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Original Scientific Paper

Qualitative and quantitative composition of the algal community in the water column of the Grlište reservoir (Eastern Serbia)

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ABSTRACT: The aim of this paper was to determine the diversity, density and biomass of algal populations in the water column of the Grlište reservoir, situated in Eastern Serbia. A total of 199 species were recorded during the study period, showing a well-diversified community. Temporal and spatial diversity patterns were investigated through seasonal variation in the abundance and biomass of taxa. Bacillariophyta, Chlorophyta and Cyanobacteria were considerably more abundant, in terms of both the number of taxa and the number of cells in the water column, than the remaining algal groups. The succession of these algal groups showed some similarities with Sommer's PEG model.

Keywords: algae, species diversity, biomass, seasonal succession, abundance.

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INTRODUCTION

The diversity and density of phytoplankton are used as an indicator of water quality in lakes and reservoirs (Badsil *et al.* 2012). Species diversity depends on changes in the environment, especially on stress and limiting factors (Khuantrairong & Traichaiyaporn 2008). Algal communities usually show a certain seasonality in their behaviour (Gallina *et al.* 2013). According to the plankton ecology group (PEG) model, seasonal succession of phytoplankton communities depends on nutrient availability, predation and competition (Sommer *et al.* 1986). The model consists of 24 statements and considers the successional sequence of phytoplankton and zooplankton in an idealised lake. Natural systems are subject to variation and depend on many physical, chemical and biotic environmental factors, among which the temperature and nutrients are the most important, as well as on many features of the lake itself that are involved in the seasonal succession of phytoplankton species (Reynolds 1989; Zohary *et al.* 2010; Gallina *et al.* 2013).

Over the years various investigations had been conducted at the Grlište reservoir, resulting in numerous publications covering various aspects of hydrology, geology and biology (Nikić *et al.* 2006a; Nikić *et al.* 2006b; Nikić *et al.* 2007; Svirčev *et al.* 2006; Svirčev *et al.* 2007; Stefanović *et al.* 2007; Stanković *et al.* 2009; Ćirić *et al.* 2012; Ćirić *et al.* 2013; Ćirić *et al.* 2015). During the last several years, the reservoir's drainage area had the greatest impact on the process of eutrophication (Ćirić *et al.* 2012). Eutrophication was often followed by the sporadic occurrence of cyanobacterial blooms (Svirčev *et al.* 2007). During the year 2012, the Serbian Environmental

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Protection Agency conducted water status monitoring at the Grlište reservoir in order to assess its ecological potential, seasonal dynamics of its phytoplankton and physical and chemical parameters of its water (Čađo *et al.* 2014; Denić *et al.* 2014). We studied this reservoir during the same year in an attempt to identify the dominant driving forces influencing phytoplankton functional groups and reveal the effect of water usage by the drinking water plant (Ćirić *et al.* 2015). In this paper we present some of our results, e.g., data on algal diversity, abundance and biomass in the water column of the Grlište reservoir.

MATERIALS AND METHODS

The Grlište reservoir is located 16 km southwest of the city of Zaječar in eastern Serbia and covers an area of 250 ha. The reservoir was created in 1989 by damming the Grliška river. It receives water from a hilly basin (an area of about 178 km^2) and two tributaries, the Lenovačka and Lasovačka rivers. Average water depth in the reservoir is 6 m, while the maximum depth is 22 m at the point just before the dam. The main purpose of this reservoir was to serve as a source of water supply, but over the course of time it has become multifunctional and is now also used for flood control and sport fishing (Stanković 2005).

The climate of the area in which the lake is situated is distinctly continental. The average temperature is about 27°C during the summer months and 4°C during the winter months. The mean annual amount of precipitation for the basin is 666.4 mm m^{-2}, while the mean annual wind speed is 1.5 m s^{-1} (Stanković 2005). The lake is monomictic due to noticeable stratification only during the summer months.

Qualitative and quantitative sampling of the algal community was conducted monthly over a period of 11 months at two sites: site 1 – in the middle of the reservoir (43° 48.983' N, 22° 13.212' E) and site 2 – at the place of water intake (43° 48.743' N, 22° 13.921' E). The sampling procedure and preservation of samples were described in detail by Ćirić *et al.* (2015).

Samples for qualitative analysis of populations from the epi- and hypolimnion were collected using a phytoplankton net, after which the samples were analysed using a Carl Zeiss AxioImager M1 microscope with AxioVision software and the following literature: Komárek & Fott (1983), Krammer & Lange-Bertalot (1986, 1991), Lenzenweger (1997, 1999), Komárek & Anagnostidis (1998, 2005), Reichardt (1999, 2001), Lange-Bertalot (2001), John *et al.* (2003), Krammer & Lange-Bertalot (2004), Coesel & Meesters (2007), Krizmanić (2009), Levkov (2009) and Lange-Bertalot *et al.* (2013). Taxa were separated into the following divisions: Cyanobacteria, Bacillariophyta, Chlorophyta, Chrysophyta, Cryptophyta, Dinophyta and Euglenophyta (Reynolds 2006).

Quantitative analysis of phytoplankton was performed using a Leica inverted microscope according to the Utermöhl method (Utermöhl 1958). Density of every taxon, expressed as the number of cells per milliliter, was multiplied by the volume of a single cell using the mean size of 25 individual specimens of each species. Biovolume was obtained using geometric approximations of individual algal cells (Hillebrand *et al.* 1999).

Diatoms were identified from subsamples treated with sulphuric acid and $KMnO_4$, which after washing with distilled water and drying in air were mounted in Naphrax and saved as permanent slides (Krammer & Lange-Bertalot 1986).

RESULTS

Algal communities of the Grlište reservoir are composed of 201 taxa (without unidentified Chlorococcales) – 199 species and 92 genera from eight divisions. The list of taxa is presented in Appendix (available online). Bacillariophyta had the highest number of species. One species, *Navicula trophicatrix* Lange-Bertalot, was recorded for the first time in Serbia (Fig. 1).

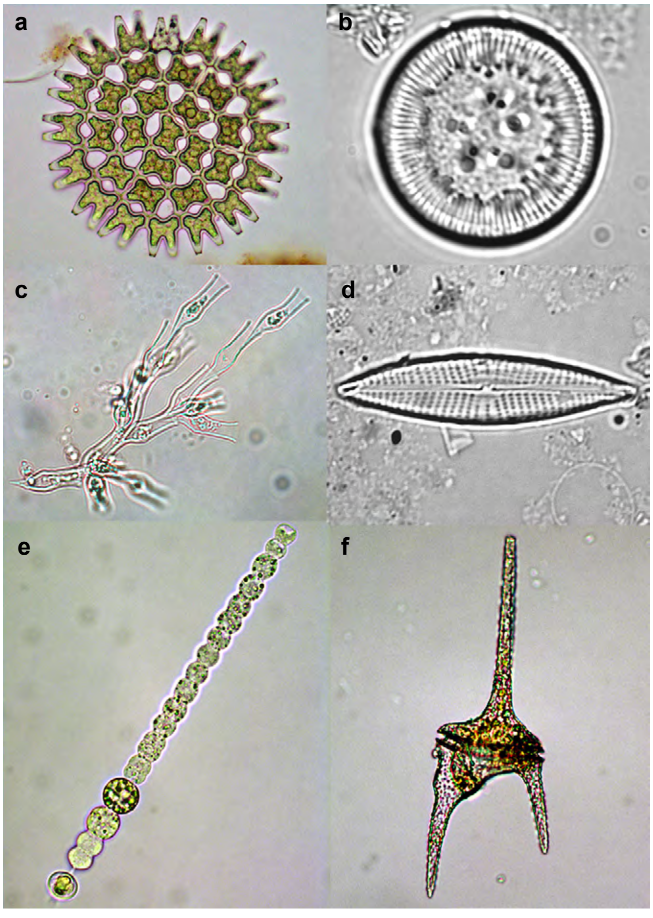

Fig. 1. Some representatives of dominant taxa in the Grlište reservoir. a – *Pediastrum duplex*; b – *Cyclotella ocellata*; c – *Dinobryon divergens*; d – *Navicula trophicatrix*; e – *Dolichospermum viguieri*; f – *Ceratium hirundinella*

Table 1. Counted numbers of taxa by seasons.

Division	Number of taxa by season			
	Spring	Summer	Autumn	Winter
Cyanobacteria	6	11	9	2
Bacillariophyta	58	39	41	71
Chlorophyta	19	41	33	12
Chrysophyta	1	1	1	0
Cryptophyta	2	3	2	2
Dinophyta	2	4	2	0
Euglenophyta	4	6	7	3
TOTAL	92	105	95	90

Total taxon numbers did not change much over the seasons, although there was considerable variation within the divisions (Table 1).

The most abundant groups were Bacillariophyta and Chlorophyta, with peak densities during May and June; and Cyanobacteria, with the highest density during October. Algae of the other divisions had considerably lower densities and attained maximum values mostly in the summer period. There was an expected similarity of total algal density and biomass. Bacillariophyta have the greatest influence on the total density and biomass throughout the year. Other groups of algae increased their numbers due to favourable conditions only during certain months (Fig. 2).

Algal density in the water column showed pronounced seasonal variations (Fig. 3). From May to July the highest density was observed at the surface. The first two observed peaks were attributable to maximal development of Bacillariophyta. The peak observed at 10 m during October is due to dominance of *Komvophoron minutum* (Skuja) Anagnostidis & Komárek (Cyanobacteria).

Among the dominant taxa of different divisions, *Cyclotella* spp. had the highest, while *Euglena clavata* Skuja and *Phacus* sp. had the lowest percentages in total biomass and number of cells per milliliter (Table 2). As for Cyanobacteria, *Dolichospermum viguieri* (Denis & Frémy) Wacklin, L.Hoffmann & Komárek was the dominant taxon at the surface, while *Komvophoron minutum* prevailed below the euphotic zone.

DISCUSSION

Of the total number of taxa recorded in the Grlište reservoir, the only three groups with considerable abundance in terms of both taxon numbers and the number of cells in the water column were Bacillariophyta, Chlorophyta and Cyanobacteria. More than half (115) of the recorded species belong to Bacillariophyta. This group showed somewhat higher diversity during the colder winter and spring months. In contrast, Chlorophyta and Cyanobacteria, represented with 51 and 16 taxa respectively, had a higher number of species during the favourable warmer conditions prevailing in summer and autumn. Our findings concerning algal dominance

Table 2. The list of all dominant taxa in each algal group, the months at which they occur and their density.

Division	**Dominant taxa**			
	by % in the total ind./ml	**Month**	**by % in the total biomass (mm^3/ml)**	**Month**
Cyanobacteria	*Komvophoron minutum* (54.3)*	Nov 2012	*Dolichospermum viguieri* (18.1)	Aug 2012
Bacillariophyta	*Cyclotella spp.* (99.6)	May 2012	*Cyclotella spp.*(99.2)	May 2012
Chlorophyta	*Scenedesmus sp.* (36.9)*	Jun 2012	*Pediastrum duplex* (69.8)*	Jun 2012
Chrysophyta	*Dynobrion divergens* (11.4)	Jun 2012	*Dynobrion divergens* (2.1)	Jun 2012
Cryptophyta	*Cryptomonas erosa* (64.2)*	Jul 2012	*Cryptomonas erosa* (54.1)*	Jul 2012
Dynophyta	*Peridinium umbonatum* (3.4)	Aug 2012	*Ceratium hirundinella* (32.9)	Sep 2012
Euglenophyta	*Phacus sp.* (0.4)*	Jun 2012	*Euglena clavata* (3.4)*	Jun 2012

Percentages are given in brackets.
An asterix denotes species found below the euphotic zone.

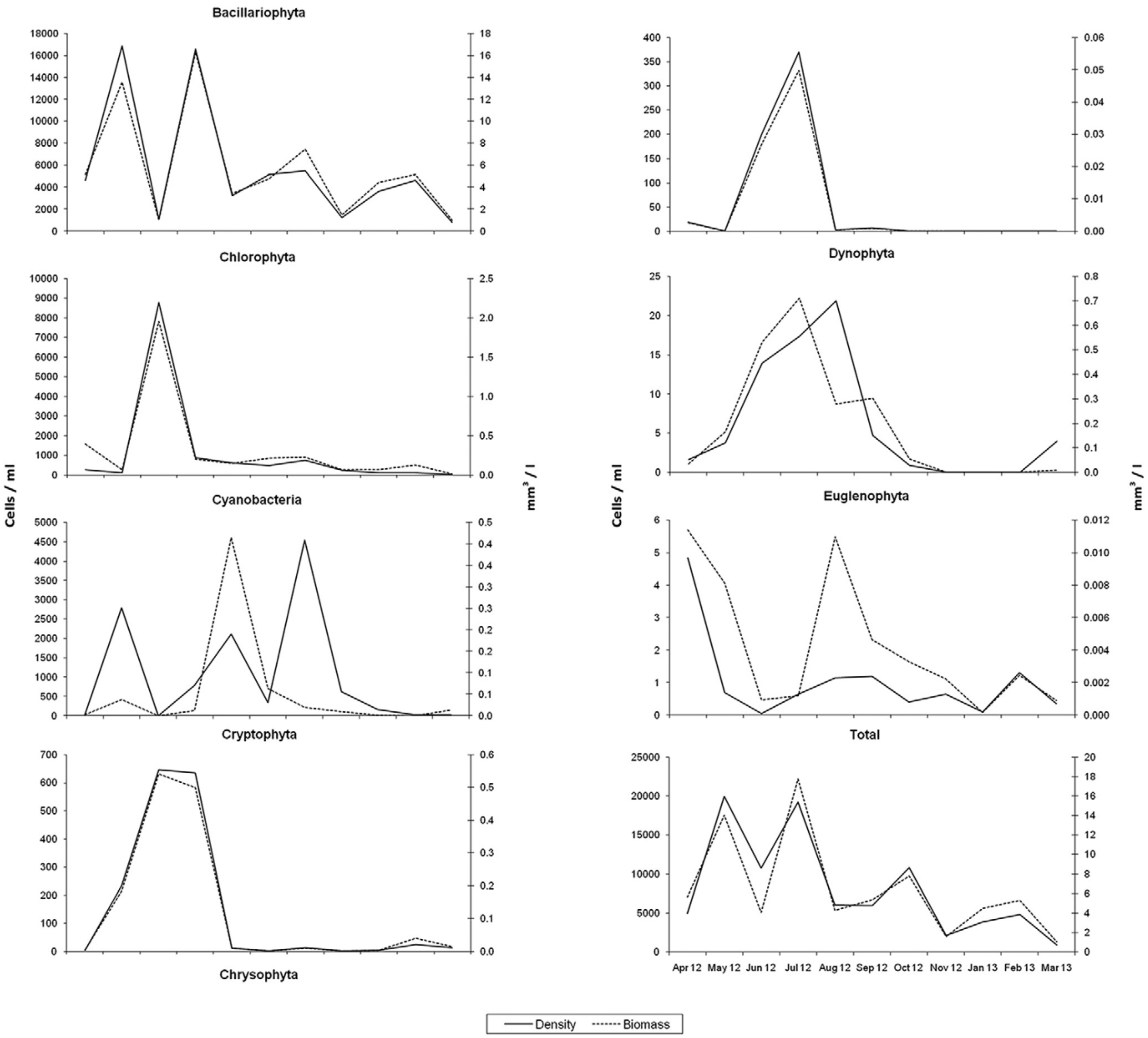

Fig. 2. Variation of algal density and biomass (calculated as the sum of all discrete samples in the water column) from different divisions in the Grlište reservoir.

coincide with the results reported by Čađo *et al.* (2014), but the number of recorded species was higher in our study. This can be explained by the fact that we sampled more often and up to a depth of 20 m, while they collected samples three times a year and not deeper than 15 m.

Bacillariophyta, Chlorophyta and Cyanobacteria were the most abundant groups of algae in the Grlište reservoir, and the succession of these algal groups showed some similarities with the PEG model (Sommer *et al.* 1986). The PEG model predicts the development of fast-growing algae such as centric Bacillariophyta in spring, due to increased light and better nutrient availability. In the Grlište reservoir, the first sudden development of Bacillariophyta occurred in late spring (May). The higher temperatures and elevated concentration of nutrients that are present during the summer allow the development of different planktonic algae, with Chlorophyta as one of the dominant groups (Sommer *et al.* 1986). In the Grlište reservoir, *Sphaerocystis planctonica* (Korshikov) Bourrelly from the division Chlorophyta was the most abundant taxon in phytoplankton in June, while *Scenedesmus* sp. and *Pediastrum duplex* Meyen were abundant below the euphotic zone. According to the PEG model, depletion of nutrients in summer occurs in the following order: phosphorus, silica, nitrogen. In our case, probably due to sedimentation of non-motile species or depletion of

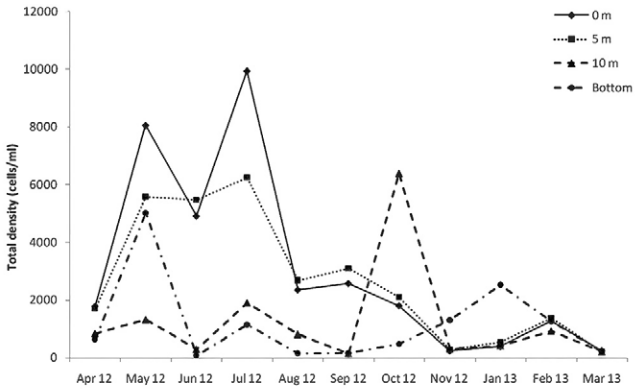

Fig. 3. Total algal density in the water column.

phosphorus during July, the biomass of Chlorophyta suddenly dropped, which allowed Bacillariophyta to have their second biomass peak. Development of Bacillariophyta depends mainly on thermal structure of the water column, but also on supplies of available silica, which becomes more available with phosphorus decline (Mukherjee *et al.* 2010). This is what happened in the Grlište reservoir – the Bacillariophyta bloom was probably promoted by relatively low concentrations of phosphates (Ćirić *et al.* 2015) and increased availability of silica. After the depletion of silica, rapid reduction of Bacillariophyta biomass occurred. Density and biomass values for both Chlorophyta and Bacillariophyta were fairly even throughout the year.

Cyanobacteria had the highest percentage in total algal density (ind./ml) in November, but the highest percentage in total biomass (mm^3/ml) in August. The most abundant species was *Komvophoron minutum*. However, the highest biomass occurred in August, due to significantly bigger cells of *Dolichospermum viguieri*. In the Grlište reservoir, this species was the most abundant up to a depth of 5 m. Cyanobacteria have gas vacuoles and maintain a certain position in the water column by regulating buoyancy. Also, their position in the water column is influenced by many other factors: nutrients, photic depth, carbon availability, stratification, etc. (Graham *et al.* 2008).

The most abundant group of algae in the Grlište reservoir was Bacillariophyta, due to their ability to utilise the nutrients. The highest density and biomass belonged to species of the genus *Cyclotella*.

The rest of the four algal groups recorded in the Grlište reservoir had significantly lower values of density and biomass compared to the afore mentioned dominant groups. Seasonal fluctuation of their density and biomass values showed similar trends.

CONCLUSION

Algal communities in the Grlište reservoir were characterised by the dominance of Bacillariophyta, Chlorophyta and Cyanobacteria in terms of taxon number and biomass. Cell density and biomass had the highest values during the late spring and summer months. The succession of algal groups showed some similarities with the PEG model. Consisting of a qualitative and quantitative analysis of the algal community in the reservoir, the present work contributes to a better understanding of its ecology.

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Botanica SERBICA

REZIME

Diverzitet i sezonska sukcesija zajednice algi u akumulaciji Grlište, Istočna Srbija

Bojan Gavrilović, Slađana Popović, Miloš Ćirić, Gordana Subakov–Simić, Jelena Krizmanić i Milka Vidović

Cilj ovog rada je određivanje diverziteta, brojnosti i biomase algi u akumulaciji Grlište, smeštenoj u Istočnoj Srbiji. Tokom perioda istraživanja zabeleženo je ukupno 199 vrsta, što ukazuje na veliku raznovrsnost. Prostorna i vremenska dinamika diverziteta je utvrđena na osnovu sezonske varijacije u gustini i biomasi taksona. Bacillariophyta, Chlorophyta i Cyanobacteria su u odnosu na druge grupe bile najbrojnije, u pogledu broja taksona i broja ćelija u vodenom stubu. Sukcesija ovih grupa algi pokazuje neke sličnosti sa Somerovim PEG modelom.

Ključne reči: alge, diverzitet vrsta, biomasa, sezonska sukcesija, brojnost.