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Original scientific paper

SEASONAL DYNAMICS OF EPILITHIC DIATOM COMMUNITY FROM THE VRLA RIVER (SOUTHEASTERN SERBIA)

Olga S. Jakovljević[1]*, Slađana S. Popović[2], Ivana M. Živić[3], Katarina Z. Stojanović[3], Jelena Ž. Krizmanić[1]

[1]*University of Belgrade, Faculty of Biology, Institute of Botany and Botanical Garden „Jevremovac", Takovska 43, 11000 Belgrade, Serbia*
[2]*University of Belgrade, Instutute of Chemistry, Technology and Metallurgy, Department of Ecology and Techoeconomics, Karnegijeva 4, 11000 Belgrade, Serbia*
[3]*University of Belgrade, Faculty of Biology, Institute of Zoology, Student Square 16, 11000 Belgrade, Serbia*
*Corresponding author; E-mail: olga.jakovljevic@bio.bg.ac.rs

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ABSTRACT. Seasonal analysis of epilithic diatom community from the Vrla River was performed in four seasons a year (six times) at six sampling sites. Between the second (VR2) and the third sampling site (VR3) was located a trout fish farm. The highest number of diatom taxa was recorded in spring (149) and the lowest in autumn (93). The number of taxa that were found to be dominant during all four seasons was twenty-four. The relationship between 45 the best fitted diatom taxa, which showed conspicuous seasonal dynamics, and seasons in which these taxa were recorded was illustrated using canonical correspondence analysis (CCA). The large number of taxa was identified in all four seasons or in winter period only. Few taxa were present only in spring and summer.

Keywords: seasonal dynamics, epilithic diatom community, Vrla River.

INTRODUCTION

Diatoms play a key role in aquatic ecosystems for millions of years, as one of the most important primary producers on Earth. This group of algae is a valuable resource of very important chemical compounds, therefore has found application in the food, chemical and pharmaceutical industry, as well as the synthesis of biofuels (BOZARTH *et al*., 2009). Their application in paleoecology and, in recent years, in forensics is also very important (KALE and KARTHICK, 2015; WAGNER *et al*., 2017). However, diatoms have been widely used in systemic monitoring of surface waters, which is necessary, according to the Water Framework Directive (WFD, 2000) (SIMIĆ *et al*., 2018). Also, ecological status assessment of surface waters in Serbia is performed by studying diatoms, calculating the value of two diatom indices (OFFICIAL GAZETTE OF THE REPUBLIC OF SERBIA 74/2011). Temporal and spatial dynamics research of diatom communities is obligatory to understand the structure and dynamics of aquatic ecosystems, but also a required and effective tool for ecological status assessment (HWANG *et al*., 2011). The study of diatoms in rivers and streams mainly referred to their role in monitoring, while the temporal and spatial dynamics of communities were less studied (LAVOIE *et al*., 2008). Also, their seasonal and annual dynamics were often studied separately (SOININEN and ELORANTA, 2004).

Numerous studies from Europe and North America on the seasonal dynamics of algae indicate regular seasonal patterns in rivers and streams in the temperate climate zone (LEIRA and SABATER, 2005; KÖSTER and PIENITZ, 2006). Diatoms are dominant during the winter and continue to be the main component of the algal flora during the spring and early summer, although the composition of the species changes. Other groups of algae become dominant during the summer. Diatoms' diversity and biomass of rivers in the temperate climate zone, are the greatest during the spring, while the second maximum usually occurs in the autumn. In these rivers, seasonal changes are primarily due to differences in light availability and nitrogen concentration (ALLAN and CASTILLO, 2007).

A large number of environmental factors and their interactions affect the diatom community structure and composition in rivers and streams (KOEDOODER *et al*., 2019). These are complex and dynamic aquatic ecosystems in which physical and chemical parameters vary, affecting the living world in them in different ways (LENGYEL, 2016). Physical and chemical parameters that most affect the composition of diatom communities are chemical properties of water (especially pH, ion, and nutrient concentration), substrate composition, flow rate, light, water temperature and grazing. Most of these factors depend on climate, geology, topography, land use and other relief characteristics, which explains the similarity of the composition of diatom communities in regions with similar ecological conditions (BERE and TUNDISI, 2009).

The temporal dynamics of diatom communities also depends on the species diversity in the community (MYKRÄ *et al*., 2011). Thus, in communities with high diversity, abundance of some species can vary greatly, without a huge impact on the community composition and biomass. In low-diversity communities, small changes of diversity have a major impact on community composition. Productivity and ecosystem size can also affect the temporal dynamics of diatom communities (KOEDOODER *et al*., 2019). There is a difference in the composition of diatom communities in rivers and streams of different productivity. If the composition of diatom communities is observed at regional level, local ecological parameters directly affect the composition of diatom communities. However, many factors and processes (e.g., land use and ecosystem interactions) operate within larger geographical areas and affect conditions at the local level (LAMBERTI *et al*., 2010). So, if the influence of factors within different spatial units is not considered, important ecological information can be missed, thus alleviating the significance of some biotic and abiotic factors on the temporal dynamics of diatom communities.

Diatom study of the Vrla River has been referred to water quality assessment (JAKOVLJEVIĆ *et al*., 2015, 2016, 2016b) and diversity (JAKOVLJEVIĆ, 2015; JAKOVLJEVIĆ and KRIZMANIĆ, 2015; KRIZMANIĆ *et al*., 2016) without temporal and spatial analysis of community structure and composition.

Seasonal study of epilithic diatom community from the Vrla River aimed to: (1) compare diversity of diatom taxa throughout the seasons at investigated sites, (2) determine dominant diatom taxa in each season and (3) examine the seasonal persistence and stability of diatom community.

MATERIALS AND METHODS

Study area and location data

The Vrla River is located in Southeastern Serbia (Figure 1). Debelska Dolina and Viljekoštica rivers are connected between Vardenik Mountain and Vlasina Lake building the Vrla River. In the upper part of the river there are high mountains with forest vegetation, while downstream are meadows, pastures, orchards and vineyards. In the Vladičin Han town, the Vrla River flows into the South Morava River. The length of the Vrla River is about 28 km and belongs to the Black Sea Basin (ĐEKOVIĆ *et al*., 2010). Four hydroelectric power stations were built in the lower part of the river, while a trout farm was built in the upper part of the river.

Our investigation of the Vrla River was performed during 2011-2012 in four seasons: spring (May 2011 and 2012), summer (July 2011 and September 2012), autumn (November 2011) and winter (March 2012) at six sampling sites (VR1 - N 42° 37.779, E 22° 18.092; VR2 - N 42° 38.141, E 22° 18.164; VR3 - N 42° 38.287, E 22° 17.972; VR 4 - N 42° 38.494, E 22° 17.938; VR5 - N 42° 39.002, E 22° 17.699; VR6 - N 42° 39.902, E 22° 17.634). Sampling was carried out in a 5 km long section of the Vrla River, which represents upper part of the river. Between the second (VR2) and the third sampling site (VR3) a trout fish farm is located. Two sampling sites were selected before the farm and four after the farm: VR1 - 770 m upstream of the farm, VR2 - 50 m upstream of the farm, VR3 - 50 m downstream of the farm, VR4 - 450 m downstream of the farm, VR5 - 1.6 km downstream of the farm and VR6 - 3.4 km downstream of the farm (Figure 1).

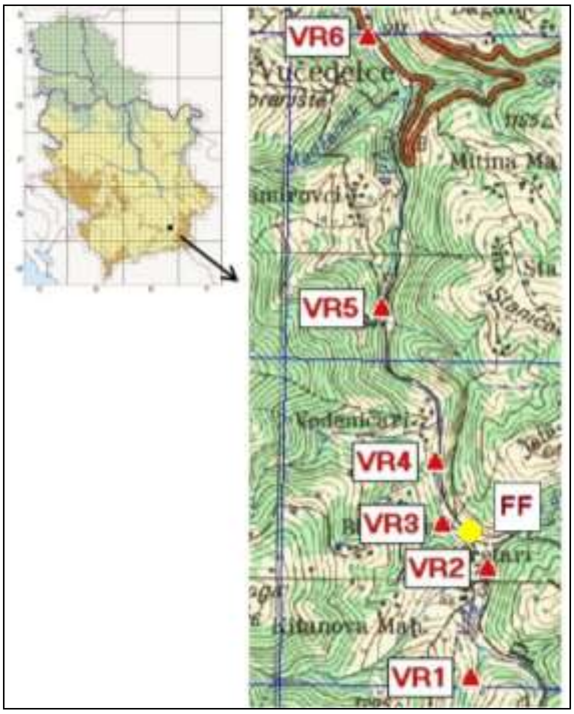

Figure 1. Position of the Vrla River in Serbia (left),
sampling sites (VR1-VR6) and fish farm (FF) (right).

Diatom sampling

Epilithic diatom samples were collected by removing from stones with a toothbrush and were placed in a plastic bottles (100 ml volume) according to following standard (EN 13946, 2015). The algological materials were preserved in 4% formaldehyde. A total of 36 epilithic diatom samples were collected from May 2011 to March 2012 during four seasons (six months) at six sampling sites.

Laboratory method

Laboratory processing of diatoms, which aims to remove organic content, was carried out applying the standard method (KRAMMER and LANGE-BERTALOT, 1986). This method involves the use of hot H_2SO_4 and $KMnPO_4$ to obtain cleaned diatom frustules. In this way, during microscopy, different details of the diatoms cell wall become visible, which is necessary for their identification. Before microscopic analysis, permanent diatom slides were made. Prepared material was air-drying on cover glasses and mounted in Naphrax® synthetic medium.

Microscopic, data and statistical analysis

Microscopic analysis of permanent diatom slides was performed using a 1000 x and 1600 x magnifications of Carl Zeiss AxioImager.M1 microscope, with AxioCam MRc5 camera and AxioVision 4.8 software.

Both qualitative and quantitative analysis of samples was done. Taxa were identified using the following literature: KRAMMER and LANGE-BERTALOT (1986, 1988, 1991, 2004), REICHARDT and LANGE-BERTALOT (1991), REICHARDT (1997, 1999), KRAMMER (1997, 1997a, 2000, 2002, 2003), LANGE-BERTALOT (2001), VAN DE VIJVER *et al*. (2004), LEVKOV (2009), LANGE-BERTALOT *et al*. (2011, 2017), HOFMANN *et al*. (2013), LEVKOV *et al*. (2013, 2016). Relative abundance of identified taxa (%) was determined by counting about 400 valves of epilithic diatoms at each permanent slide. It was the way to present quantitative analysis.

Canonical correspondence analysis (CCA) was used to illustrate the relationship of recorded diatom taxa (presence/absence) and sampling seasons. The analysis was done using the CANOCO program for Windows, Version 5.0 (TER BRAAK and SMILAUER, 2012).

RESULTS

The number of recorded taxa throughout all seasons and at all sampling sites is shown in Figure 2. By analyzing diversity for each season, considering all sampling sites, the highest diversity of diatoms was observed in spring and the lowest in autumn. The number of taxa that were found to be dominant during all four seasons was twenty-four. Their relative abundance was greater than 5% at least at one site and one season.

A total of 149 diatom taxa were recorded in the Vrla River during the spring season (May 2011 and 2012) (Figure 2). The highest number of taxa during this season was documented at VR5 sampling site (a total of 60 taxa in May 2011, and 79 taxa in May 2012). The lowest number of taxa was observed at VR1 sampling site (a total of 57 taxa in May 2011, and 61 taxa in May 2012) (Figure 2).

The number of dominant taxa, in the Vrla River during the spring season, was 14. Their relative abundance was greater than 5% at least at one site (Table 1). These taxa occured at all sampling sites during the spring period. *Achnanthidium minutissimum* (Kütz.) Czarnecki (24.5%), *Gomphonema elegantissimum* Reichardt & Lange-Bertalot (19.8%) and *Nitzschia soratensis* (20.05%) were defined as dominant taxa. *A. minutissimum* was dominant taxon at VR2, VR3 and VR6 sampling sites in May 2011, *G. elegantissimum* at the VR1 site in May 2011, and *N. soratensis* Morales & Vis at VR4 and VR5 sites in May 2012 (Table 1).

Species richness during the summer (July and September 2011) included 140 diatom taxa (Figure 2). At VR4 sampling site was identified the largest number of taxa (64 taxa in July 2011 and 72 taxa in September of the same year). The lowest number of taxa was identified at VR1 sampling site (51 taxa in July 2011 and 40 taxa in September of the same year) (Figure 2).

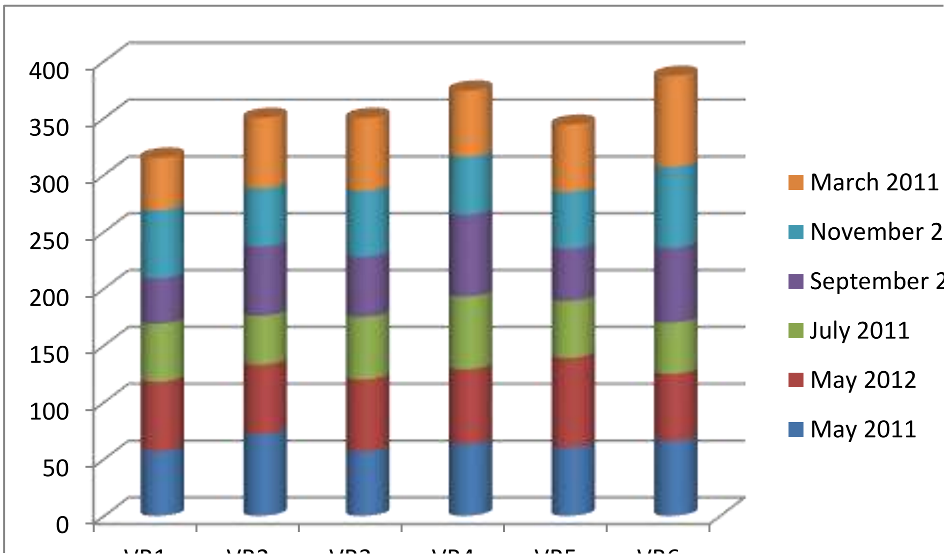

Figure 2. The number of recorded taxa in the Vrla River at six sampling sites (VR1-VR6) during four sampling seasons: spring (May 2011 and 2012), summer (July 2011 and September 2012), autumn (November 2011) and winter (March 2012).

The presence of 16 taxa with a relative abundance greater than 5% at least at one site was determined in summer (Table 2). Of these, 12 taxa occurred at all sites. *Achnanthidium subatomus* (Hust.) Lange-Bertalot (19.41%), *Cocconeis lineata* (Ehrenberg) Van Heurck (31.68%), *C. pseudolineata* (Geit.) Lange-Bertalot (24.57%) and *Nitzschia soratensis* (24.07%) were determined as dominant. *A. subatomus* represented dominant taxon at VR2 sampling site in July 2011, *C. lineata* at VR5 and VR6 in September 2011, *C. pseudolineata* at VR1 in September 2011 and *N. soratensis* at VR3 and VR4 in July 2011 (Table 2).

Diversity of diatom taxa in autumn (November 2011) period was much lower than in the previous two seasons and included a total of 93 taxa (Figure 2). VR6 sampling site characterized by the highest number of taxa (71 taxa) and VR5 the lowest (50 taxa). The number of taxa with a relative abundance greater than 5% at least at one site was 14 (Table 3). Of these, 12 taxa occurred at all 6 sites. *Nitzschia soratensis* was the dominant taxon at 4 sites (VR3, VR4, VR5 and VR6) with a relative abundance of 11.91% to 40.2%. *Achnanthidium subatomus* was dominant taxon at VR1 (14.64%) and *Cocconeis lineata* at VR2 (14.89%) (Table 3).

By analyzing diatom taxa richness in winter period (March 2012), the number of recorded taxa was 121 (Figure 2). VR6 sampling site stood out as the site with the largest number of taxa (81 taxa) and VR1 with the lowest (46 taxa). The other three sites were characterized by a similar number of taxa (VR2 - 62 taxa, VR3 - 64 taxa and VR4 - 58 taxa). A total of 16 dominant diatom taxa were identified (Table 4). *Achnanthidium minutissimum* represented dominant taxon at VR3 (10.92%) and VR6 (15.38%), *Hannaea arcus* (Ehr.) R.M.Patrick at VR4 (23.33%) and VR5 (16.34%), and *Nitzschia pura* Hustedt at VR1 (13. 15%) and VR2 (15.14%) (Table 4).

Figure 3 presents the relationship between 45 the best fitted diatom taxa, which showed conspicuous seasonal dynamics, and seasons in which these taxa were recorded. In addition to the large number of taxa identified in all four seasons, i.e., more than two seasons (central part of the chart), groups of taxa recorded only in spring (i.e. *Humidophila contenta* (Grun.) Lowe et al.), summer (i.e., *Eunotia minor* (Kütz.) Grunow and *Navicula oligotraphenta* Lange-Bertalot & Hofmann) and winter period were also distinguished. It can be noticed that a very large group of taxa was distinguished and connected to winter period.

Table 1. Relative abundance of diatom taxa (%) present in the epilithic diatom community in the Vrla River during the spring period (May 2011 and 2012).

Taxon	Spring											
	May 2011						May 2012					
	Sampling site											
	VR1	VR2	VR3	VR4	VR5	VR6	VR1	VR2	VR3	VR4	VR5	VR6
	Relative abundance of taxon (%)*											
Achnanthidium minutissimum (Kütz.) Czarnecki	16.5	24.5	18.5	16	18.6	22	16.4	10.4	15.8	18.3	+	9.8
Achnanthidium subatomus (Hust.) Lange-Bertalot	10.6	7.6	5.6	+	6.4	+	6.2	+	5.2	+	6.1	+
Amphora pediculus (Kütz.) Grunow	6.6	+	+	+	+	+	+	+	5.6	+	+	+
Gomphonema elegantissimum Reichardt & Lange-Bertalot	19.8	19	6.9	+	+	6.9	+	7.9	5.4	+	+	5.6
Hannaea arcus (Ehr.) R.M.Patrick	+	+	7.1	18.2	13.9	8.6	+	+	+	+	+	+
Mayamaea permitis (Hust.) Lange-Bertalot	+	+	+	+	/	+	5.7	+	+	+	+	+
Nitzschia frustulum (Kütz.) Grunow	+	+	+	6.1	6.7	+	+	/	+	+	+	/
Nitzschia pura Hustedt	8.9	+	15.3	18.5	15.6	7.1	+	+	/	+	+	+
Nitzschia soratensis Morales & Vis	+	+	11.3	+	8.9	19.5	8.4	+	6.1	19.3	20	9.1
Odontidium mesodon (Kütz.) Kützing	+	+	+	6.1	+	+	9.2	7.6	9.9	+	5.9	+
Planothidium frequentissimum (Lang.-Bert.) Lange-Bertalot	+	5.9	+	+	+	+	+	7.6	7.1	7.6	+	+
Planothidium lanceolatum (Bréb. ex Kütz.) Lange-Bertalot	+	6.4	+	+	8.4	5.9	8.2	15.6	12.8	6.4	7.4	16.7
Reimeria sinuata (W.Greg.) Kociolek & Stoermer	+	+	+	+	+	+	5.4	+	+	+	5.4	6.4
Sellaphora nigri (De Not.) C.E.Wetzel & L.Ector	+	+	+	+	+	+	+	5.2	+	+	/	+

(*) - Taxa with a relative abundance greater than 5% at least at one site are shown in Table 1;
(+) - Relative abundance of taxon less than 5%;
(/) - Taxon not recorded.

Table 2. Relative abundance of diatom taxa (%) present in the epilithic diatom community in the Vrla River during the summer period (July and September 2011).

Taxon	Summer											
	July 2011						September 2011					
	Sampling site											
	VR1	VR2	VR3	VR4	VR5	VR6	VR1	VR2	VR3	VR4	VR5	VR6
	Relative abundance of taxon (%)*											
Achnanthidium minutissimum (Kütz.) Czarnecki	17.2	15.9	14.1	18.8	15.1	+	+	8.6	16.3	14.6	8.4	5.4
Achnanthidium subatomus (Hust.) Lange-Bertalot	5.9	19.4	6.2	+	14.1	7.6	+	5.6	+	5.1	8.4	+
Amphora pediculus (Kütz.) Grunow	6.1	+	+	+	+	+	7.6	5.4	+	+	+	+
Cocconeis neodiminuta Krammer	+	+	/	/	/	+	5.4	+	/	+	+	+
Cocconeis lineata (Ehrenberg) Van Heurck	+	+	+	+	+	12.5	24.5	12.8	15.8	17.1	23.7	31.6
Cocconeis placentula Ehrenberg	+	+	+	/	+	+	10.9	+	5.6	+	11.8	10.4
Cocconeis pseudolineata (Geit.) Lange-Bertalot	5.1	+	+	+	+	18.7	24.5	13.6	+	+	6.6	9.6
Gomphonema elegantissimum E.Reichardt & Lange-Bertalot	15.8	11.3	+	+	14.1	15.5	+	+	+	+	+	+
Gomphonema parvulum Kützing	/	/	+	+	+	+	/	+	9.6	+	/	+
Mayamaea permitis (Hust.) Lange-Bertalot	+	8.6	6.9	11.6	+	+	+	+	+	6.3	+	+
Nitzschia archibaldii Lange-Bertalot	/	/	+	+	/	/	/	+	10.8	+	+	/
Nitzschia soratensis Morales & Vis	+	+	24	23	23.5	18.7	+	7.4	6.4	15.1	17.8	21.2
Planothidium frequentissimum (Lang.-Bert.) Lange-Bertalot	6.1	+	+	+	+	/	+	+	+	+	+	/
Planothidium lanceolatum (Bréb. ex Kütz.) Lange-Bertalot	16.3	13	+	7.1	+	+	7.6	10.1	+	+	+	+
Reimeria sinuata (W.Greg.) Kociolek & Stoermer	6.4	+	5.4	+	9.6	+	+	+	+	+	+	+
Sellaphora nigri (De Not.) C.E.Wetzel & L.Ector	+	5.4	8.9	+	+	/	+	6.4	+	+	+	+

(*) - Taxa with a relative abundance greater than 5% at least at one site are shown in Table 1;
(+) - Relative abundance of taxon less than 5%;
(/) - Taxon not recorded.

Table 3. Relative abundance of diatom taxa (%) present in the epilithic diatom community in the Vrla River during the autumn period (November 2011).

Taxon	Autumn (November 2011)					
	Sampling site					
	VR1	VR2	VR3	VR4	VR5	VR6
	Relative abundance of taxon (%)*					
Achnanthidium minutissimum (Kütz.) Czarnecki	8.9	+	5.2	13.9	22.3	6.9
Achnanthidium jackii Rabenhorst	+	5.2	+	+	/	+
Achnanthidium subatomus (Hust.) Lange-Bertalot	14.6	+	+	+	7.4	+
Amphora pediculus (Kütz.) Grunow	+	+	5.2	+	+	7.4
Cocconeis neodiminuta Krammer	+	6.9	+	+	+	7.6
Cocconeis lineata (Ehrenberg) Van Heurck	+	14.8	+	+	+	+
Cocconeis placentula Ehrenberg	+	5.7	+	+	+	+
Cocconeis pseudolineata (Geit.) Lange-Bertalot	+	+	+	+	+	12.4
Gomphonema elegantissimum Reichardt & Lange-Bertalot	+	8.6	7.6	+	+	+
Gomphonema pumilum var. *rigidum* Reich. & Lange-Bertalot	+	11.1	+	+	+	/
Nitzschia pura Hustedt	+	+	+	6.7	/	+
Nitzschia soratensis Morales & Vis	7.6	+	11.9	19.8	40.2	29.2
Planothidium lanceolatum (Bréb. ex Kütz.) Lange-Bertalot	7.9	8.1	10.4	7.6	+	+
Reimeria sinuata (W.Greg.) Kociolek & Stoermer	6.2	+	+	7.2	+	+
Sellaphora nigri (De Not.) C.E.Wetzel & L.Ector	6.4	+	+	5.2	+	+

(*) - Taxa with a relative abundance greater than 5% at least at one site are shown in Table 1; (+) - Relative abundance of taxon less than 5%; (/) - Taxon not recorded.

Table 4. Relative abundance of diatom taxa (%) present in the epilithic diatom community in the Vrla River during the winter period (1 March 2012).

Taxon	Winter (1 March 2012)					
	Sampling site					
	VR1	VR2	VR3	VR4	VR5	VR6
	Relative abundance of taxon (%)*					
Achnanthidium minutissimum (Kütz.) Czarnecki	9.1	7.6	10.9	14.8	13.3	15.3
Achnanthidium jackii Rabenhorst	+	+	+	+	+	8.4
Achnanthidium subatomus (Hust.) Lange-Bertalot	+	8.1	5.7	+	14.1	+
Amphora pediculus (Kütz.) Grunow	7.4	+	7.4	+	+	7.4
Cocconeis neodiminuta Krammer	5.9	+	+	+	+	+
Cocconeis pseudolineata (Geit.) Lange-Bertalot	6.2	+	+	+	+	/
Denticula tenuis Kützing	/	/	/	+	/	6.2
Gomphonema elegantissimum Reich. & Lange-Bertalot	+	+	5.4	5.2	+	+
Hannaea arcus (Ehr.) R.M.Patrick	9.6	12.4	7.9	23.3	16.3	6.7
Navicula tripunctata (O.F.Müll.) Bory	+	+	+	+	+	5.4
Nitzschia fonticola (Grun.) Grunow	/	+	+	+	+	9.9
Nitzschia frustulum (Kütz.) Grunow	/	6.2	+	+	+	/
Nitzschia pura Hustedt	13.1	15.1	5.46	8.93	6.44	+
Nitzschia soratensis Morales & Vis	+	+	7.9	9.9	+	+
Odontidium mesodon (Kütz.) Kützing	+	5.7	+	+	8.4	+
Planothidium lanceolatum (Bréb. ex Kütz.) Lange-Bertalot	+	5.2	+	+	+	+

(*) - Taxa with a relative abundance greater than 5% at least at one site are shown in Table 1; (+) - Relative abundance of taxon less than 5%; (/) - Taxon not recorded.

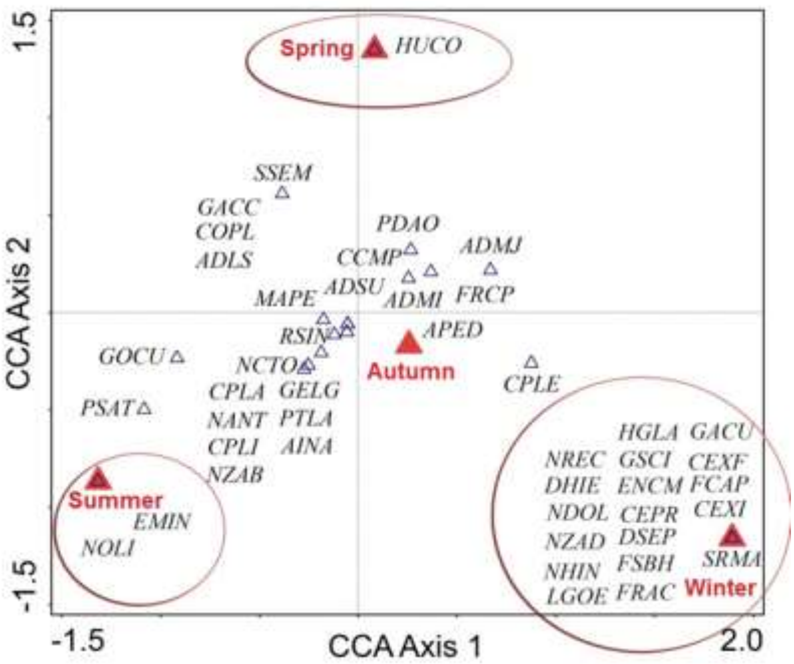

Figure 3. CCA showing the relationship between diatom taxa recorded in the Vrla River and sampling seasons. *Humidophila contenta* - HUCO, *Sellaphora seminulum* - SSEM, *Geissleria acceptata* - GACC, *Cocconeis pseudolineata* - COPL, *Adlafia suchlandtii* - ADLS, *Mayamaea permitis* - MAPE, *Psammothidium daonense* - PDAO, *Cymbella compacta* - CCMP, *Achnanthidium subatomus* - ADSU, *Achnanthidium minutissimum* - ADMI, *Achnanthidium jackii* - ADMJ, *Fragilaria recapitellata* - FRCP, *Reimeria sinuata* - RSIN, *Navicula cryptotenelloides* - NCTO, *Cocconeis placentula* - CPLA, *Gomphonema elegantissimum* - GELG, *Navicula antonii* - NANT, *Nitzschia soratensis* - NZAB, *Amphora pediculus* - APED, *Cocconeis euglypta* - CPLE, *Planothidium lanceolatum* - PTLA, *Amphora inariensis* - AINA, *Cocconeis lineata* - CPLI, *Gomphonema occultum* - GOCU, *Psammothidium subatomoides* - PSAT, *Navicula oligotraphenta* - NOLI, *Eunotia minor* - EMIN, *Nitzschia recta* - NREC, *Diatoma hyemalis* - DHIE, *Nitzschia oligotraphenta* - NDOL, *Nitzschia adamata* - NZAD, *Navicula hintzii* - NHIN, *Luticola goeppertiana* - LGOE, *Handmannia glabriuscula* - HGLA, *Girosygma sciotoense* - GSCI, *Encyonopsis microcephala* - ENCM, *Cymbella excisa* var. *procera* - CEPR, *Diploneis separanda* - DSEP, *Fallacia subhamulata* - FSBH, *Ulnaria acus* - FRAC, *Gomphonema acuminatum* - GACU, *Cymbella excisiformis* - CEXF, *Fragilaria capucina* - FCAP, *Cymbella exigua* - CEXI, *Staurosira martyi* - SRMA.

DISCUSSION

The highest number of diatom taxa from the epilithic diatom community of the Vrla River (Southeastern Serbia) was recorded in spring and the lowest in autumn (Figure 1). SOININEN and ELORANTA (2004) have indicated that seasonal dynamics of diatoms depends greatly on the type of community. They pointed that epilithic diatom communities showed greater seasonal dynamics than epipelic. They recorded the highest number of diatom taxa in the epilithic communities of three boreal rivers in South Finland in September and the lowest in August. Our results are in accordance with generally accepted view that the number of diatom taxa decreases significantly in autumn and winter, while maximum diversity is reached in spring and late summer (ALLAN and CASTILLO, 2007).

Achnanthidium minutissimum, *Gomphonema elegantissimum* and *Nitzschia soratensis* were distinguished as dominant taxa in epilithic diatom community of the Vrla River during the spring period (Table 1). *A. minutissimum* is a taxon of wide ecological valence, which successfully inhabits both oligotrophic and eutrophic waters (LOBO *et al*., 2004). Nevertheless, this taxon is usually dominant in oligotrophic waters, while its relative abundance significantly reduced in eutrophic waters (KELLY *et al*., 2007). The dominance of this taxon in our study is expected and confirms the good ecological status of the Vrla River (JAKOVLJEVIĆ *et al*., 2016). *G. elegantissimum* is a taxon characteristic of oligo- to weakly eutrophic running water with a carbonate base (LANGE-BERTALOT *et al*., 2017). Considering the composition of the substrate, as well as the ecological status of the Vrla River (JAKOVLJEVIĆ *et al*., 2016), dominance of this species was also expected in our study. *N. soratensis*, which occured as a dominant taxon in spring, has so far recorded only in fresh water with low temperature and pH > 8 (TROBAJO *et al*., 2012). However, our study showed this is not always the case, since this species was dominant at sites VR4 and VR5 in May 2012 (Table 1) where moderate temperature and pH < 8 were measured (JAKOVLJEVIĆ *et al*., 2016).

In addition to these three taxa, *Achnanthidium subatomus*, *Cocconeis lineata* and *C. pseudolineata* were dominant taxa in epilithic diatom community during the summer period (Table 2). According to VAN DAM *et al*. (1994), these two species of the genus *Cocconeis* are indicators of mesotrophic and eutrophic waters. Epilithic diatom communities research of streams in Sardinia testifies about the dominance of *A. subatomus* in winter (LAI *et al*., 2016). The authors pointed out there is no information on the preferences of this taxon when it comes to organic matter, still it is known to occur successfully in oligo- to mesotrophic waters. In our study, *A. subatomus* distinguished as the dominant taxon during three periods (summer, autumn and winter) (Tables 2, 3, 4). Nevertheless, this taxon reached the highest relative abundance during the summer (Table 2).

Taxa that were dominant during spring and summer also dominated in autumn and winter periods. *Hannaea arcus* and *Nitzschia pura* were exceptions, which dominated only in the winter (Table 4). In general, even though winter was not characterized with the highest number of taxa recorded, it was the most distinguished season according to the species composition (Figure 3). *H. arcus* is a taxon generally considered to be oligosaprobic and tolerates a certain level of organic pollution (LANGE-BERTALOT *et al*., 2017). Thus, common to all dominant taxa of the Vrla River is that they are oligosaprobes, which are widely distributed in oligo- to slightly eutrophic running waters. In general, the structure and dynamics of the epilithic diatom community from the Vrla River faithfully reflects the good ecological status of this river, which is confirmed by calculating four diatom indices (IPS, IBD, CEE and DESCY) (JAKOVLJEVIĆ *et al*., 2016). As mentioned before, a lot of taxa were present in all four seasons or in winter period only (Figure 3). This probably indicates that in addition to many physicochemical parameters, the seasonal dynamics of diatoms is also greatly influenced by microclimatic factors. VIRTANEN (2015) emphasized that the impacts of climate changes on the temporal dynamics of diatom communities will increase in the future, changing patterns of their composition.

CONCLUSION

Our results confirm that diatoms diversity is the highest during the spring in rivers in the temperate climate zone. As a result of seasonal sampling in the Vrla River a total of 149 diatom taxa were recorded during the spring, followed by summer (140), winter (121) and autumn (93) season. The large number of taxa (24) was identified in all four seasons. Few taxa were present only in spring and summer period (3) while a lot of taxa were present in winter period only (18). Results of our research indicate that study of the temporal dynamics of diatom communities in freshwaters is necessary for proper monitoring and protection of water bodies. Seasonal variation of diatom community composition was conspicuous and probably linked to seasonal variation of many physical and chemical parameters, so further, more detailed research of diatom communities should be conducted having in mind that microclimatic characteristics also play important role. It is clear that more attention should be paid in the future to the study of temporal dynamics of diatom communities in freshwaters.

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