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Investigation of periphytic algae in the Danube at Göd (1669 river km, Hungary)

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With 8 figures and 1 table in the text

Abstract: The periphyton of the Danube at Göd (near Budapest) was studied on artificial substrate in the growing season. The abundance of periphyton depends significantly on the position (direction) of the substrate. In 1985–86 we used matt-glass tubes as substrates, fixed perpendicularly to the water surface. This way we assured the most optimal position ("all" directions) for the colonization of periphytic algae. In our qualitative investigation we found 126 algal taxa from 5 phyla. The average number of algae was 2 million ind./cm^2. Diatoms represented the greatest number. The number of cyanophytes and chlorophytes was higher in the summer than in other periods. The diversity was higher at the beginning of the colonisation and the species number was greater in the low water period. Towards autumn the species composition became more or less unchanged. We have found 7 constant and dominant taxa, all from the Pennales. The colonization process and seasonal dynamics were similar for 6 taxa also from Pennales.

We showed by cluster analysis that the similarity of samples are determined by the seasonality, though in 1985 the samples of the flood periods formed a separate group.

Key words: Danube, periphyton, species composition, quantitative analysis, similarity, artificial substrate, substrate direction, constancy, dominancy, diversity.

PDC*: SS 05, 28; ST 091; EC 01, 033, 08; EH 03; EB 072; EP 024; GC 11, 14; ME 01, 02, 08, 09, 19.

Introduction

Periphyton of large rivers are much less known than their phytoplankton. It is especially true for the quantitative aspects of research. The main reason for it might be that the phytoplankton is more important in terms of primary production. Furthermore methodology of phytoplankton investigation is much simpler.

Ertl & Tomajka (1973) pointed out the importance of periphyton in the life of the Danube. In other studies periphyton proved to be a useful parameter in water-

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quality monitoring (Patrick 1973). Analysis of chlorophyll *a* content of periphyton is a more sensitive method for following the eutrophication process, than the detection of physical-chemical parameters (Heinonen 1984).

Periphyton research in the Hungarian section of the Danube has a long history. Istvánffi (1981) studied the effect of the thermal springs on the species composition of the periphyton at Budapest. Halász (1936, 1937) studied the periphyton of the litoral region and Palik (1961) the periphyton of the concrete buildings in the Soroksár arm of the Danube. Szemes (1961) and Tamás (1964, 1966) collected samples from pontoons and besides species composition, they provide some quantitative data as well.

Backhaus (1967) published data on the periphyton at the river head of the Danube. The Austrian section of the river was studied by Cholnoky (1955), Fetzmann (1963) and Bursik (1964). On the Slovakian stretch of the Danube Juriš (1973) carried out a quantitative analysis study of the periphyton of slides, Ertl et al. (1972) investigated the seasonal change of biomass and chlorophyll *a* content, and Ertl & Tomajka (1973) primary production. The periphyton of the lower reach of the Danube is known from Vladimirova's works (1961 a, b), Serbanescu (1963), Oltean (1968, 1969, 1970a, b, 1971) and Rudescu et al. (1970) studied the periphyton of the reeds of the Danube delta.

When studying the periphyton of rivers there are many problems that have to be solved either it is a study of natural or artificial substrate, or quantitative or qualitative aspect of research. Actually the sampling method for quantitative analysis of periphyton of big rivers growing on artificial substrate is not worked out in detail yet.

In our study we wanted to work out a sampling method that would be useful for the reliable quantitative analysis of periphytic algae of large rivers. Meanwhile we wanted to get data about seasonal dynamics, constancy-dominancy relations of the periphyton of the Danube at Göd. This sampling method can also be used for chlorophyll studies and estimating primary productivity.

Material and methods

The similarity and difference between natural and artificial substrates had been studied by several investigators (Lowe & Gale 1980, Castenholz 1961, Sládečková 1962, Schwoerbel 1966, etc.). In the historical outlines of periphyton investigation Wetzel (1979) writes that the periphyton on artificial substrate is very similar to the periphyton on natural substrate, although it is not a fully accepted fact. Sládečková (1962) pointed out the difficulties in collecting from natural substrates, and the advantage of using artificial ones.

For the same reason we used artificial substrate, which we positioned to the stream line side of a pontoon 1669 river km of the Danube, protected from flotsam.

It was made of glass, at this is the most similar material to the natural basesment of the Danube, the quartz pebbles.

BACKHAUS worn us in his work (1967) that the direction of the substrate is very important in respect of species composition. Therefore we carried out an experiment in 1984 to analyze the connection between the substrate directions and the number of algae. We put 2-2 slides in a frame according to the well known method (SLÁDEČKOVÁ 1962, SCHWOERBEL 1966). An important change from the original method was that the slides were matted by blowing sand on one side of them. The roughened surface resembles the natural one more. The matt side of the slides were put in 4 different directions to the water flow (Fig. 1).

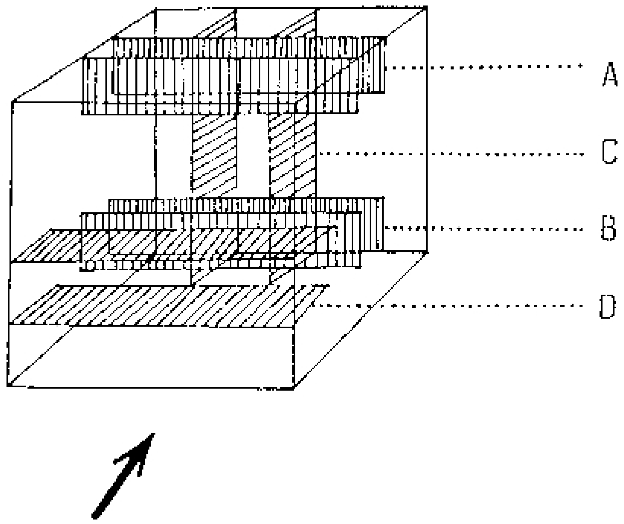

Fig. 1 The frame and slides that were used to study the connection between flow direction of the substrates. Arrow shows the direction of stream flow-regime (A, B, C, D in the text).

MEIER et al. (1983) suggested the use of glass tubes instead of slides, because the variability of data would be smaller. So we repeated our experiment in 1985 and 1986 with glass tubes (diameter 10 mm), the surface of which were matted. We put the tubes vertically in the frame leaving 5 cm between them. There was 5 cm^2 suitable surface area on each tube for colonization. The remaining area was covered with plastic tape that was removed when samples were taken. The tubes were placed 10 cm below the water surface. The tubes were put in on 21st May 1985, and 20th May 1986. Samples were taken weekly till November. The periphyton was washed of with a fine brush with known amount of water. After that the samples were handled as if they were plankton samples. Algae were identified under light and electron microscope, counted by UTERMÖHL's (1958) method taking the statistical results of LUND et al. (1958) into consideration. Samples were fixed with LUGOL solution. Diatoms were identified in light microscope after digested with H_2O_2, and mounted by Pleurax. Electron microscopic investigations (SEM, TEM) were described in an earlier paper (Kiss 1986).

The constancy of the species *(i)* was calculated as – C_i = 100 N_i/S – where N_i = number of samples in which the species *(i)* was present, and S = number of all samples. A species was given constancy value 5 if C = 80–100%, 4 if C = 60–80%, etc.

The dominancy value of a species *(i)* was calculated as – D_i = 100.A_i/M – where A_i = number of individuals of the species *(i)*, M = number of individuals of all species in a sample.

When calculating the dominancy curves, we considered those species dominant which had at least in one sample a relative abundance of 5% (Schildmacher 1982).

For the cluster analysis we used the Syn-tax III program (Podani 1988), using the function described by Czekanowski (1909).

Results

We put the slides in different directions (two slides in the same position – X_1, X_2) the water flow in September 1984, and exposed them for 25 days. The ones perpendicular to the water flow (both towards (A) and backwards (B)) had one order of magnitude more individuals than the ones standing parallel to the water flow (C). the smallest number we got when the slides were placed horizontally matt-side up (D):

	A	B	C	D
X_1 [ind./mm^2]	26528	20849	4392	394
X_2 [ind./mm^2]	21110	18928	3091	451
X [ind./mm^2]	23819	19888	3741	422
s	3831	1358	920	40

(X = average of X_1 and X_2, s = standard deviation).

Fig. 2 Distribution of taxa.

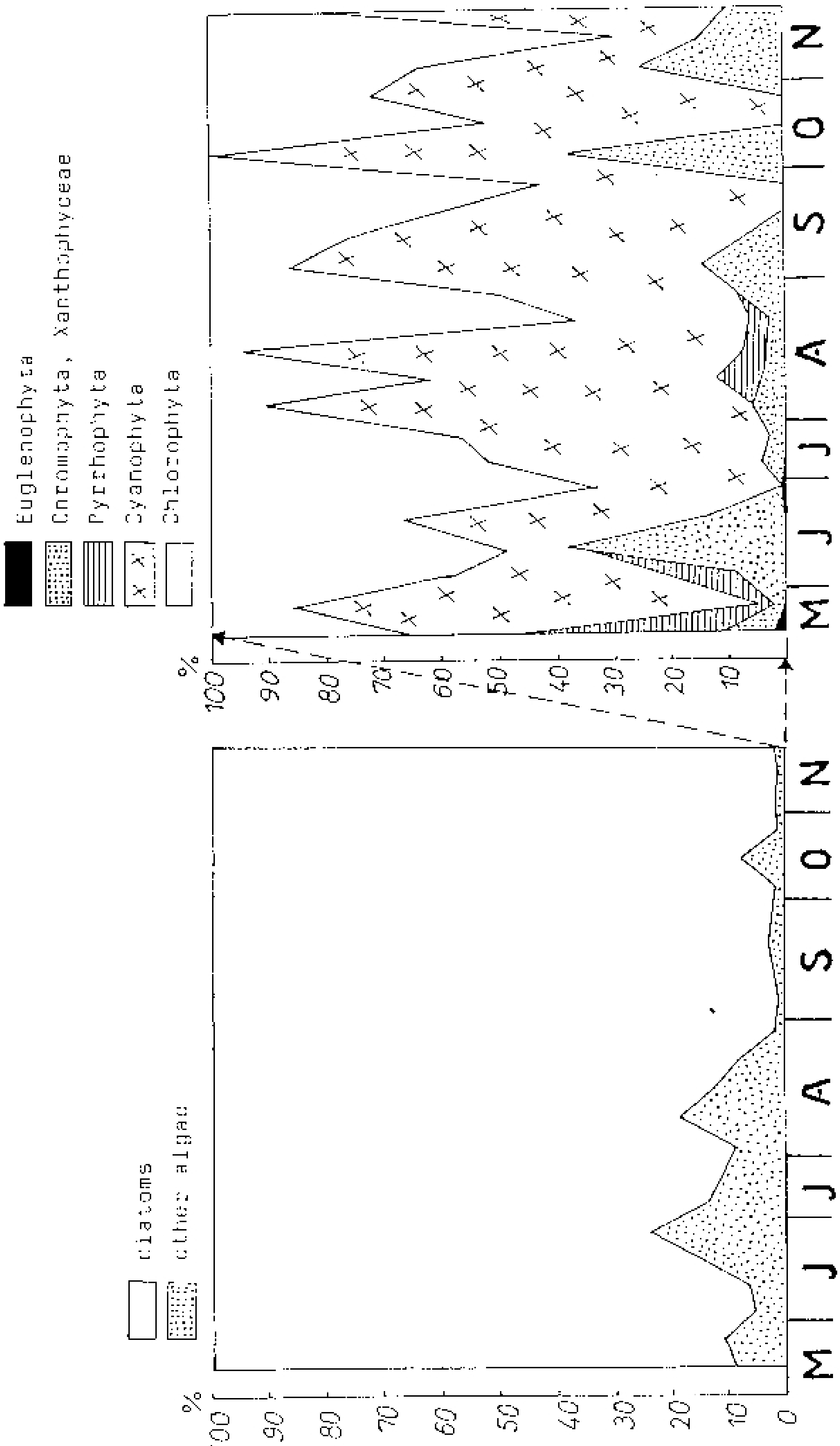

Fig. 3 Proportional distribution of phyla or classes in the samples in 1985.

Table 1. List of taxa from 1985 and 1986, constancy (C) and dominancy (D) of some species. + marks taxa that are new in the periphyton of the Danube.

Taxa	1985	1986	C 1985	C 1986	D% 1985 06.21	D% 1985 08.12	D% 1985 10.28	D% 1986 06.18	D% 1986 08.19	D% 1986 10.7
Aphanocapsa sp.	+	–	–	–	–	–	–	–	–	–
Lyngbya epiphytica Hieron.	+	+	1	1	–	–	–	–	–	–
L. hyeronymusii Lemm.	+	–	1	–	–	–	–	–	–	–
L. kützingii Schmidle	+	+	2	2	–	8.3	–	–	0.28	0.23
L. limnetica Lemm.	+	+	5	4	7.0	1.2	0.5	1.56	–	–
L. ochracea (Kg.) Thur.	+	–	3	–	–	1.8	0.5	–	–	–
L. sp	+	–	–	–	–	–	–	–	–	–
Merismopedia punctata Mey.	+	–	1	–	–	0.2	–	–	–	–
Oscillatoria irrigua (Kg.) Gom.	+	–	1	–	–	–	–	–	–	–
O. sp.	+	–	1	–	–	–	0.2	–	–	–
Phormidium luridum (Kg.) Gom.	+	–	3	–	–	–	–	–	–	–
Spirulina laxissima G. S. West	+	+	1	1	–	–	–	–	–	–
Euglena acus Ehr.	+	+	–	1	–	–	–	–	–	–
E. sp.	+	–	–	–	–	–	–	–	–	–
Phacus longicauda var. *tortus* Lemm.	+	–	1	–	–	–	–	–	–	–
Ph. sp.	+	–	1	–	–	–	–	–	–	–
Mallomonas tonsurata Teiling et Krieger+	+	–	1	–	–	–	–	–	–	–
Synura glabra (Korš.) Huber-Pest.+	+	–	1	–	–	–	–	–	–	–
S. petersenii Korš.+	+	–	1	–	–	–	–	–	–	–
Characiopsis sp.	+	–	–	–	–	–	–	–	–	–
Ellipsoidion sp.	+	+	5	2	2.0	0.5	–	–	–	–
Goniochloris mutica (A. Braun) Fott	+	+	1	1	–	–	–	–	–	–
Cyclotella atomus Hust.+	+	+	2	3	–	–	–	–	0.83	0.23
C. caspia Grun.+	+	–	1	–	–	–	–	–	–	–
C. comta (Ehr.) Kütz.	+	+	1	2	–	–	–	–	–	0.23
C. cryptica Rei., Lew. et Guill.+	+	+	2	5	–	–	–	0.67	1.38	0.70
C. meneghiniana Kütz.	+	+	2	4	–	–	0.2	0.22	0.55	0.23
C. pseudostelligera Hust.	+	+	3	4	–	–	0.2	1.34	1.65	–

C. stelligera CLEVE et GRUN.	+	–	–	–	–	–	–	–	–	–
Cyclostephanos dubius (FRICKE) ROUND+	+	+	3	5	–	–	0.2	1.12	1.10	0.23
C. invisitatus (HOHN et HELL.) THER., STOERM. et HÅK.+	+	+	3	5	–	–	0.2	0.67	1.65	0.47
Melosira granulata (EHR.) RALFS	+	–	–	–	–	–	–	–	–	–
M. granulata var. *angustissima* (GRUN.) SIM.	+	+	1	2	–	–	–	–	0.28	0.23
M. varians AG.	+	+	2	1	–	–	0.2	–	–	0.23
Skeletonema potamos (WEBER) HASLE+	+	+	2	4	0.2	–	0.2	–	2.75	0.47
Stephanodiscus alpinus HUST.	+	–	1	–	–	–	–	–	–	–
S. binderanus (KÜTZ) KRIEG.	+	+	1	1	–	–	–	–	1.10	–
S. hantzschii GRUN. f. *hantzschii*	+	+	3	3	–	0.4	0.2	–	0.28	–
S. hantzschii f. *tenuis* (HUST.) HÅK. et STOER.	+	+	4	4	–	–	0.5	0.22	1.10	2.11
S. macarovae GENKAL+ *makarovae*	+	–	–	–	–	–	–	–	–	–
S. perforatus GENKAL et KUZMIN+	+	+	3	4	–	0.2	–	0.22	0.55	–
Thalassiosira guillardii HASLE+	+	+	1	2	–	–	–	0.22	–	–
Th. pseudonana HASLE et HEIMD.+		+	5	5	0.2	0.1	0.2	0.45	1.10	0.23
Th. weissflogii (GRUN.) G. FRY. et HASLE+	+	+	1	1	–	–	0.2	–	–	–
Achnanthes affinis GRUN.	+	–	2	–	–	–	–	–	–	–
A. biasolettiana (KÜTZ.) GRUN.+	+	+	2	1	–	0.7	–	–	1.65	–
A. lanceolata (BRÉB.) GRUN.	+	+	5	4	7.8	4.1	0.9	1.79	0.83	–
A. lanceolata var. *rostrata* HUST.+	+	–	–	–	–	–	–	–	–	–
A. minutissima KÜTZ.	+	+	4	5	0.7	4.1	1.8	7.14	4.13	3.76
Amphora pediculus (KÜTZ.) GRUN.	+	+	5	5	11.3	9.9	47.4	8.04	34.71	19.72
Asterionella formosa HASS.	+	+	2	1	–	–	0.9	–	–	–
Ceratoneis arcus (EHR.) KÜTZ.	–	+	–	–	–	–	–	–	–	–
Cocconeis pediculus EHR.	+	+	1	1	–	–	–	–	–	–
C. placentula EHR.	+	+	5	5	1.7	4.8	3.6	3.57	8.26	10.33
Cymatopleura solea (BRÉB.) W. SMITH	+	+	1	–	–	–	–	–	–	–
Cymbella affinis KÜTZ.	+	–	–	–	–	–	–	–	–	–
C. gracilis (EHR.) KÜTZ.+	+	–	–	–	–	–	–	–	–	–
C. leptoceros (EHR.) KÜTZ.+	+	–	1	–	–	–	–	–	–	–
C. minuta HILSE	+	+	3	2	0.7	0.7	0.9	3.57	–	–
C. sinuata GREG.+	+	+	5	5	20.5	4.8	3.6	1.79	3.31	12.21

Table 1. (continued).

Taxa	1985	1986	C 1985	C 1986	D% 1985 06.21	D% 1985 08.12	D% 1985 10.28	D% 1986 06.18	D% 1986 08.19	D% 1986 10.7
Diatoma elongatum (Lyngb.) Ag.	+	–	1	–	–	–	–	–	–	–
D. hiemale (Lyngb.) Heiberg	+	+	1	1	–	–	–	–	–	–
D. vulgare Bory	+	+	4	3	0.7	–	0.9	0.89	–	4.69
Fragilaria brevistriata Grun.	+	+	1	1	–	–	0.9	–	–	–
F. capucina var. *vaucheriae* (Kütz.) Lange-Bert.	+	+	2	1	–	0.7	0.9	–	–	–
F. pinnata Ehr.	+	+	1	1	–	–	–	–	0.83	–
F. ulna (Nitzsch.) Lange-Bert.	+	+	2	2	–	–	–	0.89	–	–
F. ulna var. *acus* (Kütz.) Lange-Bert.	+	+	1	1	–	–	0.9	–	–	–
F. ulna var. *acus* forma *angustissima* (Kütz.) Lange-Bert.	+	–	1	–	–	–	–	–	–	–
F. ulna var. *oxyrhynchus* (Kütz.) Lange-Bert.	+	+	2	1	–	–	–	–	–	–
Gomphonema angustatum (Kütz.) Rabenh.	+	+	4	2	0.7	0.7	0.9	2.68	–	–
G. angustum Ag.	+	+	1	–	–	–	–	–	–	–
G. olivaceum (Horn.) Bréb.	+	+	4	2	0.7	0.7	0.9	–	–	–
G. olivaceum var. *calcareum* (Cleve) Cleve	+	–	1	–	–	–	–	–	–	–
G. parvulum (Kütz.) Kütz.	+	+	2	3	–	–	–	1.79	–	–
Meridion circulare Ag.	+	–	1	–	–	–	–	–	–	–
Navicula capitata Ehr. var. *capitata*	+	+	1	1	–	–	–	–	–	–
N. gregaria Donkin	+	+	3	1	–	6.0	0.9	–	–	–
N. lanceolata (Ag.) Ehr.	+	+	4	3	–	0.7	0.9	2.68	–	–
N. menisculus Schum.	+	+	5	5	–	0.7	0.9	3.57	0.83	0.94
N. minima Grun.	+	+	5	3	1.7	4.1	6.6	–	–	–
N. saprophila Lange-Bert.	+	+	5	4	9.5	1.9	0.7	2.68	0.83	–
N. subminuscula Manguin+	+	+	5	5	20.5	2.9	2.9	2.68	2.48	–
N. tripunctata (O. F. Müll.) Bory	+	+	3	3	0.7	–	–	0.89	–	4.69
Nitzschia acicularis W. Smith	+	+	3	2	–	–	0.9	0.89	–	–
N. actinastroides (Lemm.) van Goor	+	–	2	–	0.7	–	0.9	–	–	–
N. dissipata (Kütz.) Grun.	+	+	4	3	–	–	0.9	0.89	–	3.76

N. inconspicua GRUN.$^{+}$	–	+	1	5	0.7	–	–	2.68	3.31	1.88
N. palea (KÜTZ.) W. SMITH	+	–	3	–	–	–	–	–	–	–
N. palea var. *debilis* (KÜTZ.) GRUN.$^{+}$	+	+	2	2	–	–	–	1.79	–	0.94
N. palea var. *tenuirostris* GRUN.$^{-}$	+	+	1	3	–	–	1.8	0.89	–	–
N. romana GRUN.	+	+	5	5	5.2	8.2	3.1	5.36	7.44	24.41
Pinnularia viridis (NITZSCH) EHR.	–	–	1	–	–	–	–	–	–	–
Rhoicosphenia abbreviata (KÜTZ.) GRUN.	+	+	5	5	1.7	30.5	9.3	32.14	14.88	6.57
Stauroneis phoenicenteron (NITZSCH) EHR.	+	–	1	–	–	–	0.9	–	–	–
Surirella ovata KÜTZ.	+	+	2	1	–	0.7	–	–	–	–
Cryptomonas ovata EHR.	–	–	2	–	–	0.5	–	–	–	–
Characium sp. 1	+	+	4	3	3.5	0.2	–	–	0.83	–
Characium sp. 2	–	+	–	1	–	–	–	–	–	–
Chlamydomonas reinhardtii DANG.	+	+	4	3	–	0.2	0.2	2.01	0.55	–
Chlorococcales sp.	+	–	1	–	–	–	–	–	–	–
Cladophora fracta (DILLW.) KÜTZ.	+	–	1	–	–	–	–	–	–	–
C. glomerata (L.) KÜTZ.	+	–	2	1	–	–	–	–	–	–
Coelastrum microporum NÄG. in A. BR.	–	+	–	1	–	–	–	–	–	–
Crucigenia quadrata MORR.	+	–	1	–	–	–	–	–	–	–
C. tetrapedia (KIRCH.) W. et G. S. WEST	+	+	1	1	–	–	–	–	–	–
Dictyosphaerium pulchellum WOOD.	–	–	–	1	–	–	–	–	0.28	–
Gonglosira debaryana RAB.	+	+	1	2	–	–	–	–	–	0.23
Hydrianum gracile KORŠ.	–	+	–	1	–	–	–	–	–	–
H. viride (SCHERFF.) ETTL.$^{-}$	+	–	1	–	–	–	–	–	–	–
Kirchneriella contorta (SCHMIDLE) BOHL.	–	–	–	1	–	–	–	–	–	–
Monoraphidium arcuatum (KORŠ.) HIND.	+	–	1	–	–	–	–	–	–	–
M. contortum (THUR.) KOM.-LEGN.	+	+	1	1	–	–	–	–	–	–
Oedogonium sp.	+	–	1	–	–	–	–	–	–	–
Phytomonadina sp.	+	–	1	–	–	0.2	–	–	–	–
Scenedesmus acuminatus (LAGH.) CHOD.	–	+	–	1	–	–	–	–	–	–
S. acutus MEYEN	–	+	–	1	–	–	–	–	–	–
S. bicaudatus (HANSG.) CHOD.	–	+	–	1	–	–	–	–	–	–
S. ecornis (EHR.) CHOD.	+	–	–	1	–	–	–	–	–	–
S. quadricauda (TURP.) BRÉB. sensu CHOD.	+	+	1	1	–	–	–	–	0.28	–

Table 1. (continued).

Taxa	1985	1986	C 1985	C 1986	D% 1985 06.21	D% 1985 08.12	D% 1985 10.28	D% 1986 06.18	D% 1986 08.19	D% 1986 10.7
S. spinosus CHOD.	–	+	–	1	–	–	–	–	–	–
Schroederia setigera (SCHRÖD.) LEMM.	+	–	1	1	–	–	–	–	–	–
Stigeoclonium tenue KÜTZ.	+	–	4	4	0.5	–	0.2	1.12	–	0.23
Tetrastrum glabrum (ROLL.) AHLSTR. et TIFF.	+	+	1	2	0.2	–	–	0.89	–	–
Ulothrix zonata KÜTZ.	+	+	1	1	–	–	–	–	–	–
Cosmarium lanceolatum KG.	–	–	1	–	–	–	–	–	–	–

Because of this considerable difference we decided to use matted glass tubes instead. In this investigation we have found 126 taxa belonging to 5 phyla. Among the taxa 24 is new to the Danube periphyton (Table 1). The constancy and dominancy values of some typical samples are given in Table 1. There were 2 taxa that are new in the Hungarian algal-flora: *Navicula subminuscula*, *Synura glabra*. Most taxa were found from Pennales, the least from Pyrrhophyta (Fig. 2).

Diatoms were in the largest number in every sample (Fig. 3). Non-diatoms were found in the greatest number in the summer months, although it still did not reach the number of diatoms. Species from Euglenophyta were present in a small number and only in the beginning of colonization.

Minimum number of algae in 1985 – 0.01×10^6, 1986 – 0.45×10^6. Maximum number of algae in 1985 – 5.84×10^6, 1986 – 7.16×10^6. Average number in 1985 – 2.16×10^6 ind./cm^2, 1986 – 2.72×10^6 ind./cm^2 (Figs. 4, 5). In 1985 the first increase of algae was noticed at the end of June, and in 1986 at the beginning of June. The maximum number was reached in early August in both years. The values for diversity and evenness were higher at the beginning of colonization in both years (Fig. 6). The number of species was higher when the water level was low, and it got stabilized in the autumn in both years.

49% of taxa had a constancy value 1 in 1985, and 43% in 1986, 22% of taxa had constancy value 4 or 5 in 1985, and 27% in 1986.

These latter can be considered as permanent elements of the periphyton. As it can be seen from the list below, there are 7 species (*) among the 9 dominant species that are constant. (Constancy values 4 or 5). All of the dominant species and most of the constant species are diatoms:

Taxa	Constant	Dominant
	(in both years)	
Lyngbya limnetica	+	
Stephanodiscus hantzscii f. *tenuis*	+	
Thalassiosira pseudonana	+	
Achnanthes lanceolata	+	
*A. minutissima**	+	+
*Amphora pediculus**	+	+
*Cocconeis placentula**	+	+
*Cymbella sinuata**	+	+
Gomphonema angustatum		+
G. olivaceum		+
*Navicula menisculus**	+	+
N. saprophila	+	
N. subminuscula	+	
*Nitzschia romana**	+	+
*Rhoicosphenia abbreviata**	+	+
Stigeoclonium tenue	+	

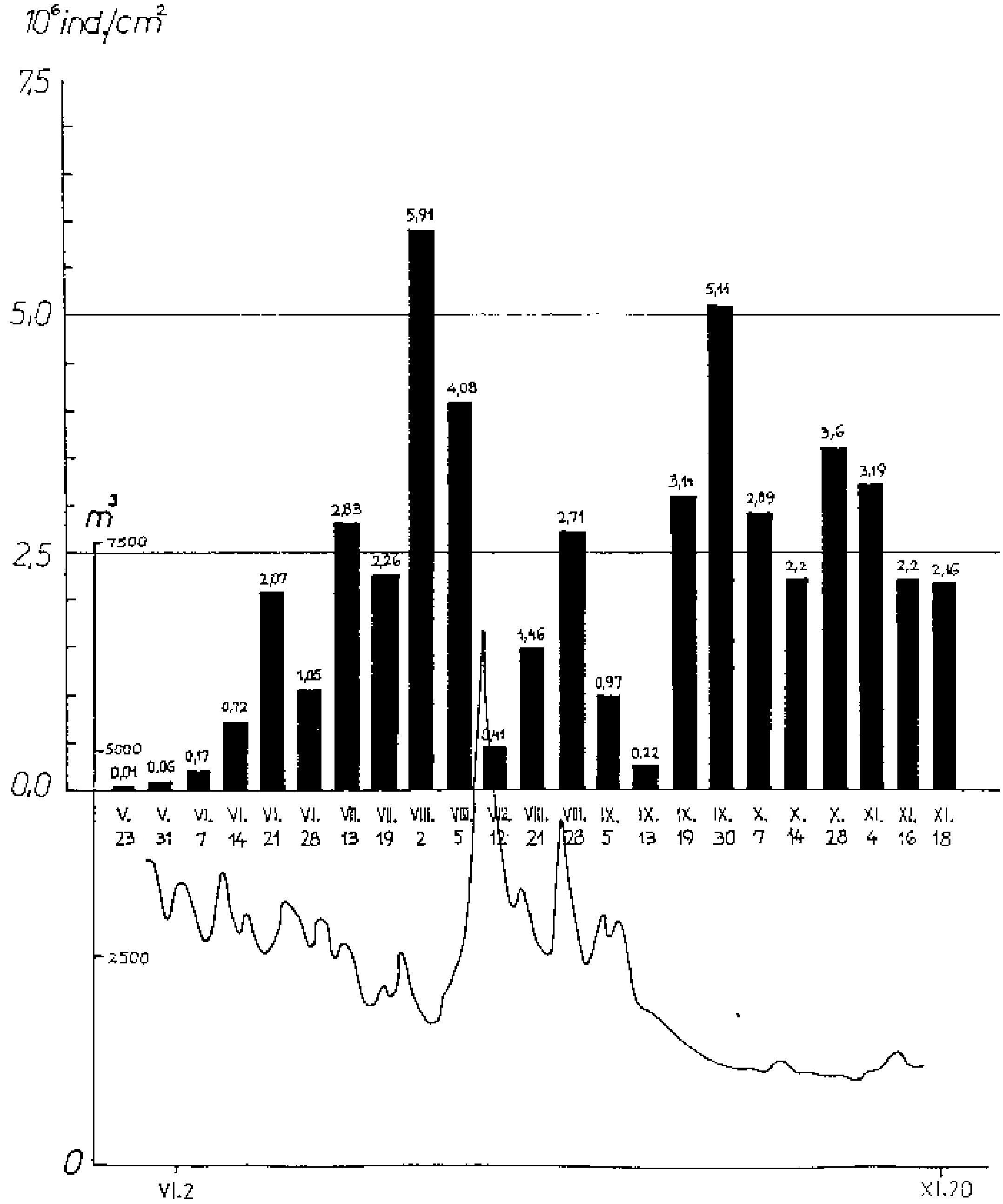

Fig. 4 Abundance values of the 1985 samples, and discharge of the Danube in 1985.

We plotted the relative abundance of the dominant species against time. The curves can be grouped according to their shapes. Several species belonged to the same group in both years (Fig. 7). Using these figures the dominant species can be grouped on the basis of their position in the colonization process. Both *Gomphonema angustatum* and *G. olivaceum* became dominant at the beginning of colonization, then soon disappeared almost completely. *Cymbella sinuata* also became dominant quite quickly, and stayed that way. *Cocconeis placentula* showed

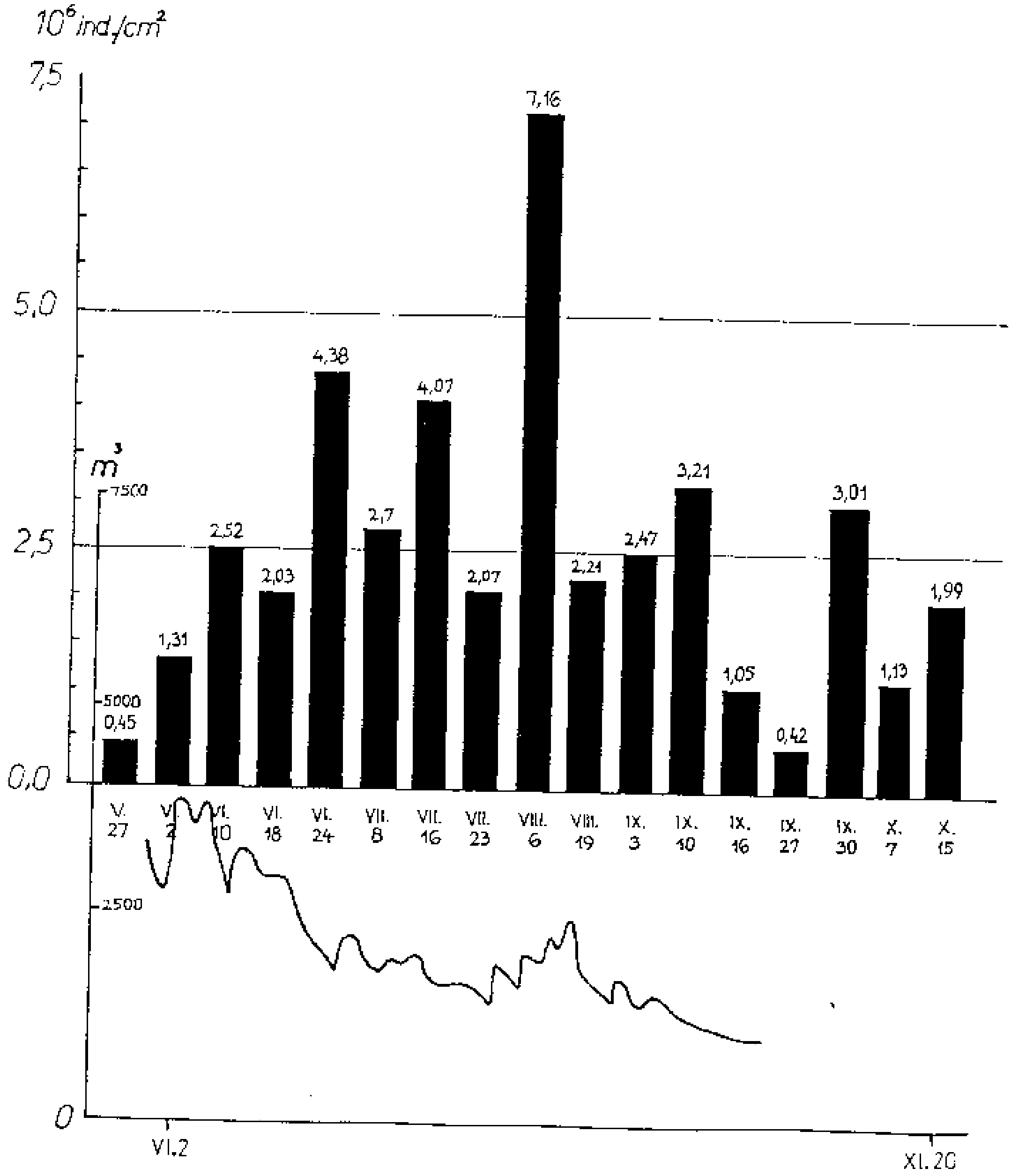

Fig. 5 Abundance values of the 1986 samples, and discharge of the Danube in 1986.

a small peak in the early time of colonization, but became dominant only at the end of August, early autumn in both years. *Amphora pediculus* became dominant in the middle or end of summer and stayed dominant. *Achnanthes minutissima* became dominant in the middle of the summer, but disappeared from the periphyton by the autumn.

In the investigated periods the stream flow-regime was significantly different in the two years (Figs 4, 5). In June and July of 1985 the water discharge was 97% and

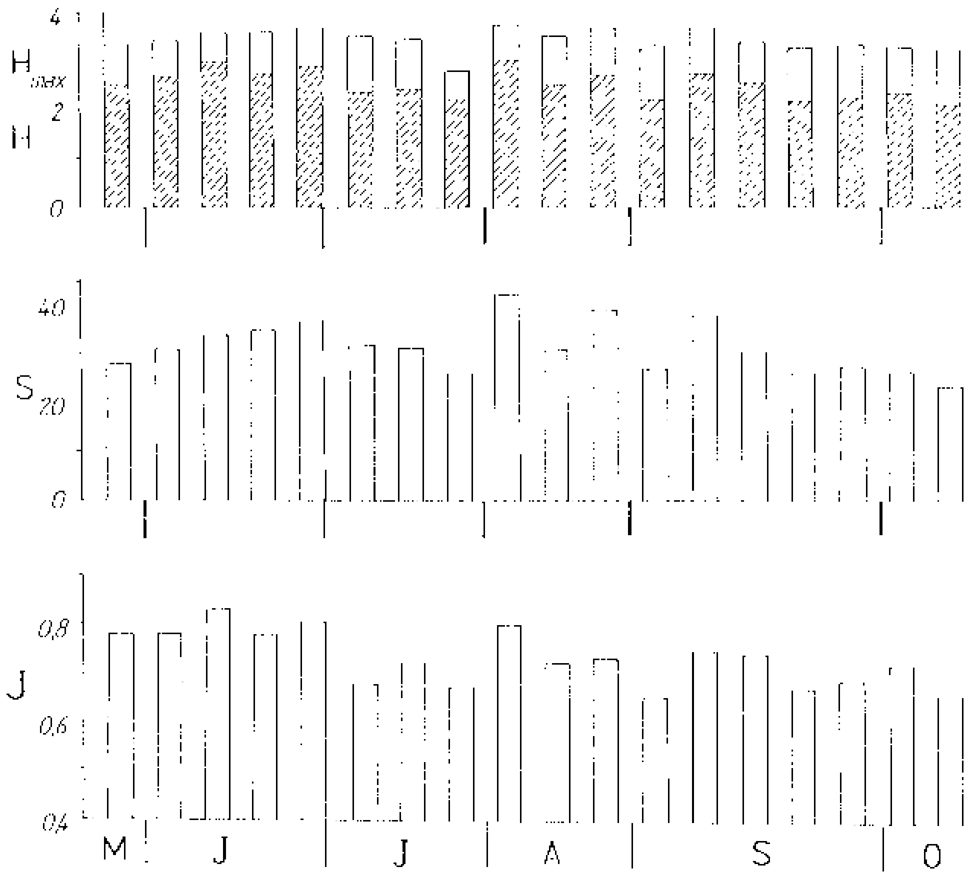

Fig. 6 Diversity (H), its maximum (H_{max}), number of species (S), and evenness (J) of samples from May to October 1986.

84% respectively (compared to the average of the last 30 years). In August it rose to 142% and in September 123%. In 1986 the water discharge was between 71–98% except for June when it was 104%. The average water discharge for May-November was 99% in 1985, and only 84% in 1986. This difference can be seen in the cluster analysis, too (Fig. 8). In 1985 the similarity of the samples depended also on the rate of flow besides the seasonal changes. (Those samples that were taken during the two flood periods can be placed in the same group with the samples from the beginning of the colonization.) In 1986 when the stream flow-regime was more balanced, we have noticed a much stronger seasonal dependence. In both years samples taken at the beginning of the colonization formed a more or less separate group.

Discussion

Backhaus (1967) noticed, based on investigation in the Danube in Germany, that the number of periphyton species depends on the direction of the substrate. Our experiments show that not only the number of species, but the number of individuals is dependent on that. The greatest number we counted when the slides (artificial

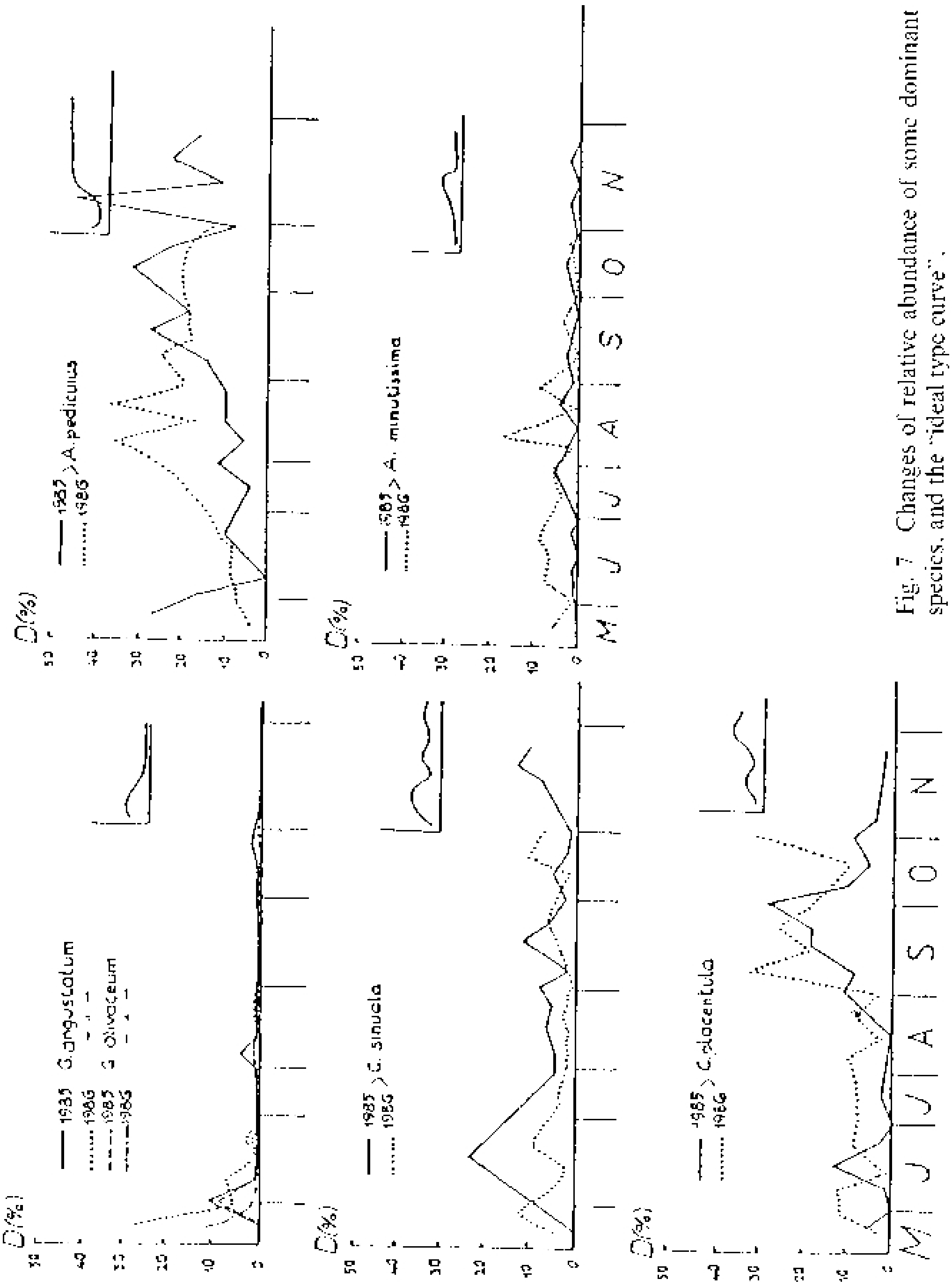

Fig. 7 Changes of relative abundance of some dominant species, and the "ideal type curve".

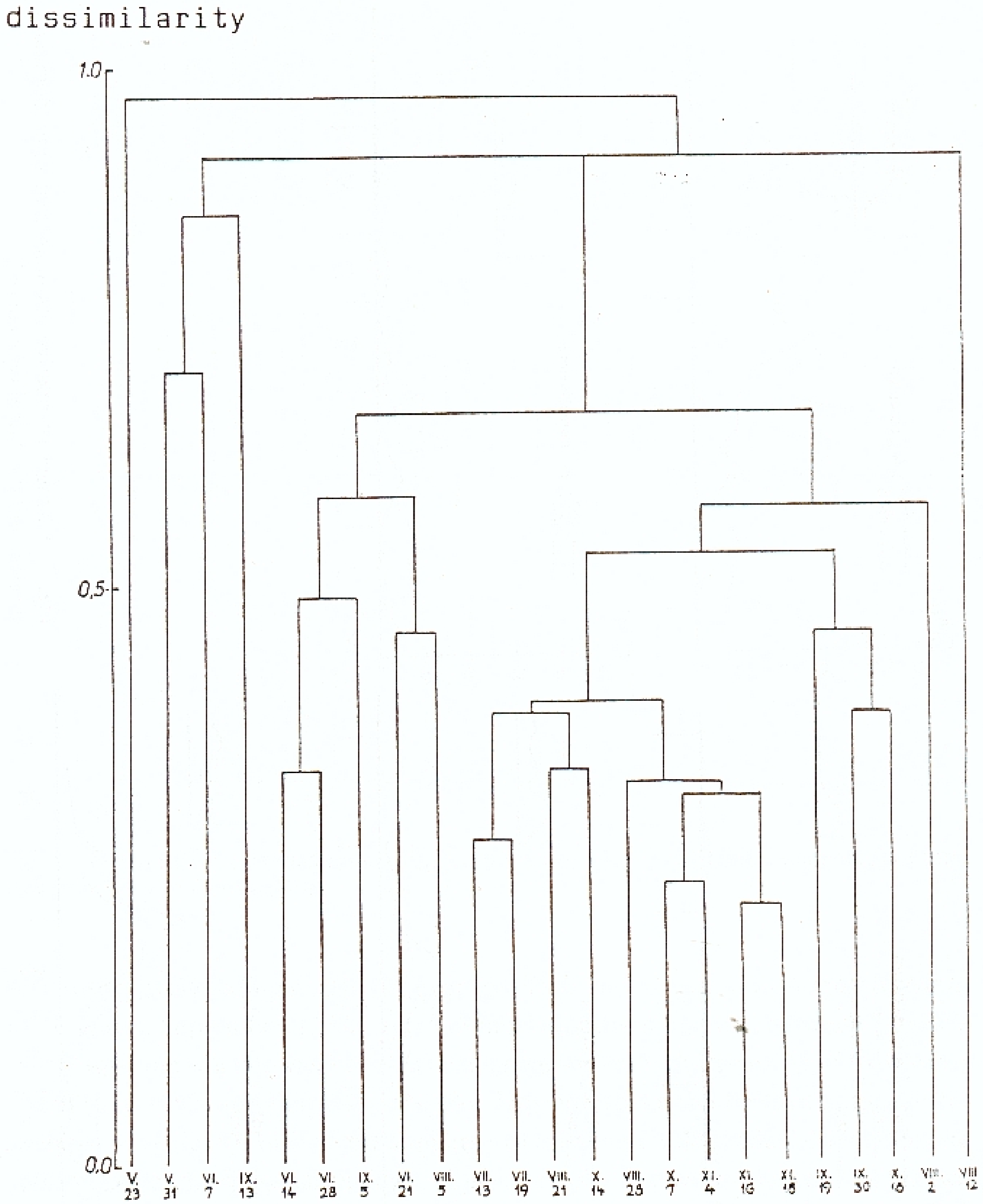

Fig. 8 Dendogram of the 1985 samples based on the CZEKANOWSKI-index.

substrate) was placed perpendicular and backwards to the water flow. The same was observed by CASAUBON (1986) and CASAUBON et al. (1986) who studied the periphyton of the upper, lower, and back sides of stones. They have counted 36 taxa on the back side, while only 16 taxa on the side towards the flow. The number of individuals was one order of magnitude less on the latter. We did not find such a great difference on the two sides. It should be noted that CASAUBON worked with stones 20–30 cm in diameter, while we used slides that were only 2 cm wide. (The bigger the microhabitat for the colonization, on the back of it.) One order of magnitude was the difference in our investigation between slides that were put perpendicular and parallel to the flow-direction, and two orders of magnitude less individuals were found on slides that were placed horizontally into the water. Besides that the quickly moving water washes off algae in this case, the effect of the waves was more significant, too.

The conclusion is that when investigating a river's periphyton composition, it is advisable to use an artificial substrate where colonization can start from every direction (e.g. a tube). We rarely find natural substrate that would have only one side for colonization.

Figure 3 shows the typical periphyton composition of rivers. Most species are diatoms, and they can be found in the highest number too. Similar composition was found e. g. by WATANABE et al. (1988) in small rivers near Toulouse, and by ANTOINE et al. (1985) in the River Wye. They found that green algae are present mainly in the summer samples and may be completely missing in other periods. In the periphyton of the Danube the number of green algae was higher in the summer too. Species from the Euglenophyta were present only at the beginning of colonization in both years.

Following the changes in individual number, we observed that the average abundance periphyton forms 3–4 weeks after placing the substrate into the water. This, naturally, depends on the starting date of exposition. At times of floods or at the end of autumn this process is slower, in the summer, when the water level is low it is quicker. Besides the microscopic picture, the diversity and evenness values can help us to understand the colonization process. These values were higher at the beginning of the colonization, because several colonizing species appeared simultaneously in about the same number then (Fig. 6). Later both of these values decrease, when one of the species grows more quickly than the others. STEVENSON (1983) explained this decrease with the propagation of *r*-strategic species. During our investigation we found that after a flood, when colonization basically restarts, small sized species are present in the greatest number, and species that can attach to the substrate more strongly. In 1985 and 1986 the constant-dominant species of the Danube periphyton at Göd were: *Achnantes minutissima*, *Amphora pediculus*, *Cocconeis placentula*, *Cymbella sinuata*, *Navicula menisculus*, *Nitzschia romana*, *Rhoicosphenia abbreviata*. SZEMES (1961) published *Cocconeis placentula* as a rare species from a pontoon at the Göd section. On the contrary, this species was one of the basic elements of the periphyton in our investigation in 1985 and 1986. SZEMES described *Gomphonema parvulum* as an abundant species; while in 1985 it had a constancy value of 2, and dominancy 0,2% and in 1986 the constancy value was 3, and dominancy max. 6.3%.

Plotting the relative abundance of dominant species against time, we found 6 species which belonged to the same group in each year. We can conclude that these species behave the same way in the colonization process and their seasonal dynamics are similar (Fig. 7).

Watanabe et al. (1988) also drew figures about the relative abundance of dominant species based on studies in small rivers close to Toulouse. One of the species was *Achnantes minutissima*. They took samples in two periods (May–June, October–November). In samples from May–June the species had a greater abundance. We observed the same in the Danube, though it can be seen that the maximum was between these two periods in the summer.

The similarity of the samples were determined by the seasonality. In 1985 though, when in the studied period there were two floods, samples taken from that time were more similar to the samples taken at the beginning of colonization. This is understandable, as the flood washes off the substrate and colonization has to restart.

Summary

During our investigation we studied the quantitative and seasonal changes of the periphyton in the Danube at Göd (near Budapest). We used matt-glass slides or tubes as a substrate. These were put in a frame that was attached to the stream line side of a pontoon at 1669 river km of the Danube.

In an other experiment, in 1984 we studied the connection between the direction of the substrate and the number of individuals. Our experiment proved that the direction of the substrate is significant for the growth of periphyton in rivers. Therefore it is advisable to use a substrate, a tube for example, where the colonization can begin from different directions.

In 1985 we used glass tubes, exposed them from May till the middle of October, and in 1986 till the middle of November. Samples were collected weekly.

We determined 126 taxa that belonged to 5 phyla. Among these, 24 taxa are new in the Danube periphyton and 2 taxa are new in the Hungarian flora.

In every sample diatoms were present in the greatest quantity. Non-diatoms were present in the greatest number in the summer but were still far from the diatoms. The average number of periphyton was around 2 million ind./cm^2. This figure was a little bit higher in 1986 when the stream flow regime was more balanced than in the previous year.

Diversity and evenness were higher in the beginning of the colonization in both years, because several species appeared simultaneously in about the same number. These values decreased when one of the species proliferated more quickly than the others. The number of species was high when the water level was low, and it got more or less stabilized in the autumn.

We have found 7 species that were constant-dominant in both years: *Achnanthes minutissima, Amphora pediculus, Cocconeis placentula, Cymbella sinuata, Navicula menisculus, Nitzschia romana, Rhoicosphenia abbreviata*. 6 of these had a similar colonization and seasonal dynamics in both years.

Similarity calculated by cluster-analysis showed that it is determined by seasonality, although samples taken in the flood periods in 1985 was more similar to the samples taken in the beginning of the colonization.

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