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# Communities of sessile algae in the River Dunajec, above and below the dam reservoirs of Rożnów and Czchów (Southern Poland)*

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Abstract — Sessile algae of the River Dunajec were studied in the region of two dam reservoirs. *Cladophora glomerata* was dominant, along with diatoms. Above the reservoirs, where the river was polluted, *Nitzschia palea* and *Navicula cryptocephala* were the most common species. *Sphaerotilus natans* was also present. Below the reservoirs the quality of the water improved; an increase in the number of diatom species was recorded, with a preponderance of *Navicula viridula* var. *avenacea*, *N. gracilis*, *Nitzschia dissipata* and *Achnanthes minutissima*. The decreasing number of clean water species demonstrates the increasing pollution of the river.

Key words: rivers, regulated streams, sessile algae, pollution.

## 1. Introduction

The construction of a dam reservoir or a series of several reservoirs has a considerable effect on a river. This is shown by physico-chemical changes of the water conditions, with a concurrent change in plant and animal communities. The river also affects the reservoir. Studies of the influence of dam reservoirs on rivers and vice-versa are carried out all over the world, and the problem is known as regulated stream (Ward, Stanford 1979). On the one hand, such studies have a purely scien-

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tific value and on the other they make it possible to predict the behaviour of future reservoirs, whether built on a given river or a different one of similar character. In the case of the Dunajec this is of some importance, since two new dam reservoirs are being built in its upper reaches (Czorsztyn and Sromowce Wyżne), similar in character to the ones at Rożnów and Czchów, which are currently being studied.

The algae of the Dunajec in the region of the Rożnów and Czchów dam reservoirs have already been studied (Siemińska 1952, Biernacka 1959, Bucka 1965, Chudybowa 1965). Data concerning the Dunajec may also be found in hydrobiological and ecological papers (Turoboyski 1979, Kawecka, Szczęsny 1984).

The aim of the present study was to investigate the communities of sessile algae in the region of the Rożnów and Czchów dam reservoirs and to indicate the differences which may be observed in the algal flora of the Dunajec, before and after its waters have run through the reservoirs. Changes observed in the communities of sessile algae are analysed in comparison both with earlier studies and with those of seston algae (Bucka 1986).

## 2. Study area

Algological studies were carried out on a sector of the Dunajec between the 101st and the 67th kilometre of its course, measured from the mouth. The riverbed is of flysch deposit rocks, with clayey shales predomimating. The river here is dammed twice and forms two reservoirs — Rożnów and Czchów. The Rożnów reservoir, used for power generation, had an initial volume of $228 \times 10^6$ m$^3$ after its construction was completed in 1941. At present, owing to continuous silting up, its volume is much smaller, about $150 \times 10^6$ m$^3$. The reservoir, which is of rheolimnic type (Siemińska 1965), has an area of 1600 ha and is 22 km long, the maximum depth being 31 m (Ministry of Communication 1966?). The dam has a bottom outlet, which is not consequence for the physico-chemical and biological properties of the river below. At a distance of 12 kilometres below the Rożnów reservoir there is a second dam, which forms the smaller reservoir of Czchów. This is mainly of regulatory character, though it is also used for the generation of small amounts of electric power. Its volume is $12 \times 10^6$ m$^3$, its area 346 ha, its length 9 km, and the maximum depth 9.5 m (Ministry of Communication 1966?). In the backwater region of the Czchów reservoir, the small River Łososina runs into the Dunajec. The submontane River Dunajec has very large fluctuations of water flow (minimum 3 m$^3$ s$^{-1}$, maximum 3000 m$^3$ s$^{-1}$, the annual mean being 64—67 m$^3$ s$^{-1}$).

For the hydrochemical and hydrobiological studies conducted by the

Institute of Freshwater Biology, 8 sampling stations were chosen, 3 of which were on the Dunajec (Stations 1, 5, 8), 4 on the reservoirs (Stations 2, 3, 4, 7) and 1 on the Łososina (Station 6) (fig. 1). The present paper deals only with communities of algae in the zone of running water, i.e. at stations 1, 5, 6, and 8.

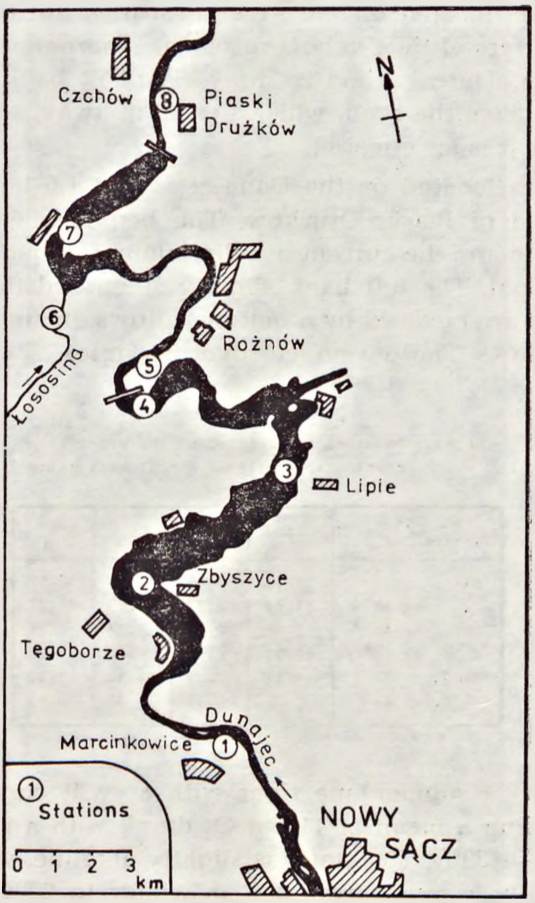


Fig. 1. Map of the study area

Station 1 was situated on the Dunajec at the village of Marcinkowice, about 2 km above the backwaters of the Rożnów reservoir. The river depth varies from 0.4—1 m at low and moderate water levels. The bed is stony gravel. The left bank is low with arable fields and pastures nearby, while the right hand bank is steep, covered by willows and grasses, and lies alongside the road. Ice covers the surface in winter.

Station 5 was located on the Dunajec about 600 m below the Rożnów dam and about 100 m below a suspension bridge. The riverbed is stony.

The banks are steep, the left one covered by mixed forest and the right hand one mainly by willows. The river depth and current are very variable and depend on the functioning of the power plant situated on the dam. The depth varies from less than one metre to several metres, while the current changes from very slow to rapid. There is no ice cover in winter, owing to the bottom outlet.

Station 6 was located on the River Łososina, not far from its outlet into the backwaters of the Czchów reservoir, approximately 500 m above the road bridge. The riverbed is stony. The left bank is a steep slope dropping down from the road, which lies 20 m away, while the left bank is flat. In winter it is ice covered.

Station 8 was located on the Dunajec, about 1.5 km below the dam, near the village of Piaski Drużków. The bed is of stony gravel. The depth is 0.6—1 m and the current usually laminar, though when the outlet is open it is rapid. The left bank slightly steep and the right hand one flat. Both banks are covered by a belt of willows, behind which lie arable fields and meadows. There is no ice cover in winter.

Table I. Chemical composition of the water at particular stations (annual mean values)

| Factors \ Stations | 1 | 5 | 6 | 8 |
|---|---|---|---|---|
| pH | 7.57 | 7.48 | 7.50 | 7.52 |
| $O_2$ mg $dm^{-3}$ | 11.42 | 9.92 | 12.73 | 11.47 |
| $BOD_5$ mg $dm^{-3}$ | 5.02 | 2.60 | 2.44 | 2.99 |
| $N\text{-}NH_4$ mg $dm^{-3}$ | 0.38 | 0.33 | 0.22 | 0.25 |
| $N\text{-}NO_3$ mg $dm^{-3}$ | 1.61 | 1.49 | 1.52 | 1.45 |
| $P\text{-}PO_4$ mg $dm^{-3}$ | 0.27 | 0.14 | 0.15 | 0.13 |

The Dunajec, a submontane river with a swift current, is well oxygenated, providing a mean of 11 mg $O_2$ $dm^{-3}$, with a high degree of saturation, i.e. 64—133%. The water is slightly alkaline, with a pH 7.1—8.0. Water temperatures range from 0°C in winter to 22°C in summer. The temperature of the water below the dams is lower than that above in summer and the opposite in winter, owing to the bottom outlet. The Dunajec is polluted with municipal sewage and with industrial wastes, mainly from the town of Nowy Sącz above the Rożnów reservoir (Station 1). Thus, the $BOD_5$ is distinctly higher here than at the remaining stations. Similarly, the content of ammonia, phosphates, and nitrates is higher (Table I). In winter, the levels of phosphates and nitrates are two to three times higher, since these compounds are not readily taken up by algae (unpublished data of the Institute of Freshwater Biology, Polish Academy of Sciences).

## 3. Material and methods

Collection and determination of the amount of material was based on methods described by Starmach (1969), Kawecka (1980), and Wasylik (1971). The study material was collected in the period from X 1982 to IX 1983, on the following days: 12 X, 16 XI, and 14 XII 1982, and 25 I, 1 III, 13 IV, 17 V, 15 VI, 12 VII, 16 VIII, and 12 IX 1983. At each station, algae were taken from a number of habitats, i.e. from stones, from silt in the zone near the bank, and from living and dead parts of plants. Altogether 106 samples were taken. The material was preserved on the spot, using 4% formalin; some of the samples, however, were transported "live" to the laboratory, viewed under the microscope, and then preserved. About half of each sample was digested in chromic acid cleaning mixture. Later, after centrifuging and rinsing in distilled water, solid slides were made of the diatoms, using the synthetic resin pleurax. The degree of coverage by macroscopic algae was described in a five degree scale (Kawecka 1980). Microscopic analyses were carried out using a Zeiss-Amplival light microscope. After determining the species in three slides, the abundance of microscopic algae (other than diatoms) was assessed, using a 6 degree scale (Wasylik 1971). Diatoms were determined under an immersion objective and then counted at a magnification of 40 ×, using a micrometric net with 400 squares fitted in the eyepiece. Cells were counted in 10 microscopic fields. Appropriate degrees of coverage were assigned to particular species, i.e. the number of squares or the fraction covered by a cell of a given species. The size of cells, multiplied by the number of cells of a given species and again by a factor of 2, gives the coefficient of coverage. The sum of these coefficients for 10 microscopic fields gives the diatom biomass index (Starmach 1969, Kawecka 1980).

Those species which quantitatively constituted at least 10% in a minimum of 50% of the samples were regarded as dominants in a given season, while those constituting from 5 to 9.9% were classified as subdominants.

## 4. Results

In the material taken for algological analysis, 228 taxa were determined, of which diatoms were the most abundantly represented (76.7%); this is a phenomenon typical of many rivers. Over the entire investigated sector of the Dunajec, *Cladophora glomerata* (L.) Kütz. was decidedly dominant. It grew densely on the rocky riverbed, forming long thalli, sometimes even nearly a metre long. *Cladophora* occurred abundantly both above and below the two reservoirs. In turn, this alga was the

habitat of many species of microscopic alga. It was overgrown by a large number of various diatom species. Some thalli were also found with the epiphyte *Characium* cf. *gracilipes* Lambert growing on them. The development of many species of blue-green algae was also observed in the area studied. Most frequently encountered were filamentous forms of the genera *Phormidium* and *Oscillatoria*. In the zone near the bank, where the river current was weaker, the development of the green alga *Ulothrix zonata* (Weber et Mohr) Kütz., was noted, mainly at Station 1. In the winter flora of macroscopic algae *Hydrurus foetidus* (Vill.) Trev. dominated. Of the diatoms, *Cocconeis pediculus* Ehr. attained the highest coefficients of coverage. This diatom frequently grew profusely on filaments of *Cladophora*, covering older ones particularly densely. Differences in the numbers of diatoms of the genus *Cocconeis* did not depend on the station but on the stage of development reached by *Cladophora* at the moment of sampling. *Cladophora glomerata* grows most abundantly in spring and autumn, but the decisive factor here is the maintenance of a more or less constant water level for a long period of time. Sudden rises in the level, which are frequent in the Dunajec, destroy its thalli. At Station 1 above the Rożnów reservoir, *Sphaerotilus natans* Kütz. was often found, indicating considerable pollution of this river. Of the diatoms, *Nitzschia palea* (Kütz.) W. Sm. and *Navicula cryptocephala* Kütz. were the most abundant throughout the year. Between the reservoirs (Station 5) a decrease in the numbers of both these species and the development of *Cymbella ventricosa* Kütz. together with, to a smaller extent, *Rhoicosphenia curvata* (Kütz.) Grun. were observed. In summer, when blooms of *Aphanizomenon flos-aquae* (L.) Ralfs dominated in the reservoir, it could frequently be found in the river below it. Other planktonic forms such as green algae of the order *Chlorococcales* (*Pediastrum* spp., *Scenedesmus* spp., *Coelastrum* spp.), and the diatom *Melosira granulata* (Ehr.) Ralfs, were also common. In the small River Łososina (Station 6) the patterns of dominance varied, though *Achnanthes minutissima* Kütz. remained in the group of dominants all the year round, and the red alga *Chantransia pygmaea* Kütz. was a frequently encountered representative of macroscopic algae. At Station 8 below the Czchów reservoir, of the dominants the following species deserve mention: *Navicula gracilis* Ehr., *N. viridula* Kütz. var. *avenacea* (Bréb.) Grun., *N. cryptocephala* Kütz., together with the variety *N. cryptocephala* var. *veneta* (Kütz.) Grun., and *Nitzschia dissippata* (Kütz.) Grun., and *Achnanthes minutissima* Kütz.

The dominant species for particular seasons and stations are presented in fig. 2. The small area of the field covered by *Achnanthes minutissima* gives a low degree of coverage, owing to its minute size, though the abundance of this species was in fact considerable.

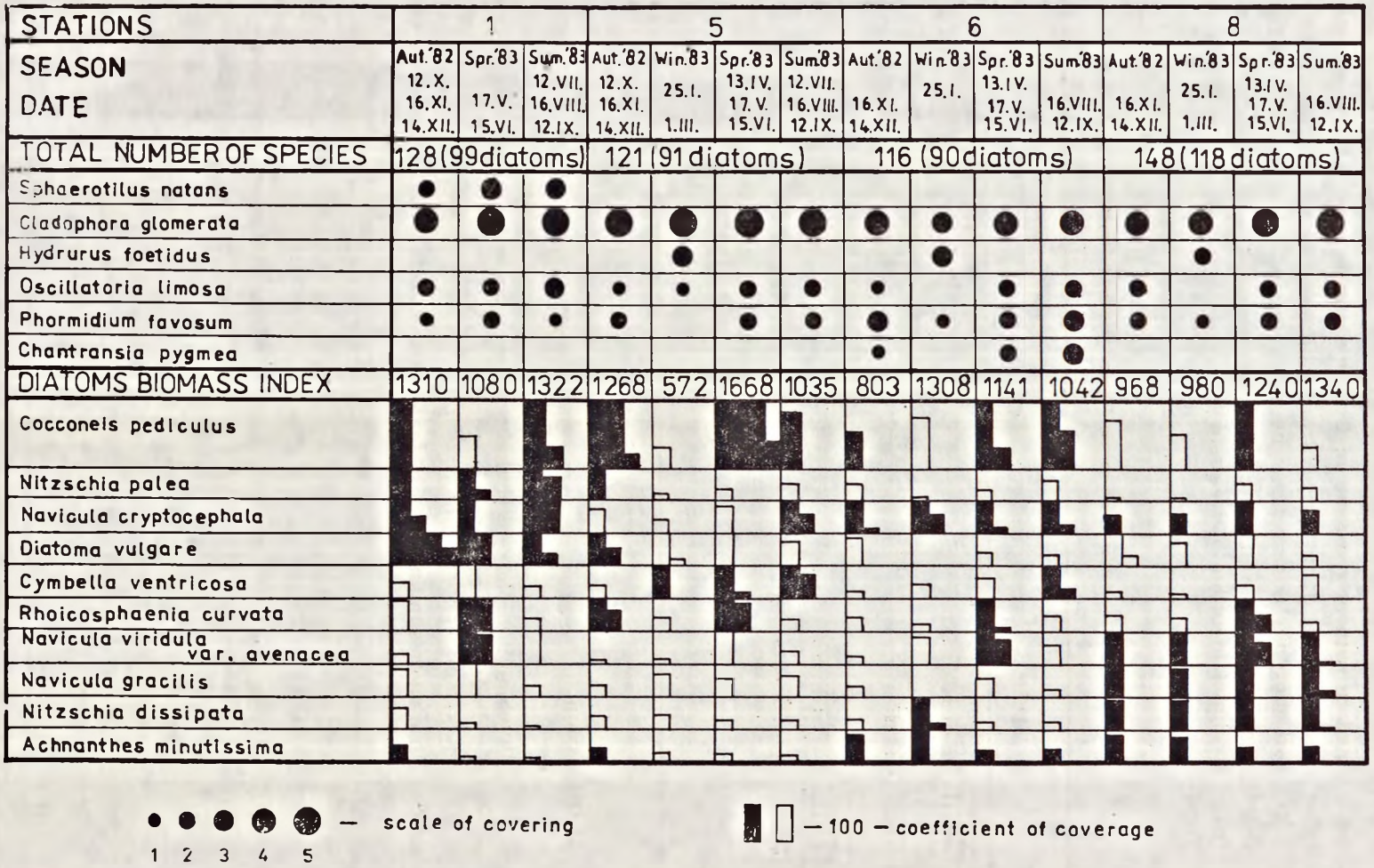


Fig. 2. Quantitative changes in dominant diatom species in the study area in particular seasons. Dark fields — species dominant in a given season, light fields — non-dominant in a given season. Scale of coverage after K a w e c k a (1980)

The biomass index of diatoms varied, its value deppending mainly on state of growth at the time of *Cocconeis pediculus* Ehr., and the other species of this genus, present in smaller numbers, i.e. *C. placentula* Ehr. var. *euglypta* (Ehr.) Cl. The mean values of biomass indices for diatoms in a given season are also presented in fig. 2. Subdominant diatoms, arranged in order of frequency of their occurrence, are given in Table II.

Table II. Subdominants among diatoms at particular stations

| Station | Species | Station | Species |
|---|---|---|---|
| 1 | Gomphonema olivaceum (Lyngb.) Kütz.<br>Synedra ulna (Nitzsch) Ehr.<br>Cyclotella meneghiniana Kütz.<br>Cymbella sinuata Greg.<br>Navicula minima Grun.<br>Cocconeis placentula Ehr. var. euglypta (Ehr.) Cl.<br>Surirella ovata Kütz. | 5 | Fragilaria vaucheriae (Kütz.) Peters.<br>Stephanodiscus astrea (Ehr.) Grun. var. minutulus (Kütz.) Grun.<br>Cyclotella meneghiniana Kütz.<br>Gomphonema olivaceum (Lyngb.) Kütz.<br>Melosira granulata (Ehr.) Ralfs<br>Cocconeis placentula Ehr. var. euglypta (Ehr.) Cl.<br>Cymbella sinuata Greg.<br>Diatoma anceps (Ehr.) Kirch. |
| 6 | Cyclotella meneghiniana Kütz.<br>Fragilaria vaucheriae (Kütz.) Peters.<br>Amphora ovalis Kütz. var. pediculus Kütz.<br>Cymbella sinusta Greg.<br>Gomphonema olivaceum (Lyngb.) Kütz.<br>Diatoma anceps (Ehr.) Kirch. | 8 | Fragilaria vaucheriae (Kütz.) Peters.<br>Amphora ovalis Kütz. var. pediculus Kütz.<br>Stephanodiscus astrea (Ehr.) Grun. var. minutulus (Kütz.) Grun.<br>Gomphonema angustatum (Kütz.) Rabh. var. productum Grun.<br>Gomphonema olivaceum (Lyngb.) Kütz.<br>Melosira varians Ag.<br>Cymbella sinuata Greg.<br>Cymbella lanceolata (Ehr.) V. H.<br>Cymbella cistula (Hemp.) Grun.<br>Nitzschia linearis W. Sm. |

## 5. Discussion

The investigation showed that the dominant species of alga was *Cladophora glomerata*. This is typical of many rivers, including Carpathian ones. The growth of *Cladophora glomerata* was described in detail earlier, in a river similar to the Dunajec, the Skawa (Chudyba 1965). In the present study, similar tendencies in the development of this species were observed. *Cladophora glomerata*, together with the diatoms which occur in abundance on its thalli, is called the *Cladophoretum glomerate* association (Margalef 1949).

The results of hydrochemical studies and the different algal associations of successive stations indicate distinctly that the quality of the river water is improved after passing through the reservoirs in which the uptake and settling of nutrients take place. This improvement is expressed mainly by the fall in numbers of *Nitzschia palea* and the gradual disappearance of the bacterium *Sphaerotilus natans*. The increase in the number of taxa at Station 8 is also a good illustration (Kadłubowska

1970). The favourable effect of the reservoirs on the water takes place on the 34 kilometre sector between the first station lying near to the source of pollution and the last one below the reservoirs. The inflow of water from the Łososina also has a favourable though slight effect.

Nevertheless, over the last 20 years the quality of the water has deteriorated considerably in the region studied. Previously, such species as *Ceratoneis arcus* Ehr., *Diatoma hiemale* (Lyngb.) Heib., or *Meridion circulare* Ag., which are all commonly regarded as clean water species, were frequently reported here (Bucka 1965, Chudybowa 1965). At present, speciments of these species are encountered only sporadically, but blooms of *Aphanizomenon flos-aquae* (L.) Ralfs (Bucka 1986) are observed in the Rożnów reservoir in summer. In the river, the dominant diatom species are *Nitzschia palea* and *Navicula cryptocephala*, i.e. those which tolerate heavy pollution (Palmer 1969). It would thus seen that the prospects for water quality in the near future are poor.

## 6. Polish summary

**Zbiorowiska glonów osiadłych w Dunajcu, powyżej i poniżej zbiorników zaporowych Rożnów i Czchów (Polska Południowa)**

Niniejsze opracowanie jest częścią kompleksowych badań hydrochemicznych i hydrobiologicznych Dunajca, prowadzonych przez Zakład Biologii Wód PAN w rejonie zbiorników zaporowych w Rożnowie i Czchowie. Badania glonów osiadłych prowadzono w cyklu rocznym na czterech stanowiskach, tj. powyżej, pomiędzy i poniżej zbiorników oraz na rzece Łososinie (ryc. 1). W tabeli I przedstawiono podstawowe wyniki analiz fizykochemicznych wody. W 106 próbach oznaczono 228 taksonów glonów, z czego większość stanowiły okrzemki. Na wszystkich stanowiskach zdecydowanie dominowała *Cladophora glomerata*, która z kolei była siedliskiem dla wielu innych glonów, głównie *Cocconeis* spp. W zimowej florze glonów obficie występował *Hydrurus foetidus*. Powyżej zbiornika Rożnów rzeka jest zanieczyszczona ściekami komunalnymi i przemysłowymi z Nowego Sącza. Odbiło się to wyraźnie na składzie gatunkowym glonów. Z okrzemek dominowały *Nitzschia palea* i *Navicula cryptocephala*, a więc te gatunki, które tolerują znaczne stężenie zanieczyszczeń. Często spotykana była również bakteria *Sphaerotilus natans*. Pomiędzy zbiornikami z okrzemek najliczniej rozwijały się *Cymbella ventricosa* i *Rhoicosphenia curvata*, liczne były też formy planktonowe spływające ze zbiornika (*Aphanizomenon flos-aquae*, *Melosira granulata* i zielenice chlorokokkowe). Poniżej zbiornika Czchów następuje wyraźna poprawa jakości wody, co jest zapewne wynikiem osadzania się zanieczyszczeń w zbiornikach i oddaleniem o 34 km ostatniego stanowiska od pierwszego. Poniżej Czchowa zaobserwowano wzrost liczby gatunków glonów, a wśród okrzemek dominowały *Navicula gracilis*, *N. viridula* var. *avenacea*, *N. cryptocephala* wraz z odmianą *N. cryptocephala* var. *veneta*, *Nitzschia dissipata* i *Achnanthes minutissima*. Dominujące gatunki glonów w badanym rejonie przedstawiono na ryc. 2, a subdominanty zestawiono w tabeli II. W porównaniu z po-

przednio prowadzonymi badaniami algologicznymi przez innych autorów w tym rejonie dał się zauważyć spadek liczebności gatunków uznawanych za czystolubne, takich jak: *Ceratoneis arcus, Diatoma hiemale* i *Meridion circulare*.

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