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Diversity of flora and fauna in running waters of the Province of Cracow (southern Poland) in relation to water quality. 3. Benthic cyanobacteria and algae communities

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Abstract – The difference in the water quality of the investigated rivers was reflected by four different groups of cyanobacteria and algae communities. Those groups represented polluted and salinated waters (the River Vistula, the Łączany Canal and the River Skawinka), those rich in nutrients (parts of the rivers Trzemeśnianka, Skawinka, Cedron, and Raba), which belong to Group I, to rivers well oxygenated with a low nutrient concentration (parts of the Rivers Raba, Krzczonówka, Trzebuńka, Krzyworzeka – Group II). Groups III and IV consist of individual types of communities, due to the wide range of water and physical parameters.

Key words: cyanobacteria, algal communities, indicators, eutrophication, organic pollution, stream, rivers.

1. Introduction

Most of the streams and rivers of the Province of Cracow had not been adequately studied in the aspects of phycological investigation. The major investigations were carried out on the River Vistula (Starmach 1938, 1948, Turoboyski 1956, 1962, 1973, Kyselowa and Kysela 1966, Pudo 1977, Hanak-Schmager 1974, Bednarz and Żurek 1988, Kwandrans 1988). Although there is some information regarding algae in the River Raba (Kawecka 1977) and some of its tributaries (Amirowicz 1988), and in some streams of the Cracow--Częstochowa Upland (Hojda 1971, Skalna 1973, Amirowicz 1981*a*, 1981*b*, 1988, Dumnicka et al. 1990), the majority of streams and rivers of this region have not been subjected to detailed study.

The aim of the present work was to determine the structure of the benthic cyanobacteria and algae communities, which have been used as an indicators for the evaluation of water eutrophication and pollution levels. The study is part of a more comprehensive programme carried out for assessing water quality with respect to fishery management. Additional information concerning water quality assessment of streams and rivers, studied on the basis of benthic diatoms and diatom indices, was given by Kwandrans et al. (1998).

2. Study area, material, and methods

The investigation was carried out in the main rivers and streams of the Cracow Province: the Vistula, the Raba, and their tributaries. The River Vistula and some of its tributaries are of lowland character, with slow-flowing waters and bottoms covered mostly by mud or sandy mud. The River Raba and its tributaries have a submountane character, with numerous rapids, and a stony and stony-gravel bottom (Table I). The Raba feeds the reservoir at Dobczyce, which provides drinking water for the conurbation of Cracow. The water quality ranges from highly polluted in sectors of the Vistula and some of its tributaries (which pass through agricultural and heavy industrial areas, receiving salinated waters from mines of the Silesian industrial region), to eutrophic but relatively less organically polluted, in the Raba (Table II). Only a few sites of the Raba and its tributaries were unpolluted. A more detailed description of the study sites and chemical characteristics is given by Wojtan (1994) and Wojtan et al. (2000).

The samples were taken once, from 10 to 30 October 1994, from 38 sites (Fig. 1). The material was sampled and preserved in 4% of formalin. The number of species was determined as low to 30 taxa in communities, medium from 31–70, high >71. The coverage of organisms forming macroscopic aggregations was estimated according to a five-grade scale as follows: 1 – organisms form small aggregations, 2 – cover less than 25% of bottom area, 3 – cover 25–50%, 4 – 50–75%, 5 – 75–100%. The numerous species were considered those which reached a degree higher than 3 in the scale of coverage, the remaining ones were described as sporadic. In order to obtain clean diatom frustules, part of the material was macerated in a mixture of sulphuric acid and potassium dichromate; it was then cleaned in a centrifuge (3000 R/min). Solid preparations were fixed in "pleurax" resin. The number of diatom cells was estimated by counting them in 10 macroscopic fields. The percentage share of each species in the community was counted, and the numerous species (over 10 %) were selected, the remaining ones being described as sporadic. The abundance of the numerous species was expressed by a 7-grade number of cells, as follows: 1 – 20–50 cells, 2 – 51–100, 3 – 101–150, 4 – 151–200, 5 – 201–250, 6 – 251–300, 7 – >300. The diatoms were identified according to Krammer and Lange-Bertalot (1986, 1988, 1991*a*, 1991*b*). As a measure of the site similarity, the SIMI index was applied. It is calculated according to the formula (Stander 1970, after Gosh and Gaur 1991):

$$\mathrm{SIMI} = \left(\sum^{S} P_{ij}\, P_{in}\right) \Big/ \left(\sum^{S} P_{ij} \sum^{S} P_{in}\right)^{1/2}$$

where P_{ij} and P_{in} are average relative abundance expressed as a proportion for the collection data of i-th species in the j-th and n-th communities and S is the number of species. SIMI values range from 0 to 1, and value 1 indicates identical communities/stations. Cluster analysis was performed using the SYSTAT program.

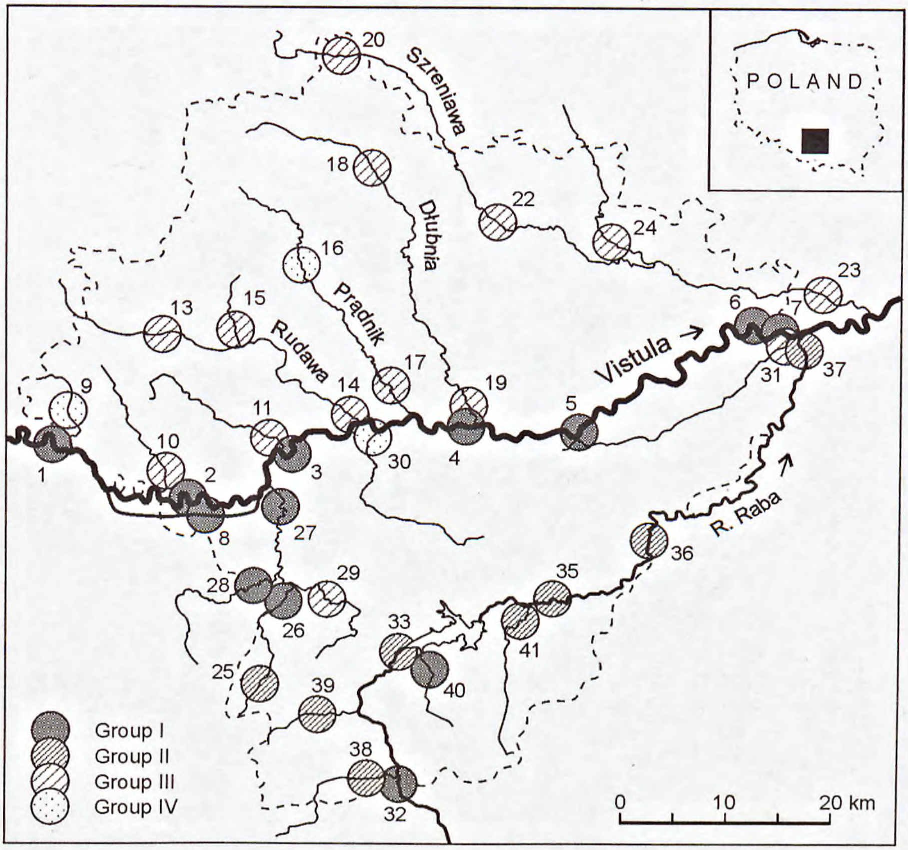

Fig. 1. Classification of the investigated sites according to groups distinguished on the basis of similarities between benthic algae and cyanobacteria communities (numbers of stations explained in Table I).

Table I. Characteristics of the studied sites in the streams and rivers of the Cracow Province.

No.	River/Site	Bottom	Current velocity ($m\ s^{-1}$)	Water temperature (^oC)	Width (m)	Depth (m)
1	Vistula/Okleśna	sand, mud	0.07	15.4	70	0.5–1.2
2	Vistula/Czernichów	sand, gravel	0.12	16.1	50–60	0.4–1.2
3	Vistula/Tyniec	mud	0.23	18.4	50	0.1–0.2
4	Vistula/Kraków	sand		15.8	100	0.2–0.4
5	Vistula/Niepołomice	mud, sand	0.12	18.1	30	0.5–1.3
6	Vistula/Sierosławiec	mud	0.21	18.8	0.5–2.0	
7	Vistula/Uście Solne	mud	0.25	16.6	0.5–2.0	
8	Łączany Canal/Zelczyna	stones, mud		16.4	30	0.7–1.5
9	Regulanka/Regulice	stones	0.1	11.0	1–1.5	0.1–0.4
10	Rudno	sand	0.08	14.8	2	0.15
11	Sanka	sand	0.1	15.5	2.5–3.0	0.5
13	Rudawa/Krzeszowice	stones	0.23	13.2	3.5	0.3–0.5
14	Rudawa/Kraków	stones, sand		13.2	3.0–4.0	0.4–0.7
15	Rudawka/Rudawa	mud, sand	0.09	11.6	2	0.3–0.4
16	Prądnik/Ojców	stones, sand, gravel	1.03	13.2	2.0–3.0	0.2
18	Dłubnia/Grzegorzowice	stones, gravel	0.4	11.8	4.0–5.0	0.5
19	Dłubnia/Zesławice	stones, sand	0.23	15.8	3	0.2–0.6
20	Szreniawa/Przybysławice	stones, mud	0.74	16.1	1.0–1.5	to 0.7
22	Szreniawa Kacice	stones, gravel	0.79	11.8	6.0–7.0	0.2–0.3
23	Szreniawa/Biskupice	mud	0.43	15.3	3.0–8.0	0.3–0.7
24	Ścieklec/Mokocice	mud	0.37	15.0	2.0–2.5	0.8
25	Harbutówka	stones	0.04	16.5	3.0–4.0	0.1
26	Skawinka/Radziszów	stones, gravel	0.1	17.2	2.0–2.5	0.2–0.5
27	Skawinka/Skawina	stones, gravel	0.21	26.0	20	1
28	Cedron	stones, sand		11.7	30	0.3–1.2
29	Głogoczówka	gravel, sand	0.05	13.0	2.0–3.0	0.1–0.4
30	Wilga/Swoszowice	stones, mud, sand	0.02	13.0	4	0.4
31	Drwinka/Świniary	sand	0.03	17.5	3	0.4–0.6

32	Raba/Lubień	mud	0.2	13.4	30	0.5
33	Raba/Zarabie	stones	0.3	13.6	30	0.3–0.7
35	Raba/Gdów	stones, gravel	0.03	14.5	35	1.0–1.2
36	Raba/Książnice	mud	0.1	15.1	40	0.3–0.7
37	Raba/Uście Solne	mud	0.23	19.2	40	0.6–1.2
38	Krzczonówka	stones, loam	0.1	12.4	2.0–4.0	0.1–0.3
39	Trzebuńka/Stróża	mud, stones	0.15	11.8	2.0–3.0	0.1–0.2
40	Trzemeśnianka	sand, stones	0.06	14.0	2.0–3.0	0.1–0.2
41	Krzyworzeka/Czasław	sand, mud, gravel	0.05	14.6	1.0–3.0	0.3

Table II. Selected physico-chemical factors of the water at studied sites in October 1994 (after

Site number	Parameters							
	pH	Conductivity ($\mu S\ cm^{-1}$)	Cl ($mg\ L^{-1}$)	SO_4 ($mg\ L^{-1}$)	NH_4-N ($mg\ L^{-1}$)	NO_2-N ($mg\ L^{-1}$)	NO_3-N ($mg\ L^{-1}$)	PO_4 ($mg\ L^{-1}$)
1	7.7	5372.2	2000.0	264.1	3.914	0.320	0.030	0.768
2	7.8	4696.8	1700.0	262.5	2.548	0.440	0.213	0.527
3	7.7	4611.1	1700.0	260.4	2.877	0.460	0.399	0.641
4	7.8	4675.2	1725.0	252.6	2.712	0.400	0.289	0.599
5	7.7	4287.2	1562.5	249.7	2.673	0.510	0.490	0.394
6	7.8	3946.6	1425.0	228.3	2.582	0.420	0.396	0.658
7	7.8	3892.2	1375.0	224.2	2.786	0.380	0.268	0.576
8	7.7	4625.2	1637.5	262.1	3.631	0.460	0.398	0.563
9	7.4	477.1	14.5	23.0	0.218	0.006	0.871	0.074
10	7.6	520.8	35.5	51.4	0.275	0.012	2.371	0.331
11	7.7	543.4	22.5	38.7	0.259	0.019	2.882	0.166
13	7.5	531.2	18.5	32.1	0.676	0.131	2.876	0.931
14	7.4	538.5	3.0	70.3	0.768	0.027	2.371	0.728
15	7.6	450.3	13.5	21.4	0.211	0.023	3.530	0.177
16	7.6	382.2	12.5	17.3	0.509	0.109	2.778	0.575
17	7.9	430.2	13.0	14.8	0.223	0.013	2.371	0.400
18	7.7	402.9	10.0	12.8	0.271	0.017	2.165	0.238
19	8.1	532.1	32.5	51.8	0.409	0.041	0.881	0.030
20	7.7	378.3	21.8	35.0	0.363	0.071	2.715	0.581
22	7.8	514.0	19.5	22.6	1.113	0.095	2.320	0.390
23	7.8	554.4	25.0	42.0	0.248	0.047	1.798	0.437
24	7.9	648.4	21.2	80.2	0.236	0.022	1.660	0.117
25	7.6	14.2	43.6	5.1	0.294	0.093	1.769	1.042
26	7.8	420.4	24.0	37.4	0.216	0.003	0.259	0.321
27	7.2	4633.2	1570.0	238.2	3.200	0.670	0.209	0.558
28	7.3	462.4	3.5	57.2	0.297	0.008	1.092	0.458
29	8.1	12.1	54.7	9.0	0.282	0.016	0.150	0.039
30	7.8	865.0	130.0	196.2	1.335	0.069	1.115	0.482
31	8.2	479.7	35.0	112.3	0.317	0.003	0.007	0.034
32	8.1	380.6	14.5	36.6	0.238	0.005	0.417	0.085
33	8.3	311.5	12.8	31.7	0.159	0.003	0.023	0.013
35	8.7	282.5	13.2	33.7	0.223	0.006	0.516	0.011
36	8.7	315.8	16.5	43.2	0.224	0.003	0.290	0.015
37	8.3	466.1	57.5	56.8	1.020	0.171	0.587	0.407
38	8.4	334.8	9.0	31.3	0.175	0.004	0.308	0.014
39	8.5	310.2	7.0	29.2	0.213	0.003	0.122	0.020
40	8.4	372.7	15.2	41.1	0.235	0.004	0.207	0.051
41	8.4	367.5	14.5	53.9	0.226	0.002	0.041	0.012

Wojtan 1994).

Ca (mg L^{-1})	Mg (mg L^{-1})	Dissolved oxygen (mg L^{-1})	Oxidability (mg O_2 L^{-1})	BOD_5 (mg O_2 L^{-1})	COD (mg O_2 L^{-1})	Suspension (mg DW L^{-1})
171.5	91.1	4.0	10.7	4.7	346.7	16.3
157.2	86.7	6.6	10.5	5.2	342.2	17.0
164.4	78.1	5.4	9.9	3.1	312.2	17.2
157.2	86.7	7.5	9.6	3.6	327.2	34.2
150.1	78.1	8.0	10.8	4.1	297.9	23.1
153.7	65.1	4.8	10.6	0.5	306.2	26.7
164.4	56.4	4.5	9.5	2.6	286.7	25.3
157.2	82.4	3.8	9.5	3.1	301.7	7.7
93.6	15.2	8.8	1.4	1.4	8.2	2.2
96.5	6.3	9.6	1.1	1.1	18.0	3.8
111.5	10.8	10.4	1.0	1.0	13.5	6.6
92.1	19.5	8.0	1.9	1.9	13.5	42.0
86.5	12.1	8.2	7.7	7.7	22.5	29.0
95.0	8.2	9.0	1.0	1.0	7.5	17.3
79.3	3.2	9.0	4.8	4.8	10.5	34.3
97.2	4.3	9.0	1.9	1.9	12.0	58.5
88.6	5.4	9.0	3.4	3.4	15.0	64.4
87.9	12.1	9.4	5.2	4.5	19.5	33.5
77.9	6.1	7.7	14.0	7.2	57.8	287.6
97.6	13.9	8.3	5.9	5.9	15.8	82.9
102.2	15.6	7.8	6.0	3.5	21.0	240.0
125.4	15.6	9.6	6.8	2.9	15.0	84.4
82.9	11.3	7.5	4.1	3.7	16.5	13.7
67.9	11.3	10.4	3.4	0.5	7.5	4.6
145.8	86.7	7.2	9.1	5.4	307.7	9.5
35.7	34.0	8.6	5.9	2.1	19.5	9.4
67.9	10.8	8.2	4.9	2.2	18.0	3.6
124.4	15.2	6.9	5.9	4.6	43.5	19.6
75.0	9.5	9.8	6.0	1.1	21.0	0.9
62.9	10.8	10.9	2.6	2.2	7.5	2.7
49.3	8.7	10.4	2.5	1.0	10.5	1.5
48.6	6.5	14.4	2.8	2.4	9.0	5.8
54.3	6.9	12.3	2.5	4.5	7.5	2.2
59.3	8.7	11.2	3.9	3.8	19.5	4.8
61.5	6.5	10.4	1.8	1.3	3.0	2.6
54.3	7.4	10.9	2.4	1.4	4.5	1.3
67.8	6.9	12.6	3.6	3.0	10.5	1.7
62.9	7.4	10.9	2.4	1.6	9.0	1.3

3. Results and discussion

In the rivers investigated, 172 taxa of algae were identified. The most abundant group were diatoms (92.4% of the total number of taxa), with *Navicula, Nitzschia,* and *Fragilaria* as the prevailing species of genera (Table III). The next largest group was of green algae (6.4%), followed by cyanobacteria (1.2%). The cluster analysis identified four main groups of sites on the basis of different type of algal communities (Fig.2, Table IV). In Group I, two subgroups, IA and IB, were distinguished. Subgroup I A consisted of algal communities which had developed in the most polluted and salinated sector of the Vistula (Sites 1–7), as well as the Łączany Canal (Site 8) and in the River Skawinka below the inflow of heated

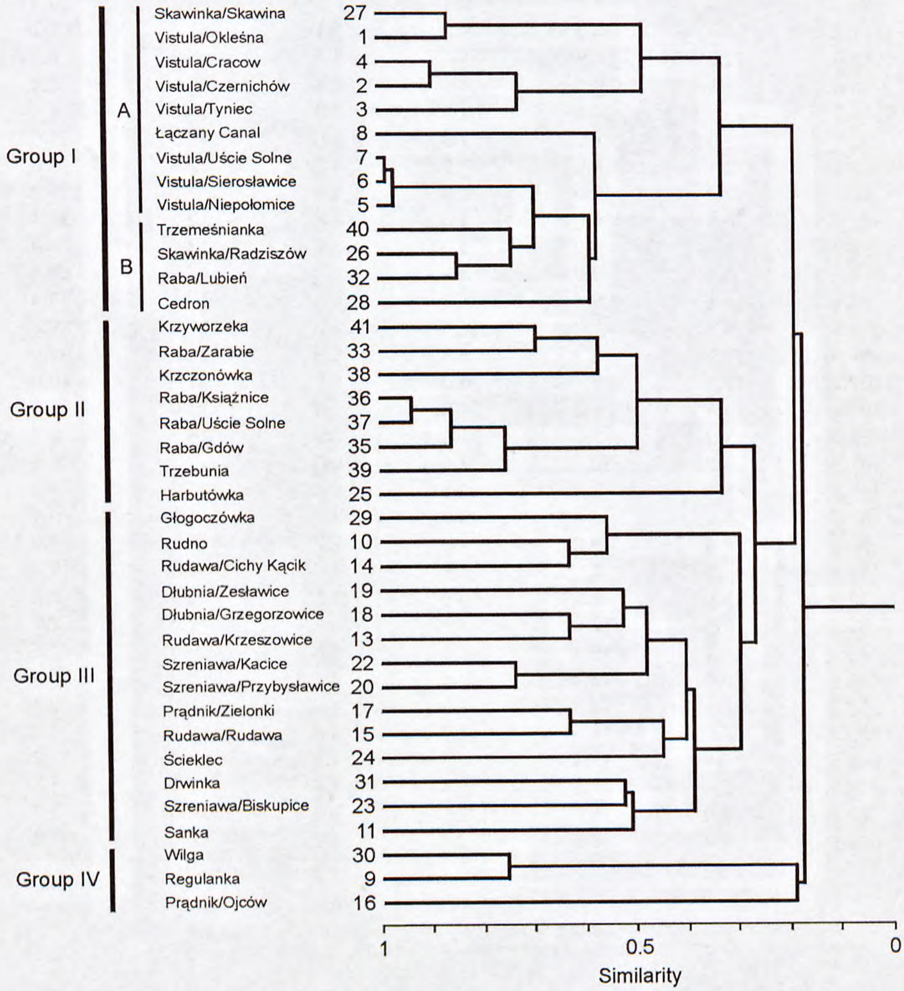

Fig. 2. Dendrogram of similarities between investigated sites according to SIMI index (Stander 1970, after Gosh and Gaur 1991).

waters (site 27). The very high conductivity, very high concentration of nutrients, chlorides, sulphates, and heavy organic pollution evident in the high level of COD and BOD_5 of such waters as well as low values of dissolved oxygen indicated those waters as beyond of classification, according to Polish water quality categories (Table II). Moreover, in the Vistula, owing to overloading with sewage, densely located water stages which reduce the current velocity, as well as changes in the type of riverbeds along its course, the self-purification process is significantly slowing down (Kwandrans 1988).

As a result of these environmental conditions, the sessile algal communities were characterized by a number of taxa varying from medium to high (Table IV), and very high abundance of eutraphentic and organic pollution-tolerant species, as well as of some brackish and inland fresh-brackish species. Comparatively, sestons of the Vistula and Łączany Canal were also characterized by the highest share of eutraphent and saprobic species such as blue-greens *Microcystins aeruginosa* and *Aphanizomenon flos-aquae* (Bucka 1989, 2000). Some populations of these taxa are toxigenic and their release into the water habitat may become a source of toxication for humans and animals (Skulberg et al. 1994).

Among the benthic communities, the green and diatom communities were abundantly represented, with a smaller proportion of blue-greens (Table IV). Among green algae, the high preponderance of some halophilous species was observed. To this group belongs *Enteromorpha* sp. characteristic of marine and fresh brackish waters (Starmach 1972). It was especially abundant in the Vistula below Kraków, and in the Łączany Canal (Site 8) where it occurred in mass. In the Vistula (Site 1), *Cladophora glomerata* had the highest share, a species which is known to occur commonly in fresh and brackish waters (Starmach 1972), and is an organism very resistant to water pollution (Whitton 1970), also reported from other Carpathian rivers (Wasylik 1965, Chudyba 1965, Sanecki 1986).

Among the diatom communities, the dominance of littoral diatom *Cyclotella meneghiniana* classified as halophilous (Kramer and Lange-Bertalot 1991*a*), as well as the numerous presence of other brackish species such as *Amphora coffeaeformis*, *Bacillaria paradoxa*, *Fragilaria pulchella*, *F. fasciculata*, and also *Nitzschia frustulum*, *Navicula tripuncata,* which are among common organisms, occurring also in brackish waters (Kramer and Lange Bertalot, 1986, 1988, 1991*a*, Van Dam et al. 1994), together testified to the very high level of salinity in the Vistula. Moreover, the prevailing species of benthic diatom communities was *Nitzschia palea*. This species (obligatory nitrogen heterotroph), Cholnoky (1968) is known as an indicator of hyper-eutrophy and organic pollution (Steiberg and Schiefele 1988, Kelly et al. 1995), it is also very resistant to toxic pollutants (Schröeder 1939).

Cyanobacteria were dominated by *Oscillatoria tenuis* (particularly abundant at site 7), which is a very widely distributed species; it is classified as an indicator of organic pollution (Sládeček 1973, Turoboyski 1979). Most of the taxa mentioned above were also found in previous investigations of the Upper Vistula River (Turoboyski 1962, Kyselowa and Kysela 1966, Hanak-Schmager 1974, Kwandrans 1988). However, an increase in halophilous taxa, as well as the presence of new ones such as *Bacillaria paradoxa* and *Amphora coffeaeformis*, which are common in the Bay of Gdańsk (A. Witkowski, personal comm.), were observed.

Subgroup I B was represented by the communities which had developed in the rivers Trzemeśnianka (site 40) and Skawinka (site 26), its tributary the Cedron (site 28), and the middle sector of the Raba (site 32) (Fig. 2, Table IV). These rivers were characterized by a high trophic level and a relatively low organic content, evident in the level of BOD_5 and COD (Table II). The concentration of chlorides was generally low, with the highest value in the Skawinka. The number of algal taxa was low in comparison with the community types of subgroups IA, varying from low to medium (Table IV). The algal communities were dominated by green alga *Cladophora glomerata* and diatoms, with *Cyclotella meneginhiana* prevailing. In some sites they were accompanied by some cosmopolitan species such as *Navicula capitatoradiata* and *Navicula veneta,* which also occur in brackish and polluted waters and *Navicula viridula* var. *rostelata* which can tolerate organic pollution (Krammer and Lange-Bertalot 1986, Van Dam et al.1994).

Group II consisted of algal communities occurring in the Raba (sites 33, 35–37), and its tributaries: Krzczonówka (site 38), Trzebuńka (site 39), Krzyworzeka (site 41) (Fig. 2, Table IV). With the exception of a sector of the Raba (site 37) which was highly eutrophicated and relatively highly salinated, the low nutrient concentration and oversaturation with oxygen in other rivers of this group clearly indicated the best water quality of all the rivers studied (Table II). The number of taxa varied from low to medium value, and algal communities were dominated by *Cladophora glomerata* and diatoms (Table III). The most abundant diatom species was *Achnnathes minutissima* var. *minutissima*, which occurs in a very wide range of trophy. It is, however, known as a species highly sensitive organic pollution (Steinerg and Schiefele 1988), and as an indicator of waters well-saturated in oxygen (Kawecka 1981). Its abundance at most of the sites of the Raba and its tributaries suggested better levels of quality and a high ability of the waters to self-purify.

The Group III communities were mainly restricted to tributaries of the Vistula – the Rudno (site 10), Sanka (site 11), Rudawa (sites 13,14) Rudawka (site 15), Białucha (site 17), Dłubnia (sites 18,19), Szreniawa (sites 20, 22 ,23), Ścieklec (site 24), Drwinka (site 31) – and only two tributaries of the Raba – the Harbutówka (site 25) and Głogoczówka (site 29); (Fig. 2, Table IV). These rivers represented different degrees of trophic level and chloride concentration (Table II). In general, they were eutrophicated and, in some cases, slightly loaded with organic pollution. The difference in water chemistry, as well as in physical parameters such as type of substratum, water turbulence, and degree of transparency in particular rivers, was clearly expressed by individual algal community types. The number of taxa varied widely, from medium to high values (Table IV).

In the Rivers Harbutówka, Głogoczówka, Rudno, the lower part of the Rudawa (site 14), the Dłubnia (site 19) and Sanka (site 11), *Cladophora glomerata* and numerous diatoms were the main components of the algal and blue-green communities. In the Drwinka, the most abundant were green algae (with the prevalence of *Spirogyra* sp.) occurring in dense masses along with accompanying diatoms and desmids. In the Szreniawa (site 23), besides numerous diatoms, blue green alga *Oscillatoria tenuis* also occurred abundantly. In the Rudawka, euglenophyes, which prefer a rich organic matter environment, were found.

Of the diatoms, the greatest share was held by widely-distributed taxa preferring waters rich in electrolytes and high nutrient level: *Navicula menisculus* (Szreniawa-site 23), *Cocconeis pediculus* (Rivers Sanka-site 11 and Szreniawa-site 23), *Diatoma vulgare* (Sanka-site 11 and Dłubnia-site 19). A relatively high proportion of pollution-indicating species such as *Nitzschia palea,* together with contributions of *Navicula trivialis* and *N. salinarum*, was also observed (Rudawa--site 14). Both these species are common in brackish waters, and waters with high conductivity; *Navicula salinarum* occurs often very frequently on seashores (Krammer and Lange Bertalot 1986).

Among Group III, sites 20 and 22 of the Szreniawa were notable, consisting of single diatom individuals and fragments of dead cyanobacteria and green filaments.

At these sites, a similar effect for zooplankton, described as "biological desert", was noted by Żurek (1994, 2000), although this phenomenon was not confirmed by seston analysis (Bucka 2000). Considering that this part of the river basin is heavily industrialised, the effect of occasional toxic industrial sewage is likely there.

A lower density of algal communities was also observed in the Dłubnia (site 18), the upper part of the Rudawa (site 13), and the Ścieklec stream (site 24). However, the factors causing lower algal development were not identified and were not supported by any distinct differences in water chemical composition (Table II). Group IV consisted of algal communities occurring in some tributaries of the Vistula – the Wilga (site 30), Regulanka (site 9), and the Prądnik stream (site 16). These rivers were differentiated mainly by nutrient and chloride concentration; they were, however, not very organically polluted (Table I). The number of taxa exhibited medium values (Table IV). In the Wilga, characterized by a high trophic level, high conductivity, and increase in chloride and sulphate content (Table III), the most abundant group were diatoms with numerous *Amphora pediculus*, which were associated with eutrophic water with relatively low levels of organic pollution (Steinberg and Schiefele 1988, Kelly et al. 1995).

The Regulanka stream (similarly to the Raba and some of its tributaries (sites 33, 38, 41) had clear water, poor in nutrients, with a low chloride concentration and the lowest oxidability among all of the rivers studied. The benthic communities developed poorly. Macroscopic aggregations consisted of algae *Vaucheria* sp. and *Microspora amoena,* typical oligotrophic species (Sládeček 1973, Turoboyski 1979). Among diatoms less well developed, the species of the genus *Achnanthes* were the most frequently recorded.

In the waters of the Prądnik flowing through the Ojców National Park, the relatively high nutrient content (especially phosphates and nitrite) and large amount of suspension were noted (Table II). The benthic communities were poorly developed, and only single specimens of cyanobacteria and red algae were observed. In the group of diatoms with small populations, the most frequent was *Fragilaria pinnata*, a common species occurring in oligotrophic to eutrophic waters (Van Dam et al. 1994).

In conclusion, it may be pointed out that the rivers and streams of the Cracow Province under study are strongly affected by human activity. The majority of these rivers, to different degrees, were eutrophicated and salinated (the Vistula), some of them being accompanied by organic pollution. Only a few of them had better water quality. The greatest degradation of the aquatic environment was noted in the River Vistula, the Łączany Canal, and in the heated sector of the Skawinka. The communities of this group (IA) were distinctly different from all the others, in both chemical parameters, and the type of algae and cyanobacteria communities. This fact was evident on the basis of cluster analysis (Fig. 2), diatom-based methods (Kwandrans et al. 1998), as well as seston communities (Bucka 2000).

It should be pointed out that some of the upper parts of the Szreniawa (sites 20 and 22) were characterized by a distinctly poor development of benthic communities. This situation was not reflected by cluster analysis or diatom indices (Kwandrans et al. 1998). It may be surmised that it was caused by incorrect quantitative analysis. This means that taken into consideration was a whole community, which consists of mostly dead cells and filaments.

The most natural types of community were noted in the middle sector of the Raba (site 33) and its tributaries: the Krzyworzeka (site 41), Krzczonówka (site 38), and Regulanka (site 9). However, this was not clearly confirmed by cluster analysis (Fig. 2), in contrast to the diatom based methods used (Kwandrans et al. 1998).

Table III. List of taxa of benthic cyanobacteria and algae found in the streams and rivers of the Cracow Province in October 1994: ● – macroscopic taxa forming large aggregations (>3 in the scale of covering) and most numerous diatom species (>10% of the total community).

	Species	Stations																		
		1	2	3	4	5	6	7	8	9	10	11	13	14	15	16	17	18	19	20
	CYANOBACTERIA																			
1	*Oscillatoria tenuis* Ag.			●		+	+	●									+			
2	*Phormidium autumnale* Ag. Gom.	+			+								+		+				+	+
	EUGLENOPHYTA																			
3	*Euglena* spp.	+	+	+	+	+	+	+	+				+		+		+	+	+	
	XANTHOPHYCEAE																			
4	*Vaucheria* sp.									+								+	+	
	BACILLARIOPHYCEAE																			
5	*Achnanthes biasolettiana* var. *biasolettiana* Grun. in Cleve et Grun.																			
6	- *lanceolata* Bréb. Grun.	+	+	+	+	+	+	+	+	+	+	+	+	+	●	+	+	+	+	+
7	- *lanceolata* var. *dubia* (Grun.) Lange-Bertalot									+						+				
8	- *lanceolata* var. *havnaldii* (Schaar Schmidt) Cl.									+	+	+								
9	- *lanceolata* ssp. *rostrata* (Oestrup) Lange-Bertalot	+	+	+	+	+			+	+				+		+	+		+	
10	- *minutissima var. gracillima* (Meister) Lange-Bertalot																			
11	- *minutissima var. minutissima* Kütz.	+	+	+	+	+	+	+	+	●	+	+	●	+	+	+	+	+	+	+
12	*Actinocyclus normanii* (Greg ex Greville) Hust.		+	+		+	+	+												
13	*Amphora coffeaeformis* (Agardh) Kütz.	●	+	+	+	+	+	+	+					+						
14	- *ovalis* (Kütz.) Kütz.	+	+		+					+	+			+	+	+				
15	- *pediculus* (Kütz.) Grun.	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+		+	
16	- *veneta* Kütz.	+	+	+	+	+	+		+					+					+	
17	*Asterionella formosa* Hassall		+	+	+	+	+	+					+	+					+	
18	*Aulacoseira alpigena* (Grun.) Krammer				+															
19	- *granulata* (Ehr.) Simonsen	+	+	+	+		+	+	+											
20	*Bacillaria paradoxa* Gmelin	+	+	+	●	+	+	+	+	+	+					+	+			
21	*Caloneis amphisbaena (Bory) Cl.*	+	+		+	+			+		+		+	+		+			+	
22	- *bacillum* (Grun.) Cl.	+					+						+		+		+		+	
23	- *silicula* (Ehr.) Cl.										+									
24	*Cocconeis pediculus* Ehr.	+	+	+	+	+	+	+	+	+	●	+	+	+	+		●	+	+	
25	- *placentula* var. *euglypta* Ehr.	+	+	+	+	+	+	+	+	+	●	+	+	+	●	+	●	+	+	+

26	*Coscinodiscus* sp.	+	+		+															
27	*Cyclotella* sp. 1	+	+	+	+	+	+	+	+				+	+	+		+	+		
28	*Cyclotella* sp. 2	+	+		+															
29	- *atomus* Hust.			+	+	+	+	+	+											
30	- *meneghiniana* Kütz.	+	+	+	+	●	●	●	●	+	+	+	+	+	+		+			
31	- *pseudosteligera* Hust.		+	+	+	+	+											+	+	
32	- *radiosa* (Grun.) Lemmermann		+		+		+							+						
33	*Cymatopleura elliptica* (Bréb.) W. Smith			+	+	+	+				+									
34	- *solea* (Bréb.) W. Smith	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
35	- *solea* var. *apiculata* (W. Smith) Ralfs		+	+	+									+	+	+	+			
36	*Cymbella affinis* Kütz.	+		+	+	+				+				+		+			+	
37	- *cistula* (Ehr.) Kirchner															+				
38	- *ehrenbergii* Kütz.										+					+				
39	- *lanceolata* (Ehr.) Kirchner		+				+	+												
40	- *microcephala* Grun.																			
41	- *minuta* Hilse / *silesiaca* Bleish	+	+	+	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+
42	- *naviculiformis* Auerswald	+												+						
43	- *perpusilla* Cleve-Euler																			
44	- *prostrata* (Berkeley) Cleve																		+	
45	- *sinuata* Gregorg	+	+	+	+	+	+	+	+		+		+	+	+		+	+	+	
46	*Denticula tenuis* Kütz.												+		+					
47	*Diatoma ehrenbergii* Kütz.	+	+	+	+	+	+	+	+				+	+			+		+	+
48	- *moniliformis* Kütz.	+	+	+	+	+	+	+	+				+	+	+		+		+	
49	- *tenuis* Agardh	+	+	+	+	+	+	+	+					+		+	+			
50	- *vulgaris* Bory	+	+	+	+	+	+	+	+			●	+	●	+	+	+	+	●	+
51	*Enthomoneis paludosa* var. *subsalina* (Cleve) Krammer	+	+	+	+	+	+	+	+											
52	*Epithemia adnata* (Kütz.) Bréb.	+				+														
53	*Eunotia pectinalis* (Dillwyn) Rabenh.														+					
54	*Fragilaria arcus* (Ehr.) Cl.			+									+							
55	- *capucina* Desmazieres	+			+				+	+	+	+	+	+	+	+	+	+	+	
56	- *capucina* var. *mesolepta* (Rabenh.) Rabenh.				+	+		+												
57	- *capucina* var. *vaucheriae* (Kütz.) Lange-Bertalot	+	+	+	+	+	+	+				+	+	+	+	+	+	+		+
58	- *crotonensis* Kitton										+									
59	- *famelica* (Kütz.) Lange-Bertalot	+	+	+	+	+							+	+			+		+	
60	- *fasciculata* (Agardh) Lange-Bertalot	+	+	●	+	+	+	+	+					+	+		+		+	
61	- *leptostauron* (Ehr.) Hust.	+	+	+			+		+								+			
62	- *parasitica* (W. Smith) Grun.		+		+	+	+		+					+	+		+		+	

Table III. *continued*

	Species	Stations																		
		1	2	3	4	5	6	7	8	9	10	11	13	14	15	16	17	18	19	20
63	- *parasitica* var. *subconstricta* Grun.			+	+	+					+			+			+		+	
64	- *pinnata* Ehr.	+	+	+	+		+	+	+	+	+				+	●			+	
65	- *pulchella* (Ralfs.) Lange-Bertalot	+	+	●	+	+	+	+	●		+			+	+					
66	- *tenera* (W. Smith) Lange-Bertalot	+	+	+	+	+	+	+	+					+	+					
67	- *ulna* (Kütz.) Lange-Bertalot / var. *acus* (Nitzsch) Lange-Bertalot	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
68	*Frustulia vulgaris* (Thwaites) De Toni	+	+	+	+		+			+				+	+	+	+		+	+
69	*Gomphonema acuminatum* Ehr.						+						+							
70	- *angustatum* (Kütz.) Rab.	+	+	+	+		+	+	+	+	+	+		+	+	+	+		+	
71	- *angustum* Agardh.									+			+				+		+	
72	- *augur* Ehr.																			
73	- *gracile* Ehr.	+	+		+		+	+	+				+		+				+	
74	- *olivaceum* (Hornemann) Bréb.	+	+	+	+	+	+	+	+				+	+	+	+	+		+	+
75	- *olivaceum* var. *calcareum* (Cleve) Cleve				+		+													
76	- *parvulum* (Kütz.) Kütz.	+	+	+	+	+	+	+	●			+	+	+	+		+		+	+
77	- *truncatum* Ehr.	+	+	+	+	+		+	+					+		+			+	
78	*Gyrosigma acuminatum* (Kütz.) Rabenh.	+	+	+	+		+		+	+	+	+	+	+	+	+	+	+	+	
79	*Hantzschia* sp.										+									
80	- *amphioxys* (Ehr.) Grun.	+		+									+						+	+
81	*Meridion circulare* (Greville) Ag.	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
82	- *circulare* var. *constrictum* (Ralfs) Van Heurck	+	+		+			+	+	+			+							
83	*Melosira* sp.	+					+												+	
84	- *nummuloides* (Dillwyn) Ag.		+	+		+	+	+	+											
85	- *varians* Ag.	+	+	+	+	+	+			+	+	+		+						
86	*Navicula* spp.		+								+									
87	- *acomoda* Hust.	+		+					+											
88	- *atomus* (Kütz.) Grun.	+			+	+	+							+						
89	- *bacillum* Ehr.			+	+	+				+	+					+				
90	- *capitata* Ehr.	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+			+
91	- *capitatoradiata* Germain	+	+	+	+	+	+	+	+		+	+	+	+	+	+	+		+	+
92	- *cincta* (Ehr.) Ralfs		+	+			+	+	+				+							
93	- *contenta* Grun.	+	+	+	+		+		+			+	+	+			+			

94 - *costulata* Grun.										+									
95 - *cryptocephala* Kütz.	+	+	+	+	+	+	+	+		+	+	●	+	+	+	+	+	+	+
96 - *cuspidata* (Kütz.) Kütz.	+	+	+	+	+	+		+	+	+			+	+		+			
97 - *exigua* (Greg.) Grun.	+	+	+	+	+	+	+	+				+	+			+		+	
98 - *gastrum* (Ehr.) Kütz.								+		+									
99 - *goeppertiana* (Bleisch) H.L. Smith	+	+	+	+	+	+		+						+		+	+	+	
100 - *lacunolanciniata* Lange-Bertalot et Bonik	+	+		+		+	+	+					+			+		+	
101 - *lanceolata* (Agargh) Ehr.	+	+	+	+	+	+	+	+	+	+	+	+	+	●	+	●	+	+	+
102 - *menisculus* Schumann	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
103 - cf. *menisculus* Schumann		+	+	+	+	+	+		+	+	+					+	+	+	
104 - *minima* Grun.				+				+										+	
105 - *pupula* Kütz.	+	+	+	+	+	+		+		+	+	+	+	+	+		+		
106 - *pygmaea* Kütz.	+	+	+		+	+		+							+				
107 - *radiosa* Kütz.	+								+	+	+	+			+				
108 - *reinhardtii* Grun.									+										
109 - *rhynchocephala* Kütz.	+	+	+	+	+	+		+	+					+				+	
110 - *subminuscula* Manguin		+	+		+													+	
111 - *tripunctata* (O.F. Müller) Bory	+	+	+	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+
112 - *trivialis* Lange-Bertalot / *salinarum* Grun.	+	+	+	+	+	+	+	+		●	+	+	●					+	
113 - *veneta* Kütz.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
114 - *viridula* (Kütz.) Ehr. / *slesvicensis* Grun.	+	+	+	+	+	+	+	+		+		+	+	+	+	+	+	+	+
115 - *viridula* var. *rostellata* (Kütz.) Cl.	+	+	+	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+
116 *Neidium affine* (Ehr.) Pfitzer				+		+				+									
117 - *dubium* (Ehr.) Cl.			+							+	+				+				
118 - *productum* (W. Sm.) Cl.																			
119 *Nitzschia* spp.		+				+		+					+					+	+
120 - *acicularis* (Kütz.) W. Smith	+	+	+	+	+	+	+	+		+						+			+
121 - *amphibia* Grun.	+	+	+	+	+	+	+	+				+	+			+	+	+	
122 - *angustata* Grun.	+	+	+	+	+	+				+	+		+		+	+		+	
123 - *calida* Grun.		+	+	+	+	+	+	+	+				+						
124 - *capitellata* Hustedt / *palea* (Kütz.) W. Smith	●	●	●	●	●	●	●	+	+	+	+	+	●	+	+	+	+	+	+
125 - *constricta* (Kütz.) Ralfs										+	+				+				
126 - *dissipata* (Kütz.) Grun.	+	+	+	+	+	+	+	+	+		+	+	+	+		+	+	●	+
127 - cf. *dubia* W. Smith					+														
128 - *filiformis* (W. Smith) Van Heurck	+	+		+	+	+	+	+											
129 - *frustulum* (Kütz.) Grun.	+	●	●	●	+	+	+	+				+	+	+	+	+	+	+	+
130 - *hantzschiana* Rabenh.	+	+				+		+	+	+							+	+	

Table III. *continued*

	Species	Stations 1	2	3	4	5	6	7	8	9	10	11	13	14	15	16	17	18	19	20
131	- *hungarica* Grun.	+	+	+	+	+													+	+
132	- *levidensis* group *salinarum*																			
133	- *linearis* (Agardh) W. Smith	+	+	+	+	+	+	+		+	+		+	+	+	+	+	+		
134	- *microcephala* Grun.	+	+	+	+	+	+		+					+			+		+	
135	- *recta* Hantzsch			+	+			+								+				
136	- *sigma* (Kütz.) W. Smith	+	+	+	+	+	+	+	+				+	+			+		+	
137	- *sigmoidea* (Nitzsch) W. Smith	+	+	+	+	+	+	+	+		+	+		+	+		+			
138	- *sinuata* (Thwaites) Grun.																			
139	- *subtilis* Grun.	+	+	+	+	+	+	+	+	+				+			+		+	
140	*Pinnularia* sp.				+		+	+		+			+							
141	- *appendiculata* (Agardh) Cleve		+																	
142	- *intermedia* (Lagerstedt) Cl.								+					+						
143	- *interrupta* W. Smith									+			+							
144	- *microstauron* (Ehr.) Cl.	+		+	+	+	+		+			+			+		+		+	+
145	- *subcapitata* Greg.									+										
146	- *viridis* (Nitzsch) Ehr.				+	+					+		+		+					
147	*Rhoicosphaenia abbreviata* (Agardh) Lange-Bertalot	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+	
148	*Skeletonema subsalsum*	+			+															
149	*Stauroneis* sp.														+		+			
150	- *smithii* Grun.		+			+		+		+	+					+	+	+		
151	*Stephanodiscus astrea* (Ehr.) Grun.				+		+													
152	- *hantzschii* Grun.	+	+		+		+												+	
153	*Surirella angusta* Kütz.	+	+	+	+	+	+		+	+	+					+				
154	- *biseriata* Bréb.			+					+		+									
155	- *brebissonii* Krammer et Lange-Bertalot / *brebissonii* var. *kuetzingii* Krammer et Lange-Bertalot	+	+	+	+	+	+	+	+	+	+	+	+		●	+	+	+	+	+
156	- *crumena* Bréb.					+					+									
157	- *linearis* W. Smith	+		+	+	+			+	+				+				+	+	
158	- *tenera* Gregory					+			+	+										
159	*Tabellaria flocculosa* (Roth.) Kütz.	+							+				+							

160	*Thalassiosira pseudonana* Hasle et Heimdal			+	+		+													
161	- *weissflogii* (Grun.) Fryxell et Hasle			+	+															
	CHLOROPHYTA																			
162	*Cladophora glomerata* (L.) Kütz.	●	●									●		●			+		+	
163	*Closterium* spp.	+	+	+		+	+	+											+	
164	*Cosmarium* spp.	+	+	+	+	+	+	+												
165	*Enteromorpha* sp.	+	+	+	+	●	●	+	●											
166	*Microspora amoena* (Kütz.) Rabenh.									+										
167	*Mougeotia* sp.		+								+		+							
168	*Pediastrum* spp.	+	+	+	+	+	+	+									+		+	
169	*Penium* spp.																		+	
170	*Scenedesmus* spp.	+	+	+	+	+	+	+					+				+	+	+	+
171	*Spirogyra* sp.																			

Table III. *continued*

	Species	Stations																		
		22	23	24	25	26	27	28	29	30	31	32	33	35	36	37	38	39	40	41
	CYANOBACTERIA																			
1	*Oscillatoria tenuis* Ag.		●					+												
2	*Phormidium autumnale* Ag. Gom.	+						+			+									
	EUGLENOPHYTA																			
3	*Euglena* spp.		+								+									
	XANTHOPHYCEAE																			
4	*Vaucheria* sp.										+									
	BACILLARIOPHYCEAE																			
5	*Achnanthes biasolettiana* var. *biasolettiana* Grun. in Cleve et Grun.											+					●	+		+
6	- *lanceolata* Bréb. Grun.	+	+	+	+	+	+	+	+	+	+			+	+			+	+	
7	- *lanceolata* var. *dubia* (Grun.) Lange-Bertalot														+					
8	- *lanceolata* var. *havnaldii* (Schaar Schmidt) Cl.					+				+				+	+				+	
9	- *lanceolata* ssp. *rostrata* (Oestrup) Lange-Bertalot							+			+									
10	- *minutissima var. gracillima* (Meister) Lange-Bertalot									+				+						●
11	- *minutissima var. minutissima* Kütz.	+	+	+	+	+	+	+	+	+	+	●	●	●	●	●	●	●	+	●
12	*Actinocyclus normanii* (Greg ex Greville) Hust.																			
13	*Amphora coffeaeformis* (Agardh) Kütz.										+									
14	- *ovalis* (Kütz.) Kütz.		+	+		+		+	+		+			+	+	+	+		+	+
15	- *pediculus* (Kütz.) Grun.	+		+	+	+	+	+	+	●	+			+	+	+			+	+
16	- *veneta* Kütz.										+									
17	*Asterionella formosa* Hassall		+								+									
18	*Aulacoseira alpigena* (Grun.) Krammer		+								+									
19	- *granulata* (Ehr.) Simonsen		+					+												
20	*Bacillaria paradoxa* Gmelin			+		+		+	+		+								+	
21	*Caloneis amphisbaena (Bory) Cl.*		+		+	+		+	+	+						+			+	
22	- *bacillum* (Grun.) Cl.	+							+		+			+						
23	- *silicula* (Ehr.) Cl.									+									+	
24	*Cocconeis pediculus* Ehr.		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	●	●	+
25	- *placentula* var. *euglypta* Ehr.	+	●	+	+	+	+	+	+	+	●	+	+	+	+	+	+	+	+	+

26	*Coscinodiscus* sp.																			
27	*Cyclotella* sp. 1							+			+									
28	*Cyclotella* sp. 2																			
29	- *atomus* Hust.		+																	
30	- *meneghiniana* Kütz.				+	●	+	●	+	+	+	●	+	+	+	+	+	+	●	+
31	- *pseudosteligera* Hust.																			
32	- *radiosa* (Grun.) Lemmermann							+			+			+		+		+		
33	*Cymatopleura elliptica* (Bréb.) W. Smith		+					+			+				+	+				+
34	- *solea* (Bréb.) W. Smith	+	+	+	+		+	+	+	+	+			+	+	+		+	+	+
35	- *solea* var. *apiculata* (W. Smith) Ralfs		+					+	+		+									
36	*Cymbella affinis* Kütz.		+			+	+	+		+	+	+	●	+	+	+	●	+	+	+
37	- *cistula* (Ehr.) Kirchner																			
38	- *ehrenbergii* Kütz.																			
39	- *lanceolata* (Ehr.) Kirchner									+			+	+	+	+	+	+		+
40	- *microcephala* Grun.																			+
41	- *minuta* Hilse / *silesiaca* Bleisch	+	+	+	+	+	+	+		+	+	+	+	●	+	+	●	+	+	+
42	- *naviculiformis* Auerswald		+		+				+											+
43	- *perpusilla* Cleve-Euler										+									
44	- *prostrata* (Berkeley) Cleve													+					+	+
45	- *sinuata* Gregorg		+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
46	*Denticula tenuis* Kütz.										+			+	+		+			+
47	*Diatoma ehrenbergii* Kütz.		+					+		+										
48	- *moniliformis* Kütz.		+	+				+			+									
49	- *tenuis* Agardh		+		+		+	+						+		+	+	+		
50	- *vulgaris* Bory	+	+		+	+	+	+		+	+	+	+	+	+	+	+	+	+	+
51	*Enthomoneis paludosa* var. *subsalina* (Cleve) Krammer																			
52	*Epithemia adnata* (Kütz.) Bréb.		+					+								+				+
53	*Eunotia pectinalis* (Dillwyn) Rabenh.										+									
54	*Fragilaria arcus* (Ehr.) Cl.																			
55	- *capucina* Desmazieres				+			+	+		+				+	+	+		+	+
56	- *capucina* var. *mesolepta* (Rabenh.) Rabenh.							+			+			+	+	+				
57	- *capucina* var. *vaucheriae* (Kütz.) Lange-Bertalot	+	+			+	+	+		+	+	+		+	+	+	+	+	+	+
58	- *crotonensis* Kitton																			+
59	- *famelica* (Kütz.) Lange-Bertalot										+									
60	- *fasciculata* (Agardh) Lange-Bertalot		+				+													
61	- *leptostauron* (Ehr.) Hust.			+												+				
62	- *parasitica* (W. Smith) Grun.	+	+	+		+		+			+									

Table III. *continued*

Species	Stations 22	23	24	25	26	27	28	29	30	31	32	33	35	36	37	38	39	40	41
63 - *parasitica* var. *subconstricta* Grun.		+														+			
64 - *pinnata* Ehr.		+	+	+	+				+				+	+	+				+
65 - *pulchella* (Ralfs.) Lange-Bertalot		+				+	+			+									
66 - *tenera* (W. Smith) Lange-Bertalot		+					+												
67 - *ulna* (Kütz.) Lange-Bertalot / var. *acus* (Nitzch) Lange-Bertalot	+	+	+	+		+	+		+	+	+	+	+	+	+	+	+	+	+
68 *Frustulia vulgaris* (Thwaites) De Toni	+	+					+	+		+									
69 *Gomphonema acuminatum* Ehr.																			+
70 - *angustatum* (Kütz.) Rab.	+	+	+	+			+	+	+	+	+	+							+
71 - *angustum* Agardh.			+	+		+	+	+	+	+			+	+	+	+	+	+	+
72 - *augur* Ehr.									+										
73 - *gracile* Ehr.				+					+	+								+	
74 - *olivaceum* (Hornemann) Bréb.	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
75 - *olivaceum* var. *calcareum* (Cleve) Cleve		+							+	+			+	+					
76 - *parvulum* (Kütz.) Kütz.	+	+	+	+						+								+	+
77 - *truncatum* Ehr.		+	+	+					+	+	+	+	+			+	+	+	+
78 *Gyrosigma acuminatum* (Kütz.) Rabenh.	+	+	+		+		+	+	+		+		+	+	+	+	+	+	+
79 *Hantzschia* sp.																			
80 - *amphioxys* (Ehr.) Grun.				+		+	+												
81 *Meridion circulare* (Greville) Ag.	+	+	+			+	+	+	+									+	
82 - *circulare* var. *constrictum* (Ralfs) Van Heurck		+																	
83 *Melosira* sp.																			
84 - *nummuloides* (Dillwyn) Ag.																			
85 - *varians* Ag.		+	+	+	+	+	+	+	+	+	+		●	+	+		●	+	+
86 *Navicula* spp.		+	+					+											
87 - *acomoda* Hust.																			
88 - *atomus* (Kütz.) Grun.				+															
89 - *bacillum* Ehr.			+		+			+					+		+	+			
90 - *capitata* Ehr.	+		+		+	+	+	+	+	+			+					+	
91 - *capitatoradiata* Germain	+	+	+	+	●	+	+	+	+	+	●	+	+	+	●	+	●	+	+
92 - *cincta* (Ehr.) Ralfs							+												
93 - *contenta* Grun.							+												

94	- *costulata* Grun.								+											
95	- *cryptocephala* Kütz.	+	+	+	+	+	+	●	+	+	+			+	+				+	
96	- *cuspidata* (Kütz.) Kütz.	+	+	+	+	+			+	+	+		+		+					
97	- *exigua* (Greg.) Grun.		+					+	+		+	+		+	+	+	+		+	
98	- *gastrum* (Ehr.) Kütz.																			
99	- *goeppertiana* (Bleisch) H.L. Smith	+	+								+									
100	- *lacunolanciniata* Lange-Bertalot et Bonik		+								+									
101	- *lanceolata* (Agargh) Ehr.	+	+	+	+	+	+	+	+	+	+			+		+		+	+	
102	- *menisculus* Schumann	+	●	+	+	+		+	+		+				+		+	+	+	
103	- cf. *menisculus* Schumann		+		+	+	+		+		+			+		+		+	+	+
104	- *minima* Grun.										+									
105	- *pupula* Kütz.		+	+					+	+	+			+					+	
106	- *pygmaea* Kütz.	+	+	+			+	+	+	+	+									
107	- *radiosa* Kütz.			+					+	+										
108	- *reinhardtii* Grun.																			
109	- *rhynchocephala* Kütz.		+		+			+			+									
110	- *subminuscula* Manguin		+		●						+									
111	- *tripunctata* (O.F. Müller) Bory	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
112	- *trivialis* Lange-Bertalot / *salinarum* Grun.		+	+	+	+			●		+									
113	- *veneta* Kütz.	+	+		+	+	+	+	+	+	+	●	+	+	+	+	+	+	+	+
114	- *viridula* (Kütz.) Ehr. / *slesvicensis* Grun.	+	+			+	+	+	+	+	+			+				+		+
115	- *viridula* var. *rostellata* (Kütz.) Cl.	+	+	+				+	+	+	+			+		+			●	
116	*Neidium affine* (Ehr.) Pfitzer		+						+		+									
117	- *dubium* (Ehr.) Cl.								+	+	+				+				+	
118	- *productum* (W. Sm.) Cl.			+																
119	*Nitzschia* spp.	+	+	+	+	+	+	+	+	+	+	+		+						+
120	- *acicularis* (Kütz.) W. Smith		+		+	+			+	+	+		+	+	+	+				
121	- *amphibia* Grun.	+						+		+	+									
122	- *angustata* Grun.			+	+	+	+	+	+	+	+		+		+			+		
123	- *calida* Grun.		+	+			+		+		+									
124	- *capitellata* Hustedt / *palea* (Kütz.) W. Smith	+	+	+	+	+	●	+	+	+	●	+		+	+	+	+	+	+	+
125	- *constricta* (Kütz.) Ralfs			+	+	+	+		+	+			+		+			+		
126	- *dissipata* (Kütz.) Grun.		+	+	+	+		+	+	+	+	+		+	+	+		+	+	+
127	- cf. *dubia* W. Smith	+							+		+									
128	- *filiformis* (W. Smith) Van Heurck										+									
129	- *frustulum* (Kütz.) Grun.		+					+			+									
130	- *hantzschiana* Rabenh.				+	+			+			+		+	+	+	+	+	+	+

Table III. *continued*

	Species	Stations																		
		22	23	24	25	26	27	28	29	30	31	32	33	35	36	37	38	39	40	41
131	- *hungarica* Grun.		+					+												
132	- *levidensis* group *salinarum*								+											
133	- *linearis* (Agardh) W. Smith		+	+	+		+	+	+		+			+	+	+		+	+	
134	- *microcephala* Grun.										+									
135	- *recta* Hantzsch	+	+	+				+	+	+					+	+			+	
136	- *sigma* (Kütz.) W. Smith		+	+			+	+	+		+									
137	- *sigmoidea* (Nitzsch) W. Smith	+	+		+		+	+	+		+					+				
138	- *sinuata* (Thwaites) Grun.										+			+	+	+				+
139	- *subtilis* Grun.		+	+					+	+	+			+				+	+	
140	*Pinnularia* sp.		+	+				+			+									
141	- *appendiculata* (Agardh) Cleve									+	+									
142	- *intermedia* (Lagerstedt) Cl.		+					+												
143	- *interrupta* W. Smith				+															
144	- *microstauron* (Ehr.) Cl.		+				+	+			+									
145	- *subcapitata* Greg.			+	+															
146	- *viridis* (Nitzsch) Ehr.		+					+	+		+									
147	*Rhoicosphaenia abbreviata* (Agardh) Lange-Bertalot	+	+		+	+	+	+	+	+	+	+		+	+	+	+	+	+	+
148	*Skeletonema subsalsum*																			
149	*Stauroneis* sp.		+						+		+									
150	- *smithii* Grun.			+					+	+	+									
151	*Stephanodiscus astrea* (Ehr.) Grun.																			
152	- *hantzschii* Grun.																			
153	*Surirella angusta* Kütz.		+	+					+					+	+			+		
154	- *biseriata* Bréb.									+										
155	- *brebissonii* Krammer et Lange-Bertalot / *brebissonii* var. *kuetzingii* Krammer et Lange-Bertalot	+		●	+	+	+	+	+	+	+	+		+	+	+		+		
156	- *crumena* Bréb.																			
157	- *linearis* W. Smith	+	+			+		+	+		+			+						
158	- *tenera* Gregory					+			+											
159	*Tabellaria flocculosa* (Roth.) Kütz.		+					+												

160	*Thalassiosira pseudonana* Hasle et Heimdal																		
161	- *weissflogii* (Grun.) Fryxell et Hasle																		
	CHLOROPHYTA																		
162	*Cladophora glomerata* (L.) Kütz.			+					+		●	●		●	●			●	
163	*Closterium* spp.	+		+			+			+	+							+	+
164	*Cosmarium* spp.	+								+									+
165	*Enteromorpha* sp.																		
166	*Microspora amoena* (Kütz.) Rabenh.																		
167	*Mougeotia* sp.	+								+			+			+			●
168	*Pediastrum* spp.	+								+		+						+	+
169	*Penium* spp.									+									
170	*Scenedesmus* spp.	+								+	+	+				+		+	
171	*Spirogyra* sp.									●									●

Table IV. Structure of benthic cyanobacteria and algae communities in the streams and rivers of the Cracow Province in 10–30 October 1994. Macroscopic thalli (scale of covering): 1 – small aggregations, 2 – <25%, 3 – 25–50%, 4 – 50–75%, 5 – 75–100%. Numerous diatom species (>10%) and their abundance (cell number in 10 microscopic fields): 1 – 20–50, 2 – 51–100, 3 – 101–150, 4 – 151–200, 5 – 201–250, 6 – 251–300, 7 – >300.

Species	Groups of stations																			
	IA									*IB*				II						
	1	2	3	4	5	6	7	8	27	40	26	28	32	33	35	36	37	38	39	41
Macroscopic algae																				
Aggregations of diatoms	1	1	3	4	3	2	1		5	3	5	4		4	5	5	4	5	5	5
Oscillatoria tenuis			3		1	2	4					1								
Phormidium autumnale	1			1								1								
Cladophora glomerata	5	3								4			5	4		5	4			
Enteromorpha sp.	1	1	2	2	3	3	1	5												
Microspora amoena																				
Mougeotia sp.		1													1			2		3
Spirogyra sp.							1													3
Vaucheria sp.																				
Bacillariophyceae																				
Achnanthes spp.										2			2	7	2	4	3	7	2	7
Amphora coffeaeformis	2																			
– *pediculus*																				
Bacillaria paradoxa				3																
Cocconeis spp.										3									3	
Cyclotella meneghiniana					7	6	7	2		6	3	2	4							
Cymbella spp.														4	2			7		
Diatoma vulgaris																				
Fragilaria fasciculata			2																	
– *pinnata*																				
– *pulchella*			3					2												
Gomphonema parvulum								2												
Melosira varians															2				3	

Navicula capitatoradiata											2		2				2		2	
– *cryptocephala*												1								
– *lanceolata*																				
– *menisculus*																				
– *subminuscula*																				
– *tripunctata*	2	1							2											
– *trivialis* + *N. salinarum*																				
– *veneta*													3							
– *viridula* var. *rostellata*										3										
Nitzschia dissipata																				
– *frustulum*		3	4	6																
– *palea* + *N. capitellata*	3	2	2	2	3	3	3		3											
Surirella spp.																				
Total number of taxa	100	101	99	109	92	99	76	87	41	51	43	75	29	23	55	48	46	32	38	47

Table IV. *continued*

Species	Groups of stations																	
	III															IV		
	10	11	13	14	15	17	18	19	20	22	23	24	25	29	31	9	16	30
Macroscopic algae																		
Aggregations of diatoms	5			4				5			4		5	5				5
Oscillatoria tenuis						1					3							
Phormidium autumnale			1		1			2	1	1					1			
Cladophora glomerata		3		4		2		2					2					1
Enteromorpha sp.																		
Microspora amoena																2		
Mougeotia sp.	1		1								1				5			
Spirogyra sp.								1			1				5			
Vaucheria sp.							1		1						5	2		
Bacillariophyceae																		
Achnanthes spp.			1		1											1		
Amphora coffeaeformis																		
– *pediculus*							1		1									3
Bacillaria paradoxa																		
Cocconeis spp.		5			1	2					3				2			
Cyclotella meneghiniana																		
Cymbella spp.																		
Diatoma vulgaris		3		2				3										
Fragilaria fasciculata																		
– *pinnata*																	1	
– *pulchella*																		
Gomphonema parvulum																		
Melosira varians																		

Navicula capitatoradiata																		
– *cryptocephala*			1															
– *lanceolata*					1	2												
– *menisculus*											4							
– *subminuscula*													2					
– *tripunctata*																		
– *trivialis* + *N. salinarum*	2			3										1				
– *veneta*																		
– *viridula* var. *rostellata*																		
Nitzschia dissipata								3										
– *frustulum*																		
– *palea* + *N. capitellata*				3											2			
Surirella spp.					1							1						
Total number of taxa	60	41	63	73	56	70	39	79	32	39	89	51	51	66	101	53	52	58

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