BIO Web of Conferences **67**, 01018 (2023) https://doi.org/10.1051/bioconf/20236701018
VVRD 2023

Assessment of the bioresource potential of Kazan city's lake ecosystems by phytoplankton indicators

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Abstract. Nowadays protection and sustainable management of biological resources is of particular importance. The most important area of hydrobiological research is the assessment of the bioresource potential of aquatic ecosystems (Alimov et al., 2005). Phytoplankton is the basis of life and the most important component of the bioresource base in the aquatic ecosystem. Phytoplankton indicators (primarily abundance and biomass) are widely used to assess the bioresource potential of lakes due to its position as an autotrophic producer at the base of the ecological pyramid of the lake ecosystem (Bulion, 2005, 2019; Alimov, 1989, 2000; Alimov et al., 2005). Our study is aimed to research phytoplankton indicators to assess the bioresource potential of Kazan city's lake ecosystems (Volga region, Russia).

1 Introduction

Biological resources are one of the most important factors of socioeconomic development, so the issue of protection and sustainable management of biological resources is of particular importance nowadays (Bioresursy, 2008). The state and sustainable management of aquatic biological resources is directly related to the quality and condition of aquatic ecosystems. At the same time, every year the problems associated with the deterioration of the water bodies quality and the decrease of its ability as hydrobiological systems to self-cleanse are felt more and more acutely (Alimov, 2000, 2010). Justification of the principles and methods of conservation and sustainable management of aquatic bioresources is possible only on the basis of a study of the current state and functioning of aquatic ecosystems and their hydrobionts.

The most important area of hydrobiological research is the assessment of the bioresource potential of aquatic ecosystems (Alimov et al., 2005). Phytoplankton is the basis of life and the most important component of the bioresource base in the aquatic ecosystem. In our case, we are meaning lake ecosystems. Phytoplankton is an integral part of the lake ecosystem, it serves as a source of primary production, due to which all higher aquatic organisms exist

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along the trophic chain. Conducting research on the state of the lake phytoplankton is an important condition in determining the fish food supply, which has a direct practical value.

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2 Research methodology

This research took place at the Department of Environmental Engineering and Water Usage, at the Laboratory for Optimization of Aquatic Ecosystems of the Kazan Federal University. The reserach presents data of phytoplankton system of 175 Kazan city's lake ecosystems. A qualitative and quantitative assessment was made by Assoc. Prof. of the Department of Environmental Management and Water Usage of KFU, Ph.D. Palagushkina O.V. We used the following phytolankton indicators: abundance and biomass. In the calculations, we used the equations for the dependence of fish production on hydrobiological indicators (Kitaev, 2007).

In the research, phytoplankton's qualitative composition was analyzed, statistical analysis of the quantitative composition was done (in the Microsoft Excel), phytoplankton was assessed as food supply for fish and the possible fish production was calculated according to phytoplankton's quantitative characteristics (biomass).

3 Research results

During the time of research in the studied lake ecosystems, representatives of 8 divisions of the lake phytoplankton were found, including 190 taxon with a rank below the genus. Particularly abundant in number of species were Chlorophyta – 39% (74 taxons, the most diverse orders Chlorococcalles (58) и Desmidiales (16)), Bacillariophyta – 32% (60); Euglenophyta - 10% (20); Cyanophyta – 9% (18), Dinophyta – 4 % (7), Chrysophyta – 4 % (7), Xanthophyta – 1% (2) and Cryptophyta – 1% (2) (Fig.1).

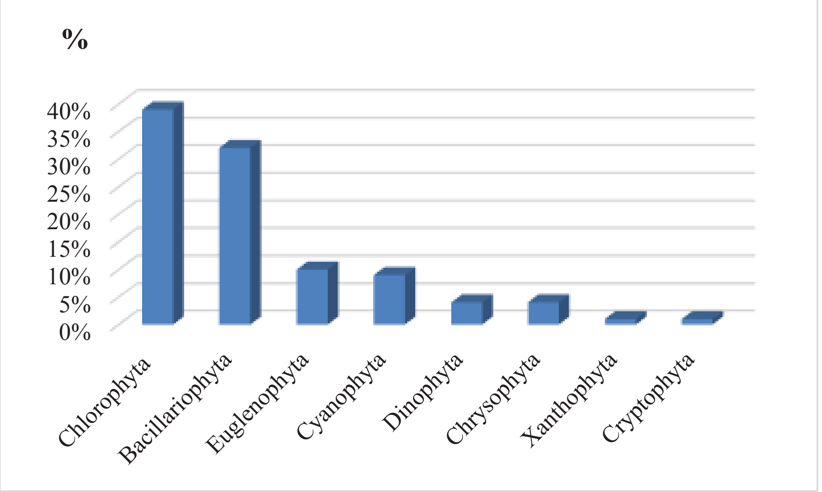

Fig. 1. Distribution of taxon within phytoplankton's qualitative composition of Kazan city's lake ecosystems.

The highest occurrence (Table 1) was found in the microscopic diatom Nitzschia palea (Kiitz). W. Sm. class Pennatophyceae (found in 121 lakes out of 175 studied (69%); then in green chlorococcus Chlamydomonas sp. (in 102 lakes (58%), euglenoic Euglena viridis Ehr.(in 97 lakes (55%)) and Trachelomonas volvocina Ehr. (in 70 lakes (40%)).

The planktonic algocenosis of Kazan city's lake ecosystems is characterized by species that were found once or twice (these species are presented in Table 1).

Table 1. Taxonomic composition of phytoplankton in lake ecosystems in Kazan and their frequency of occurrence.

Division, order	species	Occurrence
Chlorophyta, Chlorococcalles	*Chlamydomonas* sp.	58%
	Actinastrum hantzschii Lagerh.	seldom
	Chodatella longiseta Lemm.	seldom
	Coenochloris korschikoff Hindak.	seldom
	Coelastrum cambricum Arch.	seldom
	Didymocystis planctonica Korschik.	seldom
	Golenkiniopsis solitaria Korsch.	seldom
	Gonium pectorale O.Mul.	seldom
	Lagerheimia ciliata (Lagerh.) Chodat.	seldom
	Pediastrum clathratum Meyen.	seldom
	Pediastrum tetras (Ehr.) Ralfs	seldom
	Platymonas cordiformis (Cart.) Korsch.	seldom
	Pteromonas aculeata Lemm.	seldom
	Pyrobotrys elongata Korsch.	seldom
	Scenedesmus denticulaus Lagerh. var. *disciformis* Hort.	seldom
	Scenedesmus Falcatus Chodat.,	seldom
	Tetraedron arthrodesmiforme Chod.	seldom
Chlorophyta, Desmidiales	*Cosmarium botrytis* Menegh.	seldom
	Cosmarium granatum Breb.	seldom
	Cosmarium margaritiferum Menegh.	seldom
	Cosmarium subprotumidum Nordst.	seldom
	Closterium acerosum (Schr.) Ehr.	seldom
	Staurastrum brachiatum Ralfs.	seldom
	Staurastrum neglectum G.S.West.	seldom
	Xanthidium bifidum (Breb.) Pal.-Mordv.	seldom
	Виды рода *Penium*.	seldom
Bacillariophyta	*Nitzschia palea* (Kiitz).	69%
	Aulacoseira granulata (Ehr.) Simonsen	seldom
	Cymbella cistula (Hemp.) Grun.	seldom
	Cymatopleura elliptica (Breb.) W.Sm.	seldom
	Diatoma hiemale (Lyngb.) Heib.	seldom
	Species *Amphora*	seldom
	Species *Epithemia*	seldom
	Species *Neidium*	seldom
	Species *Stauroneis*	seldom
Euglenophyta	*Euglena viridis* Ehr.	55%
	Trachelomonas volvocina Ehr.	40%
	Strombomonas fluviatilis (Lemm.) Defl.	seldom
Cyanophyta	*Gloeocapsa minor* (Kuitz.)	seldom
	Gomphosphaeria lacustris Chod.	seldom
	Merismopedia tenuissima Lemm.	seldom
	Merismopedia minima G.Beck.	seldom
	Merismopedia glauca (Ehr.) Nag.	seldom
	Microcystis aeruginosa f. flos-aquae (Wittr.) Elenk.	seldom

Continuation of Table 1.

Division, order	species	Occurrence
	Phormidium sp.	seldom
Dinophyta	*Peridinium bipes* Stein	seldom
	Peridinium inconspicuum Lemm.	seldom
Xanthophyta	*Ophiocytium capitatum* Wolle.	seldom
	Vaucheria sp.	seldom

Among 190 phytoplankton species found in Kazan city's lake ecosystems, 117 species are indicators of saprobity. Most of the studied species are β-mesosaprobe, which corresponds to "moderately polluted" water (43 species, 37% of the total number of saprobity indicators); oligo-β-mesosaprobes and β-meso-oligosaprobes – 12 species and 13 species, respectively (22% in total); indicators of oligosaprobic conditions ("pure" water) are represented by 8 species (7%); indicators of high pollution ("polluted" and "dirty" water), α-mesosaprobic and polysaprobic organisms – 34 species (30%), xenosaprobic ("very clean" water) – 7 species (6%).

The number of phytoplankton cells ranged from 0,07 to 378 630 thousand cells per liter, the average value is 22 961 thousand cells per liter. Phytoplankton biomass varied from 0.09 mg per liter to 181 mg per liter, the average value is 24 mg per liter.

Table 2. Taxonomic composition of phytoplankton in lake ecosystems in Kazan and their frequency of occurrence.

№	Name of parameter	Value of parameter
1	Arithmetic mean	22 961
2	Range	378629,93
3	Minimum	0,07
4	Maximum	378 630
5	Dispersion	3 494 997 599
6	Standard deviation	59 119

Table 3. Statistical parameters of the sample for the indicator "Phytoplankton biomass".

№	Name of parameter	Value of parameter
1	Arithmetic mean	24
2	Range	180,91
3	Minimum	0,09
4	Maximum	181
5	Dispersion	2 163
6	Standard deviation	47

In the course of further analysis of quantitative data on the abundance and biomass of phytoplankton, a number of key statistical parameters were calculated: arithmetic mean, dispersion, standard deviation, range. The results of calculation are shown in Tables 2 and 3.

In the course of statistical processing of experimental data, it was found that the numerical values of the parameters have a significant range in specific abundance (more than 6 orders of magnitude) and specific biomass (more than 4 orders of magnitude), large values of dispersion and standard deviation, as a result of which they predetermine the complexity of further direct use and research. At the same time, a correlation was found between the values of the ratio of biomass to the abundance of phytoplankton.

For further statistical analysis, an additional indicator was introduced - the ratio of biomass to abundance (specific biomass of a single phytoplankton). This new indicator makes it possible to carry out a statistical comparison of lakes by the degree of growth in the specific size of phytoplankton. The indicator is integral in nature and reflects the average estimated size of phytoplankton cells. To simplify further calculations, a normalized value was used, followed by data segmentation into 5 percent pockets.

The introduction of such a transformation makes it possible to reduce the total number of intervals for further analysis to 20 (Fig. 2).

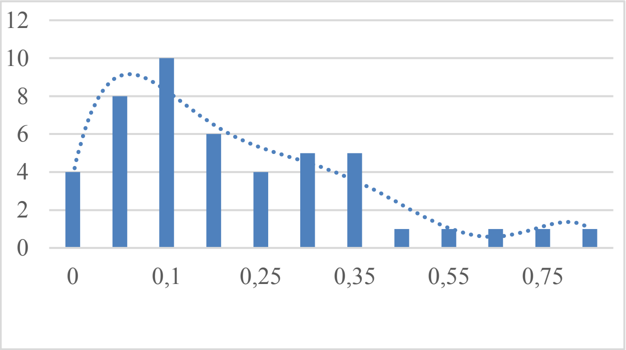

Fig. 2. Histogram of the frequency distribution function of the normalized value of the mass of a single phytoplankton.

The graphic representation of the obtained results was interpreted as a frequency function of the distribution of the normalized value of the mass of a single phytoplankton in the lakes of the study sample. To find the analytical form of recording the obtained frequency dependences, we used the tools for approximating the experimental data with a canonical polynomial of the sixth degree. As a result of processing, the frequency function of the integral indicator of phytoplankton productivity for Kazan city's lake ecosystems was obtained. This indicator can be used as a comprehensive indicator of the bioresource potential of the lake ecosystem in selected locations.

The histogram has an extremum in the area of the second 5% pocket of the normalized value of the mass of a single cell. The concentration of the sample in the pocket containing the extremum and neighboring ones is 51% of the objects. The key statistical parameters of the sample contained in the extremum pocket and neighboring ones are shown in Table 4.

Table 4. Statistical parameters of the sample contained in the extremum pocket and neighboring.

№	Name of parameter	Value of the sample pocket of the mass of a single phytoplankton		
		0,05	**0,1 (extremum)**	**0,15**
1	Specific weight in the general sample, %	17	21	13
2	Arithmetic mean	0,339	0,592	0,902
3	Range	0,25	0,26	0,19
4	Minimum, mcg	0,19	0,47	0,81
5	Maximum, mcg	0,44	0,73	1,01
6	Dispersion	0,00825	0,01273	0,00560
7	Standard deviation	0,09087	0,11283	0,07483
8	Dispersion of 51% of the sample	0,02658		

An indirect indicator of the assessment of the production potential of water bodies is phytoplankton biomass (Bioresursy, 2008). The biomass of phytoplankton can indirectly assess the feeding capacity of a reservoir and its fishery value (Koval, 1984; Kitaev, 2007).

To assess the possible fish production by the biomass of phytoplankton in the lakes of Kazan, a regression equation was used (Koval, Kazansky, 1984):

P = 4,546 B_{Ph}0,691, where P – fish production, kg/ha per year; B_{Ph} – biomass of phytoplankton, g/m3.Calculations of fish production based on phytoplankton biomass for Kazan city's lake ecosystems showed that the average value of all studied lakes is 30 kg/ha. The most highly productive was lake Peschannoe (165.7 kg/ha), the least productive lake number 6 in the Park Pobeda (0.86 kg/ha).

4 The discussion of the results

As a result of statistical processing an integral parameter was obtained - specific biomass of a single phytoplankton, which makes it possible to assess the bioresource potential of the lake ecosystem. According to the processing results, 51% of the sample is in 3 five-percent pockets, the frequency response has a pronounced extremum, the dispersion and standard deviation values allow us to consider the data obtained as one of the complex indicators of the bioresource potential of the lake ecosystem during dynamic monitoring.

All studied lakes can be divided into 5 groups according to phytolankton biomass: I - up to 0,5 mg/l, II - from 0,5 to 5 mg/l, III - from 5 to 10 mg/l IV - from 10 to 50 mg /l and V - more than 50 mg/l. Most of the lakes (36%) belong to group II, to I, III, IV groups belongs17% each, respectively, the smallest number (13%) to group V (Table 5).

Table 5. Groups of Kazan city's lake ecosystems according to phytoplankton biomass.

Groups of lake	Number of lakes	% lakes	Biomass (mg/l)
I	8	17%	up to 0,5
II	16	36%	0,5 - 5
III	8	17%	5 - 10
IV	8	17%	10 - 50
V	6	13%	more than 50

5 Conclusions

Thus, the qualitative composition of the phytoplankton in the lakes of Kazan reflects the significant anthropogenic impact on ecosystems, the vast majority are indicators of "polluted" and "dirty" water. According to quantitative characteristics, the average value of phytoplankton abundance is 22 961 thousand cells/l, the average value of phytoplankton biomass is 24 mg/l. All lake ecosystems were divided into 5 groups according to phytolankton biomass, most of the lakes (36%) belong to group II (from 0.5 to 5 mg/l). Calculations of possible fish production based on phytoplankton biomass showed that the average fish production for the studied lakes was 30 kg/ha, the most highly productive lake - 165.7 kg/ha, the least productive - 0.86 kg/ha.

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