DIVERSITY AND FUNCTIONING OF PHYTOPLANKTON IN THE DUBASARI WATER ACCUMULATION RESERVOIR

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Summary. During the period 2009-2011 the Dubasari lake phytoplankton was represented by a total of 90 species and intra-specific taxons, where Bacillariophyta, Cyanophyta and Chlorophyta species are prevailing. Numbers of phytoplankton ranged from 6.16 to 13.76 mln.cel/l with the biomass from 4.27 to 18.41 g/m^3 in the spring and from 2.13 to 35.99 mln.cel/l with the biomass from 7.02 to 24.13 g/m^3 in the summer, and from 3.5 to 13.3 mln.cel/l with the biomass from 2.91 to 17.61 during autumn. Share in the phytoplankton numbers belongs to cianofite algae, and in the algal biomass to bacilariofite algae.

The maximum intensity of production processes was recorded in the summer, primary production values being located within 0.84 to 9.95 gO_2/m^{-2} 24 h. Seasonal and spatial fluctuations in lake primary production are accompanied by fluctuations in phytoplankton biomass, community structure of plankton algae succession, changes in nutrient elements concentrations and water transparency values oscillations.

There were established variations of the saprobe index values within 1.68 to 2.72. Most saprobe index values were within limits of the β-mezosaprobe zone and indicate attribution to the water the quality classes 3a -"satisfactory pure" – 3b "moderately polluted".

Keywords: phytoplankton, primary production, destruction, trophicity, water quality

Introduction

Aquatic ecosystem functioning is ensured by continuous interaction of their components. The investigations of the diversity, bioproductivity of aquatic ecosystems and factors that influence the development of hydrobionts have a major practical importance and are realized in the context of land research and monitoring programs, ensuring the sustainable use of aquatic biological resources. It is of great current interest and practical importance the study of phytoplankton communities in aquatic ecosystems in Moldova, different in their genesis and typology, through the influence of environmental factors on diversity and their structural-functional parameters in order to determine their functioning features and assess the water quality.

Phytoplankton responds quickly to changing environmental conditions and its productivity determines the trophic level of aquatic ecosystems and characterizes its sanitary state. The intensive development of planktonic algae also entails "flowering water" – a phenomenon during which algae become a source of pol-

lution, enriching the ecosystem with organic substances in excess. At the same time they can use some organic substances, salts of heavy metals, radionuclides, as active agents of self purifying of polluted water and good indicators of water quality in environmental monitoring.

Seasonal successions of phytoplankton are one of the basic indicators characterizing the stability of algal communities and their degree of adaptation to living conditions. The seasonal succession of phytoplankton is determined by a complex of factors, of which the leading role belongs to temperature, light, water masses dynamics and nutrient elements concentration.

The study of the photosynthesis intensity is necessary to estimate the biological productivity of aquatic ecosystems, to determine the regularities of biotic transformations of matter and energy and to develop recommendations for the rational exploitation of aquatic ecosystems. The primary production and destruction of organic matter are important characteristics of aquatic ecosystem condition in terms of water quality. The ratio A/R changes during pollution and self purifying and is used to feature the organic contamination level of aquatic ecosystems.

The results of investigation of the phytoplankton in Dubasari water accumulation reservoir starting from its foundation in 1954 until 2009 have been published in a series of papers [6-10]. The scientific research over the last 20 years demonstrated that after putting into operation the Novodnestrovsk hydrotechnical node significant changes occurred in the downstream Dniester – the middle sector and the Dubasari water accumulation reservoir – of which there are to be mentioned the low thermal regime (thermal pollution) as a result of using only the deep water for turbine operation; sudden diurnal water level fluctuations; the water transparency changing and intensive development of macrophytes; the catastrophic state of fisheries resources, and reducing the flood volume.

Material and methods

The phytoplankton samples were collected seasonally during the years 2009-2011 in the representative biotopes of the Dubasari water accumulation reservoir as a part of research conducted by the Hydrobiology and Ecotoxicology Laboratory of the Institute of Zoology of the Academy of Sciences of Moldova. There were investigated six collecting points (the higher sector – 2, the middle sector -2, and the lower sector-2) and microscopically analyzed 54 samples of phytoplankton. Collecting and processing the samples of phytoplankton were performed according to the unified methods of collecting and processing the field and experimental hydrobiological samples [4].

Algae species identification was performed using the microscopes ("Jenaval" and Lomo "Микмед 2") and determinators [1].

Number of phytoplankton was estimated by counting cells of algae in camera "Goreaev" (0.9 cm^3). The phytoplankton biomass was calculated by the method

of summation biomasses of algae species identified in samples. Their volume was calculated using the similarity with geometric figures or combinations of figures and the known geometric formulas, and the linear dimensions of algae cells.The relative density of freshwater algae is considered equal to 1.0 to 1.05 [1, 4].

The primary production and destruction of organic substances were estimated by the method of vessels presented in the oxygen modification [4]. To assess the primary production of phytoplankton and the destruction of organic matter there were performed 18 series of experiments at 3 stations located in the upper, middle and lower Dubasari water accumulation reservoir.

To estimate the Dubasari water accumulation reservoir trophic dynamics there were used seasonal and multiannual values of biomass and phytoplankton primary production [3]. To estimate the pollution degree and water quality under hydrobiological indices there were used methods based on indicator organisms systems [1, 2, 3, 4]. Based on the list of indicators [1], the Rotsain saprobiologic index was calculated for saprobic valence method Zelinka – Marvan, with the formula modified by I. Toderaş [5]. To estimate the trophic dynamics of Dubasari Lake according to classification criteria and continental aquatic ecosystems trophic categories there were used seasonal and multiannual values of biomass and primary phytoplankton production [3].

To establish the accuracy of data, there were used mathematical and statistical analysis methods along with applications BIOSTAT, Statistica 7 for Windows, and EXCEL 2007.

Results and discussions

In 2009-2011, Dubasari Lake phytoplankton was represented by a total of 90 species and intraspecific taxons assigned to the following taxonomic groups of algae *Cyanophyta* – 10, *Dinophyta -1, Chrysophyta -1, Bacillariophyta* – 43, *Euglenophyta* – 5 and *Chlorophyta* – 30. The base of floristic diversity consists of groups *Bacillariophyta, Chlorophyta* and *Cyanophyta,* which recorded the highest number of taxa of different ranks.

The most of identified bacilariofite Algae are attributed to *Pennatophyceae* class, represented mainly by the *Navicula, Synedra, Nitzschia* and *Cymbella genera.* The main role in the formation of taxonomic diversity in the philum of *Chlorophyta* belongs to *Scenedesmus, Monoraphidium, Pediastrum* and *Tetraedron,* and in the composition of *Cyanophyta* philum most representative was the *Oscillatoria.* The euglenofite algae less widespread in different sectors of the Lake were represented mainly by the species of *Trachelomonas* genre.

The algoflora of Dubasari Lake is a diversified complex of species of different provenances; the most of species (82%) and intraspecific taxa of algae is assigned to the cosmopolitans group.

The Lake phytoplankton was more diverse in the summer, the Shannon diversity index increasing from the upper sector (1.00) toward the lower (4.08). In the spring the phytoplankton in the Lake was dominated by the species *Synechocystis aquatilis* Sanv., *Coelastrum microporum* Nageli, *Fragillaria capucina* Desm. var. *capucina*, *Diatoma vulgare* var. *lineare* Grun., *Nitzschia sigmoidea* (Ehr.) W. Sm. var. *sigmoidea, Cyclotella Kuetzingiana* Thw., *Synedra ulna (*Nitzsch.) Ehr. *var.ulna, Cymbella lanceolata (*Ehr.) V.H. *var. lanceolata, Cymbella tumida (*Breb.) V.H. *var. tumida,* and in the summer period were more abundant the species *Cymbella ventricosa* Kutz. var. *ventricosa*, *Melosira granulata* (Ehr.) Ralfs var.*granulata*, *Navicula cryptocephala* Kutz. var.*cryptocephala* din algele bacilariofite, *Scenedesmus falcatus Chodat., Coelastrum microporum* Nageli, *Tetrastrum triangulare* Chod. din algele verzi şi *Oscillatoria lacustris* (Kleb.) Geitl., *Synechocystis aquatilis* Sanv., *Aphanizomenon flos-aquae* (L.) Ralfs *f. flos-aquae*, *Anabaena spiroides* Kleb. *f. Spiroides, Oscillatoria subtilissima* Kutz from cianofite algae.

From the summer dominating complex, it remained in autumn to dominate only 3 species: *Synechocystis aquatilis* Sanv., *Oscillatoria lacustris (*Kleb.) Geitl., *Navicula cryptocephala* Kutz. *var. cryptocephala.* Numbers of phytoplankton varied from 6.16 to 13.76 mln.cel/l in the spring, from 2.13 to 35.99 mln.cel/l in the summer and from 3.5 to 13.3 mln.cel/l during the autumn (Figure 1).

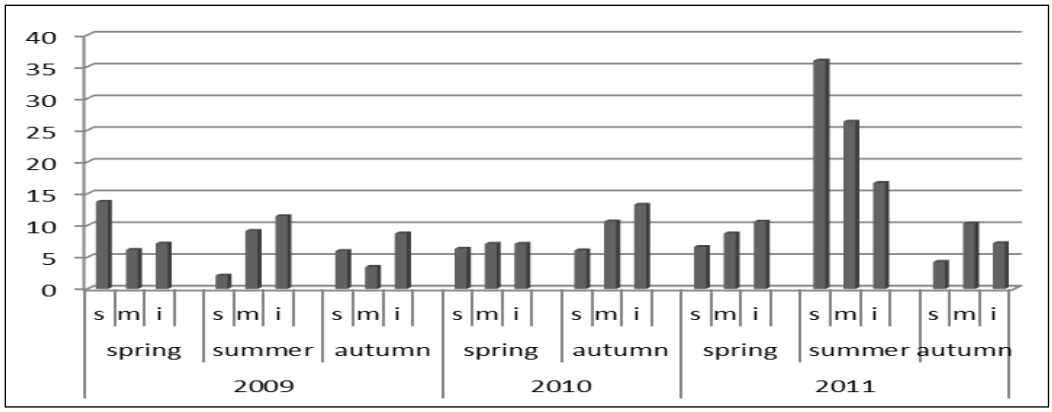

Figure 1. **Seasonal dynamics of the phytoplankton numeric values (mln cel./l) in the Dubasari water accumulation reservoir (s-sector superior, m-sector middle, i-sector inferior) in 2009-2011 years**

Higher numbers of phytoplankton were recorded in the summer 2011, these decreasing from the upper to the lower lake sector. During this period, it was registered an intense development of species *Synechocystis aquatilis* (30.67 mln.cel/l) in the superior sector, the middle sector was dominated by species *Aphanizomenon flos-aquae f flos-aquae* (9.33 mln.cel/l), *Anabaena Spiro of-*

ten Spiroides f (4.07 mln.cel/l) and *Oscillatoria subtilissima* (3.0 mln.cel/l), and the lower sector was dominated by bacilariofite algae *Cymbella ventricosa* (3.23 mln.cel/l), *Melosira granulate* (2.20 mln.cel/l) and *Navicula cryptocephala* (1.53 mln.cel/*l)*. In most of the investigated seasons there are trends of increasing the phytoplankton numbers in the upper sector toward the lower sector of the lake.

The Phytoplankton biomass values varied within the limits from 4.27 to 18.41 g/m^3 in the spring, from 7.02 to 24.13 g/m^3 in the summer and from 2.91 to 17.61 g/m^3 during the autumn (Figure 2).

Although the share in the phytoplankton numbers growth in Dubasari water accumulation reservoir belongs to cianofite algae, the leading role in biomass formation belongs to bacilariofite algae.

Thus in the summer period of 2011 when the number of phytoplankton in the upper lake was maximal due to intense development of cianofite algae in the composition of phytoplankton, its biomass was lower compared to other sectors, representing only 4.42 g/m^3.

In the middle and lower sectors where the large bacilariofite algae developed in the summer *Cymbella ventricosa Kutz. var. ventricosa, Amphora venata Kutz. var. venata, Rhoicosphenia curvata (Kutz.) Grun. var. curvata and Ceratium hirundinella* (O. F.M.) Bergh from dinofite algae, the number was lower, but the phytoplankton biomass was much higher compared to that of the upper sector. The phytoplankton biomass values change in large limits both in different seasons of the year and in different parts of the lake depending on the degree of development of certain species of algae in the phytoplankton composition.

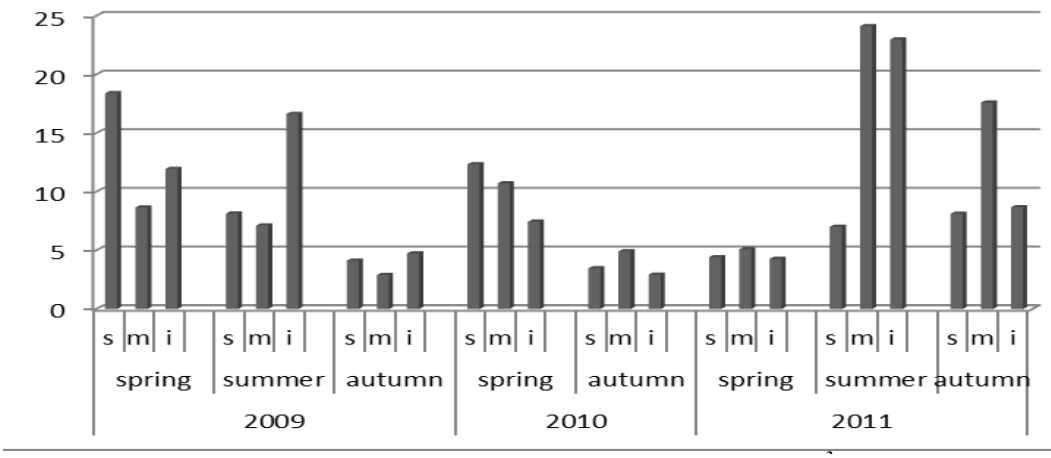

Figure 2. **Seasonal dynamics of the phytoplankton biomass values (g/m^3) in the Dubasari water accumulation reservoir (s-sector superior, m-sector middle, i-sector inferior) in 2009-2011 years**

According to the phytoplankton biomass values the Dubasari water accumulation reservoir can be attributed to periodic politrofe eutrophic ecosystems category.

There were established considerable differences between the values of primary production of phytoplankton and organic matter destructions during the growing season and in different parts of the lake. In the spring, when the suspension and humic substances content in the Dubasari water accumulation reservoir waters is increased, the lower boundary of the euphotic layer only reach 1.5 to 2.3 m. At the same time the maximum depth of euphotic layer was recorded in the lower sector of the lake and the minimum one in the upper sector, the difference between them being often about 1.5 m. During the vernal period the primary production values ranged from 0.67 to 7.26 g O_2/m^2 24 hours, with significant differences recorded between values certified in different parts of the lake (Table 1). Thus, in most cases the primary production values recorded in the lower sector of the lake overcame the primary production values in the upper sector. At the same time the destruction processes intensity was quite high, destructions values changing from 4.86 to 140.35 gO_2 /m^2·24 h in the vernal period. The ratio A/R less than 1 reflects a negative balance of oxygen content in the lake during the vernal period and shows a high content of allochthonous substances.

In the summer, although the content of mineral suspensions in the lake diminished, the water transparency was lower compared to the spring one due to more intense development of phytoplankton. Thus, during summer water transparency varied within 20-70 cm. The limits of variation of primary production values during summer (0.84 to 9.95 g O_2/m^2·24 h) were higher than during the vernal period. Along with increasing the intensity of production processes during the summer, there greatly increased also the values of organic substances destructions, and the average value of destruction overcame the production value (Table 1.).

In autumn, the lake water transparency was higher, with values ranging from 1.0 to 1.7 m, but due to lowering the incidence of light, the intensity of photosynthesis decreased with depth and the production values decreased considerably. In such cases the maximum intensity of photosynthesis was recorded in the superficial layers of the lake. During the autumn the primary production values, with fluctuations within 0.36 to 0.67 g O_2/m^2·24 h were significantly lower than in the summer and vernal periods. Like the situations documented in other seasons, the destructions values of organic substances located within 3.54 to 72.62 g O_2 m^2·24 h exceeded the primary production values, the ratio A/R being less than 1.

Table 1.

Dynamics of the phytoplankton primary production (A) and organic matter destruction (R) values in Dubasari water accumulation reservoir in 2009-2011 years

Parameters		Spring n =6	summer n =6	autumn n =6
∑A	Min	0,67	0,84	0,36
g O_2/m^2·24 h	Max	7,26	9,95	0,67
∑R	Min	4,86	5,28	3,54
g O_2/m^2·24 h	Max	140,35	41,62	72,62
A_{max}	Min	0,20	0,64	0,10
mg O_2/l·24 h	Max	6,12	2,71	0,23
R	Min	1,08	1,09	0,52
mg O_2/l·24 h	Max	20,64	6,12	10,58
A_{max}/∑A	Min	0,13	0,08	0,21
	Max	1,79	3,23	0,64
A/R	Min	0,02	0,13	0,01
	Max	1,49	0,24	0,19

Note. n – number of indices

The seasonal changes in phytoplankton productivity are determined by hydrometeorological conditions and composition of phytoplankton in the lake. The ratio A_{max}/ ΣA values were higher during the summer, which corresponds to a reduced euphotic zone due to reduced and lower transparency during the vernal and autumnal periods, having similar values. Seasonal and spatial fluctuations of the primary production in the lake are accompanied by fluctuations in phytoplankton biomass, succession in the planktonic algae community structure, changes in nutrient concentrations and water transparency values oscillations, caused by suspended matter content.

In the framework of investigations of the intensity of production-destruction processes in the Dubasari water accumulation reservoir there were established considerable differences between the values of primary production and destruction during the growing period and in different parts of the lake. At the same time, it should be noted an increasing of the primary production from spring toward summer, followed by its decreasing during autumn in connection with the decrease of temperature, solar radiation and end of the vegetation of many thermophilic species of phytoplankton composition and their replacement with species characteristic for lower temperatures. Thus, the clorococoficee algae, characterized by higher productivity, are substituted during autumn by large bacilariofite algae, less productive.

The values of destruction of organic substances far exceeded the primary production values in all seasons and in all sectors of the lake. The A/R ratio less

than 1 reflects a negative balance of organic matter formation in the lake and shows a high content of allochthonous substances.

The water quality in the Dubasari water accumulation reservoir has been evaluated on the base of phytoplankton quantitative parameters. There has been established variability of the saprobe index within the limits of 1,68-2,72 (Table 2).

Table 2.

Variability of the saprobe index values in the Dubasari water accumulation reservoir in 2009-2011 years

Sectors	Spring	summer	Autumn
Superior	2,01-2,72	1,89-2,19	2,30-2,43
Middle	1,68-1,95	1,80-1,88	2,00-2,67
Inferior	2,00-2,32	1,92-1,99	2,03-2,58

Majority of saprobe index values were within limits of the β-mezosaprobe zone and indicates attribution to the water quality classes 3a „satisfactory pure" – 3b „moderately polluted". Worse water quality has been determined in the spring period in the superior sector (I sp=2,72) and in the autumn period in the middle sector (I sp=2,67), when values of saprobe indexes indicates attribution to the water quality class 4a „polluted".

Conclusions

In 2009-2011 years, the Dubasari water accumulation reservoir phytoplankton was represented by a total of 90 species and intraspecific taxa distributed in the following taxonomic groups of algae *Cyanophyta* – 10, *Dinophyta -1, Chrysophyta -1, Bacillariophyta* – 43, *Euglenophyta* – 5 and *Chlorophyta* – 30.

The basis of the floristic diversity of the Dubasari water accumulation reservoir consists of groups *Bacillariophyta, Chlorophyta* and *Cyanophyta,* which recorded the highest number of taxa of different ranks.

The algoflora of Dubasari water accumulation reservoir is a varied complex of species of different origins. The most (82%) algae species and intraspecific taxa is assigned to the cosmopolitans group.

Although the weight in phytoplankton formation in the Dubasari water accumulation reservoir belongs to cianofite algae, the leading role in biomass formation belongs to bacilariofite algae.

The numbers of phytoplankton changed within the limits 6.16 to 13.76 mln. cel/l with biomass from 4.27 to 18.41 g/m^3 in the spring, from 2.13 to 35.99 mln. cel/l with biomass from 7.02 to 24.13 g/m^3 in the summer, and from 3.5 to 13.3 mln.cel/l with biomass from 2.91 to 17.61 during autumn.

The values of organic substances destruction far exceeded the primary production values in all seasons and in all sectors of the reservoir. The A/R ratio less

than 1 reflects a negative balance of organic matter formation in the lake and shows a high content of allochthonous substances.

Seasonal and spatial fluctuations in primary production in the lake are accompanied by fluctuations in phytoplankton biomass, planktonic algae community structure succession, changes in nutrient concentrations and water transparency values oscillations.

There has been established variability of the saprobe index within the limits of 1,68-2,72. Majority of saprobe index values were within limits of the β-mezosaprobe zone and indicates attribution to the water quality classes 3a „satisfactory pure" – 3b „moderately polluted". Worse water quality has been determined in the spring period in the superior sector (I sp=2,72) and in the autumn period in the middle sector (I sp=2,67), when values of saprobe indexes indicates attribution to the water quality class 4a „polluted".

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