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Features of the Structural Organization of Phytoplankton of Coastal Shallow Water of Volga and Volga-Kama Reaches Of the Kuibyshev Reservoir.

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ABSTRACT

Kuibyshev reservoir (Russia) is the sixth step of Volga cascade and ranks first in area in Europe and second in the world among all the reservoirs created in the river valleys. A characteristic feature of Kuibyshev reservoir is the presence of extended shallow water areas, which total area with the depth of up to 2 m is up to 15% of the total area of the reservoir, while a considerable part of shallow water overgrows with macrophytes. The most extended areas of overgrown shallow waters are located in Volga and Volga-Kama reaches of the reservoir. Biological communities of shallow waters function in the increased fluctuation of the environment modes and are characterized by specific structural and functional organization, which main feature is the adaptation mechanisms of biocoenosis components and maintenance of its stability in dynamic environment. To determine the formation features of structure of phytoplankton in different biotopes of shallow waters of Kuibyshev reservoir, we studied the latter in *Typha angustifolia L., Phragmites australis (Cav.) Trin. Ex Steud.* thickets and in open water areas (thickets-free). We were conducting studies in 2002-2005 in two shallow bays of Volga and Volga-Kama reaches differing in the severity of human impact, protection from wind and wave action and other conditions. As a result of studies we have revealed that the most aligned phytoplankton communities with a high species diversity are common to areas with macrophyte beds where anthropogenic impact is minimized. Environmental conditions in shallow open water are less stable than in macrophyte thickets, which is due to the dynamics of water masses in the water. We also revealed a tendency to the quantitative increase in heterotrophic algae in polluted thicket communities compared to areas with superior water quality. Maximum qualitative and quantitative characteristics of phytoplankton are common to protected shallow waters of the contaminated and poorly flowing bays also characterized by significant differences in species composition between the shallow open water and macrophyte thickets, while there is a slight difference in the overall quantitative indicators between the thickets and the shallow open waters. Impact of macrophytes on plankton algae vegetation in water hypertrophicity is slightly expressed, and the nutrients abounding in this area do not serve as a limiting factor for algae.

Keywords: phytoplankton, algae, Kuibyshev reservoir, macrophytes.

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INTRODUCTION

Kuibyshev reservoir is the sixth step of Volga cascade, that was filled in 1955-1957 after damming out the river Volga with hydraulic engineering constructions near the Zhiguli Mountains [1]. The reservoir ranks first in area in Europe and second in the world among all the reservoirs created in the river valleys. It is located within two natural zones: the forest zone (the subzone of coniferous-deciduous forest) and the forest-steppe zone.

A characteristic feature of Kuibyshev reservoir is the presence of extended shallow water areas, which total area with the depth of up to 2 m under flood-control storage level is up to 15% of the total area of the reservoir; the area of shallow waters with up to 1m depth is 53.2 thous. ha, and 1-2m depth is 50.3 thous. ha [2], [3]. Area of overgrown shallow waters is 8.5 thous. ha. The most extended areas of overgrown shallow waters are located in Volga and Volga-Kama reaches of the reservoir. Biological communities of shallow waters function in the increased fluctuation of the environment modes and are characterized by specific structural and functional organization, which main feature is the adaptation mechanisms of biocoenosis components and maintenance of its stability in dynamic environment [4], [5].

To determine the formation features of structure of phytoplankton in different biotopes of shallow waters of Kuibyshev reservoir (Russia), we studied the latter in the thickets of narrow-leaved cattail - *Typha angustifolia L.,* common reed grass - *Phragmites australis (Cav.) Trin. Ex Steud.* and in open water areas (thickets-free). We were conducting studies in 2002–2005 in two shallow bays of Volga (site 1) and Volga-Kama (site 2) reaches differing in the severity of human impact, protection from wind and wave action and other conditions.

MATERIAL AND RESEARCH METHODS

We were conducting studies in 2002–2005 in two shallow bays of Volga (site 1) and Volga-Kama (site 2) reaches differing in the severity of human impact, protection from wind and wave action and other conditions (Fig. 1).

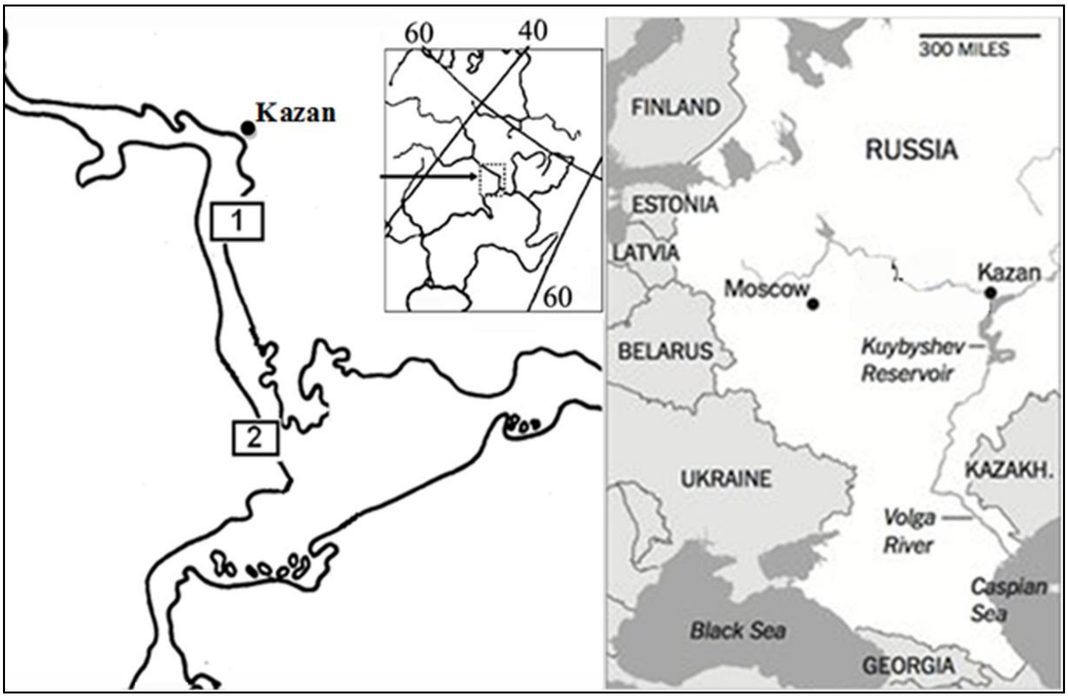


Figure 1: Layout of study areas of coastal shallows in Volga and Volga-Kama reaches of Kuibyshev reservoir: 1 – site 1 (Pobedilovo village, Kazan) 1 – site 2 (Saralinskii, Volga-Kama State natural biosphere reserve).

Site 1, located in Pobedilovo village (southern part of Kazan), is characterized by decelerated flow and protected banks, and affected by wastewater of Kazan sewage treatment facilities and the suburban areas. Site 2 is located near Tatarskie Saraly village (Laishevskii district) and refers to the Saralinskii district of Volga-Kama State Nature Biosphere Reserve (“VKGPBZ”), characterized by both a significant influence of transit flows of water masses common to water area of this reservoir and seasonal fluctuations in water level. This site has slightly rugged coastline and intense dynamics of water masses and is located in the zone of active wind activity.

We studied the phytoplankton in the thickets of narrow-leaved cattail - *Typha angustifolia L.,* common reed grass - *Phragmites australis (Cav.) Trin. Ex Steud.* and in open water areas. Water was sampled from 3 plants with different water levels starting from the top of macrophyte thickets and going further to the deepest water level at the bottom of the thickets. We investigated each site starting from the time of flooding the shallow water with overwater vegetation (June) until the time of draining the shallow water (mid-October) once every 2 weeks.

Total phytoplankton samples processed are 460 quantitative and 500 qualitative samples. When sampling, the temperature and transparency were measured with Secchi disk. In the study period we recorded weather conditions and hydrological characteristics of the reservoir. Selection and office processing of phytoplankton samples were carried out according to standard methods [9], [10].

To characterize the structural indicators of phytoplankton communities we studied dynamics of overall and relative species abundance [11]. Species with abundance or biomass greater or equal to 10% of total rate were dominant in the communities, and 5-10% were subdominant. Dominating complexes are allocated based on the function of rank distribution in terms of species abundance and biomass [12]. We calculated coefficients of species similarity by Czekanowski-Sorensen’s and Jaccard’s formula when analyzing the floristic composition of phytoplankton and comparing the investigated sites, as well as in different years [11]. We calculated trophic index according to the Milius block for each sample: $Ib = 44.87+23.22*\log B$ [13], the Pantle–Buck saprobity index modified by Sladecek [14]. To assess the diversity and uniformity of communities we used Shannon-Weaver index, calculated by the biomass and abundance of species [15].

To assess the complexity of the structure of phytoplankton community we used the coenotic value index (CVI) and the estimated coefficients obtained on the basis thereof [9], [16], [17] and [18]. Statistical data processing was performed using parametric (Student's t-test, arithmetical mean and its standard error) and nonparametric criteria (Wilcoxon test, Spearman rank correlation) [19]. To assess the significance of differences in taxonomic diversity and quantitative value of phytoplankton communities between the factors such as two sites (1 and 2) and biotopes (macrophytes and shallow open water), we used the method of multiple repeated comparisons (ANOVA; Tukey's HSD test). Before ANOVA processing we converted data into the normal distribution by using function $\mathrm{Log10}\,(x + 1)$.

RESULTS AND DISCUSSION

Water chemistry of the sites.

According to both the water chemistry laboratory of the Institute of Ecology of Natural Systems, Academy of Science of the Republic of Tatarstan, and our own data, we have found that the site 1 belongs to the a-mesosaprobic zone, class 3-4 water quality, and is considered as “polluted”; the section 2 belongs to the β-mesosaprobic zone, class 3 water quality and characterized as "satisfactory pure" [6], [7], [8]. The areas of shallow waters investigated differ significantly in their chemical composition. The integral assessment of water quality on sites 1 and 2 based on the average rank indicator is shown in Table 1.

Distribution and structure of phytoplankton in different biotopes of shallow waters of Volga and Volga-Kama reaches.

During the observation period in the investigated sites of phytoplankton we found 336 taxa, including 323 species of algae, belonging to 8 types. The greatest number of taxa of the rank order was revealed in Cyanophyta and Bacillariophyta. The most prevalent algae in the species diversity are Bacillariophyta (26.2%) and Chlorococcales (36.8%). Other groups are less diverse: Cyanophyta – 12.1%, Euglenophyta -7.8%, Chrysophyta – 6.9%, Xanthophyta – 4.4%, Dinophyta – 3.7% and Cryptophyta – 2.2% (Table 2-3).

Table 1: Average water chemical parameters of the areas of shallow waters of Kuibyshev reservoir studied in 2002-2003. [7]

Criteria	Site 1			Site 2		
	M±m	Min.	Max.	*M±m*	Min.	Max.
O_2, mg/l	10.7+0.9	2.2	19.6	7.6+0.8	0.4	16.3
Eh, mV	148.5±10.2	57.0	223.0	130.4±21.4	201.0	313.0
pH	7.3±0.1	6.0	8.7	7.2±0.1	6.4	9.1
Σmin., mg/l*	468.2±15.9	307.6	854.0	248.6±6.2	171.0	414.9
Ca^{2+}, mg/l	84.7±3.9	40.0	178.0	44.1±1.4	20.8	96.0
Mg^{2+}, mg/l	20.1±1.7	1.8	40.9	9.3±0.7	1.2	29.2
HCO_3^-, mg/l	170.6±3.8	122.0	263.6	136.8±3.5	110.0	276.1
SO_4^{2-}, mg/l	165.4±8.3	21.0	377.0	54.3±2.6	15.8	99.9
Cl^-, mg/l	39.9±1.2	24.8	59.6	22.7±0.9	15.6	46.8
DO, mgO/l*	33.9±2.6	14.3	92.8	24.0±2.3	3.1	78.0
PO, mgO/l*	12.2±0.9	1.7	28.8	11.5±0.5	6.7	20.4
BOD_5, mgO/l	5.9±0.6	0.9	11.5	4.8±0.8	0.5	18.6
P_{tot} mg/l	0.28±0.03	0.07	0.59	0.29±0.04	0.05	0.74
PO_4^{3-}, mg/l	0.09±0.01	0.003	0.46	0.10±0.02	0.001	0.80
NO_3^-, mg/l	1.88±0.22	0.10	7.86	1.15±0.11	0.11	3.60
NO_2^-, mg/l	0.09±0.02	0.003	0.69	0.07±0.02	0.001	1.25
NH_4^+, mg/l	0.67±0.10	0.02	5.34	0.49±0.04	0.02	1.48
Cd, µg/l	1.15±0.27	0.01	7.50	1.0±0.2	0.1	4.6
Pb, µg/l	11.6±2.1	0.1	48.0	9.3±1.6	0.2	31.5
Cu, µg/l	6.4±0.7	0.5	29.5	5.8±0.5	0.5	16.1
Co, µg/l	7.9±0.6	0.7	14.3	6.3±0.5	0.9	14.2
Ni, µg/l	12.5±0.9	1.0	19.7	10.8±0.8	0.5	19.9
Zn, µg/l	17.8±1.7	1.1	42.6	17.9±2.5	0.9	67.1
Cr, µg/l	4.9±0.7	1.5	9.5	3.4±0.5	1.7	8.1
Mn, µg/l	89.4±29.3	3.5	1198.0	114.6±35.7	6.0	1176.0
Fe, µg/l	239.0±47.4	1.0	1344.0	209.5±42.7	22.5	1555.0

Σmin – general mineralization, DO – dichromate, and PO - permanganate oxidation, respectively.

Table 2: Content of phytoplankton taxa in different biotopes of two sites of shallow waters of Volga and Volga-Kama reaches (2002-2005).

Group	Site 1			Site 2	
	cattail thickets	reed thickets	thicket-free	cattail thickets	thicket-free
Cyanophyta	14	19	32	14	18
Euglenophyta	17	12	8	8	7
Dinophyta	6	7	4	7	5
Bacillariophyta	51	50	30	51	40
Xanthophyta	4	6	2	1	2
Cryptophyta	4	4	2	3	3
Chrysophyta	6	9	7	9	7
Chlorophyta	62	57	44	42	41
Total:	164	164	129	135	123

Table 3: The average number of species (specie/sample) in individual systematic phytoplankton groups in different biotopes of two sites of shallow waters of Volga and Volga-Kama reaches (2002-2003).

Group	Site 1			Site 2	
	cattail	reed	thicket-free	cattail	thicket-free
Cyanophyta	5.2±0.7	5.2±0.5	4.8±0.7	3.4±0.5	3.9±0.4
Euglenophyta	3.8±0.6	3.5±0.5	3.3±0.9	3.1±0.4	1.9±0.4
Dinophyta	1.4±0.2	1.4±0.2	1.8±0.4	1.4±0.2	1.3±0.2
Bacillariophyta	17.3±1.7	16.6±1.7	10.6±1.1	19.6±1.3	7.1±1.4
Xanthophyta	1.5±0.3	1.0±0.0	1.0±0.0	0.0±0.0	1.0±0.0
Cryptophyta	1.3±0.3	1.5±0.5	1.8±0.2	2.0±0.0	2.0±0.0
Chrysophyta	1.2±0.2	1.3±0.2	1.8±0.4	2.3±0.8	2.3±0.9
Chlorophyta	18.6±2.4	21.6±2.2	17.6±2.9	11.1±1.6	8.1±1.4
Total:	50.3±4.1	52.1±3.8	42.7±4.4	42.9±2.2	27.6±2.2

The greatest species diversity is common to the genera of cyanophyta Oscillatoria, Merismopedia, Anabaena, cryptophyta Cryptomonas, bacillariophyta Navicula, Stephanodiscus, Pinnularia, Aulacosira, Nitzschia, Diatoma, dinophyta Peridinium, euglenophyta Trachelomonas, Euglena, Phacus and chlorophyta Chlamydomonas, Tetraedron, Scenedesmus. Algae in the investigated shallow waters are represented by several environmental groups that differ in species composition, growth conditions, growth dynamics, etc. and include phytoplankton, epipelon, epiphytic algae and free-floating filaments or accumulations of filamentous algae (Table 4).

Table 4: The dominant species of phytoplankton in the shallow waters (sites 1 and 2) of Volga and Volga-Kama reaches of Kuibyshev reservoir in 2002-2005.

<table>
<tr><th colspan="2">Site No 1</th></tr>
<tr><th>Macrophyte thickets</th><th>Shallow open water</th></tr>
<tr><td><i>Aphanizomenon flos-aquae, Microcystis aeruginosa, Anabaena flos-aquae, An. Scheremetievi, Oscillatoria planctonica, Stephanodiscus hantzschii, Melosira varians, Cyclotella comta, Fragilaria construens, Aulacoseira islandica, Nitzschia palea, Trachelomonas hispida, T. volvocina, Euglena viridis, Chlamydomonas sp., Pandorina morum, Carteria globosa, Coelastrum proboscideum, Crucigenia rectangularis, C. tetrapedia, Scenedesmus guadricauda, Phacotus lenticularis, Cryptomonas ovata.</i></td><td><i>Aphanizomenon flos-aquae, Anabaena scheremetievi, Stephanodiscus hantzschii, Cyclotella comta, Nitzschia palea, Trachelomonas intermedia, T. hispida, T. volvocina, Cryptomonas ovata, Chlamydomonas sp., Carteria globosa, Phacotus lenticularis, Scenedesmus guadricauda, Sc. acuminatus, Crucigenia rectangularis, Coelastrum proboscideum, Dictyosphaerium pulchellum.</i></td></tr>
<tr><th colspan="2">Site No 2</th></tr>
<tr><th>Macrophyte thickets</th><th>Shallow open water</th></tr>
<tr><td><i>Aphanizomenon flos-aquae, Anabaena flos-aquae, Microcystis aeruginosa, Melosira varians, Tabellaria fenestrata, Nitzschia palea, Aulacoseira italica, A. granulata, Synedra ulna, Stephanodiscus hantzschii, Cyclotella comta, Amphora ovalis, Trachelomonas volvocina, T. hispida, Euglena viridis, Pandorina morum, Scenedesmus guadricauda</i>.</td><td><i>Aphanizomenon flos-aquae, Anabaena scheremetievi, An. flos-aquae, Microcystis aeruginosa, Nitzschia palea, Aulacoseira islandica, A. italica, A. granulata, Melosira varians, Stephanodiscus hantzschii, Gomphonema olivaceum, Cyclotella comta, Tabellaria fenestrata, Diatoma vulgare, Cocconeis placentula, Amphora ovalis, Chlamydomonas</i> sp., <i>Navicula cryptocephala, Fragilaria construens, Scenedesmus guadricauda.</i></td></tr>
</table>

The objective of these studies included mainly the investigation of the phytoplankton in the water column, which was mainly represented by metaphyton. In the initial period of formation of the littoral community the dominating species were algae with a wide environmental range, capable to live within the plankton and benthos. These are mainly the species of filamentous centric and pennate diatoms, and Chlorococcales. The greatest species diversity was common to *Aulacosira, Cyclotella, Nitzschia, Navicula,* and *Scenedesmus*. However, at the beginning of the growing season the macrophytes are joined by epipelon and epiphytic algae (large species having heteropolar structure of cells or colonies, often able to mobility). These are the species of bacillariophyta *Caloneis amphisbaena, Nitzschia sigmoidea, N. vermicularis, Gyrosigma acuminatum, Cymatopleura elliptica, C. solea, Cymbella* sp., *Cocconeus placentula, Phoicosphenia abbreviata,* cyanophyta *Oscillatoria,* fragments of green filamentous and desmid algae.

The greatest species diversity of phytoplankton is observed near the village Pobedilovo (site 1). This site has Chlorophyta and Bacillariophyta constituting 37% and 31% of the total number of species in the macrophyte thickets. Euglenophyta constitute 9% of the total number of species, and Cyanophyta - 11%. The share of Cyanophyta rises up to 25% in the shallow open waters. Chlorophyta constitute 34% of the total number of species, Bacillariophyta - 23%, and Euglenophyta - 6%. The coefficient of species similarities between the shallow open water and macrophyte thickets is low in this area and constitutes 42.3-45.7%.

Site 2 (Saralinskii) is less favorable for the growth of many periphyton species. Bacillariophyta (32-38% of the total number of species) and Chlorophyta (31-33%) prevail in the number of species in both thickets and shallow open water. Euglenophyta constitute 6% in all investigated stations of this site. The coefficient of species similarities between the shallow open water and thickets on this site is 59.7%.

Most phytoplankton species of the investigated biotopes are widespread inhabitants of water bodies of middle latitudes. Comparing similarities of phytoplankton communities with each other by Czekanowski-Sorensen's formula [11] allows us to suggest that phytoplankton of macrophyte thickets of the first and second sites are similar in species composition (57.3-60.9%). Open shallow waters of both sites also have similar species composition (54.8%).

Maximum quantitative characteristics of phytoplankton are common to shallow waters of the contaminated and poorly flowing site 1 (*p* <0.04) (Fig. 2).

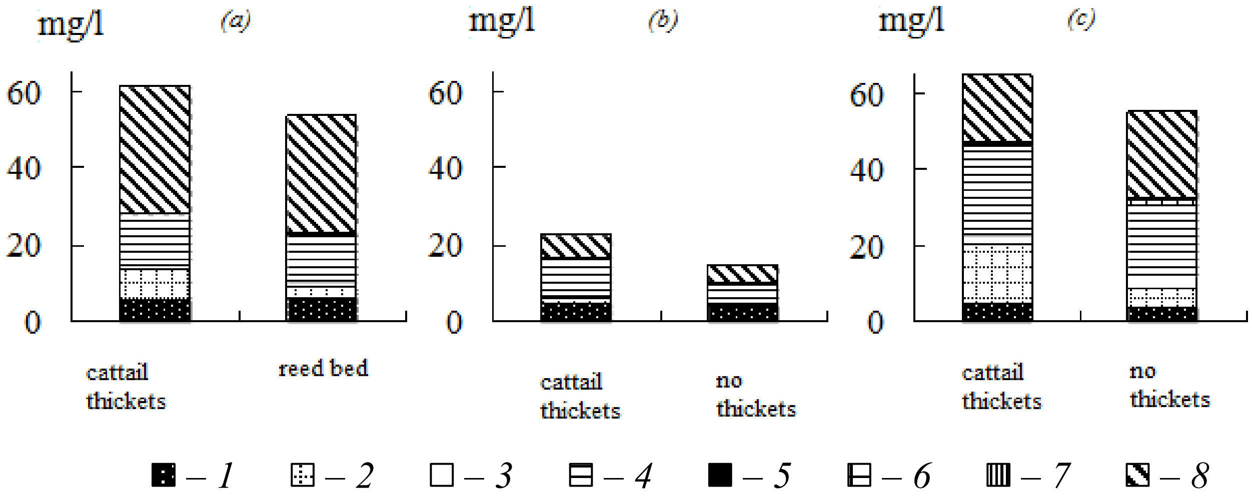


Figure 2: Average biomass (mg/l) (mg/l) of phytoplankton of shallow waters of Volga and Volga-Kama reaches: *a* – site 1, 2002; *b* – site 2, 2002; *c* - site 1, 2004; *1* – Cyanophyta, *2* – Euglenophyta, *3* – Dinophyta, *4* – Bacillariophyta, *5* – Xanthophyta, *6* – Cryptophyta, *7* – Chrysophyta, *8* – Chlorophyta.

The average abundance and biomass of phytoplankton in the site 1 during studied growth seasons constituted 104.5±18.0 thous. cells/l and 58.53±10.1 mg/l (Table 5). They exceed the values of the site 2 1.8 times in abundance and 3.2 times in biomass. The values of the total abundance and biomass of algae in the thickets of reeds and cattails, as well as areas free of overwater vegetation have insignificant difference on this site.

The average abundance and biomass of phytoplankton in the site 2 (Saralinskii) constituted 56.35±9.2 thous. cells/l and 18.45±5.7 mg/l. The total biomass of phytoplankton in the cattail thickets was 1.5 times higher than in open areas.

Table 5: Average abundance (mil. cells/l) and average biomass (mg/l) in individual systematic phytoplankton groups in different biotopes of two sites of shallow waters of Volga and Volga-Kama reaches (2002-2004).

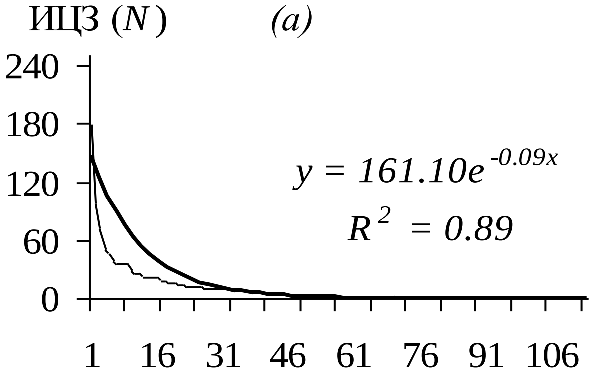
Group	Site 1 (2002)		Site 1 (2004)		Site 2 (2002)	
	cattail	reed	cattail	thicket-free	cattail	thicket-free
average abundance (mil. cells/l)						
Cyanophyta	66.2±16.2	74.6±17.9	79.2±30.2	71.7±27.2	48.8±33.0	47.2±17.0
Euglenophyta	1.0±0.3	0.7±0.2	2.2±1.8	1.0±0.6	0.4±0.1	0.1±0.0
Dinophyta	0.8±0.1	0.1±0.1	0.2±0.1	0.2±0.1	0.1±0.0	0.0±0.0
Bacillariophyta	7.7±2.0	7.5±1.8	12.4±3.4	7.8±1.4	6.7±1.1	4.4±0.9
Xanthophyta	0.1±0.0	0.0±0.0	0.1±0.0	0.0±0.0	0.1±0.0	0.0±0.0
Cryptophyta	0.0±0.0	0.0±0.0	0.5±0.2	0.9±0.3	0.1±0.0	0.2±0.1
Chrysophyta	0.1±0.1	0.1±0.1	0.4±0.2	1.2±0.5	0.1±0.1	0.1±0.1
Chlorophyta	19.3±5.7	20.5±6.8	15.0±3.6	21.6±9.9	2.4±0.7	2.2±0.6
Total:	95.2±20.2	103.5±19.00	110.0±33.04	104.4±32.07	58.7±32.1	54.2±16.06
average biomass (mg/l)						
Cyanophyta	5.8±1.7	6.0±1.6	4.7±2.0	3.9±1.4	4.7±3.5	4.2±1.6
Euglenophyta	7.7±2.9	2.8±0.8	15.7±13.2	5.2±4.1	1.6±0.5	0.3±0.1
Dinophyta	1.3±0.5	1.7±0.8	2.5±1.5	2.9±1.2	0.4±0.2	0.2±0.1
Bacillariophyta	13.1±4.5	12.5±3.3	23.2±5.5	18.6±3.8	9.6±1.9	5.2±1.1
Xanthophyta	0.1±0.0	0.0±0.0	0.1±0.0	0.0±0.0	0.1±0.0	0.0±0.0
Cryptophyta	0.1±0.0	0.0±0.0	1.1±0.5	1.5±0.3	0.1±0.0	0.2±0.1
Chrysophyta	0.1±0.0	0.1±0.1	0.2±0.1	0.5±0.4	0.1±0.1	0.1±0.0
Chlorophyta	33.1±15.0	30.3±15.4	17.0±7.6	22.5±9.5	5.8±3.9	4.5±3.7
Total:	61.3±14.9	53.4±14.6	64.5±19.8	55.1±14.5	22.4±4.5	14.7±3.5

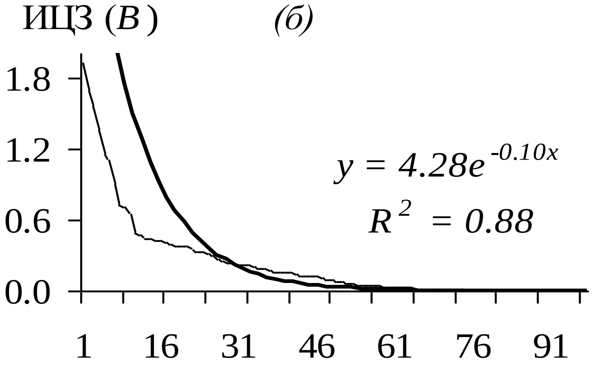
Comparing the biotopes has revealed a little difference in the content of macrophyte phytoplankton with different composition and in shallow open water of Kuibyshev reservoir. According to our observations, the composition and abundance of algae in macrophyte thickets in Kuibyshev reservoir varies depending on the landscape environment, flowage and dynamics of water masses, the degree of overgrowing, and mainly the content of biogenic compounds in water of this site. Lack of intensive dynamic processes, as well as anthropogenic pollution of the site 1 (Pobedilovo) results in excessive organic compounds in water. There are no significant differences between quantitative characteristics of phytoplankton in thickets and shallow open waters on this site. Site 2 (Saralinskii) is less favorable for the growth of many periphyton species in terms of its hydrological characteristics and location. Macrophyte thickets in this site are a biotope more favorable for many phytoplankton organisms, especially that many large-cell periphytic algae float in the water column due to the intensive mixing of water masses in this site.

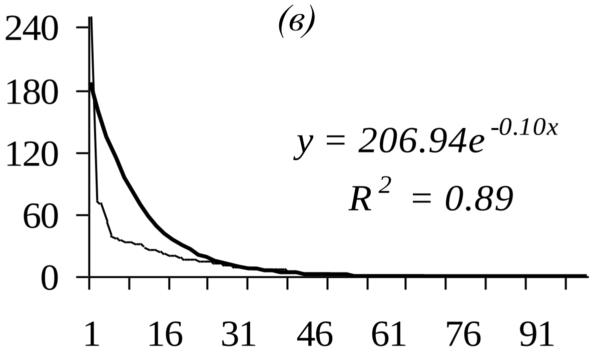
Distribution of coenotic value of phytoplankton species in different biotopes of shallow waters of Volga and Volga-Kama reaches.

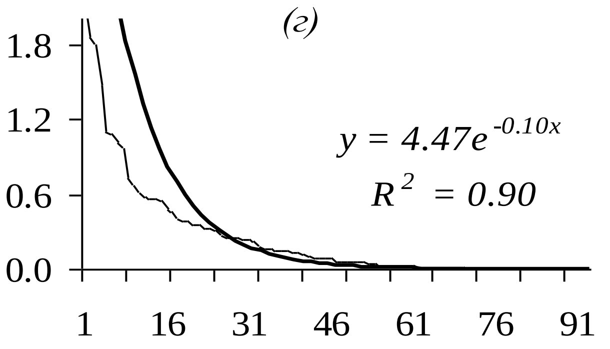
Since the main differences of phytoplankton communities of the considered biotopes were observed in the dominance structure of certain species and in the ratio of quantitative indicators of different types of algae, we assessed the complexity of the structure of phytoplankton communities by using coenotic value indices of species (CVI) and the estimated coefficients obtained on the basis thereof [16], [17].We determined the frequency of occurrence and average abundance and biomass for all species for the entire research period, and calculated further the CVI. After ranking the species descending the CVI value for each investigated biotope we obtained the dominance curves, allowing us to estimate the role of each species in phytoplankton coenosis (Fig. 3). These curves reflect the degree of dominance and uniformity of community species in terms of "significance" in coenosis, i.e. complexity of the structure and diversity of the community. They are described by exponential equations $y = ae^{-bx}$, where the constant "*a*" determines the slope of the curve (coefficient of determination R^2 = 0.87-1.00). The sharper the dominance, the steeper the slope of the curve, and hence the greater the value of the constant "*a*". It can be considered an objective criterion of dominance intensity in coenosis and complexity of the community structure [17], [18].

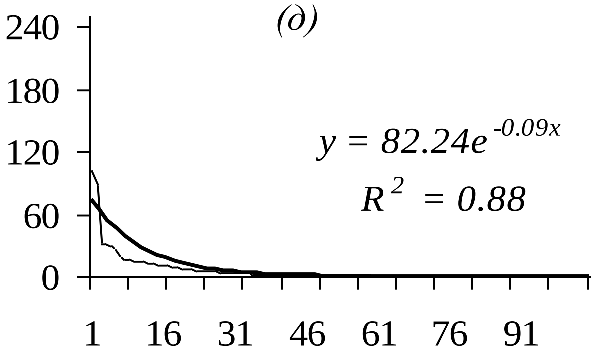
Coastal areas of reservoirs, especially one overgrown with overwater vegetation, are characterized by high biodiversity and intensive production and destruction processes. At the same time, they are the most vulnerable to human impacts, as being a zone of contact between two – land and water - natural systems. The created dominance curves allowed us to analyze the structure of algocenoses of the investigated shallow coastal waters with different degrees of anthropogenic pollution, and to compare these areas with each other (Table 6).








(г)
1.8
1.2
0.6
0.0
1
16
31
46
61
76
91
y = 4.47e^-0.10x
R^2 = 0.90


(д)
240
180
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60
0
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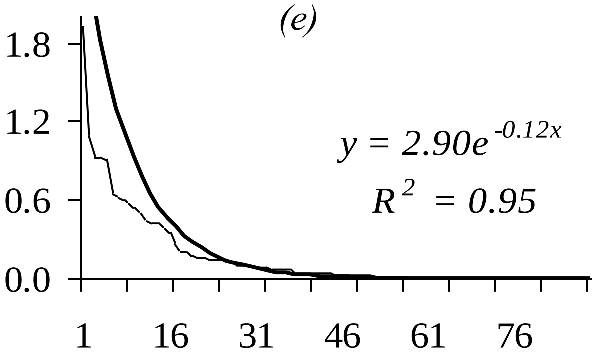
31
46
61
76
91
y = 82.24e^-0.09x
R^2 = 0.88


(е)
1.8
1.2
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0.0
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16
31
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76
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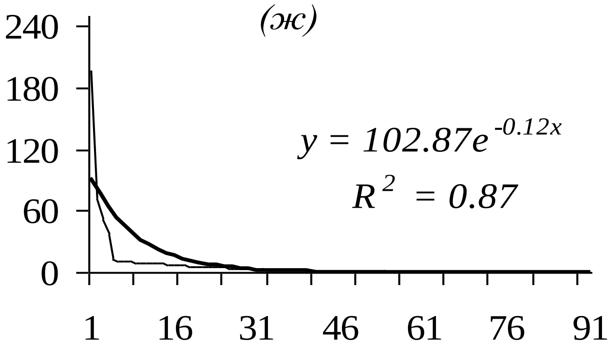
R^2 = 0.95


(ж)
240
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61
76
91
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R^2 = 0.87

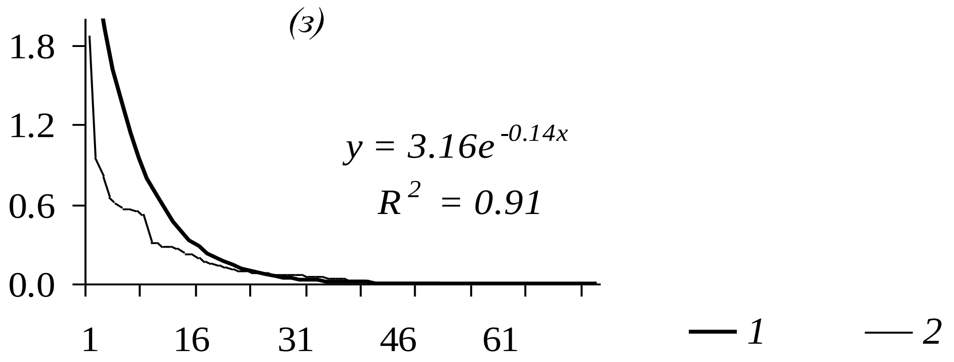

Figure 3: Dominance curves of phytoplankton communities (1): (CVI (*N*) – in abundance , CVI (*B*) – in biomass) and the exponential distribution of coenotic value of species (2) of two shallow water sites of Volga and Volga-Kama reaches (*a, b*– site 1, cattail thickets, *c, d* – site 1, reed thickets, *e, f* – site 2, cattail thickets, *g, h* – site 2, shallow open water), year 2002; numbers on the abscissa specify the species

Table 6: Structuredness indices of phytoplankton in the studied sites and biotopes of shallow waters of Volga and Volga-Kama reaches

Site, biotope		SC	*a*	CVI_{max}	∑ CVI	Diversity index	
						H (N)	*H (B)*
1 (2002)	cattail thickets	0.2	427.7	192.1	2289.2	2.5	3.4
	reed thickets	0.2	447.0	218.6	2378.8	2.2	3.2
1 (2004)	cattail thickets	0.2	441.6	359.7	2693.7	2.9	3.1
	thicket-free	0.2	554.3	363.6	2254.3	3.0	3.0
2 (2002)	cattail thickets	0.3	290.3	192.3	1463.8	2.9	2.8
	thicket-free	0.3	315.6	187.3	1130.8	2.2	2.7

Note: SC - structuredness coefficient; *a* - an indicator of dominance, the coefficient in the exponential dependence formula $y = ae^{-x}$, to which the CVI distribution by biomass of phytoplankton species is subject; CVI_{Max} - the maximum value of the coenotic value index (dominant species); Σ CVI - the sum of the indices of cenotic value of all species of phytoplankton in biotopes; *H (N), H (B)* - Shannon-Weaver diversity indices, calculated on the abundance and biomass of species.

Rank distribution of coenotic value of algocoenosis species calculated on the abundance differs significantly in sites 1 and 2. The maximum CVI values for the thickets in site 1 were 1.5-2 times higher than the same in site 2; the values of the dominance index and the total CVI were also high. The CVI distribution curves of the site 2 showed a more uniform distribution of species in phytoplankton community, as compared to the site 1, which indicates a significant increase in the degree of dominance in algocoenosis in the site 1 compared to the site 2.

When comparing the shallow open water and overgrown areas, the maximum CVI values in abundance were 1.5-2 times higher in open biotopes than in thickets, at the same time the values of dominance index were significantly higher in shallow open water.

CONCLUSION

Thus, the analysis of the species structure of phytoplankton communities of macrophyte thickets growing in areas of shallow water of Kuibyshev Reservoir that differ in the degree of anthropogenic pollution, as well as areas without overwater vegetation, shows that a more uniform phytoplankton community growths in the site 2, where anthropogenic impact has been kept to a minimum. The most aligned phytoplankton communities with a high species diversity are common to areas with macrophyte thickets. Environmental conditions in shallow open water of Kuibyshev reservoir are less stable than in macrophyte thickets, which is due to the dynamics of water masses in the water. The most aligned phytoplankton communities with a high species diversity are common to areas with macrophyte thickets.

The revealed differences also indicate that the contaminated phytoplankton communities of the site 1 also has a tendency to the quantitative increase in heterotrophic organisms and total values of abundance and biomass as compared to areas with superior water quality.

Maximum qualitative and quantitative characteristics of phytoplankton are common to protected shallow waters of the contaminated and poorly flowing bays also characterized by significant differences in species composition between the shallow open water and macrophyte thickets, while there is a slight difference in the overall quantitative indicators between the thickets and the shallow open waters. Impact of macrophytes on plankton algae vegetation in water hypertrophicity is slightly expressed, and the nutrients abounding in this area do not serve as a limiting factor for algae.

SUMMARY

The most aligned phytoplankton communities with a high species diversity in shallow waters of Kuibyshev reservoir are common to areas with macrophyte thickets. Maximum qualitative and quantitative characteristics of phytoplankton are common to protected shallow waters of the contaminated and poorly flowing bays. Impact of macrophytes on plankton algae vegetation in water hypertrophicity is slightly expressed, and the nutrients abounding in this area do not serve as a limiting factor for algae.

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