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Current state of phytoplankton in Batak reservoir (Southwestern Bulgaria)

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Abstract

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The aim of the present study was to update the current status of the phytoplankton composition in Bulgarian reservoir with high social, environmental and economic importance such as the Batak reservoir and to analyze its relationship with the total bacterial count (TVC) and the environmental factors. A total of 106 phytoplankton taxa were identified for the study period. Class Bacillariophyceae was presented by the highest number of species (34) followed by divisions Chlorophyta (26) and Cyanoprokaryota (17). The maximum of species diversity was established in the samples from September at the station situated near the dam wall (S1) with the lowest number being detected in July at the same station. The phytoplankton abundance (PhN) and biomass (PhB) has reached their maximum in September with highest values in the epilimnion samples with a steep decrease in depth of the reservoir. Seasonally and spatially waters were dominated by the diatoms *Tabellaria fenestrata* var. *asterionelloides* Grunow, *Fragilaria crotonensis* Kitton, green algae *Pandorina morum* (O.F.Müller) Bory, and *Desmodesmus communis* (E. Hegewald) E. Hegewald. *Aphanizomenon flosaquae* Ralfs ex Bornet & Flahault is presented with relatively high numbers. A *Woronichinia naegeliana* (Unger) Elenkin bloom was established in November at the tail of the reservoir. Significant positive correlations were established between phytoplankton abundance and the nitrogen forms, total phosphorus, with negative correlations between PhN and TVC. According to cluster analysis, the surveyed stations are grouped into two separate clusters each with similar spatial and seasonal characteristics. The stations at the dam wall and at the tail of the reservoir are characterized by the highest hierarchical distance.

Keywords: phytoplankton; abundance; biomass; algal bloom; TVC; Batak reservoir

Introduction

Phytoplankton is the first of the communities to respond to environmental changes based on a variety of factors of different origins (Wilk-Wozniak et al., 2013), so the temporal changes in its structure are essential for metabolism in water systems (Calijuri et al., 2002; Crossetti and Bicudo, 2008). The community reacts to changes in the environment with alteration in its qualitative and quantitative composition which makes it suitable for an environmental indicator (Cabecinha et al., 2009). Dam building along the rivers leads to changes in the water current and have a strong impact on phytoplankton composition (Dembowska, 2009). The first study on the phytoplankton in Batak reservoir was conducted by Naidenov (1964). Later the processes of formation of the community are described along with the description of the main characteristics of the water body (Saiz, 1973, 1977). Two annual maximums in the community development have been described with green algae having the highest biomass and diatoms being the most abundant. According to Saiz (1977) water level directly affects the phytoplankton dynamics, and the water temperature has a significant influence on its temporal dynamics. The altitude and the depth of the reservoir also play a major role in the community composition (Beshkova, 1996). A number of studies established an increase in the species diversity along the longitudinal axis of the reservoirs in the direction from the dam wall to the tail of the water bodies (Beshkova, 1996; Traykov, 2005; Belkinova et al., 2007; Tsanev and Belkinova, 2008; Belkinova et al., 2012). According to Dochin (2014), Dochin and Stoyneva (2014, 2016), in Kardzhali and Dospat reservoirs, where the biggest Bulgarian net-cage farms are situated, there is a clear dependence between the phytoplankton abundance and the organic matter content with highest described values near the cage farms and around the dam walls. The Batak reservoir is one of the largest in Bulgaria. It is included in the list of water bodies for drinking water supply. In the same time, it has been used for cage aquaculture for more than 10 years and other recreational activities and the microbiological and physicochemical water quality does not meet the requirements of the EU Water Directive (2000/60/EC). In recent years the data regarding the algal flora, a main environmental indicator, in Batak reservoir is scarce which sets the objective of the present study to analyze the current state of phytoplankton in the reservoir and analyze its connection with microbiological indicators for water quality and environmental factors.

Materials and Methods

Study area

Batak Reservoir (IBW1316) is part of the largest water cascade Dospat-Vacha. It is situated in the Western Rhodope Mountains, Southern Bulgaria near the town of Batak on the river Matnitsa (Michev and Stoyneva, 2007). According to Belkinova and Gecheva (2013), it is designed as heavily modified water body in oligotrophic conditions and based on the Bulgarian topology it refers to the mountain and semi-mountain lake types. The reservoir was built in 1959 and its main morphometric characteristics are present in Table 1. Currently, the reservoir is used for cage aquaculture, tourism and as a drinking water supply.

Table 1
Morphometrical characteristics during the investigation period of the Batak reservoir

Year	2015
Reservoir name	Batak (IBW1316)
Altitude (m)	1107
Water volume (m^3)	310 x 10^{-6}
Tributary	Matnitsa River
Source	Matnitsa River
Built	1959
Location	South Bulgaria
Outflow (m^3)	124.8
Catchment area (km^2)	463.29
Station	1 (Wall)
GPS coordinates	(42°00.877′N) (024°11.948′E)
Station	2 (Cages)
GPS coordinates	(41°57.371′N) (024°10.948′E)
Station	3 (Island)
GPS coordinates	(41° 57.704′N) (024°10.094′E)
Station	4 (Tail)
GPS coordinates	(41°57.965′N) (024°12.390′E)

Water sampling

Samples for phytoplankton, microbiological and physicochemical analysis were collected from four sites in the aquatory of the reservoir (Figure 1). The water samples for phytoplankton physicochemical analysis were collected by Niskin-Type water sampler 5 L model (Hydro-Bios Apparatebau GmbH, Germany) from the epi-, meta- and hypolimnion at each site. The phytoplankton samples were processed by standard methods of fixation with formalin to final concentration 4% and further sedimentation (ISO 5667-1:2006/AC:2007; ISO 5667-3:2003/AC:2007). The samples for determination of the total count of viable bacteria (TVC) were collected from the superficial layer (0.5 m below the surface), metalimnion and the bottom layer (1 m above the sediment) using MICROS water sampler (Hydro-Bios Apparatebau GmbH, Germany). TVC, determined at 22°C, was expressed as colony forming units per liter (cfu.l^{-1}).

Physicochemical analysis

Water temperature (TMP) and dissolved oxygen (DO) were measured *in situ* with an oxygen meter (WTW OXY 1970i). Electrical conductivity (Cond.) and pH were measured with WTW conductivity meter (Cond3310/SET) and WTW

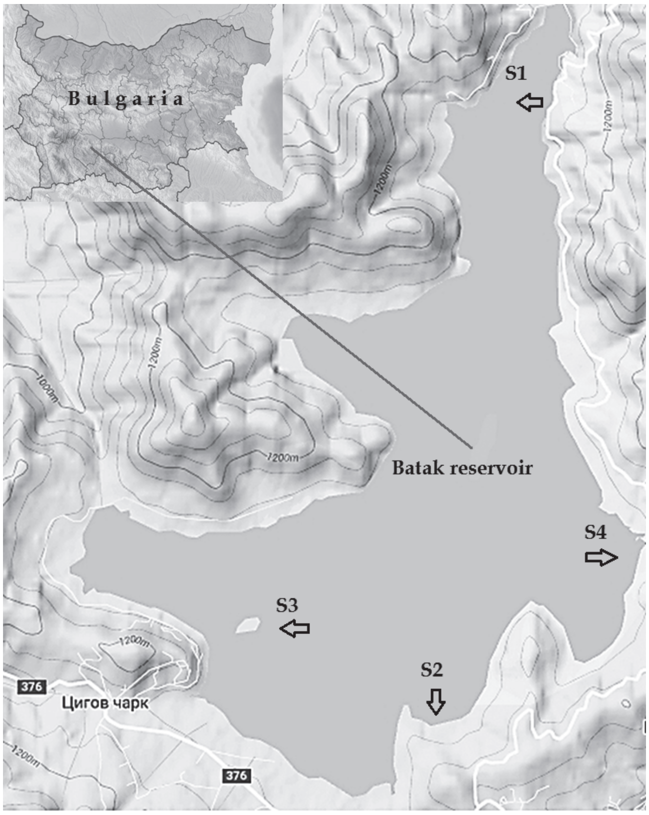

Fig. 1. Map of the Batak reservoir with his position in Bulgaria and location of the sampling sites

pH-meter (315/SET) respectively. Ammonium (NH_4-N), nitrate (NO_3-N) and total nitrogen (TN, $mg.L^{-1}$), manganese III COD (COD_{Mn} $mg.L^{-1}$) were measured in laboratory using standard analytical methods (ISO 8467:1993; ISO 5664:1984; ISO 7890-1:1986; ISO 6878:2004) as described by Iliev et al. (2017). Total phosphorus (TP $mg.L^{-1}$) concentration was measured by Phosphate Cell Test (114543, Merck Millipore).

Phytoplankton analysis

Phytoplankton abundance (PhN) was determined by direct microscope counting on Bürker chamber (Laugaste, 1974). The counting was carried out individually (cell, filament or colony). The numbers (PhN) are expressed as $x10^{-6}cells.L^{-1}$. The biomass (PhB) is expressed as $mg.L^{-1}$. The species composition was determined by light microscopy at magnification x400 on Carl Zeiss, Axioscope 2, using standard taxonomic literature with the critical use of AlgaeBase (Guiry and Guiry, 2017). Diatoms were identified after Cox (1996). The cell was used as the main counting unit and the biomass was estimated by the method of stereometrical approximations (Rott, 1981; Deisinger, 1984).

Statistical analysis

Statistical analysis was performed with SPSS 13 (IBM analytical). The experimental data were processed by correlation analysis to establish and evaluate the relationship between the tested parameters, expressed by Pearson's correlation coefficient. A hierarchical cluster analysis (Ward, 1963; Duran and Odelle, 1977) was used to identify the similarity between the samples tested and their grouping on the basis of important indicators. The Euclidean distance was used as a measure of similarity. To avoid differences in dimensions of the surveyed indicators, the data was previously standardized. The clusterization results were plotted by a dendrogram showing the cluster formation and the distance between objects.

Table 2
Mean values of abiotic indicators in Batak reservoir

Date	Station	TMP	Cond.	pH	O_2	COD_{Mn}	NH_4-N	NO_3-N	TN	TP
Measure	N	T°C	µS/cm		$mg.L^{-1}$	$mg.L^{-1}$	$mg.L^{-1}$	$mg.L^{-1}$	$mg.L^{-1}$	$mg.L^{-1}$
	S1	14.7±7.65	131.2±5.5	7.94±0.7	6.5±2.3	6.53±4.7	0.11±0.01	0.19±0.11	0.3±0.1	0.17±0.1
July	S2	17.7±7.5	129.8±2.8	7.7±0.3	6.46±2	8.81±4.5	0.13±0.03	0.36±0.24	0.5±0.24	0.08±0.08
	S4	20.7±4.5	129.1±0.8	8.3±0.4	6.13±1.6	3.78±1	0.09±0.01	0.26±0.07	0.36±0.07	0.08±0.03
	S1	14.1±6.1	134.8±4.7	7.06±0.3	4.2±4.2	3.39±0.2	0.12±0.02	1.15±0.48	1.27±0.47	0.2±0.08
September	S2	16.4±5	181.6±65.3	7.19±0.2	4.84±3.9	2.9±0.2	0.07±0.01	0.87±0.29	0.94±0.29	0.16±0.08
	S3	17.6±0.9	139.4±1.3	7.32±0.01	6.1±0.3	2.54±0.1	0.3±0.6	0.92±0.04	1.22±0.55	0.08±0.01
	S4	19.6±0.4	135.2±1	7.27±0.1	8.3±0.4	2.84±0.3	0.09±0.02	0.88±0.06	0.98±0.03	0.1±0.01
	S1	10.4±0.6	135.4±1.8	6.76±0.05	4.8±1.9	4.26±1.5	0.26±0.06	2.63±1.36	2.89±1.38	0.05±0.01
November	S2	11.3±0.2	132.2±1.4	6.97±0.15	8.22±0.2	2.95±0.4	0.1±0.02	0.72±0.09	0.82±0.09	0.12±0.05
	S3	11.3±0.2	132.9±0.4	7.28±0.05	8.16±0.1	3.08±0	0.12±0.02	0.66±0.07	0.78±0.09	0.05±0.02
	S4	11.4±0.4	133.2±0.7	7.19±0.01	7.98±0.1	2.7±0	0.1±0.01	0.56±0.08	0.67±0.06	0.06±0

Results

The detailed information regarding the physicochemical conditions in the reservoir for the studied period is presented in Table 2. We did not establish spatial differences in the water temperature and the level of dissolved oxygen (DO). Seasonally the average temperature values were in the range of 10.4°C in November to 20.4°C in July. DO levels varied in the water column with significant decrease below the 15th meter. The pH values were close to neutral with the exception of the July samples and have a strong positive correlation with the water temperature (Table 2). The values for nitrate (NO_3-N), total nitrogen (TN) and total phosphorus (TP) showed a similar trend with highest values detected near the dam wall of the reservoir (S1).

The composition of phytoplankton and seasonal variations

A total of 106 phytoplankton taxa were identified in the samples from Batak reservoir (Figure 2). The highest taxa richness was established in September (80) and the lowest was in July (34) (Figure 3). In the summer, class Bacillariophyceae dominated in the community being presented by a total of ten species, followed by the divisions Cyanoprokaryota (8) and Chlorophyta (5). In the samples from S1, 99 different taxa were identified for the studied period with eighteen species registered in July, forty-nine in September and thirty-two in November (Figure 3). Class Bacillariophyceae and division Chlorophyta were the most abundant and Cyanoprokaryota was presented by only one species. At the S2 station, 72 taxa were registered, distributed as follows: 20 in the July samples, 34 in the September samples and 18 species in the November samples with the pronounced dominance of Bacillariophyceae. At the S3 station, the phytoplankton community was presented by 31 taxa in September and 23 in November. The phytoplankton at S4 station was characterized by similar dynamics with diversity maximum in September with 39 identified species affiliated primarily to Bacillariophyceae and Chlorophyta (Figure 3). For the entire period, a total of 57 different taxa were identified at this station.

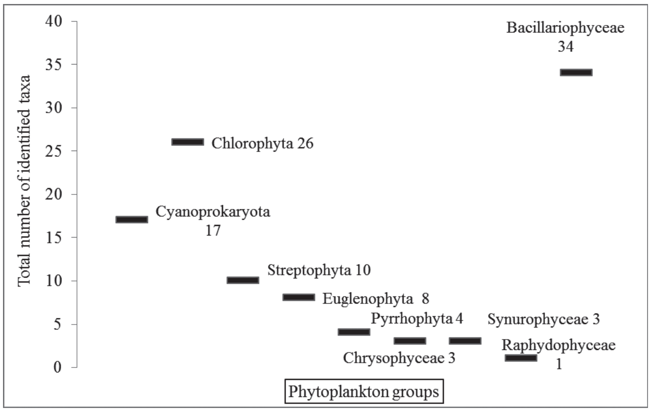

Fig. 2. Number of species and distribution of phytoplankton groups in Batak reservoir

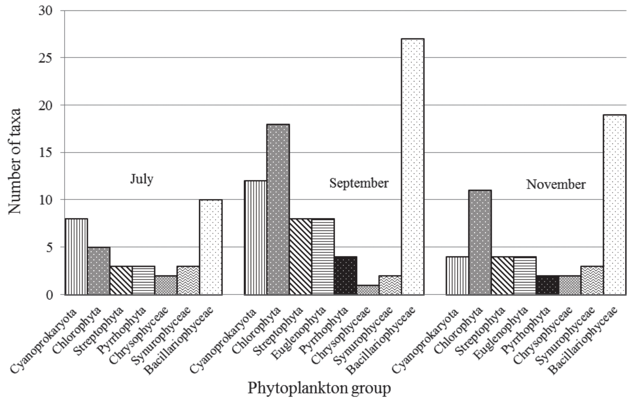

Fig. 3. Seasonal distribution of phytoplankton in Batak reservoir

At all stations, the diatoms dominated the community with some seasonal differences in the dominant complex (Table 3). In July the diatoms *Tabellaria fenestrata* var. *asterionelloides, Fragilaria crotonensis, Stephanodiscus hantzschii* Grunow and blue-green algae *Aphanizomenon flosaquae* were the most abundant in the water samples, while in September the dominant complex included also *Asterionella formosa* Hassall, *Trachelomonas planctonica* Svirenko, *Elakatothrix gelatinosa* Wille and *Ceratium hirundinella* (O.F. Muller) Dujardin. In November diatoms again dominated in the community along with species such as *Uroglena* sp., *Trachelomonas volvocina* Ehrenberg, *Mallomonas caudata* Iwanoff (Ivanov), *Pandorina morum* and *Woronichinia naegeliana*. We have established differences in the phytoplankton abundance between stations regarding the species with highest cell numbers. At S1 the highest number along with diatoms had *Aphanizomenon flosaquae* and *Cosmarium* sp., while in September *Merismopedia punctata* Meyen, *Staurastrum pingue* var. *planctonicum* (Teiling) Coesel & Meersters and *Trachelomonas planctonica* were the most abundant. The species *Desmodesmus communis*, *Trachelomonas volvocina, Ceratium hirundinella,* and *Mallomonas acaroides* dominated in November (Table 3). At S2 the species from the class Bacillariophyceae dominated along with *Aphanizomenon flosaquae* and *Cosmarium* sp. in July, *Aphanizomenon flosaquae, Elakatothrix gelatinosa*

Table 3
List of phytoplankton taxa observed in Batak reservoir

Taxa	**VII**			**IX**				**X**			
Sites	1	2	4	1	2	3	4	1	2	3	4
Cyanoprokaryota											
Anabaena sphaerica Bornet & Flahault	*	*	*								
Anabaena sp.					*						
Anathece clathrata (W.West & G.S.West) Komárek, Kastovsky & Jezberová					*						
Aphanizomenon flosaquae Ralfs ex Bornet & Flahault	**	**	**	*	**	*	*				
Aphanocapsa elachista West & G.S.West					*						
Chroococcus turgidus (Kützing) Nägeli		*	**	*	*	*	*	*		*	*
Dolichospermum scheremetieviae (Elenkin) Wacklin, L.Hoffmann & Komárek					*	*	*				
Dolichospermum spiroides (Klebahn) Wacklin, Hoffmann et Komárek	*	*									
Gomphosphaeria sp.							*			*	
Limnococcus limneticus (Lemmermann) Komárková, Jezberová, O.Komárek & Zapomelová	*			*		*	*			*	
Merismopedia punctata Meyen				**							
Microcystis aeruginosa (Kützing) Kützing	*	*									
Microcystis sp.				*							
Oscilatoria sp.			*								
Oscillatoria limosa C.Agardh ex Gomont				*							
Planktothrix agardhii (Gomont) Anagnostidis & Komárek	*										
Woronichinia naegeliana (Unger) Elenkin				*						**	
Chlorophyta											
Actinastrum hantzschii Lagerheim						*					
Ankistrodesmus fusiformis Corda				*		*					
Ankyra judayi (G.M. Smith) Fott						**	*				
Botryococcus braunii Kützing		*									
Characium angustum A.Braun	*			*							
Characium sp.								*		*	
Coelastrum microporum Nägeli in A. Braun			*							*	
Crucigenia tetrapedia (Kirchner) Kuntze				*	*			*			
Desmodesmus communis (E.Hegewald) E.Hegewald		*	*	*	*	*	*	**			
Desmodesmus protuberans (F.E.Fritsch & M.F.Rich)								*			
Golenkinia radiata Chodat								*			
*Korshikoviella limnetica (*Lemmermann) P.C.Silva						*					
*Monactinus simplex (*Meyen) Corda				*							
Monoraphidium contortum (Thuret) Komárková-Legnerová							*				
Monoraphidium sp.				*		*		*			
Pandorina morum (O.F.Müller) Bory							*		**	**	
Pediastrum duplex Meyen				*				*			
Pseudodidymocystis planctonica (Korshikov) E.Hegewald & Deason				*							

Table 3 (Continued)

Pseudotetrastrum punctatum (Schmidle) Hindák				*							
Scenedesmus arcuatus (Lemmermann) Lemmermann							*				
Scenedesmus quadricauda var. *eualternans* Proshkina-Lavrenko				*							
Stauridium tetras (Ehrenberg) E.Hegewald							*				
Tetradesmus obliquus (Turpin) M.J.Wynne			*	*		*					
Tetraedron minimum (A.Braun) Hansgirg								*			
Tetrastrum glabrum (Y.V.Roll) Ahlstrom & Tiffany				*	*						
Volvox sp.										*	
Streptophyta											
Closterium aciculare T.West										*	
Closterium acutum Brébisson		*		*			*				
Cosmarium baileyi Wolle				*		*					
Cosmarium margaritiferum Meneghini ex Ralfs		*									
Cosmarium sp.	**	**	*	*	*	*	*				*
Elakatothrix gelatinosa Wille				**	**		*				
Elakatothrix genevensis (Reverdin) Hindák				*	*	*	**				
Elakatothrix lacustris Korshikov							**				
Staurastrum pingue var. *planctonicum* (Teiling) Coesel & Meersters				**				*	*	*	
Staurastrum sp.				*							*
Euglenophyta											
Euglena granulata (G.A.Klebs) F.Schmitz				*		*	*				
Euglena sp.					*			*			
Lepocynclis acus (O. F. Müller) Marin et Melkonian				*							
Trachelomonas planctonica Svirenko				**	**	**	**				
Trachelomonas sp.				*				*		*	
Trachelomonas volvocina Ehrenberg						*		**	**	**	*
Trachelomonas hispida (Perty) F.Stein					*						
Trachelomonas oblonga Lemmermann				**		*		*			
Pyrrhophyta											
Ceratium hirundinella (O.F. Muller) Dujardin		*	*	*	*	**	**	**		*	*
Gymnodinium uberrimum (G.J.Allman) Kofoid et Swezy	*						*				
Gymnodinium sp.			*			*			*	*	
Peridinium sp.						*					
Ochrophyta											
Chysophyceae											
Chrysosphaerella longispina Lauterborn	*										
Uroglena volvox Ehrenberg										*	*
Uroglena sp.	*	*	*	*	*	**	*	**	**	**	*
Raphidophyceae											
Vacuolaria sp.								*			

Table 3 (Continued)

Synurophyceae											
Mallomonas acaroides Perty	*	*		*			*	**	**		
Mallomonas sp.	*			*	*		*	**	**	*	**
Mallomonas caudata Iwanoff (Ivanov)		*	*					*	*	*	**
Bacillariophyceae											
Achnanthes sp.					*						
Amphora sp.				*	*						
Asterionella formosa Hassall	*	**	**	**	**	**	**	**	**	**	**
Aulacoseira granulata (Ehrenberg) Simonsen				**	**		**	**	**		**
Aulacoseira granulata var.*angustissima* (Otto Müller) Simonsen								*		*	
Aulacoseira italica (Ehrenberg) Simonsen					*						
Caloneis amphisbaena (Bory) Cleve					*						
Caloneis sp.											*
Cocconeis placentula Ehrenberg			*	*				*			
Cocconeis placentula var.*eugliptoides* L.Geitler				*							
Cyclotella glomerata H.Bachmann										*	*
Cyclotella sp.		*		*		**	*	*			
Cymbella cistula (Ehrenberg) O.Kirchner									*		
Cymbella cymbiformis C.Agardh			*		*		*	*			*
Cymbella sp.				*	*				*		
Diatoma hyemalis (Roth) Heiberg							*				
Diatoma vulgaris Bory					*						
Epithemia frickei Krammer							*				
Fragilaria acus (Kützing) Lange-Bertalot							**				
Fragilaria crotonensis Kitton	**	**	**	**	**	**	**	**		**	**
Fragilaria sp.							*				
Gomphonema acuminatum Ehrenberg			*								
Gomphonema gracile Ehrenberg							*				
Gyrosigma acuminatum (Kützing) Rabenhorst					*		*				
Lindavia bodanica (Eulenstein ex Grunow) T.Nakov, Guillory, Julius, Theriot & Alverson						*	*				
Navicula sp.				*	*	*		*	*		*
Nitschia sp.				*					*		*
Rhopalodia gibba (Ehrenberg) Otto Müller								*			
Stephanodiscus astraea (Kützing) Grunow				*	*	*					
Stephanodiscus hantzschii Grunow	**	**	*	**	**	**	**		*	*	*
Stephanodiscus sp.								*			
Tabellaria fenestrata (Lyngbye) Kützing	*	*	*	*		*	*	*	*		
Tabellaria fenestrata var.*asterionelloides* Grunow	**	**	**	**	**	**	**	**	**	**	**
Ulnaria ulna (Nitzsch) Compère			*	*	*		*		*		

** dominant species

и *Trachelomonas planctonica* in September, and *Pandorina morum, Mallomonas acaroides* Perty и *Mallomonas* sp. in November. In September *Ankyra judayi* (G.M. Smith) Fott*, Trachelomonas planctonica, Ceratium hirundinella* and *Uroglena volvox* Ehrenberg had the highest abundance along with the diatoms at S3, while in November we established algal bloom of the blue-green species *Woronichinia naegeliana* in the surface water layer. The Bacillariophyceae dominated in the samples from S4, with *Aphanizomenon flosaquae* and *Chroococcus turgidus* (Kützing) Nägeli in July, which were replaced by *Elakatothrix lacustris* Korshikov*, Elakatothrix gelatinosa, Trachelomonas planctonica* and *Ceratium hirundinella* in September and *Mallomonas* sp. and *Mallomonas caudata* – in November (Table 3).

In July the peak values for phytoplankton abundance and biomass were registered in the samples from S1 with the domination of *Tabellaria fenestrata* var. *asterionelloides* and *Fragilaria crotonensis*, and the minimum in the hypolimnion again at the same station (Figure 4). In September the maximum has shifted from S1 to S4 station again with the pronounced dominance of the diatoms *Stephanodiscus hantzschii*, *Fragilaria crotonensis* and *Tabellaria fenestrata* var. *asterionelloides*. At S2 and S3 stations where the abundance was at its minimum, *Trachelomonas planctonica*, *Ankyra judayi*, *Stephanodiscus hantzschii* и *Asterionella formosa* dominated (Figure 4). In November a vertical shift was observed with highest phytoplankton numbers between 7 and 12 m depth at S1 and S3 with the mass development of *Tabellaria fenestrata* var. *asterionelloides*, *Trachelomonas volvocina* and *Woronichinia naegeliana* (Figure 4). Seasonally for the studied period, the peak values of the phytoplankton abundance were established in September and the lowest in July. Spatially the maximum values were recorded at S4, while the minimum was reported in the hypolimnion at S1. Spatial and vertical distribution of the algal flora was uneven with maximum abundance in the epilimnion followed by a steep vertical decrease.

The correlation analysis showed a significant positive correlation between pH and TMP (r = 0.711), TN and NO_3-N (r = 0.981), PhB and PhN (r = 0.857) (Table 4). Highly positive values for the Pearson correlation coefficient were established for PhB and NH_4-N; PhN and NH_4-N. Moderate positive correlations were established for TN and NH_4-N; PhN and TMP; TVC and TMP; TVC and PhN; TVC and TP, and negative for NO_3-N and TN. The nitrogen forms correlate negatively with the pH (Table 4), while TP showed no correlation with the other studied parameters. Cluster analysis (CA) grouped the studied samples in two separate clusters as shown in Figure 5. The cluster distances and description of the samples are presented in Table 5. The first cluster (CA1) includes two sub-clusters. The first sub-cluster is the most homogeneous. It includes twelve samples (25, 26, 18, 20, 21, 29, 15, 16, 17, 27, 28, and 7) taken primarily in the autumn from the euphotic water layer. All of them, with the exception of 25, had similar spatial and seasonal characteristics (Figure 5). The samples from the metalimnion and hypolimnion (5, 14, 6 and 3), gathered in the autumn are joins together in a separate sub-cluster. The second cluster (CA2) also joins two sub-clusters representing the S4 station samples (22, 23 and 24) and surface samples from the lacustrine area of the reservoir (1, 10 and 4) with similar spatial characteristics respectively. The CA showed that the samples 1 and 19 are characterized by the highest coefficient for inter-group distance. These two samples are also hierarchically distant from all of the other stations. The large hierarchical distance is mainly due to the differences in the climatic conditions, water level and seasonal changes in the reservoir during the study period. According to the analysis, hierarchically the stations in the lacustrine area near the dam wall and at the tail of the reservoir had the largest cluster distance.

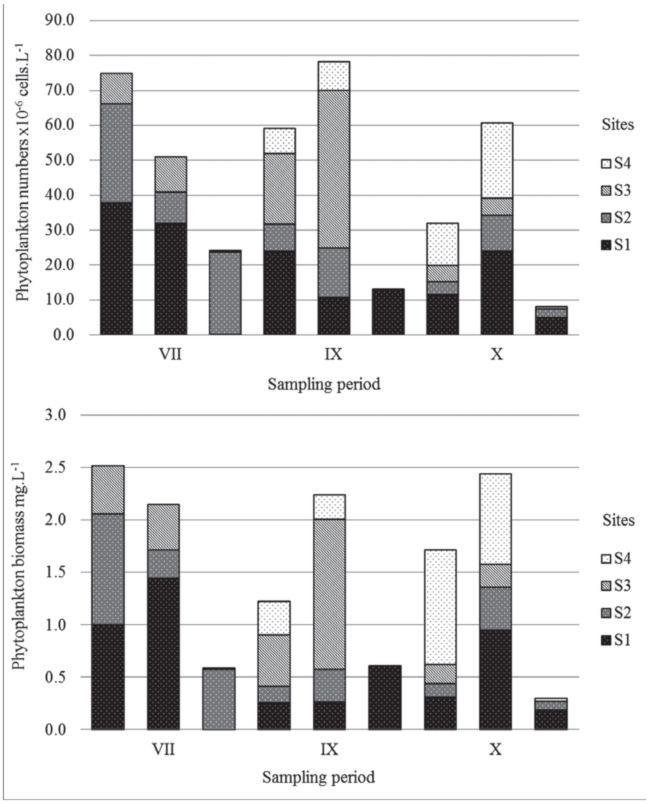

Fig. 4. Numbers (x10^{-6} cells.L^{-1}) and biomass (mg.L^{-1}) of phytoplankton in Batak reservoir

Table 4
Correlation dependencies of the abiotic and biotic indicators in the Batak reservoir

	TMP	Cond	pH	DO	COD_{Mn}	NH_4-N	NO_3-N	TN	TP	PhN	PhB	TVC 22°C
TMP	1											
Cond	0.154	1										
pH	0.711**	-0.117	1									
DO	0.357	0.065	0.190	1								
COD_{Mn}	-0.057	-0.148	0.332	-0.123	1							
NH_4-N	0.087	-0.053	-0.098	0.052	-0.042	1						
NO_3-N	-0.352	0.020	-0.593**	-0.363	-0.147	0.260	1					
TN	-0.310	0.008	-0.571**	-0.327	-0.145	0.441*	0.981**	1				
TP	0.270	0.210	0.108	-0.122	-0.285	-0.188	-0.180	-0.205	1			
Ph_N	0.379*	-0.117	0.304	0.107	0.142	0.505**	0.003	0.104	0.199	1		
Ph_B	0.219	-0.174	0.270	0.097	0.158	0.446*	0.001	0.090	-0.094	0.857**	1	
TVC 22°C	-0.378*	-0.215	-0.123	0.264	-0.052	-0.113	0.013	-0.011	-0.351	-0.394*	-0.124	1

*Correlation in significant at the 0.05 level (2-tailed)
**Correlation in significant at the 0.01 level (2-tailed)

Table 5
Combining clustering and inter-group distance

Steps	Combined Cluster 1	Clusters Cluster 2	Coefficients
1	25	26	0.272
2	20	21	0.312
3	20	29	0.584
4	15	20	1.168
5	27	28	1.435
6	15	16	1.721
7	22	23	1.837
8	18	25	2.138
9	15	17	2.829
10	5	14	3.588
11	7	27	3.740
12	1	10	3.742
13	15	18	5.562
14	5	6	6.294
15	7	15	6.535
16	22	24	7.456
17	8	9	9.261
18	11	12	10.287
19	3	5	12.166
20	1	4	12.338
21	2	11	12.807
22	3	7	16.396
23	1	22	17.344
24	1	3	20.828
25	1	2	25.922
26	1	8	39.378
27	1	13	42.807
28	1	19	53.814

Legend

Site (Depth m)	Samples	Period
S1(1)	1	VII
S1(7)	2	
S1(24)	3	
S1(1)	4	IX
S1(13)	5	
S1(19)	6	
S1(1)	7	X
S1(5)	8	
S1(15)	9	
S2(1)	10	VII
S2(6)	11	
S2(14)	12	
S2(1)	13	IX
S2(11)	14	
S2(1)	15	X
S2(6)	16	
S2(12)	17	
S3(1)	18	IX
S3(5)	19	
S3(1)	20	X
S3(8)	21	
S4(1)	22	VII
S4(4)	23	
S4(10)	24	
S4(1)	25	IX
S4(8)	26	
S4(1)	27	X
S4(1)	27	
S4(8)	28	X
S4(12)	29	

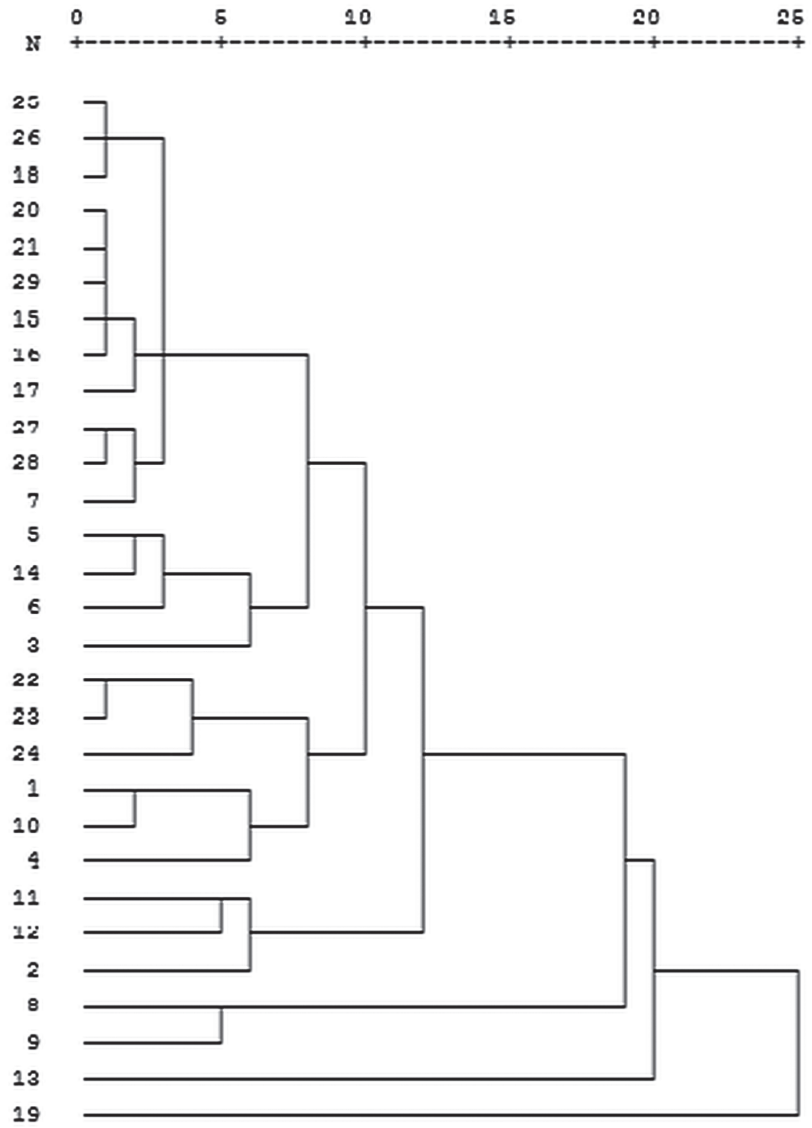

Fig. 5. Dendrogram based on mean inter-group Euclidean distances

Discussion

In the first years after the impoundment of the reservoir Naidenov (1964) identified fifty-three algae taxa and only three years later their number was reduced to forty-five. These differences are a result of the disappearance of marsh species and the appearance of lake species (Ludskanova, 1967). A total of eighty species of algae have been identified for the period 1972-1774 (Saiz, 1977). In our study, we have identified a hundred and six taxa with the pronounced dominance of Bacillariophyceae, Chlorophyta, and Cyanoprokaryota. Saiz (1977) registered two seasonal peaks in the phytoplankton development. The author has proven that the diatoms dominate in the community and the phytoplankton fluctuations are highly dependent on the water level. The water and temperature regimes have a significant impact on the development of phytoplankton. The high summer temperatures reduce the intensity of diatoms and the temperature decrease leads to increase of their number respectively. The peak in their abundance coincides with spring and autumn water overturns (Saiz, 1977). According to the same study green algae had the highest species diversity, but in terms of abundance, the diatoms had a predominant role. Seasonally the species composition remains relatively constant. Opposed to Saiz (1977) according to our findings the diatoms were the most diverse group regarding the species composition of the phytoplankton. In the seventies the dominant complex was composed by the diatoms *Fragilaria radians* (Kützing) D.M.Williams & Round, *Cyclotella* sp., *Aulacoseira granulata* (Ehrenberg) Simonsen, *A. granulata* var. *angustissima* (Otto Müller) Simonsen and the green algae *Acutodesmus acutiformis* (Schröder) Tsarenko & D.M.John, *Desmodesmus communis* and *Willea apiculata* (Lemmermann) D.M.John, M.J.Wynne & P.M.Tsarenko (Saiz, 1977). In the present study the composition has shifted to *Tabellaria fenestrata* var. *asterionelloides, Fragilaria crotonensis, Stephanodiscus hantzschii, Asterionella formosa* and *Aulacoseira granulata* from the diatoms and *Pandorina morum*, *Desmodesmus communis* and *Ankyra judayi* from the green algae. According to Saiz (1977), *Mallomonas* sp. and *Dinobryon divergens* O.E.Imhof were registered primarily in the spring and autumn, while in 2015 *Uroglena* sp., and *Uroglena volvox* had the highest number in the samples. The division Euglenophyta is presented by *Trachelomonas planctonica* и *Trachelomonas volvocina*. There are no significant changes in its composition in the last forty years. According to earlier studies the division Cryptophyta have been presented by *Cryptomonas* sp., and Cyanoprokaryota with *Microcystis aeruginosa* (Kützing) Kützing and *Spirulina* sp., presented by a small number (Saiz, 1977). At present study their number and diversity have significantly increased with 17 taxa identified in our samples. The species *Aphanizomenon flosaquae* and *Woronichinia naegeliana* were part of the dominant complex, with an algal bloom of the second one in the surface waters near the island and the cage farm in November 2015. Saiz (1977) doesn't report significant seasonal differences in the taxonomic composition; he also established highest diversity in the autumn. Our data reveal seasonal differentiation in the dominant species. We have detected a high abundance of some Cyanoprokaryota species used as eutrophication indicators at S2 and S3 stations. The S1 and S4 stations were in good ecological potential with the domination of diatoms which are indicators for meso- to oligotrophic conditions. We detected the highest taxa richness in September with a minimum in the taxonomic diversity in July. There are similar reports regarding the mountain reservoirs in Bulgaria. According to Naidenov and Saiz (1977), the diatoms dominated in the Dospat reservoir and the green algae played a negligible role. They also reported that the abundance was higher in the metalimnion where the water temperature is sufficiently low for the normal development of the diatoms. Mihaljevic et al. (2010) suggest that the diatoms preserve their dominant position during the spring elevation of the water level prior to the stratification. A similar trend was detected in Dospat reservoir with 55 identified algae taxa and pronounced prevalence of the Bacillariophyceae (Dochin and Stoyneva, 2016).

The significant correlation between the phytoplankton and NH_4-N defines it as a substantial factor for its development in Batak reservoir. Correlations between the temperature, the PhN and the total number of heterotrophic microorganisms (TVC), as well as the correlation of the latter with the total phosphorus, are also of significance. The analysis of the spatiotemporal changes of the phytoplankton allows the grouping of similar samples as well as the identification of different relations in the phytoplankton communities (Polikarpov et al., 2009). The CA grouped the studied samples in two clusters, each of them composed of two sub-clusters joining samples with a high degree of similarity. The coefficients for inter-group distance showed that the stations situated near the tail (S4) and dam wall (S1) of the reservoir had the highest cluster distance. Such similarity in seasonal and spatial characteristics is reported in the work of Kwon et al. (2009). The CA could serve as a valuable tool for accurate definition and determination of the sampling sites in monitoring programs in order to reduce the number of stations and frequency of sampling as well as to determine the similarities or differences between them based on different characteristics.

Conclusions

According to our results, Batak reservoir is characterized by a relatively rich algal flora with 106 taxa identified planktonic algae. The largest numbers of identified species belong to Bacillariophyceae (34), Chlorophyta (26) and Cyanoprokaryota (17). The variation in the species richness showed pronounced seasonal variation was highest values in September near the dam wall and the lowest in July at the same station. Phytoplankton abundance was characterized by vertical as well as seasonal differences with peak values in the epilimnion at S4 and minimum in the hypolimnion at S1. For the whole study period, at all studied sites in Batak reservoir the diatoms, green algae, and blue-green algae dominated. In November the surface water layer at S3 was dominated by *Woronichinia naegeliana*. Based on the cluster analysis, the surveyed stations were grouped into two main clusters with similar spatial and seasonal characteristics; the hierarchically most distant are the stations in the lacustrine area near the wall and the tail section of the reservoir.

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