen and Joniak, 2016). With an increase of trophic status of water bodies, the number of dominant species in zooplankton communities decreases, whereas the abundance of Rotifera and Cladocera grows, as does the ratio of Cyclopoida's biomass to Calanoida's (Andronikova, 1996; Xue et al., 2014). In Q2 contrast with these results, the Rotifera abundance declined during the eutrophication of lakes in Poland leaving more space for Cladocera and Copepoda (Adamczuk et al., 2015). The authors of the this paper found that *Daphnia longispina* O.F. Mueller and *Monospilus dispar* G.O. Sars prefer waters with elevated N-NH_4; *Cyclops kolensis*

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Lilljeborg and *Cyclops strenuus* Fischer correlate with a rising gradient in $P\text{-}PO_4$ (Adamczuk et al., 2015; Kuchko et al., 2015). Among other things, eutrophication of aquatic ecosystems leads to decrease of the average mass of individual specie (Andronikova, 1996). As the trophicity of a reservoir increases, large species such as Cladocera and Calanoida are eliminated from zooplankton communities comprised of small-eurybiont species (Adamczuk et al., 2015; Kuchko et al., 2015).

Toxic pollution as well as eutrophication lead to a decrease of stenobiont species which in turn is reflected in the reduction of zooplankton diversity (Vandysh, 2004). Rotifers are the most tolerant to heavy metal contamination (Gagneten and Paggi, 2009). Specimens with morphological abnormalities are present in populations of copepods in conditions of chronic toxic pollution of water bodies (Krupa, 2005, 2008, 2012).

Comparison of biomass curves and abundance curves (ABC-Method) may have an indicative value in assessing the ecological state of water bodies (Warwick, 1986). Biological parameters such as Clarke's *W*-statistics are based on the mutual arrangement of biomass and abundance curves (Clarke, 1990). Positive values of Clarke's *W*-statistics indicate that the biomass curve is above the abundance curve. According to Warwick (1986), this arrangement of curves is typical for natural habitats. When stress increases, the abundance and biomass curves change the location, and Clarke's *W*-statistics becomes negative.

The presence of macrophytes is proved as one of the essential factors that determine the composition and quantitative parameters of zooplankton communities (Kuczyńska-Kippen and Nagengast, 2016; Kuczyńska-Kippen and Joniak, 2016; Du et al., 2014). It has been shown that the prevailing species of macrophytes in shallow macrophyte lakes affect horizontal distribution, the abundance of bacteria, flagellates, ciliates and crustaceans, and the predator–prey ratio (Mieczan et al., 2016). Thus, the presence and abundance of macrophytes must be taken into account when analyzing the horizontal distribution of biological parameters across the water area.

The structure of zooplankton communities can be used to assess the ecological status of both the water body as a whole and its individual parts (Vandysh, 2004). This is especially true for large water bodies polluted from point and scattered sources. To assess the ecological status of different parts of large water bodies, it seems advisable to construct maps of the spatial distribution of the analyzed parameters (Barinova et al., 2016). Data visualization also makes it possible to identify potential sources of pollution of the reservoir and its individual parts.

The Shardara reservoir was formed in 1965 and represents one of the largest fisheries and irrigation water bodies of Kazakhstan. The surface area of the reservoir at full filling is 780 sq. km. Irrigation water withdrawal causes a reduction of water surface area from spring to autumn for approximately three times. The anthropogenic impact on the water body is due to its location in an area of intensive farming and industrial activities.

Primarily, the Shardara reservoir is polluted by nutrients, pesticides, and heavy metals (Amirgaliev, 2007). The highest concentrations of these substances in the reservoir water had been recorded until the mid-90s of the last century. The quantity of fertilizers in agricultural use decreased in the following years of economic recession in Kazakhstan. This led to an improvement of the ecological situation in the region (Lopareva and Amirgaliev, 1973; Amirgaliev et al., 1995; Amirgaliev, 2007). For the present, the area of irrigated land is being expanded, and the industry within the catchment area of the Shardara reservoir grows. This necessitates monitoring the ecological state of the Shardara reservoir.

Unstable hydrological regime, the influx of contaminants from the collector-drainage, surface runoff and river water transit, together with the hydrophysical parameters in the arid climate conditions cause significant differences in the spatial conditions for the existence of aquatic fauna of the Shardara reservoir.

Information on the structure of zooplankton in Shardara reservoir is given in the previously published works (Malinovskaya and Ten, 1983; Kiseleva, 1997; Krupa et al., 2009; Balymbetov, 2013). The diversity of summer-time zooplankton reached 38–77 species. The abundance of zooplankton varied within the range of 100.0–139.2 thous. spec. m^{-3}, on account of the above-mentioned papers. The biomass of zooplankton was 0.6–2.4 g m^{-3}. Rotifera was dominant by abundance, sometimes in conjunction with Copepoda. Cladocera was dominant by biomass. The zooplankton structure changed with a decrease of the water level in the reservoir from summer to autumn (Krupa et al., 2009). The Calanoida species had disappeared from the zooplankton composition by autumn. The smaller species of Cyclopoida dominated the water body. The average individual mass of a specimen decreased from 0.0224 mg in the spring–summer period to 0.0089 mg in the autumn. So, according to the above-mentioned research, changes in the structure of zooplankton communities indicated an intensifying eutrophication of the reservoir from summer to autumn during 2003–2005.

Information on the spatial distribution of the zooplankton in the Shardara reservoir due to external factors is absent in the published works. The present work fills the gap. The purpose of this study is to analyze the spatial distribution of zooplankton in connection with macrophyte, nutrient content in water, organic polyphosphates, organochlorine pesticides and heavy metals. As indicative biological parameters, the following were selected: species richness, abundance, biomass of taxonomic groups (Rotifera, Cladocera, Copepoda, facultative inhabitants of the water column) and total zooplankton, values of Shannon index, Clarke's *W*-statistics. Here, we also observe the relationship between the values of Clarke's *W*-statistics and the parameter introduced by us earlier – Δ-Shannon (Krupa and Barinova, 2016; Krupa et al., 2016). The analysis of all data is based on statistically generated maps. This method makes it possible to compare the distribution of zooplankton and abiotic indicators across the water area of the reservoir. Mapping of data shows the confinement of the abiotic indicators to the potential sources of pollution of the reservoir. Besides, widely accepted comparative statistical methods do not always give comprehensive

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