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The effect of the Goczałkowice dam reservoir on zoobenthos of the River Vistula (Southern Poland)*

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Abstract — The effects of the Goczałkowice dam reservoir on the qualitative and quantitative composition of zoobenthos in the River Vistula is presented. The investigation was carried out at three stations: 1. 3 km above the reservoir, 2. 100 m below the dam, 3. 1000 m below the dam. It was observed that even the small water discharges which occurred in 1982—1983 affected the number and biomass of the zoobenthos as well as its taxonomic composition.

1. Introduction

The Goczałkowice dam reservoir on the River Vistula was built in 1955. Since then it has served without interruption up to the present as a place for complex hydrobiological investigations, covering also the zoobenthos. From these investigations records of changes in fauna in the reservoir have been obtained (Krzyżanek in press). In 1982—1983 the investigation was extended to include determination of the reservoir's effect on the zoobenthos of the River Vistula.

2. Study area

The Goczałkowice dam reservoir supplies drinking water through water intakes for Silesia. Only small part of the water returns to the River Vistula through the bottom sluice. A determined amount of water

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— 0.45 m^3 sec^{-1} is constantly discharged through this sluice — though usually it exceeds this. The years 1982—1983 were characterized by exceptionally low rain and snowfall, hence a minimal amount of water was discharged. The discharges were slightly higher from January to February, from May to August 1982, and from March to May 1983. In those years a quarter to one third of the annual amount of flowing water was discharged through the sluice, while in more normal conditions it forms half of this discharge (K a s z a 1986).

Three stations were chosen for investigation (fig. 1). Station 1 lay 3 km above the reservoir, at the point where the River Vistula, 60 km from its springs, leaves the Cieszyn Plateau. Although it receives municipal sewage from the towns Wisła, Ustroń, and Skoczów, it is relatively unpolluted. The riverbed is stony. This station represented a river of piedmont character.

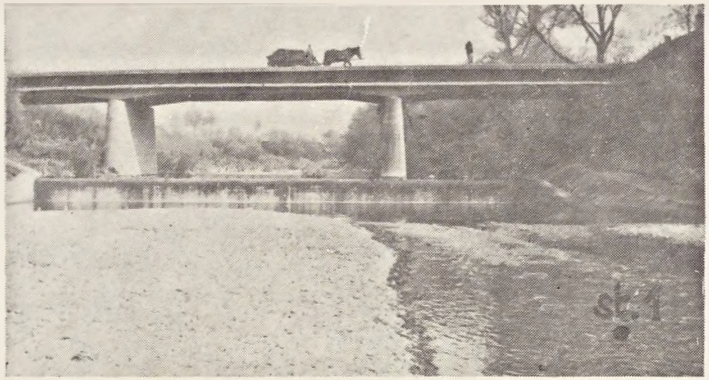
Station 2 lay 100 m from the sluice. The bottom was concrete.

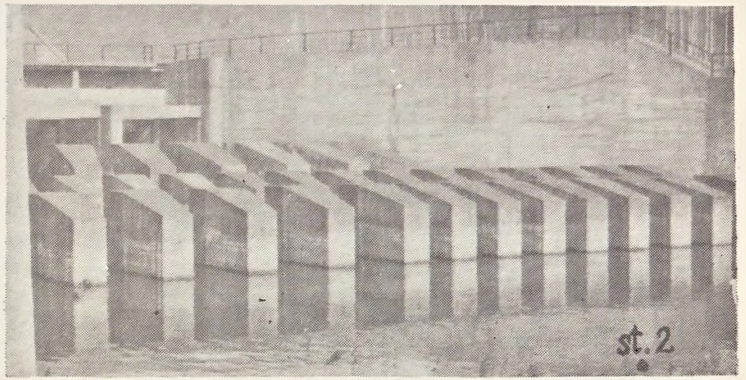
Station 3 lay 1000 m from the sluice (below the flood barrier) with a complex of rearing ponds to the left and crop fields to the right. The riverbed was stony.

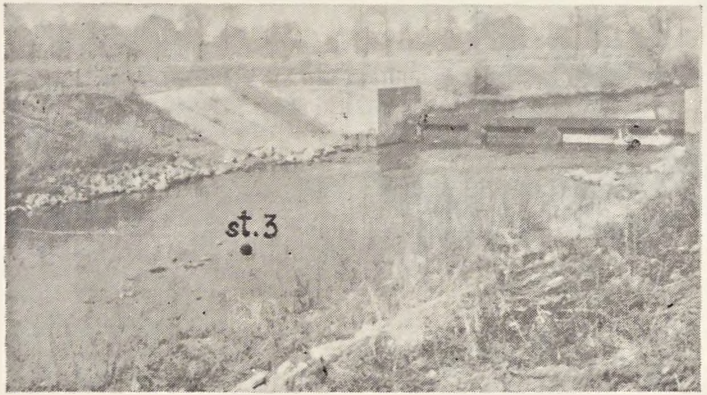
3. Material and methods

The investigation was carried out from February 1982 to December 1983. In 1982 weekly samples were taken (40 samples from each station) and in 1983 every two weeks (21 samples from each station). At station 1 samples of zoobenthos had already been taken in the period 1969—1979. At the stations with stony bottom (1 — and 3) samples were taken from 1000 cm^2 surface of the stones. At station 2 samples were taken from 1000 cm^2 of the concrete surface using a 20 cm wide scraper. At station 3, in order to make more exact quantitative analyses, 60 bricks were laid before the investigation began (the brick surface from which the samples were taken was 1000 cm^2). Each time benthos for analysis was taken from one brick. The sampling content was rinsed in a 0.5 mm mesh net and the selected animals were preserved in 4% formalin. The obtained results were calculated for 1 m^2 surface.

The species nomenclature was based on Limnofauna Europae (I l l i e s 1978). In the case of *Chironomidae* larvae were the basic material, which did not be always allow certain species determination.







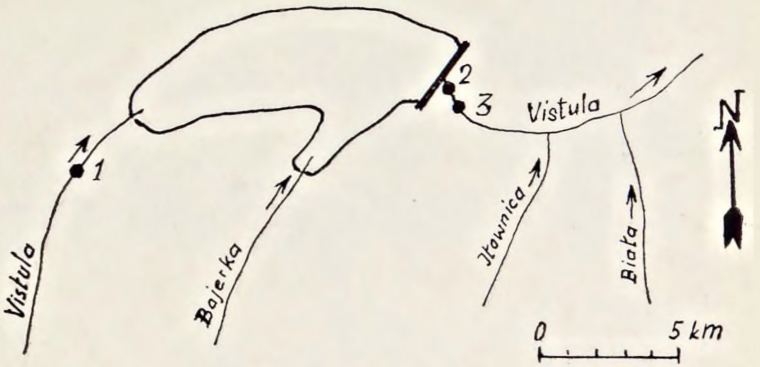


Fig. 1. Localization of sampling stations. 1—3 — stations

4. Results

4.1. Characteristics of zoobenthos at individual stations

At station 1 the average number of zoobenthos during the two years of investigation was 1186 individuals m^{-2}, biomass being 2.1 g m^{-2} (Table I), zoobenthos being more numerous in 1983. *Chironomidae* dominated and 15 taxa were distinguished (Table II). Most numerous and

Table I. Average numbers (N - indv. m^{-2}) and biomass (B - g m^{-2}) of zoobenthos of the River Vistula at stations 1, 2 and 3 in 1982-1983

Station / Family	1982						1983					
	1		2		3		1		2		3	
	N	B	N	B	N	B	N	B	N	B	N	B
Chironomidae	727	0.5	478	0.4	4223	2.9	896	0.6	1317	1.1	2335	1.3
Oligochaeta	18	0.03	22	0.01	153	0.09	35	0.04	8	0.01	38	0.05
Trichoptera	36	0.3	2	0.01	487	1.6	56	0.4	2	0.006	126	0.34
Ephemeroptera	225	0.9	5	0.006	40	0.13	353	0.65	2	0.02	4	0.02
Hirudinea	4	0.06	1	0.005	292	2.4	4	0.32	1	0.05	21	0.34
Ceratopogonidae	1	0.003	1	0.002	4	0.02	-	-	-	-	2	0.006
Gastropoda	1	0.05	5	0.3	188	6.0	2	0.16	14	1.5	21	0.4
Bivalvia	-	-	1	0.06	68	2.5	-	-	1	0.006	51	1.8
Others	11	0.16	2	0.11	98	0.56	3	0.03	4	0.009	40	0.344
T o t a l	1023	2.0	517	0.9	5553	16.2	1349	2.2	1349	2.7	2638	4.6

frequent were *Cricotopus* sp., *Ablabesmyia* sp., *Psectrocladius* spp., and *Cricotopus sylvestris* (F a b r.) . The second group as far as number and biomass were concerned were *Ephemeroptera*, with the predominance of *Caenis* genus. Periodically and in small numbers *Trichoptera*, *Oligochaeta*, *Hirudinea*, and *Gastropoda* occurred. Comparing the results obtained in 1982—1983 with those from 1969—1979 a constantly increasing participation of *Chironomidae* and a decrease in *Ephemeroptera* (fig. 2) were observed.

At station 2 the smallest amount of zoobenthos was found (Table I). The average number in 1982—1983 was 933 individuals m^{-2}, 90% consisting of *Chironomidae* with the least differentiated taxonomic composition

Table II. Percentage species composition of Chironomidae larvae at station 1 in 1982-1983

T a x a	1982	1983
Dominants		
Ablabesmyia sp.	18	11
Cricotopus spp.	26	30
- sylvestris (Fabr.)	8	12
Psectrocladius spp.	10	12
Adominants		
Procladius sp., Potthastia gaedii (Mg.), Potthastia sp., Brillia sp., Eukiefferiella sp. (? E.longicalcar Kieff.), Eukiefferiella spp., Cryptochironomus defectus K., Microchironomus sp. (? M.tener K.), Diorotendipes sp. (? D. nervosus Staeg.), Microtendipes sp., Polypedilum sp. (? P.nubeculosum Mg.), others		

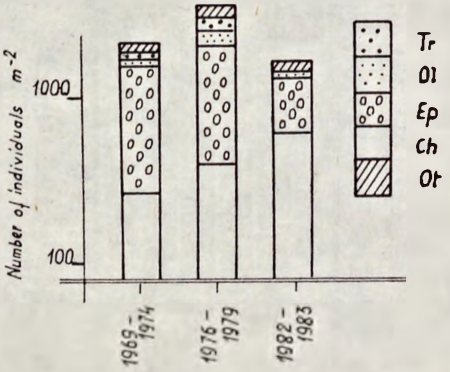


Fig. 2. Average numbers of zoobenthos at station 1 in 1969—1983

(fig. 3). The average biomass was 1.8 g m^{-2}, of which *Gastropoda* (0.9 g m^{-2}) constituted 50% despite small numbers, i.e. 10 individuals m^{-2} on the average. *Lymnaea peregra* Müll. dominated. In the period from February to September 1982 *Ancylus fluviatilis* Müll. was also caught at this station. Here, too, the zoobenthos was richer in 1983 than in 1982. This in particular concerns the biomass which was three times greater in 1983 than in 1982.

Station 3 showed the most abundant zoobenthos (Table I). The average number for the two years was 4095 individuals m^{-2}, biomass being 10.4 g m^{-2}. In 1983 there was less zoobenthos than in 1982, with a predominance of *Chironomidae* larvae. 18 taxa were determined (Table IV), the most numerous being *Cricotopus* spp., *C. sylvestris* (Fabr.), *Glyptotendipes* spp., *Dicrotendipes* sp. (? *D. nervous* Staeg.), and *Microtendipes* spp. In 1982 the number of taxa was larger; those such as *Orthocladius* sp., and *Eukiefferiella* spp. were observed which were not caught in

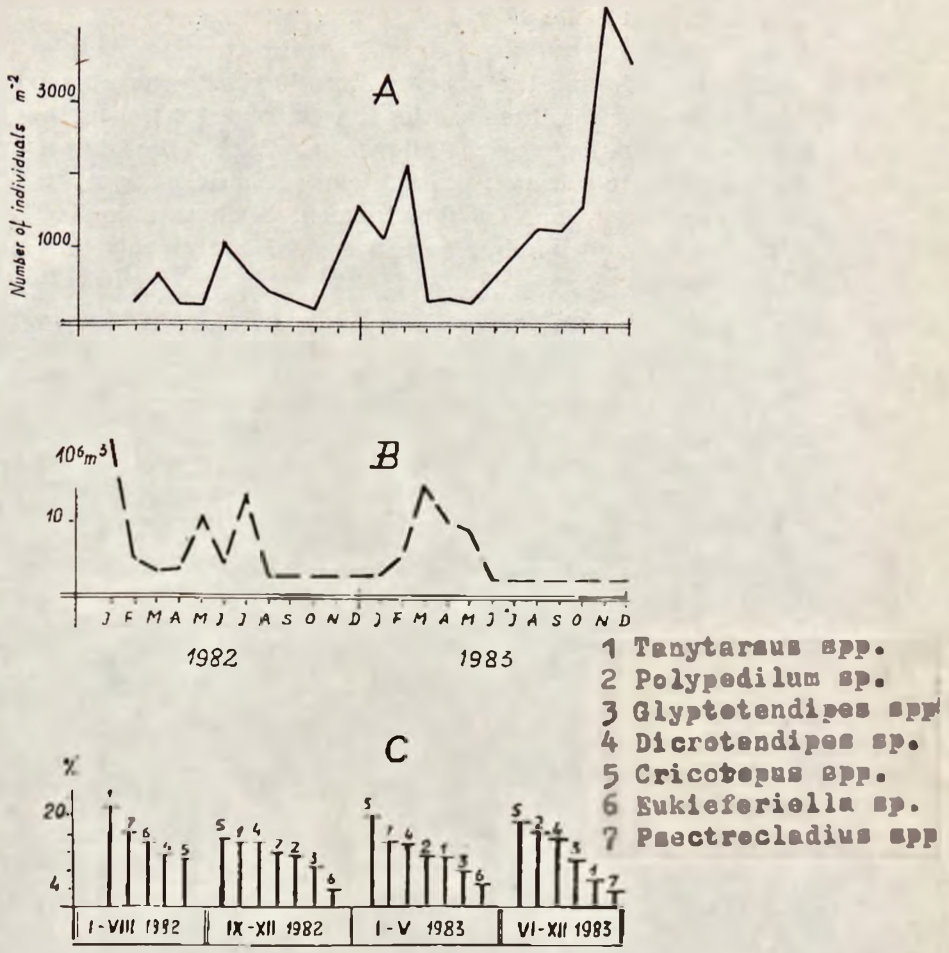


Fig. 3. Number of zoobenthos at station 2 (A) in relation to the amount of water discharged through the sluice (B) and percentage share of main *Chironomidae* genera (C) in 1982—1983

1983. In 1983 *Clinotanypus* sp. appeared, the participation of *Psectrocladius* spp. and *Ablabesmyia* sp. increased, while that of *Cricotopus sylvestris* (F a b r.) and *Dicrotendipes* sp. (? *D. nervosus* S t a e g.) decreased. The second group as far as number was concerned were *Trichoptera*. Most frequently encountered were *Polycentropus flavomaculatus* P i c t., *Oecetis ochracea* C u r t., and *Mystacides azurea* L. Fairly numerous, particularly in 1982, were *Hirudinea* and *Gastropoda*. Among the latter the dominants were *Lymnaea peregra* M ü l l. and *L. auricularia* L., but until August 8, 1982 *Ancylus fluviatilis* was also encountered in the samples.

4.2. The comparison of zoobenthos from a natural (stone) substratum and the artificial (brick) one at station 3

Before beginning the investigation 60 bricks were placed at this station. Already after three weeks it was observed that the zoobenthos composition on the two substrata was similar but the *Chironomidae* larvae were the first to settle on the artificial one, bricks appearing to be a more favourable substratum for development of these animals (Table III). In 1982 the average number here was 6337 individuals m^{-2}, the biomass

Table III. Comparison of zoobenthos at station 3 from artificial (brick) and natural (stone) substratum in 1982-1983. N - number of indiv. m^{-2}; B - biomass in $g\ m^{-2}$

Family	1982				1983			
	brick		stone		brick		stone	
	N	B	N	B	N	B	N	B
Chironomidae	3210	2.5	4223	2.9	5309	3.8	2335	1.3
Trichoptera	2509	6.0	487	1.6	1765	7.3	126	0.3
Hirudinea	209	2.0	292	2.4	128	1.2	21	0.3
Gastropoda	123	4.6	188	6.0	30	4.0	21	0.4
Bivalvia	131	3.0	68	2.5	220	7.1	51	1.8
Others	155	0.5	295	0.8	187	1.2	84	0.5
T o t a l	6337	18.6	5553	16.2	7639	24.6	2638	4.6

Table IV. Percentage species composition of Chironomidae larvae at station 3 on artificial (brick) and natural (stone) substratum in 1982-1983

T a x a	1982		1983	
	brick	stone	brick	stone
Dominants				
Ablabesmyia sp.	2	6	3	10
Dicrotendipes sp. (? D.nervosus Staeg.)	12	11	12	7
Glyptotendipes spp.	14	9	15	10
Microtendipes sp.	15	4	14	8
Cricotopus spp.	15	20	18	22
- sylvestris (Fabr.)	15	18	10	5
Psectrocladius spp.	2	2	2	9
Adominants				
Clinotanypus sp. (? C.nervosus Mg.) Procladius sp., Cladotanytarsus sp. (? C.mancus Walk.), Micropsectra spp., Tanytarsus spp., Cryptochironomus sp., C. defectus K., Endochironomus spp., Parachironomus sp. (? P.vitiosus C.), Orthocladius sp., Eukiefferiella spp., others				

being 18.6 g m^{-2}, while on the natural substratum it was 5533 and 16.2 respectively. In 1983 the differences increased considerably. The average numbers on the artificial substratum were 7639 individuals m^{-2} and the biomass 24.5 g m^{-2}, on the natural substratum being 2638 and 4.6 respectively. Brick was more favourable especially for *Trichoptera*. In 1982 there were 5 times and in 1983 even 14 times more of them. In 1983 there were also more *Bivalvia*. The remaining groups occurred in various numbers and biomass in the two years so that it is difficult to associate their presence with the substratum. It also concerns *Chironomidae* larvae (Table III), which in 1982 were slightly more numerous on the stone and in 1983 distinctly less numerous. Small changes were also observed in the taxonomic composition of this group (Table IV). A greater participation on the artificial substratum by the larvae of *Microtendipes* sp., *Glyptotendipes* spp. and *Dicrotendipes* sp. (? *D. nervosus* S t a e g.) was noted but on the natural substratum by those of *Cricotopus* sp. and *Ablabesmyia* sp.

4.3. The effect of water discharge from the reservoir on the zoobenthos of the river

The effect of water discharge from the reservoir could be observed at station 2 (fig. 3). It was noted that in periods of the largest discharges the zoobenthos was the least numerous, whereas with minimal discharges there was always a rise in number and biomass, this being particularly distinct in the second half of 1983. The qualitative composition also showed clear differentiation depending on the presence or absence of a greater water discharge. During the 2 years of investigation 3 periods of settling the bottom by *Chironomidae* were distinguished (fig. 3C). The first lasted from January to August 1982. The taxonomic composition was affected by a water discharge which took place at the beginning of 1982, having begun in 1981. Of the *Chironomidae* family dominants were *Tanytarsus* spp., *Psectrocladius* spp., and *Eukiefferiella* sp. (? *E. longicalcar* K i e f f.). It may be supposed that it was a community of bottom organisms typical for this station in normal hydrological conditions, that is, with a regular sluice outflow.

The second period lasted from September 1982 to May 1983. Two sub-periods were distinguished, the first from September to December 1982 with a minimal sluice outflow. New forms were noted besides those observed earlier in the taxonomic composition, such as *Polypedilum* sp. (? *P. nubeculosum* M g.) and *Glyptotendipes* spp., which at once reached fairly high density. The participation of *Eukiefferiella* sp. (? *E. longicalcar* K i e f f.), *Cladotanytarsus* sp. (? *C. mancus* W a l k), and *Tanytarsus* spp. was diminished. The second sub-period lasted from January till May 1983 when larger water discharges again occurred. This probably led to a pause in the process of metamorphosis of bottom organisms which was

observed in the previous sub-period. The participation of *Glyptotendipes* spp., *Polypedilum* sp. (? *P. nubeculosum* Mg.), and *Eukiefferiella* sp. (? *E. longicalcar* Kieff.) remained on the same level while that of *Tanytarsus* spp. was only slightly changed. Only *Psectrocladius* sp. and *Cricotopus* spp. increased their participation.

During the third period, from June to December 1983, the water discharges were again minimal. The density of zoobenthos rose. Among *Chironomidae* the following forms prevailed: *Cricotopus* spp., *Polypedilum* sp. (? *P. nubeculosum* Mg.), *Dicrotendipes* sp. (? *D. nervosus* Staeg.), and *Glyptotendipes* spp., that is almost exclusively phytophilous forms. The participation of *Tanytarsus* spp. decreased in number from 22 to 5% and *Eukiefferiella* sp. (? *E. longicalcar* Kieff.) was not

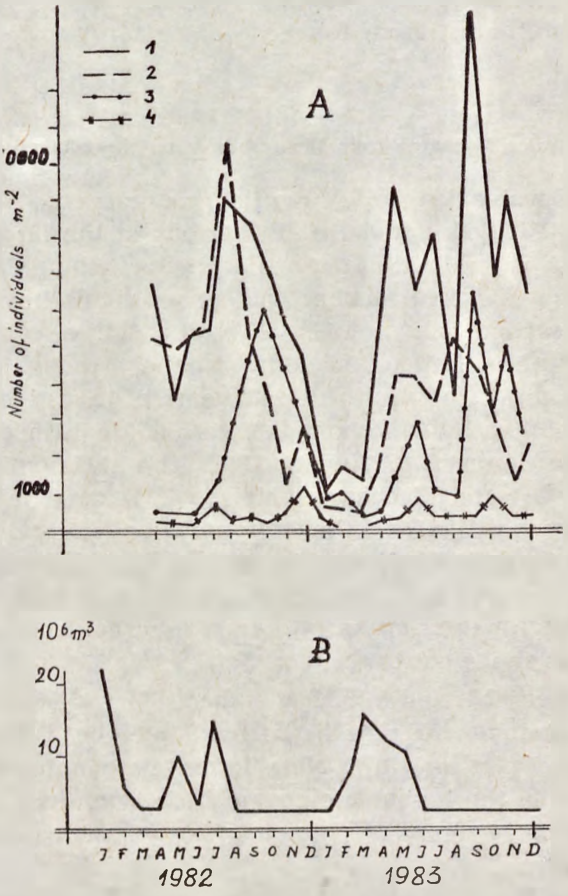


Fig. 4. The number of zoobenthos at station 3 (A) in relation to discharged water (B) in 1982—1983. Zoobenthos: 1 — on artificial substratum (brick); 2 — on natural substratum (stone). *Trichoptera:* 3 — on artificial substratum; 4 — on natural substratum

noted. However, new forms for this station appeared, such as *Chironomus* sp. (? *Ch. plumosus* L.) and *Procladius* sp., i.e. pelophilous forms. The presence of 3 communities of *Chironomidae* was observed here. In the first year it was a mixed complex with a considerable part of rheophilous forms, in the next year the complex was originally still mixed but with a small part of rheophilous forms and then in the second half of the year the complex was exclusively phytophilous.

The curve representing the numerical changes at station 3 in relation to the magnitude of outflow differed in course from that at station 2. In the period of increased outflow from the sluice and directly afterwards there was an intensified development of zoobenthos, followed by a graduall fall. It was noticeable chiefly in the case of *Trichoptera*, which particularly abundantly settled on the artificial substratum (fig. 4A). The water flowing out from the reservoir through the sluice also disturbed and transported the stagnant water from the sluice-dam section.

5. Discussion

In the many years of investigating the Goczałkowice Reservoir the problem of the river-reservoir-river system was omitted.

To fill this gap a hydrochemical investigation was begun in 1982 on the River Vistula and below the reservoir. This work presents the results obtained in an untypical period, that is, in dry years and when the water outflows from the reservoir to the river were small. The discharged water had a distinct effect as far as the composition and development of zoobenthos were concerned.

Zoobenthos communities at the particular stations on the river were both quantitatively and qualitatively greatly differentiated.

The zoobenthos of station 1, above the reservoir, represented a relatively pure piedmont river, with a considerable participation of *Ephemeroptera*. Throughout the years (1969—1983) changes in the zoobenthos showed a constant increase in the participation of *Chironomidae* and a decrease in *Ephemeroptera*. At station 2, directly below the sluice, a decisive factor concerning the composition and development of the zoobenthos was the water current. 90% of fauna were *Chironomidae* larvae, mainly phytophilous forms.

The composition and development of the zoobenthos at station 3, 1000 m from the sluice below the flood barrier, was decisively affected not only by the amount of water discharged from the reservoir but also by the amount of stagnant water from the sluice-flood barrier section which was carried below the dam with greater discharges of water from the reservoir. The zoobenthos varied and the dominant groups were *Trichoptera* and *Chironomidae*.

Thus the Goczałkowice dam reservoir strongly affected the zoobenthos of the river. It changed the community of bottom organisms from typically piedmont with forms representing pure and oligotrophic waters into one of a lowland river, rich in animals and showing strong eutrophication.

Ward and Stanford (1979) described an investigation made on a subject slightly different from the Goczałkowice Reservoir and the River Vistula but their results partly resemble those from Goczałkowice. They concern the rise in numbers of *Trichoptera* and fall in those of *Ephemeroptera* below the dam in relation to the station above the reservoir (fig. 5). A synthetic discussion of some of the results concerning the investigation of the reservoir and river zoobenthos may be found in the work of Wróbel and Szczęsny (1983).

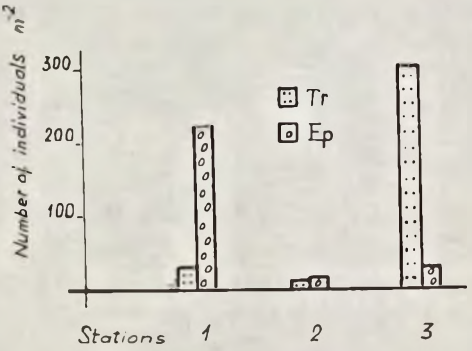


Fig. 5. Average numbers of *Trichoptera* (Tr) and *Ephemeroptera* (Ep) at stations 1, 2, and 3 in 1982—1983

6. Polish summary

Wpływ zbiornika zaporowego w Goczałkowicach na zoobentos rzeki Wisły (Polska Południowa)

Badania przeprowadzono na trzech stanowiskach rzeki Wisły (ryc. 1). Stanowisko 1 położone było około 3 km powyżej zbiornika w Goczałkowicach, stanowiska 2 i 3 poniżej zbiornika w odległości 100 i 1000 m. Badania wykazały bardzo zróżnicowany skład i wielkość zoobentosu (tabela I). Stanowisko 1 reprezentowało rzekę podgórską z dużym procentem *Ephemeroptera*. Średnia liczebność z lat 1982—1983 wynosiła 1186 osob. m^{-2}, biomasa 2,1 g m^{-2}. Badania przeprowadzone na tym stanowisku w latach 1969—1979 oraz w latach 1982—1983 wykazały wzrost liczebności *Chironomidae* i spadek *Ephemeroptera* (ryc. 2, tabela II). Najmniej zoobentosu było na stanowisku 2 o średniej liczebności 933 osob. m^{-2} i biomasie 1,8 g m^{-2}, najwięcej na stanowisku 3 o średniej liczebności z obu badanych lat 4095 osob. m^{-2} i biomasie 10,4 g m^{-2}.

Niewielkie opuszczanie wody ze zbiornika przez upust w latach 1982—1983 wykazało duży wpływ na skład i wielkość zoobentosu rzeki. Na stanowisku 2, położonym

100 m od upustu, w okresach większego opuszczania wody, zoobentos był najuboższy, natomiast przy minimalnym opuszczeniu następował zawsze wzrost liczebności i biomasy (ryc. 3A, B). Na stanowisku 3 odległym 1000 m od upustu i położonym poniżej jazu piętrzącego, w okresach zwiększonego opuszczania wody i bezpośrednio po nich następował od razu wzmożony rozwój zoobentosu, wzrastała jego liczebność i biomasa, natomiast w okresach o minimalnym opuszczaniu wody następował spadek liczebności i biomasy (ryc. 4).

Szczególną uwagę poświęcono rodzinie *Chironomidae* (tabele II, IV). Na stanowisku 2 stwierdzono wyraźny wpływ wielkości opuszczanej przez upust wody ze zbiornika na zmiany taksonomiczne (ryc. 3C) w tej grupie.

Na stanowisku 3 dla dokładnego określenia liczebności i biomasy założono 60 cegieł, z powierzchni których pobierano próby. Stwierdzono, że to sztuczne podłoże było intensywniej zasiedlane przez zwierzęta, zwłaszcza przez *Trichoptera*. W 1982 r. było ich 5 razy więcej, a w 1983 r. nawet 14 razy (tabela III).

Zbiornik zaporowy w Goczałkowicach zmienił zespół organizmów dennych z podgórskiego (stanowisko 1) z udziałem zwierząt reprezentujących wody czyste i oligotroficzne na zespół rzeki nizinnej (ryc. 5) o bardzo dużej liczebności i biomasie (stanowisko 3).

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