Algal Diversity Along the Serbian Stretch of the Sava River

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Abstract

Phytoplankton analysis is an essential part in water quality monitoring and predicting changes in aquatic ecosystems. In this study we investigated structure and diversity of algal communities along the Serbian stretch of the Sava River. We detected 109 species in four sampling localities (Bosut, Sremska Mitrovica, Jarak and Makiš). Species richness increases from Bosut to Jarak. However, a sudden decrease of species richness was recorded in the Makiš locality, probably due to increased pollution. Divisive numerical classification separates species with relatively narrow distribution (that are grouped in three clusters) from more common species (that form four clusters). Correspondence analysis clearly separates upper-stream sites (Bosut and Sremska Mitrovica) from down-stream sites Jarak and Makiš.

Keywords: Algal communities, alpha diversity, beta diversity, Species groups, the Sava River.

Introduction

Phytoplankton and phytobentos are used in the determination of water quality according to the European Water framework Directive (WFD 2000). Qualitative and quantitative analyses of phytoplankton in the Serbian part of the Sava River were done on numerous occasions starting in 1939 (Simić et al. 2014). Some of them assessed water quality through indicator algal species or biomass and chlorophyll concentrations. During the First and Second Joint Danube Survey in 2002 and 2007 (Liška et al., 2008; Literáthy et al., 2002), a section of the Sava River was investigated. Some of the recent works on the Sava River and its tributaries have been summarized by Subakov and Karadžić (2010) and Simić et al. (2014).

The ecosystems along the Sava River are under increased pressure caused by a multitude of environmental stressors (Navarro-Ortega et al., 2015). The Sava River runs through numerous cities with developed industrial facilities (Zagreb, Sisak, Slavonski Brod, Bosanski Brod, Brčko, Sremska Mitrovica, Šabac, Obrenovac, Belgrade, etc.). Waste waters discharged from municipalities and industries along the Sava River and its tributaries were treated only at certain locations so the water quality used to be considerably endangered. The most important water pollutants, with harmful effects on human health, biodiversity, and environment, are persistent organic polluters, heavy metals, fertilizers, and radioactive elements.

Algae are important primary producers, since phytoplankton communities produce approximately half of the global net primary production (Field et al. 1998). Structure of algal communities primarily depends on light intensity, nutrient loads and biotic interactions (competition, grazing by larger zooplankton).

Some algal species and taxonomic groups show a clear preferences for particular environmental conditions, and can act as potential bioindicators, important for water quality monitoring. Eutrophication, resulting from increased nutrient input into a water body, is one of the most pervasive water quality problems, affecting lakes, estuaries, streams, and wetlands. Eutrophication is often driven by human activities such as agriculture, where fertilizer run-off and soil erosion are major sources of the nutrient load. The effects of eutrophication include algal/cyanobacteria blooms, leading to hypoxia and subsequent decline in submerged vegetation, and harmful effects on fish populations.

In this study we performed numerous analyses, in order to detect the structure and diversity of algal communities along the Serbian stretch of the Sava River.

Materials and Methods

Sampling Methods

Samples were collected at 4 sampling points along 206km of the river stretch (Table 1).

Table 1: Sampling locations

Sampling point	Latitude	Longitude	Date
Bosut	44.941889	19.369525	7/9/2012
Sremska Mitrovica	44.973000	19.601090	7/9/2012
Jarak	44.91112	19.76261	8/9/2012
Makiš	44.76669	20.35653	9/9/2012

We collected samples within the euphotic zone, corresponding approximately to the main depth of light penetration. Microscopical analysis of species populations within the collected water sample involved algal identification, followed by counts of individual cells and colonies. Taxonomic determination was performed using standard algae identification guides (Krammer and Lange–Bertalot, 1986, 1988, 1991a, 1991b).

A variety of different methods have been developed to identify and enumerate phytoplankton (Karlson, Cusack, and Bresnan, 2010). In this study we used the Utermöhl method (Utermöhl 1931, 1958).

Statistical Analyses

Different components of biotic diversity may be measured using a wide spectrum of indices (Pielou, 1975; Wilson and Shmida, 1984; Vellend, 2001; Anderson et al., 2010). Alpha diversity was calculated using the Shannon-Wiener function

$$H = -\sum_{i=1}^{s} p_i \log p_i$$

where p_i is the proportion for i^{th} species within a community, and s number of species within the community. Equitability was assessed using the relation (Pielou, 1975):

$$E = \frac{H}{H_{max}} = \frac{-\sum_{i=1}^{s} p_i \log p_i}{\log s}$$

Beta diversity was detected according to

$$\beta = \frac{l_{(H)} + g_{(H)}}{2}$$

where $l_{(H)}$ is the number of species lost, and $g_{(H)}$ the number of species gained along the habitat gradient (Cody, 1975).

To obtain detailed structure of algal communities, we performed the correspondence analysis (Greenacre, 1993, 2010). In order to detect species groups that have similar distribution, we performed numerical classification. Two main groups of classification methods involve agglomerative and divisive clustering procedures (Legendre. and Legendre, 1983, Karadžić and Marinković, 2009).

All statistical analyses were performed using the "FLORA" software package (Karadžić, 2013).

Results and Discussion

Taxonomic Diversity

We detected 109 species in four sampling localities (Bosut, Sremska Mitrovica, Jarak and Makiš). The taxonomic spectrum of algal communities in all samples is presented in Figure 1. Most species belong to divisions *Cyanobacteria* (blue-green algae) and *Bacillariophyta* (diatoms) and *Dinophyta* (dinoflagellates). A few representatives of *Cryptophyta* (cryptomonads), *Chrysophyta* (golden-brown algae) were recorded in the analyzed samples.

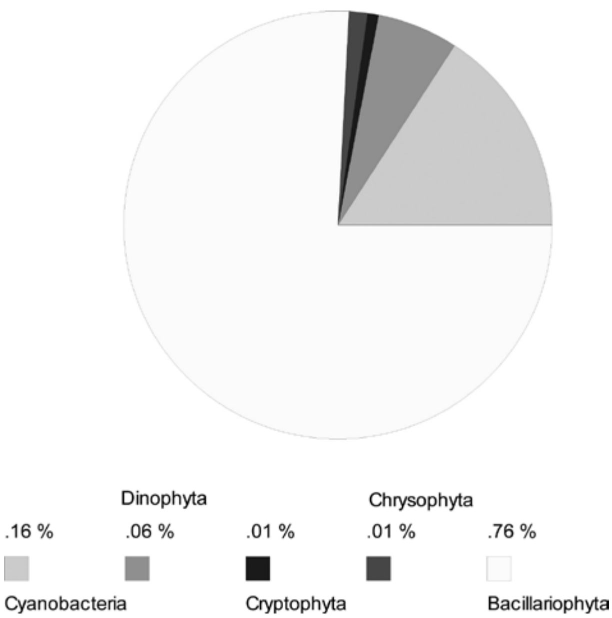

Figure 1: Taxonomic spectrum of algal communities in all sampling points.

The taxonomic spectrum for algal communities in separate samples is presented in Figure 2. Bacilariophyta dominate in Bosut and Sremska Mitrovica sampling points. The greatest proportion of Cyanobacteria was recorded in Jarak. Representatives of *Dinophyta* (*Ceratium hirundinella* (O.F.M.) Bergh, *Gymnodinium* (Stein) Kofoid & Swe sp., *Peridiniopsis* Lemm. Sp, *Peridinium* Ehr. sp., *Peridinium cinctum* (O.F.M.) Ehr., and *Peridinium umbonatum* Stein) were recorded in all sites. The largest proportion of this group of species was recorded in Makiš. Species *Dinobryon divergens* Imhof. (Division *Chrysophyta*) was observed in Bosut, Sremska Mitrovica and Makiš. Division *Cryptophyta* is represented by only one species (*Cryptomonas* Ehr. sp.), that occurs in Sremska Mitrovica and Makiš.

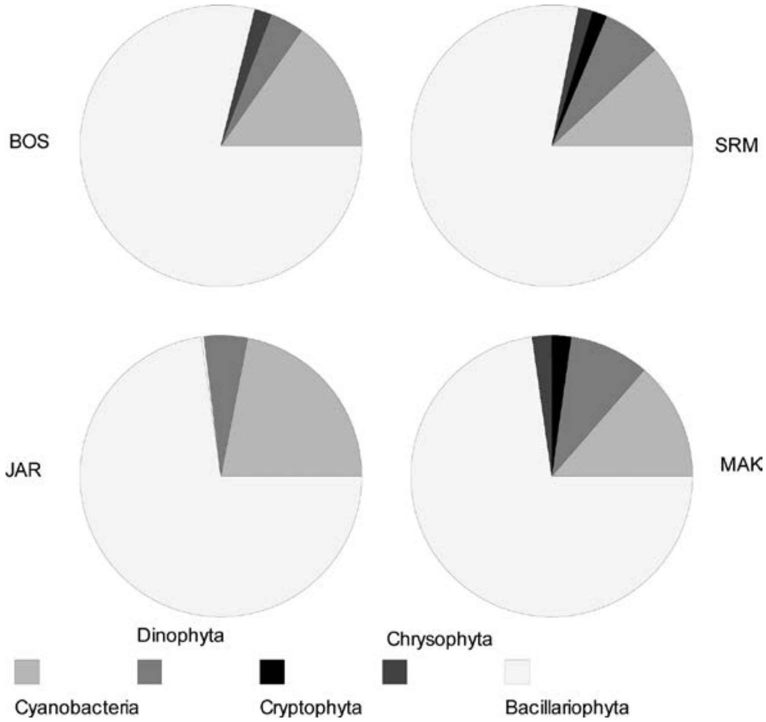

Figure 2: Taxonomic spectra of algal communities in each of the four sampling points.

Biodiversity (biotic variability) may be classified using different approaches (Gaston and Spicer, 1998). The diversity of biotic communities may be divided into alpha, beta and gamma components (Whittaker, 1972).

Alpha Diversity

Alpha diversity (within-community diversity) depends on species richness (number of species within a community) and dominance of species (proportion of individuals of a particular species with respect to individuals of all species within a community). Dominance of species is frequently referred to as “species equitability”.

Species richness increases from Bosut to Jarak. However, a sudden decrease of species richness was recorded in the Makiš locality (Figure 3), probably due to increased pollution. We assessed alpha diversity using the Shannon-Weaver coefficient (Shannon and Weaver, 1949. Although the number of species in the Bosut locality is relatively low, the alpha diversity within this site is high. It may be explained by the high species equitability in the Bosut sampling locality.

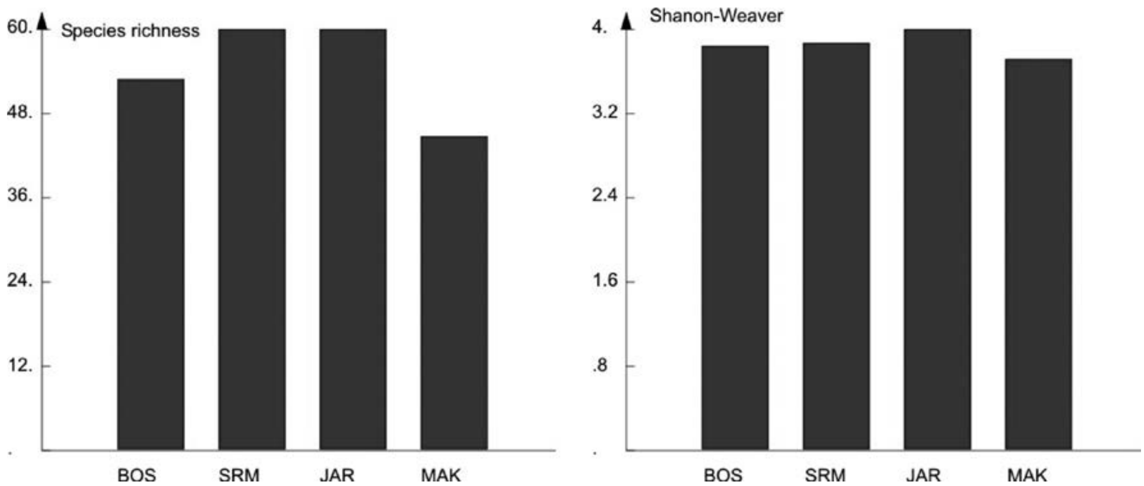

Figure 3: Species richness and alpha diversity of algal communities in investigated sampling stations.

Beta Diversity

Beta diversity (diversity between communities) may be divided into directional turnover along a gradient and non-directional variation among communities (Anderson et al., 2010). Directional turnover represents the change in community structure from one sampling unit to another along a spatial, temporal or environmental gradient. Non-directional beta diversity represents a variation among all possible pairs of sampling units, without reference to any particular gradient or direction. In this article we used Cody's index of beta diversity. Beta diversity increases from Bosut to Makiš (Figure 4). Since beta diversity is a function of species turnover along the gradient, a sudden increase of beta diversity may indicate either an increase or decrease of species in two adjacent sites. In our case, an increase in beta diversity indicates a sudden decrease of species numbers in the Makiš locality, probably due to increased pollution.

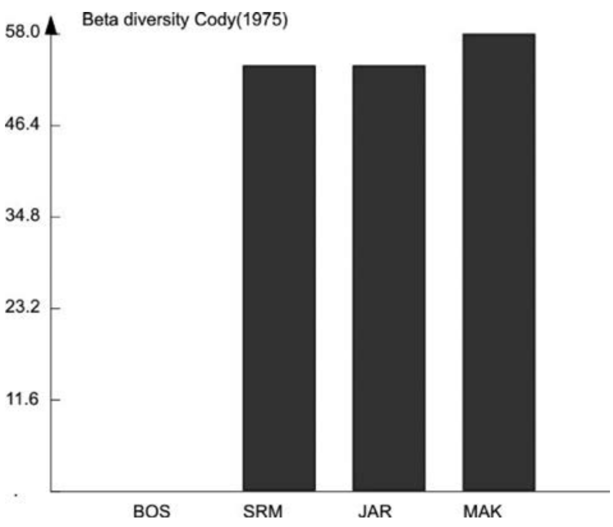

Figure 4: Beta diversity

Structure of Algal Communities

In order to detect structural patterns of algal communities along the Serbian stretch of the Sava River, we performed both, a numerical classification and correspondence analysis.

We used a divisive classification method (Lefkovich, 1976) to detect species groups with similar distribution patterns. Classification results are presented in Figure 5. The first division separates species with relatively narrow distribution (clusters 1, 2 and 3) from more common species (clusters 4, 5, 6 and 7).

The first cluster of species involves only *Cyanobacteria* and *Bacilariophyta* (*Anabaena sp., Chroococcus sp., Merismopedia elegans, Oscillatoria sp., Phormidium sp., Spirulina major, Achnanthes hungarica, Cymbella minuta, Diatoma moniliformis, Fragilaria capucina, Fragilaria ulna angustissima, Gomphonema sp., Gomphonema parvulum, Navicula radiosa, Navicula tripunctata, Nitzschia linearis, Nitzschia vermicularis, Rhoicosphaenia abbreviate, Stauroneis phoenicenteron, Stephanodiscus. sp.*). These species occur mainly in the Jarak sampling point.

The second cluster involves representatives of *Cyanobacteria* (*Aphanisomenon flos-aquae, Phormidium sp., Phormidium chlorinum, Phormidium tergestinum*), *Baclariophyta* (*Achnanthes sp., Achnanthes minutissima, Amphora ovalis, Aulacoseira muzzanensis, Cymatopleura elliptica, Cymbella prostrate, Diatoma echrenbergii, Gyrosigma scalproides, Navicula cryptocephala, Navicula radiosa, Nitzschia levidensis*), *Cryptophyta (Cryptomonas sp.),* and *Dinophyta* (*Peridiniopsis sp.)*. These species are present mainly in the Makiš sampling site.

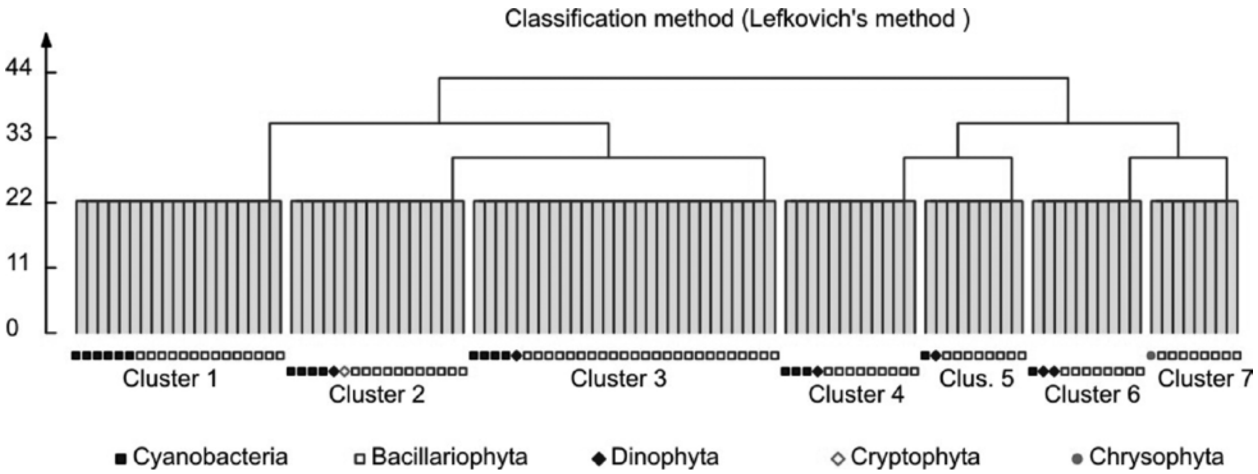

Figure 5: Algal groups specified by their distribution within analyzed sites. Seven clusters of species are divided in two broad groups.

Bacilariophyta dominate in the third cluster (*Achnanthes lanceolata, Asterionella Formosa, Gyrosigma acuminatum, Meridion circulare, Navicula capitata, Navicula capitatoradiata, Navicula cincta, Navicula cuspidate, Navicula laevissima, Navicula lanceolata , Navicula phyllepta, Navicula recens, Navicula trivialis, Navicula viridula var. rostellata, Nithzschia sp., Nitzschia fonticola, Nithzschia gracilis, Nitzschia paleacea, Nitzschia sigmoidea, Pinnularia viridis, Rhopalodia gibba, Skletonema potamos, Stephanodiscus hantzschii*), togather with representatives of *Cyanobacteria* (*Geitlerinema amphibium, Leptolyngbya sp., Oscillatoria limosa, Pseudanabaena catenata*) and *Dinophyta* (*Peridinium umbonatum*). These species occur either in the Bosut site or the Sremska Mitrovica site.

The group of more common species involves clusters 4,5,6 and 7. *Bacilariophyta* (*Komvophoron minutum, Leptolyngbya sp., Leptolyngbya valderiana*), *Dinophyta* (*Peridinium cinctum*) and *Bacilariophyta* (*Amphora lybica, Cyclotella sp., Cymbella affinis, Cymbella lanceolata, Cymbella tumida, Diatoma vulgaris, Melosira lineate, Navicula gregaria and Nitzschia fruticosa*) form the fourth cluster. These species occur in the Jarak and Sremska Mitrovica sampling points. Beside these two sites, some species are also present in Bosut.

Cluster five involves *Cyanobacteria* (*Oscillatoria tenuis*), *Dinophyta* (*Gymnodinium sp.*) and *Bacilariophyta* (*Aulacoseira granulate, Cocconeis pediculus, Cocconeis placentula. Cyclotella ocellata, Cymatopleura solea var. apiculata, Cymbella silesiaca , Didymosphenia geminata* and *Gomphonema minutum*). These species coexist in the Jarak and Makiš sites.

Cluster six involves the most common species that occur in all four sites. These species belong to *Cyanobacteria* (Pseudanabaena limnetica), Dinophyta (Ceratium hirundinella, Peridinium sp.) and *Bacilariophyta* (*Amphora ovalis, Cyclotella meneghiniana, Cymatopleura solea, Gomphonema angustum, Gomphonema olivaceum, Melosira varians, Navicula sp., Neidium dubium*).

Cluster seven is represented with *Chrysophyta* (*Dinobryon divergens*) and *Bacilariophyta* (*Diploneis oblongella, Fragilaria ulna, Navicula menisculus, Nitzschia acicularis, Nitzschia dissipata, Nitzschia palea, Nitzschia sigma*). These species coexist in the upper-stream Bosut and Sremska Mitrovica sites.

Correspondence analysis (Figure 6) clearly separates upper-stream sites (Bosut and Sremska Mitrovica) from down-stream sites (Jarak and Makiš). The Makiš sampling site is isolated with respect to all other sites, due to the poorest species richness.

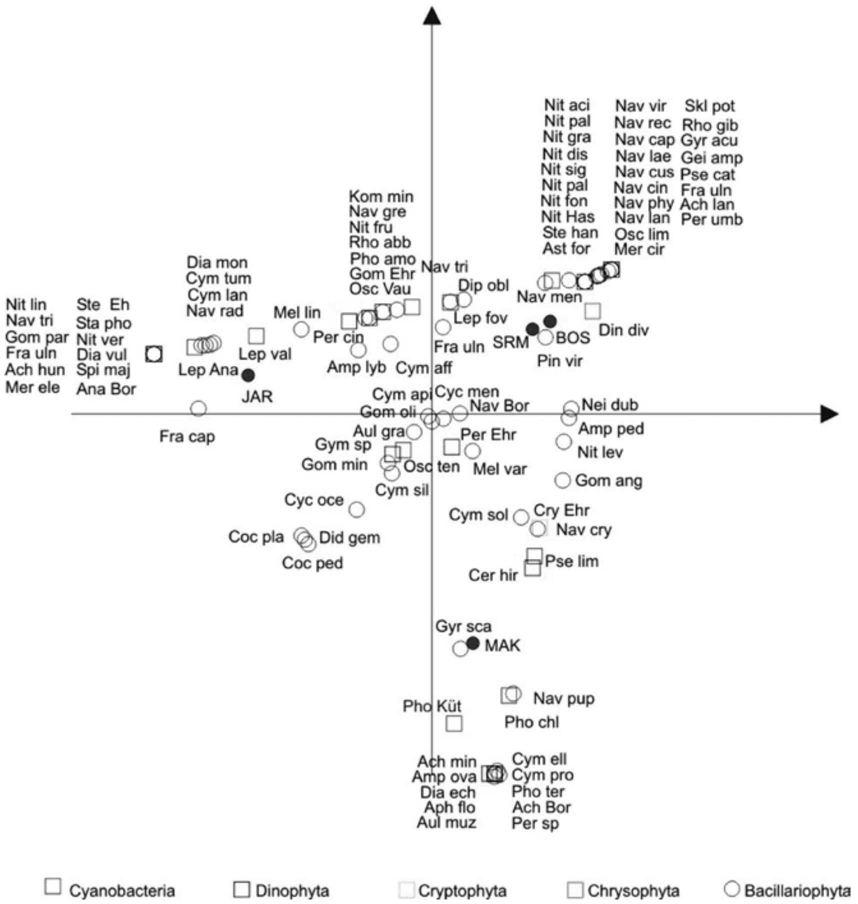

Figure 6: Correspondence analysis of algal communities in analyzed sites.

Conclusions

Freshwater phytoplankton is an integral part of all freshwater ecosystems, with representatives found from pristine to polluted water bodies. They contribute to the food webs of these systems. In this article we presented results of algal communities monitoring along the Serbian stretch of the Sava River. We detected 109 species in four sampling localities (Bosut, Sremska Mitrovica, Jarak and Makiš). Species richness increases from Bosut to Jarak. However, a sudden decrease of species richness was recorded in the Makiš locality, probably due to increased pollution. Divisive numerical classification separates species with relatively narrow distribution (that are grouped in three clusters) from more common species (that form four clusters).

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Acknowledgements

This work was supported by the European Communities 7th Framework Program Funding, Grant agreement no. 603629-ENV-2013-6.2.1-Globaqua.

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