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The response of the invertebrate fauna to organic pollution in a well oxygenated karst stream exemplified by the Prądnik Stream (South Poland)

Reakcja fauny bezkręgowców na organiczne zanieczyszczenia dobrze natlenionego potoku krasowego na przykładzie Prądnika (południowa Polska)

Wpłynęło 13 września 1979 r.

Abstract — The response of benthic invertebrates to organic pollution of a well oxygenated stream was observed during three periods; before and after the waste treatment plant was put in operation, and four years later. Two zones were found below the waste-water influx: the zone of qualitative conversion with a tendency to reduce the composition and favour the predominance of single species, and below, the zone of restoration of the composition and very intensive development of abundance. During the last period the first zone disappeared.

1. Introduction

The Prądnik, a left tributary of the River Vistula, c. 34 km long, in its upper course at a sector of 12.25 km flows through the territory of the Ojców National Park (ONP) (fig. 1). That area abounds in karst phenomena and springs supplying almost 30 per cent of water to the stream (33 springs in the Prądnik valley and 14 in the Sąspówka valley — Alexandrowicz, Wilk 1962). Its most characteristic feature is the high content of calcium reaching usually more than 80 mg/dm^3, and good oxygen saturation exceeding 80 per cent, and sometimes even 100 per cent. A detailed description of the stream and the characteristic features of its drainage area is to be found in Dratnal's paper dealing with the stream Prądnik (1976a).

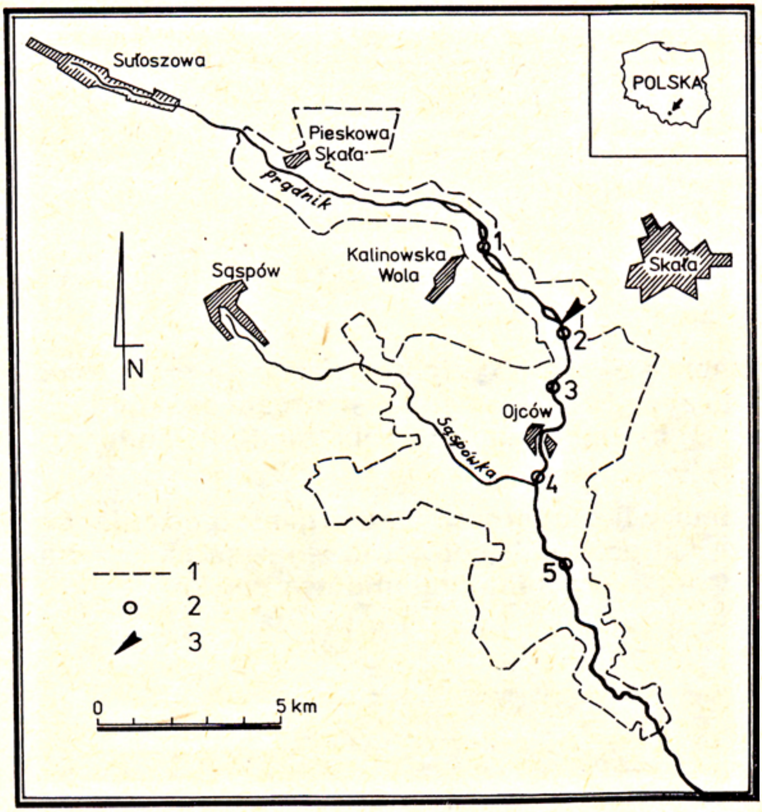

Fig. 1. Study area. 1 — border of the Ojców National Park; 2 — stations; 3 — inflow of waste water from the dairy at Skała town

Ryc. 1. Teren badań. 1 — granica Ojcowskiego Parku Narodowego; 2 — stanowiska; 3 — wpływ wód ściekowych z mleczarni w Skale

Despite the fact that the ONP area is subject to legal protection, the wastes from the dairy at the town Skała, outside the ONP area, are discharged to the stream Prądnik. Since 1957 they have contaminated the stream and caused a significant damage to the appearance of the stream as well as to the composition of its fauna and flora, at a distance of several kilometres. At the end of 1968 a new waste treatment plant was installed in the dairy, and since the spring of 1969, when the organic sediments deposited at the bottom of the stream-bed were washed off by repeated floods, the conditions have become favourable to the regeneration of the natural fauna and flora communities.

Before the waste treatment plant was set in motion (in 1968), the investigations in the benthic invertebrate communities of the whole stream were carried out. Later (in 1969) it was decided to continue field work in a stretch of the stream affected by pollution and, for comparison, above the influx of wastes. The results were published in two papers; one described the natural fauna communities, excluding the polluted zone (D r a t n a l 1976a), while the other concerned the effects of pollution (D r a t n a l 1976b). Moreover, a separate paper was dedicated to *Oligochaeta* (K a s p r z a k 1976), the species of which were not identified in D r a t n a l's papers.

However, in the course of 1969, the new waste water treatment plant broke down several times, and the effectiveness of affluents disposal was insufficient. Therefore it was decided to repeat (in 1973—1974) all the studies concerning the polluted part of the Prądnik stream. This paper presents the most important results of the three periods (1968, 1969, 1973—1974) of the research on the benthic invertebrate communities of the stream Prądnik affected by the waste waters from the dairy. The full list of species has not been presented here as it had been quoted in the above mentioned papers, which also refers to a detailed description of the stream and sampling stations.

2. Methods

Samples were taken from the stream above the influx of wastes and below it, from the whole stretch of the stream affected by pollution, during the first two periods from four stations, and during the last one from five.

Station 1: at Kalinowska Wola, above the village Grodzisko about 29 km from the estuary. It corresponds to station no. 2 in D r a t n a l's (1976b) and K a s p r z a k's (1976) papers.

Station 2: below the village Grodzisko about 27.5 km. It corresponds to station no. 3 in the above-mentioned papers.

Station 3: in the village Ojców, about 26.5 km. Established for the last period.

Station 4: about 200 m above the mouth of the stream Sąspówka, about 25 km. The same station as in the above-mentioned papers.

Station 5: near Brama Krakowska, about 23.5 km. The same station as in the above-mentioned papers.

The samples were taken at intervals of about one month, and in the successive sampling periods the following numbers of collections were made:

from April 1968 till January 1969 — 8 collections
from March till October 1969 — 7 collections
from March 1973 till May 1974 — 14 collections.

Surber's sampler was used in sampling. Each time one to three (most often two) samples from c. 3 dm^2 of the stony bottom, and the same number from the silty bottom were collected. The animals were preserved in a 4 per cent formalin solution or, in some samples, in 75 per cent alcohol.

All quantitative data (area of 3 dm^2) presented in this paper are the mean values calculated from all samples taken from the given station, in the particular period, separately for two main habitats in the stream: the stony bottom and the silty bottom.

The term „form", which is often used in the paper, concerns the items in the list of species (Dratnal 1976a, 1976b), which, for different reasons, comprise more than one species. This is especially the case with the *Chironomidae*, the larvae of which, considering the scarcity of the pupae, formed the essential material for quantitative analyses, and it is often impossible to determine the larvae to the species.

3. Results

3.1. Oxygen conditions

Of all the chemical data obtained for the polluted zone, the changes in oxygen conditions showed the most distinct regularity. The oxygen content, which at station 1 varied from 8.9—11.3 (mean 10.1) mg/dm^3, dropped to 6.8—10.1 (mean 8.8) at station 2 and 7.5—9.4 (mean 8.6) at station 4. At the last station it reached almost its normal level varying from 8.2—11.8 (mean 9.7) mg/dm^3. This was accompanied by changes in the BOD value, which increased from 0.6—4.6 (mean 2.3) mg O_2/dm^3 at station 1 to 2.3—36.4 (mean 13.3) at station 2 and 1.0—6.8 (mean 3.5) at station 4. It was most important for all regularities that in spite of a high BOD in certain periods, oxygen content in the water of the polluted zone was considerable.

No chemical analyses of sediments were performed, but the black colour and the gases escaping from the sludge in the layer of several centimetres below its surface at station 2 suggest that deoxygenation occurred there in the first and second period.

3.2. Reaction of invertebrates affected by pollution

3.2.1. Reduction of taxons

The decline in number of the taxons below the influx of organic wastes as a result of the elimination of less resistant species is a widely known phenomenon (Hynes 1963). In the stream Prądnik that decline

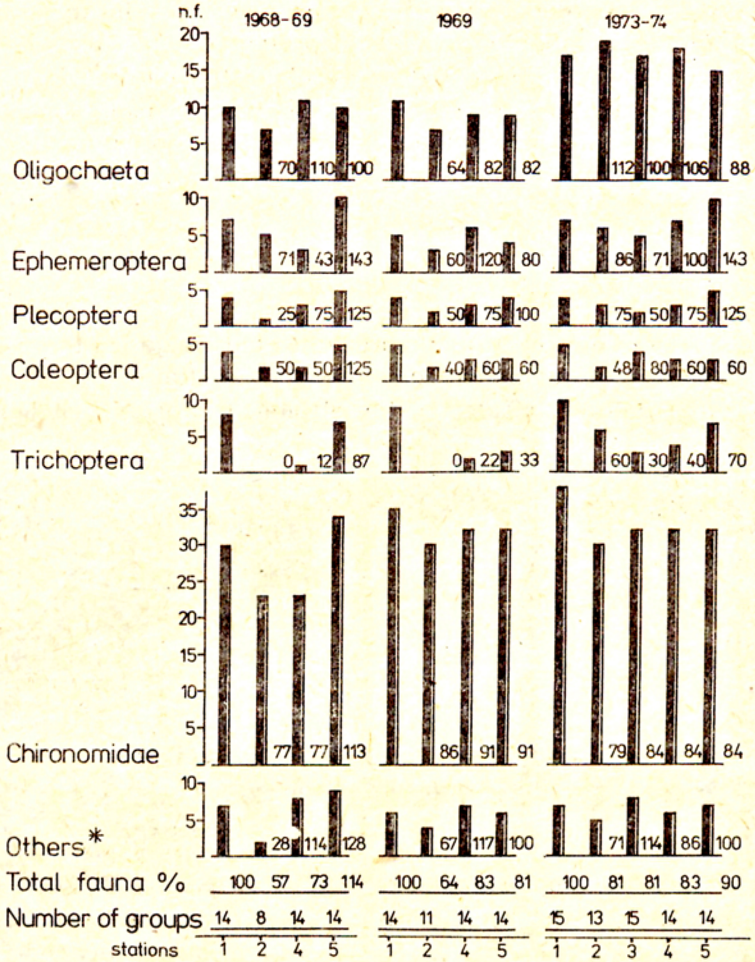

Fig. 2. Reduction of forms at stations below the inlet of waste water. On the right of bars — the percentage of forms at particular stations in relation to those of station 1 assumed as being 100 per cent. n.f. — number of forms. * *Tricladida, Gastropoda, Lamellibranchia, Hirudinea, Hydracarina, Isopoda, Amphipoda, Megaloptera,* and *Diptera* except *Chironomidae*

Ryc. 2. Redukcja form na stanowiskach poniżej wpływu wód ściekowych. Na prawo od słupków zaznaczono procentowy udział form na poszczególnych stanowiskach w stosunku do form stanowiska 1, przyjętych za 100%. n.f. — liczba form. * *Tricladida, Gastropoda, Lamellibranchia, Hirudinea, Hydracarina, Isopoda, Amphipoda, Megaloptera* i *Diptera*, z wyjątkiem *Chironomidae*

was observed in all taxonomic groups (fig. 2). The whole invertebrate fauna lost from 43 per cent to 19 per cent of species, and several taxonomic groups in different periods. The *Trichoptera* were ousted most severely of all, and in the two first periods entirely. The greatest decline was most often recorded at station 2, just below the influx of organic wastes. A higher number of species recorded in some cases at station 5 in comparison with station 1 was a result of the natural development of the stream along its course, which manifested itself, among other things, by an increase in the number of species populating the stream (Dratnal 1976a).

3.2.2. Changes in density

The changes in density (fig. 3) show different ranges in the particular periods and habitats but the same regularity, i.e., the increase in animal density in the polluted stretch of the stream. It started just below the

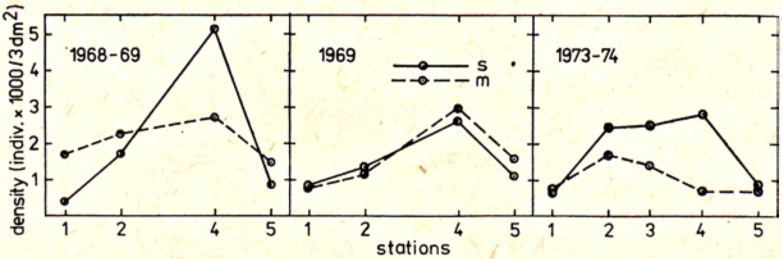

Fig. 3. Fluctuation in fauna density resulting from the waste effect. s — stony bottom; m — silty bottom

Ryc. 3. Zmiany zagęszczenia form jako rezultat wpływu ścieków. s — dno kamieniste; m — dno muliste

inlet of organic wastes but its maximum was usually noticed in the farther part of the stream (station 4). It was almost entirely the result of the quantitative development of two groups: *Oligochaeta* and *Chironomidae* (Tables I, II). These were also the only groups the density of which increased — sometimes rapidly — just below the inlet of the dairy wastes. The density of other groups declined, and among them there were only the *Ephemeroptera* and *Trichoptera* living on the stony bottom which increased in density at farther stations (4 or 5).

3.2.3. Reactions of some taxonomic groups

The changes in the number of specimens and the composition of dominating species were examined more in detail on the example of some systematic groups, i.e. *Oligochaeta*, *Chironomidae*, *Ephemeroptera*, and *Trichoptera*. These groups are represented in the stream Prądnik by

Table I. Number of specimens in more important systematic groups (+ <0.06), and percentage of Oligochaeta and Chironomidae on stony bottom

Tabela I. Liczba osobników ważniejszych grup systematycznych (+ <0.06) oraz procentowy udział Oligochaeta i Chironomidae na dnie kamienistym

Station / Stanowisko — Taxon / Takson	Investigation period - Okres badań												
	IV 1968 - I 1969				III 1969 - X 1969				III 1973 - V 1974				
	1	2	4	5	1	2	4	5	1	2	3	4	5
Tricladida	0.7		3.3	3.0	0.1		1.7	0.4	0.6	0.1	2.2	0.7	9.6
Gastropoda			1.3	2.2				0.4	0.3	+	16.7	0.3	14.5
Lamellibranchia	1.5	0.4	8.7	19.3	2.2		0.7	0.4		+	9.9	12.0	10.3
Oligochaeta	34.5	651.6	1309.3	142.7	113.3	640.1	687.5	332.3	61.0	1487.2	1318.1	815.2	83.6
Hirudinea	0.3	0.6	2.7	0.6	0.4	0.8	3.2	0.1	0.1	0.6	2.0	1.5	
Hydracarina	16.3		1.3	0.4	11.6	1.3	0.5	0.4		0.1	0.1	1.5	0.3
Isopoda	0.2		6.0		+	0.4	0.9		+	0.1	5.9	2.1	
Amphipoda	4.4				9.2	0.1		0.1	41.8		0.3		19.4
Ephemeroptera	137.0	52.3	124.0	217.1	112.4	65.0	331.5	122.7	70.0	32.2	40.5	172.6	76.2
Plecoptera	10.1	0.4	142.6	30.5	11.8	0.9	142.9	8.9	12.3	7.3	39.8	60.8	84.9
Coleoptera	9.7			0.9	2.0	0.4	0.1	0.4	1.9	0.7	2.3	1.4	2.1
Megaloptera	0.4			0.2	3.3	0.4	0.7	0.1	0.1			0.1	0.9
Trichoptera	18.4		0.7	45.9	9.5		2.4	10.7	13.2	6.2	9.7	31.7	85.8
Chironomidae	102.1	968.9	3141.3	323.4	500.3	588.4	1254.9	570.1	367.4	809.0	817.4	800.8	409.7
Diptera remain.	24.5	26.2	377.2	83.2	40.6	58.7	175.2	42.0	27.3	78.3	211.0	886.7	87.3
Total - Ogółem	360.1	1700.4	5118.4	869.4	816.9	1356.5	2602.2	1089.0	596.0	2421.8	2475.9	2787.4	884.6
% Oligochaeta + Chironomidae	37.9	95.0	87.0	53.6	75.1	90.6	74.6	82.8	71.8	94.8	86.2	57.9	55.7

Table II. Number of specimens in more important systematic groups (+ <0.06), and percentage of Oligochaeta and Chironomidae on silty bottom

Tabela II. Liczba osobników ważniejszych grup systematycznych (+ <0,06) oraz procentowy udział Oligochaeta i Chironomidae na dnie mulistym

Station / Stanowisko — Taxon / Takson	Investigation period - Okres badań												
	IV 1968 - I 1969				III 1969 - X 1969				III 1973 - V 1974				
	1	2	4	5	1	2	4	5	1	2	3	4	5
Tricladida								0.5					0.3
Gastropoda			0.7	0.5							1.2	0.4	0.5
Lamellibranchia	34.5		64.3	38.4	20.4		12.0	3.1	0.8		82.8	106.7	51.0
Oligochaeta	1366.5	1180.3	1528.3	674.3	282.0	365.9	1376.2	270.7	493.8	901.0	475.7	291.3	157.7
Hirudinea	1.8	0.4	5.7	0.7	0.2		2.7			0.1	0.4	12.5	0.3
Hydracarina	0.2		1.7	0.2									
Isopoda	0.7		1.1		0.2		0.2		+		3.7	1.2	
Amphipoda	0.7			0.4		•	0.7		3.8				23.9
Ephemeroptera	7.1	5.3	3.6	15.2	3.7		3.7	2.0	1.2	0.4	0.8	1.7	2.2
Plecoptera	0.3		5.9	1.8	1.7		16.5	5.0	1.5	0.2	4.4	5.4	9.3
Coleoptera	0.4	0.8	2.8	1.2	2.2		1.4	2.0	1.0	0.6	6.2	0.7	0.2
Megaloptera	2.7		7.4	3.1	8.6		6.2	1.5	3.1		0.4	0.9	4.2
Trichoptera	1.7			3.5	0.4		5.0	1.5	0.1	0.2	0.2	0.8	3.3
Chironomidae	253.4	1055.7	1040.6	682.5	436.4	618.6	1498.5	1232.7	222.1	700.5	772.8	256.8	423.4
Diptera remain.	25.7	36.7	30.8	28.9	6.4	139.7	16.1	16.9	9.2	56.5	19.1	13.7	6.3
Total - Ogółem	1695.7	2279.2	2692.9	1450.7	762.2	1124.2	2939.2	1535.9	736.6	1659.5	1367.7	692.1	682.6
% Oligochaeta + Chironomidae	95.5	98.1	95.3	93.3	94.2	87.5	97.8	97.8	97.1	96.5	91.3	79.2	60.3

significant numbers of species and specimens; moreover, they represent a wide behaviour range, from the forms swimming or living on stones and in mats of algae, to those burrowing in sediments.

Oligochaeta. The leap of the density of *Oligochaeta* below the discharge of wastes was accompanied by various qualitative changes in the composition of their communities. On the stony bottom (fig. 4) they were most characteristic in the first and second periods. Above the

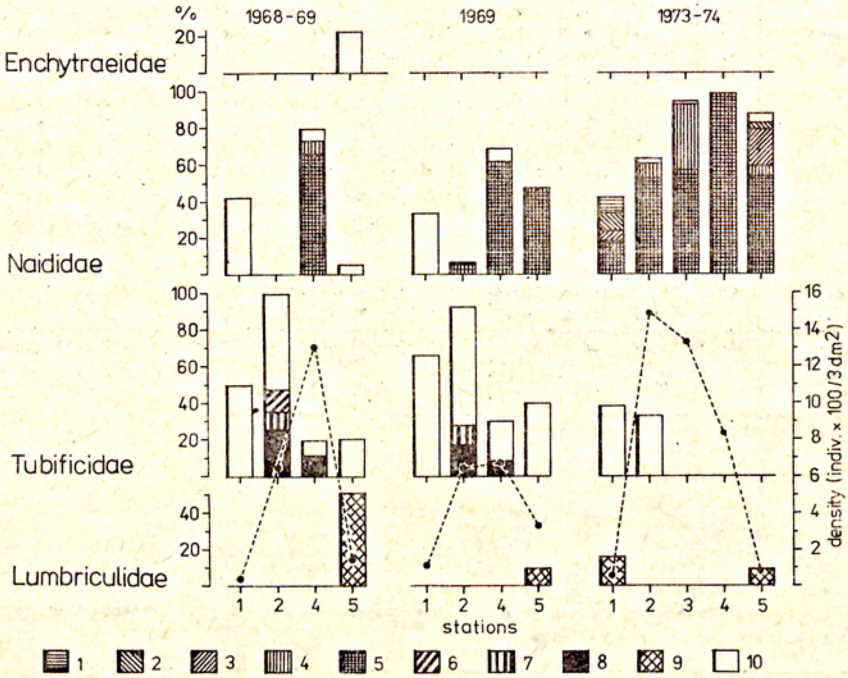

Fig. 4. Density fluctuations of the *Oligochaeta* (points) and percentage share of their dominating forms (bars) on stony bottom:

Ryc. 4. Zmiany zagęszczenia *Oligochaeta* (punkty) i procentowy udział ich dominujących form (słupki) na dnie kamienistym:

1 — *Nais alpina;* 2 — *N. bretscheri;* 3 — *N. pardalis;* 4 — *N. communis;* 5 — *N. elinguis;* 6 — *Limnodrilus udekemianus;* 7 — *L. hoffmeisteri;* 8 — *Tubifex tubifex;* 9 — *Stylodrilus heringianus;* 10 — other — inne

influx of wastes the stony bottom was inhabited mainly by *Naididae* and *Tubificidae*, with no distinctly dominating species in these two families. The influx of waste waters caused that the share of *Naididae* decreased substantially in favour of *Tubificidae*, among which *Tubifex* and *Limnodrilus* dominated. In the farther part of the stream (station 4) the share of *Tubificidae* decreased again, and became even lower than at station 1, while the *Naididae* represented mainly by *Nais elinguis* developed strikingly. At the last station the percentage of the two families

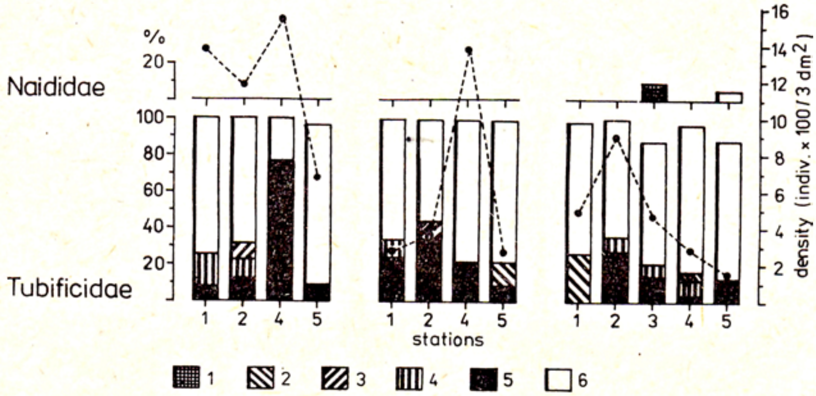

Fig. 5. Density fluctuations of the *Oligochaeta* (points) and percentage share of their dominating forms (bars) on silty bottom:

Ryc. 5. Zmiany zagęszczenia *Oligochaeta* (punkty) i procentowy udział ich form dominujących (słupki) na dnie mulistym:
1 — *Nais elinguis;* 2 — *Aulodrilus pluriseta;* 3 — *Limnodrilus udekamianus;* 4 — *L. hoffmeisteri;* 5 — *Tubifex tubifex;* 6 — other — inne

was most similar to that observed at station 1, but still with a tendency of the individual species to dominate (e.g. *Nais elinguis* in 1969). The *Lumbriculidae* (*Stylodrilus heringianus*) also appeared numerously at that station. In general, it may be stated that on the stony bottom the organic wastes caused an exchange of the particular *Oligochaeta* families with the tendency to a strong domination of individual species.

On the silty bottom (fig. 5) the density of *Oligochaeta* also increased within the polluted stretch of the stream. In the whole section examined, the *Oligochaeta* of that habitat were represented almost exclusively by *Tubificidae*, and the most essential change produced by the wastes was the increase of the share of *Tubifex tubifex*.

Chironomidae. The quantitative changes in *Chironomidae* caused by organic effluents in the two habitats considered, were very similar to those observed in *Oligochaeta* and expressed in a vehement increase in density. On the stony bottom (fig. 6) the qualitative reaction consisting in subfamily exchanges was also similar. At station 1 most *Chironomidae* were *Orthocladiinae* which were replaced by *Chironominae* below the influx of waste waters. Further on (station 4), *Chironominae* retreated, and there was noticed a very strong development of *Orthocladiinae*, mainly *Eukiefferiella* and *Cricotopus* + *Orthocladius*. At the last station the share of these two subfamilies resembled most those observed above the influx of wastes. The very high percentage of *Chironomus* gr. *thummi*

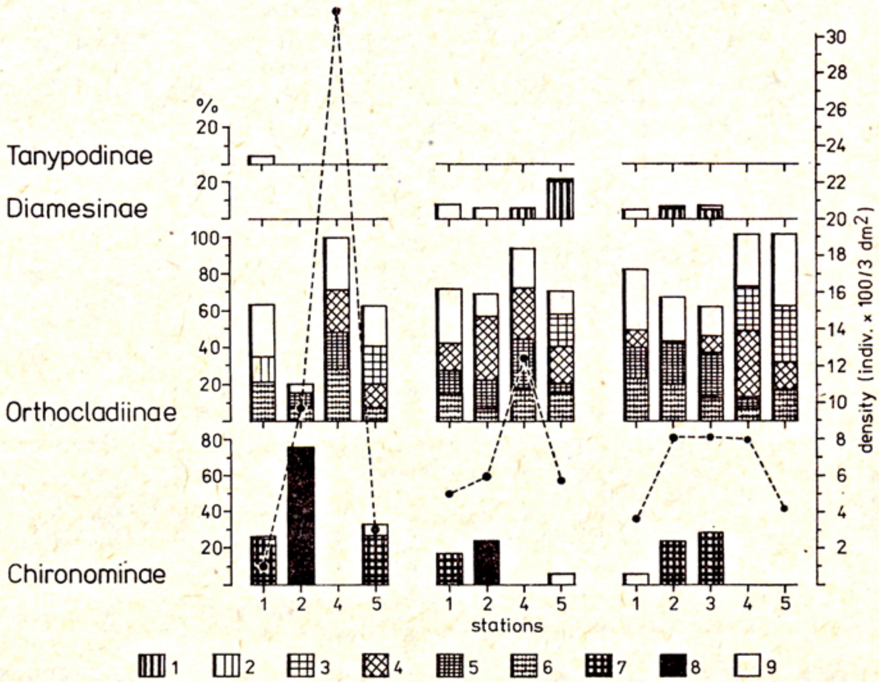

Fig. 6. Density fluctuations of the *Chironomidae* (points) and percentage share of their dominating forms (bars) on stony bottom:

Ryc. 6. Zmiany zagęszczenia *Chironomidae* (punkty) i procentowy udział ich form dominujących (słupki) na dnie kamienistym:
1 — *Prodiamesa olivacea;* 2 — *Thienemanniella* gr. *clavicornis;* 3 — *Eukiefferiella bavarica;* 4 — *E. brevicalcar;* 5 — *E. claripennis;* 6 — *Cricotopus* + *Orthocladius* spp.; 7 — *Micropsectra* gr. *praecox;* 8 — *Chironomus* gr. *thummi;* 9 — other — inne

and *Micropsectra* gr. *praecox* should be emphasized. These species predominated on stones at stations 2 and 3, although this habitat is not typical of them.

The exchange of the *Chironomidae* subfamilies was also distinct on a silty bottom (fig. 7). The subfamilies numerously represented at station 1, mainly *Diamesinae*, were outnumbered below the discharge of wastes by *Chironomus* gr. *thummi*, which developed very strongly and was practically the only representative of *Chironomidae*. In the farther part of the stream it was replaced by *Prodiamesa olivacea* and *Micropsectra* gr. *praecox*.

Ephemeroptera. The response of *Ephemeroptera* is considered only on the example of the stony bottom community, because the only species *Ephemera danica* characteristic of the silty bottom in Prądnik,

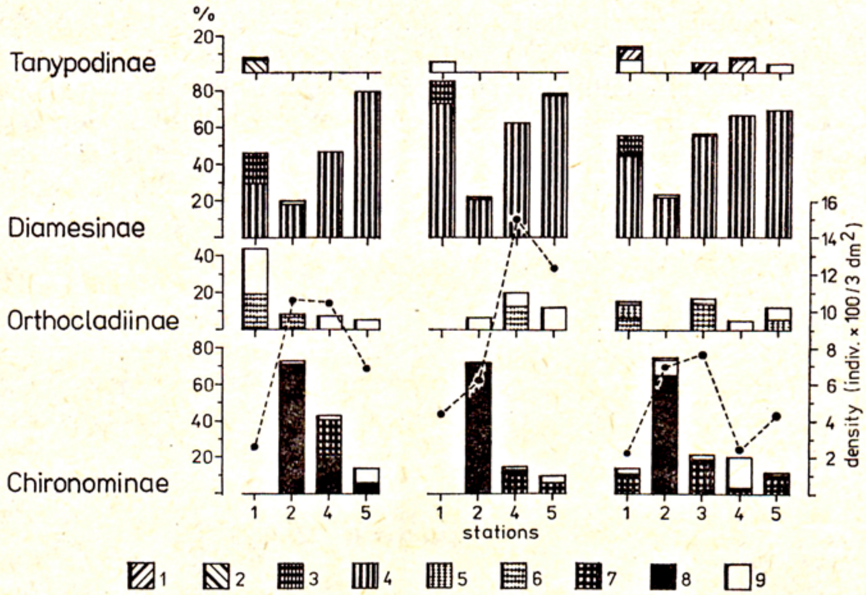

Fig. 7. Density fluctuations of the *Chironomidae* (points) and percentage share of their dominating forms (bars) on silty bottom:

Ryc. 7. Zmiany zagęszczenia *Chironomidae* (punkty) i procentowy udział ich dominujących form (słupki) na dnie mulistym:

1 — *Macropelopia nebulosa*; 2 — *Apsectrotanypus trifascipennis*; 3 — *Odontomesa fulva*; 4 — *Prodiamesa olivacea*; 5 — *Trissocladius fluviatilis*; 6 — *Cricotopus* + *Orthocladius* spp.; 7 — *Micropsectra* gr. *praecox*; 8 — *Chironomus* gr. *thummi*; 9 — other — inne

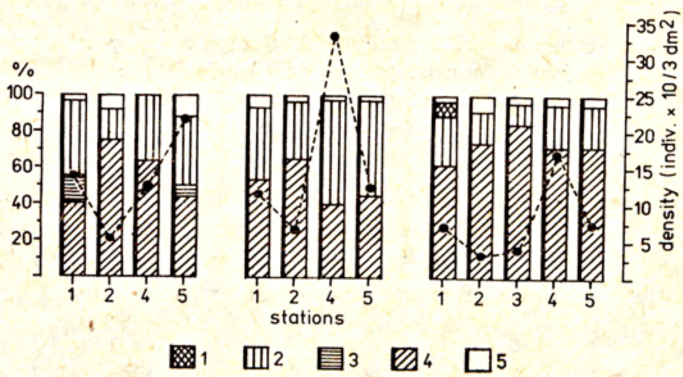

Fig. 8. Density fluctuations of the *Ephemeroptera* (points) and percentage share of their dominating forms (bars) on stony bottom:

Ryc. 8. Zmiany zagęszczenia *Ephemeroptera* (punkty) i procentowy udział ich dominujących form (słupki) na dnie kamienistym:

1 — *Habrophlebia fusca*; 2 — *Baetis* spp. juv.; 3 — *B. lutheri*; 4 — *B. rhodani*; 5 — other — inne

does not appear above station 5 (Dratnal 1976a). On the stony bottom (fig. 8) *Baetis rhodani* was the only dominating species, and the share of young, unidentified larvae of *Baetis*, probably *B. rhodani*, was also very high. The initial reduction of *Ephemeroptera* at station 2, and next their increase at stations 4 and 5 were not followed by significant changes in species composition. The only important change was the decline of the share of young larvae.

Trichoptera. This group is also discussed on the example of the stony habitat as no *Trichoptera* live on the silty bottom in Prądnik. The quantitative reaction of *Trichoptera* was similar to that of *Ephemeroptera*: it was first revealed in a reduction, and next in an increase in density.

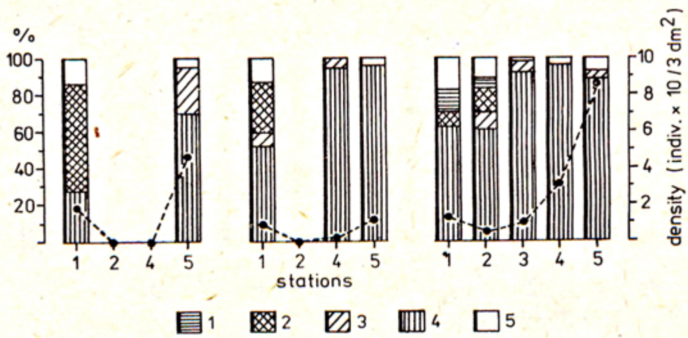

Fig. 9. Density fluctuations of the *Trichoptera* (points) and percentage share of their dominating forms (bars) on stony bottom:

Ryc. 9. Zmiany zagęszczenia *Trichoptera* (punkty) i procentowy udział ich dominujących form (słupki) na dnie kamienistym:

1 — *Rhyacophila tristis*; 2 — *R. fasciata*; 3 — *R. nubila*; 4 — *Hydropsyche instabilis*; 5 — other — inne

Of the species dominating above the discharge of wastes (fig. 9) it was only *Hydropsyche instabilis* which developed intensively at the lowest stations (4, 5). Therefore, the tendency of a single species to dominate as a result of the influence of wastes, was also marked among *Trichoptera*.

3.3. Effect of pollution in different periods

In spite of some common features of the reaction of animals to organic pollution, there were marked differences in that reaction in the particular periods connected mainly with the varying efficiency of the waste treatment plant.

In the last period the phenomenon of species reduction below the discharge of wastes became less pronounced. In the successive periods, 43, 36, and 19 per cent of species were ousted respectively, and in the last period the *Oligochaeta* even increased in the number of their species at station 2. Also the number of the systematic groups, which were ousted, decreased in the seccessive periods, and just below the influx of wastes it amounted to 6, 3, and 2 respectively.

In the changes of density of the whole invertebrate fauna a tendency was noticed to shift the maximum of density from the lower to the upper part of the polluted zone. It was noticeable also as regaıds the particular systematic groups; the maximum density of *Oligochaeta* and *Chironomidae* shifted from station 4 to station 2 (except the *Chironomidae* on silty bottom), and that of *Ephemeroptera* from station 5 to station 4. Besides, in some cases, the increase in density was lesser in the later periods (e.g. *Oligochaeta* in silt and *Chironomidae* on stones).

The qualitative reaction of the invertebrates differed, too, in the subsequent periods, which was especially evident in the case of *Oligochaeta* living on a stony bottom. The exchange of their families at station 2, very distinct in 1968 and 1969, did not occur in the last period. The reaction of the *Oligochaeta* at station 2 was then similar to that formerly observed at station 4 and was expressed by a strong development of *Naididae*. In a similar way the changes in the *Chironomidae* took place, among which *Chironomus* gr. *thummi*, which replaced most of the *Orthocladiinae* in 1968, was less numerous in 1969, and disappeared as a dominating species in 1973—1974.

On the silty bottom the differences among the particular periods were not so distinct; however, the share of *Tubifex tubifex* decreased gradually and its maximum moved from station 4 to station 2, and the section of the stream with *Chironomus* gr. *thummi* domination, became gradually shorter, while the share of *Tanypodinae* — totally ousted previously — increased below the discharge of wastes in 1973—1974.

4. Discussion

The methods applied in field work and the interpretation of data allowed only for a very rough description of the reaction of the invertebrates affected by organic wastes. However, some changes in their communities below the spot of discharge of wastes were clearly visible. The most important of all seems to be the existence of two zones within the polluted section of the stream. This was especially distinct in 1968.

The first zone situated immediately below the influx of organic wastes and comprising station 2 was the zone of sedimentation and initial decomposition of organic matter. The accumulation of sediments made the whole bottom resemble a silty habitat, while the decomposition of its organic part caused the decline of oxygen content in the upper layer, and its disappearance in the deeper silt layer. These changes of the stream-bed substratum, and the oxygen conditions arising from the toxic products of the decomposition of proteins in anaerobic conditions brought about the ousting of many species and whole systematic groups. The importance of the accumulation was revealed, among other things, by the disappearance of *Trichoptera* connected with stony bottom, and a simultaneous great development of *Tubificidae* and *Chironominae* living in silt. *Baetis rhodani,* the main representative of *Ephemeroptera* in the Prądnik stream, which lives on the upper part of stones and is able to swim, was ousted to a much lesser extent. The possibility of survival also depended very much on the kind of nutrition taken by the animal. The decay of algae at station 2 diminished the density of typical algophagous groups, such as *Naididae* and *Orthocladiinae.* The first zone was characterized chiefly by a qualitative conversion of the invertebrate communities with a tendency to reduction in their composition and favouring the predominance of the few species.

The second zone, the characteristic features of which were best visible at stations 4 and 5, seemed to be a zone of total decomposition of organic matter and drawing the nutrients released into the process of primary production. This was expressed in the regulation of oxygen conditions (no drastic decrease of oxygen content was ascertained either in the water or in the silt) and in a high primary production resulting in the intense growth of algae covering stream-bed stones. The forms living in the unpolluted stretch of the stream became dominants again; these were algophagous forms, such as *Naididae* or *Orthocladiinae.* Some filtrating species, e.g. *Simuliidae,* or net-spinners, such as *Hydropsyche instabilis,* developed even more intensively than at station 1. They had no difficulties in attaching themselves to the stones free of silt, while the amount of suspended organic matter was still very high. The living conditions in that zone were not as extreme as at station 2 but nutrient resources were still high. All this led to an intensive increase in density, which was usually the highest at station 4. One of the important mechanisms causing such a high density might be the higher survival rate of the young larvae. This is suggested by the increase in the percentage of the young larvae of *Baetis* with a simultaneous increase in density of the whole fauna (fig. 8). Summing up, the second zone may be called the zone of restoration of the fauna in its quality, and of an intensive development in quantity.

Such a situation was observed in the two first periods, and above all in 1968. In the last period it could be noticed that the second zone moved upwards the stream. Qualitative and quantitative features of the fauna occuring at station 2 became then similar to those observed at stations 4 and 5 in previous periods. That concerned density, the number of species and groups, their percentage, and the number and composition of dominants. It can be stated that most of the features of the first zone disappeared from the stream in the last period, and the second zone began directly below the influx of wastes. Their influence resulted then rather in the fertilization than contamination of the stream. That was a significant improvement but, considering that it took place in the territory of the National Park, the situation in the stream observed in 1973/1974 must still be regarded as a detrimental change of its biocenosis.

The idea of river zones formed below an influx of organic wastes was already suggested by Hynes (1963). He described the changes in the composition of invertebrates considered from a slightly different point of view; however, it may be noticed that the situation observed in the stream Prądnik showed many analogies to his suggestion of successive zones with an increased occurrence of particular systemic groups and species, especially *Tubificidae* and *Chironomidae*. The main difference lies in the lack of an initial decline of the fauna density in the stream Prądnik, which is due to relatively good oxygen conditions. Zones induced by wastes were observed also in the stream Kryniczanka (Szczęsny 1974), which is very similar to the stream Prądnik. Waste waters did not lead to a total depletion of the oxygen dissolved, but the zone of the initial decline of density was distinctly visible. Szczęsny associated it with the BOD value, which in the stream Kryniczanka often exceeded 50, and sometimes even 100 mg O_2/dm^3, while in the stream Prądnik it rarely reached more than 10 mg O_2/dm^3.

STRESZCZENIE

W trzech okresach, w latach 1968, 1969 i 1973—1974 dokonano w odstępach około 1 miesiąca poborów fauny dennej z potoku Prądnik na terenie Ojcowskiego Parku Narodowego (ryc. 1). Próby zbierano z czterech, a w ostatnim okresie z pięciu stanowisk, z których pierwsze położone było powyżej ujścia do potoku ścieków mleczarskich, a pozostałe poniżej. W pierwszym okresie ścieki dopływały w stanie surowym, w dwu ostatnich były oczyszczane biologicznie, z tym że skuteczność działania oczyszczalni ścieków w 1969 r. nie była zadowalająca. Mimo dopływu ścieków w wodzie potoku nigdy nie dochodziło do całkowitego zaniku tlenu. Próby zbierano chwytaczem Surbera, każdorazowo po dwie z powierzchni około 3 dcm^2, z dna kamienistego i mulistego. Określono skład gatunkowy zebranej fauny oraz średnią liczbę osobników poszczególnych gatunków w kolejnych okresach, osobno na dnie kamienistym i mulistym. Grupy z największą liczbą gatunków, tj. *Oligochaeta, Chironomidae, Ephemeroptera* i *Trichoptera* analizowano szczególnie dokładnie (tabele I, II).

Na zanieczyszczonym odcinku rzeki stwierdzono dwie strefy. Tuż poniżej ujścia ścieków strefa akumulacji materii organicznej i jej wstępnego rozkładu powodowała zubożenie osadów w tlen i uwalnianie toksycznych produktów rozkładu. W strefie tej

rugowanych było 79—43% gatunków w poszczególnych okresach. Gęstość zasiedlenia większości grup systematycznych malała, wzrastała zaś całej fauny w wyniku intensywnego rozwoju *Oligochaeta* i *Chironomidae* (ryc. 2-9). Grupy te stanowiły zwykle powyżej 90% fauny. Stwierdzono też tendencję do dominacji pojedynczych gatunków, głównie grzebiących w osadach i odpornych na brak tlenu *Tubificidae* i *Chironominae*. Zastępowały one żyjące na kamieniach i wśród glonów *Naididae* i *Orthocladiinae*.

W drugiej strefie, w której nastąpił pełny rozkład materii organicznej i wciągnięcie uwolnionych biogenów do procesów produkcji pierwotnej, ponownie zaczęły dominować gatunki typowe dla czystych odcinków potoku. Gęstość zasiedlenia fauny była najwyższa, a dominowały formy glonożerne (np. *Naididae* i *Orthocladiinae)* i filtratorzy (*Simuliidae* i niektóre *Trichoptera* budujące sieci). Sprzyjało temu silne porastanie dna przez glony w wyniku podwyższonej produkcji pierwotnej oraz wciąż znaczna ilość unoszonej zawiesiny organicznej.

W ostatnim okresie, w związku ze skuteczniejszym oczyszczaniem ścieków, strefa pierwsza znikła, a bezpośrednio poniżej ujścia ścieków pojawiła się strefa druga.

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