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Wpływ ścieków z miasta Krynicy na zbiorowiska bezkręgowych dna potoku Kryniczanka

The effect of sewage from the town of Krynica on the *benthic invertebrates communities* of the Kryniczanka stream

Wpłynęło 16 lutego 1973 r.

Abstract — The macrofauna of the polluted mountain stream Kryniczanka (the Carpathians) was investigated. The investigationes were conducted for a period of one year, and took into account the natural, regulated, and the polluted sectors of the stream. The physico-chemical conditions of the water and sediments were examined and described. A detailed list of the species encountered was made and their distribution along the watercourse and their numbers on various types of substrate described. Potamological classification of the stream was made according to Illies' and Botosaneanu's (1963), the epiritron zone being distinguished in it. In order to differentiate the zones in the stream several methods were applied and subsequently discussed. The effect of sewage on the macrofauna of the stream was described, changes in its numbers during the course of the year, and the pollution level of the stream which was determined as polysaprobic not only on the basis of the results of physico-chemical analysis but also on that of the macrofauna.

The majority of the representatives of the macrofauna belong to forms easily seen and distinguished with the naked eye. Almost every specimen can be classified, without difficulty, as to order or family and in many cases even as to genus or species without the use of any aids in the form of optical equipment. The great ecological differentiation of species makes it possible for them to populate various water biotopes, from the cleanest to strongly polluted ones. For this reason, the macrofauna is the most suitable group to make use of in characterizing the environment it inhabits and the changes which occur in it. This will be of special value in determining the purity of running waters and especially of those watercourses into which sewage is discharged, as in these the physico-chemical factors change in a large range and in a short period of time; the smaller the flow and the greater its gradient the faster the changes. Physico-chemical analyses performed at random will never give a proper picture of the conditions prevailing in the stream. Elster (1967) considers that by taking as a basis the occurring organisms the group of factors acting in the environment can be better determined than, e. g., by means of chemical methods. According to this author, an analysis of the whole set of organisms is especially important, though their analysis does not give any quantitative evaluation criterium of the degree of pollution.

Knowledge of the macrofauna of small mountain watercourses and especially its changes under the influence of sewage, is as yet unsufficient, there being few detailed publications on the subject. Some of the earlier ones were discussed in Hynes' (1963) paper; among more recent publications can be mentioned: Bilý, Hanuška, Winkler (1952), Rothschein (1962), Kalbe (1966), Wachs (1967), Obr (1972) and others.

In Poland no exact and systematic investigations on the effect of sewage on stream macrofauna have hitherto been carried out.

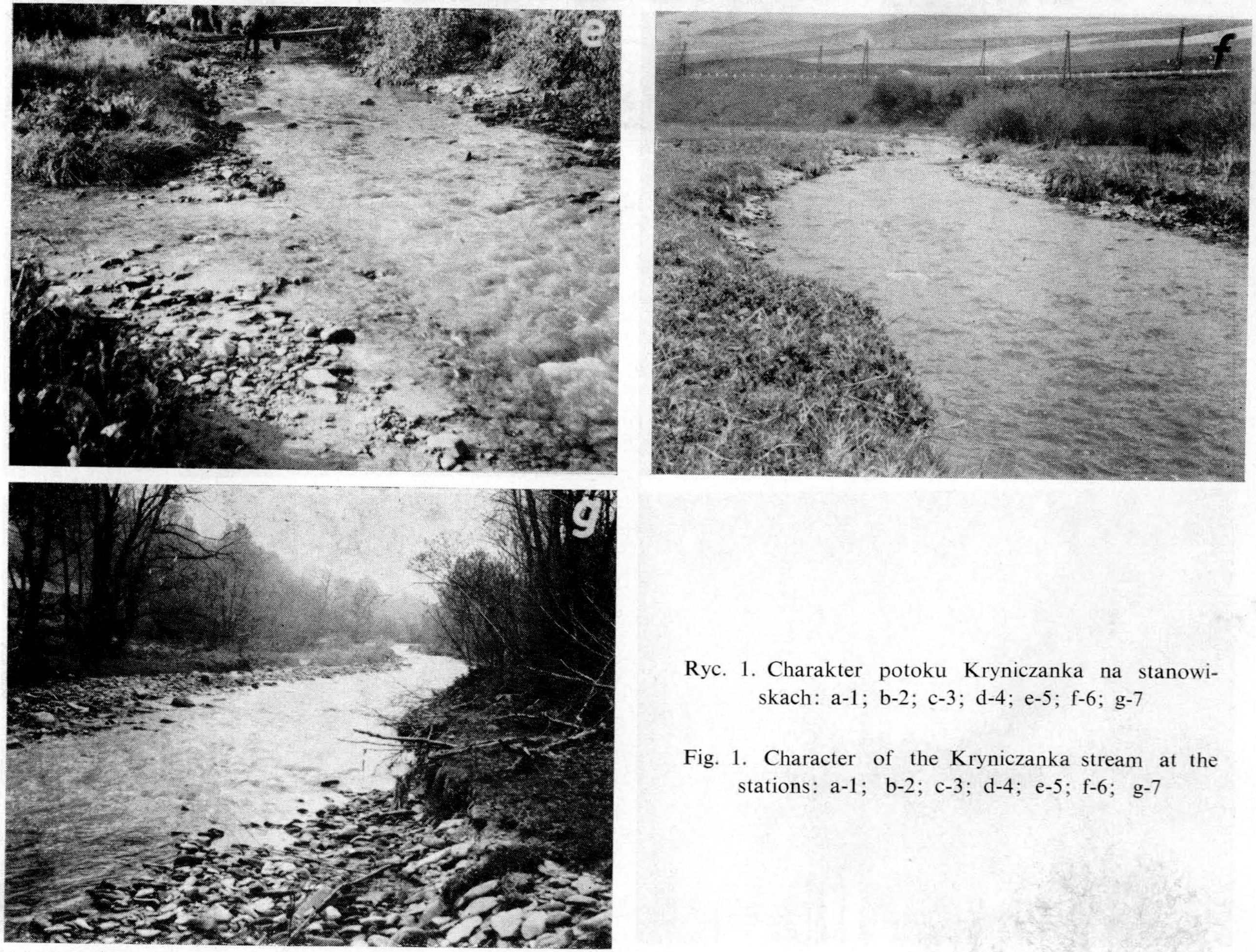
The aim of the present investigations was to follow exactly the influence of sewage from the town of Krynica on the benthic invertebrates of the small stream Kryniczanka (fig. 1), to examine their groups in the clean and polluted parts of the stream, to determine the size and degree of pollution, to establish the number of faunistic forms which disappear under the influence of sewage, and to discuss the possibilities of making use of the macrofauna for determination of the degree of pollution in mountain streams.

Territory and method of investigation

The examined stream drains the eastern part of the Beskid Wysoki (the Carpathians), the highest elevation being Jaworzyna, 1116 m above sea level. The greater part of the basin of the Kryniczanka stream lies in a zone of altitude from 600 to 800 m above sea level, the confluence of the Kryniczanka with the Muszynka lying at an altitude of 486·4 m above sea level (fig. 2). The basin covers an area of about 43·17 km². Arable land covers about 21·46 km², the other part of the basin being covered with woods. Spruce dominates in the stand of trees, fir, pine, beech and birch being less numerous. The woods are not compact but form complexes occupying mainly the peripheral parts of the basin.

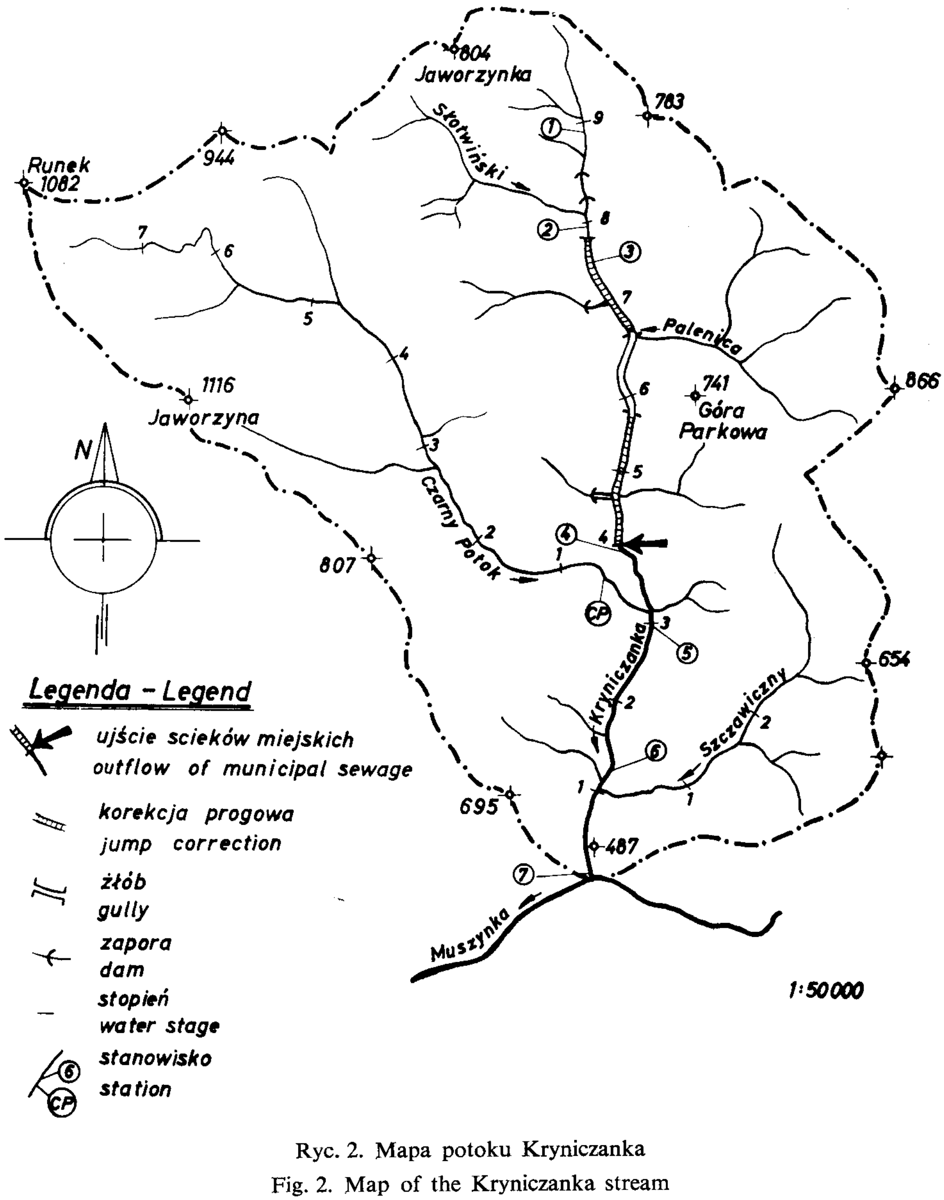
The character of the climate of Krynica (604 m above sea level) was given in Bartnicki and Wierzbicki's (1958) publication. According to these authors, the local climate of Krynica is very similar to that of the whole Western Carpathians (Hess 1965) of corresponding altitude. The average annual water flow in the stream Kryniczanka was calculated on the basis of the data of the State Institute of Hydrometeorology (PIHM) for the years 1950—1964. It amounts to about 0·3 m³/sec. above the confluence with the Czarny Potok stream and about 1·0 m³/sec. at its confluence with the Mu-


a
b
c
d



Ryc. 1. Charakter potoku Kryniczanka na stanowiskach: a-1; b-2; c-3; d-4; e-5; f-6; g-7

Fig. 1. Character of the Kryniczanka stream at the stations: a-1; b-2; c-3; d-4; e-5; f-6; g-7



Ryc. 2. Mapa potoku Kryniczanka

Fig. 2. Map of the Kryniczanka stream

szynka. The Czarny Potok at the confluence with the Kryniczanka carries about 0·3 m^3/sec. water.

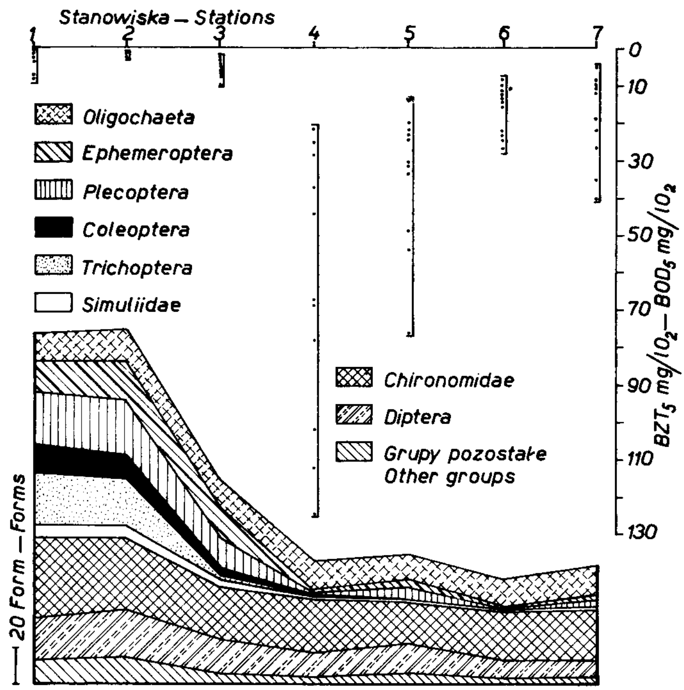
The sewage from the main human concentration — the town of Krynica (about 20 000 inhabitants, including visitors) — is discharged by the municipal sewage system, taking also wastes from 14 sanatoria and a dairy. Besides the municipal sewage which is released at about the middle of the stream's course, the Kryniczanka also collects partly purified sewage from the hospital, considerable amounts of waters from therapeutic mud-baths, and unpurified domestic sewage from all the houses situated along it. The therapeutic mud-bath waters carry into the stream such amounts of therapeutic mud that it constitutes the main component of sediments. At the time these investigations were carried out the town had a partial purification plant (settling tanks), built in the thirties, designed for a much smaller amount of sewage. Owing to its permanent overloading, purification was performed to a minimum degree and was confined only to the elimination of larger organic and mineral fragments. Now a new purification plant has been built at the confluence of the Kryniczanka with the Muszynka.

Tabela I. Ekstremalne temperatury (a), natlenienie (b) i pH wody potoku Kryniczanka w okresie badań terenowych

Table I. Extreme temperatures (a), oxygenation (b) and pH of the water of the stream Kryniczanka during field investigations

Stanowiska - Stations	Terminy badań / Date of sampling	1966										1967	Średnia - Mean
		22-23.III.	23-24.IV.	23-25.V.	27-29.VI.	27-29.VII.	26-28.VIII.	26-28.IX.	6.X.	10-11.XI.	15-16.XII.	21-22.II.	
	Pogoda - Weather												
	Słonecznie / Sunny	+	+			+	+		+		+	+	
	Deszczowo / Wet			+	+			+		+			
1	a	3.8	7.5	9.0	8.5	10.5	14.0	10.0	11.0	6.0	2.0	1.9	
	b	90.1	80.0	86.5	93.0	85.5	88.7	91.0	86.6	85.5	88.5	84.0	87.2
	pH	7.1	-	-	7.5	7.4	7.5	-	8.0	-	7.1	7.4	
2	a	5.1	10.0	14.5	9.5	13.0	14.0	11.6	14.5	6.4	1.5	2.0	
	b	-	-	-	-	-	-	-	-	-	-	84.0	84.0
	pH	-	-	-	-	-	-	-	-	-	-	7.8	
3	a	5.7	10.5	12.0	10.0	12.2	14.0	11.0	15.0	6.5	1.3	1.8	
	b	91.4	84.5	95.5	84.8	89.5	102.2	93.5	103.4	98.0	90.8	70.5	91.3
	pH	7.4	-	-	8.0	7.5	7.9	-	8.4	-	8.0	8.0	
4	a	7.5	12.5	12.0	12.5	16.4	16.0	15.5	19.5	9.5	6.4	4.9	
	b	87.3	75.3	75.0	62.2	35.0	45.2	47.3	15.1	70.0	63.5	62.5	58.0
	pH	6.8	-	-	8.0	7.1	7.0	-	7.2	-	7.2	7.8	
5	a	6.4	11.0	9.0	12.0	15.0	15.0	14.5	16.0	9.0	4.0	4.2	
	b	86.5	65.2	57.2	64.0	24.7	53.2	37.2	16.1	56.8	63.2	70.8	54.1
	pH	6.7	-	-	8.0	7.2	7.4	-	7.3	-	7.2	7.4	
6	a	6.6	12.0	22.0	13.5	16.0	14.0	13.5	16.2	8.5	3.5	4.0	
	b	82.5	68.8	56.6	70.5	41.6	60.7	63.4	38.4	86.2	77.2	61.0	64.3
	pH	6.9	-	-	7.5	7.1	7.4	-	7.5	-	7.2	7.2	
7	a	6.8	12.1	18.0	12.0	16.0	14.0	12.5	19.0	7.5	2.9	3.8	
	b	84.5	82.2	77.1	74.5	68.0	80.0	82.0	65.2	86.5	66.5	73.5	76.4
	pH	6.9	-	-	8.0	7.5	7.5	-	7.6	-	7.8	7.2	
Czarny Potok	a	4.0	6.5	7.5	10.0	12.4	14.0	10.8	14.0	8.0	1.5	1.8	

In Table I the results of measurements of water temperature in the Kryniczanka stream and its tributary the Czarny Potok, taken each time during sampling in the field, are presented. On the basis of these data an attempt can be made to classify successive stations into respective zones according to the division proposed by Illies (1952) assuming annual amplitudes (difference between the highest and the lowest monthly mean of the year) of 5°, 10°, 15°, 20°C. Station 1 should be included in the zone of the amplitude of annual temperature below 10°C, which would correspond to the upper trout zone. The amplitudes of annual temperatures at stations 2 and 3 could be determined as below 15°C, corresponding to the middle trout zone. Stations 4—7 might be expected to belong to the same zone, but the obtained temperatures and their differences did not show any regular increase. This



Ryc. 3. Ilości form różnych grup taksonomicznych bezkręgowych na kolejnych stanowiskach potoku Kryniczanka na tle uzyskanych wartości BZT_5

Fig. 3. Number of forms of various taxonomical groups of the benthic invertebrates at successive stations of the Kryniczanka on the background of the BOD_5 values

situation is caused by the inflow of sewage of higher temperature above station 4 and by the inflow of the cold waters of the Czarny Potok below this station, which evidently lowers the water temperature at station 5 in comparison with stations 4, 6 and 7.

The oxygen conditions of the water in the Kryniczanka are shown in Table I, and the O_2 content and the BOD_5 in figures 3, 6, and 7. Taking these data and the results of physico-chemical analysis obtained in the Laboratory of Water and Sewage Examinations at the District Council in Cracow as a basis, the water in the Kryniczanka stream is found to be polluted along the whole length of the examined course. This is shown by such factors as the content of ammonia, organic nitrogen, phosphates, dry residue, BOD_5, etc. In general, the Kryniczanka can be divided into two sectors: I — the upper one (stations 1—3) with comparatively clean water, II — the middle and lower parts (stations 4—7) with heavily polluted water.

Sector I — in the water at station 1 considerable amounts — as for the spring sector — of ammonia — 0·156 mg/l. N/NH_3, and organic nitrogen 1·123 mg/l. were found, the BOD_5 often being over 3·0 mg/l. O_2, and twice over 7 mg/l., phosphates 0·1—0·16 mg/l. PO_4 and dry residue up to 270 mg/l. At station 3 the amount of ammonia increased to 0·390 mg/l., oxidability (permanganate method) over 3 mg/l. O_2, BOD_5 usually up to 6 mg/l. O_2 and sometimes even to 9·9. Some other indicators increased as well. According to Sladeček and Fjerdingstad (Starmach 1969), the maximum pollution at stations 1—2 can be considered as slight, corresponding to the β-mesosaprobic zone, whereas station 3 demonstrated a fairly serious water pollution representing the β-meso or α-mesosaprobic zone.

Sector II — the BOD_5 of the water in this sector reached, during the tourist and holiday season, the value 124 mg/l. O_2, oxidability up to 37 mg/l. O_2, and a high content of volatile particles and dry residue of over 30 per cent. The intensity of decomposition of organic matter is evidenced by a low content of O_2, rising sometimes, especially during warm seasons, to only 15·1 per cent saturation, a high content of CO_2 and ammonia of 62 mg/l. and 9·984 mg/l. N/NH_3 respectively, and the easily recognizable odour of H_2S near the water. Generally, however, the O_2 content in the water of this sector was fairly high, the mean from 11 measurements being over 50 per cent saturation, in the cool months of the winter and spring reaching 70 per cent, and in the summer and autumn months falling to about 40 per cent (Table I).

According to Sladeček and Fjerdingstad (Starmach 1969), stations 4—7 lie wholly in the polysaprobic zone and in some seasons of the year — summer, autumn — the pollution of the stream at station 4 even reached the isosaprobic level (over 100 mg/l. O_2 BOD_5).

Examination of the content of organic nitrogen and organic matter in the sediments at individual stations (Table II) permits the supposition that in the investigated stream accumulation of organic matter takes place twice a year: in winter and early spring, and in late summer and autumn. In May and June the flow of spring waters probably clears the stream of sediments. In August the maximum content of organic matter was found in the sediments — up to 70 per cent at station 4. The nitrogen content follows a similar course. The irregular fall in organic nitrogen and organic matter along the course of the stream from station 4 on — i. e. a greater drop in organic matter than of organic N — can be easily explained by the known rule that carbohydrates are decomposed by microorganisms first and only then proteins.

7 sampling stations were established in the Kryniczanka and one in its

Tabela II. Procentowy udział azotu organicznego (N) i materii organicznej (M) w osadach potoku Kryniczanka w okresie badań terenowych

Table II. Percentage share of organic nitrogen (N) and organic matter (M) in the sediments of the stream Kryniczanka during field investigations

Stanowiska Stations	1		2		3		4		5		6		7	
Data Date	N	M	N	M	N	M	N	M	N	M	N	M	N	M
III. 1966	0.105	3.7	-	-	0.140	6.0	1.120	40.0	0.490	19.8	0.245	11.5	0.350	14.2
IV.	0.010	4.4	-	-	0.233	5.6	1.980	54.5	1.140	26.5	0.460	8.5	0.350	8.8
V.	-	-	-	-	0.297	6.8	0.525	15.8	1.365	25.1	0.460	9.0	0.660	8.7
VI.	0.157	3.0	-	-	0.306	3.1	0.460	13.3	0.280	5.4	0.525	11.4	0.470	8.5
VII.	0.367	5.0	-	-	0.374	6.1	2.975	59.3	2.800	26.4	0.630	10.2	0.610	13.3
VIII.	0.133	2.6	-	-	0.175	4.3	2.940	70.6	3.010	44.9	0.945	20.2	0.560	11.8
IX.	0.175	3.6	-	-	0.140	5.5	0.910	24.7	2.520	43.1	1.150	20.4	-	-
XI.	0.098	1.7	-	-	0.227	6.6	1.750	29.6	1.015	34.7	0.595	27.6	0.630	24.3
XII.	-	3.5	-	-	-	8.7	-	58.7	-	31.0	-	15.2	-	14.3
II. 1967	0.175	4.4	0.227	5.6	-	-	0.560	17.6	0.175	43.4	0.227	5.1	0.330	10.4

Tabela III. Charakterystyka badanych stanowisk

Table III. Character of investigated stations

Stanowiska Stations	Wysokość n.p.m. m Altitude above sea level	Odległość od ujścia Distance from the mouth km	Szerokość koryta potoku Width of stream bed m	Maksymalna szybkość prądu wody cm/sek. Maximum rate of water current cm/sec.	Podłoże Substrate		Rozwój "grzybów ściekowych" Development of "sewage fungi"	Rodzaj zabudowy doliny w pobliżu potoku Kind of development of valley near stream
					kamieniste, średnica kamieni stony diameter of stones cm	drobno-ziarniste, pokrycie dna w % fine-grained, coverage of bottom in %		
1	648	8.9 (od źródeł from springs 1.0)	0.9-1.2	50 - 70	10 - 15	piasek sand 5 - 10		pojedyncze domy single houses
2	615	7.9	2.5-3.0	60 - 70	15 - 20	piasek, rzadko muł sand, rarely silt 5 - 10	brak none	niezbyt liczne domy not very numerous houses
3	596	7.4	3.5-4.0	100	10 - 15	piasek, żwir sand, gravel 0 - 5 %		zwarta zabudowa miejska dense town development
4	550	3.8	4.0-5.0	60 - 70		borowina, muł, piasek, żwir mud, silt, sand, gravel 30 - 40	bardzo obfity very abundant	niezbyt zwarta zabudowa miejska not very dense town development
5	520	2.9	5.0-6.0	60 - 80	15 - 20	borowina, muł mud, silt 25 - 30	obfity abundant	luźna zabudowa wiejska loose village development
6	495	1.2	5.0-7.0			muł, borowina, piasek silt, mud, sand 20 - 25	umiarkowany moderate	
7	487	0.1	7.0-8.0	100	15 - 25	muł, borowina silt, mud 15 - 20	słaby, widoczne glony poor, algae visible	brak none
Czarny Potok	540	0.7	5.0-6.0	70 - 80	15 - 20	żwir, piasek gravel, sand 15 - 20	brak none	

tributary the Czarny Potok. The characteristic features of the stations are given in Table III. At each of these stations the samples were taken 10 times and at the station in the Czarny Potok twice, from March 1966 to February 1967 on the dates given in Table I.

Field investigations included: sampling the invertebrates, measurement of the temperature of the water and pH, collecting samples of the water for examination of oxygen and BOD_5 content, and samples of the bottom sediments.

Determination of the organic matter content in sediments was made by means of the oxidization method in a temperature of 700—800°C for two hours with reconstruction of carbonates. Organic ammonia in sediments was determined by means of Kieldahl's method, oxygen dissolved in the water being determined by means of Winkler's method (Just, Hermanowicz 1955). At each of the stations samples were taken from the following biotopes: stony substrate with a strong current, stony substrate with a moderate and slow current, sandy substrate, silty substrate. From each biotope it was attempted to take three samples. This, however, was not always possible from biotopes with a sandy and silty substrate, when a smaller number of samples or even none were taken (Table IV).

Tabela IV. Terminy uzyskania prób makrofauny (+) z podłoża drobnoziarnistego: P - piasku; M - mułu

Table IV. Time of sampling macrofauna (+) from fine-grained substrate: P - sand; M - silt

Stanowiska Stations	Miesiąc Month / Podłoże Substrate	1966									1967
		III	IV	V	VI	VII	VIII	IX	XI	XII	II
1	P			+	+	+	+	+	+	+	+
	M										
2	P	+		+	+		+	+	+	+	+
	M								+		
3	P	+		+						+	
	M										
4	P		+	+		+	+				
	M	+			+	+	+	+	+	+	+
5	P			+	+	+				+	
	M	+	+		+	+	+		+	+	+
6	P		+	+	+	+					
	M		+	+	+	+	+	+	+	+	+
7	P	+	+		+				+		
	M	+	+	+	+	+	+	+	+	+	+
Czarny Potok	P	+					+				
	M										

For taking samples a square shaped sampler, side length 22·5 cm having a bolting cloth with a mesh diameter of 0·3 mm was used. This was placed against the current, as deep as possible, and quickly moved forward for a constant distance of about 30 cm taking the substrate (sometimes aided with the hand) from an area of about 650 cm^2. It was not always possible to collect samples from such a large area when the substrate was fine-grained in which case they were taken from half or, exceptionally 2/3, of the area. The depth of the collected substrate layer varied. From a stony substrate it sometimes reached 20 cm, and from a fine-grained substrate 4—5 cm. Animals were preserved in 4 per cent formaline solution.

The fauna was calculated for the projected area of the stream bed, summing the quantitative results from individual samples for the determined biotope. Samples from smaller areas were appropriately calculated to the standard area of 20 dcm^2.

For general considerations on the benthic fauna of the stream two main groups were distinguished the fauna of a stony substrate and the fauna of a fine-grained substrate, summing the respective data for individual biotopes.

Distribution of the benthic invertebrates in the longitudinal profile of the Kryniczanka stream

The distribution of the benthic invertebrates along the stream at successive stations is presented in fig. 3. The number of distinguished taxonomic units (including also higher than species, not exactly determined units as 1) reached 190 at the first two stations. Among them dominate *Chironomidae*, followed by *Plecoptera*, *Trichoptera*, other *Diptera*, *Ephemeroptera*, and *Oligochaeta*. At station 3, where the stream is caught in jump correction and the water carries a certain amount of sewage flowing in from the neighbouring houses, the number of faunistic forms falls from 190 to 109, i. e. by 43 per cent. At further stations below the outflow of the collector discharging municipal sewage the number of these forms further decreases, reaching the minimum — 56 forms — at station 6, i. e. not even 30 per cent in relation to the upper sector of the stream. As concerns individual faunistic groups, *Trichoptera*, followed by *Coleoptera* and *Plecoptera*, retreated first.

Division of faunistic zones in the stream by means of graphic methods

On the basis of the list of species found in the stream a division of the Kryniczanka into zones was performed by means of two graphic methods: that of Illies (1963), according to the similarity in the qualitative composition of the fauna at the stations and a similar method, modified by the author, according to the similarity of the quantitative composition of the fauna at the stations.

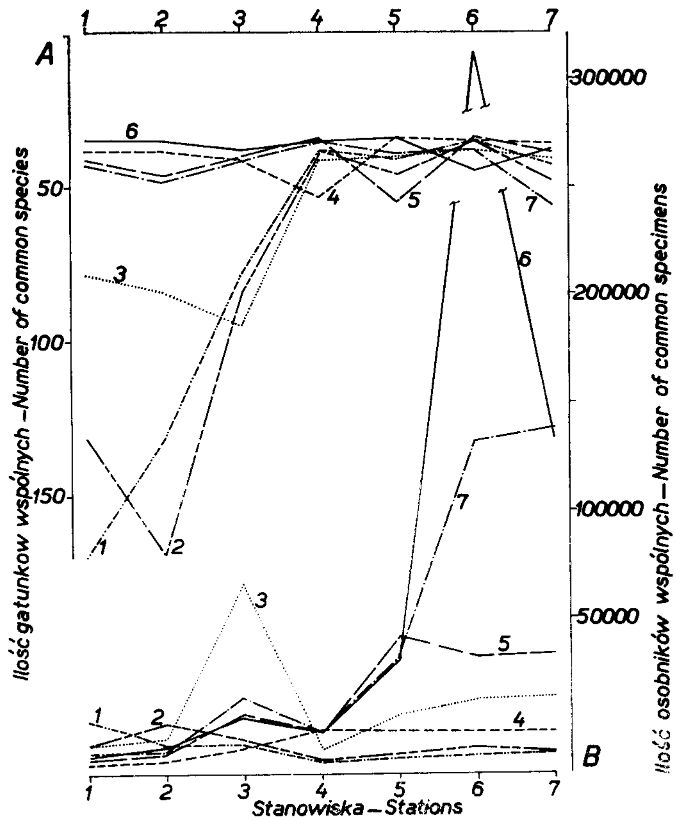
The modification of Illies' method consists in considering also the number of common specimens individual species in the operation of calculating and subsequently drawing the degree of similarity of the fauna of two optional stations. This is the smaller number of the two compared numbers of specimens of the species sampled at the considered stations. In Illies' method the peaks of the curves show the number of species found at the given station, whereas in the modified method these peaks show the number of specimens collected and identified as to species at that station. The shapes of curves in relation to one another show the degree of similarity in the faunistic composition at individual stations.

For these operations only forms in the rank of species (distinguished but not identified forms as well as, e. g., *Chaetopteryx* sp.) were considered, neglecting *Enchytreidae* with the exception of *Propappus volki* and *Cernosvitoviella atrata.*

A graphic presentation of these relations in the range of similarity in the faunistic composition at the stations of the Kryniczanka is given in fig. 4. Owing to the disturbances caused by the inflow of sewage this picture is not quite clear. It is seen, however, that the fauna of stations 1 and 2 and also 3 resemble one another and that the fauna at station 2 is quantitatively closer to that at station 3 than at 1. Stations 4—7 also have a similar fauna. In general three groups of stations in the Kryniczanka can be distinguished with respect to faunistic composition: 1, 2—3, 4—7.

The faunistic similarity of polluted stations established by means of the modified method (fig. 4B) seems to be more accurate than that obtained by means of Illies' method (fig. 4A) as, e. g., the fauna at station 7 shows a closer similarity to the fauna at stations arranged in the order 6, 5, 3, which would be more correct than in the order 2, 1, 3. A comparison of results obtained by means of these two methods suggests that they are complementary to a certain extent.

Each of the applied methods has its advantages and disadvantages. Illies' method seems more suitable for analyse on benthic communities of running waters of natural conditions, i. e. of a great number of forms. Its essential advantage is that it does not require exact quantitative investigations applied in the field; its disadvantage is that it treats all species equally and does not reflect quantitative changes in the fauna, which usually preceed qualitative ones. Quantitative changes, on the other hand, are well reflected by the modified method. It demands, however, exact quantitative data which must satisfy the following conditions: samples of the fauna of the bottom should be taken by means of the same method, at the same time, and refer to the same unit of the bottom area. If certain zones are to be distinguished in the stream (according to Illies' and Botosaneanu's (1963), for which the thermal conditions of the flow are decisive), one should aim at eliminating differences caused by the current or substrate. Hence it is necessary either to consider the biotopes of a different type of substrate separately or to group various biotopes at the same ratio.



Ryc. 4. Obraz wzajemnego podobieństwa składu jakościowego (A) i ilościowego (B) makrofauny poszczególnych stanowisk potoku Kryniczanka. Przeliczenia dla B odnoszą się do podłoża kamienistego

Fig. 4. Picture of mutual similarity of the qualitative composition (A) and quantitative (B) of the macrofauna of individual stations of the Kryniczanka. Calculations for B refer to a stony substrate

Division of the stream into zones according to the dominating species of the most numerous taxonomic groups

Dominance was expressed in terms of percentage participation of the number of specimens of a given species (or genus) within its own taxonomic group, in the year round collection from a given station, referred to a constant unit of area of the main types of substrate. Stony substrate and fine-grained substrate were accepted as basic types. The dominance for a stony substrate was calculated by summing the quantitative data for the following biotopes:

stones in a strong current and stones in a moderate or slow current. The dominance for a fine-grained substrate was calculated by summing annual means from sandy and silty biotopes.

Tabela VI. Ephemeroptera potoku Kryniczanka; ich rozmieszczenie wzdłużne i liczebność na różnych typach podłoża, wyrażone w procentach. Przeliczenie i oznaczenie podobnie jak przy Oligochaeta (tabela V)

Table VI. Ephemeroptera of the stream Kryniczanka; their longitudinal distribution and number on various types of substrate expressed in percentage. Calculation and denotation as in Oligochaeta (Table V)

Podłoże - Substrate	Kamieniste - Stony				Drobnoziarniste Fine-grained			
Gatunki Species / Stanowiska Stations	1	2	3	Czarny Potok	1^x	2	3^x	Czarny Potok
Ephemera danica Müll.	0.1	0.5	0.2		8.3	21.1	0.7	16.2
Baetis alpinus Pict.	57.1	22.0	4.9	1.4	16.7	2.2		
- fuscatus L.	1.6	0.6	0.6	50.5	20.0			21.6
- lutheri Müll.-Lieb.	0.2	0.6		3.1				
- muticus L.	+	0.2		3.6		1.1		
- rhodani Pict.	24.4	55.1	84.4	29.8	39.0	56.6	95.6	43.2
- vernus Curt.	0.8	2.1	1.6	0.2		2.8		
- beskidensis Sowa				0.2				
Centroptilum luteolum Müll.		+				1.1		
- pennulatum Etn				0.7				2.7
Epeorus assimilis Etn		+		0.2				
Ecdyonurus dispar Curt.			+	0.7				
- lateralis Curt.	0.2	0.7	0.2					
- subalpinus Clap.	0.9	0.5			+			
- submontanus Landa	+	0.1	0.2	0.7				
- venosus F.		0.3	0.3					
Rhithrogena picteti carpathica Sowa	7.5	7.3	2.3	5.7	4.1	+		
- ferruginea Navas		0.9	0.3					
Paraleptophlebia submarginata St.		+						
Habrophlebia lauta Etn	0.4	0.2					1.5	
Habroleptoides modesta Hag.	+	1.5	0.8	0.5		1.1		
Ephemerella ignita Poda.	0.5	1.4	1.0	1.4	3.9			
- krieghoffi Ulm.	6.0	5.8	3.2	0.2	7.6	13.9	2.2	16.2
- major Klap.	0.1		+					
Caenis rivulorum Etn	+	+		0:9				
Ilość osobników Number of specimens	3679	3156	1215	420	14.7	22.5	15.3	9.5

For division of the zones in the stream the most numerous faunistic groups were based upon: *Naididae*, other *Oligochaeta (Tubificidae*, *Enchytreidae*, *Lumbriculidae)* (Table V), *Ephemeroptera* (Table VI), and *Chironomidae* (fig. 5, Table VII). Treating all taxonomic groups as a whole does not seem advisable, since species of larger body size, occurring as a rule in nature less numerously, would be discriminated against to the advantage of species of smaller body size, which are usually more numerous. The dominants, i. e. those forms which exceed 10 per cent participation, and sometimes also subdominants, with 1·0—9·9 per cent participation, determine the zones in the stream.

Tabela V. Oligochaeta potoku Kryniczanka; ich rozmieszczenie wzdłużne i liczebność na różnych typach podłoża, wyrażone w procentach

Dane liczbowe dla podłoża kamienistego przedstawiają sumy całorocznych zbiorów z siedliska o prądzie silnym oraz z siedliska o prądzie umiarkowanym i słabym każdorazowo z powierzchni 40 dcm^2. Dla podłoża drobnoziarnistego - sumy średnich rocznych z siedliska piaszczystego i mulistego. Oznaczenia: + - poniżej 0,1 %; x - średnie roczne odnoszą się tylko do powierzchni 20 dcm^2

Table V. Oligochaeta of the stream Kryniczanka; their longitudinal distribution and number on various types of substrate, expressed in percentage

Numerical data for a stony substrate are presented by sums of the year round samplings from a fast current biotope and a biotope of moderate and slow current, each time from an area of 40 dcm^2. For a fine-grained substrate - the sums of annual means from a sandy and silty biotope. Denotations: + - under 0.1 %; x - annual means refer only to an area of 20 dcm^2

Podłoże - Substrate	Kamieniste Stony								Drobnoziarniste Fine-grained							
Stanowiska - Stations	1	2	3	4	5	6	7	Czarny Potok	1x	2	3x	4	5	6	7	Czarny Potok x
Gatunki - Species																
NAIDIDAE																
Chaetogaster diaphanus (Gruit.)				1.3	0.8	2.2	0.6	57.1						0.6		47.2
Ophidionais serpentina (Müll.)					+	+	0.4							0.6		
Nais alpina Sperber	3.9	2.0	+					18.1	1.6	0.7						10.1
- barbata Müll.		1.4	3.8	1.7	3.2	10.2	1.9		0.8	0.1	7.1	1.8	0.6	1.1	2.4	
- bretscheri Mich.	0.3	2.3	33.8	0.4		0.2	+	3.3	4.0	0.1		0.2			0.2	
- communis Pig.	9.7	35.9	4.2	4.4	2.9	1.9	1.3	10.8	10.3	82.5	2.8	5.7	2.5	1.0	3.0	6.7
- elinguis Müll.	79.3	53.7	45.0	87.5	90.9	85.4	95.3	2.0	82.7	6.9	90.0	90.1	97.0	93.2	93.8	6.7
- iorensis Patar.	0.5	1.7	0.6							0.3		0.2				
- pardalis Pig.	6.2	1.5	12.4	1.2	+	+	0.2		0.3	0.8				0.1	+	
- variabilis Pig.				0.2	+											
Pristina foreli (Pig.)		0.3	0.1	0.7	1.5	+	+	5.1		0.9		0.3		3.4	0.2	20.2
- rosea (Pig.)		0.6		2.5	0.6	+	+	3.6		7.6		1.6		+	0.2	9.0
Ilość osobników Number of specimens	740	2367	22877	5047	21925	234147	69747	497	227	1340	465	3717	2690	17511	10644	45
OLIGOCHAETA partim																
Tubifex ignotus (Stolc.)				0.3								1.1				
- tubifex (Müll.)	1.3	20.0	16.6	67.7	64.5	69.6	86.2	1.3	5.6	41.3	16.7	59.8	68.9	74.6	80.7	4.8
Limnodrilus helveticus Pig.						0.1	+						0.3	0.1	0.3	
- hoffmeisteri Clap.	0.1	0.8	1.8	8.7	7.5	25.2	11.8	0.9	0.6	44.8	8.3	9.9	15.8	19.7	14.6	
- udekemianus Clap.	0.9		4.9	11.6	7.4	2.9	0.8			4.1	63.2	12.1	7.4	2.2	2.5	
Propappus volki Mich.	33.3	43.6						26.3	34.0	2.8						26.8
Cernosvitoviella atrata (Bret.)	0.9	2.2						43.3	0.2	0.2						48.7
Marionina riparia Bret.	1.3	8.8	67.4	9.7	17.1	1.1	1.1	0.9	0.5	3.2	8.3	14.4	5.4	3.3	1.2	
Stylodrilus heringianus (Clap.)	54.2	6.9	+					15.6	56.8	1.0	+					9.7
Inne Other Oligochaeta	8.0	17.7	9.3	2.0	3.5	1.1	0.1	11.6	2.4	2.5	3.5	2.7	2.1	0.1	0.7	10.0
Ilość osobników Number of specimens	789	634	1472	6189	9253	51627	42451	224	456	1758	443	9017	11734	100344	74329	123

Inne Oligochaeta obejmują następujące formy: - Other Oligochaeta comprise the following forms:
Mesenchytreus armatus Lev., M. beumeri (Mich.), Henlea spp., H. perpusilla Friend, Buchholzia appendiculata (Buch.), Fridericia spp., F. gracilis Bülow, F. perrieri (Vejd.), F. ratzeli (Eisen), F. regularis Niels. Christ., Enchytreus spp., E. buchholzi Vejd., Lumbricillus spp., L. kaloensis Niels. Christ., L. pagenstecheri (Ratzel), Marionina argentea (Mich.), Lumbriculus variegatus (Müll.), Haplotaxis gordioides (Hart.), Eiseniella tetraedra (Sav.).

Taking as a basis the dominants on a stony bottom, neglecting *Nais elinguis*, dominating along the whole length of the stream, the Kryniczanka can be divided into 3 zones:

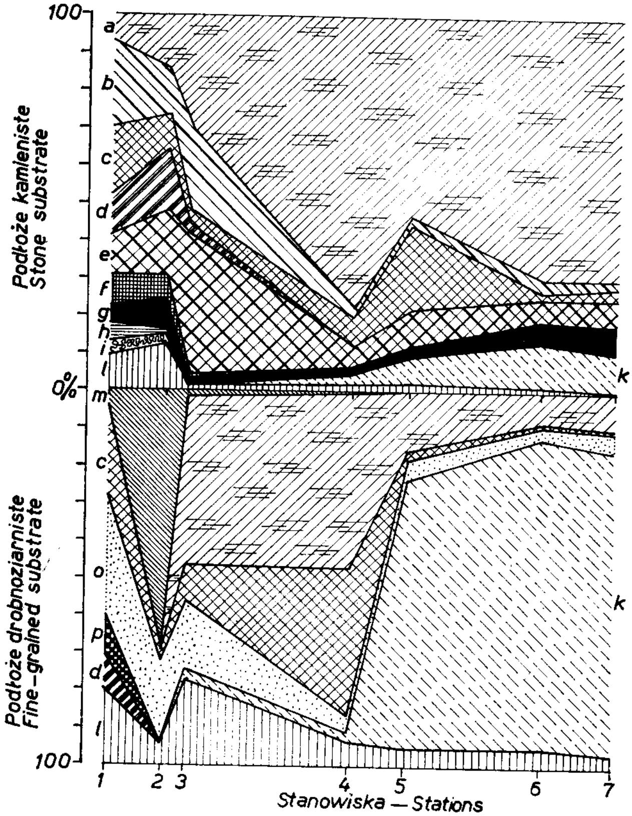
bela VII. Chironomidae pozostałe (mniej liczne) potoku Kryniczanka; ich rozmieszczenie wzdłużne i liczebność, wyrażone w procentach. Podane ilości osobników odnoszą się do całości Chironomidae. Przeliczenie i oznaczenie podobnie jak przy Oligochaeta (tabela V)

Table VII: Other Chironomidae (less numerous) of the stream Kryniczanka; their longitudinal distribution and number expressed in percentage. The given numbers of specimens refer entirely to the Chironomidae. Calculation and denotation as in Oligochaeta (Table V)

Podłoże - Substrate	Kamieniste Stony								Drobnoziarniste Fine-grained							
Stanowiska - Stations / unki - Species	1	2	3	4	5	6	7	Czarny Potok	1*	2	3*	4	5	6	7	Czarny Potok*
chapelopia pallidula (Mg.)		+														
opelopia binotata (Wied.)	+	+														
sia sp.		0.1								+						
opelopia notata (Mg.)		+								+						
rsia punctata (Fabr.)	0.2	0.3			+				1.9	+						
nemannimyia spp.	+	0.9	0.1	+	0.1	+	+	8.4	+	0.1	1.0	+			+	4.2
sopelopia flavida (K.)				+												
elimyia melanura (Mg.)	+															
lia longifurca K.				+		+						+				
desta (Mg.)	1.2	3.2	1.2	0.3	0.5	0.2	0.1	2.5	1.1	1.0	3.6	0.5	0.3	0.3	0.2	2.2
etocladius gr. vitellinus		+		+												
ynoneura gr. scutellata		+														
gr. minuta	0.1	0.7					+	0.3	0.2							
amesa gr. cinerella		+		+	+		+	+								
kiefferiella alpestris G.							+									
atrofasciata G.			+					0.7								
- clypeata (K.)	+					0.2	0.1	1.6								
- discoloripes G.	+															
- longicalcar (Potth.)	2.8	1.3	0.1	+			+	5.6	0.4	0.1	0.7					
- cfr. similis	+	0.4	0.1			+	+	2.3								
Eukiefferiella sp.		0.1	+	+	+	0.3	+								+	
Heleniella ornaticollis (Edw.)	1.0	0.8	+					0.4	1.3	0.1	+					
Limnophyes gr. prolongatus		+	+	+	+	+							+			
Metriocnemus gr. hygropetricus			+	+	+	+	+		+						0.3	
Metriocnemus sp.			+	+								0.2				
Microcricotopus bicolor (Zett.)	+															
Orthocladius frigidus (K.)	0.4							2.0	+							
- rivulorum (K.)	0.2															
Parametriocnemus stylatus K.	0.1	+	+					0.4	0.2			0.1				
Potthastia gaedii (Mg.)								1.3		+						0.5
- longimanus (K.)	0.1	+	+			+	+		+	0.2						
Psectrocladius gr. dilatatus	+															
Pseudodiamesa branickii (Now.)	0.7	+							9.6	0.1						
- nivosa G.									+							
Rheocricotopus effusus (Walk.)									+							
Smittia zavreli Fit.			+			+						+				
Thienemanniella gr. clavicornis	0.4	2.5	0.1		+		+	0.7		+						
Trissocladius sp.							+			0.2						
Cryptochironomus gr. defectus								0.2	0.4							4.1
Microtendipes gr. cloris								0.1								
Polypedilum breviantennatum Tscherm.				+					0.6				+	+		
- gr. convictum	0.2		+	+	0.4	0.5			0.7					1.1	0.6	
- gr. nubeculosum										+						
- gr. pedestre			+							+	3.0					
- gr. scalaenum												0.1				
Polypedilum sp. (Tend. "gen.3") Lip.	0.2	0.2	+	+	0.6	0.2	+	2.7	0.8	1.5		0.5	1.5	0.8	1.3	33.5
Micropsectra curvicornis Tscherm.									+	+						0.5
- gr. praecox	1.3	0.9	+	+	+	+	0.1	9.1	3.3	1.9		0.3	0.2	+		20.1
Stempelinella brevis Edw.	+								1.4							
Tanytarsus gr. exiguus								0.3	+							
- gr. gregarius								0.2	+	+						+
- gr. mancus																1.8
Ilość osobników / Number of specimens	9292	8246	58609	15787	31497	77981	89350	1186	966	4625	465	12241	5921	11098	16444	402

I — (station 1) dominant are: *Stylodrilus heringianus*, *Baetis alpinus*, *Diamesa* gr. *insignipes*.

II — (stations 2—3) dominant are: *Propappus volki* (only at station 2), *Baetis rhodani*, *Orthocladius rivicola*.



Ryc. 5. Układ dominujących form *Chironomidae* na dnie o podłożu kamienistym i drobnoziarnistym (piasek + muł) potoku Kryniczanka

Fig. 5. System of dominating forms of *Chironomidae* on a bottom of stone substrate and fine-grained substrate (sand, silt) of the Kryniczanka stream

Oznaczenia — Denotations: a — *Cricotopus* spp.; b — *Diamesa* gr. *insignipes*; c — *Rheocricotopus dispar* (G.); d — *Eukiefferiella bavarica* G.; e — *Orthocladius rivicola* (K.); f — *Eukiefferiella brevicalcar* (K.); g — *Eukiefferiella hospita* Edw.; h — *Parothocladius nudipennis* (K.); i — *Synorthoclaudius semivirens* (K.); k — *Chironomus* f. l. *thummi* K.; l — *Chironomidae* pozostałe — other; m — *Apsectrotanypus trifascipennis* (Zett.); o — *Prodiamesa olivacea* (Mg.); p — *Pseudodiamesa branickii* (Now.)

III — (polluted stations 4—7) dominant are: *Tubifex tubifex*, *Cricotopus* ssp.

Within station III two sub-zones can be distinguished, neglecting *Tubifex tubifex* and *Chironomus thummi* as these forms are not characteristic of a stony but of a fine-grained substrate.

IIIa — (stations 4—5) dominant are: *Cricotopus* spp., *Rheocricotopus dispar*, *Orthocladius rivicola*.

IIIb — (stations 6—7) dominant are: *Cricotopus* spp., *Eukiefferiella hospita*, *Orthocladius rivicola.*

The genus *Cricotopus* spp. is represented in the Kryniczanka by at least 6 different species (this being established on the ground of a certain number of nymphs found) very difficult to distinguish in the larval stage and not yet elaborated. Hence the true dominance of one of the species *Cricotopus* spp. may be different from that obtained for the whole genus.

On a fine-grained substrate the distribution of dominants is more complicated, especially at stations 1—4. *Ephemeroptera* occur on this substrate in small numbers, on the yearly average only a dozen or so individuals on 20 dcm^2 of the bottom; *Ephemera danica* — the second dominant at station 2 — is the only one of them adapted to life in this environment. *Naididae* are of little use in differentiating zones in a stream of this substrate as *Nais elinguis* dominates at almost all stations except for station 2 where it is replaced by *Nais communis.* On the basis of the dominants of the other faunistic groups, and neglecting *Rheocricotopus dispar* and *Cricotopus* spp. as forms loosely connected with a fine-grained substrate, the Kryniczanka can be divided into the following zones:

I — (station 1), dominant are: *Stylodrilus heringianus*, *Propappus volki*, *Prodiamesa olivacea*, *Pseudodiamesa branickii.*

II — (station 2), dominant are: *Limnodrilus hoffmeisteri*, *Ephemera danica*, *Apsectrotanypus trifascipennis.*

III — (stations 5—7), dominant are: *Tubifex tubifex*, *Chironomus thummi.* Stations 3 and 4 have an intermediate character between the stations of zone II and III. Besides this, there are some difficulties in including these stations into a determined zone owing to the fact that the communities of the bottom fauna on a fine-grained substrate include a great number of faunistic forms from a stony substrate, this being evidenced by a great number of *Cricotopus* spp. and *Rheocricotopus dispar.* Probably it results from the particularly low stability of this type of substrate in the sector of the stream caught in jump correction (or immediately below it) and by the inflow of sewage. This is especially visible at station 4 where 90 per cent of the *Chironomidae* fauna are species not strictly connected with a fine-grained substrate, but were most probably brought there from a built up area situated immediately above the station.

Tubificidae dominate beginning from station 2 but in a quite particular arrangement: station 2 — *Limnodrilus hoffmeisteri*, station 3 — *L. udekemianus*, other stations — *Tubifex tubifex.* This arrangement suggests, on the one hand, the effect of sewage on the macrofauna of the stream and, on the other, a correlation with the kind of substrate or, to be precise, with the size of the sediment grains. Wachs (1967) proved experimentally that *T. tubifex* prefers silt, whereas species of the genus *Limnodrillus* prefer sediments with a larger grains diameter.

In general, the basis of the dominants for the two types of substrates three zones can be distinguished in the Kryniczanka, the fauna of a stony substrate seeming more appropriate for this purpose:

zone I — station 1,
zone II — stations 2—3,
zone III — polluted stations 4—7.

It would seem correct to distinguish station 1 as a separate zone on account of the fact that many species of other taxonomic groups occur there whose range — starting from the springs — usually ends at this station. These are (Table VIII): *Bythinella austriaca*, *Rivulogammarus balcanicus*, *Ecdyonurus subalpinus*, the majority of species of the genus *Rhyacophila*, *Synagapetus iridipennis*, *Plectrocnemia*, *Ecclisopteryx madida*, *Chaetopteryx polonica*, *Eusimulium latipes*, *Natarsia punctata*, *Parorthocladius nudipennis*, and others.

Station CP — the Czarny Potok — has many dominants common with station 2: *Baetis rhodani*, *Rhithrogena pictati carpathica*, *Eukiefferiella bavarica* — 19·0 per cent, *Orthocladius rivicola* — 16·4 per cent, all on a stony substrate, and *Prodiamesa olivacea* — 23·1 per cent on a fine-grained substrate. Its individual character is shown (Tables V—VIII) by such dominants as: *Nais alpina*, *Chaetogaster diaphanus*, *Cernosvitoviella atrata*, *Baetis fuscatus*, *Polypedilum* sp. A separate zone for this station resembling zone II, could thus be, but it seems more justified to include it into zone II, as the results here are based upon only two samplings during the year and may give a distorted picture of dominance. A comparison of the arrangement of dominance of *Chironomidae* at the two stations — stony substrate — in March is as follows:

St. 2.	*Eukiefferiella bavarica*	— 18·0 per cent
	Orthocladius rivicola	— 17·6 ,, ,,
	Eukiefferiella brevicalcar	— 15·4 ,, ,,
	Brilia modesta	— 11·4 ,, ,,
	Eukiefferiella hospita	— 10·6 ,, ,,
	Rheocricotopus dispar	— 7·0 ,, ,,
	Specimens:	228

St. CP Czarny Potok.	*Orthocladius rivicola*	— 30·9 per cent
	Eukiefferiella bavarica	— 30·0 ,, ,,
	E. longicalcar	— 9·0 ,, ,,
	Diamesa gr. *insignipes*	— 6·0 ,, ,,
	Orthocladius frigidus	— 4·0 ,, ,,
	Eukiefferiella hospita	— 3·0 ,, ,,
	Rheocricotopus dispar	— 2·5 ,, ,,
	Brilia modesta	— 1·0 ,, ,,
	Specimens:	1200

Stanowiska - Stations	1		2		3		4		5		6		7		Czarny Potok	
Podłoże - Substrate / Gatunki Species	K	D	K	D	K	D	K	D	K	D	K	D	K	D	K	D
Leuctra spp. + juv.	244	11.2	1	9.5							1				42	
Perlodes microcephala Pict.	3		1												2	
Isoperla grammatica Poda	6		2	6.0											1	
- sudetica Kol.	2														24	
Dinocras cephalotes Curt.															9	0.5
Perla burmeisteriana Class.	3		2													
- marginata Panz.															2	
Chloroperla torrentium Pict.	2			0.7												
- tripunctata Scop.															1	
COLEOPTERA																
Haliplus sp.			3		2											
Bidessus sp.			1													
Oreodytes rivalis Gyll.	1	0.6	13	2.0					1						24	
Agabus sp.	1	3.0	3	55.0	1					0.1						
Ilybius sp.				1.5												
Hydraena gracilis Germ.	1															
- riparia Kug.	1														3	
Hydraena sp.	8															
Hydraena spp. larwy	1			2.0												
Hydrochus sp. (carinatus Germ.?)			3													
Laccobius striatulus F.			1													
Elodes marginata F.	1			0.7												
Helichus substriatus P. Müll.?	1															
Elmis latreillei Bed.	6		1													
- maugetti Latr.	2														3	
- obscura P. Müll.	1		1													
- rietscheli Steph.?	3															
Elmis spp. larwy	145		12	0.6	2								1		31	
Esolus angustatus P. Müll.	13	0.5	1													
- parallelepipedus P. Müll.	1		1													
Esolus spp. larwy	14	5.4	5													
Limnius perrisi Duf.	99	4.7	6		13	2.0									7	

Tabela Table VIII. cont.

MEGALOPTERA																
Sialis fuliginosa Pict.		3.5	2													
TRICHOPTERA																
Rhyacophila fasciata Hag.	50		5													
- mocsaryi Klap.	1															
- nubila Zett.	1		4												6	
- obliterata McL.	40		6												6	
- philopotamoides McL.	1															
- polonica McL.	29		2													
- tristis Pict.	65		6													
- vulgaris Pict.	8		1													
Rhyacophila spp. juv. (gr. fasciata)	53		1													
Synafophora intermedia Klap.															3	
Synagapetus iridipennis McL.	11															
Hydroptila forcipata Eat.	1		1		1		1									
- vectis Curt.			2	0.6												
Hydropsyche instabilis Curt.	1		28		5										239	
Plectrocnemia conspersa Curt.	20	0.7	3	0.6											1	
- geniculata McL.	1															
Polycentropus flavomaculatus Pict.					1											
Tinodes rostocki McL.	276	1.4	5													
Ecclisopteryx madida McL.	61	5.7	1												4	
Limnephilus auricula Curt.			1													
- centralis Curt.				5.0										0.3		
- extricatus McL.				1.4												
- griseus L.				1.4												
- vittatus Fabr.									1							0.5
Anabolia sorror McL.	1															
Potamophylax luctuosus Pill.	7	1.0	1												4	
- nigricornis Pict.			1													
- rotundipennis Brau.		0.7	1													
- stellatus Curt.	4															
Halesus radiatus Curt.		3.2	1													
Stenophylax lateralis Steph. + + sequax McL.		1.0														
Stenophylacini n. det.	10	8.6		2.5												
Allogamus auricollis Pict.	8	0.7		13.0											5	

Tabela VIII. Skład i liczebność pozostałej części makrofauny (poza Oligochaeta, Ephemeroptera i Chironomidae) na kolejnych stanowiskach potoku Kryniczanka

Oznaczenia: K - podłoże kamieniste, D - podłoże drobnoziarniste, + - stwierdzono obecność. Dane liczbowe przedstawiają: dla K - sumy całorocznych zbiorów z siedliska o dnie kamienistym w silnym prądzie oraz z siedliska o dnie kamienistym w prądzie umiarkowanym i słabym, a więc 10 poborów z powierzchni 20 dcm^2 + 20 dcm^2 = 40 dcm^2; dla D - sumy średnich rocznych z siedliska o dnie piaszczystym oraz z siedliska o dnie mulistym (jeśli na stanowisku występował tylko jeden typ siedliska, dane liczbowe odnoszą się do powierzchni 20 dcm^2).

Table VIII. Composition and the number of the remaining macrofauna (except Oligochaeta, Ephemeroptera, and Chironomidae) at successive stations of the stream Kryniczanka

Denotations: K - stony substrate; D - fine grained substrate; + - observed presence. Numerical data show: for K - sum of the year round samplings from the biotope of a stony bottom in fast current and from the biotope of stony bottom in moderate and slow current. Thus, 10 samplings from the area of 20 dcm^2 + 20 dcm^2 = 40 dcm^2; for D - sum of annual means from the biotope of a sandy bottom and from the biotope of a silty bottom (if at the station only one type of biotope occurred, numerical data refer to an area of 20 dcm^2).

Stanowiska - Stations	1		2		3		4		5		6		7		Czarny Potok	
Gatunki / Species — Podłoże - Substrate	K	D	K	D	K	D	K	D	K	D	K	D	K	D	K	D
HYDROZOA																
Hydra circumcincta P. Sch.			+	+											+	+
TRICLADIDA																
Dugesia gonocephala (Dug.)	73		9												24	
NEMATODA n. det.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
GASTROPODA																
Bythinella austriaca Frfl.	2				1											
Lithoglyphus naticoides C. Pf.	1	0.5	1	2.0										2.5	6	3.0
Bithynia tentaculata L.	2		3	0.5												2.0
Radix peregra Müll.				0.3												
Ancylus fluviatilis Müll.	30		44		7											
LAMELLIBRANCHIATA																
Pisidium personatum Malm.?	2	9.0	7	5.1	6		1	0.3								3.0
HIRUDINEA																
Erpobdella monostriata (Gedr.)	5	0.5	42	3.7	3		7		1		6	0.3	10			
Trocheta bykowskii Gedr.	2	0.2	6										1			
HYDRACARINA n. det.	+	+	+	+	+										+	+
OSTRACODA n. det.	+	+							+							
AMPHIPODA																
Rivulogammarus balcanicus Schäff.	126	13.0	1													
- fossarum Koch.	1119	455.0	23	11.0	1				2				2		2	3.0
PLECOPTERA																
Brachyptera seticornis Klap.	4		6												3	
Taeniopteryx auberti K. et S.	2		3												2	
Amphinemura borealis Mort.	30	3.4	41	0.7	8	4.0									25	
- standfussi Ris	148	7.0	95	2.0	13				1						64	
- sulcicollis Steph.	8	0.5	21		3				1						15	
- triangularis Ris	253	5.5	65	1.0	10				1						40	
Nemoura cambrica Steph.	26	0.7	19	1.2	3											
- carpathica Illies				0.5												
- cinerea Retz.	42	3.6	50	21.5	18										2	
- flexuosa Aubert	37	2.0	48	5.0												
- fulviceps Klap.				4.2												
- marginata Pict.	18	1.5	11	1.0	9											
Nemoura spp. (+ babiagorensis Sowa)	756	35.0	487	69.2	103				1					0.3	27	3.0
Nemurella picteti Klap.	47	3.6	53	8.0	2											
Protonemura intricata Ris	2															
- lateralis Pict.	69		41		7											
- nimborum Ris	8															
- nitida Pict. + autumnalis Raus.	56	2.2	10			1.1									4	
- praecox Mort.	91		19		3	0.3							2		6	
Protonemura sp. (auberti Illies ?)	29		4													
Protonemura spp. juv.	109		10		74	0.3							1		21	
Leuctra albida Kmp.	162	16.6	119	2.2	17	0.3							1		75	
- aurita Navas																1.5
- autumnalis Aubert																1.5
- braueri Kmp.	44	52.8	6	2.5	4											
- carpathica Kis															1	
- gr. fusca L. (+ hippopus juv.)	161	6.1	122						1					0.3	16	
- hippopus Kmp.	1		6												2	
- inermis Kmp.				0.1												
- nigra Ol.	24	18.8	1	2.0											2	
- pseudosignifera Aub.	92	18.8	4	0.1					1							3.0
Leuctra spp. + juv.	244	11.2	1	9.5							1				42	

– Stations – Substrate Gatunki Species	1		2		3		4		5		6		7		Czarny Potok	
	K	D	K	D	K	D	K	D	K	D	K	D	K	D	K	D
Chaetopteryx polonica Dz.		0.4														
Chaetopteryx sp. (fusca Brau.?)	11	3.7													3	0.5
Silo nigricornis Pict.	1															
- pallipes Fabr.	20	2.6	1												1	
- piceus Brau.															1	
Oecismus monedula Hag.								0.1								
Sericostoma sp. (gr. flavicorne Schneid)	25	31.2	4	1.2											7	6.0
- personatum Spence													1	0.5		
Odontocerum albicorne Scop.	5	4.0														
DIPTERA																
Tipula saginata Bergroth	3		1													
Yamatotipula lateralis Mg.					1											
Limonia sp. (Dicranomyia)				1.2		0.3										
Taphrophila vitripennis Mg.	1					2.3		12.0								
Elliptera omissa Egger				1.0												
Pedicia sp. (rivosa L.?)			1		1											
Dicranota bimaculata Schum.?	46	38.6	4		1	0.3				7.5			1		1	6.0
Pilaria nemoralis Mg.?		1.5	3		1	1.0						0.1				
Gonomyia sp.	1	2.2														
Erioptera sp.	1	0.7		48.0												
Ormosia sp.		0.1	2	6.0										0.7		
Molophilus obscurus Mg.	15	15.4	10	14.0				0.1	1	0.1			1	8.1		
Sycorax sp.			1													
Psychoda alternata Say.		0.5			5		28	350.5	132	178.5	11	60.3	16	0.7		
- phalaenoides L.									4							
- severini Tonn.			2	1.0	4	23.3	120	258.0	116	68.2	14	33.2	17	1.7		
Psychoda sp.	3	0.5			2		8	3.0			1	0.1		0.7		
Pericoma blandula Eat.				1.7												
- canescens (Meig.)	15	8.5	3		5	0.3									3	
- diversa Tonn.	28	4.0	69	18.0	17			1.5								
- fuliginosa (Meig.)			5	0.7	1				6		1	2.2				

Tabela VIII. c.d.
Table VIII. cont.

Pericoma neglecta Eat.	2	2.2			40	0.7					3					
- unispinosa Tonn.	32	13.9	84	23.2	29					15.0				1.0	33	
Ptychoptera sp.		0.6														
Helobia sp.	1		1													
Prosimulium hirtipes Fries.	14	0.4	15	0.1	6											
- rufipes (Meig.)	2		1													
Eusimulium aureum (Fries)	9		1													
- latipes (Meig.)	24															
Odagmia monticola Fried.			19		5										116	
- ornata (Meig.)	226	9.0	2289	12.0	982		73	39.4	101		1297	0.2	183	2.8	435	
Simulium sp.	1		8		8											
Bezzia sp.	32	15.5	57	21.5	11	5.0	4		1	3.7		15.0			4	
Hermione spp.	1				1											
Dolichocephala spp.			1						16							
Hemerodromia spp.	19	6.5	18	4.5	7					6.2		0.1	14			
Atalanta spp.			1						1							
Wiedemannia spp.	319	6.7	98	29.9	173	2.0	6	4.0	2	7.4		0.3			49	2.0
Dolichopodidae n. det.		1.1	3				5	18.0	3		2			0.7		
Tabanus sp.		2.5	3		1			35.0	3				1			
Atherix ibis F.	2		1		3	0.3			1	3.7						
Ephydra sp.									16							
Eristalis sp.?								0.1								
Hydrellia sp.							1									
Limnophora sp.			2													

Classification of the Kryniczanka stream

Because of its physiographical and faunistic character the Kryniczanka is typical montane stream of the West Carpathian Mts area. It shows great faunistic resemblance to the Wielka Puszcza stream in the Beskid Mały (Sowa 1965), to the Kamienica Nawojowska stream (Zaćwilichowska 1968), to the lower part of the Sucha Woda stream in the Tatras (Kownacki 1971, Kownacka 1971), and also to the lower course of the Stonów stream (Sowa, Szczęsny 1970) and, to a smaller extent, to the stream Aabach (Dittmar 1955) and the upper course of the Fulda (Illies 1953).

According to Illies and Botosaneanu's (1965) classification, only one zone can be distinguished in the Kryniczanka and its tributary, i. e. epiritron with a possible division into sub-zones: epiritron with a slight influence of hypocrenon and epiritron proper. The sub-zone of epiritron with the influence of hypocrenon corresponding to the distinguished "zone I" covers the station 1 which lies the highest. At this station are grouped the majority of such species which are determined as oligostenotherms, hence populating, above all, the spring sectors of the streams. These are mainly (as mentioned above) those which usually end their range there. The sub-zone of epiritron proper — corresponding to the distinguished "zone II" — covers the lower lying stations 2, 3, and CP. There are only a few oligostenothermic species in the fauna populating this zone.

The third distinguished zone (III), including strongly polluted stations, probably lies entirely in the epiritron zone, this being indicated by the faunistic composition of the clean station CP having a similar physiographical character to stations 4—5 (Table III). This is also corroborated by another gradual increase in the percentage participation of *Orthocladius rivicola* in the fauna of this sector when approaching station 7, hence concomitantly with the decrease in effect of the sewage.

Influence of sewage on the macrofauna of the stream

Changes in the qualitative composition of the macrofauna.

— Retreating of forms

General changes in the qualitative composition of the macrofauna of the stream along its course on the background of the obtained BOD_5 values are presented in fig. 3. A great fall in the number of the species is already observed at station 3, but it is caused here by two factors: the building up of the stream bed and an increase in pollution. It must be supposed that the first factor plays a greater role because the BOD_5, as the measure of pollution, is relatively low and does not exceed 10·0 mg/l. O_2. A further fall in the number of species, including the complete elimination of such groups as *Ephemeroptera*, *Plecoptera*, *Coleoptera*, and *Trichoptera* is observed at station 4 and is directly connected with the inflow of sewage. At further stations mainly *Chironomidae* and *Oligochaeta* with the addition of other *Diptera*, *Simuliidae*, (also are encountered, whereas representatives of the former groups are found occasionally as single individuals, being most probably carried down with the water current from stations lying higher or from side tributaries. Hence, e. g., the slight increase in the number of species at stations 5 and 7 (fig. 3).

New forms

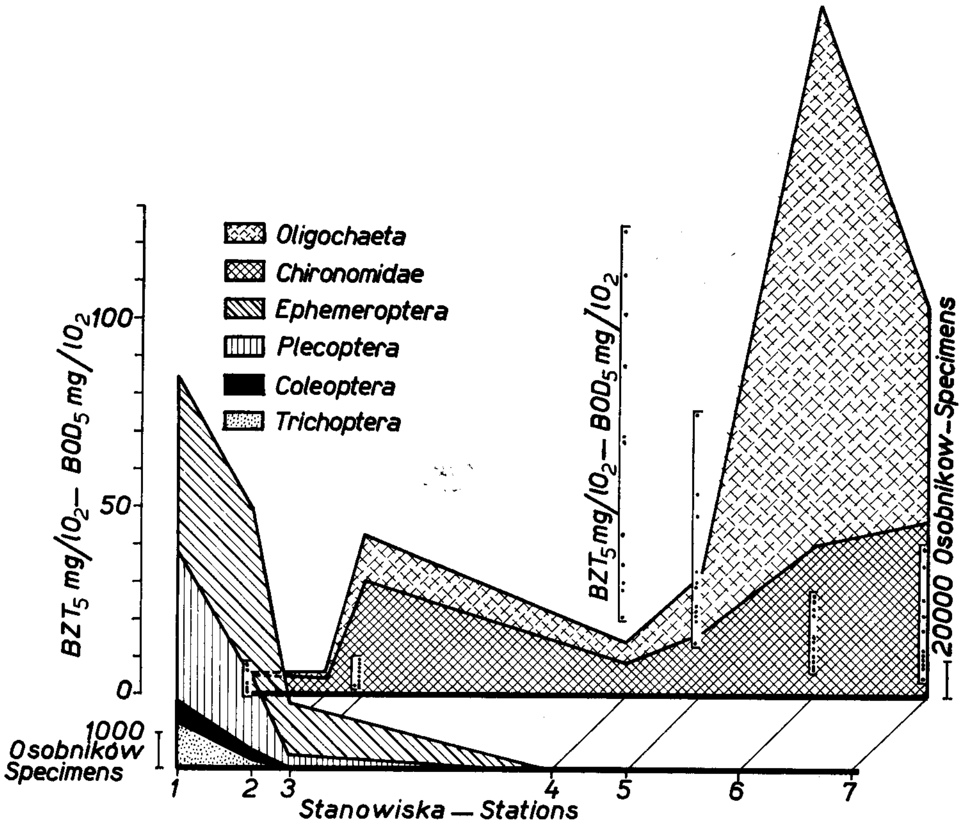
It follows from the list of species found in the Kryniczanka (Tables V—VIII) that at stations 4—7 only a few more species were found. These were: *Chaetogaster diaphanus*, *Ophidionais serpentina*, *Nais variabilis*, *Tubifex ignotus*, *Limnodrilus helveticus*, *Brillia longifurca*, *Trissopelopia flavida*, *Eukiefferiella lpestris*, and *Polypedilum* gr. *scalenum*. The mentioned forms belong to dominants, i. e. under 1 per cent participation (besides *Chaetogaster diaphanus* which reaches 2·2 per cent at station 5), and as such do not play any great role in the zoocenosis of the stream. The great majority of them can be encountered also in clean montane streams or rivers (Dratnal, Szczęsny 1965, Sowa 1965, Wachs 1967, Kownacki 1971, and others). The benthic fauna at stations 4—7 consists mainly of forms found at stations situated higher.

Changes in the quanitative composition of the macrofauna

General quantitative changes in the benthic invertebrates of the stream along its course with reference to a stony substrate and on the basis of BOD_5 are presented in fig. 6. These changes are as follows:

a) a decrease in the number of *Ephemeroptera*, *Plecoptera*, *Coleoptera*, and *Trichoptera* with a concomitant increase in BOD_5. The occurrence of these groups ceases as a rule at station 3, at further stations single individuals only being found. An almost complete elimination of *Trichoptera* already at station 3 is an interesting fact, whereas, e. g., *Ephemeroptera* are still quite numerous. Perhaps *Ephemeroptera* are better adapted to living in current conditions, moreover, being more numerous, they are more often carried downstream with the current than *Trichoptera*. Nevertheless, the presence, of these *Ephemeroptera*, living there, shows that the degree of pollution of the water at this place is not very high. It is also interesting that the number of these groups at station 2 decreased greatly in relation to station 1, the number of species remaining the same (fig. 3). One could treat this as an indication of a slight increase of pollution owing to the inflow of the waters of the Słotwiński Potok, which would be confirmed by an increasing number of *Tubificidae*. A greater influence, however, may be exerted by rubble dams situated above station 2 which reduce the downstream movements of the organisms from the sector situated above, whereas from station 2 organisms are carried away.

b) Increase in the number of *Oligochaeta* and *Chironomidae.*



Ryc. 6. "Zastępowanie się" poszczególnych grup makrofauny na podłożu kamienistym potoku Kryniczanka przy wzrastającym BZT_5. Dane ilościowe przedstawiają sumy osobników z 10 poborów każdorazowo z powierzchni 40 dcm²

Fig. 6. "Mutual replacing" by individual groups of the macrofauna on a stony substrate of the Kryniczanka with increasing BOD_5. Quantitative data show the number of specimens from 10 samplings at a time from an area of 40 dcm²

On a stony substrate as well as on a fine-grained one the number in these faunistic groups increases from station 4 on (distinctly from station 5). *Oligochaeta* reach their maximum number at station 6, *Chironomidae* at station 7 maintaining the tendency to increase concomitantly with a fall in the number of *Oligochaeta.*

c) Increase in participation of psammo- and pelophils in the fauna of the stream.

A fine-grained substrate is numerously populated by *Tubificidae* which have a great share in the population density even on a stony substrate, reaching almost 2/3 of the number of individuals of *Chironomidae*. Of the *Chironomidae*, *Chironomini* (mainly *Chironomus thummi*) develop in masses similarly as *Tubificidae*, which are adapted to living in sandy — silty biotopes of various aquatic environments, constituting along with them the main component of the fine-grained substrate fauna of the Kryniczanka. Taking into account the fact that the share of sediments in covering the stream bottom at stations 4—7 increased many times in comparison with the clean part of the stream, it will be comprehensible that the ecological group connected with them will be decisive for the character of the fauna of the lower sector of the Kryniczanka.

Changes in the dominance system.

a) *Oligochaeta*; within this group of dominants at stations 1—2 *Stylodrilus heringianus* and *Propappus volki* disappear completely, giving way at further stations to *Tubificidae* on a fine-grained substrate or to *Naididae* on a stony one. A similar regularity was observed by Wachs (1967) in the river Fulda. As concerns *Naididae*, in the polluted part a very uneven domination structure is established with the prevalence of one species, *Nais elinguis*, by about 90 per cent participation (Table V). The domination structure of *Tubicifidae* is not so drastic although here too one species only, *Tubifex tubifex*, prevails.

b) *Chironomidae*; on a stony substrate the influence of sewage is reflected in a very strong dominance of *Cricotopus* spp. (even over 70 per cent participation — fig. 5). Only at station 5 in the zone of influence of the clean waters from the Czarny Potok does the participation of *Rheocricotopus dispar* increase, being the second dominant replaced at further stations by *Chironomus thummi*. The system of subdominants, on the other hand, corresponds approximately to that of dominants at stations 2 and 3. Comparing the system of dominance on a stony substrate of the Kryniczanka with that of *Chironomidae* of the Sucha Woda in the Tatras (Kownacki 1971), stations 2 and 3 of the Kryniczanka would roughly correspond to station 9 of the Sucha Woda, i. e. its lower course, where *Orthocladius rivicola* and *Cricotopus* spp. are the dominating species. Stations 4—7 of the Kryniczanka represent in relation to the Sucha Woda the zone in which a sort of artificial accelleration of the dominance of *Cricotopus* spp. takes place, this being reflected in its prevalent dominance. Another increase in participation of *Orthocladius rivicola* towards station 7 on the Kryniczanka would support the supposition that this may be the zone of its dominance.

The fine-grained bottom is almost completely occupied by *Chironomus thummi*, which, however, starts its dominance from station 5 only (fig. 5). Prodiamesa olivacea is another important species in the position of a subdominant; its participation decreases down to station 6 and increases at station 7.

Seasonal variability

Variations in the number of *Oligochaeta* and *Chironomidae*, the main groups of bottom fauna populating the polluted part of the Kryniczanka, occur in a wide range during the course of the year. In figs 7 and 8 the range of changes during the whole year is presented on the background of its charge with organic matter.

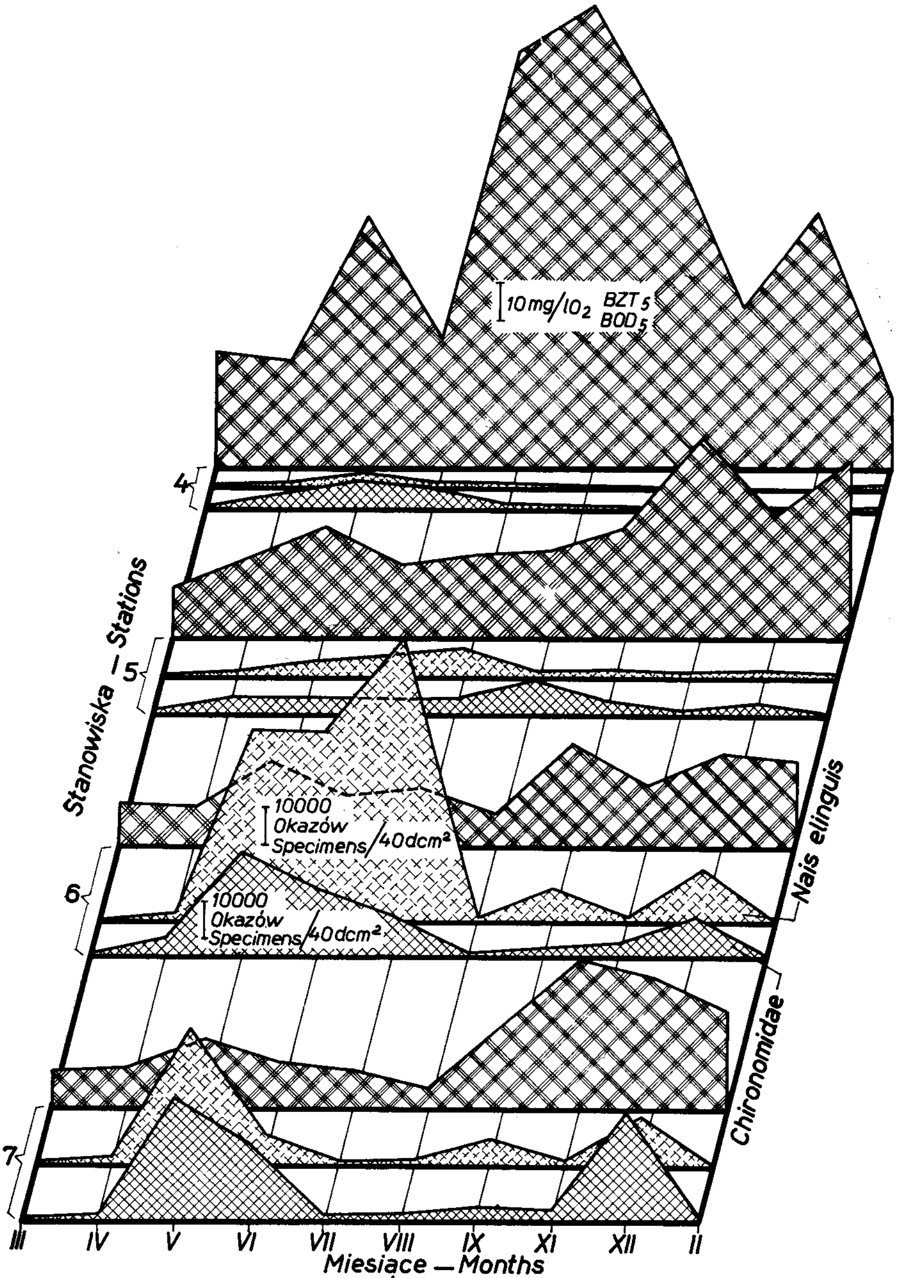
For a stony substrate the dynamics of the number of *Oligochaeta* is represented by *Nais elinguis* (85—95 per cent of *Naididae*) and *Chironomidae* as a whole. The charge with organic matter is expressed by BOD_5.

It follows from fig. 7 that variations in the number of *Nais elinguis* and *Chironomidae* are as a rule in agreement in the course of the year, showing two maxima and two minima. The main maximum of development occurs in the spring — summer season, the second maximum, — slightly smaller, takes place in the autumn — winter. The minimum number in August coincides with the maximum charge of organic matter and the greatest intensity of its decomposition process in the stream, hence, with the maximum oxygen defficiency. Moreover, August is for *Chironomidae* the time just after their flying out, a certain exception being observed at station 5 where in August the number of *Chironomidae* increased slightly owing to a mass development of *Rheocricotopus dispar* (60 per cent of the number of individuals in that month) only in the clean waters of the Czarny Potok.

It is difficult to explain the occurrence of the serious fall in the number of *Nais elinguis* and *Chironomidae* in winter and early spring. It may be caused by a number of factors, e. g. sudden changes of water temperature unfavourable for the development of "sewage fungi" of the flowing down of greater waters.

The spring maximum is surely connected with the beginning of the vegetation season with favourable oxygen conditions and a relatively small accumulation of organic matter in the stream sediments. For *Chironomidae* this is the peak of the spring development, just before the first flying out, observed by many authors in montane streams. It is also marked distinctly at station 2 of the Kryniczanka. For example, Kownacki (1971) found a similar numerical maximum in *Chironomidae* in the Sucha Woda in the Tatras, shifted slightly towards the summer months at higher altitudes above sea level. A similar numerical maximum in larvae is reached by the *Chironomidae* in autumn. In the Kryniczanka it is more clearly pronounced, increasing with the distance from the source of pollution. At station 7 the two maxima are distinct.

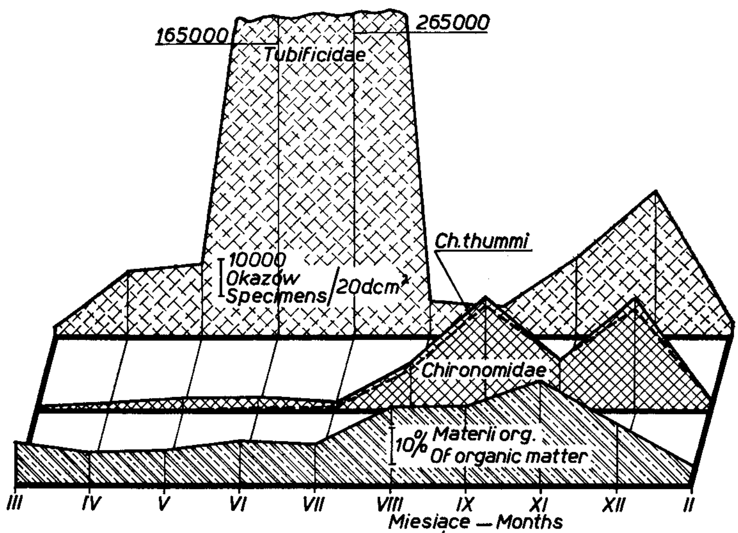
Annual changes in the number of *Tubificidae* and *Chironomidae* on a silty substrate (fig. 8) were represented on the example of station 6 where the quantitative development of the fauna was most vigorous. The percentage content of organic matter in sediments investigated at the same time was



Ryc. 7. Zmiany liczebności *Nais elinguis* i *Chironomidae* w ciągu roku na podłożu kamienistym odcinka zanieczyszczonego Kryniczanki w powiązaniu z BZT_5

Fig. 7. Numerical changes in *Nais elinguis* and *Chironomidae* during the year on a stony substrate of the polluted part of the Kryniczanka stream in connection with BOD_5

also presented. There is a fairly clear correlation in the autumn and winter months between the number of *Chironomidae* and *Oligochaeta* and the content of organic matter in the sediments. In the *Chironomidae* the spring peak is very weak, without doubt because of a poor development of the silty substrate destroyed by the spring high waters in the stream and by the inhibiting influence



Ryc. 8. Zmiany liczebności *Tubificidae* i *Chironomidae* oraz zawartości materii organicznej w ciągu roku w mule stanowiska 6

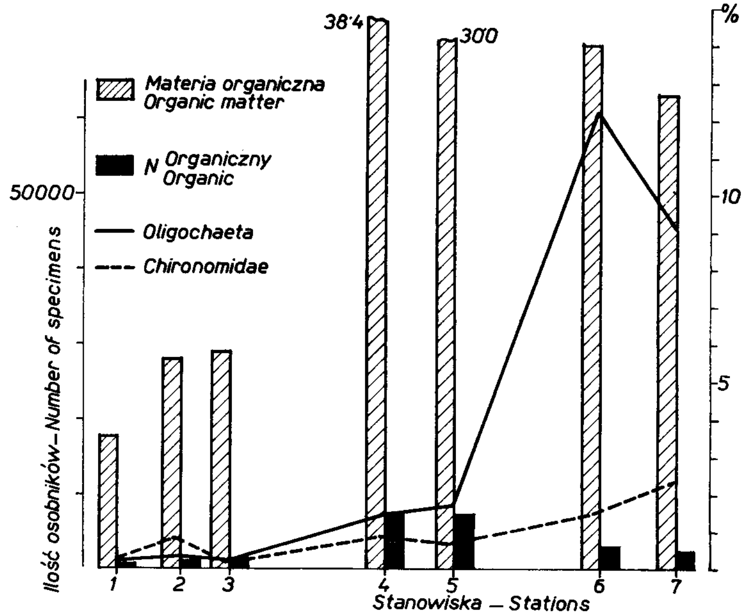
Fig. 8. Numerical changes of *Tubificidae* and *Chironomidae* and content of organic matter during the year in the silt of station 6

of the mass development of *Tubificidae*. A jump in the number of *Tubificidae* in June—July is not in accordance with the content of organic matter in the sediments but is caused by an intensive increase in young specimens, this being their time of reproduction (Wachs 1967). Participation of immature specimens at this time reached 70 per cent. The autumn maximum of *Oligochaeta* is most probably also connected with the reproduction of *Tubificidae*; this may be the laying of cocoons for the second time by two year old specimens in favourable nutrition and thermal conditions, which was observed by Poddubnaja (1972) on an allied species *Isochaetides newaensis* (Mich.).

The following general conclusions can be drawn: changes in the number of *Oligochaeta* during the year are usually in accordance with those of *Chironomidae*, spring and autumn maxima — similarly as in clean streams — being distinct. The generally high content of organic matter, expressed by BOD_5, influences negatively the number of fauna; the considerable content of organic matter in sediments at station 6 in general has a positive effect on the number of the bottom fauna of this station.

Remarks on the relations between the fauna of the benthos and the physico-chemical composition of the water and sediments in the polluted sector

The high BOD_5 of the water of the Kryniczanka caused a destruction of the macrofauna of the stream (fig. 3), the relation between the number of species and the magnitude of BOD_5, however, being not so close. The smallest number of species was found at station 6 concomitantly with almost the lowest values of BOD_5 recorded at stations 4—7.



Ryc. 9. Średnie roczne ilości zebranych osobników *Oligochaeta* i *Chironomidae* przeliczone na 20 dcm² podłoża drobnoziarnistego na tle średniej procentowej zawartości materii organicznej i azotu organicznego w osadach

Fig. 9. Annual means of quantity of sampled specimens of *Oligochaeta* and *Chironomidae* calculated for 20 dcm² of fine-grained substrate on the background of the mean percentage content of organic matter and organic nitrogen in sediments

Similarly, a fairly general relation exists between the number of *Oligochaeta* and *Chironomidae* and BOD_5 and the content of organic matter in the sediments. This relation is shown in figs. 6 and 9. The largest amounts of organic matter (also BOD_5) were found at stations 4 and 5 whereas the maximum number of *Oligochaeta* was recorded at station 6 and of *Chironomidae* at station 7 having an increasing tendency.

Observations of the proportion of the fall in organic matter with relation to organic N in sediments at station 4—7 (a rapid drop in organic matter, a slow one in organic N) suggest that the sector of stations 4—5 is the zone of decomposition above all of carbon hydrates decomposition of proteins taking place only from station 6(mainly) on. The maximum number of benthic fauna, especially *Oligochaeta*, thus, falls at the end of the zone of intensive decomposition of carbohydrates and in the zone of intensive protein decomposition. It could thus be concluded that a mass development of *Oligochaeta* contributed directly in eliminating protein components from the stream. As was shown experimentally by Wachs (1967) in his investigations on nutrition assimilation by *Tubifex tubifex*, one sexually mature specimens of this species takes up on the average 21 per cent of organic C and as much as 34 per cent of organic N at a water temperature of 12°C. The above data and the mass development of *Tubifex tubifex* at station 6 explain clearly the considerable fall in organic C and N at this station. The easily decomposable carbohydrates are doubtless decomposed in the first place by the bacterial flora immediately below the sewage outlet. Only then come *Oligochaeta* which eliminate protein compounds, most probably by consuming bacteria (Hynes 1963, Brinkhurst, Chua 1969). In the form of example Wachs (1967) states that during the period 1—31 May, at a water temperature of 18°C, 27173 mature tubifexes consumed on the area of 1 sq m. 46·54 g C and 20·39 g N at respective contents of 221·60 g C and 59·97 g N in the sediments. At that time of the year 95000 specimens of *Tubificidae*, in the majority mature, were found in Kryniczanka on 1 m^2 of silty bottom at station 6.

It is not clear, however, why the maximum number of *Oligochaeta* occurred at such a great distance from the sewage outlet. Several hypothesis may be put forward in trying to elucidate this phenomenon. Two of them seem to be the most convincing: excessive amounts of H_2S, sulphides, and ammonia occurring concomitantly with a frequent disappearence of oxygen; the second suggests the necessity of a mass development of bacteria — most probably their richer species composition — as a nutrition source for *Oligochaeta*.

Determination of the degree of pollution of the Kryniczanka on the basis of the benthic fauna

As follows from the previous chapters, different faunas populate a stony and fine-grained stream bed. In the polluted part these differences disappear to a certain extent. On the one hand it is caused by drift (strong current of the water and effect of sewage) and on the other by a great increase in fine-grained — silty substrate as the result of the inflow of therapeutic mud and organic matter from the municipal sewage. Drift and sedimentation explain the presence of many rheophilous organisms on a fine-grained substrate; the presence of psammo- and polophilous forms in the lotic zone on a stony bottom can be explained by migration. Nevertheless, differences between the fauna of the substrates exist and should be considered separately in evaluation of the degree of pollution.

Basically, two forms dominate on a stony substrate: *Nais elinguis* and *Cricotopus* spp. Determination of the pollution on the basis of these dominants is not possible. *N. elinguis* does not exist in any list of saprobes (Kolkwitz-Marsson 1909, Liebmann 1962, Wetzel 1969). In the Kryniczanka it occurs as a dominant at all the stations. Similar results were obtained for this species by Korn (1963), who came to the conclusion that it is a species very resistant to various factors in the environment and cannot be an indicator form.

Cricotopus spp. includes several species which cannot be isolated at present so that it is difficult to draw any conclusions as to its connection with sewage. Treating this genus as a unit, it could be assumed that it is a ubiquitous form occurring in all types of waters, from the Tatra streams (Kownacki 1971) to lowland rivers, occurring even in lakes (Smoleńska 1963). This genus is not mentioned in any list of saprobes. None of the other species of *Chironomidae*, populating a stony substrate, is mentioned in such a list. For these reasons the mathematical methods of Fjerdingstad (1964), Wetzel (1969) are not applicable.

To estimate the degree of pollution of the stream along the sector of stations 4—7 only *Tubificidae* and *Chironomus thummi* can be used; they inhabit a fine-grained substrate and on a stony substrate occur only from stations 5 and 6 in greater numbers. According to these forms, i. e. to be precise *Tubifex tubifex*, *Limnodrilus hoffmeisteri*, *L. udekemianus*, and *Chironomus thummi*, considered as dominants in the sector of stations 4—7, the pollution of the Kryniczanka can be determined as polysaprobic, corresponding to the zone of dominance of *Sphaerotilus natans* according to Fjerdingstad (1964).

Korn (1963) and Wachs (1967) call in question the usefulness of *Tubificidae* as indicator forms for determination of the degree of pollution because they occur and develop equally well in a very large range of values of various abiotic factors. Moreover, Wachs proved experimentally that these forms are connected above all with the kind of substrate and not with the pollution of the water. Observations on the Kryniczanka corroborate the opinions of these two authors, but it must be taken into account, however, that the occurrence of these two forms is above all conditioned by the availability of nutrition, while their great adaptability to unfavourable conditions permits them to live even in extremely bad conditions.

Taking as a basis only saprobes — *Tubificidae* as dominants within the taxonomic group *Oligochaeta* — a mistake would be made in including this station into the polysaprobic zone when determining the degree of pollution of station 2 (fine-grained substrate). The fauna of the stony substrate represents in its composition a typical montane stream. This example indicates the necessity of analysing the whole fauna and not only a limited search for saprobionts. A similar fact was presented in Goodnight and Whitley's (1961) paper. These authors found that the participation of *Tubi-*

ficidae in the fauna of a fine-grained substrate can reach 60 per cent in natural conditions in clean waters; in the Kryniczanka their participation does not exceed 20 per cent at station 2, rising to 85 per cent at station 6.

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STRESZCZENIE

Kryniczanka jest niedużym (około 10 km długim) potokiem, prawobrzeżnym dopływem potoku Muszynka, który uchodzi do Popradu. Źródła Kryniczanki leżą na wysokości około 800 m n. p. m., ujście — 487 m n. p. m. Potok przepływa przez miasto Krynicę przyjmując jego ścieki mniej więcej w połowie swej długości. W obrębie miasta potok jest uregulowany. Przy ujściu do Muszynki prowadzi średnio około 1 m^3 wody na sek.

Badania terenowe przeprowadzono w latach 1966—1967 na siedmiu stanowiskach Kryniczanki oraz jednym na jej dopływie Czarnym Potoku (ryc. 1—2, tabela III). Materiał pobierano przez okres jednego roku w odstępach miesięcznych (tabele I, IV), drapaczem dna kształtu kwadratu o boku 22,5 cm z siatką z gazy młynarskiej o średnicy oczek 0,3 mm. Pobierano po trzy próby z następujących siedlisk: dno kamieniste w prądzie silnym, dno kamieniste w prądzie umiarkowanym i słabym, dno piaszczyste i dno muliste. Powierzchnia dna potoku, z której pobrano trzy próby, wynosiła około 20 dcm^2. Badania terenowe obejmowały ponadto pomiar temperatury wody, pH oraz pobór prób na zawartość tlenu w wodzie (tabela I), BZT_5 (ryc. 3, 6) i zawartość materii organicznej w osadach (tabela II). Pełniejsza analiza fizykochemiczna wody wykonana została trzykrotnie w ciągu roku.

Na podstawie analiz fizykochemicznych wody stwierdzono, że potok jest zanieczyszczany na całej długości jaką przebadano. Świadczą o tym podwyższone zawartości amoniaku, azotu organicznego, fosforanów, suchej pozostałości, BZT_5 oraz innych czynników chemicznych w wodzie (tabela I, ryc. 3, 6). Na odcinku stanowisk 1—3 zanieczyszczenie to nie jest duże; według Sladečka i Fjerdingstada (Starmach 1969) można je określić jako β-mezosaprobowe (stanowiska 1—2) i α-mezosaprobowe (stanowisko 3). Poniżej ujścia ścieków natomiast (stanowiska 4—7) w niektórych miesiącach osiągało ono stopień izosaprobowy (powyżej 100 mg O_2/l BZT_5), a zwykle polisaprobowy. Zawartość materii organicznej w osadach na tym odcinku potoku dochodziła do 70% (tabela II).

Rozmieszczenie fauny dennej wzdłuż potoku na kolejnych stanowiskach jest bardzo zróżnicowane (ryc. 3). Na dwu pierwszych stanowiskach wyodrębniono 190 form. Dominują wśród nich *Chironomidae*, następnie *Plecoptera*, *Trichoptera*, pozostałe *Diptera*, *Ephemeroptera*, *Oligochaeta*. Na stanowisku 3, gdzie potok ujęty jest w korekcję progową, a woda niesie pewne ilości ścieków dopływających z okolicznych domostw, liczba form zwierzęcych spada ze 190 do 109, czyli o 43%. Na dalszych stanowiskach poniżej ujścia kolektora doprowadzającego ścieki miejskie ilość form jeszcze bardziej maleje osiągając minimum (56) na stanowisku 6, czyli niecałe 30% w stosunku do górnego odcinka potoku. Są to głównie przedstawiciele *Oligochaeta* i *Chironomidae* (tabele V—VIII).

Dokonano wydzielenia stref w potoku metodami graficznymi (ryc. 4) Illiesa (1963) według podobieństwa składu gatunkowego fauny na stanowiskach oraz podobną metodą, zmodyfikowaną przez autora według podobieństwa składu ilościowego fauny na stanowiskach. Wyniki i przydatność obydwu metod przedyskutowano. Wydzielenia stref w potoku dokonano także według dominujących gatunków najliczniejszych grup taksonomicznych: *Oligochaeta*, *Chironomidae* i *Ephemeroptera* (tabele V—VII, ryc. 5).

W wyniku wyżej wymienionych operacji, zgodnie z klasyfikacją Illiesa i Botosaneanu (1963), wyróżniono w Kryniczance wraz z dopływem jedną strefę — epiritron z wydzieleniem dwu podstref: epiritron z zaznaczającym się wpływem hypocrenonu (stanowisko 1) i epiritron właściwy (stanowiska 2—3, CP). Stanowiska zanieczyszczone 4—7 przynależą prawdopodobnie w całości do epiritronu. Kryniczankę zaklasyfikowano do grupy potoków średniogórskich.

Wpływ ścieków na makrofaunę Kryniczanki zaznaczył się przede wszystkim zupełnym wyeliminowaniem przedstawicieli takich grup, jak *Ephemeroptera*, *Plecoptera*, *Coleoptera* i *Trichoptera*. Wzrosła natomiast liczebność *Oligochaeta* i *Chironomidae*, a zwłaszcza tych form, które określa się jako psammo- i pelofile. Na dnie kamienistym masowo rozwinęły się *Naididae*, na dnie o podłożu drobnoziarnistym *Tubificidae*. W układzie dominacji zaznacza się bardzo duża przewaga jednego lub kilku gatunków nad pozostałymi z danej grupy taksonomicznej, np. *Nais elinguis* dominuje (do 90% udziału) w obrębie *Naididae*, *Cricotopus* spp. (powyżej 70% udziału) w obrębie *Chironomidae* na podłożu kamienistym i *Chironomus thummi* (ponad 80% udziału) na podłożu drobnoziarnistym (ryc. 5). Wśród pozostałych *Oligochaeta* dominuje *Tubifex tubifex* oraz *Limnodrilus hoffmeisteri* i *L. udekemianus*, przy czym układ dominacji jest bardziej wyrównany.

W rozmieszczeniu wzdłużnym fauny pozostającej pod wpływem ścieków da się wyróżnić trzy odcinki: 1) ogólnego wyniszczenia fauny — stanowisko 4, 2) masowego rozwoju *Oligochaeta* — stanowiska 5—6, 3) masowego rozwoju *Oligochaeta* i *Chironomidae* — stanowisko 7 (ryc. 6).

Zmiany liczebności *Oligochaeta* i *Chironomidae* na stanowiskach 4—7 (ryc. 7, 8) na przestrzeni roku wykazują dwa maksima: późnowiosenne i jesienno-zimowe, podobnie jak w potokach nie zanieczyszczonych. Maksima te (związane z terminami rozmnażania się i rozwoju zwierząt w potokach górskich) zbiegają się z korzystniejszymi dla życia warunkami w Kryniczance (niższe temperatury wody, lepsze jej natlenienie, zwolnienie procesów rozkładu materii organicznej, czyli mniejsze ilości produktów jej rozkładu) i stają się wyraźniejsze w miarę oddalania się od źródła zanieczyszczenia. Minimum liczebności makrofauny na tym odcinku przypada na koniec lata i zbiega się z największym zanieczyszczeniem potoku (najwyższe BZT_5, najgłębsze deficyty tlenu).

Prześledzono zależności pomiędzy składem i liczebnością makrofauny odcinka zanieczyszczonego a BZT_5 i zawartością materii organicznej w osadach. Stwierdzono, że znaczny spadek zawartości N org. w osadach stanowiska 6 związany jest z masowym rozwojem *Tubificidae* (ryc. 9).

Określono maksymalny stopień zanieczyszczenia Kryniczanki na podstawie makrofauny jako polisaprobowy. Określenie to było możliwe wyłącznie w oparciu o *Tubificidae* i *Chironomus thummi* — mieszkańców podłoża drobnoziarnistego. W oparciu o faunę zasiedlającą podłoże kamieniste nie można określić stopnia zanieczyszczenia w potokach górskich.

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