Diversity, abundance and volume biomass of the phytoplankton of the Morava River (Czech Republic, Slovakia) and the Dyje River (Czech Republic) in November 2005

Diverzita, abundancia a objemová biomasa fytoplanktónu rieky Moravy (Česká republika, Slovensko) a rieky Dyje (Česká republika) v novembri 2005

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Abstract

Phytoplankton qualitative and quantitative analyses from the upper, middle and lower Morava River stretches and from lowermost Dyje River in November 2005 are presented. In the late autumn phytoplankton samples taken from the Morava in two sampling points in the Czech Republic (Olomouc, Lanžhot), and in one point in Bratislava–Devín, Slovakia, 346 species and infraspecific taxa belonging to 118 genera were determined. The highest number of species (incl. infraspecific taxa) was found in Bacillariophyceae – 153, following by Chlorophyceae – 100. About 19 taxa have not been yet registered in the lowest stretch of the Morava River. *Koliella elongata* (NYGAARD) NYGAARD (Chlorophyceae, Ulotrichales) is a new record for Slovakia. In the Dyje River, the main right side tributary of the Morava, 115 species and infraspecific taxa belonging to 49 genera were found, from them 79 species and infraspecific taxa (66% of total taxa) from Bacillariophyceae, while Chlorophyceae were represented only by 16 species and 1 variety.

In the Morava River the highest phytoplankton abundance was 29 317 cells per ml, and the highest value of phytoplankton biomass was 16.0 $mm^3.l^{-1}$. In the Dyje River the respective values were 4 085 per ml and 2.4 $mm^3.l^{-1}$.

Introduction

In the middle of last century the Morava River was one of the most heavily polluted rivers in Central Europe. During the last three decades, the ecological status of the Morava changed substantially. Straightening of the river led to the creation of many shallow water bodies (dead arms) with no direct connection to the river. At the same time the level of organic pollution from point sources decreased. This resulted in a considerable increase in phytoplankton diversity and abundance throughout the river. A similar trend took place in many other Central European rivers. Less positive incidental effect of water quality improvement is the excessive increase of algal biomass with all its negative impacts for river ecosystem balance (cf. MARVAN & HETEŠA 2000, MARVAN et al. 2004).

During the last decade both the standing waters in the floodplain area and the proper river ecosystem became object of intensive research activities. In the Moravian part of the Morava floodplain area it was, on one side, a research program focused on water quality assessment in artificial lakes created as a result of straightening the river bed. In the river ecosystem, the main attention was paid to the wire impoundment between Rohatec and Hodonín, having been studied from the point of view of its influence on phytoplankton dynamics. Whereas water bloom forming cyanobacteria and smaller centric diatoms with some middle-sized chlorococcal algae generally showed a more or less pronounced tendency to increase the abundance during passing though the impoundment, greater (colonies forming) diatoms like *Aulacoseira*, *Asterionella* and *Fragilaria crotonensis* tended, on the contrary, to recede. The observed decrease of extremely small algae (*Skeletonema potamos*, *Chlorella*) may by ascribed to feeding activities of Rotatoria in lower parts of impoundment.

In history, the upper stretch of the Morava River was sampled occasionally in 1950s′ by Marvan (HETEŠA & MARVAN 1984, 1987, 1997, MARVAN et al. 2004). Recently, a few studies were made by Ms or PhD students from Palacký University (NAVRÁTIL 2000, KOČÁRKOVÁ & POULÍČKOVÁ 2001, HAŠLER & POULÍČKOVÁ 2002, KOČÁRKOVÁ et al. 2003, LELKOVÁ & POULÍČKOVÁ 2004, LELKOVÁ et al. 2004) in the pools and gravel pits neighbouring with the river. However, regular research during the last fifty years at the upper Morava River stretch has been still lacking.

Concerning lower stretch of the Morava River in Slovakia, majority of papers were devoted to the biodiversity and taxonomy of cyanobacteria and algae. Summarizing all published floristic data (HINDÁK 1978-1900, HINDÁK & HINDÁKOVÁ 1997, 1998, 2004, HINDÁKOVÁ 1994, HINDÁK & MAKOVINSKÁ 1996), 206 genera with 692 species and infraspecific taxa have been identified. The highest number of taxa was found in the Bacillariophyceae: 39 genera with 287 species, whereas in the second largest group, Chlorophyceae, it was 97 genera with 234 species and 5 varieties. Several new taxa were described from these habitats or found for the first time in Slovakia (for the review see MARVAN et al. 2004). Annual mean values of chlorophyll-*a* concentration in the Morava River at the Bratislava – Devín (later only Devín) sampling point in 1995-2002 varied from 29.3 to 70.1 $\mu g.l^{-1}$ in 2002, and the chlorophyll–*a* concentrations in 2002 varied from 4.9 $\mu g.l^{-1}$ in January to 314.5 $\mu g.l^{-1}$ in July (TÓTHOVÁ et al. 2003).

As it follows from previous analyses, the lowermost stretch of the Morava River enables existence of an extremely broad spectrum of algae from different taxonomic groups. However, all floristic data refer to the main vegetation period, whereas more recent data from the colder part of the year (in the past strongly polluted by wastes form the sugar beet factories) are completely missing. The main aim of this paper is therefore to understand the phytoplankton of Morava and its main tributary Dyje in the autumn phase of its declining development and to compare them with the stand at the time of its summer culmination. Great attention is paid to assessing the ecological status of the river from the point of view of occurrence of rare and endangered species in the context of the EU Water Framework Directive.

Material and methods

The Morava River is the first major left-side tributary of the Danube River near the point of its entry into the Pannonian Lowland. It is a typical regulated lowland river with numerous left- and right-side tributaries and, in previous times, meanders along its whole length that formed side arms considered as an important source of the phytoplankton biodiversity and biomass for the river. Draining area is about 24 000 km^2 of the Moravian Region of the Czech Republic, and parts of western Slovakia and the northeastern part of lower Austria (Fig. 1).

The phytoplankton samples of the Morava in Olomouc were collected in November 9, 2005, at Lanžhot and Devín one day later, similarly as from the Dyje (Thaya) River, a major right-side tributary of the Morava River. The Dyje drains the western part of the Moravian Region, including an adjacent region of Austria. At the sampling point at Pohansko it leads into the Morava.

The sampling points represent three segments of the Morava River and the lowermost stretch of the Dyje River:

– sampling point No. 1 at Olomouc (232 river km) is placed at the upper stretch; average discharge of 27,1 $m^3.s^{-1}$;

– sampling point No. 2 at Lanžhot (78 river km) is situated at the end of the middle stretch (from the 70 to 232 river km) upstream from the confluence of the Dyje River; average discharge of 65 $m^3.s^{-1}$;

– sampling point No. 3 representing the lowermost stretch (0 – 70 river km) is located just near the confluence of the Morava River with the Danube at Devín; discharge of 34,42 $m^3.s^{-1}$ and depth of 1,51 m (source: Water Research Institute, Bratislava, 3. Nov. 2005).;

– Sampling point No. 4 at Pohansko below Břeclav represents the lowermost stretch of the Dyje River average discharge of 41,7 $m^3.s^{-1}$ (source: Povodí Moravy s.p.).

Hydrological characteristics of the rivers Morava and Dyje are presented in Table 1. All live samples were analyzed no later than 24 h after sampling. Quantitative phytoplankton data are based on counts of organisms in a Bürker cell after concentrating the sample by ultrafiltration (pores 1.2 µm). At least 300 organisms were counted in all samples (95% confidence interval 89 – 112%).

Table 1: Some data for the rivers Morava and Dyje in November 2005 (Temp – water temperature in ºC, Cond – conductivity in $\mu S.cm^{-1}$, Ox–R-oxygen concentration in $mg.l^{-1}$, Ox-P – oxygen saturation in %).

Locality	Date	pH	Temp	Cond	Ox-R	Ox-P
Olomouc	Nov. 9	7.65	7.5	334	9.96	85.1
Lanžhot	Nov. 10	8.07	8.9	668	11.54	99.0
Devín	Nov. 10	7.67	8.9	651	12.10	107.0
Dyje-Pohansko	Nov. 10	8.27	9.4	581	10.15	88.3

For determination of planktonic microorganisms the monographs cited in references were used (HINDÁK 1977, 1980, 1984, 1988, 1900, HUBER-PESTALOZZI 1955, KOMÁREK & ANAGNOSTIDIS 1998, KRAMMER & LANGE-BERTALOT 1986, 1988, 1991a, b).

Jaccard's distance (complement of Jaccard's coefficient of similarity to 1) was used for evaluation of differences in the floristic composition of samples from 4 investigated localities. Construction of Fig. 10 is based on arithmetic mean of absolute differences between portions of biovolume for the distinguished groups of algae. In both cases UPGMA clustering strategy was used in the tree construction. Ward´s clustering was used for evaluation of differences in the environmental variables.

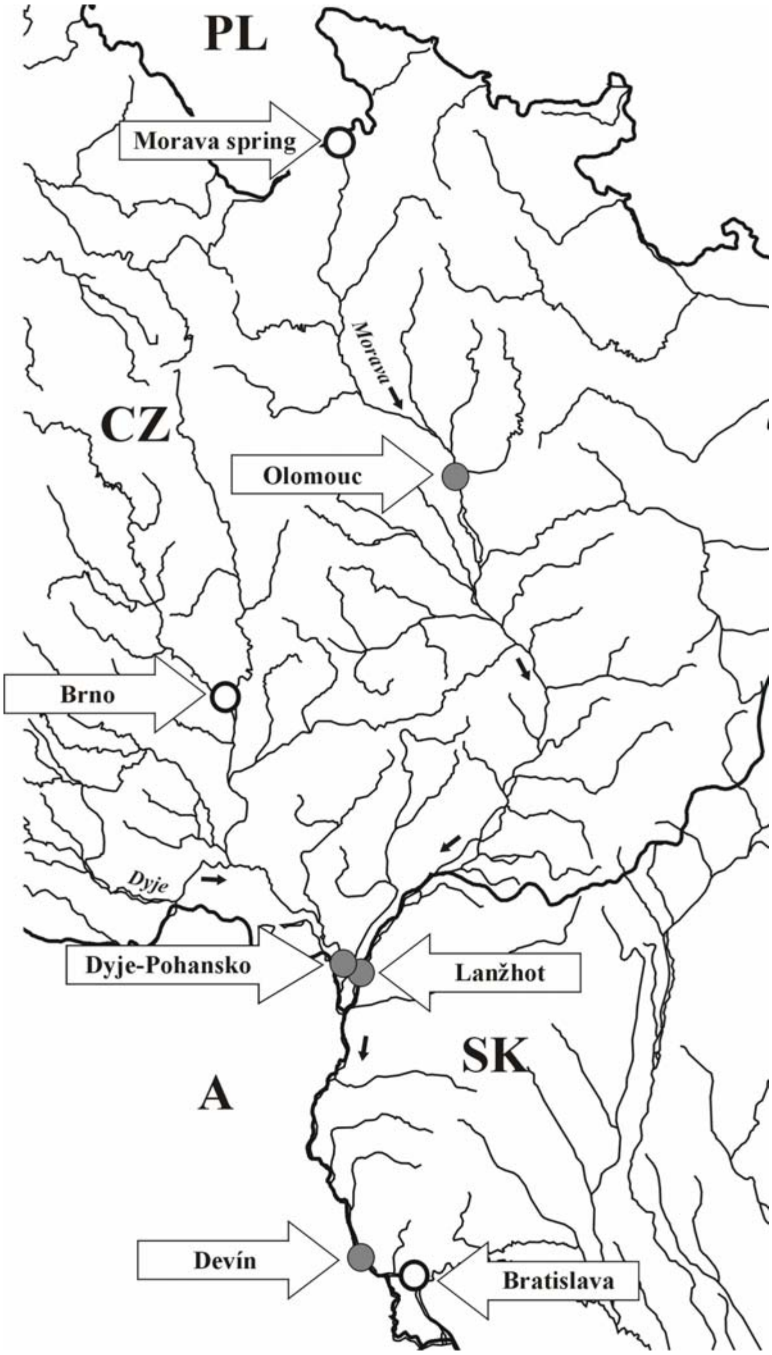

Fig. 1: Draining area of the Morava River and the sampling sites (dark circles).

Results

Phytoplankton species diversity of the Morava and Dyje rivers

In all samples from the Morava 346 species and infraspecific taxa belonging to 118 genera were determined (Table 2). The most number of species was found at Devín – 230, then in Lanžhot – 219 and Olomouc– 173 (Table 3). The highest number of species (incl. infraspecific taxa) was found in the

Bacillariophyceae: 153, and in the Chlorophyceae: 100. 19 taxa have not been yet registered in the lowest stretch of the Morava River. *Koliella elongata* (NYGAARD) NYGAARD (Chlorophyceae, Ulotrichales)(Figs. 8,9) is a new record for Slovakia (HINDÁK 1996).

The sampling points at Lanžhot and Devín did not differ essentially in the composition of the phytoplankton and the number of species. Diatoms with 153 taxa are the richest group of the phytoplankton assemblages. At the sampling point of Olomouc, 115 taxa of diatoms were found, what represents 66% of all found taxa. The second largest group are chlorophytes with 102 taxa, but in Olomouc only 17 species were recognized. From other groups of the phytoplankton, which represented 10-23% of all taxa, cyanophytes formed 9.63% (5.2-10.86%) and euglenophytes 5.8% (4-5.93%). 18 taxa have not been published from the Morava River (cf. HINDÁK & HINDÁKOVÁ 2004).

In the cyanophytes 30 taxa were determined, 18 species from Chroococcales, 6 species from Oscillatoriales and 5 species from Nostocales. No species from cyanophytes belonged to dominating or subdominating taxa, even not from the group forming water bloom.

Diatoms are a leader group in the phytoplankton of the river. The number of determined diatom taxa was similar at all sampling points. Relatively the highest number of taxa was found in Olomouc: altogether 115, from which 20 are centric and 95 pennates, then at Lanžhot (103: 22 centric and 81 pennates) and at Devín (102: 24 centric and 78 pennates). The representatives of Naviculales strongly dominated over Coscinodiscales. However, majority of the pennate diatoms comes originally from the benthos. From 153 found taxa 61 species occurred in all sampling sites. They are mostly species of cosmopolitan distribution, characteristic for mesotrophic or eutrophic running waters (cf. Figs. 2-7).

Phytoplankton diversity of the Dyje, the main right side tributary of the Morava, was much poorer in comparison with that of the Morava. In this river, 115 species and infraspecific taxa belonging to 49 genera were found, from them 79 species and infraspecific taxa are from Bacillariophyceae (66% of total taxa), while Chlorophyceae were represented only by 16 species and 1 variety.

Summarizing the above discussed comparisons of species diversity (floristric composition) of phytoplankton samples in more general level, the samples from Lanžhot and Devín have very similar floristic composition (having nearly 50% common species). Very similar is also list of taxa from these sampling sites and from Morava-Olomouc. Dyje at Pohansko has surprisingly low similarity to samples from all samplingisites on Morava (Fig. 10A).

Table 2: Phytoplankton composition of the rivers Morava and Dyje; abbreviations: O – Morava at Olomouc, L – Morava at Lanžhot, D – Morava at Devín, Dy – Dyje at Pohansko. New taxa for the lower stretch of the Morava River are marked with an asterisk (*) before scientific name.

Taxa/Localities	***O***	***L***	***D***	***Dy***
CYANOPHYCEAE				
Chroococcales				
Aphanocapsa delicatissima W. et G. S. WEST	+	+	+	
Aphanocapsa incerta (LEMMERM.) CRONBERG et KOMÁREK	+	+	+	
**Aphanocapsa minima* MIGULA			+	
**Aphanothece bachmanii* KOMÁRK.– LEGN. et CRONBERG			+	
**Aphanothece floccosa* (ZALESSKY) CRONBERG et KOMÁREK			+	
Cyanocatena planctonica HINDÁK		+		
Cyanogranis ferruginea (WAWRIK) HINDÁK		+	+	
**Cyanogranis libera* HINDÁK			+	
Merismopedia glauca (EHRENB.) KÜTZ.			+	
Merismopedia warmingiana LAGERH.		+	+	
Microcystis aeruginosa (KÜTZ.) KÜTZ.	+		+	+
Microcystis flos-aquae (WITTR.) KIRCHN.		+		+
Microcystis ichtyoblabe KÜTZ.			+	+
**Microcystis novacekii* (KOMÁREK) COMPÈRE		+	+	+
Microcystis wesenbergii (KOMÁREK) KOMÁREK		+		+
Snowella litoralis (HÄYRÉN) KOMÁREK et HINDÁK	+		+	
Woronichinia naegeliana (UNGER) ELENKIN			+	+
Oscillatoriales				
Jaaginema sp.		+	+	
Limnothrix redekei (GOOR) MEFFERT			+	
Oscillatoria sp.		+		
Planktolyngbya limnetica (LEMMERM.) KOMÁRK.-LEGN. et CRONBERG	+	+	+	
Planktothrix agardhii (GOMONT) ANAGN. et KOMÁREK	+	+	+	+
Phormidium sp.	+			+
Pseudanabaena catenata LAUTERBORN	+	+	+	+
Pseudanabaena limnetica (LEMMERM.) KOMÁREK	+	+	+	+
Pseudanabaena mucicola (NAUMANN et HUB.-PEST.) BOURR.			+	+
Nostocales				
Anabaena flos-aquae (LYNGB.) BRÉB. ex BORNET et FLAHAULT			+	+
Anabaena planctonica BRUNNTH.		+	+	
Aphanizomenon flos-aquae RALFS ex BORNET et FLAHAULT var. *klebahnii* ELENK.				+
Aphanizomenon gracile (LEMMERM.) LEMMERM.		+	+	
Raphidiopsis mediterranea SKUJA			+	
CHRYSOPHYCEAE				
Chromulina sp.			+	+
Chrysococcus diaphanus SKUJA		+	+	
Chrysococcus rufescens G. A. KLEBS	+	+		
Dinobryon divergens O. E. IMHOF		+	+	
Hymenomonas roseola F. STEIN		+	+	
Mallomonas sp.			+	
Pseudokephyrion entzii W. CONRAD		+		
BACILLARIOPHYCEAE				
Coscinodiscales				
Actinocyclus normanii (W. GREG. ex GREV.) HUST.			+	+
Aulacoseira ambigua (GRUNOW) SIMONSEN	+	+	+	+
Aulacoseira granulata var. *curvata* GRUNOW	+	+	+	+
Aulacoseira granulata (EHRENB.) SIMONSEN var. *granulata*	+	+	+	+
Aulacoseira muzzanensis (F. MEISTER) KRAMMER		+		
Aulacoseira subarctica (O. MÜLL.) E. Y. HAW.	+	+	+	
Cyclostephanos delicatus (GENKAL) CASPER et SCHEFFLER	+	+	+	+
Cyclostephanos dubius (FRICKE) ROUND	+	+	+	+

Cyclostephanos invisitatus (M. H. HOHN et HELLERMAN) E. C. THER., STOERMER et HÅK.	+	+	+	
Cyclotella atomus HUST.	+	+	+	
Cyclotella meneghiniana KÜTZ.	+	+	+	+
Cyclotella ocellata PANT.			+	
Cyclotella pseudostelligera HUST.	+	+	+	+
Cyclotella quadrijuncta (SCHRÖT.) KEISSL.		+		
Cyclotella stelligera CLEVE et GRUNOW				+
Cyclotella woltereckii HUST.	+	+	+	
Cyclotella sp.	+	+	+	
Melosira varians C. AGARDH	+	+	+	+
Skeletonema potamos (C. I. WEBER) HASLE		+	+	
Stephanodiscus binderanus (KÜTZ.) WILLI KRIEG.	+	+	+	
Stephanodiscus hantzschii GRUNOW f. *hantzschii*	+	+	+	+
Stephanodiscus hantzschii f. *tenuis* (HUST.) HÅK.	+	+	+	
Stephanodiscus minutulus (KÜTZ.) CLEVE et J.D. MÜLL..	+	+	+	+
Stephanodiscus sp.			+	
Thalassiosira duostra PIENAAR et PIETERSE	+		+	
Thalassiosira pseudonana HASLE et HEIMDAL	+	+	+	
Thalassiosira weissflogii (GRUNOW) G. A. FRYXELL et HASLE	+	+	+	+
Naviculales				
Achnanthes clevei GRUNOW			+	
Achnanthes exigua GRUNOW				+
Achnanthes hungarica (GRUNOW) GRUNOW		+		+
Achnanthes lanceolata (BRÉB. ex KÜTZ.) GRUNOW var. *lanceolata*	+	+	+	+
Achnanthes lanceolata var. *rostrata* (OESTRUP) HUST.	+	+	+	+
Achnanthes minutissima KÜTZ.	+	+	+	
Achnanthes ploenensis HUST.			+	+
Achnanthes sp. div.		+		+
Amphora libyca EHRENB.	+	+	+	+
Amphora montana KRASSKE	+		+	
Amphora ovalis (KÜTZ.) KÜTZ.	+	+		+
Amphora pediculus (KÜTZ.) GRUNOW	+	+	+	+
Amphora veneta KÜTZ.		+		+
Anomoeoneis sphaerophora (EHRENB.) PFITZER			+	
Asterionella formosa HASSALL	+	+	+	+
Caloneis amphisbaena (BORY) CLEVE	+		+	
Caloneis bacillum (GRUNOW) CLEVE	+	+		
Caloneis silicula (EHRENB.) CLEVE	+	+		+
Cocconeis pediculus EHRENB.	+	+		+
Cocconeis placentula EHRENB.	+	+	+	+
Cymatopleura elliptica (BRÉB.) W. SM. var. *elliptica*	+			+
Cymatopleura elliptica var. *hibernica* (W. SM.) VAN HEURCK				+
Cymatopleura solea var. *apiculata* (W. SM.) RALFS	+	+	+	
Cymatopleura solea (BRÉB.) W. SM. var. *solea*	+	+	+	+
Cymbella affinis KÜTZ.			+	
Cymbella cistula (EHRENB.) KIRCHN.	+		+	+
Cymbella cymbiformis C. AGARDH			+	
Cymbella helvetica KÜTZ.		+		
Cymbella lanceolata (EHRENB.) KIRCHN.	+	+		+
Cymbella minuta HILSE ex RABENH.	+			
Cymbella prostrata (BERK.) CLEVE	+	+		
Cymbella silesiaca BLEISCH	+	+	+	+
Cymbella sinuata W. GREG.	+	+	+	
Cymbella tumida (BRÉB.) VAN HEURCK		+	+	+
Diatoma ehrenbergii KÜTZ.				+
Diatoma moniliformis KÜTZ.	+	+		
Diatoma vulgaris BORY	+	+	+	+
Fragilaria arcus (EHRENB.) CLEVE	+			
Fragilaria berolinensis (LEMMERM.) LANGE-BERT.			+	
Fragilaria brevistriata GRUNOW			+	

Fragilaria capucina Desm. var. *capucina*				+
Fragilaria capucina var. *mesolepta* (Thwaites) De Toni	+			+
Fragilaria capucina var. *rumpens* (Kütz.) Lange-Bert.	+			
Fragilaria capucina var. *vaucheriae* (Kütz.) Lange-Bert.	+	+		+
Fragilaria construens (Ehrenb.) Grunow			+	
Fragilaria crotonensis Kitton			+	+
Fragilaria fasciculata (C. Agardh) Lange-Bert.		+		
Fragilaria parasitica (W. Sm.) Grunow var. *parasitica*	+	+	+	
Fragilaria parasitica var. *subconstricta* Grunow	+	+		
Fragilaria pinnata Ehrenb.	+		+	
Fragilaria tenera (W. Sm.) Lange-Bert.	+	+	+	
Fragilaria ulna var. *acus* (Kütz.) Lange-Bert.	+	+	+	
Fragilaria ulna (Nitzsch) Lange-Bert. var. *ulna*	+	+	+	+
Frustulia vulgaris (Thwaites) De Toni	+	+		+
**Gomphonema affine* Kütz.		+		+
Gomphonema angustatum (Kütz.) Rabenh.	+	+	+	+
Gomphonema augur Ehrenb.				+
**Gomphonema insigne* Gregory				+
Gomphonema olivaceum (Hornem.) Bréb.	+	+	+	+
Gomphonema parvulum (Kütz.) Kütz.	+	+	+	
**Gomphonema pumilum* (Grunow) Reichardt et Lange-Bert.	+	+	+	
Gomphonema truncatum Ehrenb.	+			
Gyrosigma acuminatum (Kütz.) Rabenh.	+	+	+	+
Gyrosigma attenuatum (Kütz.) Rabenh.	+	+	+	+
Gyrosigma scalproides (Rabenh.) Cleve	+	+		
Hantzschia amphioxys (Ehrenb.) Grunow	+		+	
Meridion circulare (Greville) C. Agardh var. *circulare*	+			
Meridion circulare var. *constrictum* (Ralfs) Van Heurck	+			
Navicula capitata Ehrenb.	+	+	+	+
Navicula capitatoradiata H. Germ	+	+	+	+
Navicula cincta (Ehrenb.) Ralfs			+	
Navicula citrus Krasske		+		
Navicula cuspidata (Kütz.) Kütz.	+		+	+
Navicula decussis Oestrup		+	+	+
Navicula elginensis (Gregory) Ralfs	+			
Navicula goeppertiana (Bleisch) H.L. Sm.		+		
Navicula gregaria Donkin	+	+	+	+
Navicula halophila (Grunow) Cleve	+			
Navicula lanceolata (C. Agardh) Ehrenb. sensu Lange-Bert.	+	+	+	+
Navicula menisculus Schum.	+	+	+	
Navicula mutica Kütz.		+		
Navicula nivalis Ehrenb.		+		+
Navicula protracta (Grunow) Cleve	+		+	
Navicula pupula Kütz.	+	+		
Navicula pygmaea Kütz.			+	
Navicula rhynchocephala Kütz.		+		
Navicula slesvicensis Kütz.	+	+	+	
Navicula subminuscula Manguin	+		+	
**Navicula subplacentula* Hust.			+	
Navicula tripunctata (O. F. Müll.) Bory	+	+	+	+
Navicula trivialis Lange-Bert.	+	+		
Navicula veneta Kütz.	+	+	+	+
Navicula viridula var. *linearis* Hust.	+	+		
Navicula viridula var. *rostellata* (Kütz.) Cleve			+	+
Nitzschia acicularis (Kütz.) W. Sm.	+		+	
Nitzschia acula Hantzsch	+		+	+
Nitzschia amphibia Grunow			+	
Nitzschia angustata (W. Sm.) Grunov	+	+		
Nitzschia calida Grunow	+	+		+
Nitzschia capitellata Hust.	+		+	+
Nitzschia commutata Grunow		+		

Nitzschia constricta (Kütz.) Ralfs	+	+	+	
Nitzschia dissipata (Kütz.) Grunow	+	+	+	+
Nitzschia dubia W. Sm.	+	+	+	
Nitzschia flexa Schum.	+		+	+
Nitzschia fruticosa Hust.	+		+	
Nitzschia graciliformis Lange-Bert. et Simonsen	+	+	+	
Nitzschia heufleriana Grunow	+	+	+	+
Nitzschia hungarica Grunow	+	+	+	+
Nitzschia inconspicua Grunow	+	+	+	+
Nitzschia intermedia Hantzsch	+	+	+	
Nitzschia levidensis (W. Sm.) Grunow	+	+	+	
Nitzschia linearis (C. Agardh) W. Sm.	+	+	+	+
Nitzschia palea (Kütz.) W. Sm.	+		+	
Nitzschia recta Hantzsch	+	+	+	+
Nitzschia sigmoidea (Nitzsch) W. Sm.	+	+	+	+
Nitzschia subacicularis Hust.		+	+	
Nitzschia tryblionella Hantzsch		+		
Nitzschia tubicola Grunow	+		+	
Nitzschia umbonata (Ehrenb.) Lange-Bert.	+			+
Nitzschia wuellerstorfii Lange-Bert.		+		+
Pinnularia microstauron (Ehrenb.) A.Cleve	+			
Pinnularia subcapitata W. Greg.		+		
Rhoicosphenia abbreviata (C. Agardh) Lange-Bert.	+	+	+	+
Stauroneis phoenicenteron (Nitzsch) Ehrenb.	+			
Surirella angusta Kütz.	+		+	
**Surirella bifrons* Ehrenb.	+	+		+
Surirella biseriata Bréb. ex Bréb. et Godey	+			+
Surirella brebissonii var. *kuetzingii* Krammer et Lange-Bert.	+	+	+	+
**Surirella capronii* Bréb.	+			
Surirella linearis W. Sm.	+			+
Surirella minuta Bréb. var. *minuta*	+	+	+	+
Surirella minuta var. *peduliformis* Freng.	+	+		+
CRYPTOPHYCEAE				
Chroomonas nordstedtii Hansg.		+	+	
Cryptomonas ovata Ehrenb.		+	+	
Cryptomonas sp.				+
DINOPHYCEAE				
Ceratium hirundinella (O. F. Müll.) Bergh				+
XANTHOPHYCEAE				
Centritractus belenophorus Lemmerm.		+		
Goniochloris fallax Fott		+	+	
Goniochloris mutica (A. Braun) Fott		+		
Goniochloris sp.			+	
Tetraedriella jovetii (Bourr.) Bourr.			+	
CHLOROPHYCEAE				
Volvocales				
Carteria globosa Korshikov ex Pascher			+	
**Carteria multifilis* (Fresen.) O. Dill		+	+	+
Carteria radiosa Korshikov ex Pascher	+	+	+	
Chlamydomonas gloeophila Skuja		+	+	
Chlamydomonas monadina F. Stein		+	+	
Chlamydomonas pseudolunata H. Ettl		+	+	
Chlamydomonas pseudopertusa H. Ettl		+		
Chlamydomonas simplex Pascher	+	+	+	+
Chlorogonium elongatum P. A. Dang.		+	+	
Chlorogonium fusiforme Matv.		+	+	
Gloeomonas lateperforata (Skuja) H. Ettl		+	+	
Gonium pectorale O. F. Müll.			+	
Nephroselmis olivacea F. Stein		+	+	
Pandorina morum (O. F. Müll.) Bory	+		+	+
Phacotus lenticularis (Ehrenb.) F. Stein			+	+

Pteromonas cordiformis LEMMERM.		+	+	
Sphaerellopsis aulata (PASCHER) GERLOFF		+	+	
Tetraselmis cordiformis (H. J. CARTER) F. STEIN			+	
Chlorococcales				
Acanthosphaera zachariasii LEMMERM.			+	
Actinastrum hantzschii LAGERH.	+	+	+	
Botryococcus braunii KÜTZ.	+			+
Chlorella vulgaris BEIJ.	+	+	+	+
Closteriopsis longissima (LEMMERM.) LEMMERM.		+		
Coelastrum astroideum DE NOT.	+	+	+	
Coelastrum microporum NÄGELI	+	+	+	
Coenochloris polycocca (KORSHIKOV) HINDÁK			+	
Coeonococcus planctonicus KORSHIKOV		+	+	
Crucigenia tetrapedia (KIRCHN.) W. et G. S. WEST		+	+	
Crucigeniella apiculata (LEMMERM.) KOMÁREK	+	+		
Diacanthos belenophorus KORSHIKOV		+		
Dichotomococcus curvatus KORSHIKOV		+	+	
Dictyosphaerium tetrachotomum PRINTZ	+	+	+	
Didymocystis inermis (FOTT) FOTT		+		
Franceia echidna (BOHLIN) BOURR.			+	
Franceia tenuispina KORSHIKOV		+	+	
Lagerheimia ciliata (LAGERH.) CHODAT			+	
Lagerheimia genevenis (CHODAT) CHODAT		+		
Micractinium pusillum FRESEN.	+	+	+	+
Micractinium quadrisetum (LEMMERM.) G. M. SMITH	+		+	
Monoraphidium arcuatum (KORSHIKOV) HINDÁK	+	+	+	+
Monoraphidium contortum (THUR.) KOMÁRK.-LEGN.	+	+	+	+
Monoraphidium convolutum (Corda) KOMÁRK.-LEGN.			+	
Monoraphidium griffithii (BERKEL.) KOMÁRK.-LEGN.	+	+	+	
Monoraphidium intermedium HINDÁK	+		+	
**Monoraphidium pseudobraunii* (J. H. BELCHER et SWALE) HEYNIG		+		
Neocystis diplococca (HINDÁK) HINDÁK		+		
Nephrochlamys subsolitaria (G. S. WEST) KORSHIKOV		+		
Oocystella borgei (J. SNOW) HINDÁK	+	+	+	
Oocystella lacustris (CHODAT) HINDÁK		+	+	+
Pediastrum boryanum (TURPIN) MENEGH.	+	+	+	+
Pediastrum duplex MEYEN	+	+	+	
Pediastrum simplex MEYEN	+		+	
Pediastrum tetras (EHRENB.) RALFS	+	+	+	
Planktosphaeria gelatinosa G. M. SMITH	+	+	+	
Polyedriopsis spinulosa (SCHMIDLE) SCHMIDLE			+	
Pseudodictyosphaerium jurisii (HINDÁK) HINDÁK	+		+	
Pseudodictyosphaerium minusculum HINDÁK	+	+		
Pseudodidymocystis inconspicua (KORSHIKOV) HINDÁK		+	+	
Pseudokirchneriella contorta (SCHMIDLE) HINDÁK	+	+	+	
Pseudokirchneriella danubiana (HINDÁK) HINDÁK		+	+	
Raphidocelis sigmoidea HINDÁK		+		
Scenedesmus abundans (KIRCHN.) CHODAT	+	+	+	
Scenedesmus acuminatus (LAGERH.) CHODAT	+	+	+	
Scenedesmus armatus (CHODAT) CHODAT var. *armatus*	+	+	+	+
Scenedesmus armatus var. *bicaudatus* (GUGLIELM.) CHODAT			+	+
**Scenedesmus bernardii* G. M. SMITH	+		+	
Scenedesmus carinatus (LEMMERM.) CHODAT			+	
Scenedesmus communis E. H. HEGEW.	+	+	+	+
Scenedesmus denticulatus LAGERH. var. *denticulatus*	+		+	
Scenedesmus denticulatus var. *linearis* HANSG.			+	
Scenedesmus dispar BRÉB.	+	+	+	
Scenedesmus longispina CHODAT	+	+	+	
Scenedesmus maximus (W. et G. S. WEST) CHODAT		+	+	+
Scenedesmus pannonicus HORTOB.	+		+	
Scenedesmus raciborskii WOŁOSZ.			+	

Scenedesmus serratus (CORDA) BOHLIN		+		
Scenedesmus subspicatus CHODAT	+		+	+
Scenedesmus verrucosus Y. V. ROLL		+		
Selenastrum bibraianum REINSCH			+	
Selenastrum gracile REINSCH		+	+	
Schroederia spiralis (PRINTZ) KORSHIKOV			+	
Siderocelis ornata (FOTT) FOTT		+	+	
Siderocelis pseudoblonga HINDÁK		+		
Siderocelopsis kolkwitzii (NAUMANN) HINDÁK		+		
Siderocystopsis fusca (KORSHIKOV) SWALE		+		
Tetraedron caudatum (CORDA) HANSG.		+	+	
Tetraedron incus (TEILING) G. M. SMITH		+	+	
Tetrastrum komarekii HINDÁK	+	+	+	+
Tetrastrum staurogeniaeforme (SCHRÖD.) LEMMERM.	+	+	+	
Westella botryoides (W. WEST) DE WILD.	+	+		
Ulotrichales				
Hortobagyiella verrucosat’ (HEYNIG) HINDÁK		+		
**Koliella elongata* (NYGAARD) NYGAARD			+	
Koliella longiseta (VISCHER) HINDÁK	+	+	+	
Koliella spirotaenia (G. S. WEST) HINDÁK		+	+	
Marvania geminata HINDÁk		+		
Planctonema lauterbornii SCHMIDLE		+		
Stichococcus contortus (CHODAT) HINDÁK		+		
Stichococcus pelagicus (NYGAARD) HINDÁK	+	+		
CONJUGATOPHYCEAE				
Desmidiales				
Closterium acerosum (SCHRÖD.) EHRENB.	+		+	+
Closterium acutum RALFS.		+	+	
Closterium limneticum LEMMERM.	+	+	+	+
Closterium lunula (O.F. MÜLLER) NITZSCH				+
Closterium moniliferum (BORY) EHRENB. ex RALFS	+	+		+
Cosmarium moniliforme TURPIN ex RALFS		+	+	
Staurastrum chaetoceros (SCHRÖD.) G. M. SMITH	+	+	+	
EUGLENOPHYCEAE				
Colacium cyclopicola (GICKLH.) BOURR.		+		
Euglena acus EHRENB.		+	+	
Euglena agilis H. J. CARTER			+	
Euglena caudata HÜBNER		+	+	
**Euglena ignobilis* JOHNSON			+	
Euglena limnophila LEMMERM.	+		+	
**Euglena rostrata* SCHILLER		+		
Euglena spirogyra EHRENB.				+
Euglena texta (DUJARD.) HÜBNER			+	
Euglena viridis EHRENB.		+	+	
Monomorphina pyrum (EHRENB.) MERESCHKOWSKY		+	+	
Phacus caudatus HÜBNER	+	+		
Strombomonas schauinslandii (LEMMERM.) DEFLANDRE		+		
Trachelomonas nigra SVIRENKO		+	+	+
Trachelomonas oblonga LEMMERM.			+	
Trachelomonas ovalis (DADAY) LEMMERM.		+		
Trachelomonas planctonica SVIRENKO	+	+	+	
**Trachelomonas scabratula* (PLAYFAIR) DEFLANDRE		+	+	
Trachelomonas volvocina EHRENB.	+	+	+	

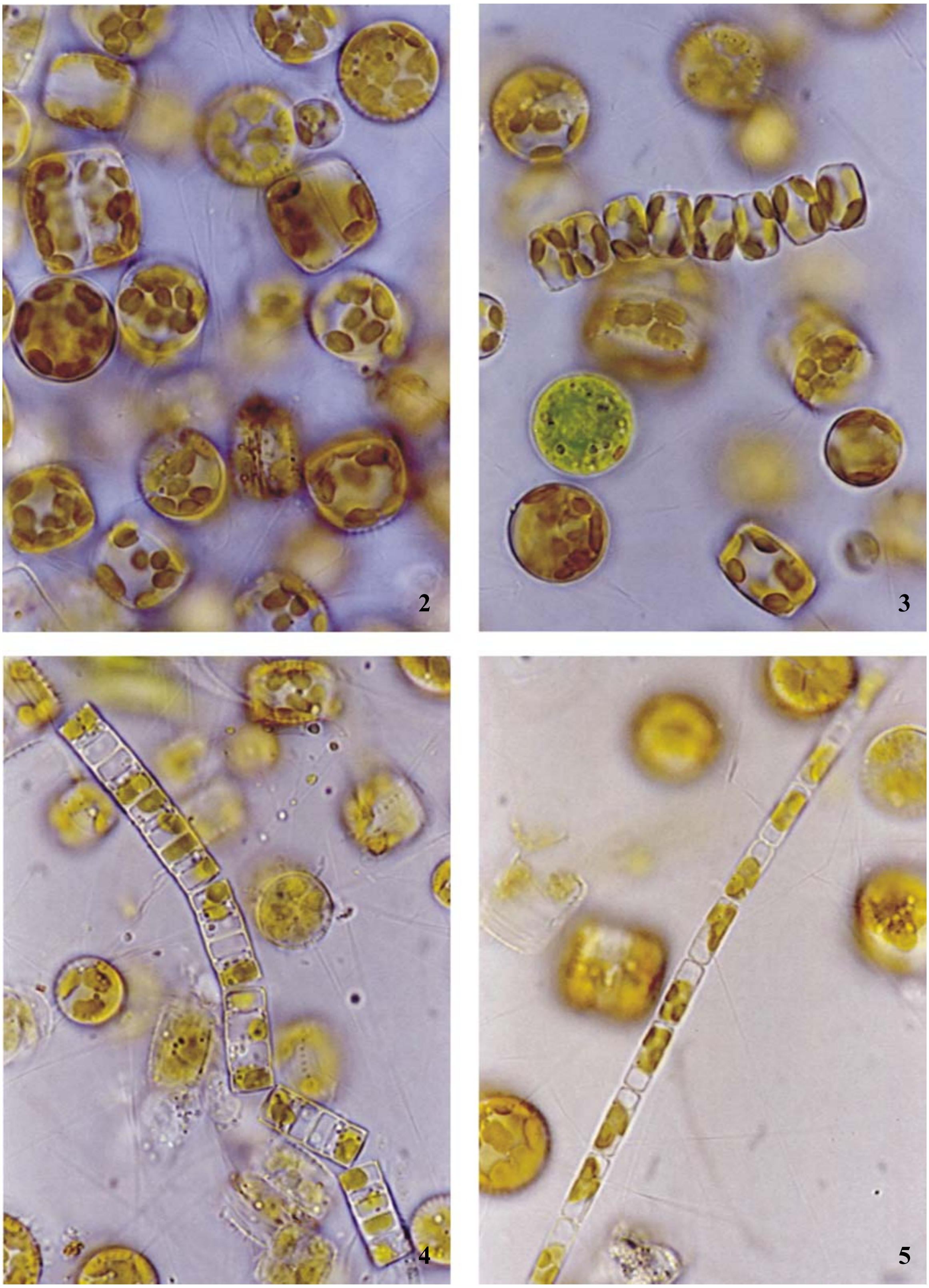

Fig. 2–5: 2: Populations of *Stephanodiscus binderanus* (KÜTZ.) WILLI KRIEG., Morava at Devín, 3: a chain of cells of *Cyclostephanos invisitatus* (M. H. HOHN et HELLERMAN) E. C. THER., STOERMER et HÅK. and solitary cells of *Stephanodiscus* spp., Morava at Devín 4: a desintegrating chain of *Aulacoseira subarctica* (O. MÜLL.) E. Y. HAW. and solitary cells of *Stephanodiscus*, Morava at Devín 5: a long chain of *Skeletonema potamos* (C. I. WEBER) HASLE and solitary cells of *Stephanodiscus binderanus* (KÜTZ.) WILLI KRIEG., Morava at Devín.

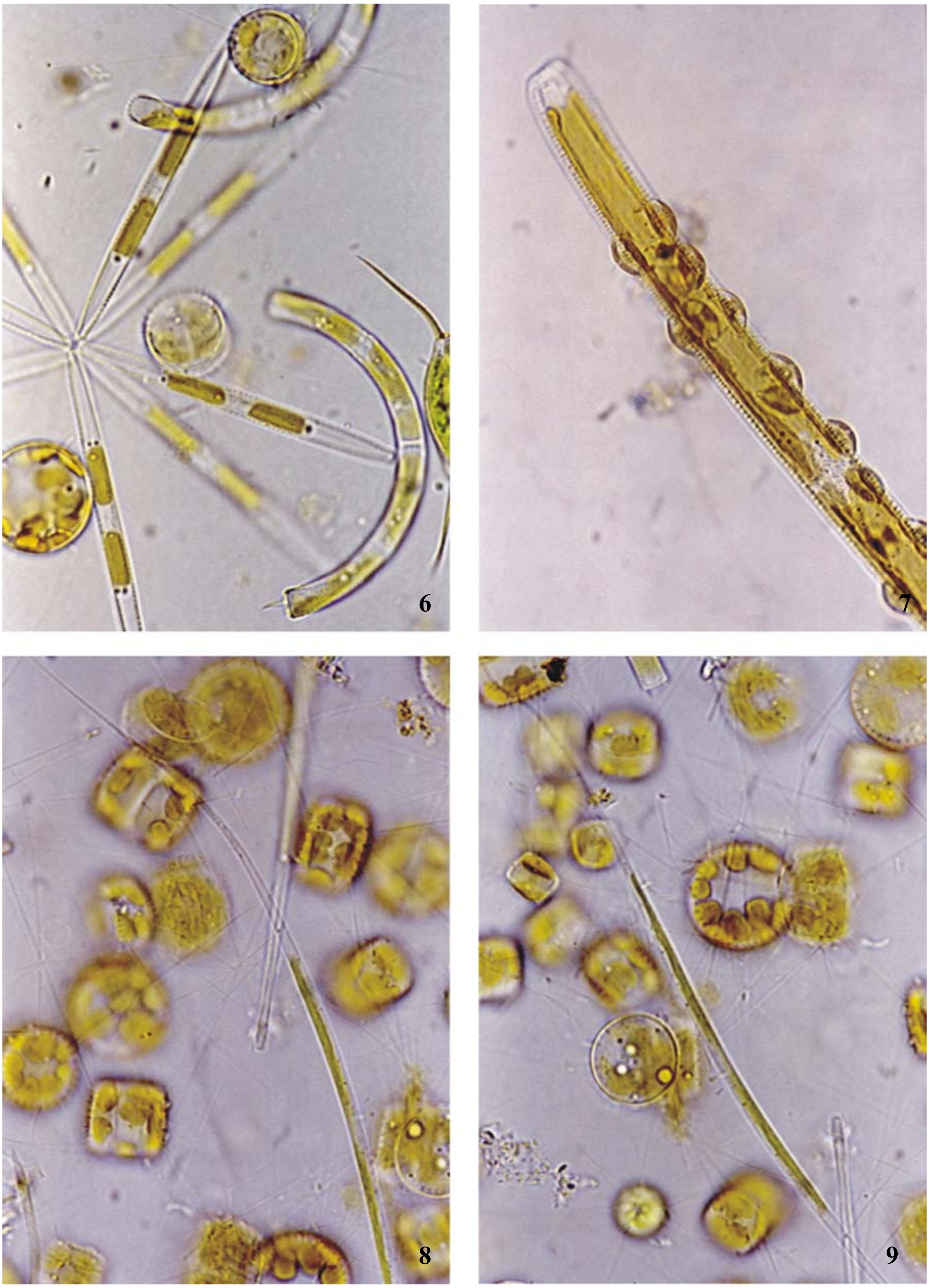

Fig. 6–9: 6: A stelloid colony of *Nitzschia fruticosa* HUST. and a chain of *Aulacoseira granulata* var. *curvata* GRUNOW, Morava at Devín, 7 *Nitzschia sigmoidea* (NITZSCH) W. SM. with attached cells of *Amphora pediculus* (KÜTZ.) GRUNOW, Morava at Olomouc, 8, 9: *Koliella elongata* (NYGAARD) NYGAARD, Morava at Devín.

Table 3: Number of species (incl. infraspecific taxa) and relative number of species [%] determined in the plankton of the rivers Morava (at Olomouc, Lanžhot, Devín) and Dyje (at Pohansko) in November 2005.

Groups/Locality	**Morava**		**Olomouc**		**Lanžhot**		**Devín**		**Dyje**	
	Σ taxa	**%**	**Σ taxa**	**%**	**Σ taxa**	**%**	**Σ taxa**	**%**	**Σ taxa**	**%**
Cyanobacteria	30	9.63	9	5.20	16	7.30	25	10.86	13	10.92
Chrysophyceae	8	2.6	1	0.57	6	2.73	5	2.17	1	0.84
[Bacillariophyceae]	[153]	[47.55]	[115]	[66.47]	[103]	[47.03]	[102]	[44.35]	[79]	[65.83]
Coscinodiscales	26	8.3	20	11.56	22	10.04	24	10.43	13	10.92
Naviculales	127	40.8	95	54.91	81	36.98	78	33.91	66	55.46
Cryptophyceae	1	0.3	0	0	1	0.45	1	0.43	2	1.68
Dinophyceae	0	0	0	0	0	0	0	0	1	0.84
Xanthophyceae	5	1.6	0	0	3	1.36	3	1.30	0	0
[Chlorophyceae]	[100]	[31.15]	[40]	[40]	[72]	[32.88]	[76]	[33.04]	[17]	[14.17]
Volvocales	19	6.1	3	1.73	13	5.93	18	7.82	4	3.36
Chlorococcales	73	23.4	35	20.23	52	23.74	55	23.91	13	10.92
Ulotrichales	8	2.6	2	1.15	7	3.19	3	1.30	0	0
Conjugatophyceae	6	1.9	4	2.31	5	2.28	5	2.17	4	3.36
Euglenophyceae	18	5.8	4	2.31	13	5.93	13	5.65	3	2.52
Σ	**321**	**100**	**173**	**100**	**219**	**100**	**230**	**100**	**120**	**100**

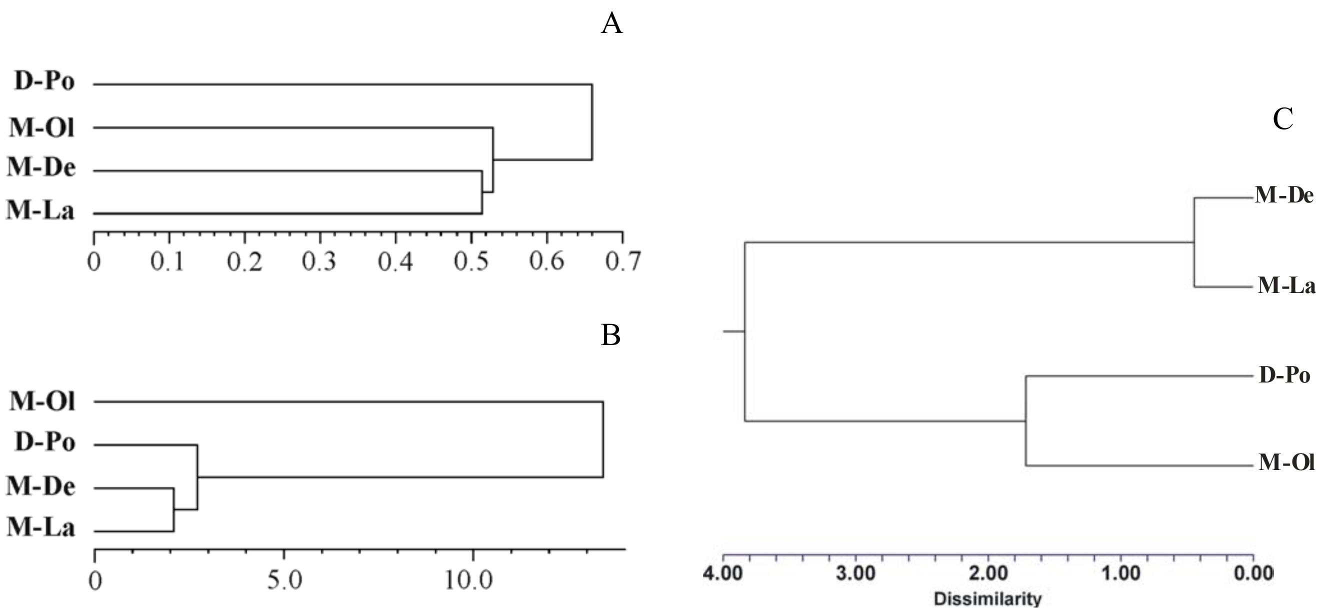

Fig. 10: Results of clustering analysis: A- based on on differences in the floristic composition of phytoplankton (Jaccard´s distance), B-based on differences in portions of main distinguished algal groups (Jaccard´s distance), C-based on differences in the environmental variables (Ward´s clustering method).

Abundance

The highest number of cells (Table 4) was counted in the sample from Lanžhot (29 317 cells.ml^{-1}) whereas the lowest one was found at Olomouc (2 745 cells.ml^{-1}). In the Dyje River was also counted low number of cells with respect to locality Lanžhot. Centric diatoms were highly abundant in the samples from Lanžhot, Devín and Pohansko. Higher amount of pennate diatoms was found at Olomouc. Generally, diatoms were detected as the most abundant group of algae in all investigated samples. Green algae and cyanobacteria were identified as the second group of dominant microorganisms in locality Olomouc, Lanžhot and Devin while in the Dyje at Pohansko green algae were more abundant than cyanobacteria. Other groups of algae occurred in low abundances.

Volume biomass

Differences in the biovolume of phytoplankton and its distinguished components for samples from the 4 sampling sites are illustrated in Fig. 11. Diatoms (mainly centric, but in the Morava at Olomouc pennate) are the prevailing group in samples from all localities (the same holds true for the data on cell counts per ml). Biovolume of phytoplankton in the Morava at Lanžhot nearly three times surpasses the value for the sample from the Morava at Devín. As it follows from Fig. 10B, the sampling site on the Morava at Olomouc is maximally separated from the ohers. However, Ward's clustering method separating the studied sites according to the silimarity in the environmental variables showed a rather high similarity between Morava at Olomouc and Dyje at Pohansko (Fig. 10C).

Table 4: Cell counts of the plankton of the rivers Morava (at Olomouc, Lanžhot, Devín) and Dyje (at Pohansko) in November 2005

Groups/Locality	per ml					in %			
	Morava			Dyje		Morava			Dyje
	Olomouc	Lanžhot	Devín	Pohansko		Olomouc	Lanžhot	Devín	Pohansko
Cyanobacteria	1050	1780	1790	270		38.25	6.07	15.72	6.61
Cryptophyceae	25	890	10	85		0.91	3.04	0.09	2.08
Chrysophyceae	0	100	50	0		0	0.34	0.44	0
[Bacillariophyceae]	[1115]	[11435]	[8045]	[3090]		[40.62]	[73.11]	[70.63]	[75.65]
Coscinodiscales	490	19590	7770	2680		17.85	66.82	68.22	65.61
Pennales	625	1845	275	410		22.77	6.29	2.41	10.04
[Chlorophyceae]	[555]	[5112]	[1485]	[630]		[20.22]	[17.14]	[13.04]	[15.43]
Volvocales	25	115	200	55		0.91	0.39	1.76	1.35
Chlorococcales	530	4772	1165	575		19.31	16.28	10.23	14.08
Ulotrichales	0	225	120	0		0	0.77	1.05	0
Conjugatophyceae	0	0	0	10		0	0	0	0.24
Euglenophyceae	0	0	10	0		0	0	0.09	0
Σ	**2745**	**29317**	**11390**	**4085**		**100**	**100**	**100**	**100**

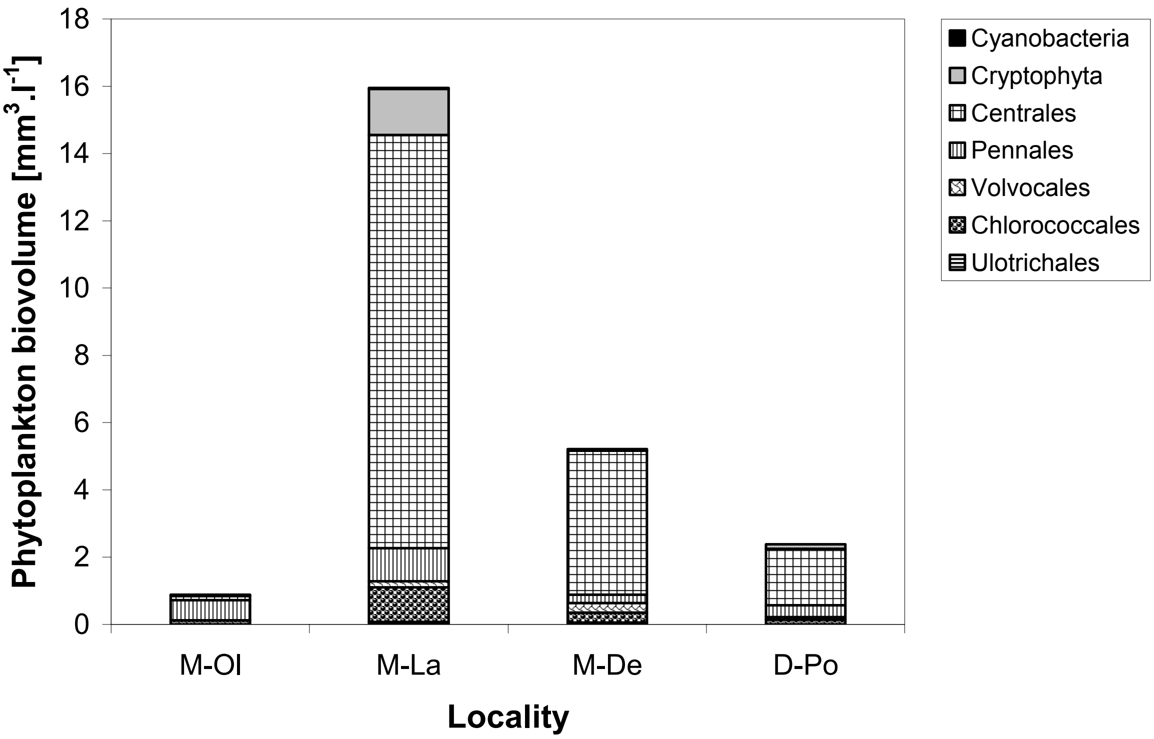

Fig. 11: Biovolume of phytoplankton (in $mm^3.l^{-1}$) of the river Morava in sampling sites in Olomouc (M-Ol), Lanžhot (M-La), Devín (M-De) and of the Dyje River at Pohansko (D-Po).

Discussion

The evaluated set of samples from the Morava and Dyje Rivers provides data on phytoplankton species composition and abundance in the transient period of declining cyanobacterial water bloom and increasing share of diatoms and chrysophytes dominating the winter period.

As it follows from older analyses, water-bloom forming cyanobacteria (first of all from the genus *Microcystis*) often become the prevailing component of summer phytoplankton of the Dyje, whereas in the Morava above the confluence with the Dyje they usually play only a quite subsidiary role (although a certain tendency to increase their share on the phytoplankton composition could be observed in course of last years). In the Morava River above the confluence, however, chlorococcal algae instead of cyanobacteria may reach dominant position. Evidently, retention of the Dyje water in the series of three shallow Nové Mlýny Reservoirs is responsible for their mass development. Besides, cyanobacterial water bloom may penetrate into the river from numerous fishponds situated in the Dyje river basin.

Great differences in the phytoplankton composition of both rivers should therefore be expected mainly in summer or early autumn. Nevertheless, according to the dendrogram in Fig. 2, based on Jaccard´s coefficients of dissimilarity, both rivers show differences in the late autumn phytoplankton composition, although period of dominance was already over and the diatoms started to dominate again, and these differences were even greater than those between sampling sites at Lanžhot and Olomouc.

Rather different relations follow from the evaluation of similarity based on portions of distinguishable groups of phototrophs participating on the phytoplankton composition. Like in previous comparisons, the Morava at Lanžhot and at Devín showed highest level of similarity, but neither the Dyje differed from them too much. A considerably greater deflection from them was found only for the Morava at Olomouc. This was evidently caused by high portions of benthic diatoms. Their share on the bioseston composition in all three lowland localities uses to be very low (at least in periods of low discharges), much lower than in the upper Morava River stretch with relatively higher riverbed slope and with still rather poorly developed true phytoplankton.

In the past, the lowermost stretch of the Morava below the confluence with the Dyje up to its mouth was exposed to extremely strong pollution form sugar-beet factories what nearly totally eliminated the autumn phytoplankton. In the present, the species spectrum of phytoplankton, on the contrary, grows up. This holds true even for late autumn months.

In the lowest Morava the autumnal phytoplankton species composition did not differ substantionally from that of the summer one, perhaps with the exception of algal flagellates, namely volvocalean algae, which were found in less number of species (HINDÁK & HINDÁKOVÁ 2004). Phytoplankton species composition of the Morava at the beginning of November corresponds well with our previous results for the autumnal plankton of this river (HINDÁK & HINDÁKOVÁ 1997, 1998, 2004, HINDÁKOVÁ 1994, MARVAN et al. 2004). The brown colour of the water at the time of sampling indicated a mass development of diatoms. Chlorophytes as the second dominating group still played an important role in this eutrophicated water.

The diatoms deserve a special attention because they have been considered a dominant group in the phytoplankton of the Morava from both diversity and primary production point of view. In the number of species, diatoms reach high abundance all the year round, with the maximum in spring and autumn, while the chlorophytes play the leading role in the summer and in the beginning of autumn plankton. Similarly like in other phytoplanktonic groups, also in the diatoms the majority of species have occurred constantly for many years but some species have not been found or new species suddenly appeared. According to our investigations of the Morava River just in the mouth at Bratislava-Devín in 1992–1993, among 135 diatom species 40 taxa were recorded for the first time (HINDÁKOVÁ 1994). Similarly, during the study in the year of 2003, 27 new diatom taxa were registered (HINDÁK & HINDÁKOVÁ 2004). Some species (e.g. *Actinocyclus normanii* at the end of last century or just recently *Cyclostephanos delicatus*) could be considered as possibly invasive diatoms.

From the centric forms several taxa have been constantly dominating in the Morava, e.g. *Aulacoseira granulata, A. ambigua, Stephanodiscus binderanus, S. hantzschii* f. *hantzschii* and f. *tenuis*, *Cyclotella meneghiniana* and *Cyclostephanos invisitatus*. In the last decades some species are occurring more and more frequently, e.g. *Aulacoseira subarctica, Cyclostephanos delicatus* and the representatives of the stellogeroid group, namely *Cyclotella woltereckii*. From the diversity point of view, the representatives of the genus *Thalassiosira* are of most interest. To the frequently occurring species belong not only *Th. weissflogii* and *Th. pseudonana*, but nowadays also *Th. duostra*. Diatoms *Achnanthes exigua, Cymatopleura elliptica* var. *hibernica* and *Gomphonema insigne* were registered only in the Dyje. On the contrary, some species previously characteristic for the Morava and Dyje rivers were not observed at all, e.g. *Cyclotella stelligera, Diatoma ehrenbergii, Fragilaria capucina* or *Gomphonema augur. Actinocyclus normanii, Achnanthes ploenensis, Fragilaria crotonensis* and *Navicula viridula* var. *rostellata* occurred only in the Dyje and in the lowest part of the Morava. All diatom taxa found in the Morava represent about 55% of all registered taxa from this group in the river (cf. HINDÁK & HINDÁKOVÁ 2004, HINDÁKOVÁ 1994).

The chlorococcalean group with 73 taxa strongly dominated among chlorophytes, the second largest group in the autumnal planktonic assemblages of the river. Several species were found in all sampling sites, e.g. *Coelastrum microporum, Dictyosphaerium tetrachotomum, Micractinium pusillum, Monoraphidium arcuatum, M. contortum, Pediastrum boryanum, P. duplex, P. tetras, Planktosphaeria gelatinosa, Scenedesmus abundans, S. acuminatus, S. armatus, S. communis, Tetrastrum komarekii, T. staurogeniaeforme. Koliella elongata* (NYGAARD) NYGAARD (Chlorophyceae, Ulotrichales) is a new record for the Czech Republic and Slovakia. To the rare occurring chlorophytes belong *Gloeomonas lateperforata, Diacanthos belenophorus, Neocystis diplococca, Raphidocelis sigmoidea, Hortobagyiella verrucosa, Marvania geminata,* and from euglenophytes *Euglena ignobilis*, *E. rostrata* and *Trachelomonas scabratula*.

Results of quantitative analyses of phytoplankton did not confirm the expected increase of algal biomass in the lowermost stretch or Morava between Lanžhot and Devín. Evidently, the losts in this stretch of the river with a relatively low slope probably caused by sedimentation appear to surpass possibilities of primary production of autumnal phytoplankton, limited by both low temperature and shortened light period.

Acknowledgements

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