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DYNAMICS OF ZOOPLANKTON OF THE LEBYAZHYE LAKE IN CONNECTION WITH THE ACTIVITIES ON ECO-REHABILITATION

Olga Yurjevna Derevenskaya*, Nazligul Alikovna Urazaeva

Institute of Management, Economics and Finance, Kazan Federal University,18 Kremlyovskaya street Kazan 420008, Russian Federation

Abstract:

The paper presents the results of longstanding (from 1991 to 2016) studies of the zooplankton community of the lake Lebyazhye (Kazan, Russia). In recent decades, under the influence of anthropogenic and natural factors, the water level has decreased and the area of the lake Lebyazhye has reduced. The area of the lake has decreased by 13 times, compared with the 1990's. The water level in the lake is artificially maintained by the supply of groundwater. This caused an increase in the mineralization of water, the predominance of sulfate ions in the ionic composition. This also led to changes in the structure of the zooplankton community. The species composition of zooplankton decreased by more than 20%. New species appeared in the lake, which did not exist before. The number of dominant species has decreased, and the complex of dominant species of zooplankton has changed. The number and biomass of zooplankton have decreased. Earlier, the values of quantitative indicators corresponded to the mesotrophic-eutrophic water bodies, but now the reservoir is characterized as oligotrophic. The community is relatively aligned, although it is represented by a small number of species. This is confirmed by the rather high values of the Shannon index, characterizing the species diversity of zooplankton. The results of studies of the zooplankton community of the lake Lebyazhye can be used to justify the measures for the lake's eco-rehabilitation.

Keywords: *Zooplankton, Eco-Rehabilitation, Lake, Bioindication.*

Corresponding author:

Olga Yurjevna Derevenskaya,

Associate Professor, Institute of Management, Economics and Finance, Kazan Federal University, 18 Kremlyovskaya street Kazan 420008, Russian Federation

E-mail: oderevenskaya@mail.ru,

QR code

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INTRODUCTION:

The problem of reservoirs maintenance in urban areas becomes more and more urgent. Kazan (Russia) is not an exception. The lake Lebyazhye is located in the forest park area of the city and is a valuable recreational facility.

Previously, the lake Lebyazhye consisted of four reservoirs: Bolshoe, Maloe, Svetloe, and Sukhoe Lebyazhye, connected together by watercourses. In the 1960s, the water balance of the lake was disturbed due to a reduction in the catchment area, and, by the end of the 1990s, the lakes have become shallow. From 1995 to 2002, the water level in the lake was maintained due to the periodically supply from a nearby quarry. After the termination of artificial recharge, the water level in the lake has greatly decreased. Currently, the water level in the lake M. Lebyazhye is maintained due to the periodic artificial replenishment with groundwater from wells, located nearby; the rest of lakes of Lebyazhye system has dried up.

According to the origin of the lakes, they presumably dune or suffosonic-karstic [1, 2]. According to the data of the 1970s, the Lebyazhye lake system had a length of 2.6 km, a width of 476 m, a maximum depth of 3.9 m, an average depth of 1.1 m. The lake area in that period was 42.9 hectares, the water volume was 586 thousand m^3 [3]. According to our observations, in 2015-2016, the area of the lake M. Lebyazhye was no more than 3.38 hectares, the volume of the water mass was 31 thousand m^3, the maximum depth was 2.9 m, the average depth - 0.92 m, the length of the lake - 891 m, the average width - 34.6 m, the maximum width - 147 m, the water level in the lake was unstable. The area of the lake system as a whole decreased by almost 13 times, compared with the 1970s.

According to the results of archive materials, water in the lake Lebyazhye was a hydrocarbonate-calcium type, it was "very soft", with "medium" mineralization. The inflow of groundwater in the lake led to an increase in the mineralization of water (from 151.5 mg/l to 975.2 mg/l); the electrical conductivity of water increased. In the lake M. Lebyazhie its value in different years was 121-410 μS/cm, in 2015 this figure was 1030-1280 μS/cm, and in 2016 - 730-1500 μS/cm. The electrical conductivity increases from spring to autumn. These indicators characterize the mineralization of water as "increased", and the reservoir - as brackish water. Earlier the sulfate content was 21.8 mg/l, in 2015 - 513.7 mg/l. Sulfates predominated among the anions.

The lake is a valuable recreational facility, located in the territory of specially protected areas of local significance "City Forest Park Lebyazhye." In the forest park, there are many holidaymakers in all seasons of the year. Sporting events, mass celebrations and festivities are held there. Therefore, the study of the state of the single remaining reservoir, which is also under threat of drying, is relevant. In the complex of actions for maintaining the lake Lebyazhye, the study of the dynamics of zooplankton community state is an important and necessary element. It will allow choosing the most optimal strategy for the preservation and restoration of the water body.

Objective: to identify changes in the zooplankton of the lake Lebyazhye; to assess the ecological state of the reservoir by the indicators of zooplankton.

MATERIALS AND METHODS:

The zooplankton of the lake Lebyazhye was studied in 1991, 1994-1995, 2000, 2003 and 2015-2016. The sampling frequency was different: in 1991 - once in the middle of the vegetation period; in 1994 and in 2003 - in May, June, July, September or October, once a month; in 1995, 2000, and in 2015-2016 - from May to September or October every 10-14 days from one or two stations, in the coastal zone with a depth of 50 cm.

Samples of zooplankton were collected by straining of 50 liters of water through the Apshtein network (mesh size - 100 microns). Cameral processing included the determination of species composition, the counting of numbers, and the calculation of biomass. The calculation of the number and biomass of zooplankton was carried out in accordance with generally accepted hydrobiological methods [4]. In total, more than 160 quantitative samples of zooplankton were selected and processed during the period of investigation.

The degree of zooplankton diversity was estimated by the Shannon index (H) (by number and biomass) [5]. The Simpson index (C) [6] was calculated to estimate the structure of the community, also in terms of number and biomass. The index of saprobity (S) was calculated by the method of Pantle and Bukk in the modification of Sladechek [7]. Statistical processing of data was performed in MS Excel.

RESEARCH RESULTS:

According to the results of previous studies [8, 9], 116 species of zooplankton, including rotifera - 60 species (52%), cladocera - 34 species (29%) and copepoda - 22 species (19%) inhabit the lakes of Lebyazhye system.

Currently, there is only one lake - Maloe Lebyazhye. Earlier, there were 102 species of zooplankton in this lake. Not all species were constantly present, but with each ten-day observation (1995, 2000), up to 55 species were identified (Table 1). In 2015-2016, in the process of similar studies, only 43-44 species were identified. Thus, the composition of zooplankton species was reduced by at least 20%; the number of copepods decreased the most of all.

Table 1: The number of zooplankton species (n), defined in the lake M. Lebyazhye in the process of each ten-days or monthly studies.

Groups	1995		2000		2003		2015		2016	
	n	%	n	%	n	%	n	%	n	%
Rotifera	29	53,7	28	50,9	35	63,6	26	59,1	24	55,8
Cladocera	17	31,5	18	32,7	11	20,0	14	31,8	12	27,9
Copepoda	8	14,8	9	16,4	9	16,4	4	9,1	7	16,3
Total	54	100	55	100,0	55	100	44	100,0	43	100

In the course of changes in the lake ecosystem, new species appeared, previously not found in the lake. Rotifers *Hexarthra mira* (Hudson, 1871), H. *fennica* (Zwander, 1892), *Lecane (M.) closterocerca, Colurella colurus* (Ehrenberg, 1830), *Trichocerca (D.) bidens* (Lucks, 1912), *Polyarthra euryptera* (Wierzejski, 1891), *Synchaeta stylata* (Wierzejski, 1893) and cladocerans *Ilyocripytus agilis* (Kurz, 1874), *Diaphanosoma mongolianum* (Ueno, 1981) were found in the lake. In some of these species it was noted the ability to tolerate high concentrations of salts. They are found in brackish waters and even in the seas (*H. fennica, C. colurus, S. stylata*). Some species belong to the thermophilic complex; they can be found in southern latitudes or in middle latitudes, but in the warm season (*H. mira, P. euryptera*), in thermal sources (*L. (M.) closterocerca, C. colurus*), as well as in waterlogged waters (*H. mira, T. (D.) bidens*).

The composition of dominant species has changed. So, in 2015-2016, the following species dominated by the number: Asplanchna priodonta (Gosse, 1850), *Chydorus sphaericus* (O.F. Muller, 1785), *Keratella cochlearis* (Gosse, 1851), *Brachionus calyciflorus* (Pallas, 1776), *Brachionus diversicornis* (Daday, 1883), rotifers *Trichocerca*. The composition of the dominant complex in different periods was formed by 2-4 species of zooplankton. It should be noted, that the above species were periodically the dominant or subdominant (before the beginning of impact), but the rotifers *Keratella quadrata* (Muller, 1786), *Filinia longiseta* (Ehrenberg, 1834) and cladocerans *Diaphanosoma orghidani* (Negrea, 1982), *Bosmina (B.) longirostris* (O.F. Muller, 1785) were also often dominated.

The conducted studies showed a decrease in the quantitative indicators of zooplankton. In 1994-1995 the community of zooplankton of Maloe Lebyazhye lake was characterized by sufficiently high values of abundance and biomass (Figures 1-2). The smallest averages during the growing season were recorded in 2015-2016.

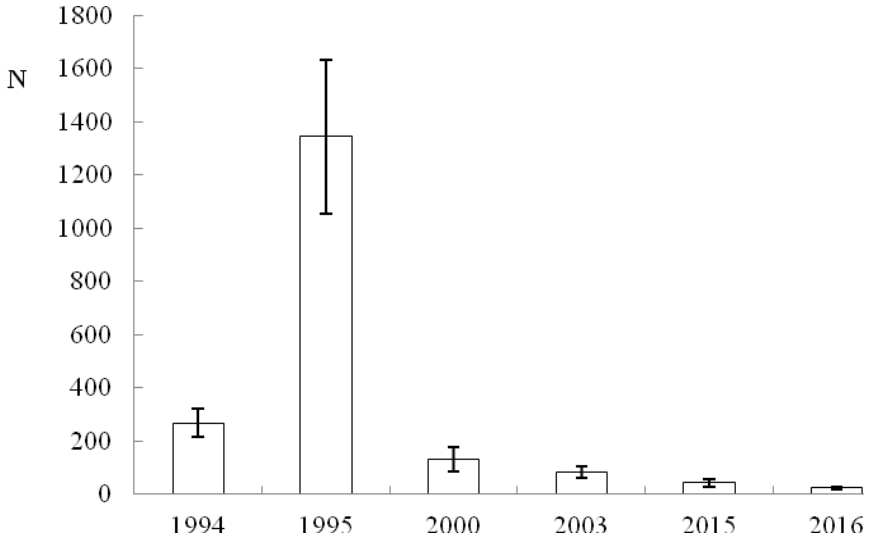

Fig 1: The abundance (N, thous. spec./m^3) of zooplankton of the lake Maloe Lebyazhye.

In 2015, the abundance was only 42,68 ± 13,14 thousand spec./m^3, and in 2016 it was 22,95 ± 5,61 thousand spec./m^3, and was the lowest for the entire period of studies. Rotifers were predominant among the groups of zooplankton.

Previously, according to the value of biomass and the classification of S.P. Kitaev (1984), the water body referred to the β- mesotrophic or α-eutrophic, that was usually characteristic for natural reservoirs of our region. Zooplankton biomass in 2015 was 0.11 ± 0.03 g/ m^3; in 2016 the values were still lower - 0.05 ± 0.01 g/m^3. By the value of biomass, the reservoir is α-oligotrophic. Herewith, the individual weight of organisms was an average of 0.003 ± 0.0004 mg in 2015 and 0.0027 ± 0.0005 mg in 2016. These values correspond to high trophic reservoirs [10]. Low values of individual weight are associated with the prevalence of rotifers and small crustaceans in the community, which have a small individual weight.

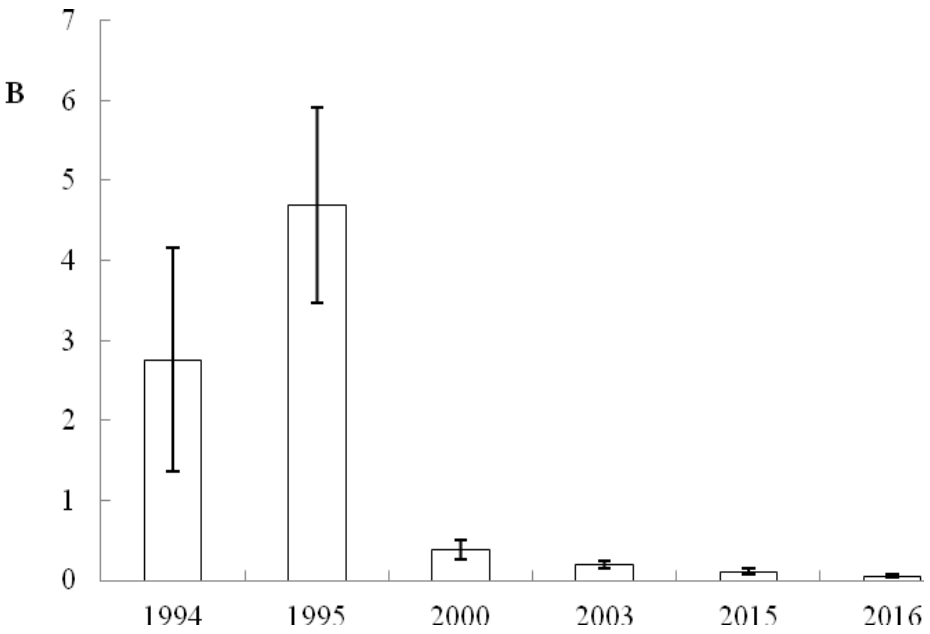

Fig 2: Biomass (B, g/m^3) of the zooplankton of the lake Maloe Lebyazhye.

The index of saprobity (S), characterizing the level of contamination with organic substances, corresponds to the β-mesosaprobic zone, moderately polluted waters, and the third class of water quality (Table 2).

Table 2: The values of the saprobity index (S), Shannon index (H) and Simpson index (C), calculated from the abundance and biomass of zooplankton.

Indices	1991	1994	1995	1996	2000	2003	2015	2016
	n=1	n=3	n=20	n=4	n=11	n=5	n=12	n=12
S	2,03	1,79±0,07	1,78±0,05	1,62±0,10	1,7±0,06	1,6±0,07	1,6±0,03	1,64±0,04
H_N	2,79	2,47±0,24	1,99±0,21	1,71±0,54	2,34±0,26	2,47±0,13	2,64±0,19	2,65±0,13
H_B	2,42	2,04±0,33	1,63±0,18	1,64±0,52	2,08±0,16	2,51±0,19	1,79±0,16	1,75±0,17
C_N	0,83	0,75±0,03	0,59±0,05	0,52±0,17	0,67±0,06	0,7±0,03	0,74±0,05	0,77±0,03
C_B	0,74	0,65±0,07	0,51±0,05	0,5±0,16	0,66±0,05	0,73±0,04	0,56±0,04	0,58±0,04

The Shannon index of the species diversity characterizes the alignment of the community structure. The values of the index are relatively high and in 2016 they were 2.65 ± 0.13. The values of the index indicate the relative alignment of the community, i.e. the species are represented by approximately the same number of individuals (although a small number), and they are the highest for the entire period of research. The absence of the dominance concentration is also indicated by the values of the Simpson index (0.74 ± 0.05 in 2015 and 0.77 ± 0.03 in 2016). By the value of the Shannon index, in accordance with the classification of I.N. Andronikova (1996), the reservoir was referred to the oligotrophic. The indices, calculated from the biomass of zooplankton, have also changed in a similar way, although they were much lower (Table 2). This is due to the difference in the individual weight of zooplankton organisms, the presence of larger organisms reduces the leveling by this indicator, and accordingly the values of the indices.

Communities of zooplankton are quite good indicators of changes, occurring in aquatic ecosystems. Many sources described changes in the structure of zooplankton communities in the process of eutrophication or under the influence of pollutants [11-13]. As eutrophication of lakes progresses, structural changes gradually take place. They are manifested not so much in the change of species diversity, but in the replacement of dominant species and in the growth of their numbers [12].

In the lake Lebyazhye there was a change in the hydrological regime of the reservoir, the water salinity has increased and the composition of the main ions has changed. There was a significant reduction in the area of the reservoir (by 13 times). Consider what changes in the zooplankton community have accompanied this process.

Due to the impact on the ecosystem of the lake Lebyazhye, there was a significant reduction in the species composition of zooplankton (by 20-60%). The change in species composition occurred as a result of significant decrease in the area of reservoir, in the number of biotopes, in the diversity of conditions for zooplankton habitat, and due to the changes in the mineralization of water in the reservoir. The composition of the main ions and the mineralization of water determine the possibility of the existence of many freshwater organisms. Groundwater, used for replenishment the lake, has increased mineralization (electrical conductivity is 1400 μS/cm), compared to surface waters. It also has a different composition of the main ions. The most important characteristics of the habitat have changed for the zooplankton. This led to reduction in the number of species, the change in the species composition. New species, which could withstand increased salinity and were able to live in brackish and even marine waters, have appeared. The good warm-up of this shallow lake contributed to the appearance of thermophilic species of plankton. The large areas, occupied by macrophytes (elodea, hornflower, and pondy), contribute to the accumulation of organic substances, the running of bogging processes and the appearance of zooplankton species, preferring to habit the macrophyte thickets and the waterlogged reservoirs.

DEDUCTIONS

During the observation period, there was a significant decrease in the quantitative indicators of zooplankton. Before the beginning of the impact, the quantitative indicators of zooplankton corresponded to mesotrophic-eutrophic water bodies, but now - to oligotrophic waters.

The value of the index of Shannon species diversity (H) usually decreases with contamination and eutrophication [11]. However, in the case, when all taxa in the community are equally affected by pollutants, the value of the index may not change even with a reduction in the total number of organisms [14-16]. In case of zooplankton of the lake Lebyazhye, the values of the Shannon index remained quite high, but most species were represented by single individuals or a small number of individuals.

CONCLUSION:

Modern studies of zooplankton of the lake Lebiazhye identified 58 species of zooplankton: rotifers - 33 species (57%), cladocerans - 17 (29%), copepods - 8 (14%). Compared with earlier studies, a decrease in the number of zooplankton species, the change in their composition, was revealed. The composition of the dominant species of zooplankton has changed and the number of dominant species has decreased. The abundance and biomass of zooplankton decreased from the values characteristic of the mesotrophic-eutrophic water body, to values corresponding to the oligotrophic one. The values of the index of Shannon species diversity did not decrease, due to a uniform reduction in the number of all species, forming the community. The index of saprobity characterizes the reservoir as β-mesosaprobic, moderately polluted.

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