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A regulated river ecosystem in a polluted section of the Upper Vistula*

6. Communities of sessile algae

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Abstract — Ninety-seven species of sessile algae were identified. Variation in the character of the algal comunities was observed at particular stations along the river course. Changes concerned the number and abundance of the species, species composition, dominance relationships, magnitude of the biomass index of the diatoms and the size of the area occupied by the algae. Sections where the riverbed had a natural character showed the greatest variety and a mass development of algae.

Key words: regulated river, pollution, sessile algae, seasonal changes.

1. Introduction

Algological investigations of the Upper Vistula were initiated by Starmach (1938), and later continued by, among others, Turoboyski (1962), Kyselowa and Kysela (1966), Hanak-Schmager (1974), and Pudo (1977).

The aim of the present work was to describe the communities of sessile algae in a heavily polluted section of the River Vistula, below and above the water stage at Łączany and in that reservoir. Moreover, the effect of the water stage on these communities was assessed on the basis of the changes observed in their species composition and quantitative relationships.

2. Study area, material, and methods

The studies embraced a 25 km section of the river on which 6 stations were located (fig. 1). A detailed description of the study area and

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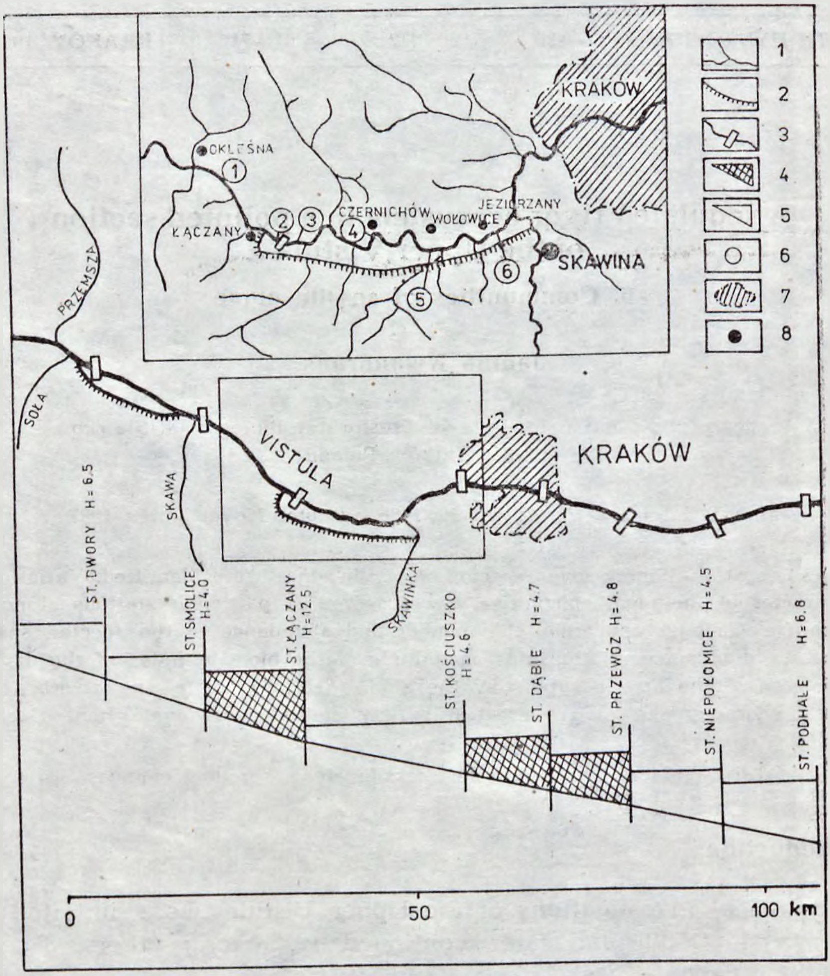

Fig. 1. The Upper Vistula, showing cascade building and stations on the investigated river section. 1 — rivers; 2 — canal; 3 — water stages, dams; 4 — water stages built; 5 — water stages under construction and planned; 6 — stations; 7 — cities; 8 — towns and villages

stations has been given by Dumnicka and Kownacki (1988).

The material for study was collected at 4—6 week intervals during the period from December 1982 to December 1983. In the zone near the bank, samples of algae together with bacterial coatings were collected from stones, silt, and the living and dead parts of higher plants. Samples from greater depths were taken using an Ekman grab fixed on a pole. The material was preserved using a 4% formalin solution. Permanent diatom slides, embedded in artificial pleurax resin, were made from part of it (Kawecka 1980).

The characteristics of the material and the method of calculation of data were based on algological methods (Starmach 1969, Kawecka 1980). In applying them, quantitative analysis was carried out by estimation. In the case of organisms forming macroscopic aggregations the percentage of their occurrence was assessed on a selected area of the bottom (about 1 m^2), using a 5-grade scale of coverage: 1) organisms forming small aggregations, 2) organisms covering up to 25% of the surface of the bottom, 3—5 those with coverages of 25—50%, 50—75%, and 75—100%, respectively.

Among the macroscopic algae those attaining a degree of coverage of 3 or more were considered as dominants. Quantitative analysis of microscopic forms (mainly diatoms) was carried out by counting the cells of particular species in 10 microscopic fields of view, limited to the outline of the micrometric grid, at a 40× magnification of the objective and a 10× one of the eyepiece.

On the basis of percentage shares the dominants were picked out, these being species that attained a share of at least 10% in the community. Later the approximate area of the cells of particular species of diatom was determined and related to the area of one square of the micrometric grid. Next, the coefficient of coverage was calculated by multiplying the number of cells of a given species by the average size of a cell. Multiplication of this value by 2 gave a conventional assimilation area of the algal cells. By summing up the values of the coefficients of coverage, the index of diatom biomass was obtained for each station (Kawecka 1980).

The share of bacteria, that were a significant component of the sessile communities, was assessed macroscopically. Their identification was carried out under the microscope, only those bacteria being determined which, owing to size, were identifiable by morphological features.

3. Results

3.1. Communities of alga along the river course

Altogether, 97 taxa of algae were determined. This number did not include species that, in relation to the total number of individuals at a station, occurred in very small quantities. Bacillariophyceae were the dominating group with respect to the number of taxa (Table I), but a considerable quantity of these were dead cells (especially at Stations 1—4).

The number of algal species was smallest at Station 1, and greatest at Stations 5 and 6 with a bed that was typically riverine in character. At Stations 1—4 the algae developed only within a narrow zone, some tens of centimetres wide, near the banks. Further along the river profile numerous bacteria, single specimens of filamentous blue-green algae, and empty diatom frustules were found. In contrast, at Station 5, profuse communities of sessile algae with a varied species composition occurred over the whole width of the riverbed. At Station 6 also, a few metres from the banks, filamentous forms and living diatom cells still occurred, covering the macroscopic plants (mainly *Potamogeton* sp.) plants.

Between stations there were also differences in the structure of

Table I. Floristic spectrum of the River Vistula (percentage share of species in the community). In brackets number of species

Systematic groups	Stations					
	1	2	3	4	5	6
Cyanophyta	3.8 /2/	7.3 /4/	7.0 /4/	3.5 /2/	5.8 /4/	5.6 /4/
Euglenophyta	11.3 /6/	7.3 /4/	5.3 /3/	8.4 /5/	4.4 /3/	5.6 /4/
Bacillariophyceae	81.1 /43/	78.1 /43/	80.7 /46/	79.7 /47/	81.1 /56/	80.3 /57/
Chlorophyta	3.8 /2/	7.3 /4/	7.0 /4/	8.4 /5/	8.7 /6/	8.5 /6/
Total number of species	53	55	57	59	69	71

dominance and species composition of the algal communities. At Station 1, filamentous and zoogloeal aggregations of bacteria had a large share (*Sphaerotilus natans* Kütz., *Beggiatoa alba* (Vauch.) Trev., *Zoogloea* sp.). In comparison with the other stations, diatoms developed poorly, their biomass index being lowest here (fig. 2). Among the dominating species of alga, the highest values of the coefficient coverage were attained by *Nitzschia palea* with its *tenuirostris* variety and by *Navicula viridula* (fig. 2). The green algae *Stigeoclonium tenue* (Agardh) Kütz. and *Schizomeris leibleinii* Kütz. had a large share in the community, blue-green algae, represented chiefly by *Phormidium autumnale* (Agardh) Gomont (fig. 3), occurring in smaller quantities. Of the group of euglenins the species *Euglena viridis* Ehrenberg was numerously found here.

Within the water stage (Station 2) bacteria were still very abundant but the quantitative share of diatoms increased. *Nitzschia palea* with its *tenuirostris* variety achieved the highest coefficient of coverage. The index of diatom biomass was high (fig. 2). Of the macroscopic algae, the blue-green alga *Phormidium autumnale* and the green alga *Stigeoclonium tenue* dominated. The number of representatives of green algae also increased (fig. 3). Of the euglenins, the genus *Trachelomonas* frequently occurred, and *Euglena viridis* was still abundant.

Below the water stage (Station 3) algae achieved a decisive preponderance, the number of bacteria falling considerably, similarly as that of the euglenins. Diatoms were numerously represented by species of the genus *Navicula*, *Gomphonema angustatum* var. *productum*, and

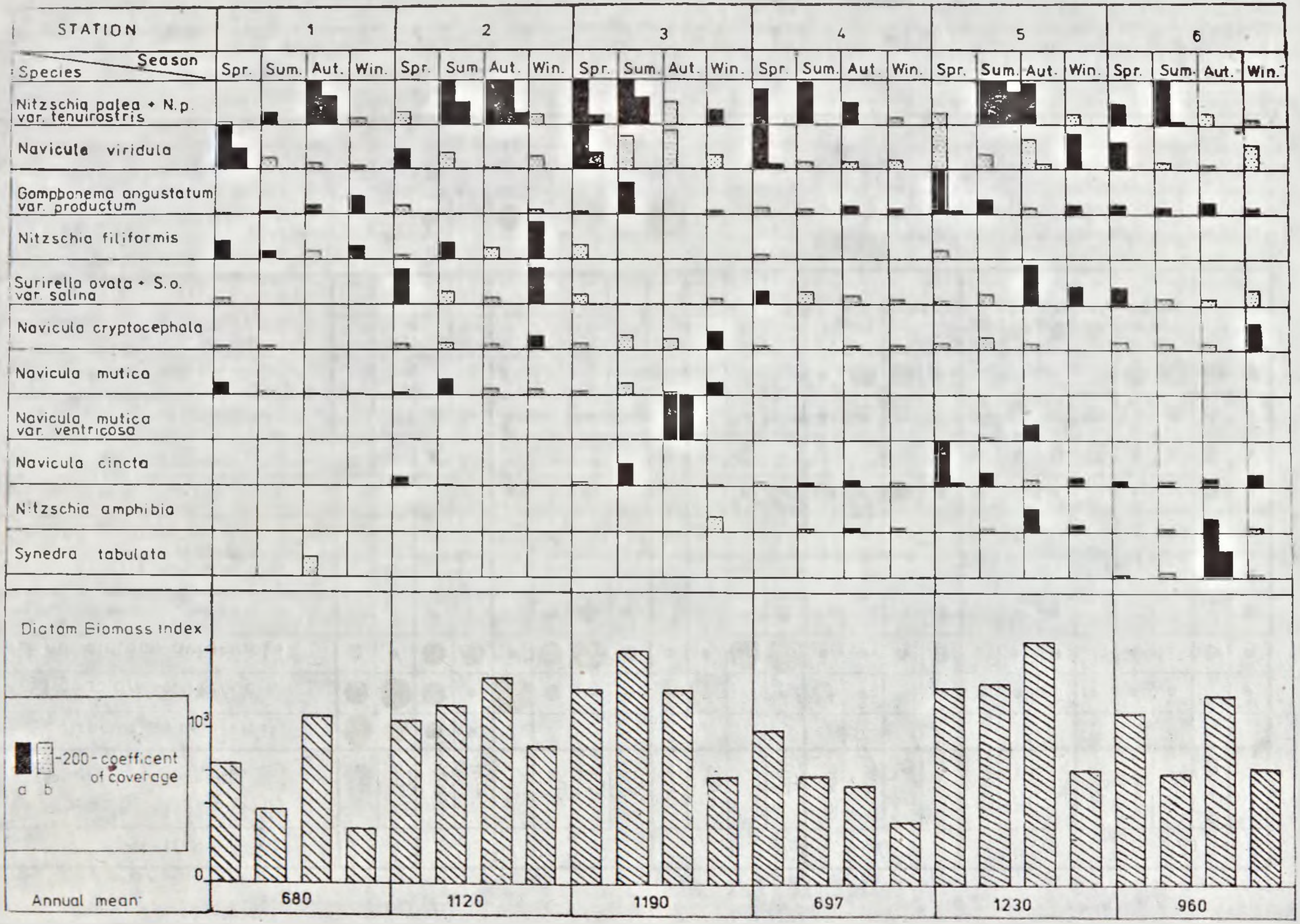

Fig. 2. Seasonal changes in dominating diatoms at particular stations. a — species dominant in a given season, b — non-dominant in a given season

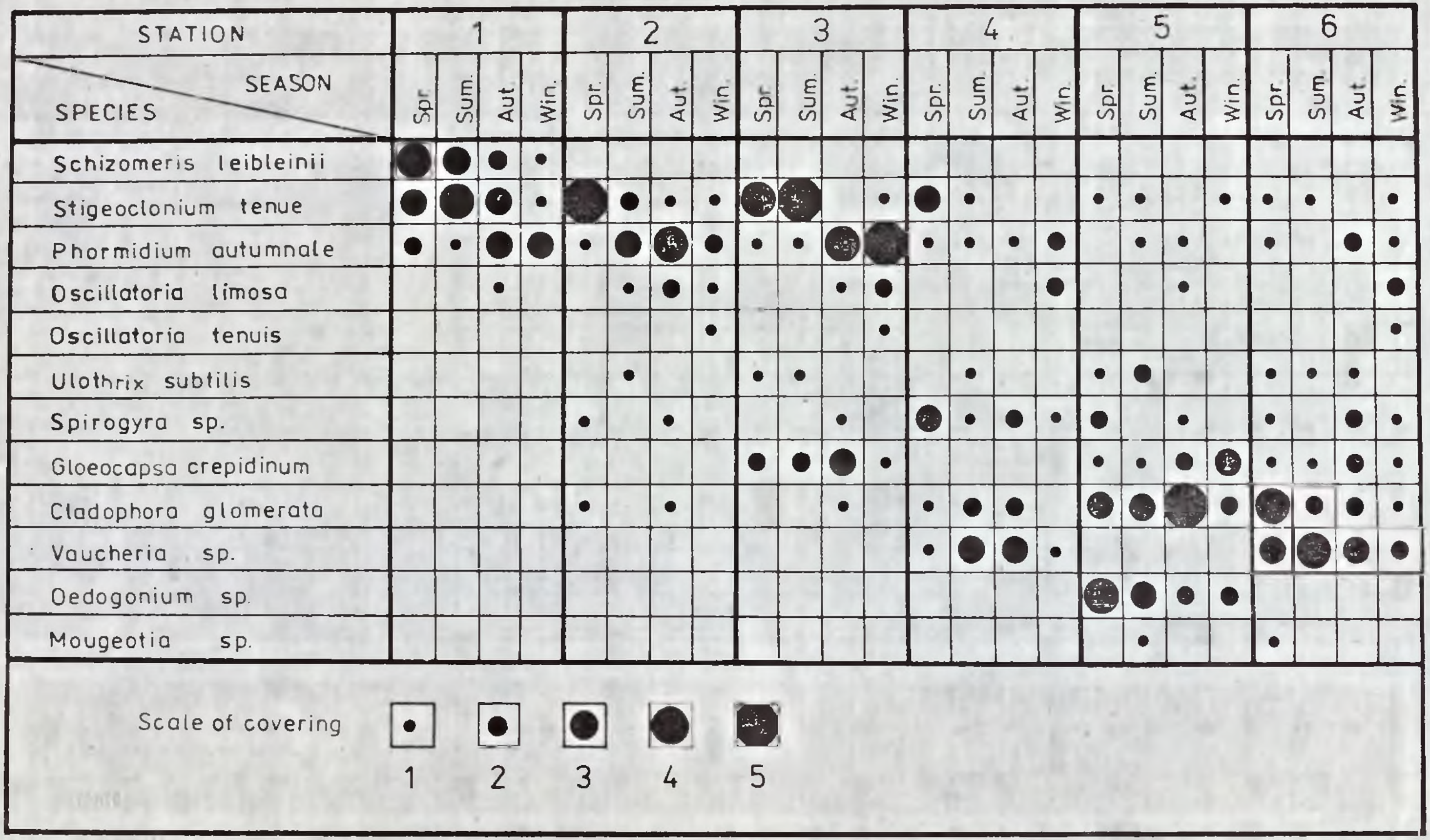

Fig. 3. Seasonal changes in macroscopic algal communities at particular stations

a species with the highest coefficient of coverage, namely *Nitzschia palea*, with its *tenuirostris* variety (fig. 2).

The index of diatom biomass also reached high values (fig. 3). Macroscopically, the greatest areas were occupied by the blue-green algae *Phormidium autumnale* and *Gloeocapsa crepidinum* Thuret, while of green algae the species *Stigeoclonium tenue* was still numerous (fig. 3). The number of euglenas, however, decreased.

At Station 4 the number of bacteria again rose. With respect to the dominance relationships of the diatoms, their low number, and low biomass index this station was similar to Station 1 (fig. 2). Of the macroscopic algae, in shallow places with a slow current, the following green algae developed well: *Vaucheria* sp., *Spirogyra* sp., *Stigeoclonium tenue*, and also, to a smaller degree, *Cladophora glomerata* (L.) Kütz. (fig. 3). Of the euglenins the share of the species *Euglena viridis* was great.

From Stations 5 and 6 the algal communities changed in character. The number of bacteria decreased markedly while algae developed profusely. An increase took place in the number of diatoms, their biomass index reaching the highest values at Station 5 (fig. 2). In the group of diatoms the dominance relationships were similar at the two stations. The species *Nitzschia palea* with its *tenuirostris* variety had the highest values of the coefficient of coverage, while at Station 6, besides that species, so had *Synedra tabulata* (fig. 2). Green algae developed very abundantly. *Cladophora glomerata* occurred at Station 5 in the form of filaments several metres long in the whole cross-section of the river; *Oedogonium* sp. appeared in large quantities, and at Station 6, besides *Cladophora*, *Vaucheria* sp. covered considerable areas (fig. 3). Like the euglenins, the blue-green algae *Gloeocapsa crepidinum* and *Phormidium autumnale* developed less well.

3.2. Seasonal changes in the communities of algae

The structure of the algal communities underwent certain changes during the year with respect to the number of taxa, their abundance, and dominance relationships. The smallest number of species was observed in winter, the greatest diversity occurring in summer.

In the spring at all the stations green algae occurred in large quantities (fig. 3) as did the diatoms, which formed gelatinous coatings on the stones and profusely covered the thalli of algae of other groups.

In summer, green algae were still numerous, especially *Stigeoclonium tenue* and *Vaucheria* sp. Blue-green algae developed better only at Station 2 (fig. 3), the development of diatoms taking place variously at particular stations. At Stations 1, 4, and 6 the abundance of the diatoms decreased, increasing at the others.

In autumn, green algae seemingly showed a tendency to fall in numbers (except for the development of *Cladophora* at Station 5), while the quantitative increase in the blue-green algae was distinct, chiefly at Station 1, 2, and 3 (fig. 3), as was that of the diatoms, which attained a second maximum of development (fig. 2).

In winter the algal community was poorer. The number of green algae and diatoms decreased considerably. The blue-green algae *Phormidium autumnale* at Stations 1 and 3 and *Gloeocapsa crepidinum* at Station 5 (fig. 3) occurred in greater quantities.

The course of changes observed in the diatom biomass index varied according to the season (fig. 2). In spring it was high at all stations, in summer and autumn it showed variations between particular ones, its lowest values being observed in winter.

Varying trends were observed in the seasonal development of some dominating species of diatom (fig. 2). The species *Nitzschia palea* with its *tenuirostris* variety developed well the whole year round, with the best growth in summer and autumn. *Navicula cryptocephala* reached its maximum numbers in winter, and *Navicula viridula* in spring, *Navicula mutica* var. *ventricosa* and *Synedra tabulata* appearing in masses in autumn. *Nitzschia amphibia* showed a tendency to increase in number in autumn and winter. The other, more numerous species of diatom showed no distinct periodicity of occurrence.

4. Discussion

Overloading with sewage, a low content of oxygen, high salinity, and low transparency of the water create very unfavourable conditions for the development of algae in the studied section of the Vistula.

The sessile algae distinguished in the communities mostly belonged to common species, developing widely in polluted waters. Organisms found in masses or fairly numerously, such as the bacteria *Beggiatoa alba, Sphaerotilus natans,* or, of the algae, *Euglena viridis, Stigeoclonium tenue, Nitzschia palea,* or *Navicula viridula*, are called indices of strongly polluted and polluted zones (Turoboyski 1979). Their presence qualifies the studied section of the Vistula as strongly polluted water. Such a condition has also been confirmed by chemical investigations (Kasza 1988), microbiological ones (Starzecka 1988), and also by studies on the seston (Bednarz, Żurek 1988).

Most of the species of alga here observed were recorded in earlier studies on the periphyton of the Upper Vistula (Turoboyski 1962, Kyselowa, Kysela 1966, Hanak-Schmager 1974) with a much lower level of sewage. This shows that increasing pollution has not brought about drastic changes in the composition of the algal communities. Owing to the long-term loading of the Vistula with sewage it would appear that the algae have become adapted to life under such conditions. Moreover, the considerable increase in the quantity of chlorrides, from about 145.9 mg Cl dm^{-3} in 1964 (B o m b ó w n a, W r ó b e l 1966) to about 800—870 mg Cl dm^{-3} in 1982—1983 (K a s z a 1988) caused the mass development of halophilous species of diatom, such as *Nitzschia filiformis*, *Synedra tabulata*, and *Surirella ovata* var. *salina*.

As stated by P a t r i c k (1962) and K a d ł u b o w s k a (1964), with a rise in the degree of pollution a decrease takes place in the abundance and number of diatom species. The opposite would evidence improvement in the quality of the water. Thus, the differences observed between stations in the abundance of diatom specimens and the number of their species, and moreover changes in the size of the area occupied by the algae demonstrate that self-purification processes are taking place along the river course and are directly associated with the type of riverbed. At Stations 1 and 4, where the water flows in a deep, silted bed, forming numerous stagnant pools, and the access of light is considerably limited by the presence of large quantities of suspended matter, as in the reservoir itself (Station 2), algae developed only in a narrow zone beside the bank. The number of diatoms and thus also their biomass index were very small at Stations 1 and 4. At Station 3 below the water stage, there was an improvement in the quality of the water, accompanied by a fall in the number of bacterial associations and a rise in that of algae. The distinct change in the phytocenosis from Station 5 onwards was due to the natural character of the riverbed. The decrease in depth, the swift current (numerous rapids), and greater transparency of the water made possible the profuse development of varied communities of alga across the whole profile of the river (Station 5), or over a considerable width of the bed (Station 6).

The quantity and type of pollution, the great variation in water level associated with the functioning of the water stage, and the changing of light conditions owing to the decrease or increase in the amount of suspended matter were also probably responsible for the differences in the course of seasonal changes in the communities of sessile algae at particular stations.

5. Polish summary

Ekosystem uregulowanego i zanieczyszczonego odcinka Górnej Wisły

6. Zbiorowiska glonów osiadłych

W cyklu rocznym (od grudnia 1982 do grudnia 1983 r.) przeprowadzono na 6 stanowiskach badania zbiorowisk glonów osiadłych silnie zanieczyszczonego odcinka rzeki Wisły w rejonie progu wodnego w Łączanach (ryc. 1). Obserwacje miały na celu określenie wpływu stopnia wodnego na jakość wody na podstawie zmian ilościowych i jakościowych w zbiorowiskach glonów osiadłych.

W toku badań oznaczono 97 taksonów glonów. Najliczniej występowały Bacillariophyceae z dominującymi gatunkami z rodzaju *Navicula*, *Nitzschia*, *Synedra*, *Surirella* i *Gomphonema* (ryc. 2). Duży udział w zbiorowiskach posiadały zielenice, z których obficie rozwijały się: *Cladophora glomerata*, *Stigeoclonium tenue*, *Schizomeris leiblenii*, *Oedogonium* sp., *Spirogyra* sp., *Vaucheria* sp. Sinice były reprezentowane głównie przez rodzaj *Gloeocapsa* i *Phormidium* (ryc. 3).

Na wszystkich stanowiskach spotykano masowo gatunki glonów określane jako tzw. wskaźniki zanieczyszczeń. Ich obecność kwalifikuje rzekę na całym badanym odcinku do wód silnie zanieczyszczonych. Ponadto wysokie zasolenie Wisły spowodowało silny rozwój halofilnych gatunków okrzemek, jak: *Nitzschia filiformis*, *Synedra tabulata*, *Surirella ovata* var. *salina*.

Między stanowiskami obserwowano zmiany liczby i liczebności gatunków, struktury dominacji, wielkości wskaźnika biomasy okrzemek oraz wielkości powierzchni zajmowanych przez glony. Zmiany te świadczyły o postępującym procesie samooczyszczania i pozostawały w ścisłym związku z rodzajem i charakterem koryta rzeki. Były one szczególnie widoczne na stanowiskach 5 i 6, gdzie rzeka zachowała swój naturalny charakter rzeki karpackiej. Natomiast stopień wodny w Łączanach tylko doraźnie wpływał na poprawę jakości wody, której pogorszenie obserwowano już kilka km poniżej, na stanowisku 4. W toku badań prześledzono zmiany sezonowe w rozwoju glonów osiadłych. Przebiegały one niejednolicie na poszczególnych stanowiskach (ryc. 2, 3). Zauważono natomiast pewne ogólne tendencje w okresowym rozwoju niektórych dominujących gatunków okrzemek (ryc. 2).

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