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Systematic Composition of Indicator-Saprobic Algae Species in the Remaining Lakes (Koksu, Shegekul and Shuak Uzyak) of The Mezhdurechensk Reservoir During 2003–2024

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Abstract
The relevance of this study is обусловлена the need to preserve biodiversity and assess the ecological state of aquatic ecosystems, which is an essential condition for sustainable regional development. Algae, as primary producers and sensitive indicators of environmental changes, are widely used for water quality bioindication. The aim of the study is to investigate the algal flora of Lakes Koksu, Shegekul, and Shuak uzyak of the Mezhdurechensk Reservoir and its ecological characteristics. Collection and processing of algological samples were carried out using generally accepted methods, and species identification was performed with the help of freshwater algae identification guides. Water quality assessment was based on saprobiological analysis and the calculation of the saprobity index. The results revealed significant species diversity of algae, identified dominant and indicator species, and determined their sensitivity to environmental factors and seasonal dynamics. Based on the obtained data, an assessment of the ecological and sanitary condition of the water bodies was provided, and the effectiveness of algal indication for monitoring aquatic ecosystems was substantiated.

Keywords: Algal Flora, Algae, Aquatic Ecosystems, Bioindication, Saprobity

Introduction

The conservation of biodiversity in aquatic ecosystems is one of the most important tasks of modern ecology. Algae play a key role in the functioning of water bodies, ensuring primary production processes and participating in nutrient cycling. Due to their high sensitivity to environmental changes, they are widely used as bioindicators of the ecological status of water bodies.

Under conditions of increasing anthropogenic impact on natural water systems, the development of effective methods for assessing their condition becomes especially important. One such method is algal indication, based on the analysis of species composition and ecological characteristics of algae.

The Mezhdurechensk Reservoir and the adjacent lakes Koksu, Shegekul, and Shuak uzyak represent important hydroecosystems of the region, playing a significant role in maintaining biodiversity and providing water resources. However, the influence of natural and anthropogenic factors necessitates comprehensive studies of their ecological condition.

Objectives

The aim of this study is to investigate the algal flora of the specified water bodies and its ecological characteristics.

To achieve this aim, the following objectives were defined: to determine the species diversity of algae and conduct their taxonomic and comparative analysis with the identification of dominant, progressive, and regressive species; to assess the sensitivity of algae to key environmental factors, taking into account seasonal dynamics and their distribution across ecological groups (by temperature, salinity, and life forms); to identify saprobic indicator species, analyze their geographical distribution, and evaluate the ecological and sanitary condition of the water bodies based on relevant indices; to compile floristic, systematic, and saprobic indicator lists, as well as to develop a database including illustrations and ecological characteristics of species and to determine their potential practical applications.

The object of the study is the algal flora of Lakes Koksu, Shegekul, and Shuak uzyak of the Mezhdurechensk Reservoir and their ecological features.

Methodology

The object of the study was the algal flora of the Mezhdurechensk Reservoir and its lakes Koksu, Shegekul, and Shuak uzyak.

Sampling and processing of algological material were carried out using classical hydrobiological methods (Hollerbach & Polyansky, 1951; Sheshukov, 1949). Samples were collected in different seasons of the year, which made it possible to assess the seasonal dynamics of algal development.

Species identification was performed using the series “Identification Guide to Freshwater Algae of the USSR” (issues 1–14), as well as other specialized sources.

Water quality assessment was conducted using saprobiological analysis according to the Kolkwitz–Marsson scale, taking into account subsequent modifications, and by applying the Pantle–Buck saprobity index. In quantitative assessment, the relative frequency of occurrence of saprobic species and their distribution across saprobity levels were considered.

Additionally, atlases of indicator organisms and comparative scales were used. The obtained saprobiological and hydrochemical data were subjected to statistical processing and interpreted in accordance with standardized methods for water quality assessment.

Findings and Discussion

The area of the Mezhdurechensk Reservoir reaches 36.0 thousand hectares at full capacity (volume 380–450 million m^3). Depending on the water availability in a given year, the water surface area varies from 4.0 to 34.0 thousand hectares. The morphological characteristics of the reservoir were determined based on field measurements (Kurbanbaev et al., 2010, 2022).

In total, 140 indicator-saprobic algae species were identified in the three lakes of the Mezhdurechensk Reservoir. The highest species diversity was recorded in Lakes Shegekul (140 species, 88.61%) and Koksu (136 species, 86.08%). In Lake Shuak-Uzyak, 92 species were identified (58.23%). Representatives of the division Bacillariophyta (diatoms) dominate in all lakes of the reservoir, followed by Cyanophyta (blue-green algae) and Chlorophyta (green algae). Representatives of other divisions occur much less frequently (Table 1).

Table 1. Geographical distribution of indicator-saprobic algae in the lakes of the Mezhdurechensk Reservoir (2009–2024).

Algal divisions	Shegekul	Koksu	Shuak uzyak
Cyanophyta	29	28	15
Chrysophyta	2	1	1
Bacillariophyta	67	64	41
Xanthophyta	4	4	1
Cryptophyta	-	-	-
Dinophyta	3	3	2
Euglenophyta	8	8	11
Chlorophyta	27	28	21
Total species	140	136	92
Percentage of total, %	88,61	86,08	58,23

Across the entire water area of the Mezhdurechensk Reservoir, β-mesosaprobic algae constitute the largest group among saprobic indicator species - 80 species (50,63% of the total 158 species). Diatoms are the most widely represented (36 species), including Cyclotella kuetzingiana, Diatoma elongatum, Synedra pulchella, Cocconeis placentula, and Navicula cryptocephala. Among green algae (20 species) and cyanobacteria (14 species), such indicators as Scenedesmus acuminatus, Ankistrodesmus acicularis, Pediastrum boryanum, Merismopedia elegans, Microcystis aeruginosa, Oscillatoria agardhii, and O. princeps were recorded (Table 2).

Oligosaprobic algae include 46 species (29,2%). Diatoms also dominate here: Tabellaria fenestrata, Cyclotella comta, Fragilaria crotonensis, Navicula radiosa, and Pinnularia mesolepta. Among green algae, Ulotrix zonata, Microspora pachyderma, and Closterium rostratum were identified; among cyanobacteria - Gloeocapsa turgida, Oscillatoria deflexoides, and Phormidium papyraceum.

Alpha-mesosaprobic species are represented by 22 indicators (13,92%), including Synedra tabulata, Navicula cryptocephala, Closterium leibleinii, Cosmarium botrytis, Oscillatoria princeps, and O. tenuis.

Xenosaprobic algae occur least frequently and include 9 species (5.7%): Fragilaria virescens, Pinnularia gibba, Oscillatoria simplicissima, Tribonema elegans, and others. Polysaprobic algae are represented by only one species (0.64%) - Euglena viridis (Table 3).

Table 2: Number of saprobic indicator algae species by divisions in the Mezhdurechensk Reservoir (2003–2012; 2019–2024)

№	Algal divisions	Saprobity (x)					Total number of species and their percentage of the total (%)
		x	o	β	α	p	
1	Cyanophyta	1	7	14	6	-	28 : 17,72
2	Chrysophyta	-	1	1	-	-	2 : 1,27
3	Bacillariophyta	5	19	36	10	-	70 : 44,30

4	Xanthophyta	2	2	-	-	-	4 : 2,50
5	Cryptophyta	-	-	-	-	-	-
6	Dinophyta	-	3	-	-	-	3 : 1,90
7	Euglenophyta	-	5	9	1	1	16 : 10,16
8	Chlorophyta	1	9	20	5	-	35 : 22,15
Total		9	46	80	22	1	158 : 100
Percentage, %		5,7%	29,11%	50,63%	13,92%	0,64%	100%

Ecological and Sanitary Condition of the Lakes of the Mezhdurechensk Reservoir Based on the Saprobity Index of Indicator Algae.

Indicator characteristics of algal composition serve as an important tool for assessing the ecological and sanitary condition of the reservoir. Based on these principles, the entire set of algae identified in this study can be classified according to the saprobity scale (Kolkwitz & Marsson, 1908, 1909; Dolgov & Nikitinsky, 1927; Liebmann, 1962) into xenosaprobic, oligosaprobic, β-mesosaprobic, α-mesosaprobic, and polysaprobic forms.

According to the analysis of saprobiological index values for the period 2003–2024, the following indicators were obtained for the division Cyanophyta: in Lake Shegekul – 1.99; in Lake Koksu – 2.04; in Lake Shuak uzyak – 1.89. The overall saprobity index for Cyanophyta is 1.97 (Table 3).

For Chrysophyta, the saprobity index values are as follows: in Lake Shegekul – 1.6; in Lake Koksu – 2,0; in Lake Shuak uzyak, saprobic algae were not detected. The overall saprobity index for the Mezhdurechensk Reservoir is 1,22.

Table 3. Saprobity index values of algae in the lakes of the Mezhdurechensk Reservoir (2003–2024), calculated using the R. Pantle and H. Buck formula: Si = Σ(sh) / Σh

Algal divisions	Frequency of algae occurrence across water bodies					
	Shegekul		Koksu		Shuak uzyak	
	h	sh	h	sh	h	sh
Cyanophyta						
General meaning of h and sh in MT	135	269	127	259,5	67	126,5
Saprobity index of a species, Si in MT	1,99		2,04		1,89	
Overall saprobity index, Si	1,97					
Chrysophyta						
General meaning of h and sh in MT	6	10	3	6	1	0
Saprobity index of a species, Si in MT	1,6		2		0	
Overall saprobity index, Si	1,22					
Bacillariophyta						
General meaning of h and sh in MT	298	566,5	265	501	147	251,5
Saprobity index of a species, Si in MT	1,90		1,89		1,71	
Overall saprobity index, Si	1,84					
Xantophyta						
General meaning of h and sh in MT	10	12,5	10	12,5	3	4,5
Saprobity index of a species, Si in MT	1,25		1,25		1,5	
Overall saprobity index, Si	1,33					
Dinophyta						
General meaning of h and sh in MT	7	7	11	11	10	10
Saprobity index of a species, Si in MT	1		1		1	
Overall saprobity index, Si	1					
Euglenophyta						
General meaning of h and sh in MT	67	123	70	129	52	109
Saprobity index of a species, Si in MT	1,83		1,84		2,09	
Overall saprobity index, Si	1,92					
Chlorophyta						
General meaning of h and sh in MT	103	201,5	106	217	94	204

Saprobity index of a species, Si in MT	1,95	2,05	2,17
Overall saprobity index, Si	2,06		
Total Si (average values across lakes)	1,84	1,91	1,89
Average Si value	1,88		
Water quality class	Moderately clean	Moderately clean	Moderately clean
Category	3a Fairly clean	3a Fairly clean	3a Fairly clean
Ecological saprobic zone	β1	β1	β1

The average saprobity index across the lakes is 1.88, which corresponds to water of **satisfactory purity (quality class 3a)** and falls within the β_1-mesosaprobic zone.
Thus, the ecological condition of the studied lakes of the Mezhdurechensk Reservoir can be characterized as relatively stable, with moderate organic pollution. The dominance of β-mesosaprobic species indicates a balanced level of organic matter and confirms the effectiveness of using algal indicators for long-term environmental monitoring of aquatic ecosystems.

Saprobity Index Values by Algal Divisions.
The saprobiological index of water for the division Bacillariophyta was as follows: in Lake Shegekul – 1.90; in Lake Koksu – 1.89; in Lake Shuak uzyak – 1.71. The overall saprobity index for this division is 1.83.
For Xanthophyta, the saprobity index values were: in Lakes Shegekul and Koksu – 1.25; in Lake Shuak uzyak – 1.50. The overall index is 1.33.
For Dinophyta, the saprobity index (Si) is equal to 1 for all lakes, with an overall value of 1.
For Euglenophyta, the index values were: in Lake Shegekul – 1.83; in Lake Koksu – 1.84; in Lake Shuak uzyak – 2.09. The overall saprobity index is 1.92.
For Chlorophyta, the index values were: in Lake Shegekul – 1.96; in Lake Koksu – 2.05; in Lake Shuak uzyak – 2.17. The overall index is 2.06.
Based on the analysis of saprobiological indices for the three lakes (Shegekul, Koksu, and Shuak-Uzyak) over the period 2003–2024, it was determined that the average saprobity index (Si) across the lakes is 1.88. According to these values, the water quality corresponds to **Class 3 (moderately clean / satisfactory purity)**, subclass **3a (fairly clean)**, and the ecological saprobic zone corresponds to the **β_1-mesosaprobic level** (Table 3).

Conclusions

During the period 2003–2012, a total of 158 species of indicator saprobic algae were identified in the lakes of the Mezhdurechensk Reservoir. Among them, β-mesosaprobic species dominate – 80 species (50.63%), followed by oligosaprobic species – 46 (29.2%), α-mesosaprobic species – 22 (13.92%), xenosaprobic species – 9 (5.7%), and polysaprobic species – 1 (0.64%).

Over the period 2003–2024, the overall saprobity index for the three lakes (Shegekul, Koksu, and Shuak-Uzyak) was 1.88. According to this index, the water quality is classified as **satisfactorily clean**, subclass **fairly clean (3a)**, and the ecological saprobic zone corresponds to the **β_1-mesosaprobic level**.

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