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PHYTOPLANKTON AS INDICATOR OF WATER QUALITY OF LAKES BUBANJ AND ŠUMARICE DURING AUTUMN

Branislav Ranković, Snežana Simić, Dragana Bogdanović

Institute of Biology and Ecology, Faculty of Sciences, University of Kragujevac, Radoja Domanovića 12, 34000 Kragujevac, Serbia and Montenegro
e-mail: snezasi@kg.ac.yu

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ABSTRACT. The algological and saprobiological investigations of Kragujevac's lakes Bubanj and Šumarice during the September 2004 were carried out.

Phytoplankton of Bubanj Lake is characterized by the presence of cosmopolitan species of algae of the divisions Cyanophyta (nine taxa), Pyrrophyta (three), Bacillariophyta (16), Euglenophyta (one) and Chlorophyta (18). At the moment of our investigations there dominated Bacillariophyta and Chlorophyta (in relation to the number of taxa) and Cyanophyta (by population density, especially species *Microcystis aeruginosa*). Mean value of saprobity index S= 1.9 points out at the high ß-mesosaprobity or II class of the water quality.

Phytoplankton of Šumarice Lake too is characterized by the presence of cosmopolitan species of algae of the divisions Cyanophyta (nine taxa), Pyrrophyta (four), Bacillariophyta (17), Euglenophyta (two) and Chlorophyta (26). At the moment of our investigations there dominated Chlorophyta and Bacillariophyta (in relation to the number of taxa) and Bacillariophyta (by population density, especially species *Fragilaria crotonensis*). Mean value of saprobity index S=1.7 points out at the high ß-mesosaprobity or II class of the water quality.

INTRODUCTION

There are three artificial lakes on the territory of Kragujevac city, and the Gruža Reservoir on the territory of nearby downtown Knić. Two of them (the Grošnica and Gruža reservoirs) are used for the supply of Kragujevac with water; one (lake in the Šumarice Park) serves for the rest and recreation of the city's residents, as well as for the streets washing; and the smallest, so-called pond Bubanj, is one of the fishering and the rest point of the city, located close to the center.

The Gruža, Grošnica and Bubanj lakes, have been the subject of many hydrobiological investigations. Among the other researches, the phytoplankton of these lakes has been studied in detail (SIMIĆ *et al.* 1994; OSTOJIĆ *et al*. 1995; RANKOVIĆ *et al.* 1999; RANKOVIĆ & SIMIĆ, 2005). Phytoplankton of Šumarice Lake has not been investigated never before.

Description of investigated locations

The Bubanj Lake actually is a pond, which has been formed in the alluvial plane of the river Lepenica, in abandoned hollow from which the soil for a former brick kiln had been exploited (STEPANOVIĆ, 1974). The process of its formation started in 1955. Pond is supplied with water from a subterranean spring, from the drinking-fountain «Bubanj» and from rainfalls. The water surface equals to approx 2.7ha. The land belt around Lake is a flat ground approx. 10ha, without buildings and with scarce woods vegetation (SIMIĆ *et al.* 1994). Moreover, lake is situated in the urban zone of the city, not far from the city centre. It is from the three sides surrounded by busy traffic, and from the fourth side with a service shop of the car company «Crvena Zastava». Lake once had an efflux trench, which is now, however, cut with a municipal sewer and is out of use.

The depth of Bubanj on the average is approx. 1.20m (max. 1.60, min. 0.50m) (SIMIĆ *et al.,* 1994). Compared with analyses conducted 30 years ago (STEPANOVIĆ, 1974), the depth decreased for about 0.50-0.60m. The greatest part of lake's bottom is muddy. The average thickness of the mud is 0.50-0.70m, with most of deposit directed towards the central parts of pond (SIMIĆ *et al.* 1994).

The Šumarice Lake has been formed on the spring Sušički potok, when the dam (246m long, 19.5m wide) was built. In the first time lake has been used for irrigation as well as for the rest and recreation of the Kragujevac's residents. Šumarice Lake is located in the memorial park «Kragujevac's October». The length of this lake is 1350m, width is 175m. The water surface equals to approx 14ha and volume is 950.000m^3. During the winter whole surface of lake is frozen. The maximal depth is 24m. Today this lake is used for the sport, recreation, fishing and keeping city's streets clean.

MATERIAL AND METHODS

The samples of the water were taken in September 2004. On the Bubanj Lake investigations were performed at three sampling sites: (I – angle toward Lepenica, II – centre of lake, III – angle beside forest). The Šumarice Lake was investigated on three sampling site (I – dam, II – centre, III – end of lake). Samples were taken at three depths: 0.5m from the surface, in the middle of the water column, and 0.5m from the bottom. The basic physical and chemical parameters were measured (temperature, pH value, oxygen concentration, conductivity, water transparence) and analyzed after APHA (1985).

For the qualitative analysis of phytoplankton, samples were taken by drawing a plankton net (with pore diameter of 25μm) from the bottom to the surface of the water column.

Samples for the quantitative analysis were taken with a 2-l Ruttner's bottle at the same sites as for the qualitative analysis, from the depths already mentioned. Quantitative processing of phytoplankton was performed in vessels for counting of planktonic organisms («Hydro-bios» vessels) by examination in an inverting microscope according to the Utermohl method (UTERMÖHL 1958). Samples were preserved with 4% formalin immediately, at the collection site.

The mark of quality of water was given by saprobity index (S) (PANTLE & BUCK 1955; SEV 1977).

RESULTS AND DISCUSSION

Bubanj Lake

Results obtained by the measurement of physical and chemical parameters in three sites of Bubanj Lake are presented in Table 1.

The average value of temperature of water for the whole lake is 26^0C (Tab. 1). The earlier dates show that the mean averagetemperature during the summer is 29^0C and during the winter is 8^0C (SIMIĆ *et al.,* 1994). During the winter the whole lake surface is frozen, except a small area where water from the drinking-fountain «Bubanj» is emptied (SIMIĆ *et al.* 1994). Water of Bubanj Lake is not stratified.

The average value of pH is 8.2 (Tab. 1). The data from earlier investigations show that mean summer's value is 6.7. During the winter period pH is lower, 5.7-6.0 (SIMIĆ *et al.,* 1994).

The level of oxygen in the water is relatively satisfied, with the lower values during the winter period (4.9-6.0mg/L). During the summer period the water becomes enriched with oxygen because of photosynthesis of the macrophytae vegetation which occupies the whole water mass of the lake (11mg/Lon the average) (SIMIĆ *et al.* 1994). In September 2004 the mean value of dissolved oxygen was 11.2 mg/L (Tab. 1).

The transparency of water is small, because of high-density (on site I it is only 0.80m and onsites II, III 1m) (Tab. 1).

Table 1. Physical and chemical characteristics of investigated sites of Bubanj Lake

Sites	Temperature of water (^{0}C)	pH	Dissolved oxygen (mg/L)	O_2 (%)	Conductivity µs/cm	Transparency of water (m)
I	25	8.1	9.64	135.3	500	0.8
II	26	8.0	10.05	136.6	530	1
III	27	8.3	13.87	183.1	540	1

Presence of 47 taxa was detected in the phytoplankton, belonging to the following divisions Cyanophyta (nine taxa), Pyrrophyta (three), Bacillariophyta (16), Euglenophyta (one) and Chlorophyta (18). Phytoplankton of Bubanj Lake is characterized by the presence of cosmopolitan species (Tab. 2).

In regard to the number of species, algae of the divisions Chlorophyta and Bacillariophyta are dominant.

Phytoplankton of the Bubanj Lake in September 2004 was characterized by relatively high values of population abundance (Tab. 3). The high density wasfound by quantitative analysis in the site I (4 074 000 ind/L), and the smallest in the site II (3 133 000 ind/L) and the site III (3 347 000 ind/L). Algae of the divisions Cyanophyta are dominant in the site III (81.7%) (Tab. 3). Dominant species are *Microcystis aeruginosa* and *Gomphospheria compacta.*

Saprobity analysis based on study of phytoplankton indicates that water of Bubanj Lake belongs to the category of β-mesosaprobic water (average index of saprobity is 1.90, which responds to II class of water) (Tab. 4).

The primary production is high throughout the whole year (SIMIĆ *et al.* 1994), with a pronounced peak during the summer and autumn (when algal "blooms" caused by the blue-green alga *Microcystis aeruginosa* are observed), indicates the eutrophic status of Bubanj Lake.

Table 2. Qualitative composition of phytoplankton in lakes Bubanj and Šumarice (September 2004)

Taxa	BUBANJ			ŠUMARICE		
	Sites			Sites		
	I Angle toward Lepenica	II Centre	III Angle beside forest	I Dam	II Centre	III End of lake
CYANOPHYTA						
Aphanisomenon elenkinii Kissel				+	+	+
Chroococcus turgidus (Kütz) Nag.	+	+	+			
Gleocapsa sp.	+	+	+			
Gleocapsa helvetica Näg.				+		
Gomphosphaeria compacta Lemm.	+	+	+			
Isocystis planctonica Kütz		+			+	
Lyngbia sp.						+
Microcystis aeruginosa Kütz	+	+	+	+	+	+
Merismopedia tennuisima Lemm.	+	+	+	+	+	+
*Merismopedia punctata*Meyen				+	+	+
Merismopedia elegans Lemm.	+					
Oscillatoria tenuis Agarh.	+	+				
Rivularia dura Roth	+					
PYRROPYTA						
Ceratium hirudinella (O. F. M.) Schr.			+	+	+	+
Cryptomonas curvata Ehr.						
Gymnodinium sp.				+	+	+
Peridinium incospicum Lem.		+	+	+	+	+
Peridinium sp.				+		+
Peridiniopsis aculeatum	+					
BACILLARIOPHYTA						
Asterionella formosa Hass.				+		
Caloneis amphisbaena (Bory) Cl.	+	+				
Cyclotella comta (Ehr.) Kütz.				+		
Cyclotella kützingiana Thwait.				+		
Cocconeis placentula Ehr.	+	+	+	+	+	+
Cocconeis pediculus Ehr.	+					
Cyclotella meneghiniana Kütz.	+	+				
Cymbella cistula (Hemp.) Grun.						+
Cymbella parva (W. Smith) Clev.					+	
Cymatopleura solea (Bréb.) W. Sm.	+					
Epithemia turgida (Her.) Kütz.	+					
Fragillaria crotonensis Kitton	+	+	+	+	+	+
Gyrosigma acuminatus Kütz.				+		
Melosira sp.				+		
Navicula cuspidata Kütz.	+	+		+	+	+
Navicula gregaria Donk.						+
Navicula radiosa Kütz.	+	+	+	+	+	+

Table 2. Continued

Taxa	BUBANJ			ŠUMARICE		
	Sites			Sites		
	I Angle toward Lepenica	II Centre	III Angle beside forest	I Dam	II Centre	III End of lake
Navicula rhynocephala Kütz.	+					
Nitzschia sp.	+					+
Surirella linearis Smith.			+			
Surirella ovata Kütz.			+			
Synedra acus Kütz.				+	+	+
Synedra ulna (Nitz.) Ehr.			+			
Rhopalodia gibba (Ehr.) Müller						+
Tabellaria fenestrata (Lyn.) Kütz.						+
EUGLENOPHYTA						
Trachelomonas sp.		+	+			+
Trachelomonas volvocina Ehr.				+	+	+
CHLOROPHYTA						
Chlamydomonas ehrenbergii Gor.		+				
Closterium aciculare (Tuffen) West.						+
Closterium dianae Ehr.						+
Closterium leibleini Kütz.				+		
Closterium moniliferum (Bory) Ehr.				+		
Coelastrum astroideum Näg.	+	+	+	+	+	+
Cosmarium formulosum Hofm.	+	+				
Cosmarium meneghinii Istvanffi	+					
Cosmarium reniforme Arch.	+				+	
Cosmarium tumidum Lund.					+	
Koliella longiseta(Vischer) Hindák					+	
Mougeotia sp.	+					
Nephrocytium lunatum W. West						+
Oedogonium sp.	+				+	
Palmodictyon viride Kütz.						+
Pediastrum boryanum (Turp) Menegh.	+		+	+		+
Pediastrum simplex Meyen	+			+		
Pleurotenium ehrenbergii (Breb) de Bary		+				
Scenedesmus acuminatus (Lag) Chod	+	+	+	+		
Scenedesmus obliqus (Turp.) Breb.						
Scenedesmus quadricauda Breb.	+	+	+	+	+	+
Sphaerocystis planctonica Bourr.					+	+
Spirogyra sp.			+			+
Staurastrum gracile Ralfs.				+		+
Staurastrum furcigerum Bréb.						+
Staurastrum teliferum Ralfs						+
Staurastrum tetracerum (Kütz.) Ralfs	+	+	+	+	+	+
Staurastrum sp.	+	+	+			
Staurodesmus cuspidatus(Br,b.) Teiling				+	+	+
Zygnema sp.						+

Table 3. Absolute numerical values and percentages of different divisions of algae in Bubanj Lake

SITES						
	I		II		III	
DIVISIONS	**ind/L**	**%**	**ind/L**	**%**	**ind/L**	**%**
Cyanophyta	2 979 000	73.12	2 142 000	68.4	2 736 000	81.7
Pyrrophyta	28 000	0.69	13 000	0.41	64 000	1.9
Bacillariophyta	594 000	14.16	739 000	25.5	279 000	8.34
Euglenophyta	-	-	-	-	83 000	2.45
Chlorophyta	473 000	11.6	239 000	7.62	185 000	5.53
TOTAL	4 074 000	100	3 133 000	100	3 347 000	100

Table 4. Values of saprobity index (S) on different sites in Bubanj Lake

Saprobity index (S)	SITES			Average
	I	II	III	
	1.98	2.05	1.81	1.9

Šumarice Lake

Results obtained by the measurement of physical and chemical parameters in three sites of Šumarice Lake are presented in Table 5.

Temperature is stratified in its water: in site I - dam, on surface of lake temperature is 22^0C, but on the depth on 10m it is 9.5^0C. On surface part, when air temperature is high, there is more oxygen (6.75mg/L). With growing depth the consume content of oxygen grows on site Dam: on depth of 10m, it is only 1.59mg/L. Conductivity is smallest on depth of 10m, what means that on this position concentration of mineral substances is low (Tab. 5).

At site II – centre, on surface temperature amounts 22.5^0C, but on 5m depth it is lower (14.5^0C). Concentration of oxygen decreases with depth and on 5m amounts only 1.64mg/L. Conductivity is bigger on surface of lake (360 mg/L). The biggest value for conductivity on this site is registered (Tab. 5).

In site III - end of lake, temperature of water surface and on the depth of 3m is the same. Decreasing of oxygen concentration with depth is slower. The highest value of saturation is in this site and amounts 89.6%; on surface; and 81.3% on the depth of 3m. Conductivity is the same on surface and on the depth of 3m (Tab. 5).

Value of pH is approximately the same through the whole lake - 7.5 (Tab. 5).

The transparency of Šumarice Lake is low. The maximum of transparency isin sites I - dam and II - centre (2.2m), lower in site III - end of lake (1.8m) (Tab. 5).

Table 5. Physical and chemical characteristics of investigated sites of Šumarice Lake

Sites	**Temperature of water (^{0}C)**	**pH**	**Dissolved oxygen (mg/L)**	**O_2 (%)**	**Conductivity µs/cm**	**Transparency of water (m)**
I - DAM						
0.5	22	7.7	6.87	87.8	350	2.2
5 m	21	7.4	4.56	81.3	350	
10 m	9.5	7.3	1.59	19.5	300	
II -CENTRE						
0.5	22.5	7.6	6.69	86.2	360	2.2
5 m	14.5	7.1	1.64	19.1	320	
III - END OF LAKE						
0.5	22	7.6	6.48	89.6	340	1.8
5 m	21	7.6	6.43	81.3	340	

Phytoplankton of Šumarice Lake is characterized by the presence of cosmopolitan species (Tab. 2).

The presence of 59 taxa was detected in the phytoplankton. They belong to the following divisions Cyanophyta (nine taxa), Pyrrophyta (four), Bacillariophyta (17), Euglenophyta (two) and Chlorophyta (26).

In regard to the number of species, algae of the divisions Chlorophyta are dominant, especially species from genera *Closterium, Scenedesmus, Cosmarium, Pediastrum* and *Staurastrum* (Tab. 2).

Table 6. Absolute numerical values and percentages of different divisions of algae in Šumarice Lake

I-DAM						
	0.5 m		**5 m**		**10 m**	
DIVISIONS	**ind/L**	**%**	**ind/L**	**%**	**ind/L**	**%**
Cyanophyta	250 000	46.0	133 000	44.6	82 000	30.7
Pyrrophyta	34 000	6.26	32 000	10.7	6 000	2.25
Bacillariophyta	168 000	30.9	99 000	33.2	128 000	47.9
Euglenophyta	-	0.0	0.0	0.0	4 000	1.5
Chlorophyta	91 000	16.8	34 000	11.4	47 000	17.6
TOTAL	543 000	100	298 000	100	267 000	100
II-CENTRE						
	0.5 m		**5 m**			
DIVISIONS	**ind/L**	**%**	**ind/L**	**%**		
Cyanophyta	129 000	28.1	78 000	21.8		
Pyrrophyta	22 000	4.79	5 000	1.4		
Bacillariophyta	187 000	40.7	142 000	39.8		
Euglenophyta	46 000	10	91 000	25.5		
Chlorophyta	75 000	16.3	41 000	11.5		
TOTAL	**459 000**	**100**	**357 000**	**100**		
III-END OF LAKE						
	0.5 m		**3 m**			
DIVISIONS	**ind/L**	**%**	**ind/L**	**%**		
Cyanophyta	115 000	25.8	2 028 000	21.4		
Pyrrophyta	5 000	1.12	260 000	2.7		
Bacillariophyta	244 000	54.7	6 542 000	68.9		
Euglenophyta	23 000	5.2	18 000	0.19		
Chlorophyta	59 000	13.2	644 000	6.8		
TOTAL	**446 000**	**100**	**9 492 000**	**100**		

Density of algal community of Šumarice Lake is different on investigated sites and on the different depth (Tab. 6). The high-density has been found by quantitative analysis in the site III - end of lake, in the depth of 3m (9.492.000 ind/L, and the smallest in the site I - dam in the depth of 10m (267.000 ind/L). Algae of division Bacillariophyta show very high density on every sites and depth, except the site I-dam (surface, 5m) where are dominant species from division Cyanophyta. Dominant species is *Fragillaria crotonensis.* This species was dominated in the Barje Reservoir at the end of August (SIMIĆ 2004).

Algae of the division Bacillariophyta are dominant in the site III – end of lake (81.7%). Beside species *Fragillaria crotonensis* in this site are dominant species *Navicula radiosa* and *N. gregaria.* (Tables 2 and 6)

Average values of saprobity index for sites I – dam was 1.74, II - centre 1.80 and III - end of lake 1.78 (average value for whole lake is 1.77 - β mezosaprobic, which responds to II class of water) (Tab. 7).

Table 7. Values of saprobity index (S) on different sites in Šumarice Lake

Saprobity index (S)	**I - DAM**			**Average**
	0.5 m	**5 m**	**10 m**	
	1.65	1.82	1.76	1.74
Saprobity index (S)	**II - CENTRE**			**Average**
	0.5	**5 m**		
	1.77	1.83		1.80
Saprobity index (S)	**III - END OF LAKE**			**Average**
	0.5	**3 m**		
	1.76	1.80		1.78

CONCLUSION

Phytoplankton of Bubanj Lake and Šumarice Lake is characterized by the presence of cosmopolitan species of algae from the divisions Cyanophyta, Pyrrophyta, Bacillariophyta, Euglenophyta and Chlorophyta. At the moment of our investigations there were dominant. Bacillariophyta and Chlorophyta (in relation to the number of taxa).

In Bubanj Lake average value of saprobity index is S=1.9 and pointing out the high ß-mesosaprobity, or II class of the water quality. The significant presence of indicators of increased saprobity in the phytoplankton shows that the bonity will soon change saprobity, with all the negative consequence for the living world of Lake. The dominant presence of Cyanophyta, especially species *Microcystis aeruginosa*, confirmed that.

Water quality of Šumarice Lake is better (S=1.7, II class). This lake is deeper than Bubanj Lake; have stratification; and it is surrounded by forest. Dominant species is *Fragilaria crotonensis*, which is indicator of o-ß mesosaprobic water.

Owing to insight in real state of water quality of both lakes, we suggest to establish permanent monitoring with at least four seasonal aspects.

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