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NET-PHYTOPLANKTON SPECIES DOMINANCE IN A TRAVERTINE RIVERINE LAKE VISOVAC, NP KRKA

Marija Gligora Udovič[1]*, Koraljka Kralj Borojević[1], Petar Žutinić[1], Laszlo Šipoš[2] & Anđelka Plenković-Moraj[1]

[1]University of Zagreb, Faculty of Science, Division of Biology, Rooseveltov trg 6, HR-10000 Zagreb, Croatia

[2]University of Zagreb, Faculty of Chemical engineering and Technology, Department of General and Inorganic Chemistry, Marulićev trg 19. HR-10000 Zagreb, Croatia

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Species composition of the net-phytoplankton assemblage and seasonality of the dominant species were investigated in the travertine monomictic stratified riverine Lake Visovac in relation to the environmental variables. The one year investigation was based on monthly sampling from April 1995 to March 1996 at the two deepest vertical profiles, with a maximum depth of 25 m. Diatoms, especially *Asterionella formosa* Hass. dominated net-phytoplankton assemblages except in late summer and autumn when dinoflagellate species *Ceratium hirundinella* (O. F. Müller) Bergh became the dominate form. The effects of the short term dynamics of environmental factors on the algal growth in the barrage lenitic area of the calcareous river stressed several variables as important factors controlling annual net-phytoplankton distribution. Temperature was the variable that most affected species abundance, changes in dominance and species composition (Primer 5, BIO-ENV; http://www.primer-e.com/). CCA analysis performed on abundance dataset and environmental variables confirm the importance of temperature but also highlighted total phosphorus, conductivity and silica.

Key words: phytoplankton assemblages, *Asterionella formosa*, *Ceratium hirundinella*, Lake Visovac

Gligora Udovič, M., Kralj Borojević, K., Žutinić, P., Šipoš, L. & Plenković-Moraj, A.: Dominantne vrste mrežnog fitoplanktona u Visovačkom jezeru, NP Krka. Nat. Croat., Vol. 20, No. 2., 411–424, 2011, Zagreb

Tijekom jednogodišnjeg razdoblja od travnja 1995. do ožujka 1996. istraživana je, u jednomjesečnim intervalima, vertikalna i sezonska distribucija mrežnog fitoplanktona u lenitičkom području Visovačkog jezera. Naglasak tijekom istraživanja bio je na sastav vrsta te povezanost dominantnih vrsta i okolišnih čimbenika. Najzastupljenija vrsta tijekom kasnog proljeća je dijatomeja *Asterionella formosa* Hass, dok ljeti i u jesen dominaciju preuzima dinoflagelat *Ceratium hirundinella* (O. F. Müller) Bergh. Od mjerenih ekoloških parametara, temperatura vode najznačajnije je utjecala na promjene u sastavu vrsta, njihovu zastupljenost i dominaciju (Primer 5, BIO-ENV). CCA analiza dobivena na osnovi zastupljenosti fitoplanktonskih stanica i praćenih ekoloških čimbenika potvrdila je znatan utjecaj temperature vode, kao i ukupnog fosfora, provodljivosti i silicija.

Ključne riječi: fitoplankton, *Asterionella formosa*, *Ceratium hirundinella*, Visovačko jezero

INTRODUCTION

Phytoplankton assemblages respond to environmental variations with changes in species composition (NASELLI-FLORES, 2000). The dominant species of a phytoplankton community and the definition of the optimum environmental conditions needed for the optimal growth of each species have been the subjects of numerous ecological investigations. Phytoplankton is important part of the ecology of large rivers, as it is of lake ecology. In rivers, the majority of species in phytoplankton assemblages belong to a few diatom genera. Pennate diatoms especially contribute to the river phytoplankton assemblages due to simultaneous adjustment to certain river conditions (REYNOLDS & DESCY, 1996; WEHR & DESCY, 1998). The karstic River Krka is characterized by lenitic areas produced by travertine barrages, which provide a special river ecosystem less exposed to the mainstream. Currently, it is difficult to define conditions for optimal growth of phytoplankton species. Environmental requirements for given species alternate in different type of ecosystem and usually are dependent on its natural properties (PÉREZ-MARTÍNEZ & SÁNCHEZ-CASTILLO, 2001; GLIGORA *et al.*, 2003; NOGES *et al.*, 2003). The lentic area of River Krka, the karstic barrage Lake Visovac, provides the opportunity to study common freshwater plankton species and especially diatoms and dinoflagellates in a habitat different to the usual temperate habitat. This paper is focused on defining the annual net-phytoplankton assemblages in a karstic barrage lake in the Mediterranean region, with special attention to the definition of correlations between selected environmental variables and seasonal changes in dominant species.

STUDY AREA

The karstic Krka River was proclaimed a national park in 1985. From the spring to the flooded part of the mouth, the Krka River is 72.5 km long, with a 52 km long freshwater course. It has a total basin area of 2088 km^2, 25.6 km^2 belonging to the freshwater surface. Lake Visovac is a lentic area situated in the lower course of the river with a maximum depth of 25 m, a surface area of 572 m^2, and a volume of 103×10^6 m^3. This monomictic system originated in the Quaternary by the formation of the Skradin fluvial travertine barrage. With current velocity lower than river flow, it represents a unique ecosystem. Also, this part of the River Krka has far greater current flow and flux than other lakes in the Mediterranean area. Annual investigation was based on monthly sampling from April 1995 to March 1996 at vertical profiles K1 and K2, with maximum depth of 25 m (Fig. 1).

MATERIAL AND METHODS

Net phytoplankton densities were established by filtrating 20 liters of the Lake water through a plankton net (25 μm). Samples were obtained at 1, 5, 10, 15, 20, and 25 m, and preserved with 4 % formaldehyde solution. For quantitative analyses, cells of each species were counted using counting chambers with a millimeter grid and volume of 0.05 ml (STILINOVIĆ & PLENKOVIĆ-MORAJ, 1995).

The general chemical parameters of the water chemistry were determined using standard analytical methods (APHA, 1995). Ammonium was determined spectro-

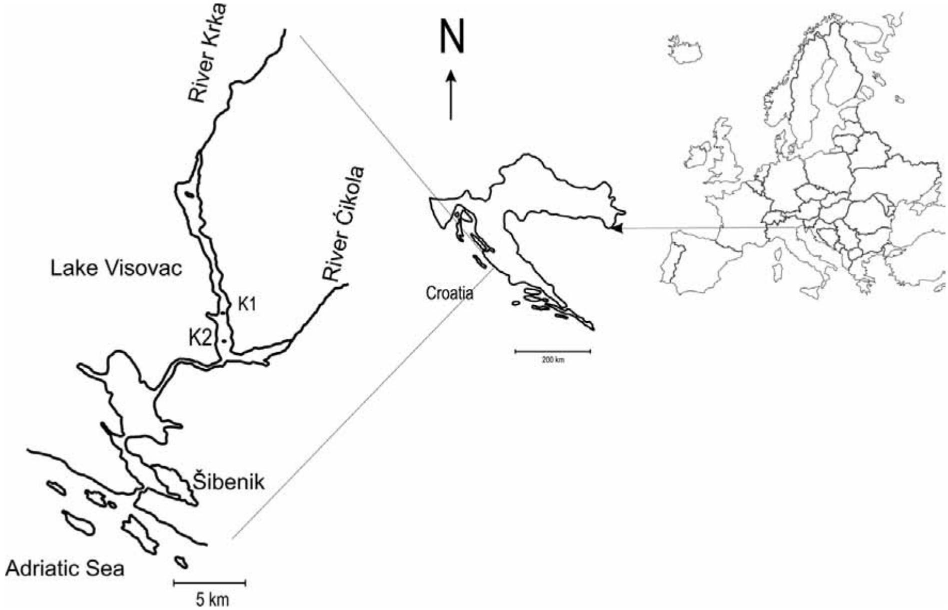

Fig. 1. Sampling points K1 and K2 in the karstic barrage Lake Visovac, River Krka.

photometrically by the method according to WAGNER (ISO, 1984); while nitrites were determined by the method with sulfanilic acid and α-naphthylamine, and the nitrates by dimethylphenol (HÖLL, 1979).

A field spectrophotometer (HACH, Model DR2000) was used for the spectrophotometric measurement and field instruments (ISKRA, Slovenia) were employed for determination of the values of pH (Model MA 5750), electrical conductivity (Model MA 5950), and oxygen concentration (Model MA 5485).

Differences between samples and sites were tested by standard analysis of variance ANOVA using Statistica software. Diversity index was expressed as Shannon-Wiener diversity index: $H' = -\Sigma_i \, p_i \log(p_i)$ where p_i is the proportion of total count arising from i^{th} species. Equitability was expressed as Pielou's evenness index: $J' = H'/H'_{max}$ (PRIMER 5) (CLARKE & WARWICK, 2001). Data sets were reduced (> 4% of total abundance) and logarithmically transformed. Hierarchical agglomerative clustering and non metric multidimensional scaling (NMDS) were performed using the computer software package PRIMER 5. The PRIMER submodule BIO-ENV and CCA analysis of PC-ORD software package were used to examine the effects of nutrients on the phytoplankton composition.

RESULTS

Nutrient concentrations measured during the investigation period showed high concentrations of nitrogen and phosphorus compounds (Tab. 1). The concentrations of total nitrogen and total phosphorus reached 0.665 mg l^{-1} and 0.56 mg l^{-1}, in April and August, respectively (Fig. 2). The measured conductivity values were be-

Tab. 1. Range, mean values, median and standard deviation of physical and chemical variables of the study area during investigation period.

	Mean	Med	Min	Max
Temperature (°C)	13.5	13.3	6.4	23.4
pH	7.93	7.93	7.34	8.32
CO_2 (mg l^{-1})	5.51	4.6	2.0	18.6
Oxygen (mg l^{-1})	9.73	10.41	0.58	13.13
Alkalinity ($CaCO_3$ mg l^{-1})	211	210	182	266
Total hardness ($CaCO_3$ mg l^{-1})	287	284	232	374
Conductivity (µScm^{-1})	503	511	380	580
SO_4^{2-} S (mg l^{-1})	64.09	68.95	31.34	83.05
DIN (mg l^{-1})	0.42	0.42	0.25	0.66
NH_4^+-N (mg l^{-1})	0.034	0.029	0.0	0.253
NO_2^--N (mg l^{-1})	0.005	0.004	0.0	0.02
NO_3^--N (mg l^{-1})	0.24	0.24	0.01	0.66
TP (mg l^{-1})	0.192	0.168	0.009	0.56
PO_4^{3-}-P (mg l^{-1})	0.002	0.0	0.0	0.025
SiO_2 (mg l^{-1})	2.2	2.2	0.3	4.4

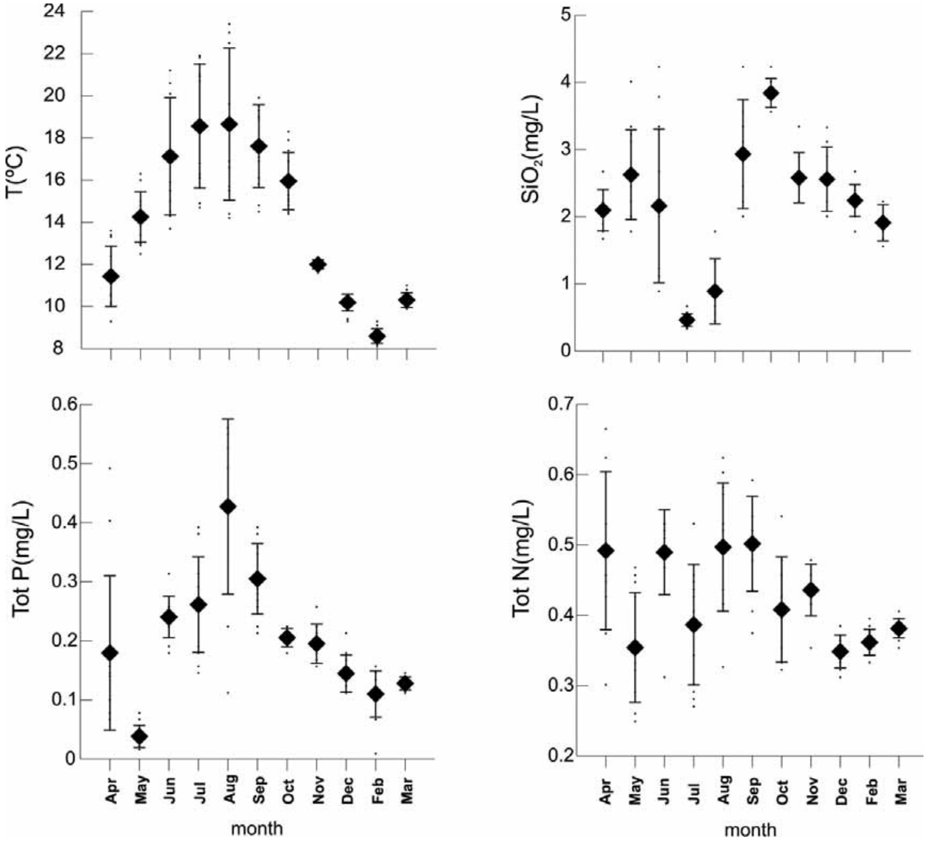

Fig. 2. Temperature, SiO_2, total phosphorus and nitrogen data set at K1 and K2 in the karstic barrage Lake Visovac, River Krka

tween 380 μS cm^{-1} and 580 μS cm^{-1}. The temperature varied seasonally from 6.4 °C to 23.4 °C. Surface temperature rose after winter homeothermy during early spring. Thermal stratification in the lake occurred from the spring to the late autumn. Autumn, winter and spring silica concentrations ranged between 0.9 mg l^{-1} and 4.2 mg l^{-1} with a mean value of 2.5 mg l^{-1} (Fig. 2). The highest silica concentrations were measured during September and October. Annual minimum concentrations were reached during summer (range from 0.3 mg l^{-1} to 1.7 mg l^{-1}, with mean value of 0.7 mg l^{-1}). Depletion of silica was observed in July (average 0.5 mg l^{-1}) and August (average 0.9 mg l^{-1}) after high development of *Asterionella formosa* Hass.

There were no significant differences between investigated vertical profiles K1 and K2 in terms of net phytoplankton composition, abundance and environmental variables (ANOVA, $p < 0.05$).

A total number of 39 species was noted on vertical profile K1 (Tab. 2). Bacillariophyceae were the most abundant group, represented with 24 species and Chlorophyceae with 11. Cyanobacteria, Dinophyta and Chrysophyceae were a lot less represented with one to two species. At sampling station K2, a total of 36 species was determined, with 23 species of Bacillariophyceae, 8 of Chlorophyceae, 3 Dinophyta, and 1 representative of Cyanobacteria and Chrysophyceae. The greatest number of net-phytoplankton species was noted at K1 in February and March. At both sampling stations the most abundant species was *Asterionella formosa* with codominant dinoflagellate *Ceratium hirundinella* (O.F.Müller) Bergh and diatom *Cyclotella trichonidea* Economou-Amilli. Species *Fragilaria capucina* Desm., *Fragilaria crotonensis* Kitt. and *Dinobryon divergens* Imhof were also well represented (Tab. 2).

The analysis of variance (ANOVA) showed a significant monthly variation in diversity due to the variation in the number of species and distribution of cells among the different species ($p < 0.01$). Species diversity was highest during February, while late spring and early summer presented the lowest mean diversity (Fig. 3). Low diversity and low equitability was result of the dominance of a single species. *A. formosa* with increased number of cells contributed most (>90%) to the total net-phytoplankton abundance during May, June and July. Also, in June the annual maximum of *A. formosa* abundance was observed (16.7 × 10^5 cells l^{-1} and 30.8 × 10^5 cells l^{-1}, at K1 and K2, respectively). *Ceratium hirundinella* contributed mostly to the summer net-phytoplankton in August and reached density maximum during autumn, replacing diatom-dominated summer assemblages. Cluster analysis of the abundance data set indicates the separation of three groups at the 55% similarity level (Fig. 4). Cluster 1 contained autumn samples with *C. hirundinella* and *A. formosa* reaching 95 % of cells density in association with *Peridinium cinctum* Ehrenberg. A high number of species, with the same dispersed dominance among *A. formosa*, *Cyclotella trichonidea* and *Fragilaria capucina* characterized net-phytoplankton assemblages in February and resulted in the strong grouping of cluster 2. The cluster 3 joined all samples with *A. formosa* as dominant form. Within this cluster two subgroups (>60% similarity) were formed according to the presence of *Fragilaria crotonensis* in the assemblages. Two dimensional MDS ordination supported cluster separation of net--phytoplankton assemblage according to the similarity of species composition during the investigation period. *F. crotonensis* contributed to the net-phytoplankton assemblages during winter and spring (Fig. 5) and strongly affected the grouping of samples in cluster 3b (Fig. 4). Except in September, *C. trichonidea* appeared as ac-

Tab. 2. Taxonomical composition of net-phytoplankton in the Lake Visovac (max – maximal abundance cell l^{-1}, fr-relative frequency)

	K1		K2	
	max	fr	max	fr
Cyanobacteria				
Limnothrix planctonica (Woloszynska) Meffert	174	7.6		
Tychonema bornetii (Zukal) Anagnostidis & Komárek			210	4.5
Dinophyta				
Ceratium hirundinella (Müller) Dujardin	3.1×10^4	80.3	6.6×10^3	80.3
Peridinium cinctum (Müller) Ehrenberg	174	10.6	40	1.5
Peridinium incospicuum Lemmermann			1.0×10^3	9.1
Chrysophyta				
Chrysophyceae				
Dinobryon divergens Imhof	2.1×10^3	43.9	4.6×10^4	37.9
Bacillariophyceae				
Achnanthidium affine (Grunow) Czarnecki	120	1.5	100	1.5
Achnanthidium minutissimum (Kützing) Czarnecki			230	3.0
Amphora ovalis (Kützing) Kützing	37	1.5	30	1.5
Asterionella formosa Hassall	1.6×10^6	100.0	3.1×10^6	100.0
Aulacoseira granulata (Ehrenberg) Simonsen	864	4.5	4.5×10^3	4.5
Cyclotella ocellata Pantocsek	2.0×10^3	13.6	570	16.7
Cyclotella radiosa (Grunow in van Heurck) Lemmermann	2.6×10^3	30.3	1.5×10^3	22.7
Cyclotella trichonidea Economou-Amilli.	4.8×10^4	69.7	1.6×10^4	68.2
Cymbella affinis Kützing			30	1.5
Cymbella laevis Nägeli	40	1.5		
Cymbella lanceolata Kirchner			20	1.5
Diatoma ehrenbergii f. *capitulata* (Grunow) Lange-Bertalot	702	4.5		
Diatoma vulgare Bory de Saint-Vincent	192	1.5	440	3.0
Eolimna minima (Grunow) Lange-Bertalot	37	1.5	40	1.5
Fragilaria capucina Desmazières	1.1×10^4	12.1	3.4×10^3	13.6
Fragilaria crotonensis Kitton	2.2×10^4	50.0	2.4×10^4	47.0
Gomphonema acuminatum Ehrenberg	37	1.5	30	1.5
Gyrosigma attenuatum (Kützing) Cleve	27	3.0	40	3.0
Gyrosigma scalproides (Rabenhorst) Cleve	290	7.6	30	1.5
Melosira varians Agardh	2.1×10^3	21.2	440	7.6
Navicula radiosa Kützing	37	3.0	30	4.5
Navicula tripunctata (Müller) Bory de Saint-Vincent	216	3.0	40	7.6
Surirella biseriata Brébisson	178	13.6		
Synedra ulna (Nitzsch) Ehrenberg	39	1.5	310	12.1
Ulnaria capitata (Ehrenberg) Compère	117	13.6	80	13.6
Ulnaria danica (Kützing) Compère & Bukhtiyarova	600	37.9	450	43.9
Chlorophyta				
Ankistrodesmus falcatus (Corda) Ralfs	20	1.5		
Coelastrum astroideum De Notaris	37	4.5		
Cosmarium botrytis Meneghini ex Ralfs			30	1.5
Cosmarium impressulum Elfving	23	3.0	30	3.0
Cosmarium laeve Rabenhorst	23	3.0		
Golenkinia radiata Chodat	22	1.5		
Kirchneriella lunaris (Kirchner) Möbius	22	4.5	30	1.5
Lagerheimia chodatii Bernard	2.8×10^3	12.1	300	9.1
Mougeotia sp. Agardh			100	3.0
Scenedesmus quadricauda (Turpin) Brébisson	29	1.5	30	1.5
Sphaerocystis schroeteri Chodat	528	15.2	830	13.6
Spirogyra sp. Link	60	1.5		
Tetrabaena socialis (Dujardin) Nozaki & Itoh	132	1.5	30	1.5

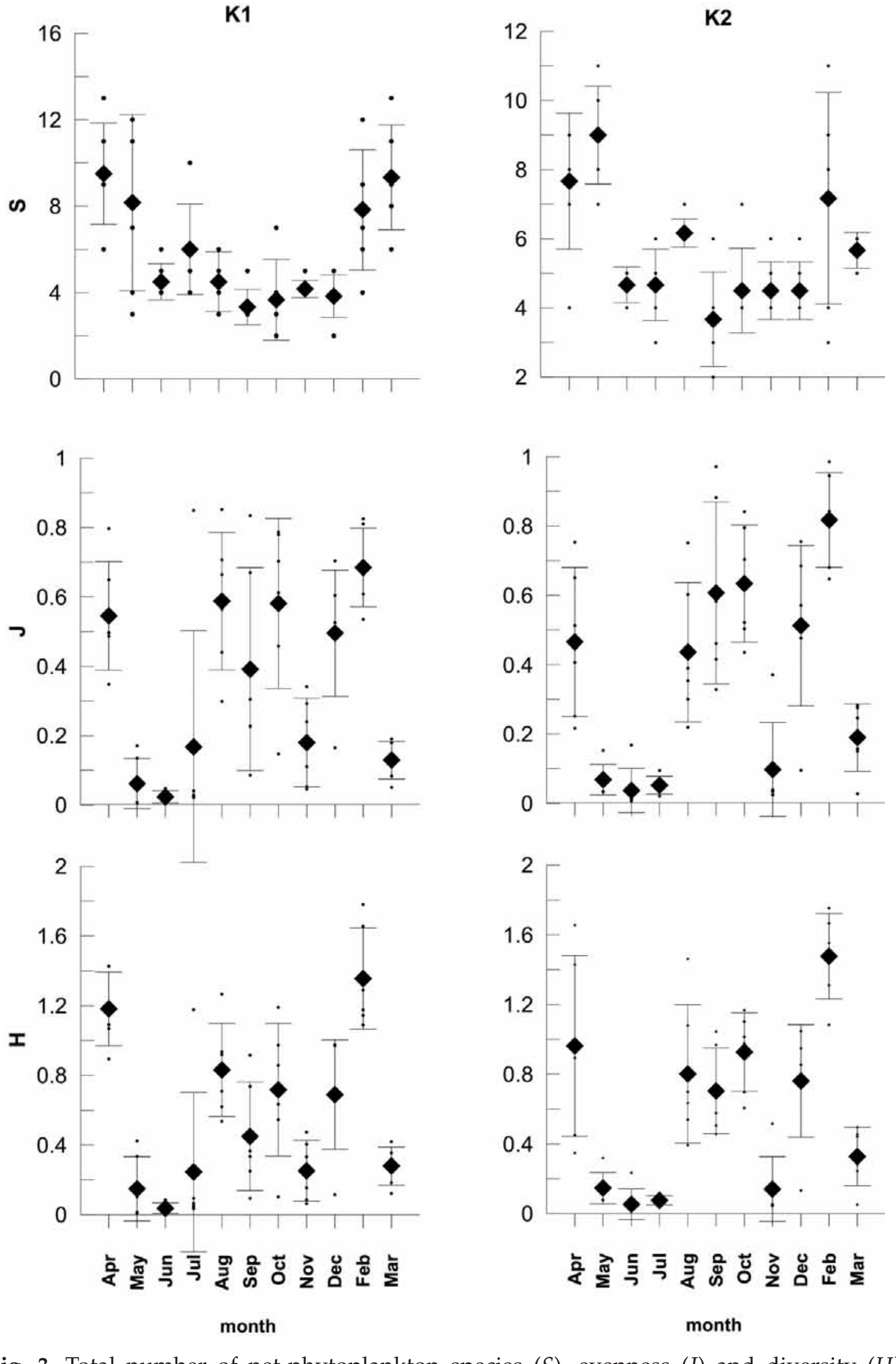

Fig. 3. Total number of net-phytoplankton species (*S*), evenness (*J*) and diversity (*H*) based on net-phytoplankton abundance data set at K1 and K2 sampling points.

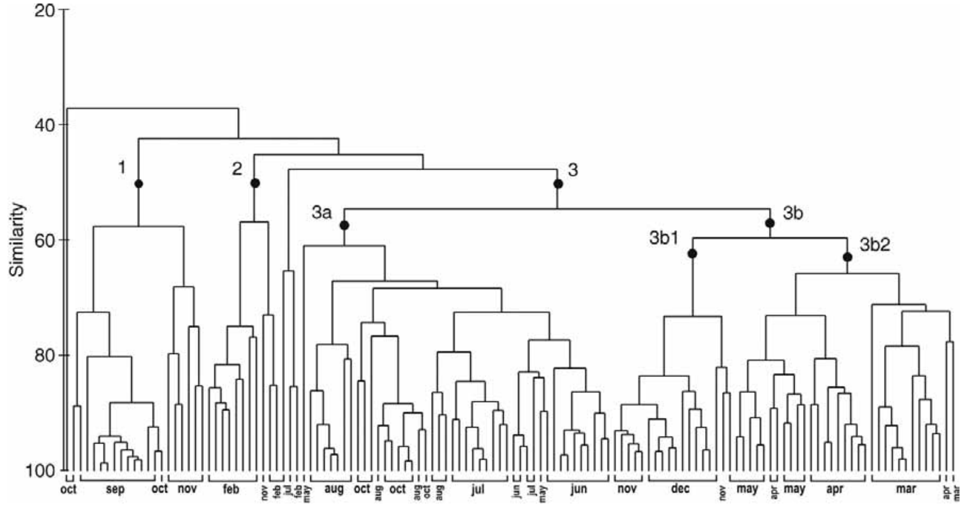

Fig. 4. Dendrogram for hierarchical clustering of net-phytoplankton abundance at sites K1 and K2, based on the Bray-Curtis similarity matrix.

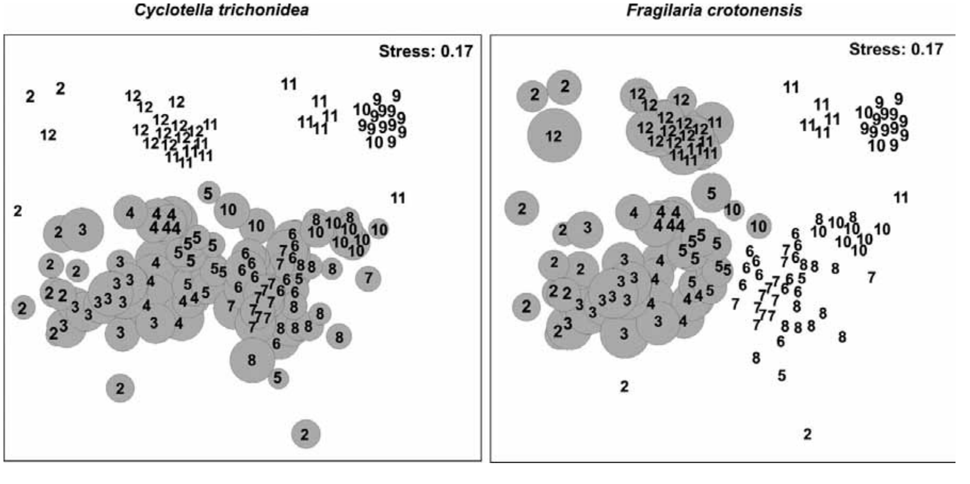

Fig. 5. Two dimensional MDS ordinations of annual K1 and K2 samples based on log(x+1) transformed data and a Bray-Curtis similarity matrix. Superimposed circles represent species abundance during investigation period and numbers represent months.

companying species in spring, summer and autumn periods (Fig. 5). This temporal distribution of *C. trichonidea* mostly affected the subgrouping of the 3a and 3b2 clusters (Fig. 4).

To evaluate the most important environmental variables BIO-ENV procedure was performed. A standard Spearman rank correlation highlighted temperature as environmental variable which best grouped samples, with ρ_w value of 0.401. The best 4-variable combination involved temperature as primary but also added oxygen, concentration of SO_4^{2-} and ammonia (ρ_w = 0.363). CCA analysis performed on abundance dataset and environmental variables presented in Tab. 1 confirm the importance of temperature. The first three axes explained 13% of the species variance. The eigenvalues for the CCA axis 1 and 2 were 0.284 and 0.132, respectively (Fig. 6). The most important variable was temperature which positively correlated with axis 1 (r=0.782). Concentration of total phosphorus positively correlated with axis 1 (r=0.438). Significance of conductivity was expressed by negative correlation with axis 2 (r=–0.695). The importance of silica concentration in variation of phytoplankton abundance and temporal species assemblages was explained by axis 3 (r=–0.423).

DISCUSSION

Diatoms dominated the phytoplankton assemblage of the lentic barrage area of the karstic River Krka. The master species in Lake Visovac was *A. formosa*. As species which has cosmopolitan distribution, *A. formosa* usually develops within a wide range of environmental conditions (REYNOLDS, 1984; DUTHIE & HART, 1987; NEGRO *et al.*, 2000; TEUBNER *et al.*, 2003). Broadly distributed at a higher trophic gradient (BORISC *et al.*, 2000; MARCHETTO & MUSAZZI, 2001), it is also encountered in

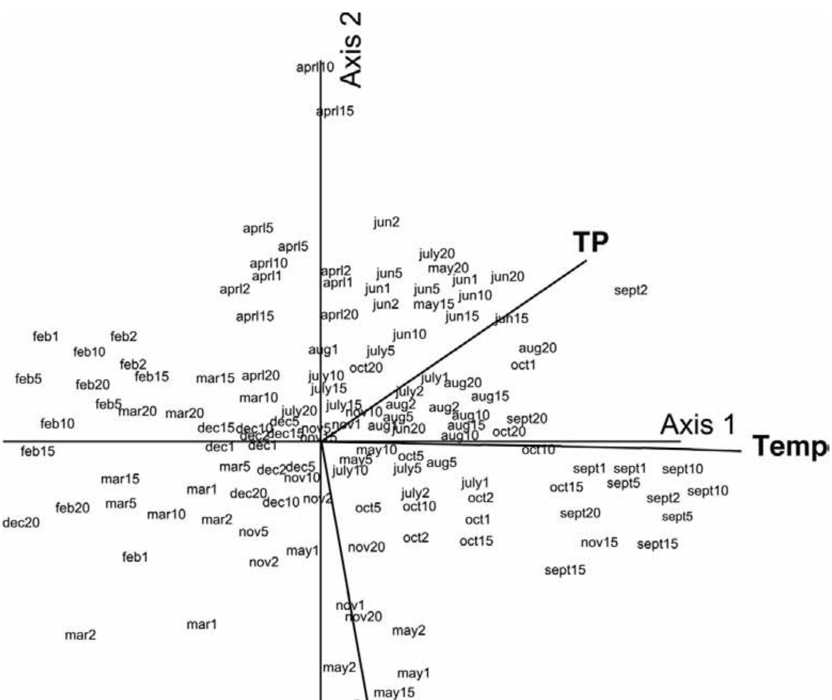

Fig. 6. Canonical correspondence analysis (CCA) ordination of the net-phytoplankton annual assemblages.

oligotrophic conditions (SPAULDING *et al.*, 1993, NOGES *et al.*, 2000; RAKAJ *et al.*, 2000), and it can become one of the predominant species in conditions of ultraoligotrophy (EDLUND *et al.*, 2003). Lake Visovac is characterized as mesotrophic system (BUKVIĆ-TERNJEJ *et al.*, 2001; PRIMC-HABDIJA *et al.*, 2001) and *A. formosa* in this calcareous water body showed wide seasonal distribution. Among the planktonic pennate diatoms, *A. formosa* is known to be present in rivers just as it is in lakes. Also, as a dominant species of phytoplankton, in rivers it produces large, low-diversity populations (REYNOLDS & DESCY, 1996). The species *A. formosa* contributed at least 90 % of total abundance during the warm and stratifying months in the mesotrophic, calcareous Lake Visovac, producing very low diversity values. Net-phytoplankton abundance and changes in dominance followed changes of temperature. *A. formosa* reached maximum during the stable stratified period in conditions of water temperature range from 14 to 21°C, while in a series of calcareous reservoirs in France it became dominant species only at temperatures ranging from 3.7°C to 8.8°C (BERTRAND *et al.*, 2003). Otherwise, the best growth rate for *Asterionella* cells was described at a temperature close to 20°C (TOSHIYUKI *et al.*, 1994), although the dominance of this species was described under conditions of low temperature (0°C to 4°C) (SPAULDING *et al.*, 1993). High and fluctuating conductivity values are comparable to the conductivity of other calcareous water bodies, and the association of *A. formosa* with conductivity values supports the potentially positive effect of high conductivity on its development (BERTRAND *et al.*, 2003). Statistical analysis suggests a positive correlation of phytoplankton density with nitrogen and phosphorus concentrations. The development of *A. formosa* is usually described under conditions of high nutrient concentrations (OLSÉN & WILLÉN, 1980; KUDOH & TAKAHASHI, 1990; SALMASO, 2003) and its growth is sensitive to phosphorus and nitrogen depletion (REYNOLDS, 1984; BERTRAND *et al.*, 2003). With very low statistical support in the canonical correspondence analysis, the development of *A. formosa* in Lake Visovac can be described in terms of higher silica concentration. The observed depletion of silica after maximum abundance of *Asterionella* cells supports some previous studies of *A. formosa* (REYNOLDS, 1984). In seasonal studies, *Cyclotella* species are observed as vernal and estival populations (REYNOLDS, 1984). In Lake Visovac the species *C. trichonidea* coexisted during spring with *F. crotonensis*, but its presence during summer is a consequence of low silica requirements. However, *F. crotonensis* was mainly present during the spring and autumn, developing during high silica concentration (MORABITO *et al.*, 2003; SALMASO, 2003). These changes in silica concentration during a stable stratified period can be regarded as disturbance since it brought about distinct changes in species diversity (WEITHOFF *et al.*, 2001).

The dinoflagellates were generally the second most representative group in terms of abundance. Their annual development was shifted to the late summer and autumn period. In contrast to the pattern of *Ceratium* development in lakes located mostly in temperate altitudes (REYNOLDS, 1984; HEANEY *et al.*, 1988; LINDSTROM, 1992), the prolongation of dinoflagellate development to the colder part of the year has been known in Mediterranean lakes as well as their development in winter period (PÉREZ-MARTÍNEZ & SÁNCHEZ-CASTILLO, 2002; TOMEC *et al.*, 2002; GLIGORA *et al.*, 2003). As species affected by temperature conditions (GRIGORSZKY *et al.*, 2003b), *C. hirundinella* can be associated with long stratifying period in deep lakes in Mediterranean climate conditions due to the extension of the summer period or certain temperature conditions (PÉREZ-MARTÍNEZ & SÁNCHEZ-CASTILLO, 2002).

The simplest way of aggregating species is in the phylogenetic groups. Such an approach assumes that different phylogenies somehow reflect important ecological differences among species (WEBB *et al.* 2002). The second approach is to use functional classifications (PADISAK & REYNOLDS 1998; MCGILL *et al.* 2006) and this approach proved to be more useful for ecological purposes (KRUK *et al.*, 2002; SALMASO & PADISAK, 2007). Such functional classifications proposed for phytoplankton by several authors (REYNOLDS *et al.* 2002; SALMASO & PADISAK 2007) are based not only on individual functional traits, but also on the range of environmental conditions over which the species are likely to occur, as well as co-occurrence patterns. According to the functional classification of phytoplankton (REYNOLDS, 1997; REYNOLDS *et al.*, 2002) *A. formosa* is representative of two distinct associations named B and C. This common pennate diatom occurs during the vernal period as dominant or subdominant species with *Cyclotella* and *Aulacoseira* species or *F. crotonensis* and *Stephanodiscus* spp. of Associations B and C, respectively. Also, according to some revisions, codon C is the best in description of ecological preferences of *A. formosa* (PADISAK *et al.* 2009). According to the functional group approach (REYNOLDS, 1997; REYNOLDS *et al.*, 2002; and PADISÁK *et al.*, 2008) *Cyclotella* (genus) spp. can be classified into coda A, B and C depending on their morphological and ecological properties and corresponding habitat traits. Namely, *C. trichonidea* is noted by Reynolds in Association B together with selected species of *Aulacoseira* and *Synedra*. Obviously, in Lake Visovac, under mesotrophic conditions, Reynolds groups B and C are present during a one year period, with exception of late summer and autumn assemblages, which are characterized by an association of large dinoflagellate species known as Group L_M. This association is originally based on coexistence of species *Microcystis aeruginosa* Kütz. emend. Elenk. This typical representative of Group L_M was not recorded during this investigation. The existing facts of dinoflagellate environmental preferences (GRIGORSZKY *et al.*, 2003a) and its widespread distributions together with present investigation also support separation of *Ceratium* in the L_O but not in B functional group (PADISÁK *et al.*, 2003; PADISÁK *et al.*, 2009). While this classification integrates a rich base of information, an alternative classification based exclusively on objective morphological aspects such as individual volume, surface area, and maximum length has also been proposed by Kruk *et al.* 2010. A morphologically based functional classification in phytoplankton does not invalidate other already motioned ecological classifications of phytoplankton (REYNOLDS, 1988; REYNOLDS *et al.*, 2002; SALMASO & PADISAK, 2007) but provides an easy-to-use, grouping, attempting to understand and predict the composition of phytoplankton communities. The dominant morphologically based functional group in Lake Visovac is Group V, which presents unicellular flagellates of medium to large species. In this group there is variety of types ranging from r-selected species such as *Chlamydomonas* to K-selected, such as *Ceratium hirundinella*, species well adapted to conditions in Lake Visovac in late summer and autumn. Also, the other dominant species in Lake Visovac are grouped in Group VI (non-flagellated organisms with siliceous exoskeletons) the group of diatoms from the small r-selected *Cyclotella* to large K-selected diatoms.

The effects of the short term dynamics of environmental factors on algal growth in the lentic barrage area of a calcareous river stressed several variables as important factors controlling annual net-phytoplankton distribution. Cumulative variances suggest that population diversity, like density, is changing with the temperature change. Species distribution is correlated and influenced by temperature and also by water ionic content such as concentration of sulfates, calcium and carbon hydrates. So far, there has been no clustering of the species when it comes to predicting the effects of environmental change on community composition in this area. All the data on net species dominance in Lake Visovac together with environmental preferences and tolerance provide a useful pool for phylogenetic grouping but also for possible functional and morph-based functional grouping, which in the future will prove to be more useful for ecological purposes and also coincides with the needs of the implementation of the Water Framework Directive.

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SAŽETAK

Dominantne vrste mrežnog fitoplanktona u Visovačkom jezeru, NP Krka

M. Gligora Udovič, K. Kralj Borojević, P. Žutinić, L. Šipoš & A. Plenković-Moraj

Rad opisuje sezonsku raspodjelu i dominaciju fitoplanktonskih vrsta u donjem, ujezerenom dijelu rijeke Krke na području Visovačkog jezera te opisuje utjecaj fizikalno-kemijskih čimbenika na rast dominantnih vrsta. Rijeka Krka predstavlja lotičko-lenitički ekosustav u predjelu srednje Dalmacije. Donji ujezereni dio rijeke, nizvodno od Roškog slapa je Visovačko jezero (površina 572 m^2, volumen 103×10^6 m^3) u kojem su istraživanja provedena jednom mjesečno na vertikalnim profilima postaja K1 i K2. Uzorci vode za kemijske analize uzimani su istovremeno s uzorcima planktona. Tijekom istraživanog razdoblja zabilježene su visoke koncentracija dušika i fosfora na objema istraživanim postajama. Provodljivost se na istraživanim postajama kretala između 380 $\mu S\ cm^{-1}$ i 580 $\mu S\ cm^{-1}$ i bila je očekivana za krški ekosustav. Temperatura se mijenjala sezonski (6,4°C – 23,4°C) s utvrđenom termalnom stratifikacijom od proljeća do kasnojesenskog razdoblja. Zabilježene su i znatne razlike u koncentraciji silicija tijekom istraživanog razdoblja na objema postajama. Godišnji minimum silicija zabilježen je tijekom ljetnog razdoblja nakon razvoja dominatne vrste *Asterionella formosa* Hass.

Raznolikost vrsta bila je najveća u veljači. Izrazito niska brojnost vrsta tijekom ljetnog i jesenskog razdoblja uvjetovana je dominacijom vrsta *A. formosa* tijekom ljeta i vrste *Ceratium hirundinella* (O. F. Müller) Bergh tijekom jeseni. Tijekom svibnja, lipnja i srpnja vrsta *A. formosa* obuhvaća više od 90% ukupnog broja stanica po litri. Tijekom lipnja zabilježen je i najveći broj stanica vrste *A. formosa*. Najveći broj stanica po litri vrste *C. hirundinella* zabilježen je na postaji K1 u rujnu i na postaji K2 u listopadu kada vrsta *C. hirundinella* obuhvaća više od 90% ukupnog broja stanica po litri mikrofitoplanktonske zajednice. Tijekom zime i proljeća značajna vrsta u zajednici je *Fragilaria crotonensis* dok zajednicu tijekom proljeća, ljeta i jeseni karakterizira vrsta *Cyclotella trichonidea*. Od mjerenih ekoloških parametara, temperatura vode najviše je utjecala na promjene u sastavu vrsta, njihovu brojnost i dominaciju. CCA analiza dobivena na osnovi broja stanica po litri mikrofitoplanktonskih vrsta i praćenih ekoloških čimbenika potvrdila je znatan utjecaj temperature vode, kao i ukupne koncentracije fosfora, silicija i provodljivosti.