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

8. Macroinvertebrates

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Abstract — Detritivore Oligochaeta (Tubificidae) prevail in the Upper Vistula above and below the water stage at Łączany. In the lower section of the river with a stony bottom there also appear algivores (Naididae, Chironomidae, and Gastropoda) and predatory forms (Hirudinea). The greatest production and respiration of macrofauna are noted just below the water stage and the smallest at the stations where the fauna is varied. The course of seasonal changes in the numbers of macrofauna is irregular at all stations.

Key words: regulated river, pollution, macroinvertebrates, seasonal changes, functional feeding groups, production.

1. Introduction

Preliminary observations concerning the macrofauna of the Upper Vistula were reported by Starmach (1938), while a complete inventory of the fauna in the sector between Oświęcim and Kraków was carried out in the sixties (Zięba, Zaćwilichowska 1966).

Investigation of the bottom fauna was repeated in 1982—1983, the aim of the study being to determine the effect of the water stage at Łączany on the benthos macrofauna and to evaluate the significance of the stage in the self-purification processes of the river. For this purpose the composition, number, and biomass of the fauna and the structure and seasonal changes of zoocenoses were investigated at the stations above and below the Łączany water stage and within the reservoir itself. Moreover, the food structure of zoocenoses was determined on the basis of functional feeding groups and the secondary production and respir-

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ation, which manifested the role of macrofauna in the self-purification processes of the river, were computed.

2. Study area, material, and methods

The investigation was carried out on a 25-kilometre section of the Upper Vistula at 6 stations (fig. 1). A detailed description of the area and stations has been given by Dumnicka and Kownacki (1988).

At all stations samples were collected 12 times on the following dates:

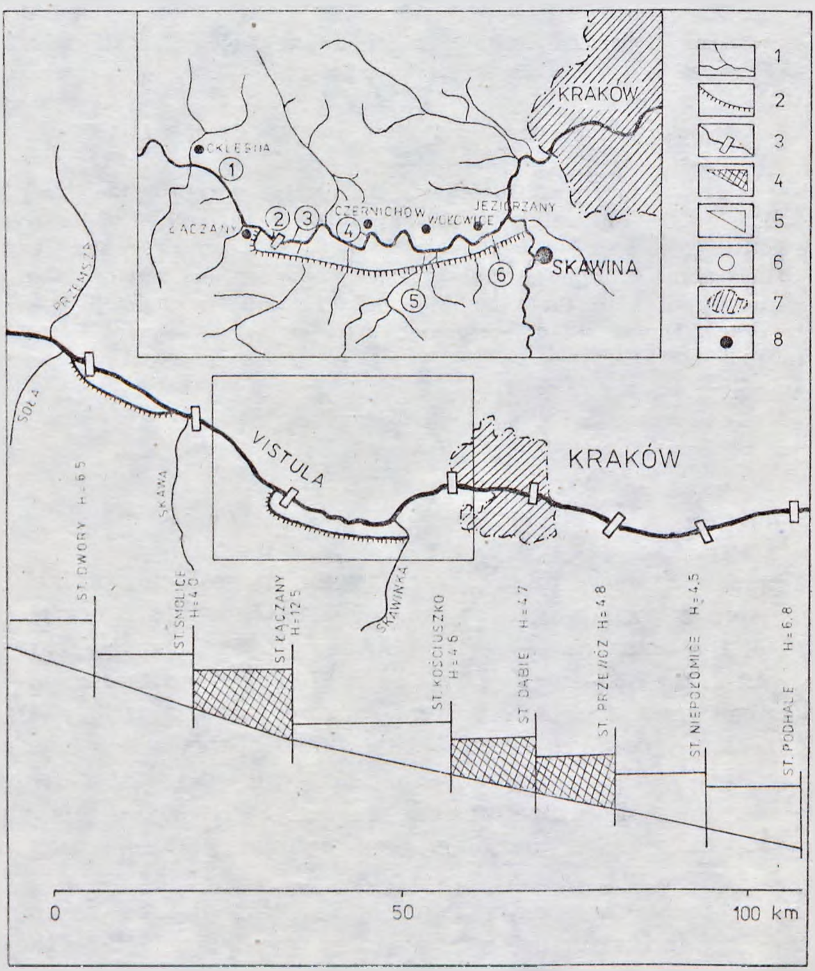

Fig. 1. The Upper Vistula, showing cascade building and stations on the investigated river section. 1 — rivers; 2 — canal; 3 — water stages, dams; 4 — water stages built; 5 — water stages under construction and planned; 6 — stations; 7 — cities; 8 — towns and villages

9 Oct., 8 Nov., 14 Dec., 1982, 26 Jan., 15 Mar., 27 Apr., 7 Jun., 4 Jul., 25 Jul., 30 Aug., 25 Oct., and 13 Dec., 1983. From the muddy bottom the samples were taken with a tube grab from an area of about 80 cm^2 (2 sub-samples of 40 cm^2 each). On the stony bottom they were taken with a bottom net from an area of 400 cm . The samples were fixed with a 4% formalin solution. After selection, animals belonging to the particular systematic groups were weighed separately and their wet weight was determined with accuracy to 0.05 mg. The fauna was then identified and its density computed within each taxon. The number and biomass of animals were converted to 1 m^2 of the bottom. The structure of particular taxocens within a zoocenosis was presented using the so-called predominance index (Kownacki 1971). The trophic role of the particular taxa was determined on the basis of the literature: for Oligochaeta — Brinkhurst and Jamieson (1971), Hirudinea — Pawłowski (1936), and Gastropoda — Piechocki (1979). For the dominant species of Chironomidae analyses of the alimentary canal were carried out by Docent Barbara Kawecka, information contained in the work by Kawecka and Kownacki (1974) was also used. In computing the caloricity of animals it was assumed that the dry weight constitutes 15% of the wet weight while the caloric value of 1 g dry weight equals 5 kcal (Jørgensen 1979). Production was computed from P/B coefficients of the following values for the particular groups of animals: Tubificidae 3.4 and Naididae 7.4 calculated according to the Banse and Mosher formula (1980), Hirudinea 2, Chironomidae 5, and Gastropoda 4 (Jørgensen 1979). Respiration was computed on the basis of the respirations rates (Berg, Ockelmann 1959, Berg et al. 1962, Jørgensen 1979) or as a function of production using the method of least squares regression equations (McNeill, Lawton 1970).

3. Results

3.1. Characteristics of benthos macrofauna

The fauna was chiefly represented by Oligochaeta, with 20 species (fig. 2), and Chironomidae with 12 taxa (fig. 3). An important element were Gastropoda (*Ancylus fluviatilis*, *Physa acuta*, and *Radix peregra*) and Hirudinea (*Helobdella stagnalis*, *Glossiphonia complanata*, and *Erpobdella octooculata*), chiefly found at Stations 4—6. Single specimens of Amphipoda (*Gammarus fossarum*), Diptera of the families Simuliidae, Chaoboridae, and Psychodidae, and Coleoptera were also encountered.

Distinct changes both in the number and biomass of the particular groups of animals and in the predominance structure of zoocenoses were

OLIGOCHAETA

TAXONS / STATIONS	1	2	3	4	5	6
LIMNODRILUS HOFFMEISTERI	70	83	86	47	(24)	(23)
NAIS ELINGUIS	1.2	1.5	+	(32)	64	62
LIMNODRILUS UDEKEMIANUS	7.9	2.9	7.7	1.3	+	+
TUBIFICIDAE (JUV.)	6.6	4.3	+	9.2	7.9	5.4
TUBIFEX TUBIFEX	19	+	+	+	+	+
ENCHYTRAEIDAE (JUV.)	+	+	+	+	+	+
LIMNODRILUS PROFUNDICOLA	+	+	+	+	+	+
NAIS BARBATA	+	+		+	+	
DERO (D.) DIGITATA	+	+		+	+	+
DERO (A.) FURCATA	+	+			+	+
LUMBRICILLUS RIVALIS	+	+			+	
CHAETOGASTER DIAPHANUS		+		+	+	+
STYLARIA LACUSTRIS				+	+	+
PSAMMORYCTIDES ALBICOLA				+	+	+
PARANAIS FRICI					+	+

FIRST DOMINANT   DOMINANT   + ADOMINANT

Fig. 2. The Oligochaeta taxocene at the particular stations (according to the predominance index). Besides, the occurrence of single specimens of the following species was noted: *Chaetogaster diastrophus*, *Limnodrilus claparedeanus*, *Spirosperma ferox*, *Peloscolex moszynskii*, *Marionina riparia*, *Enchytraeus buchholzi*, and *Eiseniella tetraedra*

observed at the different stations. At Stations 1—3 oligochaetes appeared almost alone in the benthos macrofauna, constituting 99.4—99.9% of the numbers and 99.3—99.8% of the biomass (Table I). The dominant species was *Limnodrilus hoffmeisteri* and juvenile specimens of this genus (fig. 2). Since the participation of *L. profundicola* and *L. claparedeanus* in the Oligochaeta taxocen was very small, it may be assumed with small error that all specimens of *Limnodrilus* spp. juv. belonged to the species *L. hoffmeisteri*. The more numerous subdominants were *L. udekemianus* (identified) at to species already at the juvenile stage, hence changes in its numbers did not contribute to an erroneous quantitative estimate of *L. hoffmeisteri*) and juvenile specimens of the family Tubificidae. Apart from Oligochaeta, only single Chironomidae, chiefly *Cricotopus (Cricotopus) bicinctus* and *Chironomus* sp., were encountered (fig. 3).

From Station 4 the composition of the zoocenosis changed, the station showing transitory character. Although Oligochaeta were still the most numerous groups of the macrofauna (63.6—95.7%) nevertheless their

CHIRONOMIDAE

TAXONS / STATIONS	1	2	3	4	5	6
CRICOTOPUS (C.) BICINCTUS	12	1.1	4.0	18	51	22
DICROTENDIPES NERVOSUS	+			37	(37)	64
CHIRONOMUS SP.	1.4	1.3			+	+
CHIRONOMINI (JUV.)	+	4.4	1.0	1.1	+	+
THIENEMANNIMYIA RHEIE	+	1.1	1.0	+	+	+
ORTHOCLADIUS SPP.	+					
POLYPEDILUM SP.	+					+
PARACHIRONOMUS ARCUATUS		4.4	1.0	2.9	1.5	3.7
BRYOPHENOCLADIUS SP.			1.0			
CRICOTOPUS (J.) SYLVESTRIS				+		+
CONCHAPELOPIA SP.				+		
TANYTARSINI (JUV.)					+	

FIRST DOMINANT DOMINANT + ADOMINANT

Fig. 3. The Chironomidae taxocene at the particular stations (according to the predominance index)

Table I. Mean number (N - indiv. m^{-2} and %) and biomass (B - g m^{-2} and %) of macrofauna

Group of benthos		Stations 1	2	3	4	5	6
Oligochaeta	N	64035 99.4	290482 99.9	275953 99.9	42646 95.7	30018 63.6	77058 91.2
	B	106.73 99.3	126.72 99.8	289.42 99.8	10.85 13.0	16.70 32.5	23.55 34.3
Chironomidae	N	391 0.6	229 0.1	183 0.1	1027 2.3	16339 34.6	6745 8.0
	B	0.75 0.7	0.3 0.2	0.48 0.2	0.50 0.6	7.32 14.2	3.48 5.1
Hirudinae	N				206 0.5	264 0.6	440 0.5
	B				22.67 27.2	15.96 31.0	25.75 37.5
Gastropoda	N				694 1.5	561 1.2	245 0.3
	B				49.29 59.2	11.44 22.2	15.92 23.1

share in the biomass decreased greatly — only 13—34.3%. There appeared the representatives of other taxonomic groups, Gastropoda and Hirudinea, and their share, especially in the macrofauna biomass became important. The structure of dominance within Oligochaeta changed. *Limnodrilus hoffmeisteri* still occurred as the first dominant, followed by *Nais elinguis* with a high predominance index. Chironomidae continued to appear only in small numbers, though a distinct structure of dominance began to develop in the Chironomidae taxocene with *Dicrotendipes nervosus* and *Cricotopus (C.) bicinctus* as dominants. The occurrence of Gastropoda and Hirudineae, which constituted an important element of the biomass at this station, made it similar to further stations. At Stations 5 and 6 fauna distinctly changed. The participation of oligochaetes in the total number of animals decreased. In the Oligochaeta taxocene *Nais*

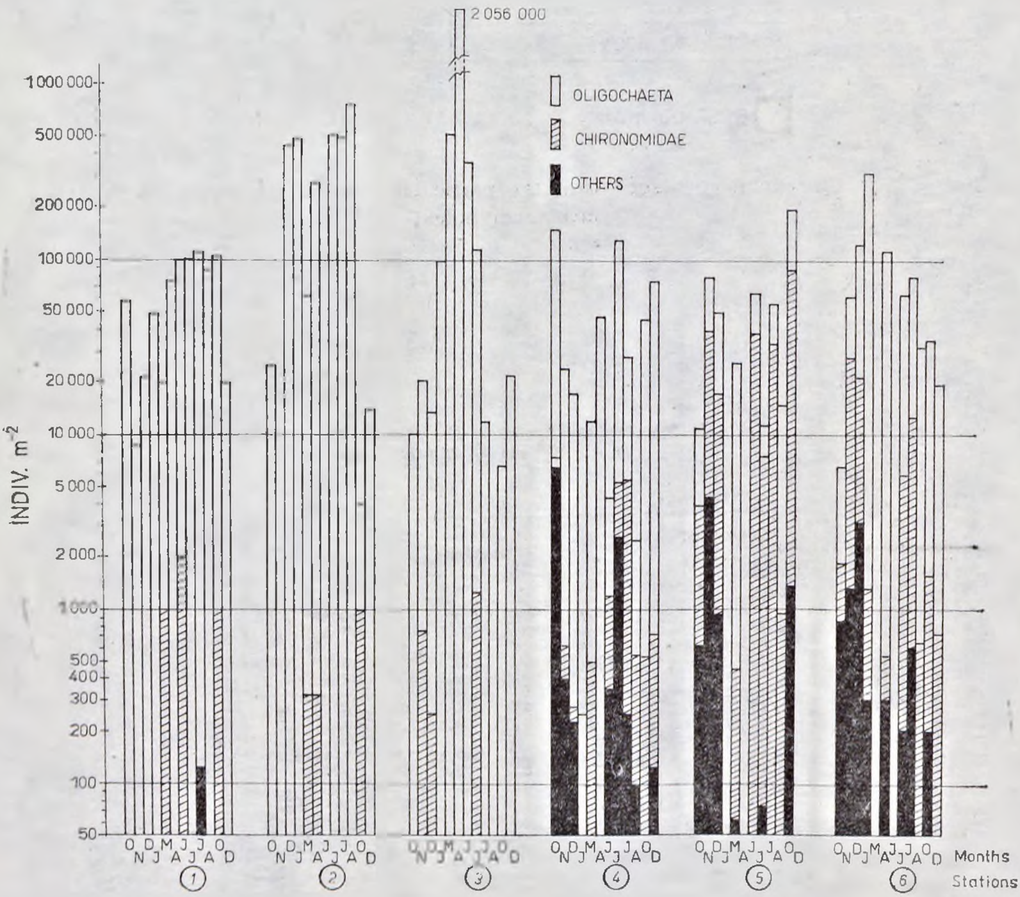

Fig. 4. Seasonal changes in the numbers of macrofauna at Stations 1—6. Others — Gastropoda, Hirudinea, Diptera (except Chironomidae)

elinguis was the first dominant with a very high index of predominance. The number of Chironomidae considerably increased with *Cricotopus (C.) bicinctus* and *Dicrotendipes nervosus* as dominants. Hirudinea and Gastropoda still appeared as important elements, especially in the biomass.

3.2. Seasonal changes

Seasonal changes in the number of the whole fauna were very irregular (fig. 4), many factors contributing to this. A high water level leads to the washing out of fauna from the sediments. At low water the bottom becomes silted up, this favouring the development of pelophilous species. However, changes in the numbers of fauna are above all caused by the life cycles of dominant species.

Oligochaeta — the variation in numbers was very great and followed a different course at the particular stations. At Station 1 the maximum

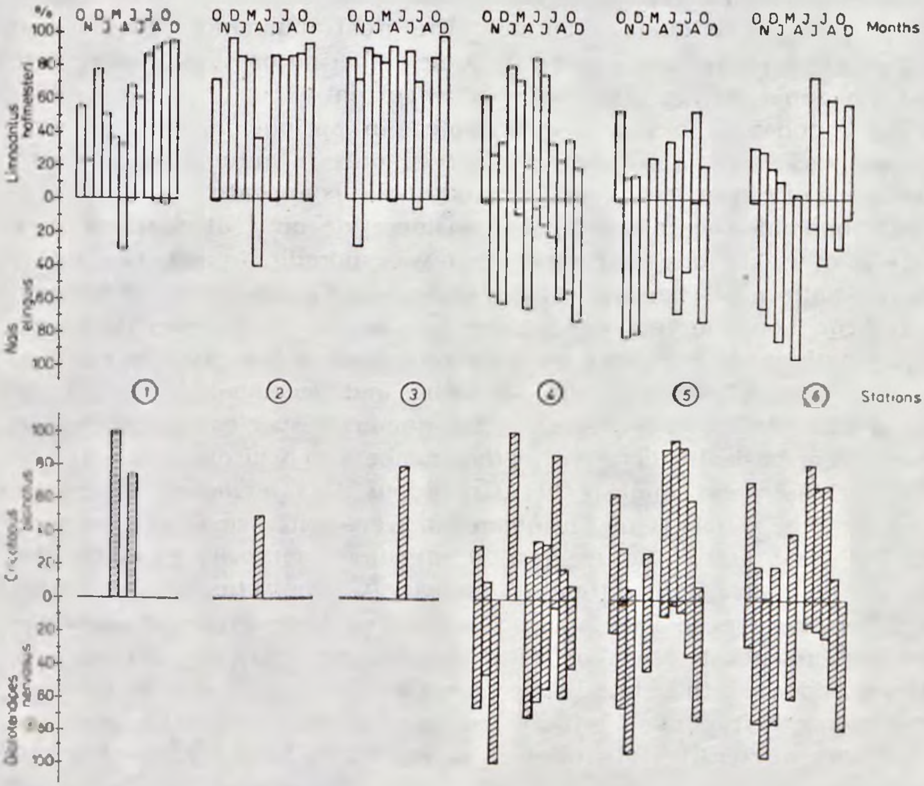

Fig. 5. Changes in the percentage share of the dominant Oligochaeta and Chironomidae species at Stations 1—6

Oligochaeta numbers occurred in summer when the dominant species *Limnodrilus hoffmeisteri* developed most abundantly. In the reservoir (Station 2) large numbers were maintained for some months. At Station 3 below the reservoir the numbers began to increase as early as January, reaching a maximum in April. From Station 4 the greatest numbers were noted in cool months when the dominant *Nais elinguis* occurred most abundantly (fig. 5). At the first three stations *Limnodrilus hoffmeisteri* dominated throughout the year, the presence of mature specimens and cocoons being observed during the entire period of the investigation. Mature forms of other species of the Tubificidae family appeared periodically — *Limnodrilus profundicola* in spring and summer and *Tubifex tubifex* chiefly in autumn and winter. From Station 4 *Limnodrilus hoffmeisteri* prevailed in warm and *Nais elinguis* in cool months. This was particularly manifested at Stations 4 and 6, while at Station 5 the changes were not so distinct. Some species of the Naididae family (*Dero digitata, Aulophorus furcatus* or *Stylaria lacustris*) occurred seasonally (in summer and autumn).

Hirudinea chiefly appeared in summer (with the exception of Station 6) and young individuals in autumn. The great abundance of leeches at Station 4 in summer was caused by their gathering on stones overgrown with algae in a shallow place with a slow current.

Gastropoda — no snails were noted in spring; in summer their number was small, a rise being observed only in autumn when young specimens of *Physa acuta* and *Ancylus fluviatilis* appeared.

Chironomidae were taken into consideration only at Stations 4—6 since at other stations their appearance was sporadic. In spite of a rather uneven pattern of changes in the numbers of Chironomidae at Stations 4—6 throughout the year, certain regularities may be distinguished here. At all stations very distinct maxima were observed in June-July and at Stations 5 and 6 additionally in November and December (fig. 5). At Station 4 *Dicrotendipes nervosus* was the dominant species throughout the year, being basically decisive in the numbers of Chironomidae. It was only in March and August that *Cricotopus (C.) bicinctus* dominated. However, the numbers of Chironomidae were fairly small at that time. At Stations 5 and 6 the species *Dicrotendipes nervosus* accounted for the late autumn maximum and *Cricotopus (C.) bicinctus* for the spring--summer one (fig. 5). This is associated with the life cycles of these two species. In August larvae of *Dicrotendipes nervosus* in medium age classes appeared, this state being maintained until June of the following year when their number rapidly increased, pupae appeared, and the emergence of adult insects followed. In early July larvae at the youngest developmental stages were observed. Their development was very rapid and they most probably gave rise to the second generation which completed its development with emergence towards the end of July. This

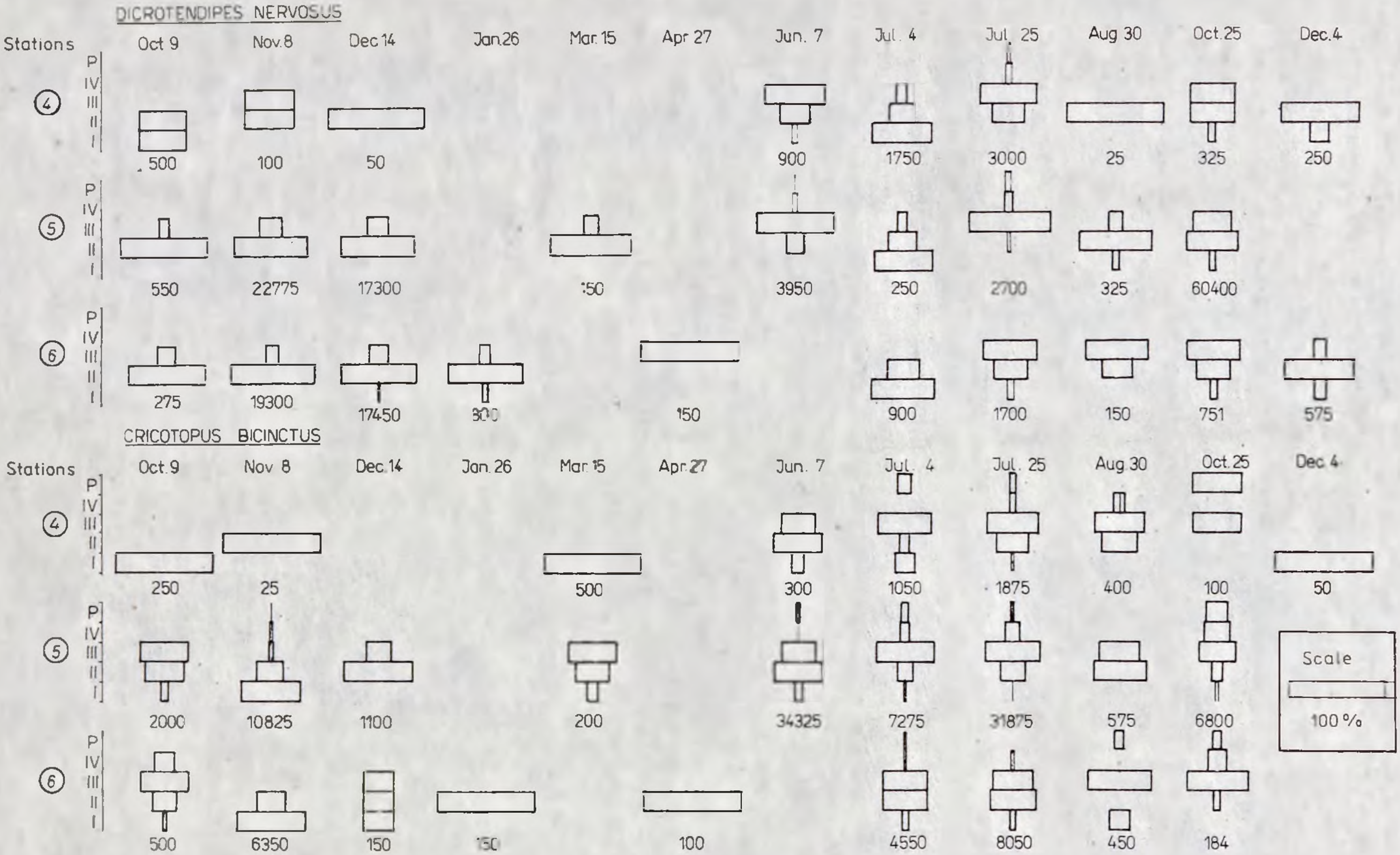

Fig. 6. Percentage share of developmental stages of *Dicrotendipes nervosus* and *Cricotopus (C.) bicinctus* at Stations 4—6 in the annual cycle. I—IV — classes of magnitude; p — pupae. Figures under the diagrams denote the number of specimens m^{-2}

second generation initiated the autumn-winter population (fig. 6). *Cricotopus (C.) bicinctus,* on the other hand, showed a prolonged period of growth and emergence from July to early November. At that time some generations overlapped. The development of this species was inhibited during the winter (fig. 6). Attention should also be paid to the accompanying species *Parachironomus arcuatus* which in some periods may appear as one of the dominants. Larvae of this species at early developmental stages were encountered throughout the year. From June a rapid increase occurred and in July-August the species attained maturity.

3.3. The trophic structure

In examining the trophic structure within macroinvertebrates at the particular stations only three trophic groups were differentiated: a — detritivores, feeding on organic matter from sediments or that suspended in the water, and on bacteria; b — algivores, and c — predatory forms. This is a very simplified classification since the way of feeding is not so strictly limited in different forms. In the alimentary canal of Chironomidae larvae (*Dicrotendipes nervosus)*, which were classified as algivores, only 50% of diatoms and other algae were found. The remainder was composed of unidentified organic matter and bacteria. On the other hand, *Cricotopus (C.) bicinctus*, also classified as an algivorous form, fed on 80% algae, unidentified organic matter constituting only 20%.

The main predatory forms were Hirudinea which consumed both detritivorous (Tubificidae) and algivorous forms (Naididae, Chironomidae, and Gastropoda). Of oligochaetes the only predatory form (*Chaetogaster diaphanus*) consumed other Naididae species alone, while *Thienemannimyia* Rheie larvae fed on small oligochaetes and Chironomidae.

At Stations 1—3 the zoocenosis was almost entirely composed of detritivorous forms (Tubificidae) (fig. 7). At Station 4 detritivorous forms still dominated numerically, algivores, above all Oligochaeta (*Nais elinguis*), constituting only 30%. With regard to biomass algivorous forms prevailed owing chiefly to the large mass of snails. Predatory forms were not numerous but their biomass was considerable, since thes were mainly large leeches with a small number of oligochaetes and Chironomidae (fig. 7).

At Station 5 algivorous forms dominated. With regard to numbers they constituted about 80% of the total and were chiefly represented by Oligochaeta (*Nais elinguis*) and Chironomidae (*Cricotopus* (*C.*) *bicinctus* and *Dicrotendipes nervosus*). The biomass of algivores constituted 52%, chiefly on account of snails, and in smaller measure of Chironomidae and Oligochaeta. The participation of predatory forms (mainly Hirudinea) in numbers was small but in biomass very large — 31%.

At Station 6 algivorous forms still dominated, though their prevalence

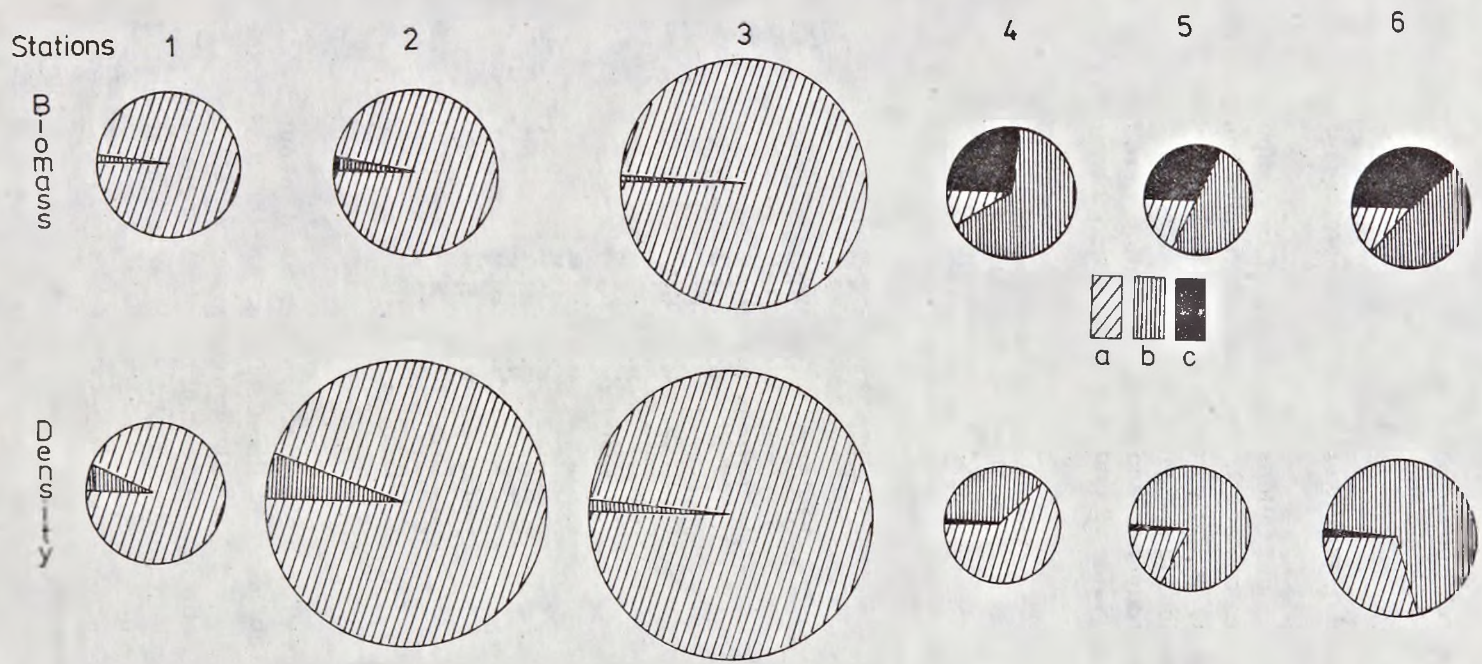

Fig. 7. Trophic structures of the benthos — percentage share of functional trophic groups in the number and biomass at Stations 1—6.
a — detritivores; b — algivores; c — predators

was reduced in relation to Station 5. The numbers and biomass of predatory forms did not change (fig. 7).

3.4. Production and respiration of macroinvertebrates

Since certain simplifications were adopted in computing production and respiration (see methods), the obtained results indicate only the order of magnitude of the parameters calculated and allow their comparison at the stations investigated.

The greatest production and hence respiration were found at Station 3 (Table II), while values found at Stations 1 and 2 were lower by half.

Table II. Estimated magnitude of production (P) and respiration (R) in kcal $m^{-2}y^{-1}$ of macroinvertebrates at Stations 1-6

Station	Taxon	P	R	P/R
1	Tubificidae	252.96	904.48	
	Chironomidae	2.75	4.48	
	Total	255.71	908.96	0.28
2	Tubificidae	310.25	1149.39	
	Chironomidae	1.25	1.77	
	Total	311.50	1151.16	0.27
3	Tubificidae	736.78	3172.86	
	Chironomidae	1.8	2.72	
	Total	738.58	3175.58	0.23
4	Naididae	18.50	41.96	
	Tubificidae	19.04	43.40	
	Chironomidae	2.00	3.08	
	Hirudinea	34.00	104.58	
	Gastropoda	147.80	506.30	
	Total	221.34	699.32	0.31
5	Naididae	43.29	113.85	
	Tubificidae	22.61	53.11	
	Chironomidae	27.00	65.41	
	Hirudinea	23.90	71.64	
	Gastropoda	34.40	105.90	
	Total	151.20	409.91	0.36
6	Naididae	76.22	221.18	
	Tubificidae	24.99	59.73	
	Chironomidae	13.00	27.73	
	Hirudinea	38.60	119.84	
	Gastropoda	47.80	150.74	
	Total	200.61	579.22	0.34

though still high. The high values were brought about by the mass appearance of Tubificidae at these stations. At Stations 4—6 the annual production was smaller while the lowest values were found at Station 5. At the two last stations Naididae had the largest share in production and respiration in spite of the fact that their biomass was smaller than that of snails and leeches.

The P/R coefficient varied from 0.23 to 0.36. At the stations where Tubificidae dominated the P/R value did not reach 0.3, while at the stations with a more varied bottom fauna it always exceeded 0.3.

4. Discussion and conclusions

The species composition, numbers, and predominance structure of macroinvertebrates indicate very heavy pollution of the investigated section of the River Vistula with wastes. The fauna was represented by only 40 taxa, chiefly the species of Oligochaeta and Chironomidae. The absence of many systematic groups (e.g. mayflies, stoneflies, or caddis flies) characteristic for pure or slightly polluted rivers (Dratnal, Szczęsny 1965, Sowa 1975, 1980, Dratnal et al. 1979) was noted.

On the basis of the aggregations of fauna in the investigated section of the Vistula, two distinct zones may be differentiated. In the first, which included Stations 1—3, there developed an association composed almost solely of Oligochaeta with the dominant species *Limnodrilus hoffmeisteri*. In the second, which includes Stations 5—6, a more diversified association developed. Besides Oligochaeta (*Nais elinguis*) there appeared numerous Chironomidae (*Dicrotendipes nervosus* and *Cricotopus (C.) bicinctus*), snails and leeches. Station 4 showed intermediate traits.

Distinct changes in the faunistic communities did not coincide with changes in the chemical parameters of water quality. Over the entire length of the investigated river section the range of changes in the average concentrations of chlorides, ammonia, phosphates, oxidability, and BOD_5 showed no great differences (Kasza 1988) and only at Station 3 was oxygen saturation of the water doubled.

A similar two zone distribution was observed in this section of the Vistula almost 20 years ago (Zięba, Zaćwilichowska 1966). The species composition, numbers, and structure of predominance of zoocenoses which developed in the zones were almost identical with those observed to-day. Certain differences result from the methods applied in the elaboration of the material (Naididae were not taken into consideration then). However, the chemical composition of the water has been greatly changed since that time. Among other factors, the content of chlorides and ammonium nitrate has drastically increased and that of dry residue doubled (Bombówna, Wróbel 1966). Thus, the zoonecoses of the River Vistula developed many years ago and became adapted to living in strongly polluted water. An increase in pollution did not change their qualitative and quantitative composition. The adaptation of macroinvertebrates to life in a strongly polluted river is also shown by unchanged or only slightly changed life cycle of the dominant species. Only in some species it is modified: the maximum numbers may occur in an untypical season, e.g. in the case of *Nais elinguis,* or the periodicity of reproduction disappears, as was observed in *Limnodrilus hoffmeisteri* and *Tubifex tubifex,* the phenomenon having already been noted in polluted waters (Kennedy 1966). In the Vistula leeches and snails begin reproduction later than on other waters (Pawłowski 1936, Piechocki 1979), since young individuals do not appear before autumn.

The factor differentiating the zoocenoses of the Vistula is the character of the river and of its bottom and the possibility of turbulent oxygenation of water. Above the water stage, in the reservoir, and just below the stage the river was deep, the bottom muddy or sandy, without any vegetal cover. From Station 5 stones overgrown by algae began to prevail on the bottom (Kwandrans 1988), the current was rapid, and the water strongly oxygenated.

Hence the question arises as to how the water stages constructed on the Vistula will affect the composition and numbers of macroinvertebrate communities. Above all, the current will be more laminar, the oxygenation will deteriorate, and the bottom will be silted up in the entire regulated river section. In such an environment only Oligochaeta will develop, as is at present observed in the vicinity of the Łączany water stage. This will decrease the rate of self-purification processes, as was observed in the River Saale, strongly polluted with paper-mill wastes (Schräder 1958). The retardation of self-purification processes becomes obvious since it can be seen that on water stages the trophic chain will undergo marked simplification. The typical chain of detritivores is: organic matter — Oligochaeta. In this chain the magnitude of production is very great, this being typical for polluted waters (Alimov, Finogenova 1976). On the other hand, losses of energy and thereby the irreversible dispersal of organic matter flowing in with sewage are greater in more complicated biocenoses (Odum 1982), such as may been observed at Stations 5 and 6. At these stations besides the chain of detritivores there also appeared the grazing food chain of: algae — Chironomidae + Oligochaeta (Naididae) — predators.

The literature concerning the effect of pollution of macroinvertebrates in rivers is very abundant and was many times surveyed in comprehensive elaborations (Hynes 1960, Sladeček 1973). The composition of macrobenthos occurring in the Upper Vistula at Stations 1—3 is typical for polluted waters. A similar fauna was noted in the River Bobrza, strongly polluted with sewage from the town of Kielce (Dumnicka 1978, Srokosz 1980). Likewise, a certain similarity was found between the zoocenoses of the water stage at Łączany and below the Warsaw intercepting sewer (Kaniewska-Prus 1983), where Oligochaeta also dominated. However, it seems that the numbers quoted by the above author are diminished and, since she does not give any detailed identifications, the interpretation and comparison of results is difficult. Below the point of sewage discharge on the River Łyna (Wielgosz et al. 1982) a community developed on the stony bottom was similar to that found at the first three stations in the investigated section of the Upper Vistula. On the other hand, it is more difficult to find an analogy with the macrofauna of the polluted sector of the River Warta below Poznań (Biesiadka, Kasprzak 1977). The fauna developing there is much richer than that noted in the Vistula. Below the point of sewage discharge were observed Trichoptera, single specimens of mayflies and fairly numerous representatives of other groups, though, the percentage of Oligochaeta increased distinctly in relation to other groups of fauna.

Intense pollution accounts for a different course of changes depending on which zone of a river has been polluted. Therefore, the macrofauna of the polluted sections of the Kryniczanka, Rybi Potok, and Prądnik streams (Szczęsny 1974, Dratnal 1976, Kownacki 1977) differs considerably from that found in the Vistula.

5. Polish summary

Ekosystem uregulowanego i zanieczyszczonego odcinka Górnej Wisły

8. Makrobezkręgowce

Celem pracy prowadzonej w latach 1982—1983 na Wiśle w rejonie stopnia wodnego w Łączanach, było określenie wpływu zabudowy rzeki na makrofaunę oraz ocena jej roli w procesach samooczyszczania się rzeki. Badania prowadzono na 6 stanowiskach (ryc. 1).

W silnie zanieczyszczonym i zasolonym odcinku Wisły występuje 20 gatunków skąposzczetów (ryc. 2) i 12 taksonów Chironomidae (ryc. 3). Na stanowiskach 1—3 powyżej stopnia, w samym stopniu i tuż poniżej występowały prawie wyłącznie Oligochaeta (Tubificidae), na stanowiskach 4—6, gdzie rzeka zachowała swój naturalny hydrologiczny charakter, bentos był bardziej zróżnicowany: prócz Oligochaeta występowały też Chironomidae, Gastropoda i Hirudinea (tabela I).

Zmiany liczebności całej fauny były gwałtowne i nieregularne (ryc. 4), gdyż zależały od różnych czynników, jak: długość cykli życiowych dominujących gatunków, wymywanie i osadzanie fauny. Zmiany liczebności dominujących gatunków Oligochaeta i Chironomidae wykazywały bardziej regularny przebieg (ryc. 5). Dominujące gatunki Chironomidae miały cykle życiowe o różnej długości: *Dicrotendipes nervosus* — 2 generacje w ciągu roku, a *Cricotopus (C.) bicinctus* — kilka nakładających się generacji (ryc. 6).

Struktura troficzna badanych zespołów była bardzo prosta — na trzech pierwszych stanowiskach występowały prawie wyłącznie, detritusofagi, na następnych udział tej grupy spadał, wzrastała natomiast liczebność, a zwłaszcza biomasa glonofagów (ryc. 7). Liczniej występowały też formy drapieżne.

Najwyższą produkcję i respirację stwierdzono na stanowisku 3 (tabela II), na następnych stanowiskach ich wielkość spadła 3—4-krotnie.

Zmiany zespołów makrofauny nie pokrywały się ze zmianą parametrów chemicznych jakości wody. Korelowały one natomiast wyraźnie z charakterem dna rzeki. Tak więc budowa stopni wodnych, powodując zamulenie dna, zmniejszenie szybkości prądu wody, ograniczy różnorodność makrofauny. W bentosie zostaną tylko Oligochaeta, odporne na czasowe braki tlenu i silne zanieczyszczenie wody.

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