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Composition and zonation of benthic invertebrate communities in some chemically stressed aquatic habitats of Niepołomice Forest (South Poland)[*]

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Abstract — Four types of the invertebrate communities are distinguished in which *Oligochaeta* and *Chironomidae* are dominant groups. The changes of some chemical factors along the water courses are presented and their influence on the benthic macroinvertebrate communities is discussed. High acidity of the water reduces the number of taxons occurring in chemically stressed sites.

Key words: running waters, invertebrate communities, zonation.

1. Introduction

The Niepołomice Forest (NF) (110 km^2) is situated some 15—35 km to the East from Cracow, and from the industrial agglomeration of the Lenin Steelworks. This area receives dusty and gaseous pollutants from the urban-industrial agglomeration of Cracow, and from the more distant Upper Silesian Industrial District. Continuous pollution, mainly with sulphur dioxide and heavy metals (Myczkowski, Lesiński 1976,

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Manecki et al. 1982) exerts a detrimental effect upon the functioning of the forest (Grodziński 1978). Sulphur compounds and heavy metals acidify the soil while penetrating it, reduce its absorption ability, cause changes in the rate of organic matter decomposition and in the rate of nutrients and heavy metals cycling (Zieliński 1982). These disturbances in connection with complicated water regime of the NF (Grodziński, Lesiński 1978) affect the chemical and biological character of environment in streams and lodes draining the NF area.

In previous years investigations of the NF area were undertaken to elaborate proper methods for the management of the forest ecosystems. The research covered also the field of hydrobiology, and this report describes the part concerning benthic invertebrates communities.

2. Study area

The NF area is divided by the Drwinka River into a southern and a northern part. In the northern part a decidous forest predominates, while the southern one is mixed. Soil in the northern part is more abundant in nutrition than in the southern one. Both parts are humid (Grodziński, Lesiński 1978).

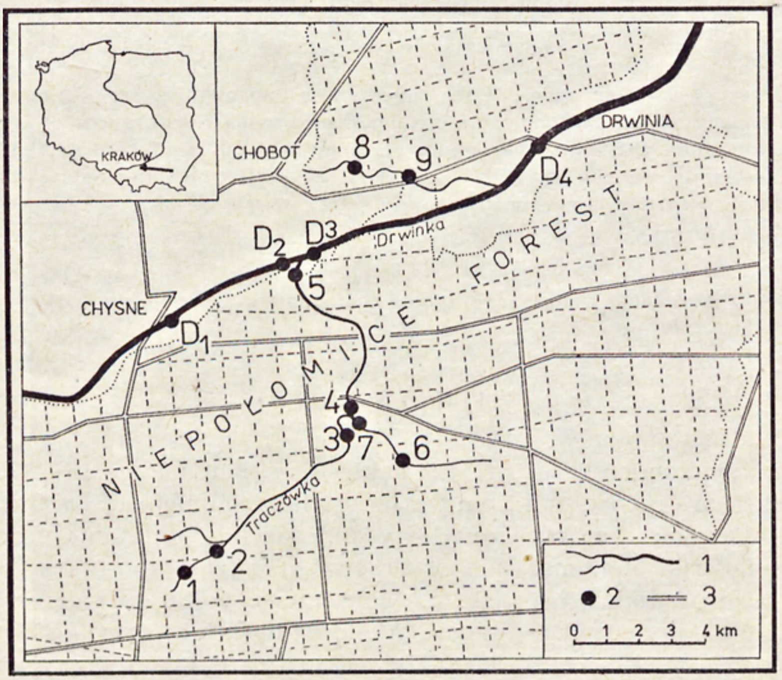

Fig. 1. Study area. 1 — network of running waters; 2 — sampling sites; 3 — roads

The running waters consist of natural streams and artificial lodes flowing into the Drwinka River. For the field work 13 study sites were designed (fig. 1), as follows:

1. Four sites along the middle stretch of the Drwinka River (sites D1--D4).

2. Five sites along the Traczówka Stream in the southern part of NF (sites 1—5)

3. Two sites in the lode in the southern part of NF, tributary of the Traczówka Stream (sites 6—7).

4. Two sites in the lode in the northern part of NF (sites 8—9).

The Drwinka River is 3—5 m wide, and 0.4—0.7 m deep for most of its course within the investigated area. The current is low or medium being mostly 0.3—0.4 m/sec. The bottom is partly covered with stones and gravel, partly with silt which is often mixed with sand. During the vegetation season the bottom is locally overgrown with macrophytes, mainly *Batrachium* sp., which sometimes cover about 30% of the bottom surface at the sites. At site D4 the Drwinka River is about 10 m wide, and about 1 m deep. The current is very low, often below 0.3 m/sec. The bottom consists of clay covered with silt and partly overgrown with emergent aquatic macrophytes.

The Traczówka Stream is the longest of the streams in NF (about 10 km). Its width amounts in most cases to about 3 m (at site 3 to about 5 m), its depth varying from 0.3 to 0.5 m. The current varies greatly according to the place and water level. During high levels it reaches even 0.5 m/sec, at the time of low level water it often stagnates (except at sites 2 and 5 where the current is the fastest). The bottom is covered most often with silt mixed with detritus and bigger plant particles, and sometimes consists of small stones and gravel. Sand is often added to all kinds of substrate.

The common features of lodes (sites 6—7 and 8—9) are: very slow current or stagnated water, and the bottom covered with silt and leaf litter partly decomposed.

The temperature of water varries from the decimal part of one centigrade in winter, to 20 centigrades in summer. Most often it amounts to a dozen or so centigrades, and is 2—5°C lower in the forest streams than in the Drwinka River (Wróbel, Bombówna 1982).

One of the most biologically essential features of the waters in the NF area is a high content of CO_2 with a simultaneous low content of Ca, Mg and K. These conditions result in a low pH value of water, especially in the lode of the southern part of the NF. In the northern lode and in the Drwinka River water is more abundant in cations which buffer bicarbonate (Wróbel, Bombówna 1982).

The waters in the NF area also abound in iron and organic matter, of which humus compounds are the most common. A high content of sulphates, derived mostly from industrial input is characteristic of waters in the NF. In the water of the Traczówka Stream sulphates predominate over carbonates, which form ion composition unusual in streams of the temperate climate region (Wróbel, Bombówna 1982).

3. Methods

The localization of study sites allowed for an estimation of how the lode influenced the stream, and how the forest stream influenced the Drwinka River. It was also possible to compare the lodes in the northern and southern parts of the NF.

From each site samples were taken five times during 1977. The dates and the habitats are shown in Table I. A core sampler was used for the silty bottom, and a Surber's sampler with a mesh of 300 μm for the stony bottom. Five samples were taken each time from both habitats. On the silty bottom each sample was taken from a surface of 0.38 dm², and on the stony bottom from a surface of about 3 dm².

Table I. Datos of samplings. a - silty bottom.
b - stony bottom

Sites	1	2	3	4	5	6	7	8	9	D1	D2	D3	D4
Habitats / Dates	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab
15.IV. 1977	+	+	+	+	++	+	+	+	+				
19.IV. 1977										++	++	++	+
28.V. 1977										++	++	++	+
1.VI. 1977	+	++	++			+	+						
26.VII.1977	+	++	++	+	+	+	+			++	++	++	+
7.IX. 1977	+	++	++	+	++	+	+	+	+	++	++	++	+
25.X. 1977	+	+	+	+	++	+	+	+	+	+			

All the data presented in this paper were then calculated for the surface of 10 dm². Animals were separated from the substrate under binocular microscope, and preserved in 4% formalin solution.

4. Results

4.1. Specific composition

The composition and distribution (the mean of all the samplings) of caught invertebrate species and forms is shown in Table II. The term „form" is used here to describe morphologically identical specimens belonging to two or more different species (often in young instars).

Table II. Distribution of invertebrates at the study sites (mean values of five samplings).
Classes of density per 10 dm^2: 1:1-6; 2:7-12; 3:13-25; 4:26-50; 5:51-100;
6:101-200; 7:200-500; 8-500; + 0.6; 1 - larvae; p - pupae; i - imago

Habitat	Silty bottom													Stony bottom					
Species / Sites	1	2	3	4	5	6	7	8	9	D1	D2	D3	D4	2	3	5	D1	D2	D3
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Dugesia gonocephala (Dug.)																	+		
TRICLADIDA TOTAL																	+		
Anisus (D.) vorticulus Trosch.								1	2									1	
GASTROPODA TOTAL								3	7									1	
Pisidium spp.	4	3	1	2	2			6	6	6	5	1	3				1	3	1
LAMELLIBRANCHIA TOTAL	29	17	5	9	9			132	104	171	56	4	13				3	14	1
Chaetogaster sp.	1																		
Specaria josinae (Vejd.)		1	1																
Ophidonais serpentina (Müll.)								1											
Nais communis Pig.	1							1	1							+			
- pseudobtusa Pig.									+										
- sp.																		1	
Slavina appendiculata (Od.)									1										
Stylaria lacustris (L.)	3								4	6	5							1	
Dero sp.									1										
Pristina foreli (Pig.)												1							+
- rosea (Pig.)																			+
Tubifex ignotus (Stolc.)		1								1									
- templetoni (South.)			1					1											
- tubifex (Müll.)	3	1	1					2	1		1	1			+			1	
Psammoryctides moravicus (Hrabe)										4	3							1	3
Limnodrilus claparedeanus Ratzel									1				2						+
- hoffmeisteri Clap.	2		1		3			1	1	7	7	3	4		1		6	7	1
- udekemianus Clap.								1			1		2			+			
- spp. juv.	4	2	1		3		1	1	4	8	8	3	6	1	+	+	6	7	3
Peloscolex ferox (Eisen)		1							1										+
- sp.								1			2								
Potamothrix hammoniensis (Mich.)								3		6	2						1		
Aulodrilus limnobius Bret.										1									
- pluriseta (Pig.)	1	1						2	1	1	1	5							1
Tubificidae gen. spp. juv.	5	4	3	1	3	2	1	3	4	6	6	6	2	1	1	1	3	4	2
Cernosvitoviella atrata (Bret.)																			+
- sp.							1									+			
Marionina riparia Bret.												1					1		
Enchytraeidae gen. spp. juv.	1									1	2				+			1	
Lumbriculus variegatus (Müll.)							1	1											+
Stylodrilus heringianus Clap.	1				1		1									1	2	1	+
Rhynchelmis limosella Hoffm.									1										
Lumbriculidae gen. spp. juv.			1						1										1
Eiseniella tetraedra (Sav.)								1											
OLIGOCHAETA TOTAL	165	60	36	4	56	8	13	76	171	1578	1295	153	344	5	5	5	348	515	30
Glossiphonia complanata (L.)										2	1						2	1	+
Erpobdella octooculata (L.)										4	3		1				3	1	1
HIRUDINEA TOTAL										55	18		1				33	2	2
HYDRACARINA TOTAL										1	2							5	10
Asellus aquaticus	7	6	5			1		3	6	5	6	1		2			2	3	1
ISOPODA TOTAL	325	146	67			3		16	126	75	118	4		8			7	24	1
Ephemera vulgata L. 1												1	2						
Baetis vernus Curt. 1	1	1									2			1				1	1
Cloeon dipterum L. 1																		1	
Centroptilum luteolum Müll. 1				1						1	3					1		1	1
- pennulatum Etn. 1	3																		
Lephtophlebia vespertina L. 1	3	3	1	1	1														1
Caenis horaria L. 1																			1
- moesta Bgtss. 1											1	1	1						1
Ephemeroptera gen. spp. juv. 1	1		4	1							1				2	1		1	
EPHEMEROPTERA TOTAL	43	21	45	6	9									1	8	4			
Nemoura cinerea Ritz. 1. i	3	4		1	2									2	+		1		1
Plecoptera gen. spp. juv.	3	1		1	1									1					
PLECOPTERA TOTAL	42	47		4	14									8	+		2		3
HETEROPTERA TOTAL			1							1	5								
Haliplus (H.) heydeni Wehn. 1. i										2	1							1	1
Noterus clavicornis Deg. i											1								
Laccophilus hyalinus Deg. 1. i											2							1	
Coelambus sp. 1.																	+		
Hydroporus sp. 1, i				1			1									+			
Potamonectes sp. 1											1								
Agabus sp. 1		1																	
Rhantus sp. 1	1	1	1			1								+	+				
Elminthidae gen. sp.																		1	+
Donacia sp.	1	1	1			1				1	1							1	
Coleoptera gen. spp. juv.					1														
COLEOPTERA TOTAL	9	3	4		1	10				12	18			+	+	+	+	6	1

Cont. tab. II

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Sialis lutaria L. 1	1	3	1	1	1	1	1	1	2	1	2	2	1	1		1	+		
MEGALOPTERA TOTAL	5	20	5	4	5	1	2	5	9	5	9	7	2	2		2	+		
Hydroptila gr. forcipata 1																			+
Hydropsyche angustipennis Curt. 1										1		1					1	1	3
- bulbifera Mcl. 1																			1
Plectrocnemia conspersa Curt. 1				1															
- geniculata Mcl. 1	1	2												+	+				
Oligotricha striata L. 1						1	1	1											
Oligostomis reticulata L. 1		1	1												+	+			
Limnephilus sp. 1							1												
Anabolia laevis Zett. 1										1	1						1	1	
Potamophylax rotundipennis Bran. 1					1														
Stenophylacini gen. sp.										1									
Goera pilosa Fbr. 1																			1
Atripsodes aterrimus Steph. 1										1		1							
- cinereus Curt. 1					1						1							1	1
Mystacides longicornis L. 1												1					+		
Trichoptera gen. spp. juv.		1	1			1						1			1				
TRICHOPTERA TOTAL	2	12	2	1	2	3	2		1	7	4	11		+	3	+	2	11	19
Macropelopia notata (Mg.) 1,p	4	6	6	3	1	4	6	5	5	4	4	5	1	3	4	1	1	1	+
Psectrotanypus sp. 1								1											
Apsectrotanypus trifascipennis (Zett.) 1														1					
Notarsia sp. 1							1								+	+			
Thienemannimyia "Reihe" 1		1							2	1	3	2		+	2	1		2	2
Zavrelimyia barbatipes (K.) 1,p	3	5	5	4	1	1						2		1	4	1	+		
Larsia sp. (culticalcar K.)?) 1	1	1	1	1	1	1	1												
Tanypodinae gen. spp. juv.	1		1											1		1			
Prodiamesa olivacea (Mg.) 1	1	1	1		1		1		1			1		1	1	1	1		
Brillia modesta (Mg.) 1						1													
Hydrobaenus sp. 1			1										1					1	
Heterotrissocladius sp.(marcidus)Walk.(?)1,p	1	1	4	1		1	1								5		1		
Eukiefferiella brevicalcar (K.) 1																1			1
- claripennis Lundb. 1																			1
- discoloripes G. 1													1					1	
- sp.															1				
Synorthocladius semivirens (K.) 1,p											1						+		3
Orthocladius (O.) rubicundus (Mg.) p,1																	1	1	1
- spp.	1		1							1	6	4			1			5	6
Cricotopus spp.			1							1	1	1	1			1		4	3
Psectrocladius gr. psilopterus K. 1	1		3			2	1			1		2		1	3	+	+		1
Rheocricotopus gr. fuscipes K. 1		1				1	1				1			+		1	+		+
Nanocladius (N) sp.										1									
Limnophyes sp.		1							1						1				
Metriocnemus sp.		1	1			1					1				+				
Pseudorthocladius curtistylus (G.) 1					1														
Epoicocladius ephemerae (K.) 1													1						
Thienemanniella gr. clavicornis K. 1					1					1				+		+	+	1	1
Corynoneura gr. validicornis K. 1	1	2			3	1				1	3	1		1	2	3	+	1	1
Orthocladiinae gen.? triquetra Tsh. 1												1							
- gen. spp. juv.	1										1	2						1	4
Chironomus gr. thummi K. 1								1	3				1						
- gr. anthracinus Zett. 1													1						
Cryptochironomus gr. defectus K. 1					1					2	1	3	1			1	2	1	1
Parachironomus sp. (vitiosus G.?) 1											1								
Einfeldia sp. (pagana (Mg.?) 1																		1	
Microtendipes gr. chloris (Mg.) 1								1		1							1	1	1
Paratendipes gr. albimanus (Mg.) 1					1					3	2	3					1	1	
Pentapedilum exsectum K. 1	1	1	1	2	1										+	+		1	
Polypedilum scalaenum Schr. 1		4	1	1	5					1	3	5	3	1		1		5	5
- gr. convictum (Walk.) 1	1	1	1		1							1	2		+	+		+	2
- bicrenatum K. 1										4	5	1	1				1	1	
Stictochironomus gr. histrio (Fabr.) 1																1			
Cladotanytarsus (gr. mancus (Walk.)?) 1										1	1						2	3	4
Micropsectra gr. praecox Meig. 1			1						3	1					1	1			
Paratanytarsus sp.									4	4	5	6	1			2	2	4	3
Rheotanytarsus sp.					2						1					1		1	
Stempellinella minor Edw. 1					1							4							
Tanytarsus gr. gregarius K. 1	3		1	1	2				2	5	4	2				3	2	3	4
- sp. (gr. palidicornis (Walk.)?)1			1									3			2				1
Chironomidae gen. spp. juv.									3	3	3					5		2	
CHIRONOMIDAE TOTAL	110	254	293	73	149	59	113	89	195	255	444	479	55	29	190	108	57	306	472
Antocha sp. 1																		+	
Tipula sp. 1															+				+
Tipulidae gen. spp. juv. 1		1				1									+	+			
Dicranota sp. 1					1														3
Limnophila sp. 1	1	1	1	1			1												1
Erioptera sp. 1																			+
Ptychoptera sp. 1								1											
Culex sp. 1	1	1			1		2				2								1
Eusimulium sp. 1, p														1					
Simuliidae gen. spp. 1	2	2												4	1		1		1
Bezzia sp. 1						1				2							1	1	2
Ceratopogonidae gen. spp.	1	1	1					1		1	1				+			1	
Chrysops sp.																		1	
Tabanus sp.					1									+	+		+		
DIPTERA OTHERS TOTAL	19	15	2		4	4	10	11		8'	13			37	1	+	2	5	25

Of all taxonomic groups *Oligochaeta* and *Chironomidae* are represented by the highest number of species, and among them most species belong to high classes of density. It is only *Limnodrilus hoffmeisteri* which reaches the 7th class of density at three of its sites. Among the eight species of the 6th class, four are *Oligochaeta* and two are *Chironomidae*, and of nine species from the 5th class, one belongs to worms and six belong to *Chironomids.*

Of the other groups *Asellus aquaticus* and *Pisidium* spp. belong to more common taxons.

4.2. Longitudinal changes in community structure

The analysis of mutual relations of more common taxonomical groups in their relative abundance allowed to distinguish four types of invertebrate communities. They are especially visible on the silty bottom (fig. 2A), where chironomids and oligochaetes are one of the most common dominant groups. In the Drwinka River the community (except at site D3) with worms predominance occurs, while chironomids are the main dominant group in the central part of the NF (sites 3, 4, 6 and 7). The third type occurs in the upper stretch of the Traczówka Stream (sites 1 and 2)

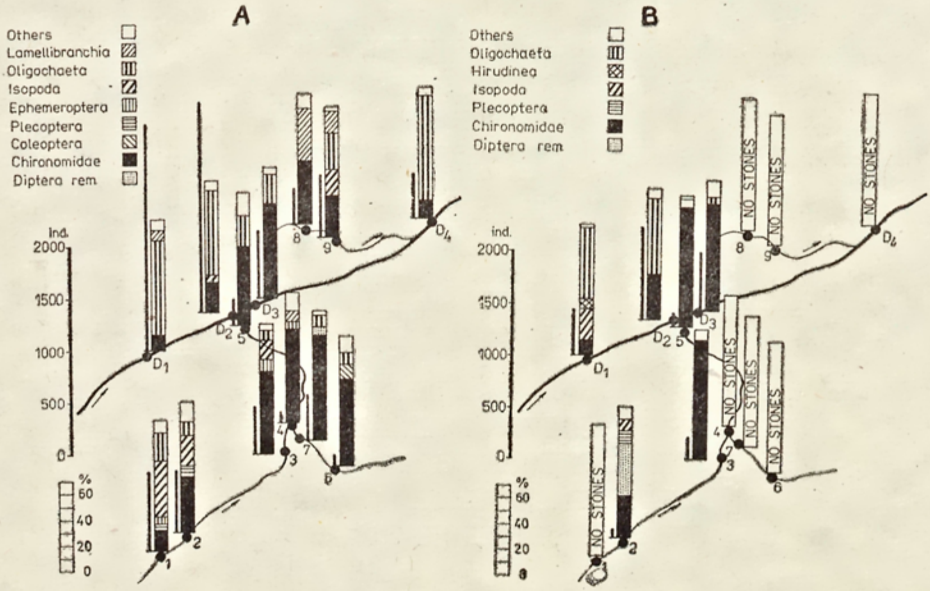

Fig. 2. Longitudinal changes in relative abundance of more common invertebrate taxonomic groups (wide bars), and abundance of all invertebrates (thin bars) on silty bottom (A) and stony bottom (B) (10 dm²)

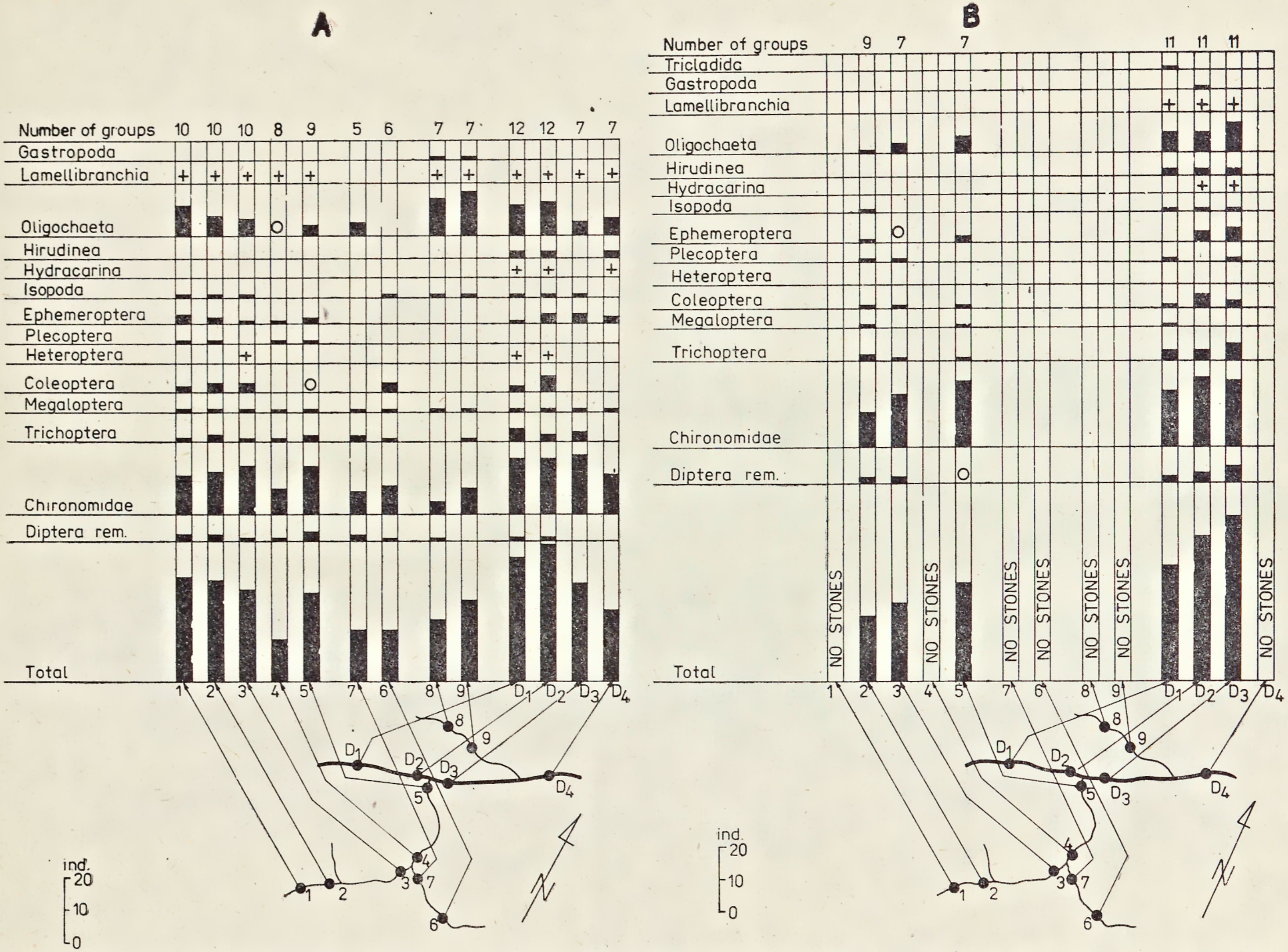

Fig. 3. Number of invertebrate species (bars) and taxonomic groups (marked above the bars) on silty bottom (A) and stony bottom (B). + — groups not identified to species; ○ — only young unidentified specimens of this group were caught at the site (gen. spp. juv. at Table II)

where *Isopoda (Asellus aquaticus)* predominates over chironomids and oligochaetes, and the fourth type exists in the northern lode where the community is mixed. There, the main groups are *Lamellibranchia, Oligochaeta, Isopoda* and *Chironomidae.*

The influence of the Traczówka water on the Drwinka River is very distinct, and is expressed by an increase in the domination of chironomids accompanied by a decrease in all invertebrates density just below the mouth of the Traczówka (site D3).

Stony bottom occurred only at some of the sites, hence the picture of invertebrate communities is incomplete there (fig. 2B). The best visible of all is the introduction of a community with the absolute domination of chironomids (typical of the middle course of the Traczówka Stream) into the Drwinka River at site D3.

The number of species found at the sites on silty bottom (fig. 3A) was the smallest in lodes (sites 6, 7, and 8, 9), especially in the southern part of the NF. The distinct drop in the number of species was noticed also in the Traczówka Stream below the mouth of the lode (site 4), and in the Drwinka River below the inlet of the Traczówka Stream (sites D3 and D4). At site D4 this might be also caused by the clay bottom. This drop is not observable on the stony bottom (fig. 3B) because the material is incomplete. Nevertheless the influence of the Traczówka Stream water on the Drwinka River seems to be different than on the silty bottom. The number of species even increases at site D3, which should be connected with the type of habitat. The stony bottom is a zone of riffle while the silty bottom is a zone of accumulation, and it is the suspended matter that influences mostly streams or rivers below the mouth of their tributaries.

4.3. Zonation

The essay in ascertaining whether the distribution of aquatic invertebrates forms zones in the NF, has been made according to the distribution of dominating species and forms. Only the species of relative abundance of at least 10% were taken into consideration, and divided into two groups: 10% and more, and 25% and more. Results are shown in fig. 4, and suggest the existence of five groups of dominant species with different distribution:

1. Species dominating in the central part of the southern forest (sites 3, 4, 6, 7).

2. Dominant species in the low Traczówka, and in the short stretch of the Drwinka River below the mouth of the Traczówka Stream (sites 5,D3).

3. Dominant forms in the Drwinka River without the short stretch below the mouth of the Traczówka Stream (sites D1, D2, D4). (Most of

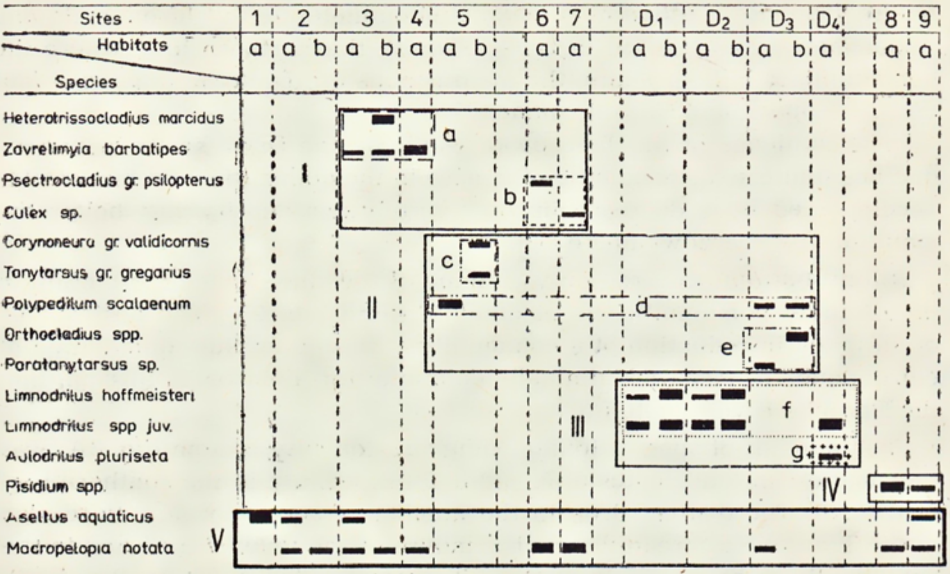

Fig. 4. Essay in determining of faunistic zones on the base of distribution of dominant invertebrate species. I—V — zones, a—g — subzones; a — silty bottom, b — stony bottom

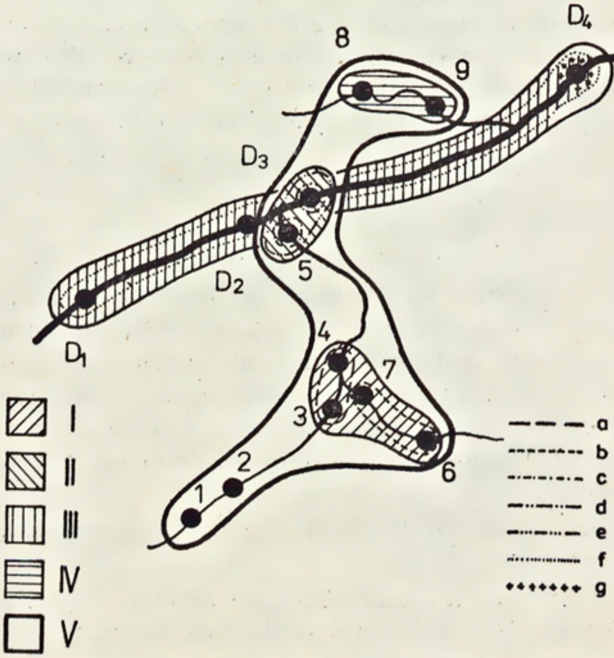

Fig. 5. Faunistic zones put on the schematic map of the study area. I—V — zones; a—g — subzones

Limnodrilus spp. juv. belong to *L. hoffmeisteri;* thus both items may be treated together).

4. Dominant species in the lode of northern forest (sites 8, 9).

5. Species of a high relative abundance on a large area, but restricted to the forest stream and lodes (sites 1, 2, 3, 4, 6, 7, D3, 8, 9).

These five groups delimit four superficially separate zones (fig. 5, zones I—IV) and one zone (No. V) comprising the sites in the upper stretch of the Traczówka Stream and covering zones 1, 2 and 4. Some of these zones may be divided in greater detail into subzones (a—g in figs 4—5). This division suggests the individual faunistic pecularity of almost all the sites, except for the upper stretch of the Traczówka Stream, and confirms the strong effect of the Traczówka water on the Drwinka River. Below the mouth of the Traczówka Stream zone No. 2 from the low Traczówka is introduced into zone No. 3 typical of the Drwinka River.

4.4. Some chemical features

Of all the chemical features of the water in the NF area, only those were chosen (fig. 6A) which followed the longitudinal changes in the invertebrate communities (figs 2—3), and which seem to explain chemical mechanisms, to some extent decisive about the species distribution.

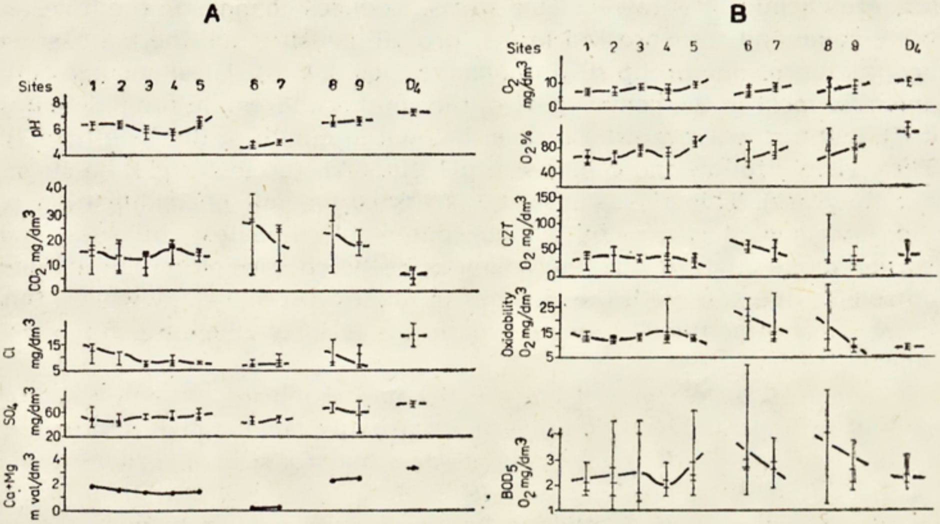

Fig. 6. Some chemical features of water important for invertebrate distribution (A) and oxygen conditions in the waters of study area (B)

Very characteristic changes along the stream course were noticed in pH value. The lowest value, below 5 (mean) occurred in the southern lode (sites 6, 7), and pH below 6 (mean) was ascertained in the middle stretch of the Traczówka Stream (sites 3, 4).

Among acidifying compounds chlorides, and especially sulphates were abundant in the waters of the NF area. However, the changes in the content of carbon dioxide, accompanied by the changes in the content of calcium and magnesium seem to influence pH mostly. The levels of CO_2 and of pH value are almost inversely proportional at all sites, and only the ability of calcium and magnesium to buffer bicarbonates modifies this proportion (fig. 6A).

The content of the oxygen dissolved in the water at all sites (fig. 6B) was quite sufficient, and oxygen saturation below 50% occurred but seldom. This considerable amount of dissolved oxygen was not, however, the result of organic matter scarity. COD and oxydability levels reveal that the NF waters are rich in organic matter, but it consists mainly of humus compounds resistant to bacterial decomposition. The acidic environment also hampers very much the thrive and enzymatic activity of bacteria, which inhibits oxygen consumption. This is reflected in low BOD_5.

5. Discussion

The data described in the previous chapters suggest that the NF waters are chemically stressed. This stress produces changes in the invertebrate communities expressed by the drop in density, and the increase in domination of one group (*Chironomidae*, figs. 2A, B). These changes are apparent most in the central part of the southern forest, in the lode (sites 6, 7), and in the Traczówka Stream below the mouth of the lode (site 4). They visibly follow the changes in pH (fig. 6A) (the lower pH the stronger they are). This shows that the stress is a result of acidification of the environment caused by a high content of sulphates, chlorides, and carbon dioxide. However, only changes in the content of carbon dioxide correlate reversely with the changes in pH level (fig. 6A). However, this correlation is modified at some sites by the level of calcium and magnesium.

Carbon dioxide comes from the decomposition of organic matter, mainly leaf litter, and it acidifies most strongly stagnated waters in the lodes. Because of the higher content of calcium and magnesium the pH of the water in the northern lode (sites 8, 9) is much higher than in the southern one (sites 6, 7), though both are quite similar in morphology (stagnant water, bottom covered with leaf litter, canopy of the forest).

Chemical stress is not due to the level of oxygen saturation (fig. 6B)

Considerable value of COD and oxydability prove a high amount of organic matter in the water, but the rate of its decomposition is very low. This is shown by the low BOD_5. When there is low enzymatic activity of bacteria, due to acid environment (Bednarz, Trela, Zygmuntowa 1982) oxygen consumption is insignificant. All these chemical and biochemical mechanisms, combined with the physical differentiation of the waters, diversify so much the particular sites that almost in each of them there are different dominating species (fig. 4). Some zones of domination (fig. 5) correspond very well with different community structures, and with chemical features of the water. For example waters in the middle part of the southern forest, which form faunistic zone No. 1 are most acid stressed, and poor in nutrition and bacteria (Bednarz, Trela, Zygmuntowa 1982). In the northern part of the NF, in zone No. 4 acidity is attenuated by a buffer ability of bicarbonates and waters are richer in nutrition. Finally, zone No. 3 covers not chemically stressed water of the Drwinka River.

Table III. Changes in number of species in some classes of abundance, and in some groups of feeding of invertebrates in comparison with pH value (mean) on silty bottom

Number of species / Sites	1	2	3	4	5	6	7	8	9	D1	D2	D3	D4
Classes from 2 - 8	15	13	7	4	9	3	2	7	10	19	26	15	10
Classes from 4 - 8	5	6	4	1	1	1	1	2	7	13	11	4	3
Worms in classes 2 - 8	5	2	1	-	3	1	-	4	3	6	8	3	6
Worms in classes 4 - 8	2	1	-	-	-	-	-	-	3	6	4	1	3
Predators in classes 2 - 8	2	3	3	2	-	2	1	1	2	2	3	5	-
Predators in classes 4 - 8	1	2	3	1	-	1	1	1	1	1	1	1	-
Chironomid predators in classes 2 - 8	2	2	3	2	-	2	1	1	2	1	2	4	-
Chironomid predators in classes 4 - 8	1	2	3	1	-	1	1	1	1	1	1	1	-
pH	6.4	6.4	5.8	5.7	6.4	4.6	5.0	6.5	6.7				7.3

A more detailed analysis of the changes in the number of species in higher density classes and different types of feeding (Table III) seems to clear up the mechanism in which chemical stress influences invertebrates. As the acidity raises (fig. 6A), the decline in the number of species from the highest density classes can be observed (Table III). It concerns mainly *Oligochaeta* which dwell in the substrate and conduct it through their alimentary canals. To a much lesser extent predators, mainly or entirely *Chironomidae,* are reduced. Predators living on the surface of the silt, and feeding on other animals, are not so much tied down to the substrate. The most common chironomid predators are *Macropelopia notata* and *Zavrelimyia barbatipes* which, for the insufficiency of other food, may feed on *Ostracoda* (Konstantinov 1961). *Ostracoda* were not examined but they were ascertained in great numbers when macroinvertebrates were separated under a microscope. *Ostracoda* tolerate extreme ranges of pH (Sprules 1975), and feed on mould (Pennak 1978) which is also resistant to strong acidity.

The reduction of *Oligochaeta* may result from the high content of heavy metals in the silt acting on their sensitive cuticule, or on their alimentary canal (Dean 1974). High content of organic matter and low degree of its decomposition may also reduce the density of *Oligochaeta* Čvetkowa 1972). It may also be caused by the scarcity of bacteria in acid silt, which may imply deficiency.

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We wish to thank Professor Stanisław Wróbel, Ph. D. for kindly giving us the run of his data on the chemical composition of the waters in the NF area.

Polish summary

Skład i strefowe rozmieszczenie bentosowych ugrupowań bezkręgowców w niektórych chemicznie zanieczyszczonych wodach Puszczy Niepołomickiej

Na obszar Puszczy Niepołomickiej (PN) opadają zanieczyszczenia pyłowe i gazowe z terenu Krakowa (Nowa Huta), a także Śląska. Największe zagrożenie dla biocenozy stanowią metale ciężkie i SO_2. W niniejszej pracy omówiono wpływ tego typu zanieczyszczeń na ugrupowania bezkręgowców wodnych. Badaniami objęto potok Traczówka (stan. 1—5), 2 rowy melioracyjne (stan 6—7 i 8—9) i środkowy bieg rzeki Drwinki (stan. D1—D4) (ryc. 1). Charakter siedliska, z którego pobierano próby, i daty poboru prób podane są w tabeli I.

Głównymi składnikami bentosu w badanych ciekach były *Oligochaeta* i *Chironomidae* (tabela II).

Na dnie zamulonym *Oligochaeta* dominowały w rzece Drwince (z wyjątkiem stan. D3), *Chironomidae* w środkowym biegu Traczówki (stan. 3, 4) i w rowie melioracyjnym w południowej części puszczy (stan. 6, 7). W górnym biegu Traczówki (stan. 1, 2) dominuje *Asellus aquaticus*, a w rowie melioracyjnym w północnej części puszczy nie ma wyraźnego dominanta (ryc. 2A). Ugrupowania dna kamienistego zbadano tylko dla tych stanowisk, gdzie to siedlisko istniało (ryc. 2B).

Dla dna mulistego najniższą liczbę gatunków i form oznaczono w rowach melioracyjnych (ryc. 3A), a także na stanowiskach położonych poniżej ujścia rowu do Traczówki i Traczówki do Drwinki. Tej regularności nie stwierdzono dla zespołu dna kamienistego (ryc. 3B).

W badanych ciekach wyróżniono 5 grup gatunków dominujących o różnym rozmieszczeniu (ryc. 4) i na tej podstawie utworzono kilka stref i podstref (ryc. 5). Tak duża ilość wyróżnionych stref świadczy o dużym zróżnicowaniu faunistycznym badanych stanowisk.

Zmiany zawartości wybranych czynników chemicznych przedstawione są na ryc. 6A i B. Zmniejszenie różnorodności gatunkowej i spadek liczebności bentosu (ryc. 2A i 3A) najwyraźniej skorelowany jest ze wzrostem kwasowości siedliska (pH), co z kolei najbardziej uzależnione jest od poziomu CO_2 oraz kationów wapnia i magnezu. Zakwaszenie środowiska powoduje przede wszystkim spadek liczby detritusofagów (*Oligochaeta*) (tabela III) penetrujących kwaśne osady i przepuszczających je przez przewody pokarmowe, nie wpływa natomiast na formy drapieżne (głównie *Chironomidae*) powiązane z osadami w znacznie mniejszym stopniu. Redukcja gatunkowa skąposzczetów może też wynikać ze słabego rozwoju bakterii w kwaśnych osadach, co ogranicza ich bazę pokarmową.

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