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CHANGES OF ATTACHED DIATOMS IN A DEAD ARM OF THE DANUBE BETWEEN 1992–1999 AT ÁSVÁNYRÁRÓ (SZIGETKÖZ SECTION)

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Periphytic diatoms and diatoms living on algal mats have been studied in a dead arm of the Szigetköz section of the Danube for 9 years. Altogether 123 taxa were recorded. In the last year of the study period notable changes were observed in the flora and in the relative abundance of the dominant taxa. The changes may be attributed to the invasion (and shading) of duckweed (*Lemna minor* and *Spirodela polyrrhiza*). In 1999, the coatings were characterised by *Achnanthes hungarica*, *Cocconeis placentula* and *Navicula* cf. *saprophila*. For years long, *Achnanthes minutissima* was the dominant species. This means that with the appearance of duckweed the attached flora, especially the dominance of the diatom species, has changed sharply.

Key words: biomonitoring, diatoms, Danube, Szigetköz

INTRODUCTION

Researchers of the Department of Botany, Hungarian Natural History Museum began to study the cryptogams of the Szigetköz in 1991. Our investigation on the attached algae has been part of the Hungarian biomonitoring research in the Szigetköz, coordinated by the Szigetköz Committee of the Hungarian Academy of Sciences. The tasks of this committee are to co-ordinate and to synthesise the results of ecological research in the Szigetköz region after the diversion of the Danube. In October of 1992 the main arm of the Danube was diverted into a new, artificial bed at Dunacsúny (Čunovo) as a part of the construction of the Gabčikovo Water Project.

"The constructions at Bős (Gabčikovo) involved water management interventions that have brought about significant changes on the Hungarian side, particularly in the Szigetköz region which had formerly been interwoven by a whole system of river branches. These interventions included the so-called variant C of the barrage system construction and the diversion of the Danube, both arbitrarily carried out by the Slovak party, as well as the building of the temporary river-bed sills to make up for at least part of the ensuing catastrophic water loss." (LÁNG *et al.* 1997).

Our task in the Department of Botany has been to follow the changes of attached algae (esp. diatoms) living on different substrata. During the 9 years of our monitoring work in the Szigetköz more than 700 algal samples were collected and analysed. The detailed data and results of monitoring were submitted to the Hungarian Ministry for Environment and Regional Policy in Annual Reports. Meanwhile, some of our previous observations appeared in publications (ÁCS and BUCZKÓ 1996, BUCZKÓ 1999, 2001, BUCZKÓ and ÁCS 1992, 1994, 1996, BUCZKÓ *et al.* 1997).

In this paper we present the results of the study of 38 samples, restricted to one dead arm of the Danube in the branch system near Ásványráró (Figs 1–2).

Our first collecting trip was led here in 1992. Between 1995 and 1999 we collected samples from different substrata regularly, twice a year. Beginning from 1996, we also made observations on the algal mats.

In the summer of 1999 during our regular biomonitoring collecting trip in the Szigetköz we recognised, that two of our standard sampling locations have markedly changed. Astonishingly, almost the whole water surface of the dead arm was covered by duckweed (*Lemna minor* and *Spirodela polyrrhiza*). Only a few square metres of the water surface at the entrance of the dead arm were free of duckweed; *Lemna minor* and *Spirodela polyrrhiza* have almost totally overrun the rest of the surface. In the autumn we also went to this dead arm to collect samples. At that time we found larger free water surface, but 80–90% of the dead arm surface was still covered by duckweed. There was a sharp border between the free and the covered surface.

Although we regularly collect periphyton samples from this place from 1992, we never observed such an overrun by duckweed here. Otherwise, duckweed invasion is not a rare phenomenon in Hungary (FELFÖLDY 1990).

With the studies we aimed at learning how the shading of duckweed influences the quantitative and qualitative parameters of periphyton.

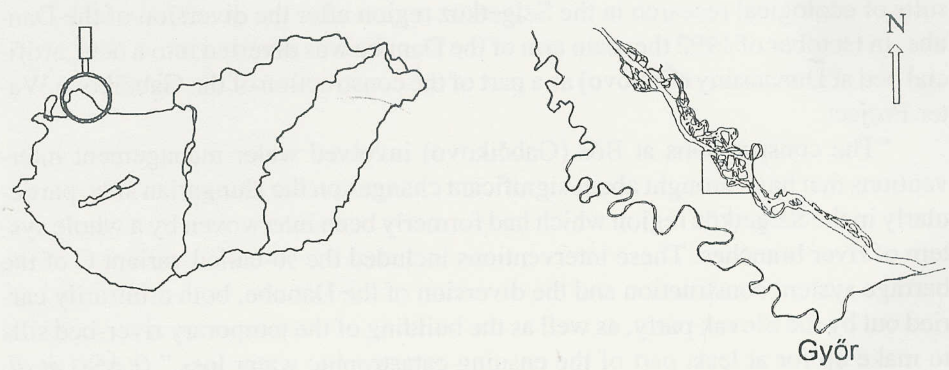

Fig. 1. Location of the Szigetköz in Hungary and that of the Ásványráró branch system within it (shown by a box).

The algological studies of the Danube river have a long history, marked by results of several authors. Nowadays we have to emphasise the works of K. T. Kiss (*e.g.* KISS 1999), who especially studies the phytoplankton. É. Ács deals with the periphytic algae of the river (*e.g.* SZABÓ *et al.* 2001). A. Schmidt and G. Fehér study the southern stretch of the Hungarian Danube including the side arms (SCHMIDT 1996). É. Tevanné Bartalis published results on the research of algae living in side arms at the Szigetköz before the diversion of the Danube took place (TEVANNÉ BARTALIS 1978).

MATERIAL AND METHODS

Study area. The Szigetköz is a big island of the Danube, situated in northwest Hungary, where the river enters the Carpathian Basin (Fig. 1). This island is bounded by the main arm of the river (Old Danube) and the Moson Danube. It is 52 km long, on average 7–8 km wide and its surface totals at 375 square kilometres. Here the big, quick flowing river is divided into several smaller arms, forming a multiple branch system. The dead arm of our study is situated in the biggest, still existing Hungarian branch system near the village of Ásványráró. It is connected only with a narrow channel to one of the main arms of the branch system. Consequently, it has a direct junction with the flowing water at its lower end but actually the river never flows through it.

The Danube is the only river in Hungary that has a complex and extended branch system. Thus the Szigetköz is one of the most remarkable and rare habitats of Hungary. It has been strongly affected by the construction of the Gabčikovo Water Project.

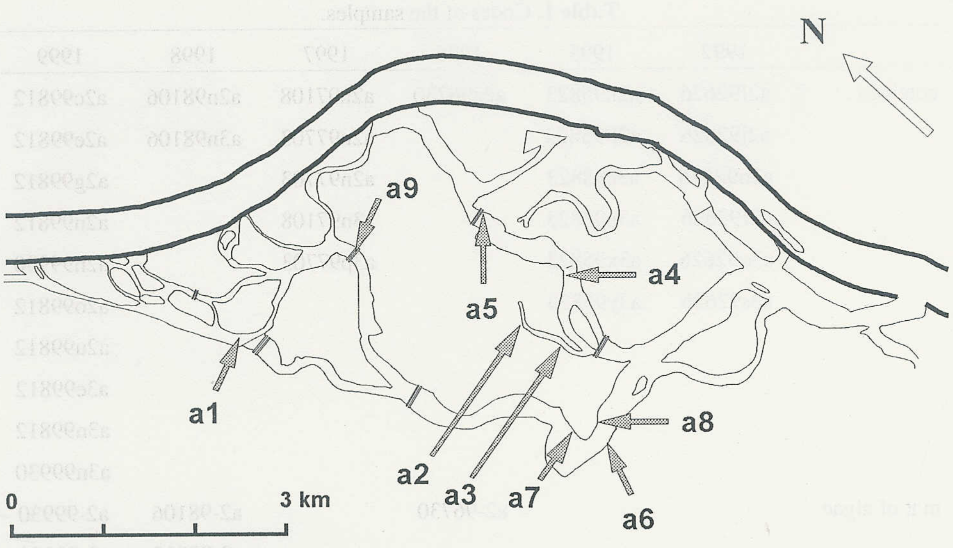

Fig. 2. The detailed map of the Ásványráró branch system with the other sampling points of biomonitoring. The investigated locations in the dead arm are a2 and a3.

Methods. The samples (38) were collected at 2 locations in the big branch system in the Szigetköz called “Ásványráró branch system” between 1992 and 1999 (Table 1, Fig. 2). Each sample has an accession code referring to the place, time and substrate. The first two characters of the code refer to the location (Fig. 2). The 3rd character means the name of the substrate. The stem of macrophyta (n, N = reed, *Phragmites australis*, g = *Typha* sp.) were cut off at water level, and about 10 cm below it. The submerged plants (c = *Ceratophyllum* sp., e = *Elodea canadensis*, f = branches (carried by the water), j = *Najas* sp., o = *Potamogeton crispus*, p = *Potamogeton perfoliatus* leaf, P = *Potamogeton perfoliatus* stem, q = *Ranunculus circinatus*, r = *Rorippa* sp., s = *Solidago gigantea*, u = *Potamogeton lucens*, x = *Carex* sp., y = *Polygonum* sp., z = *Potamogeton nodosus*) were carefully taken off, the leaves cut off, and only the stems were placed into the sampling jars. The 4th and the 5th characters indicate the year and the 6th stands for the month (4 = April, 5 = May, 6 = June, 7 = July, 8 = August, 9 = September, 10 = October), see Table 1. The last 2 characters mean the day of collection. The algal mats were collected in jars (formaldehid solution was used for their preservation) as well as in dried form.

Laboratory methods. The coating was washed into water, which later was homogenised. The diatoms were treated with H_2O_2, after which the preparata were embedded into Styrax. The first 400 diatoms were counted. Permanent slides are accessible in the Collectio Algarum of the Department of Botany of the Hungarian Natural History Museum (BP).

In the course of the statistical treatment a constancy value was given to each species as follows. First the percentage was calculated on the basis of the function:

$$K = N/S \times 100$$

where N = the number of preparata where the taxon had occurred, and S = the total number of preparata. The constancy of a species was 5 when its K value was between 80–100%, 4 when K was between 60–80%, and so on.

Table 1. Codes of the samples.

	1992	1995	1996	1997	1998	1999
coatings	a2f92626	a2n95823	a2z96730	a2n97108	a2n98106	a2c99812
	a2j92626	a2P95823		a2n97703	a3n98106	a2e99812
	a2n92626	a3c95823		a2n97703		a2g99812
	a2r92626	a3n95823		a3n97108		a2n99812
	a3q92626	a3x95823		a3p97703		a2n99930
	a3s92626	a3y95823				a2o99812
						a2u99812
						a3e99812
						a3n99812
						a3n99930
mat of algae			a2-96730		a2-98106	a2-99930
					a3-98812	a3-99930
					a3-98106	

Hierarchical cluster analysis (Czekanowski measure, UPGMA fusion technique), and principal component analysis (standardised PCA) were carried out with the raw data. For the computations, the program package SYN-TAX was used (PODANI 1993).

RESULTS AND DISCUSSION

Altogether 38 samples were collected from this dead arm in the Ásványráró branch system between 1992 and 1999. Following the microscopical analysis 36 samples were suitable for statistical analysis (2 from 38 samples contained only a few cells of algae). The later omitted two samples were the 2p92626 and a2n98812.

Only a few valves (26) occurred in sample a2p92626, collected in 1992. We can only assume that most of the algae belonged to order Centrales. It is well-known, that this group has been characteristic of the phytoplankton of the Danube for decades, throughout the year (KISS 1999). In 1992 they were very common also in the periphyton of the Szigetköz (BUCZKÓ 1999).

Sample a2n98812 was collected in the summer of 1998. It contained only a few *Nitzschia* valves which was insufficient for further study.

About the taxa

During the analysing of the remaining 36 samples altogether 123 diatom taxa were identified (Tables 2–4). The combined form of these three tables contains the complete list of diatom taxa found in that dead arm of the Danube. Only 6 taxa were found in all of the 6 investigated years: *Achnanthes minutissima*, *Cocconeis placentula*, *Cymbella affinis*, *Gomphonema parvulum*, *G. truncatum* and *Nitzschia dissipata*. Among them three (*A. minutissima*, *C. placentula* and *N. dissipata*) are mass forming species.

Below we provide a brief summary on the periphyton samples collected from different substrata (including coatings of reed). Later we give a separate analysis of the periphyton samples collected only from reed. Then the enumeration of the diatoms found in algal mats follows.

Periphyton samples

A total of 119 diatom taxa were recorded in the 30 samples. Table 2 contains the occurrences of taxa in the years between 1992 and 1999.

Achnanthes minutissima occurred in all of the samples, and the following taxa were also very abundant (with constancy 5): *Cymbella affinis*, *Navicula veneta*,

Table 2. Detailed list of taxa in the periphyton samples from different substrata. The number indicates in how many samples the taxon occurred in the given year (see Table 1).

	1992	1995	1996	1997	1998	1999
Number of samples were collected in that year	6	6	1	5	2	10
Achnanthes clevei Grun.	1					1
Achnanthes delicatula (Kütz.) Grun.	1					
Achnanthes hungarica (Grun.) Grun.					1	6
Achnanthes lanceolata Bréb.		1				
Achnanthes minutissima Kütz.	6	6	1	5	2	10
Achnanthes plönensis Hust.	1					2
Amphora coffeaeformis (Agardh) Kütz.		3				
Amphora ovalis (Kütz.) Kütz.		1		1		3
Amphora pediculus (Kütz.) Grun.		5		4	2	9
Amphora thumensis (Mayer) Cleve-Euler			1			
Amphora veneta Kütz.			1	2	1	8
Asterionella formosa Hass.	1	1		2		3
Aulacoseira ambigua (Grun.) Simonsen				1		
Aulacoseira distans (Ehr.) Kütz.	2					
Aulacoseira granulata (Ehr.) Sim.				2		2
Aulacoseira granulata var. *angustissima* Müll.	1	1		1		1
Aulacoseira italica (Ehr.) Sim.	1			2		3
Aulacoseira italica var. *tenuissima* (Grun.) Sim.						2
Caloneis bacillum (Grun.) Cleve				1		1
Caloneis silicula (Ehr.) Cleve				1		1
Centrales	6	6		5	2	9
Cocconeis neodiminuta Krammer			1			
Cocconeis pediculus Ehr.	1	4		4	1	
Cocconeis placentula Ehr.	3	6	1	3	2	1
Cymatopleura solea (Bréb.) W. Smith				1		
Cymbella affinis Kütz.	6	6	1	5	1	7
Cymbella aspera (Ehr.) Cleve	6		1			
Cymbella caespitosa (Kütz.) Brun.			1			3
Cymbella cistula (Ehr.) Kirchner	2	1	1	2		4
Cymbella cymbiformis Agardh		1				
Cymbella ehrenbergii Kütz.				1		
Cymbella lacustris (Agardh) Cleve	1					
Cymbella lanceolata (Ehr.) Kirchner						1
Cymbella microcephala Grun.		1		2	2	4

Table 2 (continued)

	1992	1995	1996	1997	1998	1999
Cymbella minuta Hilse						2
Cymbella prostrata (Berkeley) Cleve		1				
Cymbella proxima Reimer				1		
Cymbella silesiaca Bleisch	6	4		2		2
Cymbella sinuata Gregory				1		
Cymbella tumida (Bréb.) Van Heurck			1	1		
Diatoma tenuis Agardh	5			1		
Diatoma vulgare Bory	1					3
Diploneis ovalis (Hilse) Cleve						1
Epithema adnata (Kütz.) Bréb.	1			1		1
Eunotia bilunaris (Ehr.) Mills	1					
Fragilaria biceps (Kütz.) Lange-Bert.				2		
Fragilaria brevistriata Grun.	5		1	1		1
Fragilaria capucina Desm.		4		3	1	1
Fragilaria capucina var. *gracilis* (Oestrup) Hust.	2			1		
Fragilaria capucina var. *mesolepta* Rabh.	3			2	1	8
Fragilaria capucina var. *rumpens* Lange-Bert.			1			
Fragilaria construens (Ehr.) Grun.	1				1	3
Fragilaria construens var. *binodis* (Ehr.) Grun.	1					
Fragilaria crotonensis Kitton	5			1		
Fragilaria dilatata (Bréb.) Lange-Bert.			1			
Fragilaria pinnata Ehr.	6	1		1		
Fragilaria ulna (Nitzsch) Ehr.	6	2		3	1	2
Fragilaria ulna (Nitzsch) Ehr. var. *acus* (Kütz.) Lange-Bert.	5	3		3	1	3
Fragilaria sp. I	4					
Fragilaria sp. II	5					
Gomphonema acuminatum Ehr.	3	1	1	1		4
Gomphonema angustatum (Kütz.) Rabh.		1				2
Gomphonema augur Ehr.			1			2
Gomphonema clavatum Ehr.				1	1	
Gomphonema gracile Ehr.						2
Gomphonema minutum Agardh		2		3		2
Gomphonema olivaceum (Hornemann) Bréb.	2			1	1	1
Gomphonema parvulum (Kütz.) Kütz.	6	1	1	4	1	7

Table 2 (continued)

	1992	1995	1996	1997	1998	1999
Gomphonema truncatum Ehr.	1	1	1	3	1	2
Gomphonema sp.	1				2	
Gyrosigma acuminatum (Kütz.) Rabh.		3				
Gyrosigma sp.	2					
Hantzschia amphioxys (Ehr.) Grun.				1		
Melosira varians Agardh	3	1		2	1	1
Navicula capitata Ehr.				1		2
Navicula capitatoradiata Germain		2		3		
Navicula cryptocephala Kütz.	4			3	2	5
Navicula exigua (Gregory) Grun.						1
Navicula gallica (W. Smith) Lagerstedt	1					
Navicula gastrum (Ehr.) Kütz.						1
Navicula gregaria Donkin	2					
Navicula lanceolata (Agardh) Ehr.	1					
Navicula laterostrata Hust.				1		
Navicula menisculus Schumann	1					
Navicula placentula (Ehr.) Grun.						1
Navicula pupula Kütz.	2					1
Navicula radiosa Kütz.	5					
Navicula rhynchocephala Kütz.	2	3	1		1	3
Navicula saprophila Lange-Bert.					2	2
Navicula subminuscula Manguin						1
Navicula tripunctata (O. F. Müller) Bory		2		3	1	5
Navicula veneta Kütz.	4	5		5	1	1
Nitzschia acicularis (Kütz.) W. Smith				2		2
Nitzschia amphibia Grun.	3				1	
Nitzschia angustata Grun.	1	2		2		3
Nitzschia angustatula Lange-Bert.				1	1	1
Nitzschia capitellata Hust.			1			
Nitzschia constricta (Kütz.) Ralfs				1		
Nitzschia dissipata (Kütz.) Grun.	1	3	1	5	2	6
Nitzschia fonticola Grun.		1				
Nitzschia frustulum (Kütz.) Grun.	5	3		3	2	2
Nitzschia fruticosa Hust.	4					3
Nitzschia cf. *gracilis* Hantzsch		1				

Table 2 (continued)

	1992	1995	1996	1997	1998	1999
Nitzschia inconspicua Grun.	3					
Nitzschia levidensis (W. Smith) Grun.	1					
Nitzschia linearis (Agardh) W. Smith	2	2			1	4
Nitzschia palea (Kütz.) W. Smith		2		2		6
Nitzschia pellucida Grun.			1			
Nitzschia recta Hantzsch	1	1		3	1	5
Nitzschia sigmoidea (Nitzsch) W. Smith				1		
Nitzschia sinuata var. *delongei* (Grun.) Lange-Bert.						1
Nitzschia sinuata var. *tabellaria* (Grun.) Grun.				1		
Nitzschia sublinearis Hust.		2				
Nitzschia small	1		1	2	2	6
Nitzschia sp. (spine-like)			1			1
Pinnularia viridis (Nitzsch) Ehr.				1		
Pinnularia sp.	1					
Rhoicosphaenia abbreviata (Agardh) Lange-Bert.	4	4		3	1	2
Rhopalodia gibba (Ehr.) O. F. Müller						4

and *Cocconeis placentula*. Almost every sample contained a few valves belonging to Centrales.

We gave constancy 4 *Gomphonema parvulum* and *Amphora pediculus*.

The following 8 taxa had constancy 3: *Cymbella silesiaca*, *Fragilaria capucina* var. *mesolepta*, *Fragilaria ulna*, *Navicula cryptocephala*, *Rhoicosphaenia abbreviata*, *Fragilaria ulna* var. *acus*, *Nitzschia frustulum*, and *Nitzschia dissipata*.

Naturally most taxa (82 by number) had constancy 1; 14 of these occurred in two samples, and 37 taxa were found only in one sample.

On Figure 3 we present the result of PCA. The isolation of the samples collected in 1999 is conspicuous. The biplot clearly shows that *Cocconeis placentula*, *Navicula* cf. *saprophila* and *Achnanthes hungarica* caused this isolation.

Cocconeis placentula is a very common, well known species all over the Danube. Its abundance increases usually from spring to autumn (BUCZKÓ 2001). Recently in a side arm of the Danube at Soroksár the abundance of the *Cocconeis placentula* on reed was also studied by Szabó *et al.* (SZABÓ *et al.* 2001). They found that the abundance of *Cocconeis placentula* increased from the water sur-

Table 3. The relative abundance of diatoms living on reed.

	a2n92	a2n95	a3N95	a2n97	a2n97	a2n97	a3n97	a2n98	a3n98	a2n99	a2n99	a3n99	a3n99
	626	823	823	108	703	703	108	106	106	812	930	930	812
Achnanthes hungarica (Grun.) Grun.								2.37		2.82	12.08	8.26	27.00
Achnanthes minutissima Kütz.	72.68	85.03	89.43	41.80	23.26	44.55	86.00	34.72	64.94	26.76	5.07	13.76	15.00
Achnanthes plönensis Hust.											0.48		
Amphora coffeaeformis (Agardh) Kütz.		0.32											
Amphora ovalis (Kütz.) Kütz.										4.23			
Amphora pediculus (Kütz.) Grun.		0.64	0.27	11.25	0.47	0.50	2.70	5.34	0.65	4.23	6.04	7.34	1.00
Amphora veneta Kütz.				0.64			0.25	2.97		1.41	2.42	0.92	5.00
Asterionella formosa Hass.		0.32				0.25							
Aulacoseira ambigua (Grun.) Simonsen							0.49						
Aulacoseira distans (Ehr.) Kütz.	0.26												
Aulacoseira granulata (Ehr.) Sim.				0.64		0.25							
Aulacoseira granulata var. *angustissima* Müll.			0.54										
Aulacoseira italica (Ehr.) Sim.					0.47								
Caloneis bacillum (Grun.) Cleve				0.32									
Caloneis silicula (Ehr.) Cleve					0.47								
Centrales	0.52	3.50	2.71	0.64	1.86	0.25	0.49	0.59	1.08	2.82	2.17	0.92	3.00
Cocconeis pediculus Ehr.				0.32	0.47	5.94	1.23		1.08				
Cocconeis placentula Ehr.	3.09	0.32	2.17	8.04	0.47	1.98		2.08	0.22	29.58	8.45	7.34	20.00
Cymatopleura solea (Bréb.) W. Smith					0.47								
Cymbella affinis Kütz.	1.03	0.32	3.52	1.61	2.33	0.25	0.25		0.65	2.82	0.24		1.00
Cymbella aspera (Ehr.) Cleve	0.77												
Cymbella cistula (Ehr.) Kirchner					0.47		0.25						

Table 3 (continued)

	a2n92	a2n95	a3N95	a2n97	a2n97	a2n97	a3n97	a2n98	a3n98	a2n99	a2n99	a3n99	a3n99
	626	823	823	108	703	703	108	106	106	812	930	930	812
Cymbella ehrenbergii Kütz.					0.47								
Cymbella lacustris (Agardh) Cleve	0.77												
Cymbella microcephala Grun.					2.79		1.23	0.30	21.21				
Cymbella minuta Hilse											0.24		
Cymbella proxima Reimer							0.25						
Cymbella silesiaca Bleisch	5.15	0.96				0.74							
Cymbella sinuata Gregory					0.93								
Diatoma tenuis Agardh					1.86								
Diatoma vulgare Bory										1.41		0.92	
Epithema adnata (Kütz.) Bréb.							0.25					2.75	
Eunotia bilunaris (Ehr.) Mills	0.26												
Fragilaria biceps (Kütz.) Lange-Bert.					0.47								
Fragilaria brevistriata Grun.	1.03					0.50							
Fragilaria capucina Desm.		0.32			20.93	29.70		0.30				0.92	
Fragilaria capucina var. *gracilis* (Oestrup) Hust.						0.50							
Fragilaria capucina var. *mesolepta* Rabh.				0.96	11.63			15.43		7.04	1.21	0.92	
Fragilaria construens (Ehr.) Grun.									0.43				
Fragilaria crotonensis Kitton					2.33								
Fragilaria pinnata Ehr.	0.26				1.40								
Fragilaria sp. II	1.55												
Fragilaria ulna (Nitzsch) Ehr.	2.06	0.64	0.27		1.86	0.50		2.97					
Fragilaria ulna var. *acus* (Kütz.) Lange-Bert.	0.26	0.32			9.77	0.25		0.30					

Table 3 (continued)

	a2n92	a2n95	a3N95	a2n97	a2n97	a2n97	a3n97	a2n98	a3n98	a2n99	a2n99	a3n99	a3n99
	626	823	823	108	703	703	108	106	106	812	930	930	812
Gomphonema acuminatum Ehr.	0.26	0.96		1.29								0.92	1.00
Gomphonema angustatum (Kütz.) Rabh.		0.32									0.24		
Gomphonema augur Ehr.											0.24		
Gomphonema clavatum Ehr.						0.25			0.22				
Gomphonema minutum Agardh				0.64		1.98	0.74			2.82			
Gomphonema olivaceum (Hornemann) Bréb.	1.55			0.32				1.48					
Gomphonema parvulum (Kütz.) Kütz.	2.58			5.79	2.33	3.22		1.78			0.24		1.00
Gomphonema sp.								0.30	0.65				
Gomphonema truncatum Ehr.					3.26	0.25		1.19			0.24		
Gyrosigma acuminatum (Kütz.) Rabh.		0.32											
Gyrosigma sp.	0.26												
Hantzschia amphioxys (Ehr.) Grun.					0.47								
Melosira varians Agardh	0.26	1.27			0.93			1.19					
Navicula capitatoradiata Germain		1.27		0.96	0.47								
Navicula cryptocephala Kütz.	0.77			1.93			0.25	1.78	0.43			4.59	
Navicula laterostrata Hust.					0.47								
Navicula pupula Kütz.	0.77										0.24		
Navicula radiosa Kütz.	0.77												
Navicula rhynchocephala Kütz.								0.30					
Navicula saprophila Lange-Bert.								7.12	4.11		53.14	44.95	
Navicula tripunctata (O. F. Müller) Bory				0.64	0.47				0.65	2.82			
Navicula veneta Kütz.		0.96	0.54	4.50	0.47	0.99	2.21		1.52	1.41	1.93	3.67	4.00

Table 3 (continued)

	a2n92 626	a2n95 823	a3N95 823	a2n97 108	a2n97 703	a2n97 703	a3n97 108	a2n98 106	a3n98 106	a2n99 812	a2n99 930	a3n99 930	a3n99 812
Nitzschia acicularis (Kütz.) W. Smith					0.47		0.49						
Nitzschia amphibia Grun.								1.19					
Nitzschia angustata Grun.							0.25						
Nitzschia angustatula Lange-Bert.						0.25			0.43				
Nitzschia constricta (Kütz.) Ralfs					0.47								
Nitzschia dissipata (Kütz.) Grun.				2.89	0.47	1.24	0.74	0.30	0.43	7.04	0.24		2.00
Nitzschia fonticola Grun.		0.32											
Nitzschia frustulum (Kütz.) Grun.	0.77	0.96		5.79		3.47	0.98	12.76	0.87		2.17		
Nitzschia gracilis Hantzsch		0.32											
Nitzschia inconspicua Grun.	1.03												
Nitzschia linearis (Agardh) W. Smith								0.30					4.00
Nitzschia palea (Kütz.) W. Smith			0.27		0.47						0.24		16.00
Nitzschia recta Hantzsch	0.26			1.61	3.26		0.25	0.59					
Nitzschia sigmoidea (Nitzsch) W. Smith					0.47								
Nitzschia sinuata var. *delongei* (Grun.) Lange-Bert.											0.24		
Nitzschia sinuata var. *tabellaria* (Grun.) Grun.					0.47								
Nitzschia sublinearis Hust.		0.32											
Nitzschia small				5.14		0.25		2.37	0.22		0.72		
Nitzschia sp. II											1.69		
Pinnularia viridis (Nitzsch) Ehr.						0.25							
Pinnularia sp.	0.26												
Rhoicosphaenia abbreviata (Ag.) Lange-Bert.	0.77	0.32	0.27	2.25		1.73	0.74		0.22	1.41		0.92	
Rhopalodia gibba (Ehr.) O. F. Müller										1.41		0.92	

Table 4. The relative abundance (pc) of diatoms were found in algal mats.

	a2-96 730	a2-98 106	a3-98 812	a3-98 106	a2-99 930	a3-99 930
Achnanthes minutissima Kütz.	59.52	84.54	66.31	49.77	74.07	38.98
Amphora lybica Ehr.		0.72			0.49	2.26
Amphora ovalis (Kütz.) Kütz.						1.69
Amphora pediculus (Kütz.) Grun.	1.19		0.72		0.74	11.30
Amphora veneta Kütz.	10.71	4.35	13.98	1.36	9.63	
Aulacoseira distans (Ehr.) Kütz.						0.56
Aulacoseira granulata var. *angustissima* Müll.		0.24				
Caloneis silicula (Ehr.) Cleve			0.18			
Centrales		0.48	2.87		4.20	10.17
Cocconeis pediculus Ehr.						0.56
Cocconeis placentula Ehr.	0.89	0.24	0.36		0.25	3.39
Cymbella affinis Kütz.	3.57	0.48	0.72	0.45		0.56
Cymbella caespitosa (Kütz.) Brun.	0.30					
Cymbella cistula (Ehr.) Kirchner	0.60					0.56
Cymbella lanceolata (Ehr.) Kirchner						0.56
Cymbella microcephala Grun.			0.18		0.25	0.56
Cymbella silesiaca Bleisch	0.30			0.45		
Fragilaria capucina Desm.	4.76			6.79	2.72	1.69
Fragilaria capucina var. *gracilis* (Oestrup) Hust.	1.49					
Fragilaria capucina var. *mesolepta* Rabh.	0.30	1.21	1.25			
Fragilaria construens (Ehr.) Grun.				9.05		
Fragilaria pinnata Ehr.			0.36	0.90		
Fragilaria ulna (Nitzsch) Ehr.				1.81		
Gomphonema acuminatum Ehr.					0.49	
Gomphonema angustatum (Kütz.) Rabh.					0.25	
Gomphonema clavatum Ehr.			0.36			
Gomphonema olivaceum (Hornemann) Bréb.				2.26	0.25	
Gomphonema parvulum (Kütz.) Kütz.	2.68		0.36			
Gomphonema truncatum Ehr.	1.19	0.24		1.81		
Gyrosigma sp.						0.56
Melosira varians Agardh	0.30					
Navicula capitata Ehr.						0.56
Navicula cryptocephala Kütz.				0.45		
Navicula halophila (Grun.) Cleve	0.30					

Table 4 (continued)

	a2-96 730	a2-98 106	a3-98 812	a3-98 106	a2-99 930	a3-99 930
Navicula lenzii Hust.					0.25	1.13
Navicula menisculus Schumann						0.56
Navicula pupula Kütz.			0.36			0.56
Navicula radiosa Kütz.						0.56
Navicula rhynchocephala Kütz.	0.60	0.72	0.54	0.45	1.23	0.56
Navicula saprophila Lange-Bert.		3.38	3.76	7.69		
Navicula subminuscula Manguin						0.56
Navicula tripunctata (O. F. Müller) Bory	0.30				0.25	1.13
Navicula veneta Kütz.	1.49	0.24	1.08	0.45	0.49	5.65
Nitzschia acicularis (Kütz.) W. Smith						0.56
Nitzschia angustata Grun.						5.08
Nitzschia angustatula Lange-Bert.						1.69
Nitzschia dissipata (Kütz.) Grun.					0.99	5.08
Nitzschia frustulum (Kütz.) Grun.	3.57	1.45	1.97	0.45	1.73	
Nitzschia fruticosa Hust.					1.23	
Nitzschia linearis (Agardh) W. Smith	0.30		1.25	0.45		2.82
Nitzschia palea (Kütz.) W. Smith	0.30					
Nitzschia recta Hantzsch				14.48		
Nitzschia sinuata var. *tabellaria* (Grun.) Grun.			0.18			
Nitzschia small	5.36		3.05		0.25	
Nitzschia sp. (spine-like)		0.48	0.18			
Rhoicosphaenia abbreviata (Agardh) Lange-Bert.		1.21				
Surirella ovalis Bréb.				0.90	0.25	

face to the bottom of the river. Our results contribute to their statement, as *Cocconeis placentula* is probably a shadow-adapted species.

But we must lay special emphasis on the appearance and growing abundance of *Navicula* cf. *saprophila* and *Achnanthes hungarica.* We have not found them earlier in other parts of the Szigetköz. These two species were also unknown before 1998 in this dead arm at Ásványráró. *Achnanthes hungarica* was found only in one sample in 1998, *Navicula* cf. *saprophila* in two samples in 1998. In 1999 they became abundant, and even dominant taxa of periphyton in this dead arm.

Reed periphyton

Altogether 89 taxa were found in the 13 samples collected from reed. *Achnanthes minutissima* and the Centrales group occurred in all samples. *Amphora pediculus* and *Cocconeis placentula* were also frequent, they were absent only in 1 sample. The constancy of *Cymbella affinis* and *Navicula veneta* was also 5. Twelve taxa had constancy 2, and 58 taxa had constancy 1 (15 taxa occurred only in two samples, and the occurrence of 43 taxa was sporadic).

The result of the cluster analysis shows the separation of the samples collected in 1999 from the others. The dendrogram (Fig. 4) indicates that the

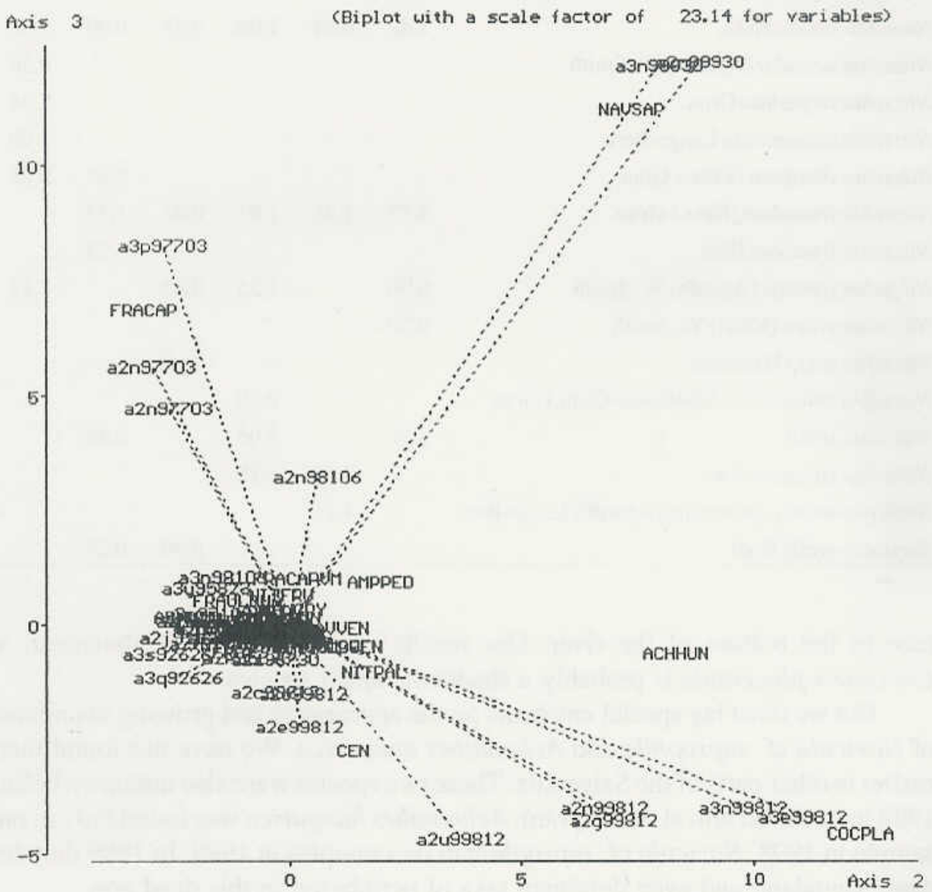

Fig. 3. Biplot of PCA analysis, the arrangement of the sampling points and species along the 2nd and 3rd axis.

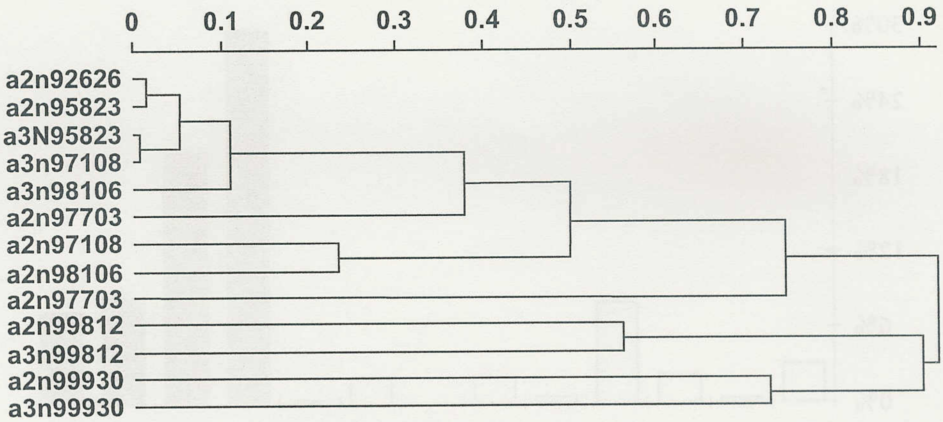

Fig. 4. Dendrogram of the sampling points.

periphyton changed in 1999 on reed. The most similar samples were collected in 1992, 1995, and 1997. Some differences (more dissimilarities) can be observed in the comparison of years 1997 and 1998, respectively, but the sharp change happened in 1999. This phenomenon corresponds well to the result of PCA (Fig. 3). It means that all coatings have changed in the dead arm as well as the reed periphyton.

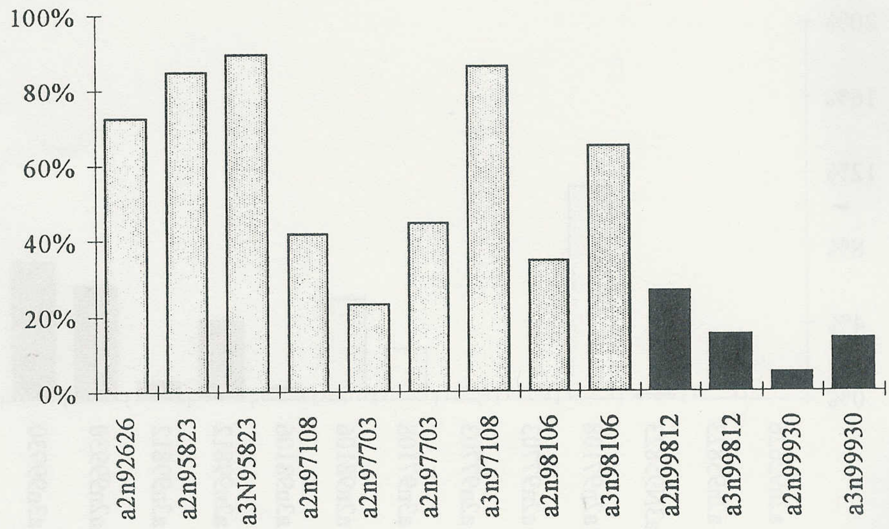

Fig. 5. Changes of relative abundance of *Achnanthes minutissima*, the most common taxon on reed between 1992 and 1998. The black blocks indicate the samples collected in 1999.

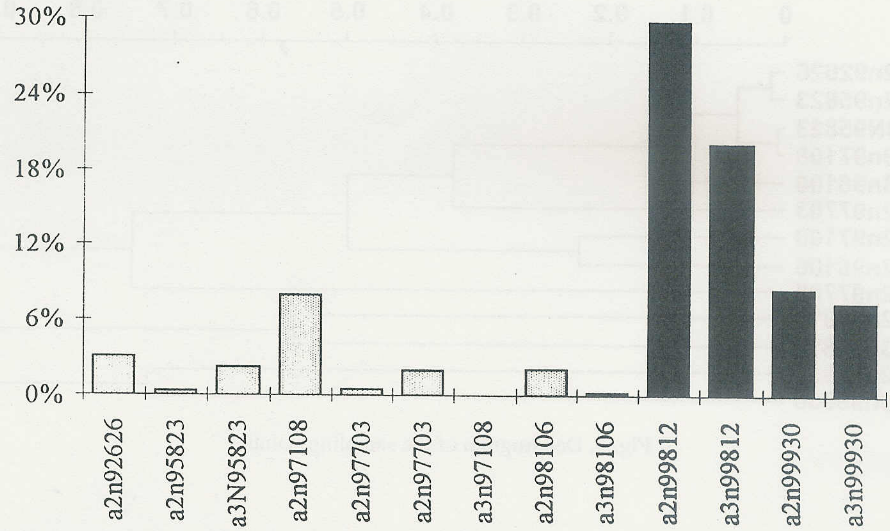

Fig. 6. Changes of relative abundance of *Cocconeis placentula* between 1992 and 1999. The samples collected in 1999 are black.

The changes between 1999 and the earlier years can easily be followed by the relative abundance of the dominant taxa. The dominant species of the nineties was *Achnanthes minutissima*. Its relative abundance decreased in 1999 (Fig. 5). The

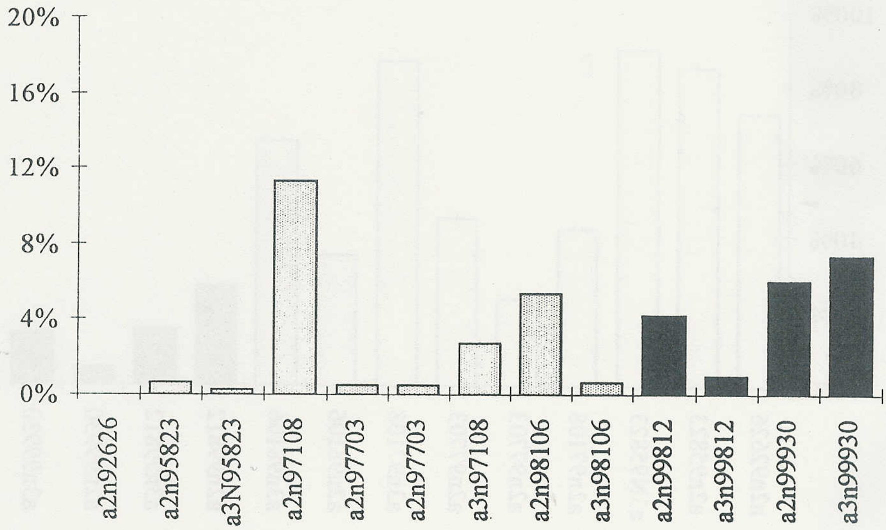

Fig. 7. Changes of relative abundance of *Amphora pediculus* between 1992 and 1999. The samples collected in 1999 are black.

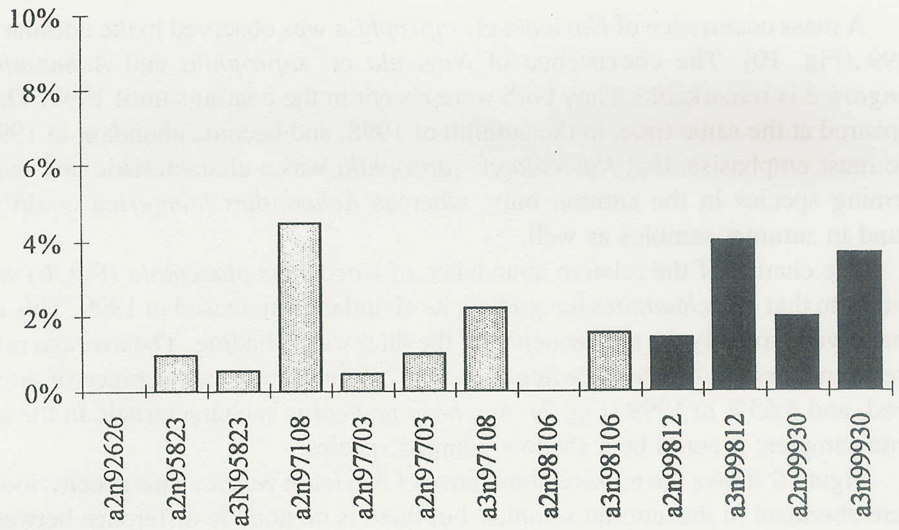

Fig. 8. Changes of relative abundance of *Navicula veneta* between 1992 and 1999. The samples collected in 1999 are black.

abundance of this small diatom usually was higher than 50% between 1992 and 1998. In 1999 its contribution became less than 30%.

Parallel with the decrease of *Achnanthes minutissima*, the relative abundance of *A. hungarica* has increased (Fig. 9).

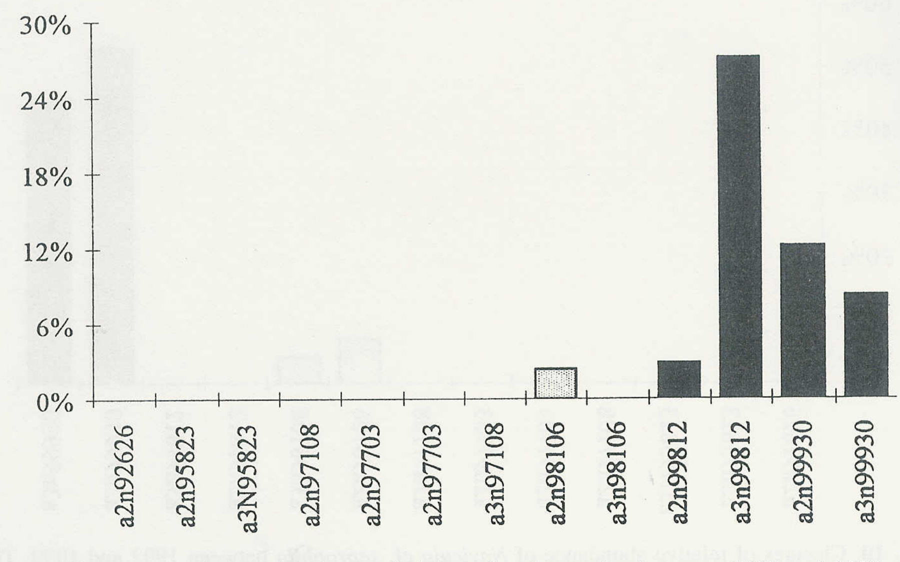

Fig. 9. Changes of relative abundance of *Achnanthes hungarica* between 1992 and 1999. The samples collected in 1999 are black.

A mass occurrence of *Navicula* cf. *saprophila* was observed in the autumn of 1999 (Fig. 10). The coexistence of *Navicula* cf. *saprophila* and *Achnanthes hungarica* is remarkable. They both were absent in the coatings until 1997. They appeared at the same time, in the autumn of 1998, and became abundant in 1999. We must emphasise, that *Navicula* cf. *saprophila* was a characteristic and mass forming species in the autumn only, whereas *Achnanthes hungarica* could be found in summer samples as well.

The change of the relative abundance of *Cocconeis placentula* (Fig. 6) was similar to that of *Achnanthes hungarica*; its abundance increased in 1999. This increase was probably the consequence of the duckweed shading. The average relative abundance of *Amphora pediculus* was 2.73% before the appearance of duckweed, and 4.65% in 1999 (Fig. 7). *Amphora pediculus* is characteristic in the autumn samples; it could be a shadow-adapted species.

Figure 8 shows the relative abundance of *Navicula veneta*. This species looks more abundant in the autumn samples, but there is no notable difference between before and after the invasion of duckweeds.

Algal mats

In the beginning of the biomonitoring we paid no special attention to algal mats. During the collecting trips the mass of filamentous algae was so eye-catching

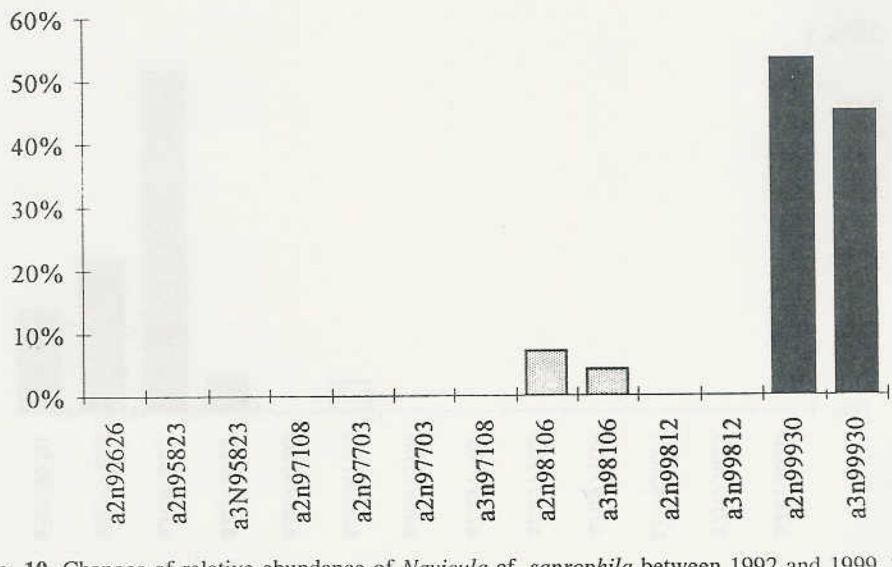

Fig. 10. Changes of relative abundance of *Navicula* cf. *saprophila* between 1992 and 1999. The samples collected in 1999 are black.

that in 1996 we began to collect them. Unfortunately only 1 sample was collected in 1996, 3 in 1998 and 2 in 1999 in that arm.

Altogether 57 diatom taxa were recorded in these 6 samples. Among them 4 (namely *Amphora lybica*, *Navicula lenzii*, *Surirella ovalis*, *Navicula halophila*) were found only in mats. *Achnanthes minutissima* was the dominant species as in the periphyton, its contribution in the total number of algae was more than 40%, in the autumn of 1998 it exceeded 80% (Fig. 11).

The second most abundant species was *Amphora veneta* in mats. It is interesting, because this taxon is usually absent or has a very limited presence in periphyton samples. However, it looks characteristic in the mats.

One of the main problems we faced in our biomonitoring studies, that we have no sufficient data for the comparison of the conditions before and after the diversion of the Danube. Before the dramatic changes caused by the diversion only sporadic collections were made in the region. We managed to find only one paper (HALÁSZ 1937) to compare our data on algal mats. Halász worked in a side arm of the Danube at Soroksár, and investigated the diatoms on *Cladophora*. She mentioned 11 taxa as abundant or very abundant. SZEMES (1967) affirmed that these taxa were dominant there for decades. (The only exception was *Gomphonema augur*, which was very abundant according to Halász, while Szemes mentioned it as a rare taxon.) *Diatoma vulgare* and *Rhoicosphaenia abbreviata* were abundant and constant also in our algal mat samples, *i.e.* only 2 of Halász's 11 taxa.

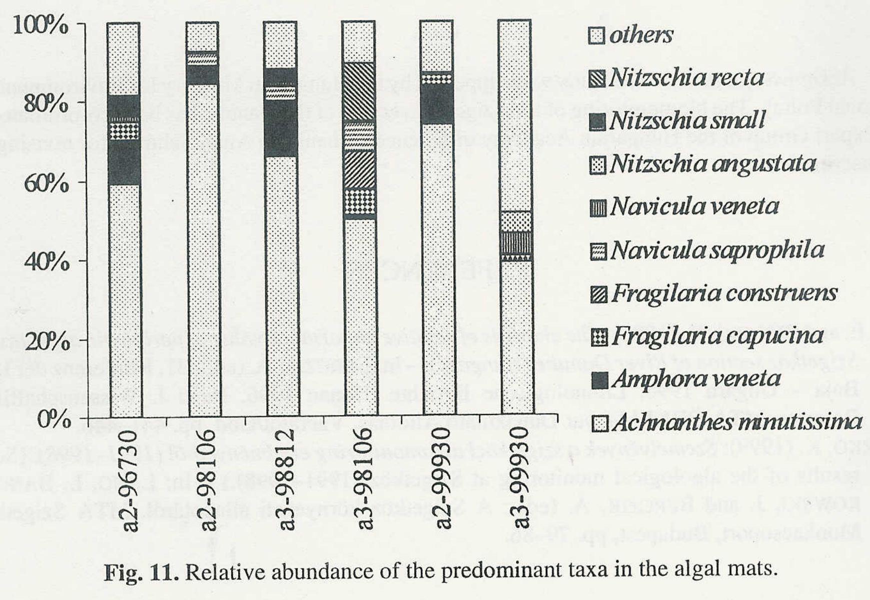

Fig. 11. Relative abundance of the predominant taxa in the algal mats.

About the effect of duckweed invasion

Duckweed often form dense homogeneous mats on the water surface all over Hungary. We failed to find any Hungarian publication about the attached algae on duckweed. It is not too surprising, because the study of periphyton is usually neglected, perhaps partly due to methodological problems.

In the case of small plants like duckweed the collection of periphyton is more difficult and the application of usual methods (scraping or brushing the coatings) is impossible. We have not found reports on attached algae living under the duckweed carpet either.

GOLDSBOROUGH (1993) studied the diatoms living on common duckweed (*Lemna minor*) in Canada. In spite of the geographical distance he also found *Achnanthes hungarica* as a dominant taxon from midsummer to autumn. He established that *Achnanthes hungarica* was found in more than 90% on the air/water boundary (GOLDSBOROUGH 1993).

It would be hard to know whether the occurrence of *Achnanthes hungarica* (and maybe *Navicula* cf. *saprophila*) is connected with the presence and density of duckweed. We know a reference of Hustedt who in the beginning of the 20th century commented on the occurrence of *A. hungarica* as "anscheinend mit Vorliebe an Lemna" (HUSTEDT 1930). It would also be interesting to explore other water bodies in Hungary and see if duckweed and their algal epiphytes coexist or not. We plan further study in different rivers and lakes in Hungary, where duckweed is common and to study the diatoms living on them.

* * *

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