ACTA HYDROBIOL.	19	3	271—292	KRAKÓW 1977

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Biocenoza potoku wysokogórskiego pozostającego pod wpływem turystyki. 3. Zbiorowiska glonów osiadłych w Rybim Potoku (Tatry Wysokie, Polska) zanieczyszczonym ściekami bytowymi*

Biocenosis of a high mountain stream under the influence of tourism. 3. Attached algae communities in the stream Rybi Potok (the High Tatra Mts, Poland) polluted with domestic sewage

Wpłynęło 8 lipca 1976 r.

Abstract — Differentiation of attached algae communities along the course of a mountain stream (altitude 1393—1100 m) polluted with domestic sewage from a shelter serving yearly about one million tourists is described.

In the highly eutrophicated environment (to 30 m from the sewage outlet) dominated: *Phormidium favosum, Nitzschia palea, Navicula cryptocephala, Cymbella ventricosa,* species of the genus *Gomphonema,* and the fungus *Leptomitus lacteus.* As mineralization of the sewage proceeded development of green algae and diatoms took place with the concomitant disappearance of the above-mentioned organisms. The final stage of sewage mineralization, about 500 m from the outlet, was marked by a mass development of diatoms, especially *Fragilaria capucina* and of the green alga *Oedogonium* sp. In the lower course of the stream *Hydrurus foetidus, Homoeothrix janthina, Diatoma hiemale* with the variety *mesodon, Ceratoneis arcus,* and *Achnanthes minutissima* were dominants similarly as in other pure Tatra streams at that altitude.

Moreover, quantitative changes of dominating algae were described in the annual cycle, their ecological characteristic also being made.

The post-glacial Lake Morskie Oko (altitude 1393 m, depth 50.8 m, surface area 34.93 ha) situated in the south-western part of the Tatra National Park is a great tourist attraction. Every year over a million tourists stay in this region and use the services of the shelter situated at

* Praca wykonana w ramach problemu resortowego PAN-21.

the lake, three-quarters of them visiting in the summer-autumn period (Table I). After partial purification the domestic sewage from the shelter is released into the Rybi Potok. Presumably the amount of sewage discharged is correlated with the intensity of tourist frequency, hence it varies in the course of the year, reaching its maximum from July to October and its minimum during the winter-spring period.

Complex investigations of the Rybi Potok (water chemistry, geology of the substrate, bottom flora and fauna) initiated by Professor K. Starmach within the framework of investigations on the Tatra streams

Tabela I. Ruch turystyczny przy Morskim Oku (1971/1972) wg. danych kierownika schroniska mgr Czesława Łapińskiego

Table I. Tourist traffic at Morskie Oko (1971/1972) according to data of the manager of the shelter Czesław Łapiński

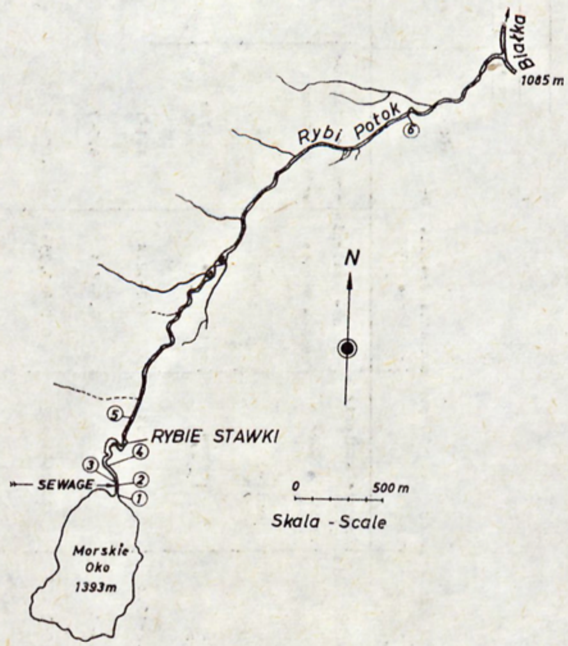
1971 Miesiąc Month	Liczba turystów Number of tourists	1972 Miesiąc Month	Liczba turystów Number of tourists
V	10.414	I	10 721
VI	61 448	II	10 711
VII	303 589	III	12 020
VIII	354 752	IV	10 125
IX	272 450	V	15 640
X	150 500		
XI	3 059		
XII	7 810		
		Razem: Total:	1 223 239

were started in 1962. Only the lower sector of the stream was at that time investigated in its annual cycle: Pasternak (1971), Bombówna (1968), Kawecka (1965), Kownacka, Kownacki (1965). In 1971/72 complex investigations of the whole Rybi Potok were again undertaken from the aspect of the influence of sewage from the shelter on the biocenosis of the stream: the water chemistry was investigated by Bombówna (1977), development of the bacterial flora by Starzecka (1977), and the bottom fauna by Kownacki (1977). Apart from the above investigations, the state of the ichtyofauna was elaborated by Żarnecki, Bieniarz (1967).

Description of the stream

The Rybi Potok drains Lake Morskie Oko. It is 4 km long, the difference in altitude being 300 m (outflow at 1393 m, mouth into the River Białka Tatrzańska at about 1100 m, width of the riverbed about

5 to 10 m, depth from 5 cm to about 1 m). Its whole course lies in the region of the upper montane forest zone which, on account of the primeval character of the forest, is in the lower course of the stream a strict nature reserve. Its subsoil along the whole course is constituted by granite (P a s t é r n a k 1971). Its upper sector, about 1 km long, is flat with a gradient of 6 to 10%. Two small ponds about 3 m deep are crossed by the stream. In the middle and lower course of the stream the gradient increases to about 80%. The sewage flows into the stream through a pipe about 100 m from its outflow from the lake.



Ryc. 1. Lokalizacja stanowisk
Fig. 1. Situation of stations

The material was collected at 6 stations. One station was situated above the sewage outlet and five below it (fig. 1). Table II shows the characteristics of the stations. Environmental factors such as temperature, pH, ammonium nitrogen, phosphates, and oxidation were given in the annual range of variations according to the data by B o m b ó w n a (1977). In the investigated months the water temperature and its pH remained on almost the same level along the whole course of the stream. The figures were: in spring and late autumn (May, June, October) 5.3 to 5.9°C, pH 6.6 to 7.1; in summer (July) 10.1 to 12.1°C, pH 6.6 to 6.8; in autumn (September) variations were more pronounced; the temperature was from 10.9 to 12.6°C, pH from 6.5 to 7.8; in winter (December — March)

Tabela II Charakterystyka stanowisk * kamienie drobne 3-10 cm, kamienie średnie 10-20 cm; kamienie duże powyżej 20 cm

Table II Station characteristics * small stones 3-10 cm; medium stones 10-20 cm; large stones over 20 cm

Parametry Parameters	Stanowiska · Stations					
	1	2	3	4	5	6
	Powyżej ścieku około 10-50 m od wypływu z jeziora Above outlet of sewage, ca 10-50 m from the lake outflow	Odległość od ujścia ścieków (w m) Distance from sewage outlet (in m)				
		1-10	15-30	100-120	500-550	3200-3250
* Charakter dna przeważającą Bottom character prevailing	drobne kamienie small stones	średnie kamienie - muł medium stones - slime	średnie kamienie medium stones	średnie kamienie medium stones	średnie kamienie medium stones	duże kamienie large stones
Pokrycie mchami w % Moss cover in %	25-50	poniżej 25 under 25	50-75	50-75	poniżej 25 under 25	skąpo sparse
Nasłonecznienie Insolation	dobre good	dobre good	dobre good	dobre good	bardzo dobre very good	bardzo dobre very good
Temperatura wody Water temperature °C	1.2-12.4	1.2-12.6	1.2-12.4	1.1-11 9	1.1-12 7	1.2-10.9
pH	6.4-7	6 4-6.9	6.5-7 1	6.5-7 1	6 4-7 8	6 4-7
Amoniak Ammonia $N\text{-}NH_4$ mg/l	0-0.106	0.016-1 192	0.008-0.356	0.008-0.176	0.008-0.136	0-0.106
Fosforany Phosphate PO_4 mg/l	0-0.054	0.010-0.268	0.005-0.111	0.006-0.082	0-0 090	0-0 100
Nasycenie Saturation O_2 %	67 2-114.5	69.2-90.1	66.2-95.6	64.3-94	69 2-95 1	67 5-91 8

the temperature was 0.8 to 1.6°C; pH 6.4 to 6.7. The amount of ammonium nitrogen and phosphates gradually decreased along the course of the stream during low tourist frequency, falling to zero by station 5.

Method

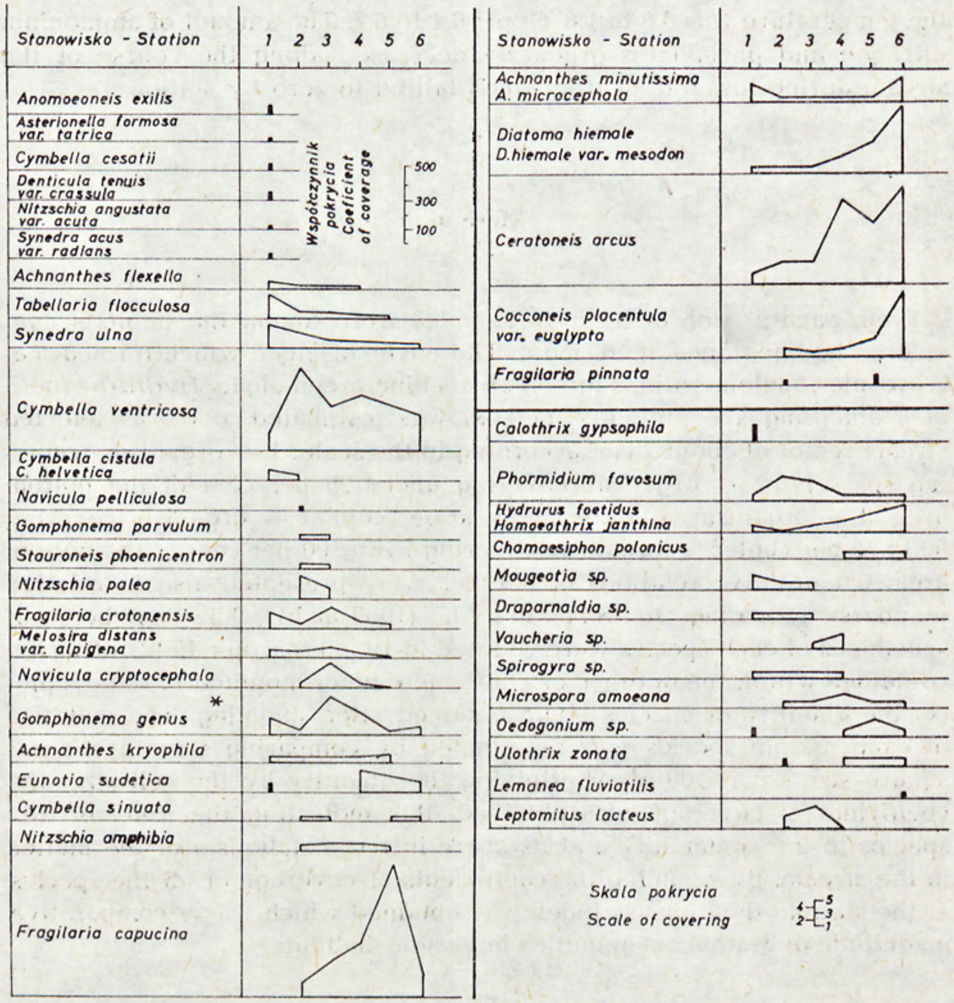
From each station at least 10 samples were taken, the habitats considered being: stones, mud, moss. The cover of algae which formed macroscopic conglomerations (green algae, blue-green algae, *Hydrurus foetidus*, and fungus *Leptomitus lacteus)* was estimated over a selected stream sector of about 25 m² according to the scale: 1 — organism occurring sparsely, 2 — organism covering under 25 per cent of the bottom area, 3 — organism covering 25 to 50 per cent, 4 — organism covering 50 to 75 per cent, 5 — organism covering 75 to 100 per cent of the bottom area. Quantitative relations of diatoms were presented also in relative numbers according to Starmach (1969 a, b). The numbers of specimens of each species were counted in 10 microscopic fields of vision contained within the outlines of a net micrometer mounted in the eyepiece, the quantity of species being obtained after summing. The cell size of each diatom species was determined by comparing it with the net square size equal 100 μ^2. Multiplying the quantity by the cell size, the coefficient of coverage was obtained, this indicating the role of the species in the community and its share in the metabolism of the matter in the stream. By summing the coefficients of coverage of all the species at the station, the biomass index was obtained which was a comparative magnitude of diatom communities in various habitats.

Results

1. Differentiation of algae communities and development of sewage fungus along the course of the stream

In the Rybi Potok 153 taxonomic units were identified in which diatoms constituted 86.3 per cent, green algae 6.3 per cent, blue-green algae 4.6 per cent, red algae 1.3 per cent, and yellow-brown algae and fungi 0.6 per cent.

Vegetation communities developing along the course of the stream



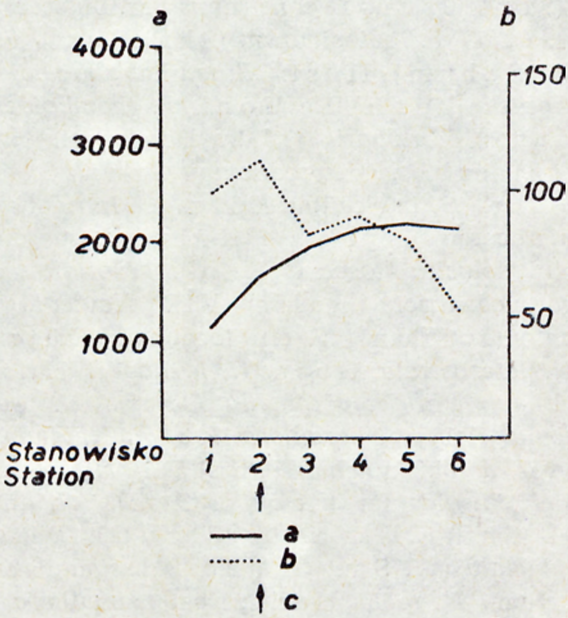
Ryc. 2. Zróżnicowanie zbiorowisk glonów wzdłuż biegu Rybiego Potoku
Fig. 2. Differentiation of algal communities along the whole course of the Rybi Potok
* *Gomphonema* genus: *G. acuminatum, G. acuminatum* var. *Brebissonii, G. longiceps* var. *montanum, G. montanum*

are presented in fig 2 the number of diatoms was expressed as the annual mean of the coefficient of coverage, the number of the other algae and of the fungus as the annual mean of cover. All the diatoms whose coefficient of coverage was under 5 and other algae which did not form macroscopic conglomeration were considered to be accidental species, as follows:

Bacteriophyta: Sphaerotilus natans. Cyanophyta: Nostoc sp., *Oscillatoria* sp., *Pleurocapsa* sp. *Bacillariophyceae: Achnanthes lanceolata* (Bréb). Grun., *A. lapidosa* Krasske, *A. lapponica* Hust., *A. laterostrata*

Hust., *Amphora ovalis* Kütz. var. *pediculus* Kütz., *Anomoeoneis serians* (Bréb.) Cl. var. *brachysira* (Bréb.) Hust., *Caloneis silicula* (Ehr.) Cl., *Cocconeis disculus* (Schum.) Cl., *C. disculus* var. *diminuta* Pant., *C. pediculus* Ehr., *C. placentula* Ehr. var. *klinoraphis* Geit., *Cyclotella compta* (Ehr.) Kütz., *Cymbella aequalis* W. Sm., *C. affinis* Kütz., *C. delicatula* Kütz., *C. gracilis* (Rabh.) CL., *C. Gaeumanni* Meister, *C. lanceolata* (Ehr.) V.H., *C. microcephala* Grun., *Denticula tenuis* Kütz., *Diatoma anceps* (Ehr.) Kirch., *D. elongatum* (Lyngb.) Ag. var. *tenue* (Ag) V.H., *D. vulgare* Bory, *D. vulgare* var. *Ehrenbergii* (Kütz.) Grun., *Didymosphaenia geminata* (Lyngb.) M. Schmidt, *Diploneis* sp., *Eunotia arcus* Ehr., *E. diodon* Ehr., *E. flexuosa* (Bréb.) Kütz., *E. lunaris* (Ehr.) Grun., *E. pectinalis* (Dillw.? Kütz.) Rabh. var. *minor* (Kütz.) Rabh., *E. praerupta* Ehr., *E. robusta* Ralfs var. *tetraodon* (Ehr.) Ralfs, *Epithemia zebra* (Ehr.) Kütz., *Fragilaria alpestris* Krasske, *F. construens* (Ehr.) Grun., *F. construens* var. *binodis* (Ehr.) Grun., *F. intermedia* Grun., *F. leptostauron* (Ehr.) Hust., *F. pinnata* Ehr. var. *lancettula* (Schum.) Hust., *Frustulia rhomboides* (Ehr.) De Toni var. *saxonica* (Rabh.) De Toni, *F. rhomboides* var. *saxonica* fo. *undulata* Hust., *F. vulgaris* (Thw.) De Toni, *Gomphonema angustatum* (Kütz.) Rabh. var. *productum* Grun., *G. capitatum* Ehr., *G. constrictum* Ehr., *G. intricatum* Kütz., *G. intricatum* var. *pumilum* Grun., *G. olivaceum* (Lyngb.) Kütz., *Hantzschia amphioxys* (Ehr.) Grun., *Melosira Roseana* Rabh., *Meridion circulare* Ag., *M. circulare* var. *constricta* (Ralfs) V.H., *Navicula cocconeiformis* Greg., *N. contenta* Grun., *N. cryptocephala* Kütz. var. *intermedia* Grun., *N. laterostrata* Hust., *N. levanderi* Hust. var. *tatrensis* Bilý et Marvan, *N. perpusilla* Grun., *N. pseudoscutiformis* Hust., *N. pupula* Kütz., *N. radiosa* Kütz., *Neidium affine* (Ehr.) Cl., *N. affine* var. *amphirhynchus* (Ehr.) Cl., *N. affine* var. *longiceps* (Greg.) Cl., *N. bisulcatum* (Lagerst.) Cl., *N. dilatatum* (Ehr.) Cl., *N. dubium* (Ehr.) Cl., *N. iridis* (Ehr.) Cl., *Nitzschia acicularis* W. Sm., *N. angustata* (W. Sm.) Grun., *N. dissipata* (Kütz.) Grun., *N. fonticola* Grun., *N. recta* Hantzsch, *Pinnularia borealis* Ehr., *P. Brauni* (Grun.) Cl. var. *amphicephala* (Mayer.) Hust., *P. dactylus* Ehr., *P. episcopalis* Cl., *P. gibba* Ehr., *P. legumen* Ehr., *P. mesolepta* (Ehr.) W. Sm., *P. microstauron* (Ehr.) Cl., *P. subcapitata* Greg., *P. subcapitata* var. *Hilseana* (Janisch) O. Müll., *P. viridis* (Nitzsch) Ehr., *P. viridis* var. *sudetica* (Hilse) Hust., *Rhoicosphenia curvata* (Kütz.) Grun., *Stauroneis anceps* Ehr., *Surirella biseriata* Bréb., *S. elegans* Ehr., *Syndera rumpens* Kütz., *S. Vaucheriae* Kütz., *Chlorophyta: Draparnaldia* sp., *Closterium Ehrenbergii* Menegh., *C. Leibleini* Kütz., *C. lunula* (Müll.) Nitzsch., *Rhodophyta: Chantransia* sp.

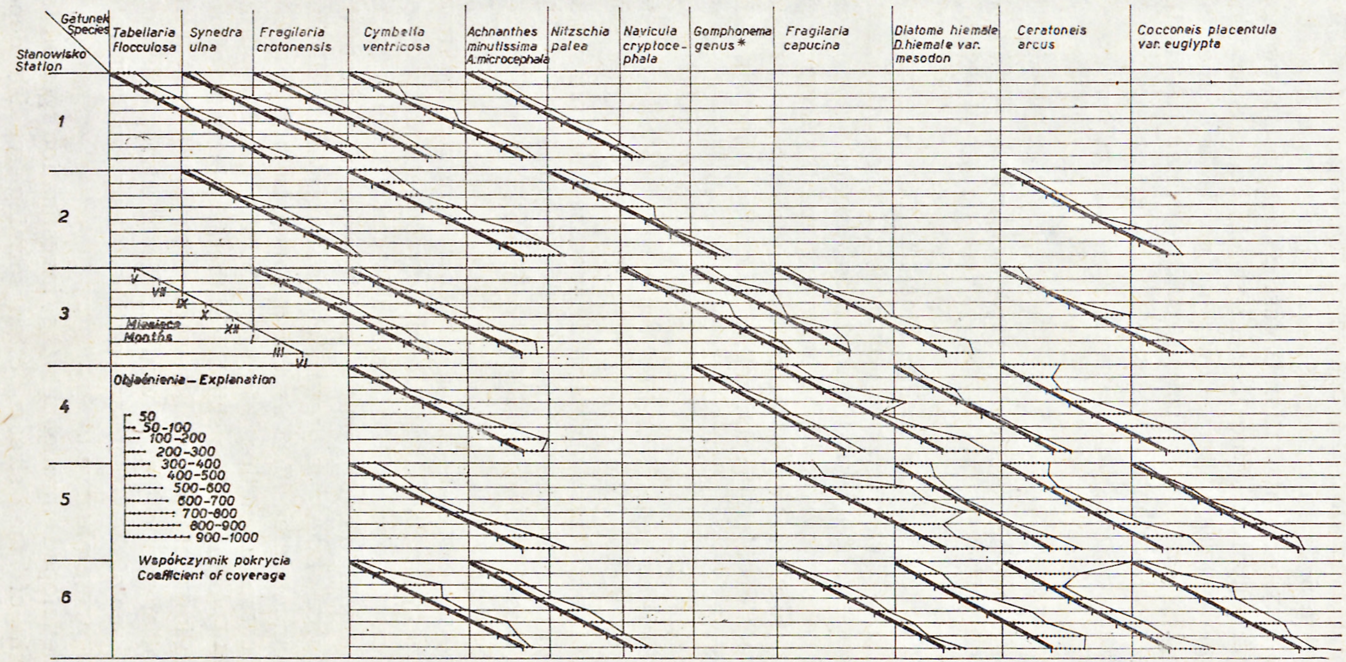
Four areas with characteristic vegetation communities were distinguished. 1 — The area above the sewage outlet (station 1) represented an oligotrophic environment remaining under the influence of the lake. The dominating species here were the blue-green algae *Calothrix gypsohila*, of the diatoms *Tabellaria flocculosa*, *Achnathes microcephala*, *A. minutissima*, and *Synedra ulna*. *Asterionella formosa* var. *tatrica*, *Fragilaria crotonensis*, *Synedra acus* var. *radians* occurring here were washed down from the lake and arrested on moss clumps. 2. The highly eutrophicated environment below the sewage outlet (stations 2, 3) with *Phormidium favosum*, the fungus *Leptomitus lacteus*, *Cymbella ventricosa*, *Navicula cryptocephala*, *Nitzschia palea*, and species of the genus *Gomphonema* developing in masses. 3. The zone of final sewage mineralization phase (stations 4 and 5) with developing green algae, *Hydrurus foetidus*, *Homoeothrix janthina*, *Fragilaria capucina*, *Ceratoneis arcus*,



Ryc. 3. Wskaźnik biomasy okrzemek oraz liczba taksonów wzdłuż biegu Rybiego Potoku. a — wskaźnik biomasy; b — liczba gatunków; c — ścieżki

Fig. 3. Diatom biomass index and taxon number along the course of the Rybi Potok. a — biomass index; b — number of species; c — sewage

and *Cymbella ventricosa*. 4. The oligotrophic environment in the lower course of the stream (station 6) with dominance of *Hydrurus foetidus*, *Homoeothrix janthina*, *Ceratoneis arcus*, *Diatoma hiemale* with the variety *mesodon*, *Cocconeis placentula* var. *euglypta*, *Achnanthes minutissima*, and *A. microcephala*.



Ryc. 4. Zmiany liczebności w cyklu rocznym dominujących gatunków okrzemek Rybiego Potoku
Fig. 4. Quantitative changes in diatom species dominating in the Rybi Potok in the annual cycle

* *Gomphonema* genus: *G. acuminatum, G. acuminatum* var. *Brebissonii, G. Longicapsa* var. *montanum, G. montanum*

The diatom biomass index was lowest at station 1 above the sewage outlet, and increased with the course of the stream, reaching its maximum at station 5. The number of taxonomic units was high at station 1, reaching a maximum at station 2, just below the sewage outlet, and decreasing subsequently along the course of the stream (fig. 3). The highest diatom biomass index below the ponds and the local mass development of green algae demonstrated an intensive fertilization of the water and marked the zone below which the conditions prevailing in the stream returned to natural.

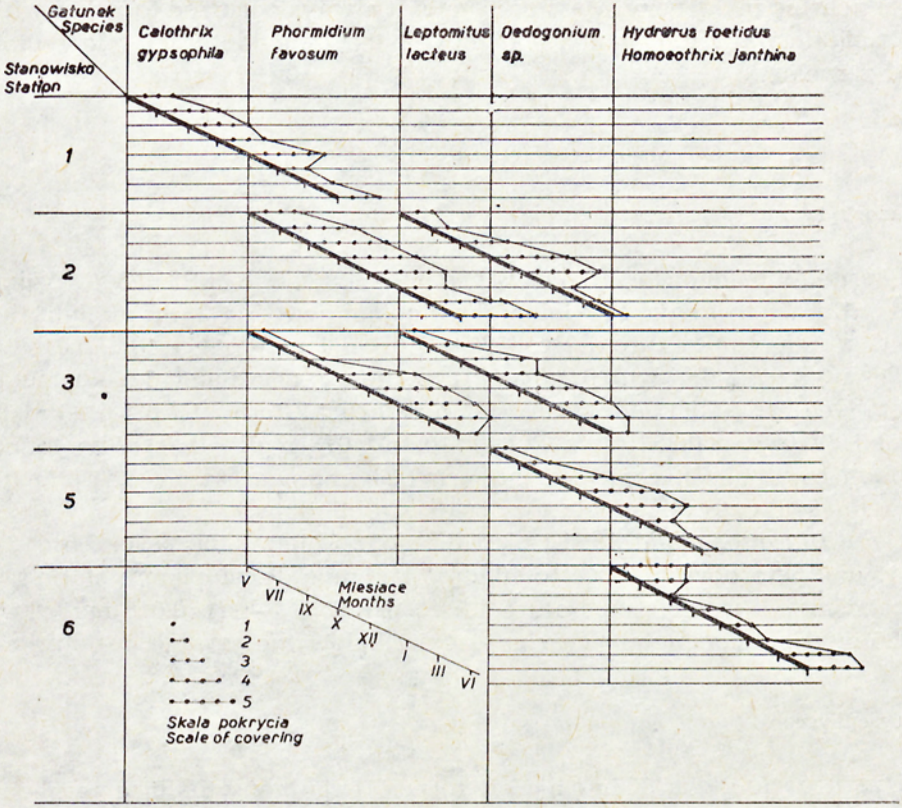
2. Algae communities and development of the sewage fungus in the annual cycle

Quantitative changes of 17 species (figs 4 and 5) were presented in the annual cycle. The chosen species occurred at a given station throughout the whole investigation period, the diatoms reaching a mean annual coefficient of coverage over 100, other algae and the fungus covering on the average 25 to 50 per cent of the bottom surface. A detailed description of these changes in given in section 3. Here on the other hand, the developmental course in time of characteristic species groups along the stream course in considered.

Hydrurus foetidus together with *Homoeotrix janthina* occurred sporadically above the sewage inflow throughout the whole investigation period. Below it both these organism disappeared, only in winter *Hydrurus foetidus* developing fairly numerously already at station 3. Only at station 6 did these species reach their quantitative maximum during the spring-winter season.

Green algae were sparse just below the stream outflow from the lake throughout the year, but about 50 m downstream they developed intensively from October till March. This could have been caused by pollution additional to that from the main sewage inflow into the stream. Below the source of sewage green algae occurred in small numbers but their development intensified as the distance from it increased. They occurred in masses at station 4 in May and June and at station 5 from September till December. The shifting of the development of green algae up the stream in months of small sewage dose (low tourist traffic, raised water level after spring thaws) would indicate a shortening of the self--purification zone of the stream at that time. At station 6 no water-blooms of green algae were observed.

Diatoms developed throughout the investigation period along the whole length of the stream, often forming reddish deposits and filamentous concentrations on mosses and stones. Most species showed a quantitative increase in the winter-spring season, only *Nitzschia palea,*



Ryc. 5. Zmiany liczebności w cyklu rocznym dominujących gatunków Rybiego Potoku (sinice, złotowiciowce, zielenice, grzyb)

Fig. 5. Quantitative changes in species dominating in the Rybi Potok in the annual cycle (blue-green algae, yellow-brown algae, green algae, fungus)

Navicula cryptocephala, species of the genus *Gomphonema* — organisms preferring organic matter in the environment — markedly increassing in number during the summer-autumn season during the greatest intensity of tourist traffic. At station 5 *Fragilaria capucina* developed in correlation with the development of *Oedogonium* sp. during autumn and early winter. From general observation a regularity may also be noted: the same diatom species showed at various stations a similar developmental curve and the various species developed at the same stations in such a way that their peaks followed one another in time (fig. 4).

Leptomitus lacteus formed clumps at stations 2 and 3, only reaching station 4 in small numbers from September till December. In that period the fungus developed directly below the sewage outlet but usually it did not appear until about 5 to 6 m from the source of sewage, optimum development being reported at a distance of about 15 to 30 m. It developed in masses during the period from September till December, distinctly disappearing in January, May, and June. It always occurred together with *Phormidium favosum*, which also developed abundantly in this region of the stream.

3. Ecological characteristic of dominating species

Cyanophyta

Phormidium favosum (Bory) Gomont: cell length* 2.5 to 5 μm, cell width 7.5 to 10 μm. Maximum development: station 2 (throughout the year, water temperature 1.2 to 12.5°C, pH 6.4 to 6.9, N—NH_4 0.016 to 1.192 mg/l, PO_4 0.010 to 0.268 mg/l), station 3 maximum development: (from October to January, water temperature 1.2 to 5.5°C, pH 6.5 to 6.6, N—NH_4 0.068 to 0.356 mg/l, PO_4 0.110 to 0.078 mg/l). It is often found in high mountain streams but, hitherto, never in masses. Fjerdingstad (1965) determines this species as saprophilous.

Calothrix gypsophila (Kütz.) Thuret. Cells at the base: 2.5×12.5 to 15 μm, heterocyst 6.25×5 to 10 μm. Maximum development: station 1, (December, — water temperature 1.2°C, pH 6.6, N—NH_4 0.016 mg/l, PO_4 0.026 mg/l). It completely ceased to exist below the sewage outlet.

Chrysophyceae

Hydrurus foetidus Kirchn. It formed gelatinous thalli, amorphous or digitate, 5 cm long. Maximum development: station 6 (May, March, June, water temperature 1.4 to 5.9°C, pH 6.4 to 7, N—NH_4 0 to 0.074 mg/l, PO_4 0 to 0.061 mg/l). It occurred concomitantly with *Homoeothrix janthina*. Both species are dominants in the Tatra streams in the montane forest zone (altitude 890 to 1550 m), water temperature 0.4 to 12.5°C, pH 6.4 to 6.9 (Kawecka 1971). The author found that in the Alpine streams *Hydrurus foetidus* developed both in a natural environment and in an environment polluted with organic matter. Backhaus (1968 a) included these two species in the group of oligotrophic ones, but later (Backhaus 1973) he considered *Hydrurus foetidus* an ubiquitous species, with no indicator value.

Bacillariophyceae

Achnanthes minutissima Kütz. 12.5 to 20×2.5 to 3.75 μm, about 30 striae in 10 μm on each valve; *A. microcephala* (Kütz.) Grun.

* Note: In further descriptions of cell size the first size refers to length, the second to width.

15.4 to 25.3×2.2 to 3 μm, about 30 striae in 10 μm on each valve. Maximum development of these two species: station 6 (December, water temperature 1.5°C, pH 6.7; N—NH_4 0.032 mg/l, PO_4 0.026 mg/l). The species disappeared also in the eutrophicated part of the Alpine streams (Kawecka 1974 b). In high mountain streams in a natural environment both of these species are frequently found (Kawecka 1965, 1971, 1974 a, b, Wasylik 1971, Besch et. al. 1972 a). *A. minutissima* is a good indicator of oligotrophic waters rich in oxygen, moderately alkaline at a pH of 7.5 to 7.8 (Cholnoky 1968). This species dominates in the unpolluted zone of streams, numerous at pH 7 (Besch et al. 1972 b). It occurs in various shallow water environments with sufficient oxygen content, even with moderate pollution at a pH of 6.7 to 8.4, oftenest at about 7 (Schoeman 1973). It is one of the most frequent diatom species in the streams of the upper course of the Danube, disappearing in the polluted sector and reccurring after self-purification of the stream (Backhaus 1968 b). A saprophilous ubiquitous species probably cannot be an indicator in the saprobe system (Fjerdingstad 1965). *A. microcephala*, the best indicator of waters with constant oxygen saturation, optimum at a pH of 6.4 to 6.6 (Cholnoky 1968) or one slightly under 7 (Cholnoky 1970), dominates in a polluted environment at a pH of 5 to 7.5 (Besch et al. 1972 b).

Ceratoneis arcus (Ehr.) Kütz. 26.5 to 100×5 to 7.5 μm, 15 striae in 10 μm. Maximum development: station 6, May, water temperature 5.7°C, pH 7; N—NH_4 0.074 mg/l, phosphates absent; optimum development probably at a pH of 7.2 to 7.3 (Cholnoky 1968); frequent in high mountain streams in clean and polluted environments (Kawecka 1965, 1971, 1974 a, b).

Cocconeis placentula Ehr. var. *euglypta* (Ehr.) Cl. 30 to 32.5×15 to 17.5 μm. 19 striae and 21 striae in 10 μm on the upper and lower cover respectively. Maximum development: station 6, September, water temperature 10.9°C, pH 7; NH_4 0.106 mg/l, PO_4 0.015 mg/l. *C. placentula* develops optimally at pH 8. It is a good indicator of moderately alkaline waters (Cholnoky 1968). It develops in the final self-purification phase of the river (Butcher 1947), in the lower course of the Danube it is an indicator of trophy (Backhaus 1968 a). Maximum development is reached in a relatively pure water environment, while it is at a minimum in polluted regions (Scheele 1952). It is an oligotrophic (Hustedt 1957), oligo-β-mezosaprobic species (Friedrich 1973).

Cymbella ventricosa Kütz. 10 to 26×5 — 8.8 μm; 12—14 striae in 10 μm both in the ventral and dorsal parts of the valve. Mass development: below the sewage outlet at station 2, January — June, water temperature 1.2 to 5.5°C, pH 6.4 to 6.6; N—NH_4 0.370 to 0.996 mg/l, PO_4 0.012 to 0.216 mg/l, also in the polluted part of the Alpine streams (Kawecka 1974 b). It is widespread in the Tatra streams at a water temperature of 0.3 to 16.5°C, and pH of 6.2 to 8.5 (Kawecka 1965, 1971), in the stream Maljovica in the Rila Mts in Bulgaria at water temperature 6 to 21.5°C, pH 6.2 to 7.2 (Kawecka 1974 a), in the Alpine streams (Kawecka 1974 b). Optimum development is at a pH of 7.5 to 7.8 (Schoeman 1973), pH 7.7 to 7.8 (Cholnoky 1968). It lives in small streams with fast current having a high content of mineral compounds and decaying organic substances (Backhaus 1968 a), in well oxygenated water with a high content of nutrient substances at a pH of about 8 or over (Friedrich 1973).

Diatoma hiemale (Lyngb.) Heib. 27.5 to 35×8.6 to 10 μm, 3 to 4 striae in 10 μm. *D. hiemale* var. *mesodon* (Ehr.) Grun. 10—15×7.5 μm, 3 striae in 10 μm. Maximum development: station 6, March, water temperature 1.4°C, pH 6.4, N—NH_4 0.016 mg/l, PO_4 0.061 mg/l. Taxons characteristic of the High Tatra streams (890 to 1550 m), water temperature 0.4 to 12.5°C, optimum 4 to 5.5°C, pH 6.4 to 8.3 (Kawecka 1971); it appears also in the streams of the Western Tatras (altitude 1500 to 1000 m) (Wasylik 1971). Oligotrophic species (Backhaus 1968 a).

Fragilaria capucina Desm. 26.9 to 35×2.2 to 3.3 μm, 13—14 striae in 10 μm. Maximum development: station 5, September — December, water temperature 1.1 to 12.7°C, pH 6.4 to 7.8, N—NH_4 0.032 to 0.136 mg/l, PO_4 0.044 to 0.005 mg/l. Optimum at pH 7.4 to 7.8 (Cholnoky 1968). In the Tatra streams widespread, dominant locally in the Rybi Potok. A heliophilous species (Rice 1938).

F. crotonensis Kitt. 50—117.5×2 — 2.5 μm, 16 striae in 10 μm. A plankton eurythermic species (Huber-Pestalozzi 1942). Washed down from Lake Morskie Oko arrested on moss clumps and maintaining the same numbers throughout the investigation period at station 1 (water temperature 1.2 to 12.4°C, pH 6.4 to 7, N—NH_4 0 to 0.106 mg/l, PO_4 0 to 0.054 mg/l) and at station 3 (water temperature 1.2 to 12.4°C, pH 6.5 to 7.1, N—NH_4 0.008 to 0.356 mg/l, PO_4 0.005 to 0.111 mg/l). Optimum at a pH of 8 (Cholnoky 1968).

Genus *Gomphonema*: *G. acuminatum* Ehr. 30 to 42.5×6.6 to 6.7 μm, 10 to 11 striae in 10 μm. *G. acuminatum* var. *Brebissonii* (Kütz.) Cl. 79.2×9.9 μm, 9 striae in 10 μm; *G. montanum* Schum. em. Mayer 27.5 to 38.5×6.6 to 7.7 μm, 9 to 11 striae in 10 μm; *G. longiceps* Ehr. var. *montanum* (Schum.) Cl. 57.2 to 69×7.7 to 9.9 μm, 9 to 10 striae in 10 μm. Maximum development of taxons: station 3, September, water temperature 12.4°C, pH 6.9, N—NH_4 0.226 mg/l, PO_4 0.012 mg/l. Optimum pH for *G. acuminatum* and varieties is 8 or over, for *G. longiceps* var. *montanum* 7 to 7.5 (Cholnoky 1968). In a natural environment of the Tatra streams *G. longiceps* var. *montanum* is fairly frequent on granite (pH 6.4 to 6.9, Ca 14.3 mg/l) but disappears at the transition from granite to flysh and limestone (pH 6.8 to 8.3, Ca 14.3 mg/l) (Kawecka 1971).

The genus *Gomphonema* belongs to a group of organisms highly tolerant of pollution (P a l m e r 1969).

Navicula cryptocephala K ü t z. 20.9 to 27.5×5.5 to 6.6 μm, 16 striae in 10 μm. Maximum development: station 3, October, water temperature 5.5°C, pH 6.6, N—NH_4 0.068 mg/l, PO_4 0.110 mg/l. Optimum pH about 8; the organism develops well in a eutrophicated environment, but not because it is adapted to it physiologically, but rather owing to a high resistance to variations of osmotic pressure (C h o l n o k y 1968). In a natural Tatra stream environment this species is widespread but not frequent. It is characteristic of rapid waters with great amounts of organic and mineral matter (B a c k h a u s 1968 b). It is a saprophil, chemobiont (F j e r d i n g s t a d 1965).

Nitzschia palea (K ü t z.) W. S m. 27.5 to 30.6×2.5 to 3.3 μm, 11 to 14 fibulae in 10 μm, striae not visible. Maximum development: station 2, September-October, water temperature 5.5 to 12.6°C, pH 6.5 to 6.6, N—NH_4 0.732 to 0.328 mg/l, PO_4 0.138 to 0.150 mg/l. Obligatory heterotroph, it decomposes aminoacids rapidly, hence it is of a great importance in the self-purification process. Optimum in an environment highly eutrophicated, rich in oxygen, at a pH of over 8, a very good indicator of the trophic level (C h o l n o k y 1968). One of the species most tolerant of pollution (P a l m e r 1973). A good indicator of eutrophic conditions (S c h o e m a n 1973), it is a species characteristic of running oxygenated waters, loaded with organic matter (B a c k h a u s 1968 a). A saprophil, chemobiont (F j e r d i n g s t a d 1965).

Synedra ulna (N i t z s c h) E h r. 117.5 to 300×5.0 to 7.5 μm, 10 striae in 10 μm. Maximum development: station 1, October, water temperature 5.5°C, pH 6.6, N—NH_4 0.016 mg/l, PO_4 0.054 mg/l and at station 2, October-March, water temperature 1.2 to 5.5°C, pH 6.4 to 6.7, N—NH_4 0.176 to 0.996 mg/l, PO_4 0.150 to 0.216 mg/l. In high mountain streams widespread but not frequent; more numerous in the streams of the Tatra Highlands in the stream Białka Tatrzańska (K a w e c k a 1965) at a pH of 7.1 to 7.8 (B o m b ó w n a 1968), in the stream Rogoźnik in a lenitic environment (K a w e c k a 1964), in the lower course of the River Dunajec polluted with industrial wastes (C h u d y b o w a 1965). Optimum development takes place in winter at a pH of about 7 both in pure and polluted environments (B e s c h et al. 1972 b), in the poly- and a mezosaprobic zone (B a c k h a u s 1968 b), at a pH of 7.6 in oligotrophic water (C h o l n o k y 1968).

Tabellaria flocculosa (R o t h) K ü t z. 20 to 27.5×5.5 to 10 μm, 18 striae in 10 μm. It developed throughout the investigation period in constant numbers at station 1 (water temperature 1.2 to 12.4°C, pH 6.4 to 7, N—NH_4 0 to 0.106 mg/l, PO_4 0 to 0.054 mg/l). A species common in a natural Alpine stream environment (K a w e c k a 1974). In an environment polluted with organic matter it decreases drastically in number. Optimum development at a pH of about 5 (Cholnoky 1968), at pH 4 (Knudson 1954). It is an indicator of a low water pH. (Besch et al. 1970). A species typical of oligotrophic streams (Backhaus 1968 a).

Chlorophyta

Oedogonium sp. 45 to 107.5×30 to 37.5 μm, occurred only in vegetative stages. Maximum development: station 5, September-December, water temperature 1.1 to 12.7°C, pH 6.4 to 7.8, N—NH_4 0.032 to 0.136 mg/l, PO_4 0.005 to 0.044 mg/l.

Fungi

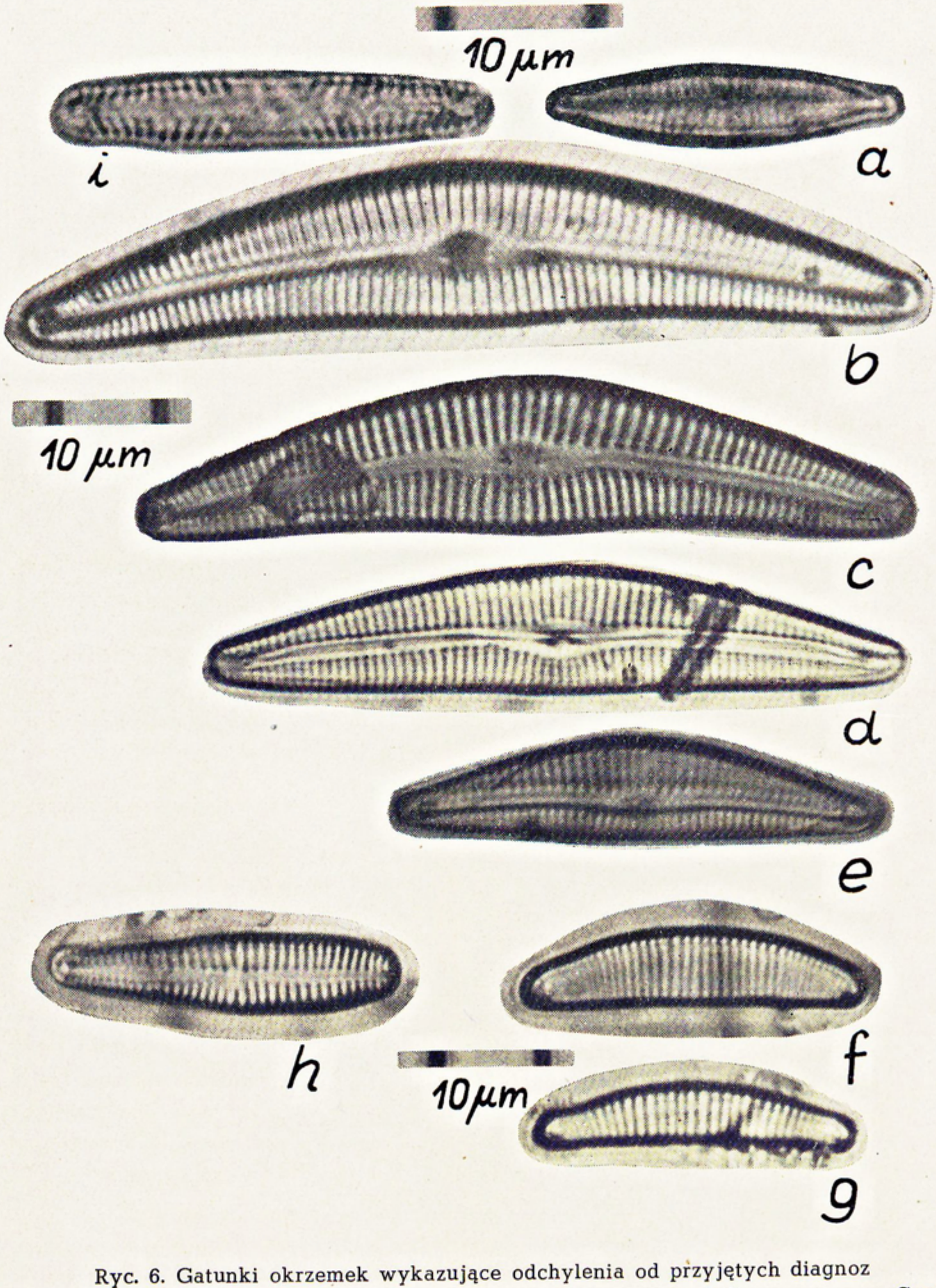
Leptomitus lacteus Ag. Maximum development: station 2. October--December, water temperature 1.2 to 5.5°C, pH 6.6 to 6.7, N—NH_4 0.176 to 0.328 mg/l, PO_4 0.150 mg/l, and at station 3, September, water temperature 12.4°C, pH 6.9, N—NH_4 0.226 mg/l, PO_4 0.012 mg/l. This fungus develops in well-oxygenated streams in a slightly acidic environment, with optimum development from November till May, since in summer bacteria compete with it as to food. A mass development takes place at a certain deconcentration of sewage waters, therefore it is a good indicator of the transition from the α- to the β-mezosaprobic zone (Liebmann 1962). According to Fjerdingstad (1965) it is a saprobiont.

Remarks on taxonomy of species

In some diatom species deviations in the cell size from the known diagnoses were observed.

Cymbella Cesatii (Rabh.) Grun. (fig. 6 a). 26 to 71×5.5 to 6.6 μm, 18 to 20 striae in 10 μm on the ventral and dorsal sides. According to Siemińska's diagnosis (1964), the cell sizes are 40 to 80×6 to 7 μm and after Cleve-Euler (1955) 25 to 50×5 to 7 μm. Similarly small cells were found in Alpine streams (27.5 to 41.8×5.5 μm, Kawecka 1974).

C. cistula (Hemp.) Grun. (fig. 6 b, c). 55 to 82.5×11.0 to 16.5 μm, 8 to 9 striae in 10 μm on both the ventral and dorsal parts of the frustule and 18 points in 10 μm of the stria. 1 to 4 middle striae end in separate points. After Siemińska (1964) the cell width is 15 to 36 μm, after Cleve-Euler (1955) 12 to 25 μm.



Ryc. 6. Gatunki okrzemek wykazujące odchylenia od przyjętych diagnoz
Fig. 6. Diatom species showing some deviations from the accepted diagnoses: a — *Cymbella Cesatii*, b, c — *C. cistula*, d, e — *C. helvetica*, f, g — *Eunotia sudetica*, h — *Gomphonema montanum*, i — *Pinnularia microstauron*

C. helvetica Kütz. (fig. 6 d, e). 44 to 77×7.7 to 13.3 μm, 10 to 11 striae in 10 μm on the ventral and dorsal parts and 20 lines in 10 μm of a stria. According to Siemińska (1964), the cell width is 10 to 20 μm, according to Cleve-Euler (1955) 9 to 15 μm.

Eunotia sudetica O. Müll. (fig. 6 f, g). 25.3 to 42.5×5.0 to 6.6 μm, 9 to 11 striae in 10 μm. Cell width according to Siemińska (1964) 7 to 8 μm, according to Cleve-Euler (1953) 4 to 9 μm.

Gomphonema montanum Schum. em. Mayer. (fig. 6 h). 27.5 to 38.5×6.6 to 7.7 μm, 8 to 11 striae in 10 μm. According to Cleve-Euler (1955) the cell width is 8 to 12 μm. This species with similarly narrow cells of 6.4 to 7.2 μm is reported by Starmach (1973) from the Tatra Mts.

Pinnularia microstauron (Ehr.) Cl. (fig. 6 j). Apart from cells corresponding with the diagnosis of the species, smaller individuals were found with dimensions 22 to 27.5×5.5 μm, 12 to 13 striae in 10 μm. Small cells 22.4 to 28 μm × 5.6 to 7 μm, 12 to 13 striae in 10 μm are also reported by Starmach (1973) from the Wielki Staw in the Tatra Mts. According to Siemińska (1964) the cell dimensions are 25 to 80×7 to 11 μm, 10 to 13 striae in 10 μm.

Discussion

The necessity arises to evaluate the changes which have taken place in the Rybi Potok under the influence of sewage in relation to other Tatra streams not affected by human activity. As concerns the territory, the Rybi Potok lies in the region of the montane forest zone of the Tatra Mts (890—1550 m), where in natural conditions algal communities develop with *Hydrurus foetidus* and *Homoeothrix janthina* dominating, these being numerously accompanied by diatoms — *Diatoma hiemale* with the variety *mesodon*, *Cymbella ventricosa*, *Ceratoneis arcus*, *Achnanthes minutissima*, and *A. microcephala* (Kawecka 1971). It cannot be said, however, that along the whole course of the Rybi Potok the above-given algal communities should develop. The upper course of the Rybi Potok, polluted with domestic wastes, does not present physiographically a typical Tatra montane forest zone stream, since it is an area below the outflow of a lake which exerts a special influence on the algal development. For this reason it cannot be maintained with absolute certainty that the absence of *Hydrurus foetidus* and *Homoeothrix janthina* in the polluted environment of the Rybi Potok is caused by the influence of sewage, as these organisms also occur sporadically below the outflow from the lake. It may, however, be accepted that a negative reaction to the inflow of sewage is demonstrated by species of the genus *Achnanthes*, which develop numerously above the sewage outlet and disappear in the polluted environment. The consequence of sewage is also a mass development of the fungus *Leptomitus lacteus*, of the blue--green alga *Phormidium favosum*, of the green algae, especially *Oedogonium* sp., and of the diatoms: *Cymbella ventricosa, Fragilaria capucina, Nitzschia palea, Navicula cryptocephala*, species of the genus *Gomphonema* — organisms which do not anywhere also attain such rich populations as in the Rybi Potok.

The above-described quantitative species changes show that the sewage causes eutrophication of the environment. The question arises as to what area of the stream is affected by eutrophication. Under conditions of high oxygenation of the mountain stream, mineralization of the sewage proceeds rapidly and probably 500 m from its source, after crossing the small ponds which here play the role of natural sedimentation tanks, it is in its final stage. With a small inflow of sewage this zone shifts up the stream above the ponds. As concerns physiography and the development of algal communities at station 6 (about 3 km from the sewage outlet), the stream region virtually corresponds with the montane forest zone of the neighbouring Tatra streams. A temporary development of algae here, indicating increased eutrophication, is surprising. In summer 1962 a local mass development of the green alga *Ulothrix zonata* and of the diatoms *Fragilaria capucina* var. *lanceolata* (Kawecka 1965) was observed here. Such a drastic situation was never repeated during our later investigations but, nevertheless, in September 1971 an increase in the number of *Cymbella ventricosa* was observed. Simultaneously there was a rise in the number of heterotrophic bacteria (Starzecka 1977). The possibility should be considered that the above-described changes might be a biological result of the effect of sewage which, although weak and local, causes fertilization of the water even at a long distance from the source of pollution, this being mentioned by Hynes (1973). Taking into consideration that mountain tourism becomes ever more popular and that consequently there is an increase in domestic sewage, it is possible to foresee the threat to the natural protected ecosystem of the stream, leading to its destruction.

Organism dominating in the zone of the direct effect of sewage are: *Leptomitus lacteus, Nitzschia palea, Navicula cryptocephala*, and species of the genus *Gomphonema* are known for their resistance to pollution (Palmer 1973, Cholnoky 1968, Liebmann 1962). Their occurrence in this environment is in accordance with their position in the saprobe system (Sladeček 1973). This is interesting, as there is a thesis that the saprobe system is completely broken in the mountain streams (Chandler 1970).

Of the species dominating in the Rybi Potok diatoms proved to be very sensitive to tropic changes in the environment. This was reflected by changes in their communities along the course of the stream with increasing distance from the source of pollution as well as by quantitative changes in the species *Navicula cryptocephala*, *Nitzschia palea*, in the species of the genus *Gomphonema* in their annual cycle in correlation with variations in the amount of organic matter flowing into the stream. Sensitivity to trophic changes in the environment caused by domestic sewage was also shown by diatoms in the Alpine streams Finstertaler and Gurgler investigated in winter 1970/71 (Kawecka 1974 b). The reaction to pollution of a number of diatom species in the Rybi Potok and in the Alpine streams proved similar. In the polluted environment of any stream the number of *Cymbella ventricosa* increases rapidly. In the Rybi Potok and in the Finstertaler a marked numerical development of the *Fragilaria capucina* and disappearance of *Tabellaria flocculosa* and *Achnathes minutissima* occurred, whereas in the Rybi Potok and in the Gurgler the number of species of the genus *Gomphonema* increased.

The ecological value encountered as indicators of the diatoms is in fact not known, since for this physiological investigations of the organisms would be required, but their role cannot be neglected especially in the streams where they constitute a characteristic group, richest in taxons, occurring in every habitat along the whole stream course.

The author would like to express her gratitude to Prof. K. Starmach for verification of the blue-green algae identification.

STRESZCZENIE

Rybi Potok (długość 4 km, odpływ na wysokości 1393 m) został zanieczyszczony ściekami bytowymi pochodzącymi ze schroniska, położonego nad Morskim Okiem. W rejonie tym w ciągu roku 1971/72 przebywało ponad milion turystów, ze szczytem w okresie letnio-jesiennym. Powyżej działania ścieków, w zbiorowisku glonów, dominowały: *Calothrix gypsophila*, *Tabellaria flocculosa*, *Achnanthes minutissima*, *A. microcephala* i *Synedra ulna*. Dopływ ścieków spowodował eutrofizację środowiska, co pociągnęło za sobą różnicowanie zbiorowisk glonów wzdłuż biegu potoku w miarę samooczyszczania się i powrotu warunków oligotroficznych. Na odcinku potoku do 30 m od źródła ścieków dominowały *Phormidium favosum*, *Nitzschia palea*, *Navicula cryptocephala*, *Cymbella ventricosa*, gatunki z rodzaju *Gomphonema* oraz grzyb *Leptomitus lacteus*, z których większość znana jest jako organizmy żyjące w wodach o dużej zawartości materii organicznej. Wyżej wymienione okrzemki (poza *Cymbella ventricosa)* wykazywały wyraźny wzrost ilościowy w okresie letnio-jesiennym w korelacji z najwyższą frekwencją turystów. W miarę mineralizacji ścieków następował rozwój zielenic oraz okrzemek: *Fragilaria capucina*, *Diatoma hiemale*, *Ceratoneis arcus*; zanik: *Leptomitus lacteus*, *Nitzschia palea*, *Navicula cryptocephala*; znaczne obniżenie liczebności: *Phormidium favosum*. Końcową fazę mineralizacji ścieków wyznaczał masowy rozwój okrzemek, w tym głównie

Fragilaria capucina oraz zielenicy *Oedogonium* sp. Strefa ta występowała około 500 m od źródła ścieków po przejściu potoku przez Rybie Stawki, które odgrywały rolę naturalnych osadników. W dolnym biegu potoku dominowały *Hydrurus foetidus, Homoeothrix janthina, Diatoma hiemale* z odmianą *mesodon, Ceratoneis arcus, Achnanthes minutissima, A. microcephala* podobnie jak w innych czystych potokach tatrzańskich na tej wysokości. W cyklu rocznym gatunki te osiągały maksimum liczebności w okresie wiosenno-zimowym.

Występowanie organizmów dominujących w Rybim Potoku w stosunku do źródła zanieczyszczeń potwierdzało obserwacje innych autorów na temat ich ekologii.

Spośród gatunków dominujących okrzemki okazały się dobrymi wskaźnikami zmian troficznych w środowisku, co potwierdziły także podobne badania prowadzone w potokach alpejskich.

REFERENCES

Bombówna M., 1968. Hydrochemiczna charakterystyka potoku Białka Tatrzańska — Hydrochemical characteristics of the Białka Tatrzańska stream. Acta Hydrobiol., 10, 27—37.

Bombówna M., 1977. Biocenoza potoku wysokogórskiego pozostającego pod wpływem turystyki. 1. Chemizm wody Rybiego Potoku i zawartość chlorofilu w glonach osiadłych oraz sestonie a zanieczyszczenie — Biocenosis of a high mountain stream under the influence of tourism. 1. Chemism of the Rybi Potok waters and the chlorophyll content in attached algae and sestone and the relation to the pollution. Acta Hydrobiol., 19, 243—255.

Backhaus D., 1968 a. Ökologische Untersuchungen an den Aufwuchsalgen der obsersten Donau und ihrer Quellflüsse. 3. Die Algenverteilung und ihre Beziehungen zur Milieuofferte. Arch. Hydrobiol., Suppl., 34, 130—149.

Backhaus D., 1968 b. Ökologische Untersuchungen an den Aufwuchsalgen der obersten Donau und ihrer Quellflüsse. 4. Systematisch — autekölogischer Teil. Arch. Hydrobiol., Suppl., 34, 251—320.

Backhaus D., 1973. Fliesswasseralgen und ihre Verwendbarkeit als Bioindicatoren. Verh. Ges. Ökol. Saarbrucken, 149—167.

Besch W. K., M. Ricard, R. Cantin, 1970. Utilization des diatomées benthiques comme indicateur de pollutions minières dans le bassin de la Miramichi N. W. Fish. Res. Board Canada., Techn. Rep., 202, 1—72.

Besch W. K., D. Backhaus, J. Capblanco, P. Lavandier, 1972 a. Données écologiques sur les algues bentiques de haute montagne dans les Pyrénées. 1. Diatomées. Annales Limnol., 8, 103—118.

Besch W. K., M. Ricard, R. Cantin, 1972 b. Benthic diatoms as indicators of mining pollution in the northwest Miramichi River system. New Brunswick, Canada. Intern. Rev. ges. Hydrobiol., 57, 39—74.

Butcher R. W., 1947. Studies in the ecology of rivers. 7. The algae of organically enriched waters. J. Ecol., 35, 186—191.

Chandler J. R., 1970. A biological approach to water quality management. I. Water Poll. Control, Fed. 69, 415—422.

Cholnoky B. J., 1968. Die Ökologie der Diatomeen in Binnengewässern. Weinheim, J. Cramer Verl.

Cholnoky B. J., 1970. Hydrobiologische Untersuchungen in Transvaal 3. Die Fischteiche von Marble Hall. Bot. Mar., 5—44.

Chudybowa D., 1965. Benthic algae in the river Dunajec. Limnological investigations in the Tatra Mts. and Dunajec river basin, Komitet Zagospod. Ziem Górskich PAN, 11, 153—159.

Cleve-Euler A., 1953. Die Diatomeen von Schweden und Finland. Handl. Kg. Svenska Vet. Acad. Fjärde, Ser. 4, No 5.

Cleve-Euler A., 1955. Die Diatomeen von Schweden und Finland. Handl. Kg. Svenska Vet. Acad. Fjärde, Ser. 5, No 4.

Friedrich G., 1973. Ökologische Untersuchungen an einem thermisch anomalen Fliesgewässer (Erft/Niederrhein). Schriftenr. Landesanst. Gewässerk. Gewässerschutz Landes Nordrhein- Westfalen, 33, 7—125.

Fjerdingstad E., 1965. Taxonomy and saprobic valency of benthic phytomicro--organisms. Intern. Rev. ges. Hydrobiol., 50, 475—604.

Hustedt F., 1957. Die Diatomeenflora des Flussystems der Weser im Gebiet der Hansestadt Bremen. Abh. Nat. Ver. Bremen, 34, 181—440.

Huber-Pestalozzi G., 1942. Das Phytoplankton des Süsswassers. Die Binnengewässer, 16, 2.

Hynes H. B. N., 1963. The biology of polluted water. Liverpool, Univ. Press.

Kawecka B., 1964. Zbiorowiska glonów w dolnej części potoku Rogoźnik-Communities of algae in the lower part of the Rogoźnik stream. Acta Hydrobiol. 6, 119—128.

Kawecka B., 1965. Communities of benthic algae in the river Białka and its Tatra tributaries the Rybi Potok and Roztoka. Limn. Investigations in the Tatra Mts. and Dunajec river basin. Komitet Zagospod. Ziem Górskich PAN, 11, 113—127.

Kawecka B., 1971. Strefowe rozmieszczenie zbiorowisk glonów w potokach Polskich Tatr Wysokich — Zonal distribution of alga communities in streams of the Polish High Tatra Mts. Acta Hydrobiol., 13, 393—414.

Kawecka B., 1974 a. Vertical distribution of algae communities in Maljovica stream (Rila-Bulgaria). Pol. Arch. Hydrobiol. 21, 211—228.

Kawecka B., 1974 b. Effect of organic pollution on the development of diatom communities in the alpine streams Finstertaler Bach and Gurgler Ache (Northern Tyrol, Austria). Ber. nat.-med. Ver. Innsbruck, 61, 71—82.

Kownacka M., Kownacki A., 1965. The bottom fauna of the river Białka and of its Tatran tributaries the Rybi Potok and Roztoka. Limnol. Investig. in the Tatra Mts. and Dunajec river basin. Komitet Zagospod. Ziem Górskich PAN, 11, 129—151.

Kownacki A., 1977. Biocenoza potoku wysokogórskiego pozostającego pod wpływem turystyki. 4. Fauna denna Rybiego Potoku (Tatry Wysokie) — Biocenosis of a high mountain stream under the influence of tourism. 4. The bottom fauna of the stream Rybi Potok (the High Tatra Mts). Acta Hydrobiol., 19, 293—312.

Knudson B. M., 1954. The ecology of the diatom genus *Tabellaria* in the English Lake District. J. Ecol., 42, 345—358.

Liebmann H., 1962. Handbuch der Frischwasser und Abwasserbiologie. München, G. Fischer Verl.

Palmer C. M., 1969. A composite rating of algae tolerating organic pollution. J. Phycol., 5, 78—82.

Pasternak K., 1971. Fizjografia i charakter podłoża zlewni potoków Polskich Tatr Wysokich — The physiography and character of the substratum of the drainage areas of streams of the Polish High Tatra Mts. Acta Hydrobiol., 13, 363—378.

Rice C. H., 1938. Studies in the phytoplankton of the river Thamas (1928—1932) 1, 2. Annales Bot., N. Ser., 2. (7).

Scheele M., 1952. Systematisch-ökologische Untersuchungen über die Diatomeenflora der Fulda. Arch. Hydrobiol., 46, 305—423.

Sladeček V., 1973. System of water quality from the biological point of view. Ergebn. Limnol., 7, 1—218.

Schoeman F. R., 1973. A systematical and ecological study of the diatom flora of Lesotho with special reference to the water quality, Pretoria, V. R. Printers.

S i e m i ń s k a J., 1964. Chrysophyta 2, Bacillariophyceae-Okrzemki. Flora Słodkowodna Polski 6, Warszawa, PWN.

S t a r m a c h K., 1969. a. *Hildebrandtia rivularis* i glony towarzyszące w potoku Cedronka koło Wejherowa (Województwo Gdańsk). *Hildebrandtia rivularis* and associating it algae in the stream Cedronka near Vejherowo (Gdańsk voivode). Fragm. Flor. et Geobot., 15, 387—398.

S t a r m a c h K., 1969 b. Glony źródeł na wybrzeżu morskim w Chłapowie — Algae of springs on the sea coast at Chłapowo (Northern Poland). Fragm. Flor. et Geobot., 15, 503—511.

S t a r m a c h K., 1973. Glony osiadłe w Wielkim Stawie w Dolinie Pięciu Stawów Polskich w Tatrach — Benthic Algae of the Great Lake in the Valley of the Five Polish Lakes in the Tatra Mountains. Fragm. Flor. et Geobot, 19, 481—511.

S t a r z e c k a A., 1977. Biocenoza potoku wysokogórskiego pozostającego pod wpływem turystyki. 2. Bakterie jako wskaźnik zanieczyszczenia wody Rybiego Potoku — Biocenosis of a high mountain stream under the influence of tourism. 2. Bacteria as an index of water pollution of the Rybi Potok stream. Acta Hydrobiol., 19, 257—270.

W a s y l i k K., 1971. Zbiorowiska glonów Czarnego Dunajca i niektórych jego dopływów — Algal communities in the Czarny Dunajec river (Southern Poland) and in some of its affluents. Fragm. Flor. et Geobot. 17.2. 256—354.

Ż a r n e c k i S., B i e n i a r z K., 1967. Wiek i tempo wzrostu pstrąga potokowego Rybiego Potoku w Tatrach. Acta Agrar. Silv., Ser. zootechn., 1, 83—95.

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