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Influence of External Factors on Algae Biomass in Lake Khadicha (Bukhara, Uzbekistan)

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Abstract

Aquatic plant communities, which largely determine the ecological state of aquatic ecosystems and the quality of their waters, are the most important components in the biological monitoring system. Lake Khadicha is a unique natural body of water that is used for growing commercial fish. In recent years, due to heavy loads of abiotic and anthropogenic factors, the lake water has become highly saline. This phenomenon greatly affects the biodiversity of aquatic organisms, in addition to algae. During 2019-2021, the algae flora of Lake Khadicha was studied. 216 species of algae were identified as part of the algal flora. Their relationship with external factors such as water temperature, salinity and pH was studied. The seasonal abundance and biomass of algal flora areas of the lake were determined. Quantitative indicators of the dominant species in each season and their bioecological characteristics are identified.

Keywords

Abundance, Algae, Biomass, Environmental Factors, Lake Khadicha

1. Introduction

Seasonal dynamics of phytoplankton, defined as a consistent, natural replacement of some communities or groups of planktonic algae by others, is associated with a change in abiotic conditions in the annual cycle [1] [2] [3]. By studying the composition of phytoplankton in water bodies located in the same region and experiencing varying degrees of anthropogenic pressure, we can establish the main changes occurring in it during the process of eutrophication, taking into account the biological seasons of the year.

The species composition and structure of phytoplankton communities serve as one of the indicators of the state of aquatic ecosystems. Numerous studies indicate that algae quickly respond to disturbances in biological balance when environmental conditions deteriorate [4]. Signs of trouble and the response of phytoplankton communities to eutrophication are considered to be a sharp increase in productivity, an increased role of species characteristic of highly eutrophic and saprobic waters, a decrease in species diversity, as well as the development of "blooms", which is accompanied by the release of algal metabolites, deterioration of the oxygen regime, and water use problems.

Water resources in the lowland region of Central Asia are limited, and the biological diversity of organisms in it is unique. There are several natural lakes on the territory of the Republic of Uzbekistan in the Southwestern part of the Kyzylkum desert.

Most of these lakes are saline, and their area has expanded significantly in recent years. The salinity level of natural lakes is increasing from year to year due to the drying climate of the region, and a significant decrease in the supply of fresh and waste water coming from the population and agricultural land. Increased pollution of lake water with organic substances leads to a significant decrease in biological diversity [5] [6] [8]. In the southern part of the Bukhara region, there is Lake Khadicha, the area of which is 12.300 hectares. In subsequent years, an increase in the salinity of the lake water is observed. This, in turn, leads to a decrease in the species composition of the flora and fauna of the lake.

Research is being carried out on the algal flora of reservoirs in the Bukhara region and adjacent territories, and monitoring the ecological and sanitary condition of reservoirs [6] [7] [8]. The influence of external environmental factors on the biomass of algal algae in the algal flora of Lake Khadicha has been little studied; studies are mainly carried out on the bioresource potential of some dominant species [9].

2. Object and Methods of the Research

2.1. Morphometry

Lake Khadicha is located in the Karaulbazar district of the Bukhara region. The morphometric data of the lake are as follows:

Lake Khadicha was formed in 1980 as a result of flood waters coming from the Kashkadarya channel. The pastures and the Saxons remained underwater. The area of the lake is 12,300 hectares, length 18 - 20 km, the widest part is 8 km, the greatest depth is 10.8 meters, the average depth is 4.6 meters. The lake's water volume is 57.5 million/m^3, and the shore circumference is 18.3 km (**Figure 1**). The topography of the lake bottom has its own characteristics and is flat in shape. The lake bottom is divided into the following biotopes: phytophilic, pelophilic and psammophilic. The phytophilic biotope occupies 75% - 85% of the area.

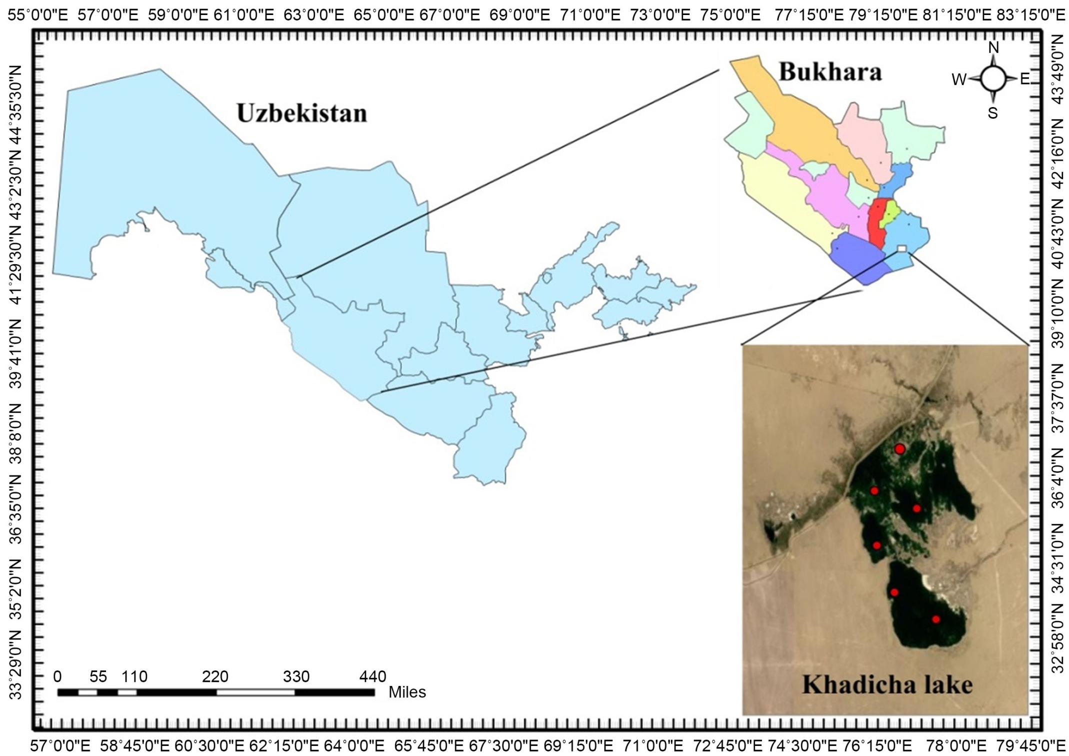

Figure 1. Map of the location of Lake Khadicha. (the red dot shows the sample location).

2.2. Hydrochemistry

In places where the height of the lake is 10 - 12 meters, transparency is 1.8 - 2.5 m, in shallow water and off the coast it is 1.0 - 1.5 m. The greatest clarity is observed in January-February in winter (2.8 m), the smallest - in summer and autumn (1.0 - 1.3 m). This is due to a decrease in water volume and shallowing. The color of the water changes depending on the season. The oxygen saturation level of Lake Khadicha water is 8.2 - 8.8 mg/l from 12:00 to 18:00 during the period from March to April. From October to November, the amount of oxygen dissolved in water decreases.

In August, dissolved oxygen is 2.0 - 2.5 mg/l. In the straight part of the lake, where the depth is 1.5 - 2.0 m, the distribution of oxygen dissolved in the water is the same. There is a lack of oxygen at the bottom of Lake Khadicha in winter and early spring. It even decreases from 1.0 - 1.5 mg/l. This feature is typical for eutrophic lakes.

It has been observed that the salinity of the water of Lake Khadicha varies from year to year depending on the amount of water poured into the lake and changes between the years of observation. This situation depends on the irrigation of crops during the growing season, and the amount of minerals also varies between seasons (**Figure 2**). Air and water temperatures also vary between years and seasons (**Figure 3**).

The magnitude of the reaction of the aquatic environment is generally closely related to the CO_2 concentration in the water. Using this relationship, you can determine the concentration of CO_2 in water depending on the pH value. Over the years of research, the ecological concentration of Lake Khadicha ranged from pH 6.2 to 8.2. In winter, its indicator increases significantly and approaches 8.2 - 8.5 (Figure 4). At the bottom of the water, the pH is 7.5 - 7.6, which indicates the presence of CO_2. This feature is typical for shallow water bodies. Lake Khadicha is rich in nutrients, as are the reservoirs of the southwestern part of the Kyzylkum (Dengizkol, Zamonbobo, Karakir) (Table 1).

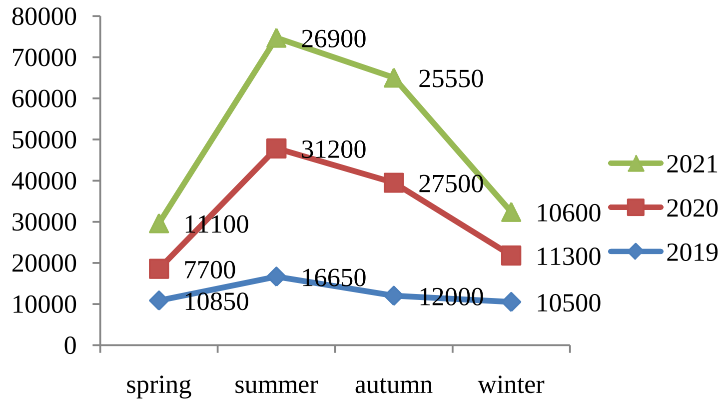

Figure 2. Seasonal mineralization of water in Lake Khadicha.

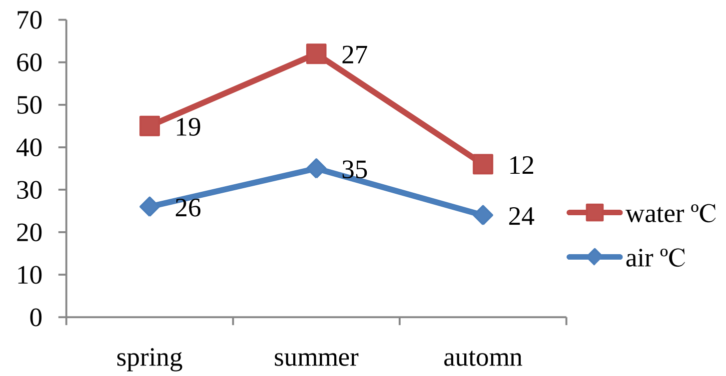

Figure 3. Water and air temperature of Lake Khadicha.

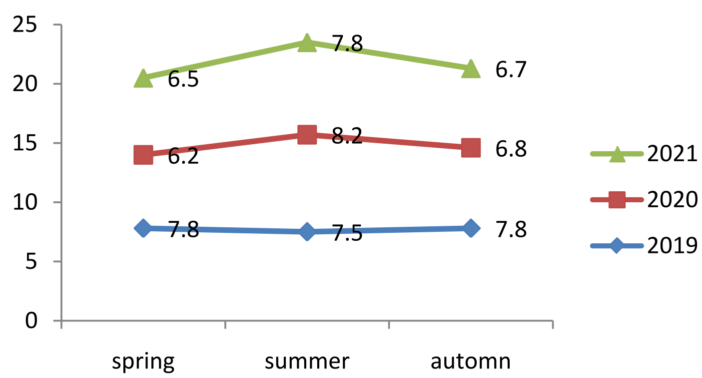

Figure 4. pH values of Lake Khadicha water.

Table 1. Chemical parameters of Lake Khadicha water in 2019-2021.

Indicators	Spring	Summer	Autumn	Winter
Suspended substances, mg/l	105	90	95	85
Dry residue, mg/l	10,850	16,650	12,000	10,500
Chlorides, mg/l	2103	9560	4484.7	2152.6
Sulfates, mg/l	5667.6	5236.3	6484.0	5136
Dissolved oxygen, mg/l	8.7	8.8	8.2	5.8
pH	7.8	7.5	7.8	8.5
Ammonium nitrogen, mg/l	2.6	2.6	2.6	2.0
Nitrates, mg/l	14.0	14.0	13.0	11.2
Nitrites, mg/l	0.04	0.04	0.04	0.04
Phosphates, mg/l	1.4	1.6	1.2	1.3
Iron, mg/l	0.1	0.1	0.1	0.1

The source of nutrients is created mainly from water generated on agricultural land. For example, 30% - 35% of fertilizers applied to plants are absorbed, and the rest of the fertilizers enter the lakes through ditches. The abundance of nutrients on the shores of Lake Khadicha ensures flowering and high productivity of aquatic plants.

2.3. Research Methods

Algological material was collected from April to October 2019-2021. Phytoplankton was collected using a BM-48 bathometer. A total of 62 phytoplankton samples were collected and processed. Samples were processed according to generally accepted methods [8].

The species composition of algae was determined using Carl Zeiss light microscopes. Identification of algae was carried out using classical and modern determinants [10] [11] [12] [13] [14]. The names of the authors of the taxa are given in an abbreviated version of their citation, unified in accordance with the recommendations of P.M. Tsarenko [15]. The ecological and floristic characteristics of algae are based on data contained in keys and large summaries [16] [17]. Modern names of taxa have been clarified using http://algaebase.org (Guiry, Guiry, 2015).

3. Results and Its Discussion

It has been established that the quantity and biomass of algae in the algal flora of Lake Khadicha change under the influence of seasonal environmental factors of the water. In the spring months, cyanoprocaryotes were the leaders in the algal flora of the lake in terms of numbers, but diatoms clearly predominated in terms of biomass, accounting for 48.23%. The total biomass of green algae, which had a significant proportion in terms of quantity and biomass, was 32.56%.

Although the number of cyanoprocaryotes increased significantly in the summer, the amount of biomass increased by 3.4 mg/l compared to the spring due to the small size of the cells. At this time, the total biomass of diatoms was 55.00. Although the number and biomass of green algae have increased slightly, they have maintained their place. A significantly greater increase was observed in dinophytes. In autumn, a decrease in abundance and biomass was observed in all sections except golden algae. The smallest decrease occurred in dinophytes and euglena (Table 2).

Statistical analysis of the research results showed that the total number of species of algal flora of Lake Khadicha is proportional to the increase in water temperature, and the correlation is quite high. (Figure 5). Similar results were observed in other regions adjacent to the Bukhara region [17] [18] [19] [20]. Temperature and water salinity have a weak correlation between external environmental factors and the total biomass of algae species in the algal flora of the lake. Khadicha. (Figures 6-8), A relatively higher correlation was observed in water pH values.

Table 2. Quantity and biomass of algae by season of Lake Khadicha 2019-2021.

Divisions	spring		summer		autumn		average	
	1	2	1	2	1	2	1	2
Cyanoprocaryota	71.3	4.8	94.2	7.4	88.3	6.7	84.61	6.26
Dinophyta	0.3	0.6	0.7	1.7	0.6	1.4	0.53	1.23
Chrysophyta	0.1	0.1	0.3	0.2	0.3	0.2	0.23	0.16
Bacillariophyta	16.4	31.4	27.3	52.2	25.8	48.1	23.16	43.9
Euglenophyta	1	7	1.1	6.8	1	6.3	1.06	6.7
Chlorophyta	14.4	21.2	18.4	26.6	16.8	21.7	16.53	23.16
Σ	103.5	65.1	142	94.9	132.8	84.4	126.12	81.41

Notes: 1- quantity, mg/l; 2- biomass, mg/l.

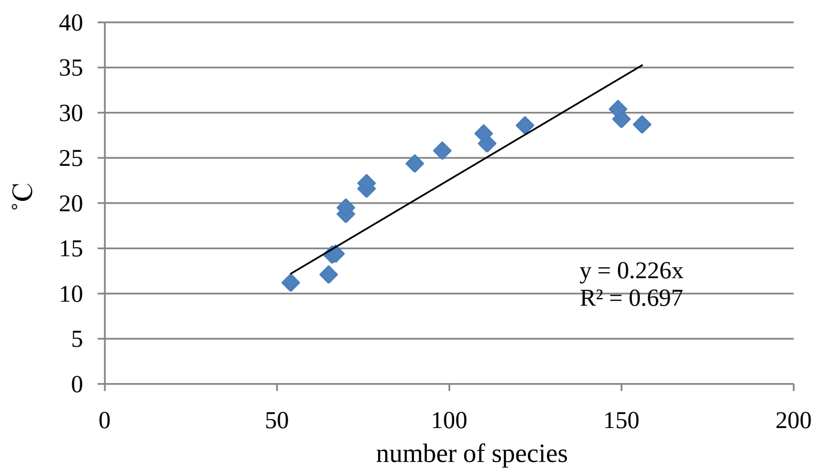

Figure 5. Correlation between water temperature and number of species.

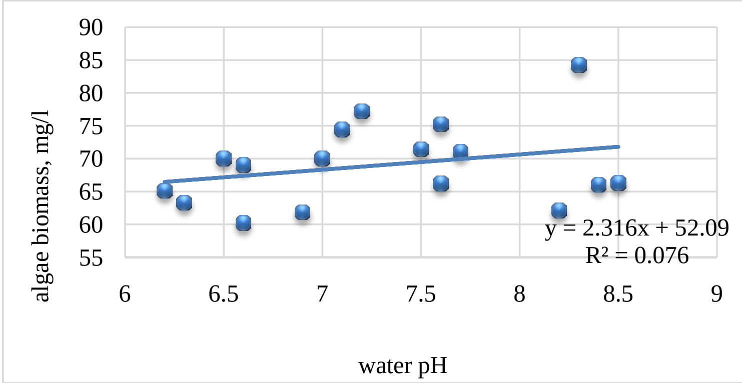

Figure 6. Correlation between algae biomass and water pH.

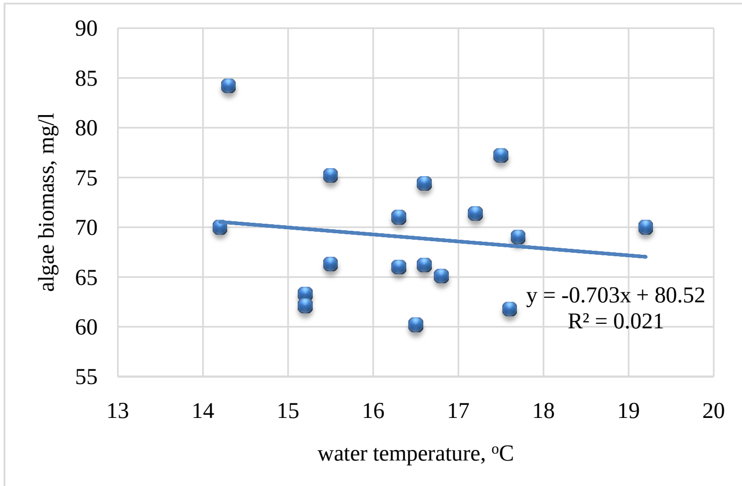

Figure 7. Correlation between algae biomass and water temperature.

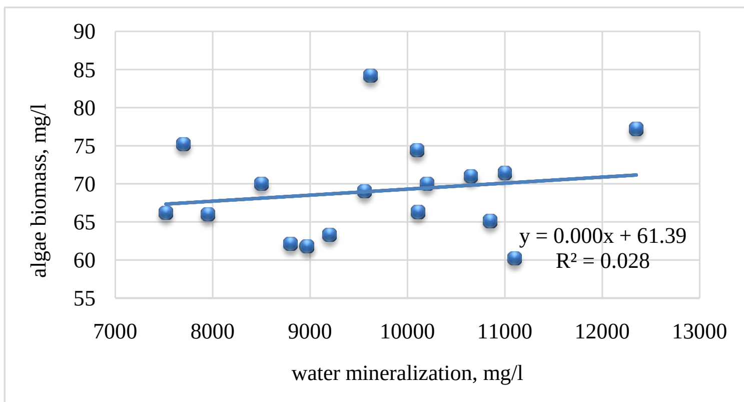

Figure 8. Correlation between algae biomass and water salinity.

In Lake Khadicha in May, the dominant species in terms of numbers were *Microcystis aeruginosa* Kutz. (Elenk.) и *M. elegans* A.Br. from the blue-green division. The first species was present in the phytoplankton throughout the biological season. Its maximum abundance (0.272 million cells/l) and biomass (0.014 mg/l) were recorded in May at the water surface. This species is found in plankton of various types of reservoirs of different geographical latitudes and is a β-mesosaprobe. from the blue-green division. The first species was present in the phytoplankton throughout the biological season. Its maximum abundance (0.272 million cells/l) and biomass (0.014 mg/l) were recorded in May at the water surface. This species is found in plankton of various types of reservoirs of different geographical latitudes and is a β-mesosaprobe. planktonic organism with a wide geographical distribution, oligo-β-mesosaprobe. It was present in phytoplankton from May to October, with an occurrence frequency of 87%.

Moreover, *Merismopedia elegans* A.Br.-planktonic organism with a wide geographical distribution, oligo-β-mesosaprobe. It was present in phytoplankton from May to October, with an occurrence frequency of 87%. Moreover, *M. aeruginosa* Kutz. (Elenk.) dominated in numbers in 13 cases out of 15 considered, regardless of the season of the year. The maximum abundance of the species at the water surface was observed in July (9.96 million cells/l). This alga has extremely small cells, the diameter of which is about 1 micron, due to this, even with high numbers, its biomass is very small, and it has never been included in the composition of the dominant algal species complex in terms of biomass.

In terms of biomass in May, *Trachelomonas lacustris* Drez. Drez. emend. Balech. from the division of euglena algae dominated at the water surface. This is a planktonic organism with a wide geographical distribution, living in reservoirs with varying degrees of water salinity, preferring alkaline waters, and is an o-α–mesosaprobe. It was found in phytoplankton only in May, in 2 samples, singly, but, due to the large size of the cells, at the surface of the water, it became dominant in biomass with a value of 0.03 mg/l. In July, the composition of the dominant species complex in addition to *M. aeruginosa* Kutz. (Elenk.) also included another representative of cyanoprokaryotes—*Coelosphaerium dubium* Grun.—littoral, north-alpine species, a typical inhabitant of fresh waters (halophobe), which is a β-mesosaprobe. The species was recorded in the reservoir only in July with a population of 1.88 million cells/l and a biomass of 0.0113 mg/l. In terms of biomass in summer, the rank of dominants included diatoms—*Cymbella lanceolata* (Ehr.) V.H. —living either at the bottom of reservoirs or in fouling, having a wide geographical distribution, being an oligohaline with respect to the salinity of water, an alkaliphile with respect to its acidity, o-α-mesosaprobe. The species was recorded as part of phytoplankton only twice—in July and in September, and both times it was among the dominant ones in terms of biomass, with an indicator of 0.27 mg/l and a minimum number of 0.004 million class/l.

The other dominant species was a representative of green algae *Ankistrodesmus acicularis* (A.Br.) Korschik. Just like the previous species, it has fairly large cell sizes, and almost always, when recorded, it was among the dominant in biomass (from 0.0564 to 0.451 mg/l) with even a small number (from 0.004 to 0.032 million cells /l). This alga is from the order Desmidiaceae, littoral, a widespread organism that prefers fresh waters (oligohaline), indifferent to the acidity of water, an o-β-mesosapbiont.

In September, the number of *M. aeruginosa* Kutz. (Elenk.), and by biomass *P.boryanum* (Turp.) Menegh. and *P. duplex* Meyen. from the order Chlorococcales, a division of green algae, common in the plankton of eutrophic reservoirs of various types. Both species were observed in half of the selected samples, but they entered the rank of dominants only in September. The course of seasonal dynamics in a lake with varying degrees of anthropogenic load differs in both the direction and composition of the dominant algae complexes.

In the part of the lake with a low degree of anthropogenic load, from spring to autumn in the pelagic part of the reservoir there is a decrease in the quantitative indicators of phytoplankton development (both numbers and biomass); in a lake with a significant load, the maximum numbers and biomass of phytoplankton were observed in the summer and were associated with the active growing season of blue-green algae.

In the part of the lake with low anthropogenic load, the dominant complex of algae species is based on golden algae, which are present in the planktonic community of the pelagic part of the reservoir almost the entire season and are part of the dominant species. Along with golden algae, diatoms, which prefer clean waters and are generally absent from the phytoplankton of Lake Khadicha, reached significant development in the summer. In the part of the lake with a significant degree of anthropogenic load, there is a fairly large diversity of Chrysophyta and diatom algae that are absent from the phytoplankton of Lake Khadicha, which casts doubt on the assumption that algae in this department prefer clean waters.

4. Conclusions

Throughout the entire growing season, Lake Khadicha was dominated in abundance by a representative of blue-green algae with small cells *M. aeruginosa* Kutz. (Elenk.) –a species that takes part in the process of formation of "blooming" of water in standing reservoirs. In terms of biomass, the dominant complexes often included "random" species, which were found singly and entered the rank of dominants often with minimal numbers, due to the significant size of the cells. The average seasonal index of phytoplankton biomass in the lake was about 1 mg/l, which belongs to the second quality class "pure", depending on the saprobity coefficient calculated for phytoplankton and amounting to an average of 1.67 in both reservoirs and in terms of abundance and biomass—the second class—"satisfactory cleanliness".

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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