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PERIPHYTON AND PHYTOPLANKTON IN THE SOROKSÁR-DANUBE IN HUNGARY. I. PERIPHYTIC ALGAE ON REED STEMS

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Periphyton samples from the reed-belt and phytoplankton samples were taken in November 1996 and in January, April, July 1997 at the upper part of the Soroksár-Danube (the second largest side arm of the River Danube in Hungary) at Taksony, and in July, November 1998, January, April 1999 at the middle part of the side arm at Ráckeve. The aim of this study was to investigate the seasonal and vertical distribution of periphyton growing on old and green reed stems at both parts of the side arm, focussed on taxonomic composition, abundance and chlorophyll *a* content.

Based on the chlorophyll *a* content of the phytoplankton the upper part of the side arm at Taksony was oligotrophic in November and July (in July caused by a flood), mesotrophic in January and eutrophic in April. The middle part of the Soroksár-Danube was eutrophic in April and July, oligotrophic in November and January at Ráckeve.

The values of abundance and chlorophyll *a* of periphyton were the highest at the middle part of the Soroksár-Danube, while that of phytoplankton was the highest at the upper part.

A few diatoms showed the same distribution along the reed stems. Relative abundance of *Amphora libyca*, *Cocconeis placentula* and *Eunotia arcus* increased close to the bottom, while that of *Gomphonema minutum*, *G. parvulum*, *Navicula capitatoradiata* and *Nitzschia dissipata* decreased.

Key words: diatoms, periphyton, trophic state, water quality

INTRODUCTION

The Soroksár-Danube is the second biggest side arm in the Hungarian reach of the river, with a length of 58 km. The water level is regulated independently of that of the main arm by two locks at the upper and lower end of the side arm. This large side arm has a recreational, industrial and agricultural water supply function for the region even though it receives half of the treated waste water of Budapest. The water is the most polluted in the

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upper part of the side arm, which makes it unsuitable for bathing and less polluted in the lower part where there are some recreational beaches. The current velocity is very low (annual average is about 0.1–0.2 m s^{-1}), so it can be regarded as a still water. The fluctuation of the water level is only a few decimetres.

A few earlier studies were carried out in connection with the algal flora of the Soroksár-Danube. Though Filarszky and Simonkai gathered algae in the side arm in 1890, they did not evaluate all their data and they never published it (Halász 1936). The first data about the algae of the side arm were published by Cholnoky (1922); he investigated the algal flora of several water bodies near Budapest and he found that *Navicula lanceolata* was the dominant species in the benthos of the Soroksár-Danube.

In the years 1934–36, algae of the Soroksár-Danube were observed by Márta Halász (1936, 1937). She took 57 samples from the upper part of the side arm. On the basis of the investigated habitats, she divided the algae into planktonic, benthic and reed-belt algae. These investigations were semiquantitative and characterised the abundances with the attributes: mass, many, few, scattered. Altogether 223 species and varieties were found and of these 141 were diatoms, comprising the majority of the algal flora of the side arm. She realised that there was only a slight difference in the taxonomic composition of the side and main arm at the Danube, but the dominance of diatoms increased in the side arm. Reasons for this – as it is written in Halász's article – could be the slower current, less disturbance and easier warming-up of the water in the side arm. Palik (1961) dealed with algae damaging concrete and took samples from the concrete pier of the upper part of the side arm.

In 1983 Kiss started to study the phytoplankton of Soroksár-Danube with fortnightly to monthly frequency (Kiss and Bothár 1984, Kiss and Genkal 1993). Several Centrales blooms were observed: caused in November, by *Stephanodiscus hantzschii* f. *tenuis* and, in February, by *Stephanodiscus minutulus*. During high water periods the phytoplankton of the main and side arm was very similar but when water level and velocity was low, the suspended matter content decreased, the algal composition of the side arm was different from that of the main arm. In 1983 the centric diatoms, *Cyclotella atomus* Hustedt, *C. meneghiniana*, *Skeletonema potamos* and *Stephanodiscus hantzschii* f. *hantzschii* dominated in the phytoplankton. The average algal number in the phytoplankton was 41,700 ind. ml^{-1} and the average chlorophyll *a* value was 87 mg m^{-3}.

Based on the chlorophyll *a* concentration of phytoplankton (1983–99) the actual trophic level of Soroksár-Danube was meso- or eutrophic in winter at Dunaharaszti and in some years also at Ráckeve. It was hypertrophic in the other seasons (Kiss et al. 2000).

Some reed periphyton investigations were also carried out from two Hungarian shallow lakes (Lakatos and Ács 1990, Ács et al. 1991, 1994, Lakatos et al. 1991), but the algal flora of them are totally different, because they are sodic lakes.

The aim of this study was to investigate the seasonal and vertical distribution of periphyton growing on old and green reed stems at two parts of the side arm (at the upper part and the middle part), focussed on taxonomic composition, abundance and chlorophyll *a* content. Simultaneously with these, phytoplankton investigations were also carried out, the main results of them are available in Kiss et al. (2000).

MATERIALS AND METHODS

The samples were collected in November 1996, January, April and July 1997 at Taksony, in the middle part of the side arm (43 river km), in July and November 1998, January and April 1999 at Ráckeve, in the middle part of the side arm (18 river km, Fig. 1). In January 1997 the side arm was covered with 15 cm thick ice, so a hole was cut in the ice to obtain the samples. Periphyton-samples were collected from old as well as green *Phragmites australis* (Cav.) Steud. substrata at the water-side of the reed stands, in five replicates. Reed stems were cut just at the river-bed and at the water surface, they were sliced into 10 cm long pieces in five replicates. In the laboratory the samples were washed into water of known volume which was subsequently split into two parts. One part of the sample was used for chlorophyll a measurement according to the method of Goodwin (1976), the other part was used to count and determine algae by Utermöhl (1958) method according to statistical instructions of Lund et al. (1958). To determine the diatoms, samples were sedimented, treated by H_2O_2 and washed with distilled water. The treated samples were mounted in Naphrax for light microscopy. The taxonomy of diatoms follows Krammer and Lange-Bertalot (1986, 1988, 1991a, 1991b).

Phytoplankton samples were collected by a modified Mayer-flask sampler, in the current-line, from the upper 20 cm of the water. Measure-

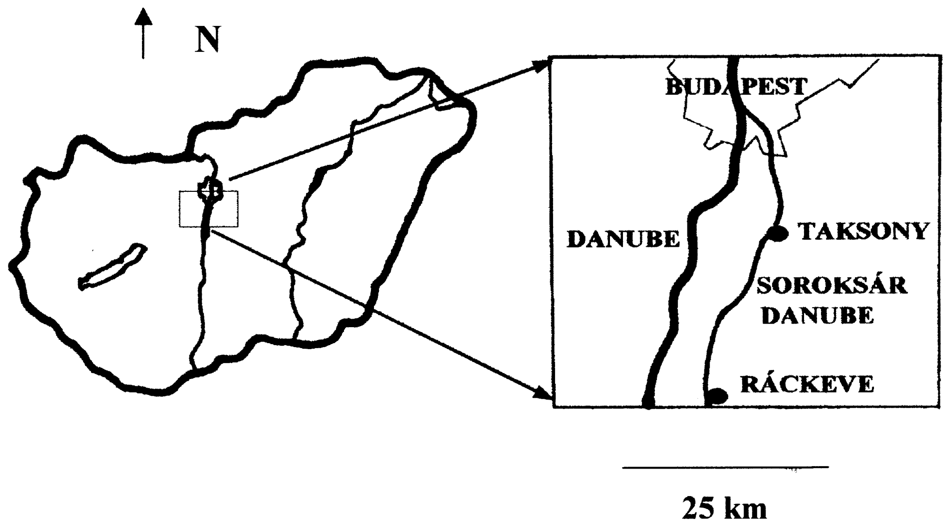

Fig. 1. Sketch map of Hungary with the sampling points in the Soroksár-Danube

ment of the chlorophyll *a* content and counting of algae under the light microscope were performed as detailed above.

Parallel with sampling, the following parameters were measured in the field: water depth, water temperature, Secchi transparency, pH, conductivity; and dissolved oxygen, reactive phosphorus, ammonia, nitrate, nitrite and COD in the laboratory (Table 1).

RESULTS AND DISCUSSION

The Soroksár-Danube is potentially hypertrophic because of the nutrient content (mineral N, P; Kiss and Genkal 1993). During our study the chlorophyll *a* concentration of phytoplankton indicated that the actual trophic level was oligotrophic in November and July, eutrophic in April and mesotrophic in January at Taksony, while it was eutrophic in July and April and oligotrophic in November and January at Ráckeve (according to the OECD (1982) standard, Table 2). The low trophic level of the side arm in July at Taksony can be explained by a flood at the time of sampling (see below). The phytoplankton abundance and chlorophyll *a* content are higher at Ráckeve than at Taksony (Kiss et al. 2000).

Table 1

Physical and chemical parameters of the Soroksár-Danube at the time of sampling

	Taksony				Ráckeve			
	Nov.	Jan.*	April	July	July	Nov.	Jan.	April
Secchi transparency (cm)	120		45	26	45	140	120	48
Water depth (cm) **	63	56	58	68	105	60	65	75
Water temperature (°C)	10.4	1.0	9.5	17.1	21.0	3.9	2.8	15.2
Conductivity (μS cm^{-1})	507	790	470	370	352	490	570	450
Total dissolved salt (g l^{-1})	0.25	0.49	0.25	0.19	0.18	0.25	0.29	0.23
pH	7.95	6.80	7.00	7.00	6.25	8.22	7.99	8.46
Dissolved oxygen (mg l^{-1})						10.10	11.95	6.56
Reactive phosphorus (mg l^{-1})					0.39	0.33	0.26	1.66
Ammonium (N-NH_4) (mg l^{-1})	1.40	4.00			0.21	0.62	0.68	0.22
Nitrate (N-NO_3) (mg l^{-1})	11.4	16.6			0.8	2.0	0.9	
Nitrite (N-NO_2) (mg l^{-1})	0.22	1.10			0.08	0.03	0.04	
COD (Mn) (mg l^{-1})	3.84	5.28				4.10	2.80	5.35

*covered with 15 cm ice
**at the reed-belt

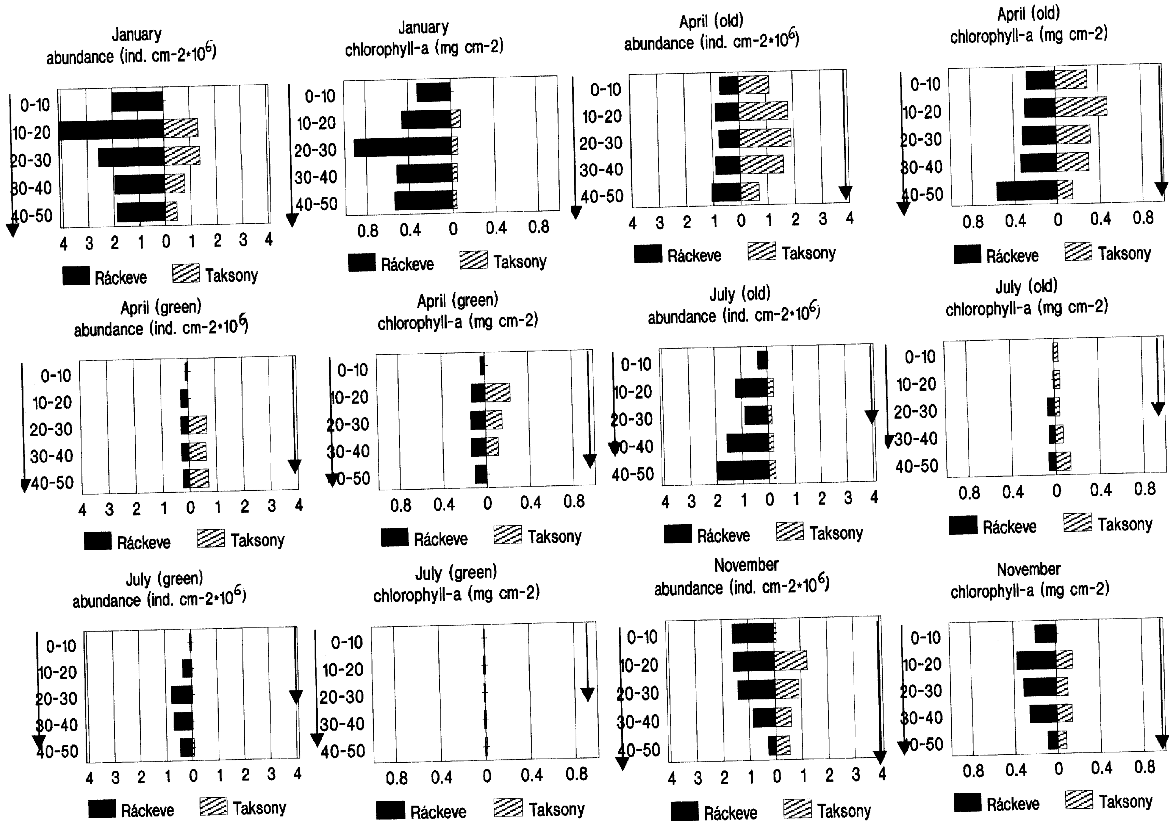

Fig. 2. Changes of individual numbers and chlorophyll *a* content of reed periphyton from the surface towards the bottom (in November 1996, January, April and July 1997 at Taksony; in July and November 1998, January and April 1999 at Ráckeve). Unit of y axis is in centimetre. Arrows indicate the Secchi transparency of the water

The periphyton abundance was generally higher at Ráckeve than at Taksony (Fig. 2). The large amount of suspended matter of the main arm water settles down slowly in the side arm. This causes more favourable light conditions in the middle and lower part of the side arm (the Secchi transparencies were higher at Ráckeve than at Taksony, Table 1).

In July 1997 there was a big flood in the main arm and the abundance of periphyton was extremely low at Taksony because of the unfavourable light conditions. During floods, the current of the water as well as suspended matter content increase in the main arm of River Danube and also in the upper part of the side arm.

In January, the abundance of periphyton was also much higher at Ráckeve than at Taksony. In January 1997 (in sampling time at Taksony) the side arm was covered by ice. In spite of the ice covering, the species composition of periphyton was surprisingly rich (Barreto et al. 1998). The chlorophyll *a* content showed the same kind of pattern as the abundance values in every case (Fig. 2). When the Secchi transparency was higher than the water depth, the vertical distribution of periphyton on reed stems showed that the values of abundance and chlorophyll *a* were less close to the water surface than the maximal below it, and they decreased more or less regularly to the bottom. This tendency was opposite on the reed stems when the transparency was smaller than the water depth. There was a typical correlation between periphyton abundance on old and green reed stems (Fig. 2). One can find a higher abundance on the old than on the green reed stems. As the dead reed stems contain and release only a small amount of phosphorus, it is unlikely that epiphytes use the phosphorus of their host (Meulemans 1988). The reason of this phenomenon is more probably the longer time of colonization and reproduction avalaible for algae (Fig. 2). The same phenomenon was described about the reed periphyton of Szigetköz branch system by Buczkó and Ács (1992).

Table 2
The phytoplankton abundance and chlorophyll *a* content at Taksony and Ráckeve during our study

Sample	Abundance (ind. ml^{-1})		Chlorophyll *a* (μg l^{-1})	
	Taksony	Ráckeve	Taksony	Ráckeve
Winter	11,680	1,170	23.5	<5
Spring	28,560	37,340	46.5	65.5
Summer	2,240	16,350	5.5	37.1
Autumn	2,070	310	5.1	<5

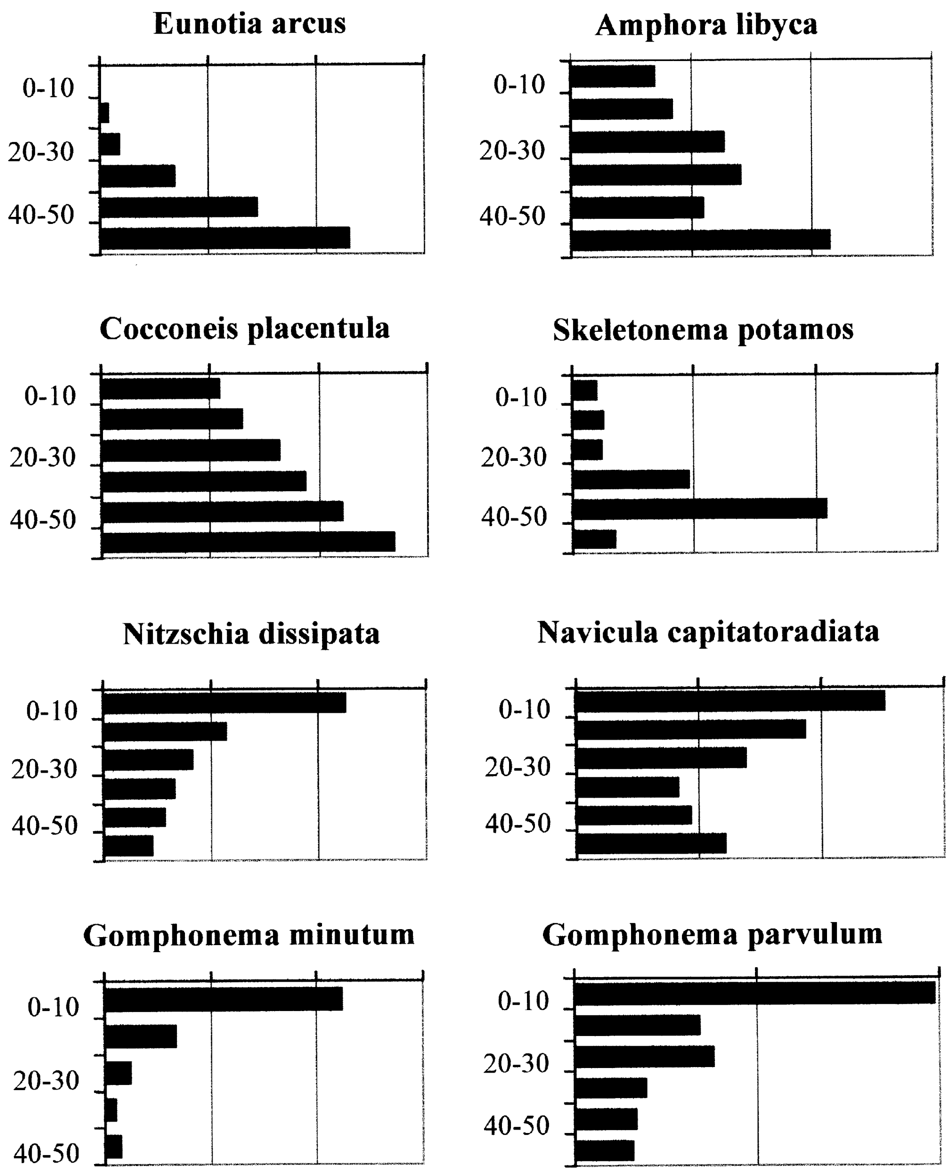

Fig. 3. Changes in the relative abundance (average value, counted from all of the samples) of some dominant diatom species of the reed periphyton from the surface towards the bottom. Unit of y axis is in centimetre

The vertical distribution of some diatom species was the same along the reed stems in every case. Abundance of *Cocconeis placentula*, *Amphora libyca* and *Eunotia arcus* increased towards the bottom, while those of *Nitzschia dissipata*, *Navicula capitatoradiata*, *Gomphonema parvulum* and *Gomphonema minutum* decreased towards the bottom. The former species are probably shadow-adapted and the latter are light-adapted (Fig. 3). In Figure 3 the vertical distribution of the normally planktonic *Skeletonema potamos* found in periphyton can also be seen. Numerous species of the phytoplankton, like *Skeletonema potamos*, settle into the periphyton because of the decreased velocity of the side arm. *Skeletonema potamos* was found in high amounts only in summer. It is a warm stenothermic species which demands high light intensities (Kiss et al. 1994), so its occurrence is obviously influenced by these two factors, that is why we observed it in higher abundances only in July. *Skeletonema potamos* has also been a regularly dominant species in the phytoplankton of the main arm of the Hungarian section of the River Danube in the last 10–20 years. It has become abundant parallel to the increasing eutrophication of the river (Kiss et al. 1994).

We found a remarkable difference in the species composition of periphyton of the two parts of the side arm (Table 3). *Achnanthes minutissima*, *Amphora pediculus*, *Cocconeis placentula*, *Melosira varians*, *Navicula cryptotenella*, *N. menisculus*, *N. tripunctata* and *Rhoicosphenia abbreviata* were dominant species at both sampling points. *Achnanthes minutissima*, *Amphora pediculus*, *Cocconeis placentula*, *Rhoicosphenia abbreviata* are also dominant species in the Danube at Göd, near Budapest (Ács and Kiss 1991). The considerable abundance of *Eunotia arcus* found at Ráckeve, but not at Taksony provides a new record for this part of the Danube. Its occurrence is surprising because most Eunotiaceae species prefer low nutrient levels (Krammer and Lange-Bertalot 1991a). Many *Vorticella* sp. were found in the periphyton at Taksony indicating a poor water quality. *Gomphonema parvulum* and *Nitzschia palea* also occurred more frequently on the upper part of the arm. These two species are either facultative or obligate nitrogen heterotrophs and they prefer organic-polluted waters (Fukushima and Fukushima 1991).

Table 3

List of taxa occurring in the periphyton at Taksony (T) and Ráckeve (R – during our study) and found by Halász (M.H. – between 1934–36). When known, the trophic level is also indicated: tol = possible occurrence under oligo-eutrophic conditions, eu= strictly under meso- and eutrophic conditions, o = occurrence under oligotrophic conditions

	T	R	M.H.	trophic level
Cyanobacteria				
Anabaena sp.	+	+	+	
Chroococcus minutus (Kütz.) Näg.	+	+	+	
Coelosphaerium cf. *pusillum* van Goor.	+			
Gomphosphaeria cf. *aponina* Kütz.	+		+	
Komvophoron constrictum (Szafer) Anagn. et Kom.	+			
Lyngbya circumcreta G. S. West			+	
L. limnetica Lemm.	+			
Lyngbya sp.	+	+	+	
Merismopedia elegans A. Br.			+	
M. punctata Meyen		+	+	
M. tenuissima Lemm.			+	
Oscillatoria aghardii Gomont	+		+	
O. amoena (Kütz.) Gomont	+			
O. curviceps Ag.			+	
O. limosa var. *disperso-granulata* Schorb.			+	
O. planctonica Wolosz.			+	
O. okeni Ag.	+			
O. splendida Grev.			+	
O. tenuis Ag.			+	
Phormidium cf. *molle* (Kütz.) Gomont	+			
Spirulina jenneri (Stiz.) Geitler			+	
S. maior Kütz.			+	
Heterocontophyta				
Chrysophyceae				
Bicosoeca campanulata (Lackey) Bourr.	+			
Chromulina cf. *pseudopyriformis* (Bachmann) Matvienko	+			
Chromulina sp.	+			
Chrysococcus biporus Skuja	+			
C. rufescens Klebs.	+			
Chrysococcus sp.	+	+		
Dinobryon divergens Imhof	+		+	
D. stipitum Stein.			+	
Kephyrion litorale Lund	+			
K. moniliferum (Schmid) Bourr.	+			
K. rubri-claustri Conrad	+			
K. tubiforme Fott	+			
Mallomonas akrokomos Ruttner	+			
M. tonsurata Teiling et Krieger	+			
Mallomonas sp.	+			
Ochromonas sp.	+			
Synura petersenii Korš.	+			
Xanthophyceae				
Goniochloris fallax Fott	+			
Vaucheria sessilis De Candolle			+	

Table 3 (cont.)

	T	R	M.H.	trophic level
Bacillariophyceae, Centrales				
Aulacoseira ambigua (Grun.) Sim.			+	
A. distans (Ehr.) Sim.	+			
A. granulata (Ehr.) Sim.	+	+	+	
A. islandica (O. Müller) Sim.	+			
A. italica (Ehr.) Sim. var. *tenuissima* (Grun.) Sim.	+		+	
A. subarctica (O. Müller) Haworth	+			
Aulacoseira sp.	+		+	
Cyclostephanos dubius (Fricke) Round	+			
Cyclotella meneghiniana Kütz.	+	+	+	
C. ocellata Pantocsek	+			
Melosira varians Ag.	+	+	+	
Skeletonema potamos (Weber) Hasle	+	+		
S. subsalsum (Cleve-Euler) Bethge	+	+		
Stephanodiscus delicatus Genkal	+			
S. hantzschii Grun. f. *hantzschii*	+		+	
S. hantzschii f. *tenuis* (Hust.) Hakansson et Stoermer	+		+	
S. invisitatus Hohn et Hellermann	+			
S. minutulus (Kütz.) Cleve et Möller	+			
S. neoastrea Hakansson et Hickel			+	
Thalassiosira pseudonana Hasle et Heimdal	+			
Bacillariophyceae, Pennales				
Achnanthes clevei Grun.		+		eu
A. conspicua Mayer		+		tol
A. exigua Grun.		+		eu
A. laevis Oestrup	+			tol
A. lanceolata (Brébisson) Grun.	+	+	+	
A. minutissima (Kütz.)	+	+		eu
A. oblongella Oestrup		+		o
A. petersenii Hust.	+			o
A. ploenensis Hust.	+	+		eu
A. silvahercynia Lange-Bert.		+		o
A. subsalsa Petersen	+			
Amphora aequalis Krammer	+			
A. inariensis Krammer	+			o
A. libyca Ehr.	+	+	+	
A. ovalis (Kütz.) Kütz.	+	+	+	
A. pediculus (Kütz.) Grun.	+	+	+	
A. veneta Kütz.		+		
Anomoeneis sphaerophora (Ehr.) Pfitzer			+	eu
Asterionella formosa Hassall	+	+	+	
Caloneis amphisbaena (Bory) Cleve			+	eu
C. bacillum (Grun.) Cleve	+	+		eu
C. silicula (Ehr.) Cleve	+		+	
Campylodiscus hibernicus Ehr.			+	
Cocconeis pediculus Ehr.	+	+	+	
C. placentula Ehr.	+	+	+	
Cymatopleura elliptica (Brébisson) W. Smith			+	tol
C. solea (Brébisson) W. Smith	+	+	+	

Table 3 (cont.)

	T	R	M.H.	trophic level
C. solea var. *apiculata* (W. Smith) Ralfs	+		+	
Cymbella affinis Kütz.	+	+	+	
C. aspera (Ehr.) Cleve		+		
C. austriaca Grun.			+	eu
C. caespitosa (Kütz.) Brun	+	+		eu
C. cistula (Ehr.) Kirchner	+	+	+	
C. helvetica Kütz.	+	+	+	
C. lanceolata (Ehr.) Kirchner	+	+	+	
C. minuta Hilse ex Rabh.	+			
C. prostrata (Berkeley) Grun.		+	+	
C. proxima Reimer	+	+		tol
C. silesiaca Bleisch	+	+	+	
C. sinuata Gregory		+		tol
C. tumida (Brébisson) Van Heurck	+	+	+	
C. turgidula Grun.	+			
Diatoma anceps (Ehr.) Kirchner			+	
D. ehrenbergii Kütz.	+		+	
D. hyemale (Roth) Heiberg			+	o
D. mesodon (Ehr.) Kütz.	+		+	
D. moniliformis Kütz.	+	+		eu
D. tenuis Ag.	+		+	
D. vulgaris Bory	+	+	+	
Diploneis subovalis Cleve	+			
Epithemia sorex Kütz.			+	eu
E. zebra (Ehr.) Kütz.			+	
Eunotia arcus Ehr.		+		o
E. exigua (Brébisson et Kütz.) Rabh.			+	o
E. glacialis Meister			+	o
Fragilaria arcus (Ehr.) Cleve	+		+	
F. biceps (Kütz.) Lange-Bert.	+			o
F. brevistriata Grun.	+	+		tol
F. capucina Desmazičres	+	+	+	
F. capucina var. *gracilis* (Oestrup) Hust.	+		+	
F. capucina var. *mesolepta* (Rabh.) Rabh.	+		+	
F. capucina var. *perminuta* (Grun.) Lange-Bert.		+	+	
F. capucina var. *radians* (Kütz.) Lange-Bert.	+		+	
F. capucina var. *rumpens* (Kütz.) Lange-Bert.	+	+	+	
F. capucina var. *vaucheriae* (Kütz.) Lange-Bert.	+	+	+	
F. construens (Ehr.) Grun.	+	+	+	
F. construens f. *binodis* (Ehr.) Hust.	+	+	+	
F. construens f. *venter* (Ehr.) Hust.	+		+	
F. crotonensis Kitton	+		+	
F. dilatata (Brébisson) Lange-Bert.			+	
F. famelica (Kütz.) Lange-Bert.	+			eu
F. fasciculata (Ag.) Lange-Bert.	+	+	+	
F. heiberg Kütz.	+			
F. leptostauron (Ehr.) Hust.		+		
F. nanana Lange-Bert.		+		
F. parasitica (W. Smith) Grun.	+	+		eu

Table 3 (cont.)

	T	R	M.H.	trophic level
F. parasitica var. *subconstricta* Grun.	+	+		eu
F. pinnata Ehr.	+	+	+	
F. pinnata var. *lancettula* (Schumann) Hust.			+	
F. pseudoconstruens Marciniak		+		o
F. pulchella (Ralfs ex Kütz.) Lange-Bert.			+	
F. tenera (W. Smith) Lange-Bert.		+	+	
F. ulna (Nitzsch) Lange-Bert.	+	+	+	
F. ulna var. *acus* (Kütz.) Lange-Bert.	+	+	+	
F. ulna var. *danica* (Kütz.) Lange-Bert.	+		+	
F. ulna var. *oxyrhynchus* (Kütz.) Lange-Bert.	+		+	
Fragilaria sp.	+		+	
Gomphonema acuminatum Ehr.	+	+	+	
G. affine Kütz.	+	+		
G. angustatum (Kütz.) Rabh.	+	+	+	
G. angustum Ag.	+	+		o
G. augur Ehr.	+	+	+	
G. clavatum Ehr.			+	
G. gracile Ehr.		+		
G. grovei M. Schmidt		+		
G. insigne Gregory		+		
G. intricatum Kütz.			+	
G. lagerheimii Cleve			+	o
G. minutum (Ag.) Ag.				eu
G. olivaceum (Hornemann) Brébisson	+	+	+	
G. olivaceum var. *calcareum* (Cleve) Cleve	+		+	
G. parvulum (Kütz.) Kütz.	+	+	+	
G. parvulum var. *parvulius* Lange-Bert. et Reichardt	+		+	
G. pumilum (Grun.) Reichardt et Lange-Bert.	+			eu
G. cf. *pumilum* (Grun.) Reichardt et Lange-Bert.	+		+	
G. tergestinum Fricke	+	+		
G. truncatum Ehr.	+	+	+	
G. ventricosum Gregory			+	o
Gomphonema sp.	+		+	
Gyrosigma acuminatum (Kütz.) Rabh.	+	+	+	
G. attenuatum (Kütz.) Rabh.	+	+	+	
G. nodiferum (Grun.) Reimer	+			eu
G. scalproides (Rabh.) Cleve			+	
G. spenceri (W. Smith) Cleve		+	+	
Hantzschia amphioxys (Ehr.) Grun.		+	+	
Meridion circulare Greville (Ag.)		+	+	
M. circulare var. *constrictum* (Ralfs) Van Heurck			+	
Navicula accomoda Hust.	+			eu
N. angusta Grun.	+			o
N. atomus (Kütz.) Grun.	+	+		eu
N. atomus var. *permitis* (Hust.) Lange-Bert.	+	+		eu
N. capitata Ehr.	+	+	+	
N. capitata var. *hungarica* (Grun.) Ross	+		+	
N. capitatoradiata Germain ex Gasse	+	+		eu
N. charlatii Peragallo			+	

Table 3 (cont.)

	T	R	M.H.	trophic level
N. cincta (Ehr.) Ralfs	+			eu
N. cryptocephala Kütz.	+	+	+	
N. cryptotenella Lange-Bert.	+	+		
N. cuspidata Kütz.			+	eu
N. digitatoria (Ralfs) Gregory		+		
N. elginensis (Gregory) Ralfs	+			eu
N. gastrum Ehr.			+	eu
N. gracilis Ehr.	+		+	
N. gregaria Donkin	+	+		
N. halophila (Grun.) Cleve	+			
N. helensis Schulz	+	+		
N. ignota Krasske		+		o
N. kotschyi Grun.			+	
N. lanceolata (Ag.) Ehr.	+	+		eu
N. menisculus Schumann	+	+	+	
N. menisculus var. *upsaliensis* Grun.	+		+	
N. minima Grun.	+	+		tol
N. mutica Kütz.	+			tol
N. muticopsis Van Heurck	+			
N. phyllepta Kütz.		+		
N. placentula (Ehr.) Kütz.		+		eu
N. protracta (Grun.) Cleve		+		
N. pupula Kütz.		+		eu
N. pygmaea Kütz.			+	eu
N. radiosa Kütz.	+	+	+	
N. recens (Lange-Bert.) Lange-Bert.		+		tol
N. reichardtiana Lange-Bert.		+		eu
N. reinhardtii Grun.	+			eu
N. rhynchocephala Kütz.	+		+	
N. salinarum Grun.	+			
N. schoenfeldii Hust.	+			eu
N. seminulum Grun.	+	+		eu
N. subhamulata Grun.	+			tol
N. subminuscula Manguin	+	+		eu
N. tenera Hust.	+			
N. tripunctata (O. F. Müller) Bory	+	+	+	
N. trivialis Lange-Bert.	+	+		eu
N. veneta Kütz.	+			eu
N. viridula var. *linearis* Hust.	+		+	
Neidium affine (Ehr.) Pfitzer			+	o
N. ampliatum (Ehr.) Krammer			+	
N. dubium (Ehr.) Cleve	+		+	
Nitzschia acicularis (Kütz.) W. Smith	+	+	+	
N. amphibia Grun.	+	+	+	
N. angustata Grun.	+	+		tol
N. angustatula Lange-Bert.	+	+		
N. archibaldii Lange-Bert.	+			
N. calida Grun.	+			eu
N. capitellata Hust.	+	+		eu

Table 3 (cont.)

	T	R	M.H.	trophic level
N. constricta (Kütz.) Ralfs	+	+		eu
N. desertorum Hust.	+			
N. dissipata (Kütz.) Grun.	+	+		
N. draveillensis Coste et Ricard	+			eu
N. flexoides Geitler	+			
N. fonticola Grun.	+	+	+	
N. frustulum (Kütz.) Grun.	+	+		eu
N. fruticosa Hust.	+	+		
N. graciliformis Lange-Bert. et Sim.	+			
N. gracilis Hantzsch	+	+		tol
N. heufleriana Grun.	+			
N. hungarica Grun.	+	+	+	
N. incognita Krasske	+	+		
N. inconspicua Grun.	+	+		eu
N. intermedia Hantzsch ex Cleve et Grun.	+	+	+	
N. levidensis (W. Smith) Grun.		+	+	
N. levidensis var. *salinarum* (W. Smith) Grun.	+		+	
N. linearis (Ag.) W. Smith	+	+		
N. linearis var. *subtilis* (Grun.) Hust.	+			eu
N. linearis var. *tenuis* (W. Smith) Grun.	+			tol
N. palea (Kütz.) W. Smith	+	+		eu
N. palea var. *debilis* (Kütz.) Grun.		+		
N. paleacea (Grun.) Grun.	+	+		eu
N. pellucida Grun.	+	+		tol
N. recta Hantzsch	+	+		tol
N. sigma (Kütz.) W. Smith	+			
N. sigmoidea (Nitzsch) W. Smith	+	+	+	
N. sinuata (Twaites) Grun.	+	+	+	
N. sociabilis Hust.	+	+		eu
N. subacicularis Hust.	+			
N. sublinearis Hust.	+	+		tol
N. tryblionella Hantzsch	+		+	
N. tubicola Grun.	+			
N. umbonata (Ehr.) Lange-Bert.		+		eu
N. vermicularis (Kütz.) Hantzsch	+			eu
Nitzschia sp.	+		+	
Opephora pacifica (Grun.) Petit	+			
Pinnularia borealis Ehr.			+	
P. maior (Kütz.) Rabh.			+	
P. microstauron (Ehr.) Cleve			+	o
P. microstauron var. *brebissonii* (Kütz.) Mayer			+	
P. viridis (Nitzsch) Ehr.			+	
Rhoicosphenia abbreviata (Ag.) Lange-Bert.	+	+	+	
Rhopalodia gibba (Ehr.) O. Müller			+	
Stauroneis anceps Ehr.			+	o
S. phoenicenteron (Nitzsch) Ehr.			+	tol
S. smithii Grun.			+	eu
Surirella angusta Kütz.	+		+	
S. biseriata Brébisson		+	+	

Table 3 (cont.)

	T	R	M.H.	trophic level
S. brebissonii Krammer et Lange-Bert.	+			eu
S. capronii Brébisson			+	
S. elegans Ehr.			+	
S. minuta Brébisson	+	+		eu
S. ovalis Brébisson	+	+	+	
S. ovata Kütz.			+	
S. robusta Ehr.			+	eu
S. suecica Grun.		+		
S. visurgis Hust.		+		
Tabellaria fenestrata (Lyngbye) Kütz.			+	
T. flocculosa (Roth) Kütz.	+	+	+	
Cryptophyta				
Chroomonas acuta Uterm.	+			
C. coerulea (Geitl.) Skuja	+			
Cryptomonas erosa var. *reflexa* Marss.	+			
C. marssonii Skuja	+			
C. ovata Ehr.	+			
C. cf. *phaseolus* Skuja	+			
C. rosratiformis Skuja	+			
Cryptomonas sp.	+			
Euglenophyta				
Euglena clara Skuja		+		
E. tripteris (Duj.) Klebs			+	
E. viridis Ehrbg.	+			
Euglena sp. I	+	+	+	
Euglena sp. II	+			
Euglena sp. III	+			
Phacus pleuronectes (O. F. Müller) Duj.			+	
P. pyrum (Ehr.) Stein	+			
P. skujae Skvorz.	+			
Phacus sp.	+		+	
Trachelomonas sp.	+			
Chlorophyta				
Chlorophyceae				
Actinastrum fluviatile (Schröd.) Fott			+	
Ankistrodesmus bibraianum (Reinsch.) Korš.			+	
A. gracilis (Reinsch.) Korš.			+	
Characium ornithocephalum var. *pringsheimii* (A. Br.) Kom.			+	
C. subulatum A. Br.			+	
Cladophora crispata (Roth.) Kütz.			+	
Chlamydomonas ehrenbergii Goros.			+	
C. intermedia Chod.	+			
C. cf. *latifrons* Nygaard	+			
C. reinhardtii Dang.	+			
Chlamydomonas sp. I	+		+	
Chlamydomonas sp. II (round)	+		+	
Chlamydomonas sp. III (oval)	+		+	
Chlorella sp.	+		+	

Table 3 (cont.)

	T	R	M.H.	trophic level
Chloroclonium cf. *elongatum* Borzi	+			
Chlorogonium intermedium Skuja	+			
Chlorotetraëdron incus McEntee		+		
Chrysococcus sp.		+	+	
Coelastrum astroideum De Not.		+	+	
C. microporum Näg. in A. Br.	+	+	+	
C. reticulatum (Dang) Senn		+		
C. sphaericum Näg.	+			
Coelastrum sp.	+		+	
Crucigenia fenestrata (Schmidle) Schmidle		+		
C. quadrata Morren	+	+	+	
C. tetrapedia (Kirchn.) W. et G. S. West		+		
Crucigeniella rectangularis (Näg.) Kom.			+	
Dictyosphaerium ehrenbergianum Näg.	+		+	
D. pulchellum Wood	+			
Didymocystis inermis (Fott) Fott		+		
D. planctonica Korš.		+		
Didymogenes palatina Schmidle		+		
Diplochloris lunata (Fott) Fott		+		
Eudorina elegans Ehr.			+	
filamentous Chlorophyta sp.	+	+	+	
Golenkinia radiata Chod.	+			
Gonium pectorale Müller			+	
Haematoicoccus droebakensis Wollen.			+	
Hydrodictyon reticulatum (L.) Lagerh.			+	
Kirchneriella contorta (Schmidle) Bohlin	+	+		
K. obesa (W. West) Schmidle	+		+	
Koliella longiseta (Kirchner) Hind.	+			
Lagerheimia balatonica (Scherff.) Hind.	+			
L. genevensis (Chod.) Chod.	+	+		
Micractinium pusillum Fres.			+	
Monoraphidium arcuatum (Korš.) Hind.	+	+		
M. contortum (Thuret) Komárkova-Legenerová	+	+		
M. griffithii (Berkeley) Komárkova-Legenerová	+		+	
M. mirabile (W. et G. S. West) Pankow		+	+	
Neodesmus danubialis Hind.	+			
Nephrochlamys subsolitaria (G. S. West) Korš.	+			
Nephrocytium agardhianum Näg.	+			
Oedogonium sp.	+	+		
Oocystis borgei Snow	+			
Palmellaceae sp.		+	+	
Pediastrum boryanum (Turpin) Meneghini	+	+	+	
P. duplex Meyen		+	+	
P. tetras (Ehr.) Ralfs			+	
Quadriococcus ellipticus Hortob.		+		
Rhizoclonium hieroglyphicum (Kütz.) C. A. Ag.			+	
Scenedesmus acuminatus (Lagerh.) Chod.	+	+		
S. acutiformis Schröd.		+		
S. acutus Meyen	+	+		

Table 3 (cont.)

	T	R	M.H.	trophic level
S. armatus Chod.	+		+	
S. apiculatus (W. et G. S. West) Chod.		+		
S. bicaudatus Dedus		+		
S. coalitus Hortob.		+		
S. columnatus Hortob.		+		
S. costato-granulatus Skuja	+	+		
S. danubialis Hortob.		+		
S. denticulatus Lagerh.		+	+	
S. ecornis (Ralfs) Chod.	+	+		
S. ellipticus (W. et G. S. West) Chod.		+		
S. exaltatus Hortob.		+		
S. granulatus W. et G. S. West		+		
S. intermedius Chod.	+	+		
S. intermedius var. *acaudatus* Hortob.	+			
S. intermedius var. *bicaudatus* Hortob.	+			
S. linearis Kom.		+		
S. longispina Chod.		+		
S. magnus Meyen	+			
S. nanus Chod.		+		
S. obliquus (Turpin) Kütz.			+	
S. opoliensis P. Richter	+	+	+	
S. opoliensis f. *bicaudata* Hortob.		+	+	
S. ovalternus Chod.		+		
S. protuberans Fritsch	+			
S. pseudoquadricauda Hortob.		+		
S. quadricauda (Turpin) Brébisson	+	+	+	
S. cf. *quadricauda* (Turpin) Brébisson	+		+	
S. quadricauda var. *longispina* f. *gibberus* (Hortob.) Uherkovich	+		+	
S. serratus (Corda) Bohl.	+			
S. spinosus Chod.	+			
S. subspicatus Chod.		+		
S. transilvanicus Kirj.		+		
Scenedesmus sp.	+	+	+	
Schroederia setigera (Schröd.) Lemm.	+	+		
S. spiralis (Printz) Korš.	+			
Scourfieldia cordiformis Takeda	+			
Siderocystopsis fusca (Korš.) Swale	+			
Chlorophyta sp. (thallic)		+	+	
Tetraëdron caudatum (Chod.) Hansg.	+	+	+	
T. minimum (A. Br.) Hansg.		+		
Tetrastrum glabrum (Rdl.) Ahlstr. et Tiff.		+		
T. staurogeniaeforme (Schröd.) Lemm.	+	+		
T. triangulare (Chod.) Kom.		+		
Trebouxia cladoniae (Chod.) G. M. Smith		+		
Treubaria triappendiculata Bern.	+			
Westella botryoides (W. West) De Wildeman	+			
Ulvophyceae				
Draparnaldia plumosa Ag.			+	
Ulothrix tenuissima Kütz.			+	
U. zonata Kütz.	+	+		

Table 3 (cont.)

	T	R	M.H.	trophic level
Zygnematophyceae (Conjugatophyceae)				
Closterium acutum Brébisson	+			
C. leiblenii Kütz.			+	
C. littorale Gay			+	
C. moniliferum (Bory) Ehr.			+	
C. pritchardianum Arch.			+	
C. strigosum Brébisson			+	
C. venus Kütz.			+	
Cosmarium granatum Brébisson		+	+	
C. impressulum Elfv.			+	
C. margaritiferum (Turpin) Meneghini			+	
C. meneghinii Brébisson			+	
C. protractum (Näg.) De Bary			+	
C. punctulatum var. *subpunctulatum* (Nordst.) Börg.			+	
C. reniforme (Ralfs) Arch.			+	
C. sexangulare Lund			+	
C. subgranatum (Nordst.) Lüth.			+	
C. subprotumidum Nordst.			+	
Cosmarium sp. I	+		+	
Cosmarium sp. II	+		+	
Staurastrum avicula Brébisson			+	
S. longipes (Nordst.) Teil			+	
S. paradoxum Meyen			+	
S. polymorphum Brébisson			+	
Number of taxa	281	194	226	

Chemical characteristics of water show that the values of nitrogen-forms are higher at Taksony than at Ráckeve (Table 1).

On close examination of the saprobial indications of these species (as given in Krammer and Lange-Bertalot 1986, 1988, 1991a, 1991b), it becomes obvious that some of these species (*Amphora pediculus*, *Navicula tripunctata* and *Rhoicosphenia abbreviata*) are of beta-alfa-mesosaprobic tolerance, while another and even not smaller portion of the dominant species are indifferent to the saprobic state of the water. These are *Cocconeis placentula*, *Melosira varians* and *Nitzschia dissipata*. It is also conspicuous, that *Navicula cryptotenella*, an indicator species of beta-mesosaprobic and better water quality is dominant at Ráckeve in every season while at Taksony it only occurs in one case. Simultaneously, species, which tolerate even alfa-mesosaprobic conditions like *Navicula lanceolata*, *Navicula gregaria* were frequent and dominant at Taksony (Fig. 4). *Navicula menisculus*, which is of alfa-mesosaprobic tolerance, was dominant in the middle part only in one case, whereas in the upper part it was found in three samples.

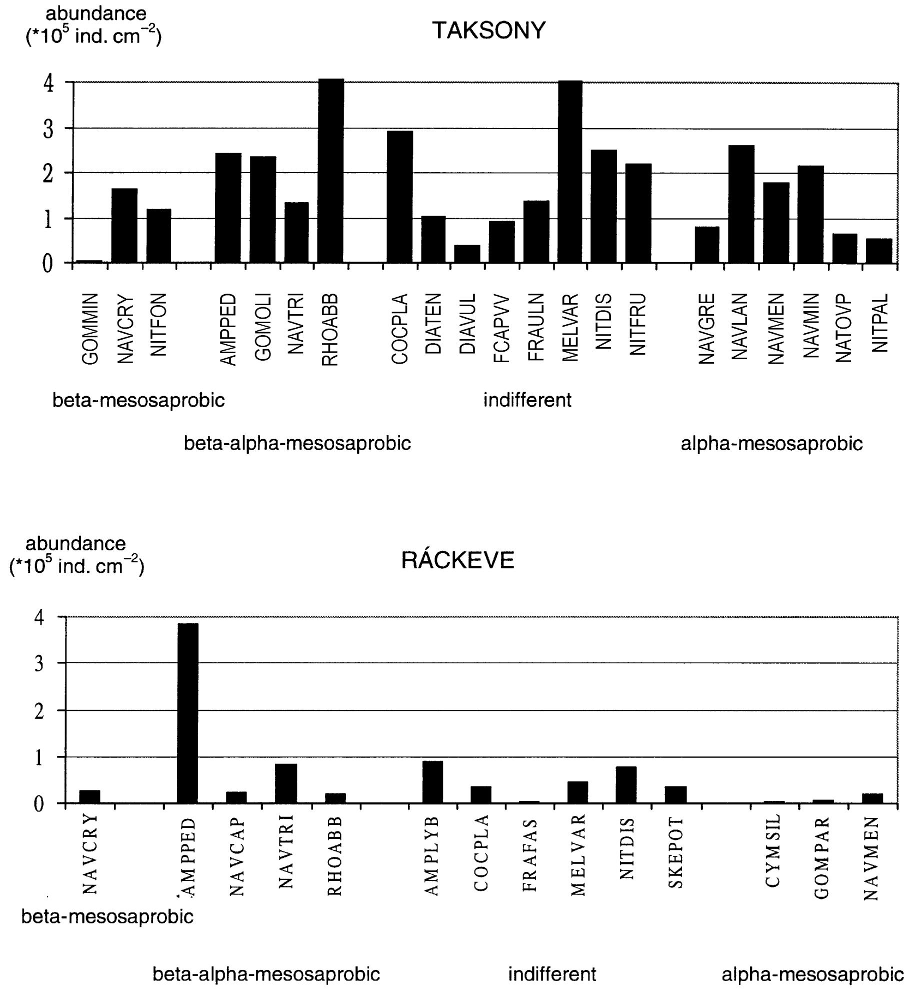

Fig. 4. Distribution of abundance of dominant diatom species at Taksony (in November 1996, January, April and July 1997) and at Ráckeve (in July and November 1998, January and April 1999) with saprobic indications. (GOMMIN = *Gomphonema minutum*, NAVCRY = *Navicula cryptotenella*, NITFON = *Nitzschia fonticola*, AMPPED = *Amphora pediculus*, NAVCAP = *Navicula capitatoradiata*, GOMOLI = *Gomphonema olivaceum*, NAVTRI = *Navicula tripunctata*, RHOABB = *Rhoicosphenia abbreviata*, COCPLA = *Cocconeis placentula*, AMPLYB = *Amphora libyca*, DIATEN = *Diatoma tenuis*, DIAVUL = *Diatoma vulgaris*, FCAPVV = *Fragilaria capucina* var. *vaucheriae*, FRAULN = *Fragilaria ulna*, FRAFAS = *Fragilaria fasciculata*, MELVAR = *Melosira varians*, NITDIS = *Nitzschia dissipata*, NITFRU = *Nitzschia frustulum*, SKEPOT = *Skeletonema potamos*, NAVGRE = *Navicula gregaria*, NAVLAN = *Navicula lanceolata*, NAVMEN = *Navicula menisculus*, NAVMIN = *Navicula minima*, NATOVP = *Navicula atomus* var. *permitis*, NITPAL = *Nitzschia palea*, GOMPAR = *Gomphonema parvulum*, CYMSIL = *Cymbella silesiaca*)

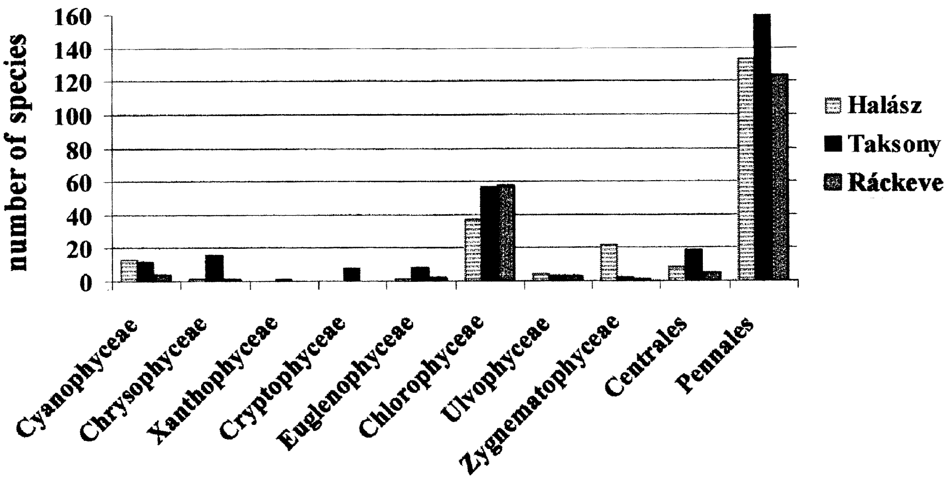

Fig. 5. Taxonomic composition of samples taken at Taksony (in November 1996, January, April and July 1997) and at Ráckeve (in July and November 1998, January and April 1999), and the samples taken by Halász between 1934–36

We have also compared our results with those of Halász, who made her qualitative periphyton studies in the side arm between 1934–36. We made a comparison between the taxonomic composition of Taksony, Ráckeve and the samples of Halász (Halász 1936, 1937). We took into account the number of species belonging to certain families because Halász did not publish any quantitative data. In all three cases diatoms were present in the highest species number, but there is a significant difference in the ratio of species of the families Zygnematophyceae and Chlorophyceae. Halász found more Zygnematophyceae species while in our samples there were more Chlorophyceae ones (Fig. 5). A possible explanation of this phenomenon is that the concentration of nutrients and – parallel to this – the trophic level of the side arm was lower in the 1930s than today. Probably the Zygnematophyceae species have an advantage under low-nutrient conditions, because generally these species are "storage-adapted", while Chlorophyceae species are "velocity-adapted" (Sommer 1985). Though Zygnematophyceae are not able to take up nutrients very fast, they can exploit the continuously absorbed and stored nutrients, and therefore gradually grow in size and number. Under high nutrient conditions "velocity-adapted" Chlorophyceae species have an advantage, because their nutrient-uptake is very fast and so they can grow more quickly.

We have made also use of the data of Halász (1936, 37), while we compared the trophic-level indication of the diatom species of Ráckeve and Taksony and that of Halász's species, on the basis of the "Rote Liste" by Lange-Bertalot (1996). Though the number of species was not very different between the two lists, the species composition has changed drastically in the last 60 years. Among the diatoms, we found many eutrophic-tolerant species, mainly *Navicula* and *Nitzschia* species. In the list of Halász, there were many oligotrophic species such as *Pinnularia microstauron*, *Surirella robusta*, *Neidium affine*, etc. (Table 3). These facts also support that the water quality declined compared to the earlier data.

*

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REFERENCES

Ács, É. and Kiss, K. T. (1991): Investigation of periphytic algae in the Danube at Göd (1669 river km, Hungary). – *Archiv für Hydrobiologie-Algological Studies* 62: 47–67.

Ács, É., Buczkó, K. and Lakatos, Gy. (1991): A Velencei-tó és a Fertő nádbevonatának összehasonlító algológiai elővizsgálata. (Comparative algological study of the reed-periphyton in Lake Velencei and Lake Fertő.) – *Bot. Közlem.* 78(1–2): 95–111.

Ács, É., Buczkó, K. and Lakatos, Gy. (1994): Changes in the mosaic-like water surfaces of Lake Velence as reflected by reed periphyton studies. – *Studia bot. hung.* 25: 5–19.

Barreto, S., Ács, É., Kiss, K. T. and Makk, J. (1998): Jég alatti algológiai vizsgálatok a Soroksári Dunaágban. (Algological investigations on the ice covered Soroksár Danube arm.) – *Hidrológiai Közlöny* 78: 300–302.

Buczkó, K. and Ács, É. (1992): Preliminary studies on the periphytic algae in the branch-system of the Danube at Cikolasziget (Hungary). – *Studia bot. hung.* 23: 49–62.

Cholnoky, B. J. (1922): Beiträge zur Kenntnis der Verbreitung der Bacillarien von Budapest. – *Bot. Közlem.* 20: 66–79.

Fukushima, S. and Fukushima, H. (1991): Seasonal succession of attached algal flora in the arm with effluent from sewage treatment plant. – *Verhandlungen Internationale Vereinigung für Limnologie* 24: 2117–2121.

Goodwin, T. W. (ed.) (1976): *Chemistry and biochemistry of plant pigments*. – London, 235 pp.

Halász, M. (1936): Daten zur Kenntnis der Algenvegetation des Soroksárer Donauarmes. – *Bot. Közlem.* 33(1): 139–181.

Halász, M. (1937): Die Bacillariaceen des Soroksárer Donauarmes I. – *Bot. Közlem.* 34: 202–222.

Kiss, K. T. and Bothár, A. (1984): Phyto- und Zooplanktonuntersuchungen in Donauarm "Ráckeve". – *Internat. Assoc. Danube Res.* 24: 85–88.

Kiss, K. T. and Genkal, I. S. (1993): Winter blooms of centric diatoms in the River Danube and in its side-arms near Budapest (Hungary). – *Hydrobiologia* 269/270: 317–325.

Kiss, K. T., Ács, É. and Kovács, A. (1994): Ecological observations on Skeletonema potamos (Weber) Hasle in the River Danube near Budapest (1991–92, daily investigations). – *Hydrobiologia* 289: 163–170.
Kiss, K. T., Pápista, É. K., Ács, É. and Makk, J. (2000): Comparison of the phytoplankton of 80s and late 90s in a large side arm of the River Danube (Soroksár-Danube – Hungary). – *Internat. Assoc. Danube Res.* 33: 103–110.
Krammer, K. and Lange-Bertalot, H. (1986): *Bacillariophyceae. Teil 1: Naviculaceae.* – In: Ettl, H., Gerloff, J., Heynig, H. and Mollenhauer, D. (eds): Süsswasserflora von Mitteleuropa. Band 2/1. G. Fischer Verlag, Jena, 876 pp.
Krammer, K. and Lange-Bertalot, H. (1988): *Bacillariophyceae. Teil 2: Bacillariaceae, Epithemiaceae, Surirellaceae.* – In: Ettl, H., Gerloff, J., Heynig, H. and Mollenhauer, D. (eds): Süsswasserflora von Mitteleuropa. Band 2/2. G. Fischer Verlag, Jena, 610 pp.
Krammer, K. and Lange-Bertalot, H. (1991a): *Bacillariophyceae. Teil 3: Centrales, Fragilariaceae, Eunotiaceae.* – In: Ettl, H., Gerloff, J., Heynig, H. and Mollenhauer, D. (eds): Süsswasserflora von Mitteleuropa. Band 2/3. G. Fischer Verlag, Jena, 576 pp.
Krammer, K. and Lange-Bertalot, H. (1991b): *Bacillariophyceae. Teil 4: Achnanthaceae. Kritische Ergänzungen zu Navicula (Lineolatae) und Gomphonema Gesamtliteraturverzeichnis. Teil 1–4.* – In: Ettl, H., Gärtner, G., Gerloff, J., Heynig, H. and Mollenhauer, D. (eds): Süsswasserflora von Mitteleuropa. Band 2/4. G. Fischer Verlag, Jena, 437 pp.
Lakatos, Gy. and Ács, É. (1990): Nád élőbevonat vizsgálatok a Velencei-tavon (1978–88). (Investigations on the reed periphyton in Lake Velence (1978–88).) – *IV. Fejér megyei Környezetvédelmi Szeminárium* 2: 291–302.
Lakatos, Gy., Ács, É. and Buchtijarova, L. N. (1991): Study on reed periphyton in Lake Velence. – *Annls hist.-nat. Mus. natn. Hung.* 83: 187–197.
Lange-Bertalot, H. (1996): Rote Liste der limnischen Kieselalgen (Bacillariophyceae) Deutschlands. – *Schriftenreihe für Vegetationskunde* 28: 633–678.
Lund, J. W. G., Kipling, C. and Lecren, E. D. (1958): The inverted microscope method of estimating algal numbers and the statistical basis of estimations by counting. – *Hydrobiologia* 11: 143–170.
Meulemans, J. T. (1988): Seasonal changes in biomass and production of periphyton growing upon reed in Lake Maarsseveen I. – *Archiv für Hydrobiologie* 112(1): 21–42.
OECD (1982): *Eutrophication of Waters. Monitoring, assessment and control. Final Report, OECD cooperative programme of monitoring on inland waters (Eutrophication control).* – Environment Directorate, OECD, Paris, 154 pp.
Palik, P. (1961): Beiträge zu Algenvegetation an den Betonbauten in der Donau. – *Annales Universitatis Scientiarum Budapestinensis de Rolando Eötvös nominatae, Danubialia Hungarica* 10: 139–150.
Sommer, U. (1985): Phytoplankton natural community experiments: a reinterpretation. – *Limnology and Oceanography* 30: 436–440.
Utermöhl, H. (1958): Zur Vervollkommnung der quantitativen Phytoplankton-Methodik. – *Mitteilungen Internationale Vereinigung für Limnologie* 9: 1–38.