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ALGAE ON TRAVERTINE BARRIERS OF THE KRKA RIVER NEAR ŽUŽEMBERK, SLOVENIA

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Algal occurrence, with particular emphasis on diatoms, was investigated over a two-year period on the travertine barriers of the Krka River in Slovenia. The purpose of the investigation was to establish qualitative composition and the relative abundance of the periphyton. In 1999 and 2000, basic physical and chemical parameters were measured. Altogether, 81 algal taxa were determined. Most of them belonged to Bacillariophyceae. Fifteen species and subspecies were new to Slovenia, 14 of them belonging to Bacillariophyceae and one to Cyanobacteria. Most of the new species and subspecies belonged to genera *Nitzschia* (5) and *Navicula* (4).

Key words: algae, periphyton, Krka River, travertine barriers

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Tijekom dvije godine istraživana je prisutnost algi s posebnim naglaskom na dijatomeje na sedrenim barijerama rijeke Krke u Sloveniji. Cilj je bio utvrđivanje kvalitativnog sastava i relativne brojnosti perifitona. Tijekom 1999. i 2000. mjereni su temeljni fizikalni i kemijski parametri. Utvrđen je 81 takson algi. Većina pripada u Bacillariophyceae. Petnaest vrsta i podvrsta bilo je novo za Sloveniju, od čega 14 spada u Bacillariophyceae i 1 u Cyanobacteria. Većina novih vrsta i podvrsta pripadalo je rodovima *Nitzschia* (5) i *Navicula* (4).

Ključne riječi: alge, perifiton, Krka, sedrene barijere

INTRODUCTION

The Krka River is the only Slovenian river with travertine barriers. The numerous karst springs in the upper part of the river lead to saturation of the river water

with calcium carbonate, which can under specific conditions be eliminated from the river water as travertine. The differentiated habitats of the travertine barriers in the Krka River is reflected in the occurrence of many specifically adapted species of flora and fauna (HUDOKLIN, 1994).

LAZAR (1975) studied algae in the Krka at Vavta vas, Srebrniče and Otočec. Some data on algal species relating to the travertine barrier at Srebrniče (in *Research into the Quality of Surface Waters in Slovenia* in 1992, ZUPAN /ed., 1994/), where the sampling site of the Hydro-Meteorological Institute of Slovenia is situated, can be found.

VRHOVŠEK *et al*. (1996) studied algae on the travertine barriers at Žužemberk and Otočec. They found 72 different species of algae with Bacillariophyceae as a dominant group.

The aim of the investigation was to determinate the species composition and relative abundance of the periphyton on the travertine barrier of the Krka River near Žužemberk in Slovenia.

Description of the sampling site

The sampling site (Fig. 1) is located at the beginning of the town of Žužemberk, behind the old mill. Co-ordinates according to Gaus-Krüger are: X=5076625, Y= 5494375. The width of the rivebed at the sampling site is about 50 meters. The travertine barriers at the sampling site are overgrown with water mosses. The most common trees and bushes on both sides of the course were as follow: *Corylus avellana* L., *Alnus glutinosa* (L.) Gaertn., *Carpinus betulus* L., *Acer campestre* L., *Quercus robur* L., *Cornus sanguinea* L., and *Fraxinus ornus* L.

MATERIALS AND METHODS

In August and October 1999 and February 2000 temperature, conductivity, pH, dissolved oxygen and percentage saturation were measured (APHA, 1992).

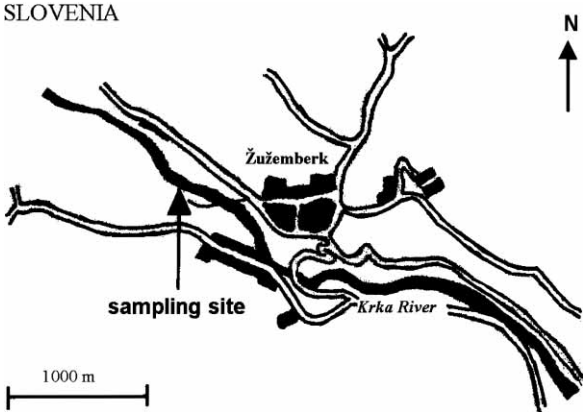

Fig. 1. The location of the sampling site.

Five samples of periphyton were collected in different seasons during the years 1998, 1999 and 2000. The samples were scraped from the surface of stones and rocks by means of a razor and also squeezed out of the water mosses. The samples were immediately preserved in a solution of four per cent formaldehyde. Each of the samples was treated with concentrated HNO_3 to determine Bacillariophyceae species (APHA, 1992).

Species were determined by light microscope (magnification 400× and 1000×) and the following identification monographs: LAZAR (1960), STARMACH (1966, 1972, 1980), KRAMMER & LANGE-BERTALOT (1986, 1988, 1991a, 1991b), HINDÁK *et al*. (1978), HINDÁK (1996), CVIJAN & BLAŽENČIĆ (1996). Relative abundance was estimated according to PANTLE & BUCK (1955) with numbers 1, 3 and 5 (1–single, 3–customary, 5–dominant).

The saprobe content of the Krka (Saprobic Index) was calculated on the basis of a list of indicator organisms (according to WEGL, 1983) using the Pantle-Buck Index (PANTLE-BUCK, 1955)

RESULTS AND DISCUSSION

The values of physical and chemical parameters measured in the Krka River are presented in Tab. 1. Results confirm the connection of water temperature and conductivity. An increase of water temperature caused an increase of the conductivity. WETZEL & LIKENS (1991) found out that conductivity increases about 2 to 3% per 1°C. Despite the span of pH values in inland waters being from 2 to 12 pH, in Slovenia it ranges mostly between 6 and 8.5 (REJIC, 1988). During the study period pH values range from 7.90 to 8.10. The amount of dissolved oxygen in water was from 10.2 to 16.0 mg/l at the time of measurement and the saturation was from 102 to 118%.

Altogether 81 taxa of algae were determined (Tab. 2). Most of them (65) belonged to Bacillariophyceae, six belonged to Cyanobacteria, six to Chlorophyceae, three to Zygnematophyceae and one to Florideophyceae. VRHOVŠEK *et al.* (1996) studied algae on a travertine barrier at Žužemberk. They registered 57 different species of algae, with Bacillariophyceae prevailing, followed by Chlorophyceae, Cyanophyceae, Chrysophyceae and Florideophyceae.

Tab. 1. Values of some physical and chemical parameters from a travertine barrier of the Krka River in the years 1999 and 2000.

Parameter	27.8.1999	23.10.1999	13.2.2000
Temperature (°C)	14.5	10.8	7.9
Conductivity (μS/cm)	480	415	394
pH	7.97	8.10	7.9
Oxygen (mg/l)	10.2	12.8	16.0
Saturation (%)	102	112	118

Tab. 2. Qualitative and quantitative composition of periphyton from a travertine barrier of the Krka River in the years 1998, 1999 and 2000.

Taxa	Date of sampling				
	20.9.98	24.4.99	27.8.99	23.10.99	13.2.00
PROKARYOTA					
CYANOBACTERIA					
Chamaesiphon curvatus Nord.					1
Gloeocapsa crepidinum Thur.	1				
Oscillatoria sp.		1			
**Phormidium henningsii* Lemm.		1		1	
Phormidium retzii (Ag.) Gom.				1	1
Phormidium sp.	1		1	1	
EUKARYOTA					
RHODOPHYTA					
FLORIDEOPHYCEAE					
Audouinella chalybea (Lyng.) Fr.	1	1	1	1	
HETEROKONTOPHYTA					
BACILLARIOPHYCEAE					
Achnanthes delicatula (Kütz.) Grun.	1		1	1	1
**Achnanthes lanceolata* ssp.*dubia* (Grun.) Lan.-Bert.			1		
Achnanthes lanceolata ssp.*lanceolata* var.*lanceolata* (Bréb.) Grun.		1			
Achnanthes minutissima Kütz.	1	1	1	1	
Achnanthes sp.	1				
Amphora libyca Ehren.	1		1	1	1
Amphora montana Krass.				1	
Amphora ovalis (Kütz.) Kütz.	1	1		1	1
Amphora pediculus (Kütz.) Grun.	5	1	3	1	1
Caloneis silicula f. *silicula* (Ehren.) Cl.	1				
Cocconeis pediculus Ehren.	1	1	3	1	1
Cocconeis placentula Ehren.	1	3	3	1	3
Cyclotella sp.				1	
Cymatopleura solea (Bréb.) W. Sm.			1	1	
Cymbella prostrata (Berk.) Cl.		1	1		
Cymbella silesiaca Bleis.	1		1	1	1
Cymbella sinuata Greg.	1		1	1	1
Denticula tenuis Kütz.		1	1		
**Diatoma moniliformis* Kütz.		1			1
Diatoma vulgaris Bor.	1	3	3	1	5
Diploneis oblongella (Naeg.) Cl.-Eu.				1	
Ellerbeckia arenaria (Mo.) Craw.	1			1	1
Fragilaria capucina Desm.	1	1			1
Fragilaria construens (Ehren.) Grun.	1				
Fragilaria ulna var. *ulna* (Nit.) Lan.-Bert.	1		1	1	1
Gomphonema angustum Ag.	1	1	1		1
**Gomphonema clevei* Hust.	1				
Gomphonema olivaceum (Horn.) Bréb.		1	3	1	1
Gomphonema parvulum Kütz.	1		1		1
Gyrosigma attenuatum (Kütz.) Raben.	1	1	1	1	1

**Gyrosigma nodiferum* (Grun.) Reim.					1
Gyrosigma scalproides (Raben.) Cl.			1	1	
Gyrosigma spencerii (Quek.) Grif. & Hen.				1	
Melosira varians Ag.	1	1	1	1	1
Meridion circulare (Grev.) Ag.		1		1	1
Navicula bacillum Ehren.			1		1
Navicula capitatoradiata Germ.	1		1	1	1
Navicula cryptocephala Kütz.			1	1	
Navicula lanceolata (Ag.) Ehren.		1	1		
Navicula menisculus var. *menisculus* Schum.			1		
Navicula reinhardtii Grun.			1		
Navicula rhynchocephala Kütz.				1	
**Navicula salinarum* Grun.			1		
**Navicula schroeterii* Meis.				1	
**Navicula subhamulata* Grun. & Van He.	1				
Navicula tripunctata (Müll.) Bor.	5	3	3	1	5
Navicula veneta Kütz.	3	1	1	1	3
**Navicula viridula* var. *linearis* Hust.		1	1		
Navicula viridula var. *viridula* (Kütz.) Ehren.			1		
Navicula sp.				1	1
**Nitzschia constricta* (Kütz.) Ral.				1	
Nitzschia dissipata var. *dissipata* (Kütz.) Grun.	1	1	1	1	1
Nitzschia fonticola Grun.	1	1	1	1	1
Nitzschia linearis var. *linearis* (Ag.) W. Sm.		1			
**Nitzschia linearis* var. *subtilis* (Grun.) Hust.	1				
Nitzschia palea (Kütz.) W. Sm.	1		1	1	
Nitzschia recta var. *recta* Hant.			1		
Nitzschia sigmoidea (Nit.) W. Sm.				1	
**Nitzschia sinuata* var. *delognei* (Grun.) Lan.-Bert.				1	
**Nitzschia vermicularis* (Kütz.) Hant.	1		1		
**Nitzschia wuellerstorffii* Lan.-Bert.		1			1
Rhoicosphenia abbreviata (Ag.) Lan.-Bert.	1	1	1	1	1
Surirella angusta Kütz.			1		
**Surirella brebissonii* Kramm. & Lan.-Bert.			1		1
Surirella spiralis Kütz.			1		1
CHLOROPHYTA					
CHLOROPHYCEAE					
Cladophora glomerata (L.) Kütz.	1	1	1	1	
Microspora amoena (Kütz.) Rab.		1			
Microspora pachyderma (Will.) Lagerh.	1		1		
Microspora stagnorum (Kütz.) Lagerh.		1			
Stigeoclonium sp.		1			
Ulothrix zonata (Web. & Mohr.) Kütz.	1		1		1
ZYGNEMATOPHYCEAE					
Closterium ehrenbergii Menegh.			1		
Closterium moniliferum (Bor.) Ehren.			1		
Mougeotia sp.		1			
Saprobic Index	1.73	1.62	1.71	1.77	1.66

Legend: * species and subspecies new to Slovenia

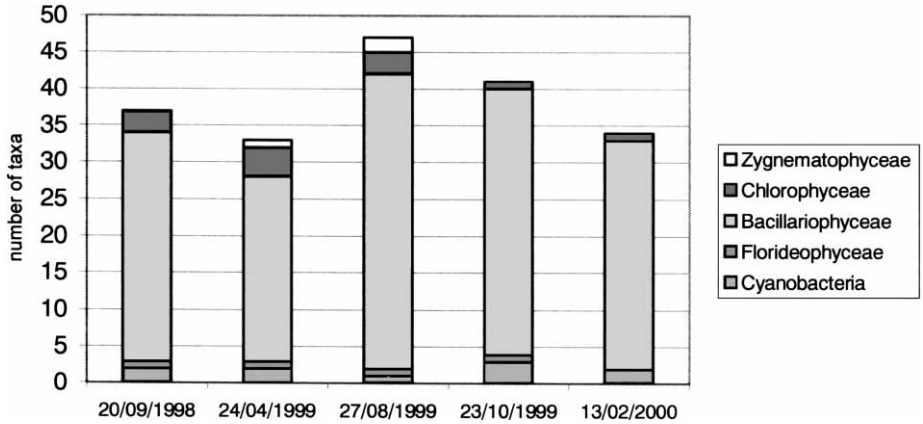

Fig. 2. Number of species from a travertine barrier of the Krka River during the investigation.

Most frequent in the periphyton community were Bacillariophyceae (Fig. 2). Bacillariophyceae are well known to be the most frequent in various types of rivers in Slovenia (VRHOVŠEK *et al.*, 1994; KRIVOGRAD, 1997; SMOLAR, 1997). Cyanobacteria and Chlorophyceae were equally frequent. *Audouinella chalybea* (Lyng.) Fries was present. The highest number of species was found in August and October 1999. In researches by others authors too, the highest number of species was found in summer and autumn (VRHOVŠEK *et al.*, 1994; SZAREK, 1994; SMOLAR, 1997).

In all periphyton samples from the travertine barrier of the Krka River, the following species and subspecies were recorded: *Amphora pediculus* (Kütz.) Grun., *Cocconeis placentula* Ehren., C. *pediculus* Ehren., *Diatoma vulgaris* Bory., *Gyrosigma attenuatum* (Kütz.) Raben., *Melosira varians* Agardh, *Navicula tripunctata* (Müll.) Bory., *N. veneta* Kütz., *Nitzschia dissipata* var. *dissipata* (Kütz.) Grun., *N. fonticola* Grun., and *Rhoicosphenia abbreviata* (Agardh) Lan.-Bert. The predominant species (relative abundance 5) were: *Amphora pediculus* in the sample taken in September, *Navicula tripunctata* in the samples taken in October and February and *Diatoma vulgaris* in the sample taken in February. Customary species (relative abundance 3) found were: *Amphora pediculus*, *Cocconeis pediculus* and *Gomphonema olivaceum* (Horn.) Bréb. in the sample taken in August, *Cocconeis placentula* in the samples taken in April, August and February, *Diatoma vulgaris* and *Navicula tripunctata* in the samples taken in April and August, and *Navicula veneta* in the samples taken in September and February. The genus *Closterium* occurred only in the summer samples.

On travertine barrier of the Krka River 15 species and subspecies new to Slovenia were determined (according to Limnos and National Institute of Biology algal data base DABA) 14 of them belonging to Bacillariophyceae and one to Cyanobacteria. The most frequent genera among the new species and subspecies were *Nitzschia* with five and *Navicula* with four new species and subspecies (Tab. 2).

The Saprobic Index (Tab. 2) ranged from 1.62 in April 1999 to 1.77 in October 1999. According to the results of the Saprobic Index we can classify the Krka River

at sampling site Žužemberk as being between oligosaprobic (unpolluted) and β-mesosaprobic (moderate impurity). The river water was cleaner in April and February. In September, August, and October (warmer season) the values of the Saprobic Index were higher but they did not reach the β-mesosaprobic level.

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SUMMARY

Algae on travertine barriers of the Krka River near Žužemberk, Slovenia

A. Krivograd Klemenčič, D. Vrhovšek & G. Kosi

Investigation of periphyton was carried out on a travertine barrier of the Krka River near Žužemberk in Slovenia. The purpose of the investigation was to determinate the qualitative composition and relative abundance of algae. Five samples of periphyton were taken. Algal species were determined using a light microscope. Relative abundance was estimated with numbers 1, 3 and 5 (1-single, 3-customary, 5-dominant). In years 1999 and 2000 basic physical and chemical parameters were measured.

Altogether 81 taxa of algae were determined. The most frequent were Bacillariophyceae, followed by Cyanobacteria and Chlorophyceae. Common species and subspecies were: *Amphora pediculus*, *Cocconeis placentula*, C. *pediculus*, *Diatoma vulgaris*, *Gyrosigma attenuatum*, *Melosira varians*, *Navicula tripunctata*, *N. veneta*, *Nitzschia dissipata* var. *dissipata*, *N. fonticola*, and *Rhoicosphenia abbreviata*.

On a travertine barrier of the Krka River 15 species and subspecies new to Slovenia were determined, 14 of them belonging to Bacillariophyceae and one to Cyanobacteria. The most frequent genera among the new species and subspecies were *Nitzschia* with five and *Navicula* with four new species and subspecies.

According to the results of the Saprobic Index we can classify the Krka River at the Žužemberk sampling site as between oligosaprobic and β-mesosaprobic.

SAŽETAK

Alge na sedrenim barijerama rijeke Krke kod Žužemberka, Slovenija

A. Krivograd Klemenčič, D. Vrhovšek & G. Kosi

Tijekom dvije godine istraživana je prisutnost algi s posebnim naglaskom na dijatomeje na sedrenim barijerama rijeke Krke u Sloveniji. Cilj je bio utvrđivanje kvalitativnog sastava i relativne brojnosti algi u 5 uzoraka perifitona. Vrste algi su determinirane svjetlosnim mikroskopom. Relativna brojnost procjenjivana je brojevima 1, 3 i 5 (1 – jedna, 3 – uobičajena, 5 – dominantna). Tijekom 1999. i 2000. mjereni su temeljni fizikalni i kemijski parametri.

Utvrđen je 81 takson algi. Najčešće su bile Bacillariophyceae, a slijedile su Cyanobacteria i Chlorophyceae. Uobičajene vrste i podvrste bile su: *Amphora pediculus*, *Cocconeis placentula*, C. *pediculus*, *Diatoma vulgaris*, *Gyrosigma attenuatum*, *Melosira varians*, *Navicula tripunctata*, *N. veneta*, *Nitzschia dissipata* var. *dissipata*, *N. fonticola*, i *Rhoicosphenia abbreviata*.

Na sedrenoj barijeri Krke determinirano je petnaest vrsta i podvrsta novih za Sloveniju, od čega 14 spada u Bacillariophyceae i 1 u Cyanobacteria. Većina novih vrsta i podvrsta pripadalo je rodovima *Nitzschia*, s pet, i *Navicula*, s 4 vrste i podvrste.

Prema rezultatima Saprobnog Indeksa možemo klasificirati Krku kod Žužemberka između oligosaprobnosti i ß-mezosaprobnosti.