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Stream ecosystems in mountain grassland (West Carpathians)

14. The use of the experimental stream method in evaluating the effect of agricultural pollution*

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Abstract — The chemistry, algal, and bacterial populations, and micro- and macrofauna of a natural stream and four experimental streams differing in the load of nutrients (C, N, N+P, P) were investigated in the period October 3 — November 3, 1977. In the experimental streams with increased loads of nutrients there was an increase in the number of bacteria, this leading to an increased number of *Ciliata*. The greater amounts of nutrients affected the communities of algae and invertebrates to a smaller degree.

Key words: streams, pastoral economy, experimental stream method, nutrients, bacteria, sessile algae, ciliates, invertebrates.

1. Introduction

The inflow of nutrients to streams and rivers from agricultural areas does not occur at points but over long sectors. Therefore, it is difficult to find control stations which allow interpretation of the results of investigations (Kownacki 1983c).

The aim of the study was to find out and check a method of determin-

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ing the effect of pastoral economy on stream biocenosis without the necessity of comparing the results of field investigations, which are difficult to interpret. In a designated sector of the Biała Woda stream some experimental streams were built, whose characteristics (light, temperature and chemical composition of the water, substratum etc.), corresponded as nearly as possible to the natural environmental conditions, the differentiating factor being an additional dose of nutrients, such as nitrogen and phosphorus. An attempt was made to determine the dose of nitrogen and phosphorus which under natural conditions would bring about measurable changes in biocenosis. Qualitative and quantitative differences between the biocenosis of a natural stream and of experimental streams, between the different experimental streams, and between the upper and lower sectors of the experimental streams were taken into consideration.

The project included some experiments with different concentrations of nitrogen and phosphorus compounds. Because of a reduction in funds only a preliminary experiment was carried out in October 1977. The authors decided to publish the results as a presentation of a method which could be used in determining the impact of area pollution on stream biocenoses.

A similar method was used in an investigation on the productivity and drift of macrobenthos in the River Ricklea (Karlström 1973), and in a study of biocenoses in rivers polluted with municipal sewage (Wuhrmann 1974).

2. Description of the experiment

The investigation was carried out in four wooden experimental streams, 7 m long and 0.4 m wide (fig. 1) built in the Biała Woda stream at station BW2 (a detailed description of the station was given in the work of Kownacki (1983a) and Bombówna (1983)). The weirs in the first metre of the experimental streams played the role of mixers. The bottom of the experimental streams was lined with stones from a neighbouring stream. The discharge was invariable and reached 2 dm^3 sec^{-1}.

The first experimental stream was used as control (C), the second, as experimental stream N, was treated with nitrogen in the form of ammonia ($N—NH_4$); to the third one, N+P, nitrogen was added in the form of ammonia and phosphorus in the form of $Na_2HPO_4 \times 12\ H_2O$; to the fourth experimental stream P phosphorus was added in the form of $Na_2HPO_4 \times 12\ H_2O$. The addition was made continously during the experiment. Owing to technical difficulties, the concentrations of ammonia and phosphorus were lower than those planned (1 mg $N—NH_4$

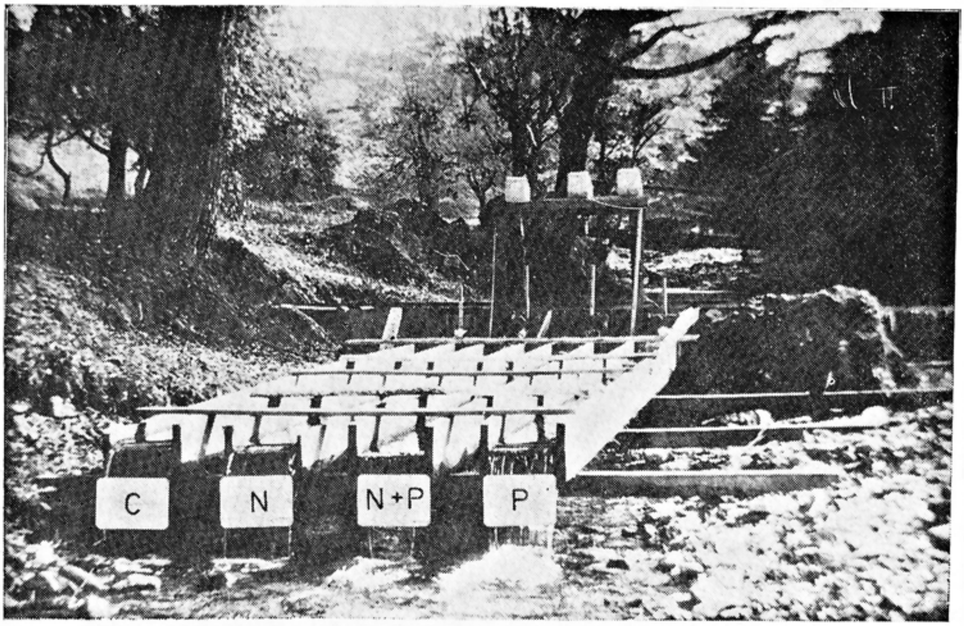


Fig. 1. Experimental streams with feeders in the Biała Woda stream

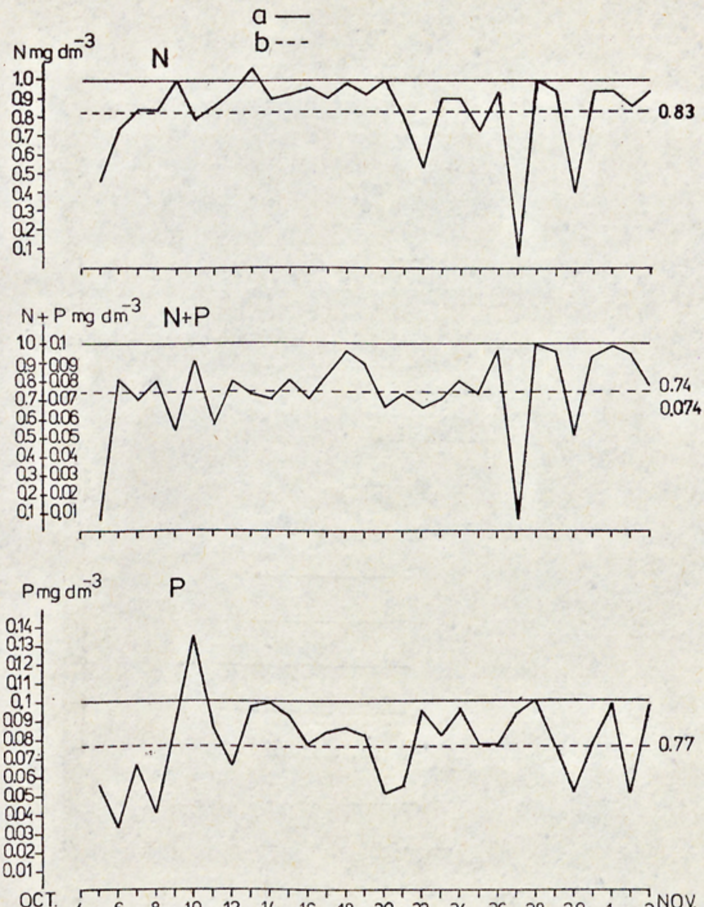


Fig. 2. Range of variation in the feeding of nutrients to experimental streams N, N+P, and P. a — the planned dose; b — the actual average monthly dose

dm^{-3} and 0.1 mg P dm^{-3}). Finally, throughout the period of the experiment the average doses were 0.83 mg N—NH_4 dm^{-3} in experimental stream N, 0.74 mg N—NH_4 dm^{-3} and 0.074 mg P dm^{-3} in N+P, and 0.077 mg P dm^{-3} in experimental stream P, though fairly considerable diel differences occurred in the content of the individual elements (fig. 2).

The experimental streams were built and lined with stones on August 28, 1977, i.e. 18 days after a flood which almost completely destroyed the stream biocenosis (Kownacki 1983b). Stabilization of the biocenosis lasted until October 3, 1977. The experimental streams were not stocked with fish. The experiment was carried out from October 3 to November 3 in sunny weather and with rain on the last two days only. Marked differences were observed in the temperatures of the water; in the middle of October ground frost occurred (fig. 3).

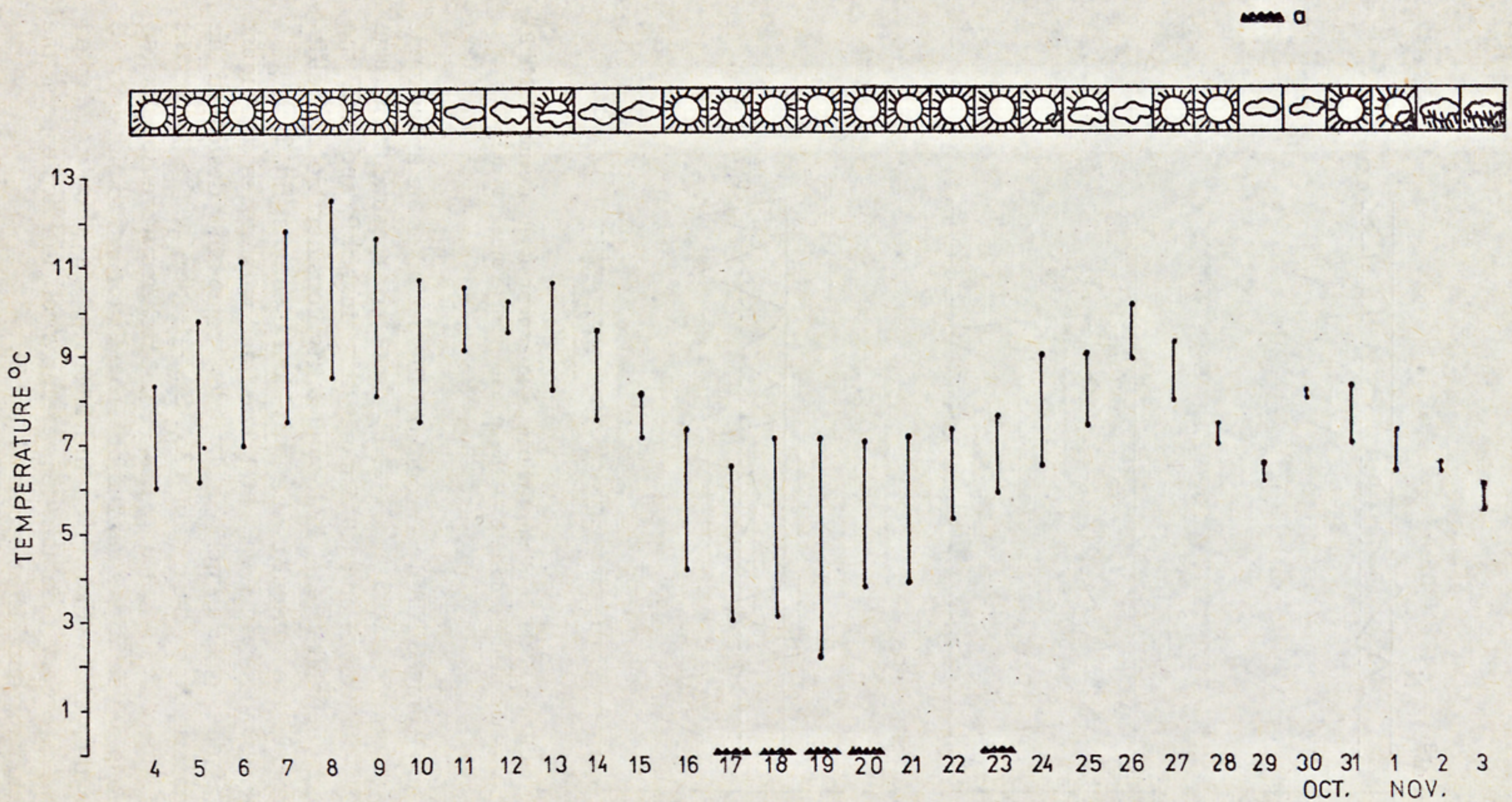


Fig. 3. Weather conditions and diel range of temperature of the water during the experiment. a — ground frost

Table I. Chemical composition of water in the natural stream and in the experimental streams in the period of the experiment (according to Pasternak's unpl. data)

Factor	3 October natural stream	19 October experimental streams				3 November natural stream
		C	N	N+P	P	
Dissolved oxygen O_2 mg dm^{-3}	11.68	12.16	12.16	11.84	11.20	19.04
Oxygen saturation O_2 %	96.8	103.7	103.7	100.9	95.5	155.8
pH	7.6	7.6	7.8	7.8	7.8	7.6
Alkalinity mval dm^{-3}	3.00	3.05	3.05	3.05	3.05	3.00
Total hardness °G	9.0	9.1	9.1	9.1	9.1	9.2
Calcium Ca mg dm^{-3}	52.53	50.74	50.74	50.74	51.46	50.74
Ferrum Fe mg dm^{-3}	0.168	0	0	0	0	0.013
Ammonia $N-NH_4$ mg dm^{-3}	0.050	0.022	0.876	0.776	0	0.226
Nitrite $N-NO_2$ mg dm^{-3}	0.004	0	0	0	0	0.002
Nitrate $N-NO_3$ mg dm^{-3}	1.305	0.975	0.695	0.850	0.575	0.670
Phosphates PO_4 mg dm^{-3}	0.025	0.018	0.037	0.093	0.400	0.086
BOD_5 O_2 mg dm^{-3}	2.56	1.76	1.76	1.60	0.96	8.0
Oxidability O_2 mg dm^{-3}	2.16	2.32	1.86	1.92	1.84	5.04
Free carbon dioxide CO_2 mg dm^{-3}	0	0	0	0	0	–

Chemical samples were taken from the natural stream on October and November 3 and from the experimental streams on October 19 (Table I) (Pasternak, MS). In this period no great changes in the chemical composition of the water were observed.

Microbiological samples of the water in the experimental streams were taken 8 times: on October 3, 11, 13, 17, 19, 24, and 27 and on November 3. The samples from the natural stream were collected twice: on October 3 and November 3. The determinations included total number of heterotrophic bacteria, the number of proteolytic bacteria, the titre of ammonifying bacteria, the titre of bacteria decomposing proteins with release of H_2S, and the titre of denitrifying bacteria. The investigations of bacteria were carried out according to methods given by Starzecka (1979). In order to compare the number of bacteria and the intensity of the determined microbiological processes (the titre), the coefficients illustrating the ratio of the number of bacteria in the different experimental streams to that in the natural stream: $\frac{C}{E}, \frac{N}{E}, \frac{N+P}{E}, \frac{P}{E}$ and the coefficients illustrating the ratio of the number of bacteria in the experimental streams enriched with mineral fertilizers to that in the control experimental stream: $\frac{N}{C}, \frac{N+P}{C}, \frac{P}{C}$ were calculated.

The samples of sessile algae, and micro- and macrofauna from the experimental streams were taken three times: on October 3 and 19, and on November 3. At the same time control samples were taken from the natural stream. Samples of algae were collected and elaborated according to the method described by Kawecka (1983). Faunistic samples were collected from stones using standard method (Grabacka 1983, K o w n a c k i 1983b). On each date two samples of macrofauna were collected in the lower sectors of the experimental streams and on the last date two additional samples were taken from the upper sectors.

3. Results

3.1. Bacteria

3.1.1. Comparison of the number of bacteria in the experimental streams and in the water of the natural stream

In the initial (October 3) and final (November 3) period of the experiment the number of bacteria and the intensity of the microbiological processes were greater in the experimental streams than in the natural one, larger differences being noted in October and smaller ones in November. This was mainly due to an increase in the number of bacteria in the water of the stream in consequence of the inflow of large amounts of nutrients and soil bacteria from the surrounding area after heavy rain on November 2 and 3. Only the number of proteolytic bacteria was maintained at the same level as that noted on October 3. However, in this case the decreased number of proteolytic bacteria in the experimental streams C, N, and N+P caused a reduction in the value of the coefficient expressing the ratio of the number of bacteria between the variants of the experiment and the natural stream (fig. 4).

3.1.2. Comparison of the number of bacteria in the experimental streams fertilized with mineral compounds and in experimental stream C

At the beginning of the experiment no differences in the total number of heterotrophic bacteria were noted in the experimental streams. The greatest difference was found after 10 days (October 13) in experimental stream N. From October 17 onward in all variants of the experiment the numbers of heterotrophic bacteria decreased in comparison with the control. In the final phase the quantitative level of heterotrophs in experimental streams N and N+P was similar to that in the control, while in experimental streams P the number of bacterial cells was distinctly increased (fig. 5).

Apart from experimental stream N, the group of ammonifying bacteria was most numerous in experimental streams N+P and P already in the first phase of the experiment. In further stages a distinct variation in the number of these bacteria occurred. On October 27 a marked decrease in the number of ammonifiers was found in experimental streams N, N+P,

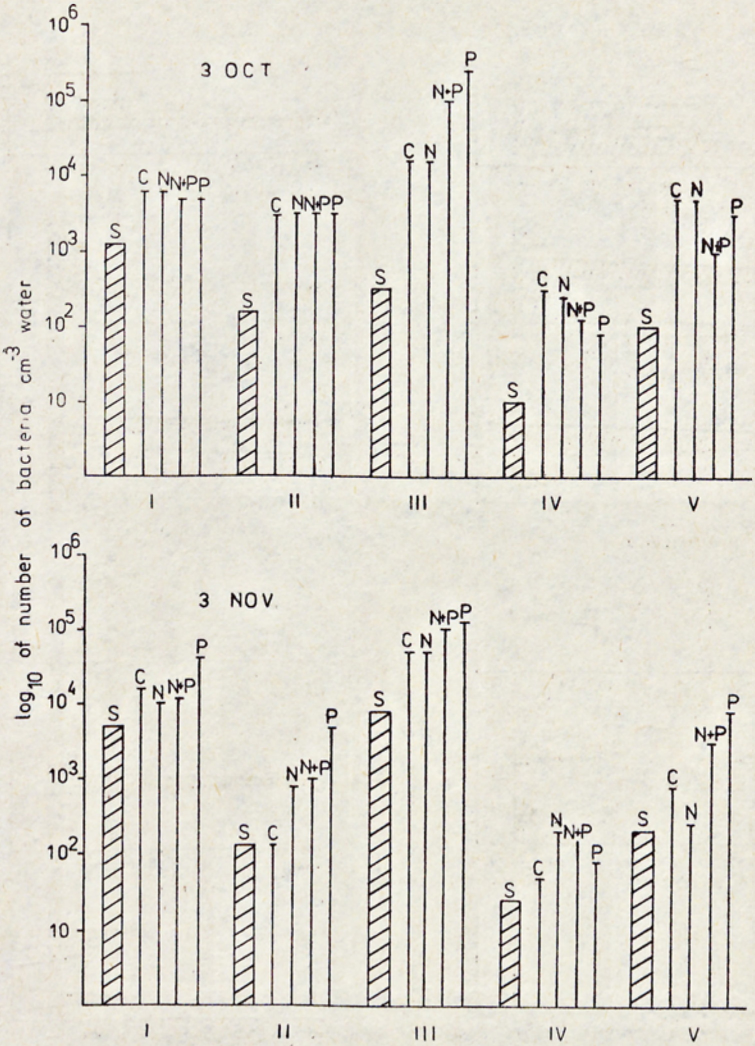


Fig. 4. Total number of bacteria in the natural stream (S) and in the experimental streams (C, N, N+P, P). I — total number of heterotrophic bacteria; II — proteolytic bacteria; III — ammonifying bacteria; IV — H_2S releasing bacteria; V — denitrifying bacteria

and P as compared with the control. In the final phase of the experiment the situation was similar to that found on October 3. In experimental stream N the quantitative level was almost identical with the control, while the greatest differences appeared in experimental streams N+P and P (fig. 5).

At the beginning of the experiment the number of bacteria decomposing protein substances with release of hydrogen sulphide was smaller in experimental streams N, N+P, and P than in the control. A further

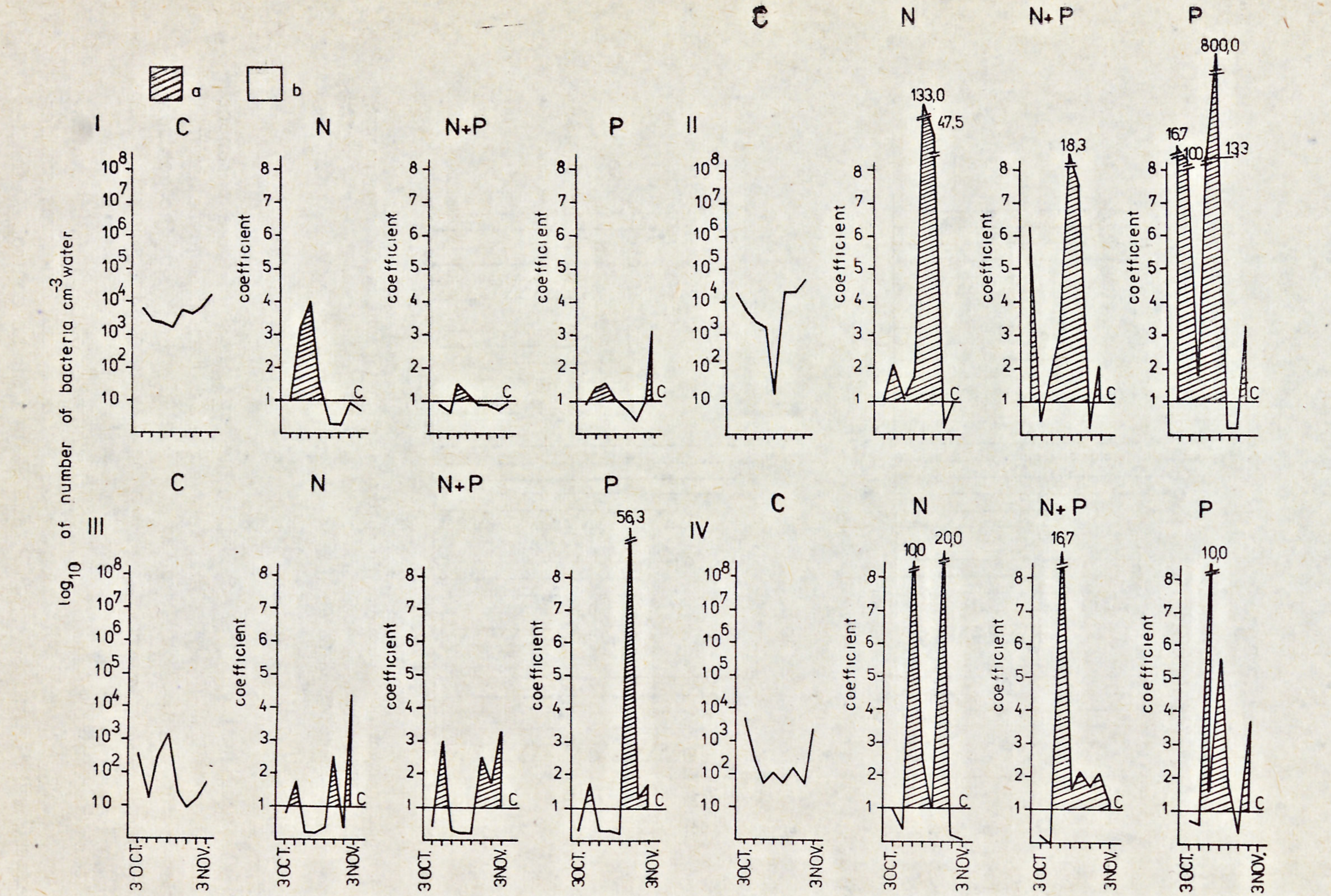


Fig. 5. Changes in the number of bacteria in experimental stream C and the coefficient of the number of bacteria in experimental streams N, N+P, P to the number of bacteria in experimental stream C. a — positive coefficient; b — negative coefficient. I — total number of heterotrophic bacteria; II — ammonifying bacteria; III — H_2S releasing bacteria; IV — denitrifying bacteria

decrease was noted between the 10th and 16th day of the experiment (October 13—19). On other dates (with the exception of October 17, experimental stream N) the situation changed in favour of experimental streams treated with nutrients. In the final phase of the experiment, contrary to the ammonification, the process of hydrogen sulphide release occurred most intensely in experimental stream N and least intensely in experimental stream P (fig. 5).

In the first phase of the experiment the bacteria reducing nitrates were less numerous in the experimental streams with nutrients than in the control. On further dates the quantitative relations varied in the different experimental streams. However, in most cases the number of denitrifiers was larger in the experimental streams enriched with nutrients (fig. 5).

In the initial phase of the experiment the quantitative level of proteolytic bacteria was similar in all experimental streams. On November 3 a distinct increase in the number of proteolytic bacteria in relation to the control was noted in experimental streams N, N+P, and P.

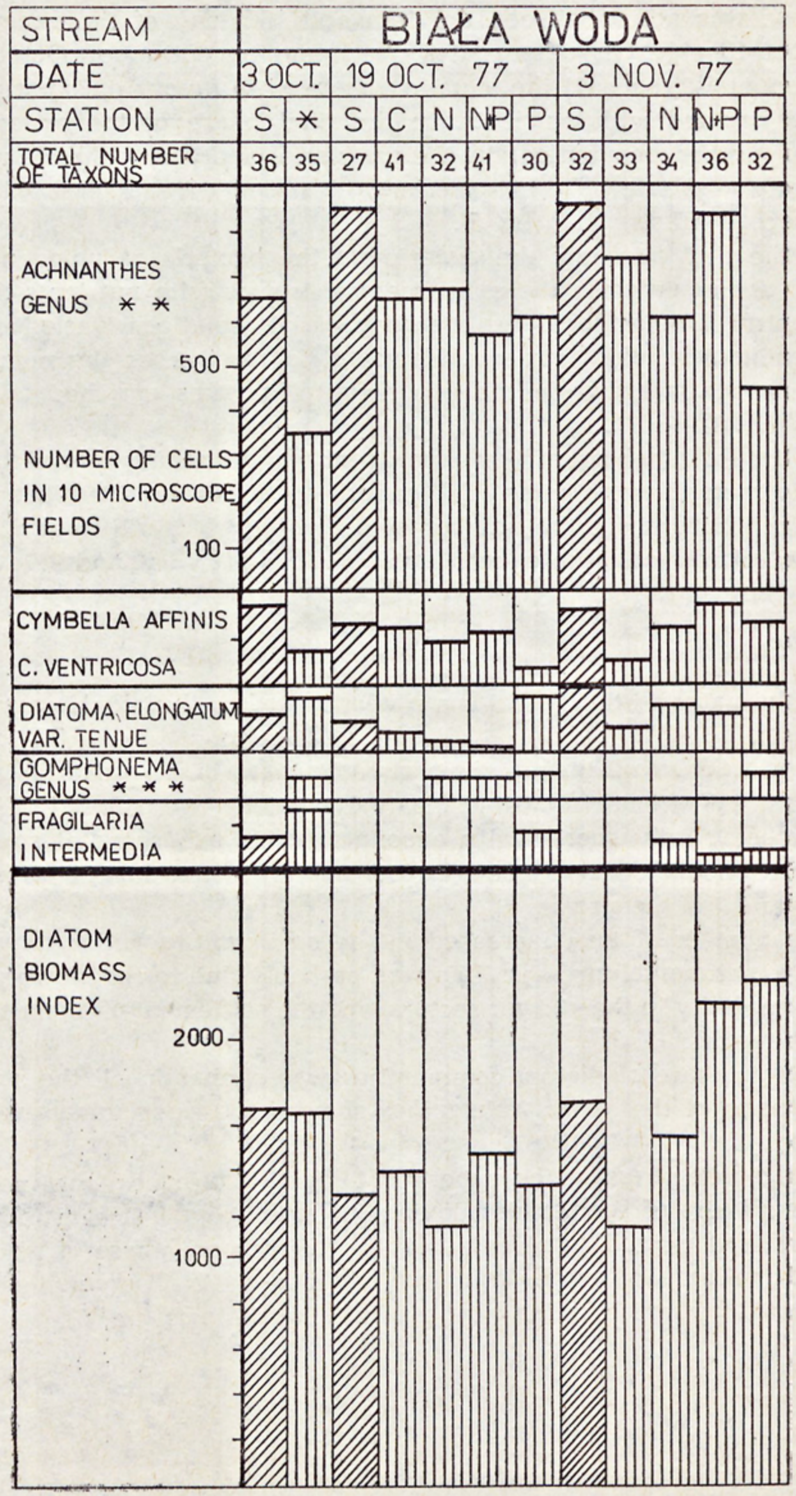
3.2. Algae

In the natural stream diatoms predominated in the algal community, besides which *Phormidium favosum, Ulothrix zonata,* and *Cladophora glomerata* occurred, though their abundance was not great. In all the experimental streams almost exclusively diatoms were found, *Ulothrix zonata* being only sporadically encountered. In experimental stream C the abundance of diatoms was always less pronounced than in the natural environment of the stream.

The number of taxa increased in the communities which developed in the experimental streams. This was probably due to the slower water flow, especially in their lower sectors, and the settlement of algae coming in with the drift.

The structure of diatom communities was similar in all the streams. The species of the genus *Achnanthes* showed the most numerous participation.

In the first phase of the experiment slight differences were noted in the abundance of species developing in experimental stream C and in the fertilized experimental streams. In the second phase a tendency towards an increase in the population of diatoms was observed, this being manifested by a rise in the biomass index of diatoms (fig. 6).


STREAM
BIAŁA WODA
DATE
3 OCT.
19 OCT. 77
3 NOV. 77
STATION
S * S C N N+P P S C N N+P P
TOTAL NUMBER OF TAXONS
36 35 27 41 32 41 30 32 33 34 36 32
ACHNANTHES GENUS * *
500
NUMBER OF CELLS IN 10 MICROSCOPE FIELDS
100
CYMBELLA AFFINIS
C. VENTRICOSA
DIATOMA ELONGATUM VAR. TENUE
GOMPHONEMA GENUS * * *
FRAGILARIA INTERMEDIA
DIATOM BIOMASS INDEX
2000
1000

3.3. Bottom *Ciliata*

In the experimental streams the community of microfauna which developed in the mud gathering between stones and in the peryphyton, was composed of *Ciliata* and rotifers. Nematodes were also encountered. *Ciliata* formed the dominating group with regard to numbers and species composition. Quantitative and qualitative differences were noted both between the environment of the natural stream and the experimental streams and between the different experimental streams. As compared with the natural stream, the number of species of *Ciliata* and their more abundant occurrence were noted in the experimental streams.

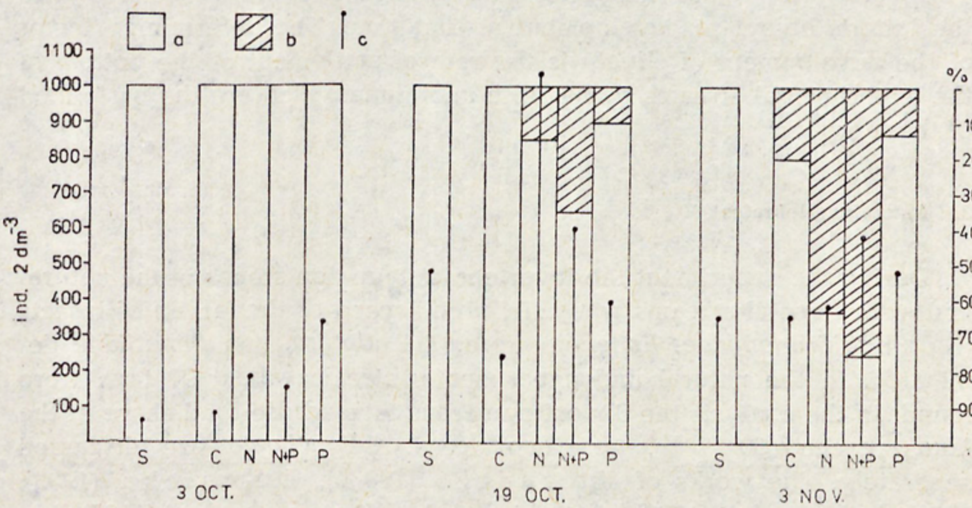


Fig. 7. Number of *Ciliata* against the background of the percentage participation of forms feeding on algae and bacteria in the natural stream (S) and in the experimental streams (C, N, N+P, P). a — group of *Ciliata* feeding on bacteria; b — group of *Ciliata* feeding on algae; c — total number of *Ciliata*

In the experimental streams the settlement of microfauna in the bottom took place rather rapidly. At the beginning of the experiment (October 3) in all the experimental streams small numbers of *Ciliata* were found (fig. 7). A distinct, several times, increase in their number was observed halfway through the experiment, especially in experimental streams N and N+P, which was maintained till the end of the experiment

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Fig. 6. Dominating species of algae in the natural stream (S) and in the experimental streams C, N, N+P, P. * — mean value of abundance of all experimental streams (C, N, N+P, P); ** — *Achnanthes minutissima, A. microcephala, A. pyrenaica, A. amphicephala;* *** — *Gomphonema angustatum* var. *productum, G. olivaceum, G. olivaceum* var. *calcareum, G. intricatum* var. *pumilum*

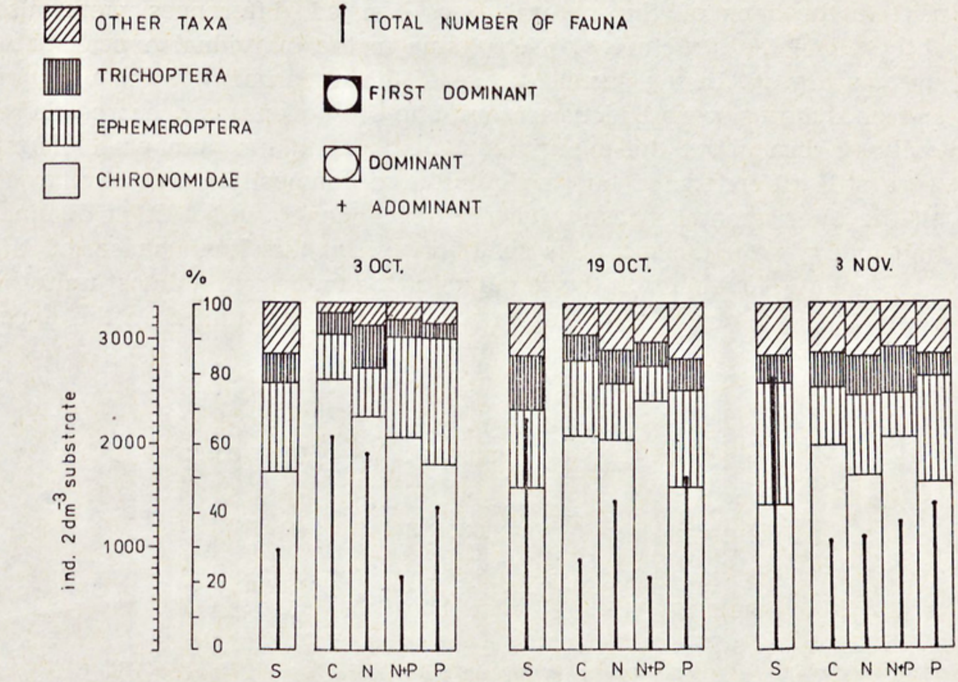
(November 3). Qualitative differences between the experimental streams were slight throughout the period of the experiment, being distinct only in comparison with the natural stream. In the investigated period the number of species in the experimental streams was double (a total of 17 species) that in the natural one, while the qualitative composition also varied there. In the first half of the experiment the *Ciliata* species feeding on bacteria prevailed, among them *Aspidisca costata, A. lynceus, Cinetochilum margaritaceum,* and *Chilodonella uncinata* being dominants. Towards the end of the experiment the species feeding on algae increased, among them being *Didinium* sp., *Euplotes patella, Frontonia acuminata, Nassula parva, Nassula* sp., *Trachelophyllum* sp., and *Urostyla* sp. The increased number of species feeding on algae was associated with the latter's abundant development at that time. The determining factor of the development of *Ciliata* is the rate of settlement of the bottom of the experimental streams by bacteria and algae which are the basic food of these organisms.

3.4. Macroinvertebrates

During the experiment the invertebrate fauna on stones in the natural and experimental streams was chiefly composed of the larvae of insects (fig. 8). *Chironomidae, Ephemeroptera, Trichoptera,* and *Simuliidae* dominated. In the natural and experimental streams about 90 taxa were found. In the analysis the 8 most numerous taxa whose total share in the fauna reached 50—70%, were considered. *Oligochaeta* are discussed separately. The works of Kownacki (1983b), Dumnicka (1983), Niesiołowski (1983), Jażdżewski, Konopacka (1985) provided more detailed data concerning macroinvertebrates.

3.4.1. Comparison of macroinvertebrates of the experimental streams and the natural stream

Fairly great differences were observed here (fig. 8). In the initial period the total number of macrofauna was lower in the natural stream than in the experimental ones. However, halfway through the experimental period (October 19) the total number of macrofauna in the stream increased, this situation being maintained until the end of the experiment (November 3). At the beginning of the experiment both in the experimental streams and in the natural one the first dominants were indeterminable larvae of *Cricotopus* spp. + *Orthocladius* spp. in juvenile instars, and juvenile larval instars of the genus *Baetis*. In the middle of the experiment the dominants were juvenile stages of mayflies of the genus *Baetis* in the natural stream and *Orthocladius* sp. I in the experimental ones. In the



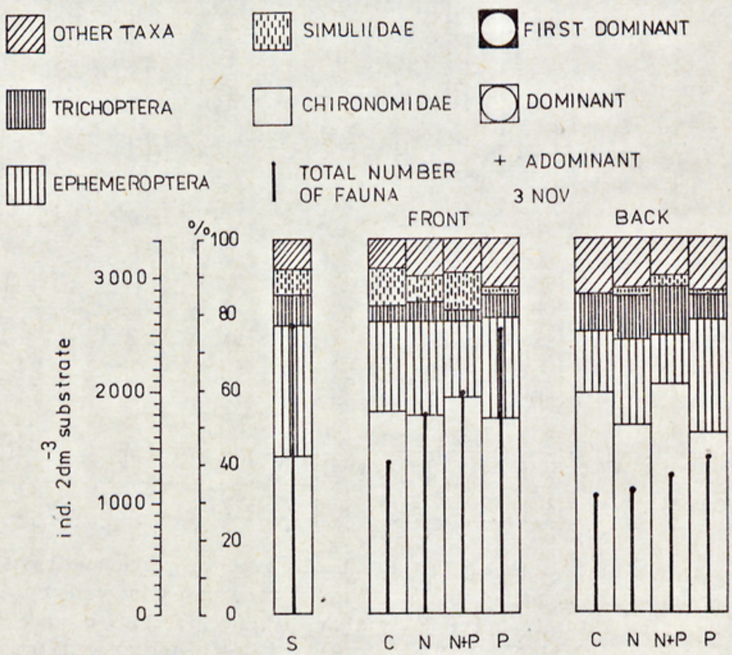
	3 Oct. S	3 Oct. C	3 Oct. N	3 Oct. N+P	3 Oct. P	19 Oct. S	19 Oct. C	19 Oct. N	19 Oct. N+P	19 Oct. P	3 Nov. S	3 Nov. C	3 Nov. N	3 Nov. N+P	3 Nov. P
CRICOTOPUS SPP. + ORTHOCLADIUS SPP.	22	19	22	19	17	5,5	5,4	2,6	5,4	4,3	7,5	6,1	–	2,8	3,1
ORTHOCLADIUS SP.	4,5	20	19	18	15	16	23	30	37	24	1,7	6,9	6,7	8,7	6,6
BAETIS SP. (JUV.)	16	9,4	8,7	20	28	18	9,5	5,5	3,7	10	28	11	14	7,6	15
ORTHOCLADIINAE (JUV.)	51	6,8	6,1	3,3	1,6	12	3,3	5,2	6,5	3,6	15	13	14	17	12
MICROPSECTRA SP.	+	15	4,7	+	+	–	12	3,6	4,8	1,7	+	15	7,7	9,5	5,9
PSYCHOMYIA PUSILLA	1,4	5,0	11	2,8	2,0	7,7	5,1	6,6	5,5	8,1	5,1	9,1	9,9	11	6,0
BAETIS RHODANI	1,5	1,2	2,1	2,2	4,4	+	6,3	7,3	4,5	15	2,8	4,2	8,2	3,8	14

Fig. 8. Number of the fauna against the background of percentage participation of the main groups and the percentage structure of zoocenoses (only dominating species considered) in the natural stream (S) and in the lower sectors of the experimental streams (C, N, N+P, P) on particular dates of the experiment

final phase the zoocenotic structure changed owing to the emergence of *Orthocladius* sp. I. Both in the experimental streams and in the natural stream juvenile instars of *Baetis* and *Orthocladiinae* larvae dominated.

3.4.2. Comparison of the settlement of macrofauna in the experimental streams with nutrients and in the control experimental stream

The distribution of fauna in the experimental streams was found to be rather fortuitous at the beginning of the experiment. The largest number of fauna were noted in experimental streams C and N, lying next to the bank of the natural one. Marked differences were also observed in the structure of macrofauna in the individual experimental streams (fig. 8). In the second phase of the experiment, when nitrogen and phosphorus were added, a rebuilding of zoocenoses occurred there. Halfway throughout the experiment (October 19) the numbers of fauna were still differentiated but the qualitative composition was similar in all the experimental streams. The first dominants, with a high domination index, were *Orthocladius* sp. I larvae. In the final phase of the experiment (November 3) the numbers of the fauna were almost uniform, while the structure of domination was more differentiated in the expe-



	S	C	N	N+P	P	C	N	N+P	P
BAETIS SPP. (JUV.)	28	18	19	17	14	11	14	7,6	15
ORTHOCLADIINAE (JUV.)	15	29,	16	24,	19	13	14	17	12
MICROPSECTRA SP.	+	1,0	2,4	+	4,8	15,	7,7	9,5	5,9
SIMULIIDAE	7,4	9,9	7,0	10	1,7	+	2,3	2,8	1,5
CRICOTOPUS SPP. + ORTHOCLADIUS SPP.	7,5	2,7	9,2	7,2	10	6,1	–	2,8	3,1
PSYCHOMYIA PUSILLA	5,1	3,8	3,6	2,4	5,5	9,1	9,9	11	6,0
BAETIS RHODANI	2,8	4,9	4,7	2,9	9,8	4,2	8,2	3,8	14

Fig. 9. Numbers of the fauna against the background of percentage participation of the main groups of fauna and the percentage structure of zoocenoses (only dominant species considered) in the natural stream (S) and in the upper and lower sectors of the experimental streams (C, N, N+P, P) on November 3

rimental streams. In all the experimental streams juvenile instars of *Baetis* and *Orthocladiinae* prevailed, though in experimental stream C the larvae of *Micropsectra* sp. were the first dominant.

3.4.3. Comparison of fauna in the upper and lower sectors of the experimental streams in the final phase of the experiment

The samples from the upper and lower sectors of the experimental streams were collected on November 3. The distance between these two points was only 5—6 m yet very distinct differences were observed (fig. 9). In the upper sectors of the experimental streams the fauna was very similar to that of the natural stream. Even though the abundance of fauna was smaller than in the natural stream (except for experimental stream P), it was nevertheless markedly larger in the lower sector. Similarly as in the natural stream, in the upper sectors of the experimental streams the percentage of mayflies and *Simuliidae* in the total number of fauna was relatively high, while in the lower sectors of the experimental streams the numbers of these groups were much smaller. Since in this period there occurred a mass emergence of juvenile instars of *Baetis* and *Orthocladius*, these two taxa dominated in the upper and lower sectors of the experimental streams. The *Micropsectra* sp. larvae, which were sporadically found in the natural stream and were also infrequent in the upper sectors of the experimental streams, appeared as the dominant form in the lower sector (experimental stream C) or as of the more important subdominants. A similar distribution of the caddis fly *Psychomyia pusilla* was observed. These results show that in the upper sector of the experimental streams, as in the natural stream, the fauna is more rheophile in character than in the lower sector where there is a weaker and laminar current.

3.4.4. Distribution of *Oligochaeta* in the experimental streams and in the natural stream

In the Biała Woda stream *Oligochaeta* constituted a very small part of the bottom fauna (Dumnicka 1983). In the experimental streams the same situation was observed. *Oligochaeta* reached 0.1—5% of the total macrobenthos and were represented by 10 species.

At the beginning of the experiment the number of *Oligochaeta* in the natural stream was several times greater than that found in the experimental streams (fig. 10). During the investigation a further settlement of the experimental streams occurred, bringing about a distinct increase in the number of *Oligochaeta*. In experimental stream N+P only *Oligochaeta* occurred very infrequently up to the end of the experiment.

The composition of the oligochaete fauna in the natural stream and in the experimental streams was similar; *Nais pardalis* decisively do-

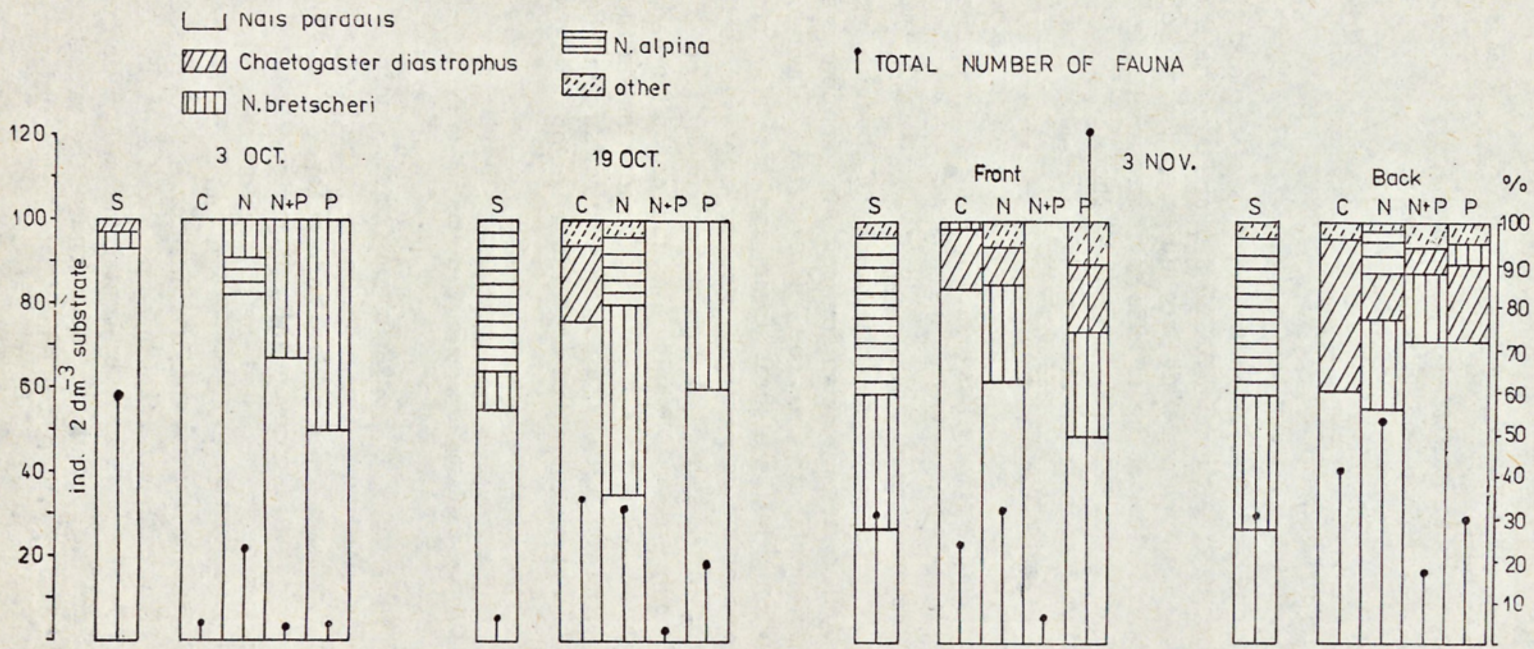


Fig. 10. Numbers of *Oligochaeta* against the background of the percentage composition of the dominant species in the natural stream (S) and in the experimental streams (C, N, N+P, P) on particular dates of the experiment

minated everywhere, *N. alpina* also being numerous. These are typical species of mountain waters. One species only, *Chaetogaster diastrophus*, occurred in large numbers in the experimental streams, though it was not found in the natural one. Specimens of this species were noted in the samples from October 19, their occurrence being more numerous at the end of the experiment, *Chaetogaster diastrophus* is not a typical species of mountain streams and its abundant appearance in the experimental streams suggested the formation of a separate community there. *Ch. diastrophus* was chiefly noted in the lower sectors of the experimental streams, where the water current was weaker. In three experimental streams the numbers of *Oligochaeta* were also greater in this sector, with the exception of experimental stream P where the settlement was more abundant in the upper sector.

4. Discussion

There occurred certain differences between the biocenoses in the natural stream and experimental streams. They are chiefly expressed by changes in the domination structure of communities. The changes are not great enough to render the method of experimental streams useless in the investigation of processes occurring in natural streams. The biocenoses of the natural stream and of the experimental streams were similar, but in the application of the method certain conditions have nevertheless to be considered.

An important factor is the site of sampling in the experimental streams. The obtained results concerning the communities of invertebrate fauna show that in the upper sector of the experimental streams the zoocenosis is of more rheophile character owing to the proximity of mixers where the water is strongly oxygenated and where turbulent currents occur. In the lower sector of the conduit the flow is laminar and the forms associated with weak currents begin to prevail. In the natural stream rheophile species appear in large numbers as in the upper sectors of the experimental streams.

Another important factor is the length of the period in which the biocenosis is stabilized in the experimental streams. In the present experiment this period lasted 37 days (August 28 — October 3), being sufficiently long for the formation of fairly uniform communities of algae and *Ciliata* and for a general stabilization of the number of bacteria. On the other hand, the communities of bottom fauna were not yet fully stabilized, this being shown by fairly great quantitative and qualitative differences in the structure of domination at the time of starting the experiment. The initial period of settlement affected the later formation of macrobenthos communities. In experimental stream C *Micropsectra* larvae developed abundantly and were numerous there throughout the experimental period. Similarly, in experimental stream P numerous mayflies *Baetis rhodani* appeared during the investigation period. The occurrence of this species in the different experimental streams was brought about by factors other than the lack or addition of nutrients.

It is more difficult to answer the question as to what influence increased doses of nutrients have on the biocenoses of experimental streams. At any rate, similarly as in natural streams (Kownacki 1983c), increased doses of nutrients affected to a greater degrees the number of bacteria and, indirectly, that of *Ciliata* which feed on bacteria, and to a lesser degree the communities of algae and the complexes of invertebrate fauna associated with them.

In most cases the obtained bacteriological results show a more abundant development of bacteria in the experimental streams enriched with mineral nutrients of nitrogen and phosphorus, especially in the case of specific groups of microorganisms. For example, on October 13 a distinct increase in the intensity of the denitrification process in experimental stream N as compared with the control (experimental stream C) was preceded by a high content of ammonia nitrogen (above the average concentration of 0.83 mg dm^{-3}), which was maintained in the water for a few days and, being subjected to oxygenation, released nitrates used in the reduction process. In the experimental streams enriched with nutrients also the intensity of ammonification processes was markedly increased, and the number of proteolytic bacteria was slightly greater than in the control. This suggested the presence of larger amounts of compounds undergoing hydrolysis and desamination in the experimental streams enriched with nutrients.

Halfway through the experiment, when the temperature of the water markedly fell, the number of ammonifying bacteria was reduced. The most pronounced reduction in the number of these bacteria was found in experimental stream C, a slightly smaller one in experimental streams N+P and P, and the smallest in experimental stream N. This observation suggests that nitrogen stimulated the development of ammonifiers and, under these conditions, eliminated the negative effect of the low temperature.

The effect of nitrogen and phosphorus on the microfauna was also observed. Particularly distinct changes were found in experimental stream N. Within 16 days the number of *Ciliata* increased sixfold; these were the species feeding on bacteria. At the same time, in this experimental stream the numbers of heterotrophic bacteria diminished. In the final phase of the experiment the number of bacteria increased at the time when the number of *Ciliata* feeding on bacteria decreased. In experimental stream N+P the pattern of changes was similar, though they were less distinct. In experimental streams C and P a constant rise in the number of *Ciliata* was observed.

Among algae a marked increase in the index of diatom biomass was observed after completion of the experiment in experimental streams N+P and P. This was caused by a general increase in the abundance of diatoms, particularly of species of the genus *Gomphonema*, *Cymbella*, and *Diatoma elongatum* var. *tenue*. Halfway through the experiment, in spite of the inflow of nutrients, the value of the index of diatom biomass in experimental streams N+P and P was similar to that in experimental stream C. It is therefore difficult to evaluate the dependence of the observed increase in the population of diatoms upon the chemical environment.

The most difficult question is the association between an increase in the content of nutrients and the invertebrate fauna. In the final phase of the experiment the number of the fauna was stabilized at almost the same level in all the experimental streams. A slight tendency to increasing numbers of the fauna from the control experimental stream to experimental stream P could be observed but this should rather be associated with a similar increase in the index of diatom biomass and, hence, with better trophic conditions.

5. Polish summary

Ekosystemy potokowe na terenach pastwisk górskich (Karpaty Zachodnie)

14. Zastosowanie potoków eksperymentalnych w ocenie wpływu zanieczyszczeń rolniczych

Celem pracy było znalezienie i sprawdzenie metody pozwalającej na określenie wpływu gospodarki pasterskiej na biocenozę potoków. Badania prowadzono w 4 potokach eksperymentalnych (ryc. 1); pierwszy stanowił kontrolę (C), do drugiego dodawano azot ($N—NH_4$), do trzeciego azot ($N—NH_4$) i fosfor ($Na_2HPO_4 \times 12\ H_2O$), a do czwartego sam fosfor ($Na_2HPO_4 \times 12\ H_2O$). Biogeny dozowano nieprzerwanie (ryc. 2). Eksperyment prowadzono od 3 X do 3 XI. Przez większość tego czasu utrzymywała się słoneczna pogoda (ryc. 3). Skład chemiczny wody w badanym okresie nie wykazywał większych zmian (tabela I).

Liczebność bakterii i intensywność procesów mikrobiologicznych były większe w eksperymentalnych potokach niż w naturalnym potoku (ryc. 4). Lepszy rozwój bakterii (zwłaszcza specyficznych grup) stwierdzono w eksperymentalnych potokach nawożonych niż w eksperymentalnym potoku kontrolnym (ryc. 5). W zbiorowiskach glonów dominowały okrzemki (głównie *Achnanthes*). W czasie trwania eksperymentu populacja okrzemek w eksperymentalnych potokach nawożonych wzrasta, o czym świadczy wzrost wskaźnika biomasy okrzemek (ryc. 6). Nawożenie wpłynęło też na wzrost liczby gatunków i liczebności orzęsków w eksperymentalnych potokach (ryc. 7). Porównując faunę potoku z fauną potoków eksperymentalnych i faunę rynny kontrolnej z fauną rynien nawożonych oraz faunę początkowego i końcowego odcinka poto-

ków eksperymentalnych stwierdzono pewne różnice w strukturze ugrupowań i liczebności fauny (ryc. 8, 9, 10).

Na podstawie otrzymanych wyników można stwierdzić, że zwiększone dawki biogenów w większym stopniu wywarły wpływ na liczebność bakterii, a pośrednio na liczebność orzęsków odżywiających się nimi, w mniejszym zaś stopniu na zbiorowiska glonów i związane z nimi zespoły fauny bezkręgowców.

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