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Stream ecosystems in mountain grassland (West Carpathians)*

8. Benthic invertebrates

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Abstract — The effect of pastoral management in the mountains on the invertebrate fauna in some streams of the upper Grajcarek basin (the Western Carpathians) was investigated. The influence of sheep grazing was chiefly manifested by the growing percentage of *Chironomidae* in the whole fauna, changes in the domination structure, and disturbances in regular seasonal cycles of benthic invertebrates. In the qualitative composition of the fauna, however, there was little change. The changes in the communities were brought about not only by the increasing content of mineral nutrients in the water but also by the variability of water flow, insulation, and temperature caused by the cutting-down of forests and associated with pastoral land use.

Key words: stream ecosystems, influence of pastoral economy, the Western Carpathians, invertebrates, seasonal cycles, floods.

1. Introduction

The aim of the work was the determination of dependences between the intensification of pastoral economy and the communities of benthic invertebrates in streams. The quantitative and qualitative changes in the fauna in the different habitats at the stations, the percentage structure, and the pattern of seasonal cycles at the stations were analysed.

* The investigations were carried out within Project 10.2.

2. Study area

The investigation was carried out in the basin of the upper Grajcarek stream at three stations established in streams draining water from catchment areas having a various degree of intensification of the pastoral system. Station BW1 was established on the outskirts of a large forest complex; station BW2 lay in meadows where traditional grazing was practised; station K2 lay in pastures of the Institute for Land Reclamation and Grassland Farming where an intensive pastoral system with the application of large amounts of mineral fertilizers was practised for many years. The stations were selected in such a way as to ensure as far as possible that the only modifying factor should be the character of the agricultural land use of the catchment area. Unfortunately, it was

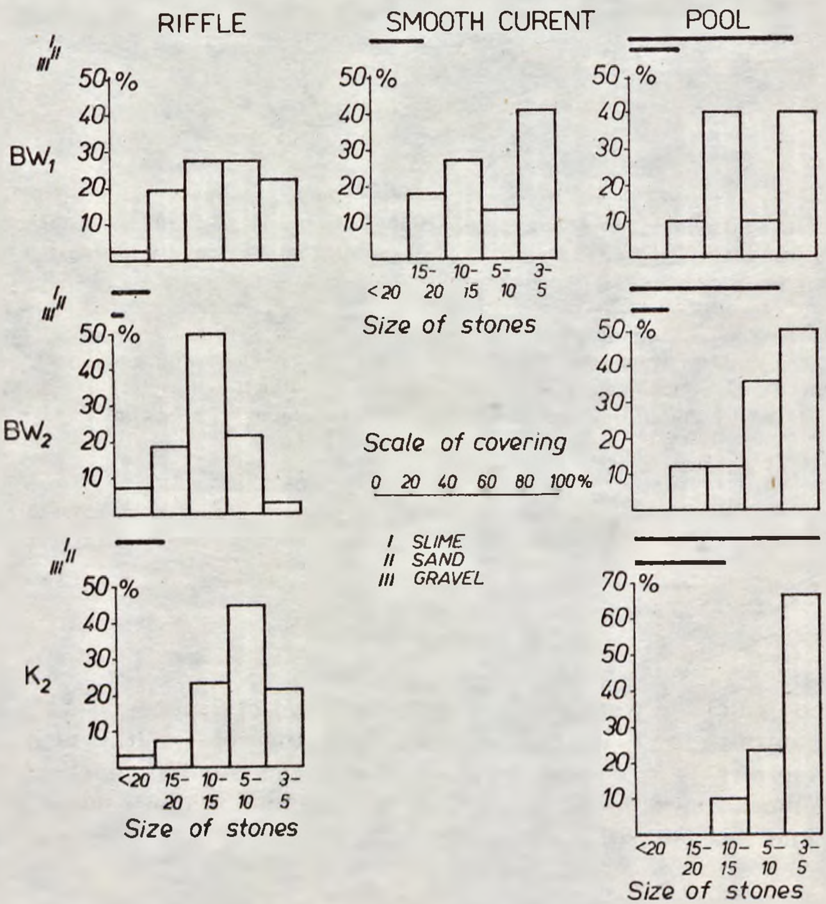


Fig. 1. Various types of bottom deposit at the different stations

impossible to avoid some differences in the chemical composition of the water (Bombówna 1982) associated with the geological structure of the basin or the character of the stream bed (fig. 1). Detailed desorptions of the catchment basin and of the stations have been given by Kownacki (1982), Kurek, Pawlik-Dobrowolski (1982), and Bombówna (1982).

3. Method

From March 1977 to April 1978, at 1-month intervals at each station types of habitat were determined and the percentage of the different habitats in relation to the investigated sector of the stream was estimated. A stony lotic habitat, stony habitat of „regular current", lenitic habitat, and marginal pools were determined. One sample was then collected from each habitat at the station. The samples were taken with a hand net, 22.5 cm in diameter, covered with 0.3 mm mesh bolting cloth. The volume ofstones was measured in a calibrated vessel, after which the animals and algae were washed off and the obtained material was preserved in 4% formalin. The animals were selected, identified, and counted in the laboratory. The number of animals in the sample was calculated per 2 dm^3 of the substratum. On the basis of the obtained results, means for all samples collected throughout the entire period of the investigation from the different habitats at the stations were computed. The percentage domination structure was found for these means. The „monthly sample" (Q_M) was calculated on the basis of samples from all habitats at a station, collected at one time, according to the formula:

$$Q_M = \frac{(Q_{jI} \cdot \%_I + (Q_{jII} \cdot \%_{II}) + \dots (Q_{jn} \cdot \%_n)}{100}$$

where: $Q_{jI}, Q_{jII}, \dots Q_{jn}$ = the numbers of species „j" at different habitats (I, II, ... n);
$\%_I, \%_{II}, \dots \%_n$ = percentage of the different habitats.

4. Results

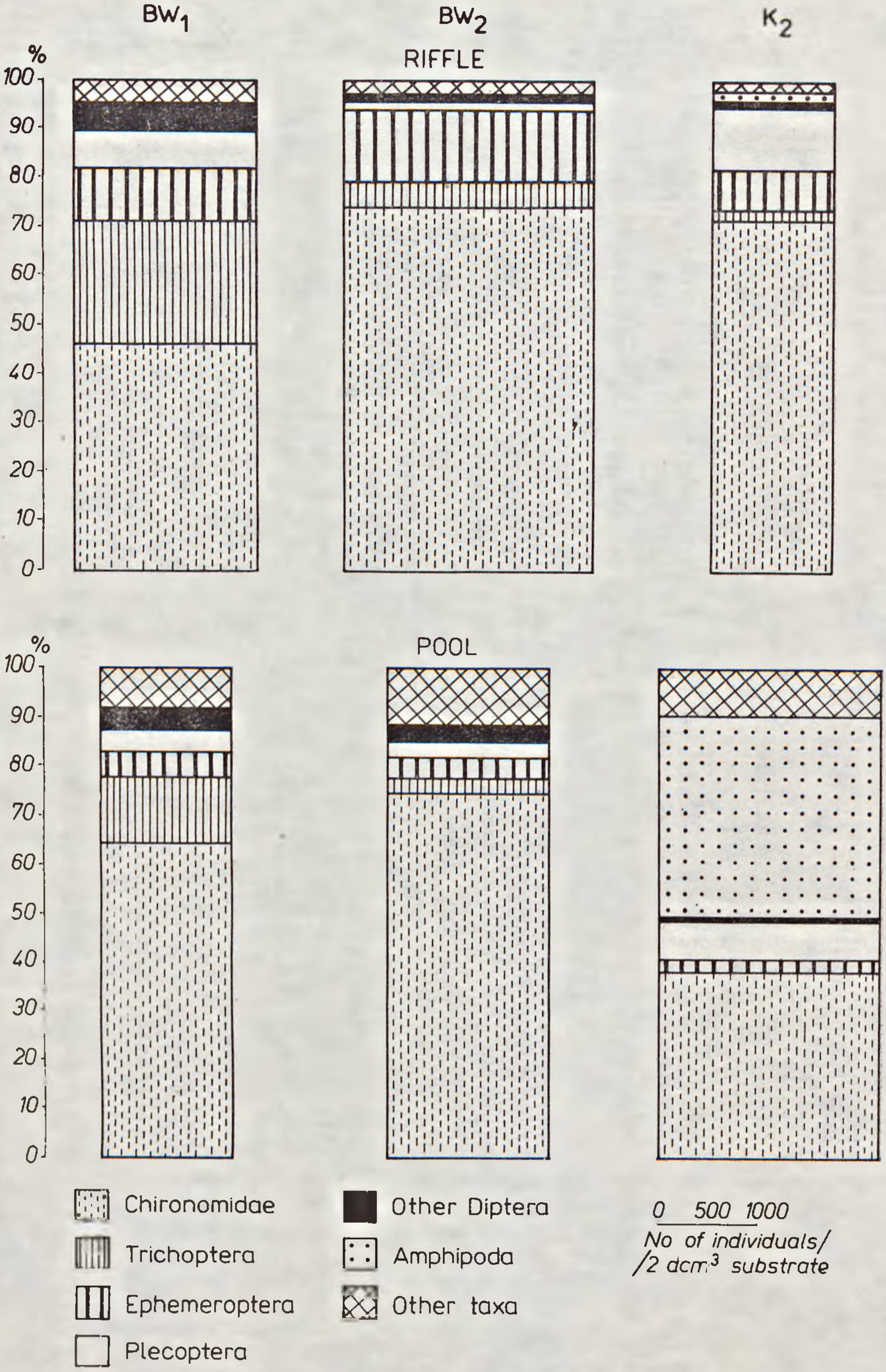
4.1. The species composition of animals

In the investigated streams 162 taxa of invertebrates were identified (Table I). The lost is not complete because only *Ephemeroptera, Plecoptera* (partly), *Trichoptera*, and *Chironomidae* were exactly iden-

Table I. Mean numbers of specimens from each taxon (per 2 dm^3/substratum) found during the 1977-1978 season at the stations BW 1, BW 2, and K 2 in various part of the stream: A - stony bottom in a fast current; B - stony bottom in a "regular" current; C - bottom in slow current or pools. - - not present in samples; x - present at the station (imago and specimens in quantitative samples). ♂ - imago; p - pupae. 1 - see: Dumnicka 1982; 2 - see: Biesiadka 1979; 3 - determined as: Antocha, Dicranota; 4 - see: Niesiołowski 1982

Taxon / Station, Part of stream	BW 1			BW 2		K 2	
	A	B	C	A	C	A	C
TURBELLARIA	4.7	3.6	0.9	6.5	-	10.8	14.7
NEMATODA	2.8	0.6	3.4	0.6	16.8	0.4	0.3
OLIGOCHAETA[1]	12.7	21.1	17.7	42.8	92.0	10.4	82.0
MOLLUSCA	-	-	0.6	-	-	-	-
HYDRACARINA[2]	12.3	12.6	9.7	7.6	16.0	9.1	61.3
OSTRACODA	0.2	2.9	30.3	0.5	41.6	0.2	2.7
AMPHIPODA	-	1.5	5.1	0.5	-	27.0	917.3
Gammarus fossarum Koch.	x			x		x	
Gammarus balcanicus Schäf.						x	
COLLEMBOLA	36.7	65.5	25.7	3.9	1.0	0.6	1.3
EPHEMEROPTERA	187.9	138.5	61.9	368.4	69.6	97.6	63.2
Baetis alpinus Pict.	11.1	1.4	-	8.2	-	7.0	-
Baetis lutheri M.-L.	17.3	2.7	-	54.4	2.4	0.7	-
Baetis rhodani Pict.	9.8	10.7	12.0	61.2	8.4	14.3	17.0
Baetis gr. fuscatus (? fuscatus L.)	-	-	-	0.8	1.6	0.7	1.3
Baetis gr. fuscatus (? beskidensis Sowa)	-	-	-	-	-	0.1	-
Baetis muticus L.	9.1	8.9	0.7	4.6	1.6	16.3	0.7
Baetis spp. (juv.)	89.9	26.7	12.3	206.9	8.0	35.4	5.3
Oligoneuriella sp.	-	-	-	0.25	-	0.1	-
Epeorus sylvicola Pict.	3.7	3.1	-	0.4	0.8	0.9	-
Rhithrogena sp.	3.7	2.1	-	4.3	-	10.6	1.3
Ecdyonurus spp.	1.5	6.3	8.0	1.2	6.4	3.9	2.0
Ecdyonurus dispar Curt.				x			
Ecdyonurus gr. venosus						x	
Ephemerella ignita Poda	0.7	-	-	2.9	-	-	-
Ephemerella mucronata Bgtn.	0.8	0.8	0.6	-	3.2	1.1	1.3
Ephemerella major Klap.	24.1	23.8	19.7	5.6	22.8	0.1	0.7
Ephemerella spp. (juv.)	9.3	43.7	4.0	14.0	7.2	0.8	0.3
Caenis pseudorivulorum Keff.	3.0	-	0.7	0.5	3.2	-	28.3
Caenis spp. (juv.)	0.5	0.6	0.6	0.6	-	-	-
Habroleptoides modesta Hag.	0.6	0.8	0.6	0.6	0.8	2.6	4.7
Habrophlebia fusca Curt.	-	-	-	-	2.4	-	-
Ephemeroptera (juv.)	2.8	6.9	2.7	2.0	0.8	2.3	-
PLECOPTERA	137.9	68.7	60.8	44.7	54.0	161.2	183.7
Brachyptera sp.	0.2	-		0.1	-	1.9	
Protonemura spp.	54.3	6.9	0.6	6.6	-	65.1	2.7
Protonemura autumnalis Rauser ♂				x			
Protonemura hrabei Rauser ♂				x			
Protonemura nitida Pict. ♂				x			
Protonemura praecox Morton ♂						x	
Amphinemura spp.	25.6	17.8	11.6	9.7	10.0	12.7	6.0
Nemoura spp.	2.2	3.6	15.3	0.4	7.6	25.2	30.3
Nemoura sp (? cinerea Retz.) ♂	x						
Nemoura sp (? flexuosa Aubert) ♂	x						
Leuctra spp.	38.8	27.4	31.3	20.9	32.4	39.1	74.0
Leuctra digitata Kmp. ♂				x			
Leuctra fusca L. ♂	x			x		x	
Leuctra inermis Kmp. ♂	x			x			
Leuctra mortoni Kmp.				x			
Leuctra pseudosignifera Aubert						x	
Perlodes intricata Pict.	0.2	-	-	-	-	-	-
Isoperla sudetica Kol.	-	-	-	-	-	1.6	-
Isoperla oxylepis Desp.	-	-	-	0.1	2.4	-	-
Isoperla buresi Raus.	-	-	-	-	-	0.2	-
Isoperla spp. (juv.)	0.3	0.6	-	0.2	-	0.7	-
Dinocras cephalotes Curt.	0.4	1.1	-	0.7	-	-	-
Chloroperla sp.	-	-	-	-	1.6	-	-
Plecoptera (juv.)	15.9	10.7	2.0	6.0	-	14.7	70.7
TRICHOPTERA	448.6	172.4	122.6	111.0	45.6	13.6	16.6
Rhacophila fasciata Hagen	-	-	-	-	-	0.1	-
Rhacophila mocsaryi Klap.	1.6	-	3.5	-	0.4	1.3	-
Rhacophila nubila Zett.	2.2	0.3	-	16.4	3.6	-	-
Rhacophila polonica Mc L.	0.1	-	-	-	-	0.5	-
Rhacophila obliterata Mc L.	-	-	-	0.4	-	0.1	-
Rhacophila pubescens Pict.	-	-	-	-	-	0.1	-
Rhacophila tristis Pict.	5.1	2.9	2.5	0.1	-	1.4	-
Rhacophila philopotamoides Mc L.	-	-	-	-	-	0.2	-
Rhacophila spp. (juv.)	3.0	2.7	-	1.7	-	2.5	-
Glossosoma conformis Neb.	14.6	6.3	0.5	1.4	-	-	-
Agapetus ochripes Curt.	-	1.7	-	-	-	-	-
Agapetus fuscipes Curt.	-	1.7	-	-	-	-	-
Hydroptila forcipata Eat.	-	2.3	-	-	-	-	-
Hydropsyche instabilis (Curt.)	40.8	16.1	2.5	16.6	1.6	-	-
Hydropsyche saxonica Mc L.	-	-	-	-	-	0.1	-
Plectrocnemia conspersa (Curt.)	-	-	-	0.3	-	0.4	-
Polycentropus flavomaculatus Pict.	-	-	-	0.6	4.0	-	-
Psychomyia pusilla Fabr.	21.6	24.6	2.7	47.4	12.0	-	-
Tinodes rostocki Mc. L.	0.3	0.7	-	-	-	4.4	1.3
Drusus discolor (Ramb.)	-	-	-	0.1	-	-	-
Ecclisopteryx guttulata dalecarica Kol.	0.1	1.1	-	0.4	-	-	-
Ecclisopteryx madida Mc L.	-	-	-	-	-	0.3	-
Potamophylax cingulatus Steph.	0.3	-	0.1	-	8.8	0.1	-
Halesus sp (? radiatus (Zett.))	-	-	-	-	0.8	-	-
Stenophylacini (juv.)	-	-	0.5	-	1.6	-	0.7
Chaetopteryx fusca Brau.	-	-	-	-	0.8	-	-
Chaetopterygini (juv.)	-	-	-	-	-	-	6.6
Psilopteryx psorosa carpathica Schmid	-	-	-	-	-	-	2.0
Annitella obscura (Mc L.) ♂				x			
Silo pallipes (Fabr.)	0.2	-	0.2	x	-	0.1	-
Silo piceus Brau.	-	-	-	-	0.8	-	-
Micrasema minimum Mc L.	354.6	95.2	98.2	23.8	-	-	-
Odontocerum albicorne Scop.	0.2	0.3	-	-	-	0.3	2.7
Ernodes articularis Pict.	-	-	0.2	-	-	-	-
Sericostoma spp.	1.8	12.5	7.2	1.6	9.2	1.3	3.3
Trichoptera (juv.)	2.3	4.0	4.5	0.2	2.0	0.4	-
MEGALOPTERA							
Sialis lutaria L.	0.3	-	1.3	0.5	-	-	-

Taxon / Part of stream (Station)		BW 1 A	BW 1 B	BW 1 C	BW 2 A	BW 2 C	K 2 A	K 2 C
DIPTERA (without Chironomidae)		111.2	42.2	58.2	35.5	60.4	18.2	26.7
Blepharoceridae		-	-	-	-	-	0.4	-
Tipulidae		-	-	4.0	-	-	0.3	-
Limoniidae [3]		13.9	20.0	22.6	10.0	3.2	3.6	3.0
Psychodidae		-	0.6	5.3	1.2	2.4	0.2	0.3
Dixidae		-	-	1.3	-	-	-	-
Simuliidae [4]		83.5	7.2	8.3	15.8	5.2	5.9	-
Ceratopogonidae		0.7	1.3	5.3	0.2	36.4	0.9	22.7
Empididae [4]		13.1	13.1	10.0	8.3	13.2	6.9	0.7
Tabanidae		-	-	0.7	-	-	-	-
Ephydridae		-	-	0.7	-	-	-	-
CHIRONOMIDAE		832.2	410.0	824.5	1843.9	1189.1	880.8	845.8
Macropelopia sp.		-	-	0.6	-	-	-	-
Apsectrotanypus trifascipennis (Zett.)		-	-	1.3	-	0.8	-	0.3
Paramerina divisa (Walk.)	p					x		
Conchapelopia pallidula (Mg.)	p				x			
Thienemannimyia - Reihe		0.9	1.3	18.0	1.3	62.8	2.5	18.3
Nilotanypus dubius (Mg.)		0.7	-	0.3	0.1	11.2	1.1	2.0
Tanypodinae (juv.)		0.5	1.4	8.7	0.7	13.6	3.4	14.7
Syndiamesa sp.		-	-	-	0.2	-	-	-
Diamesa gr. cinerella		0.2	-	-	1.6	-	8.5	-
Diamesa starmachi Kown., Kown.		-	-	-	1.1	-	3.5	-
Diamesa spp. (juv.)		6.2	-	-	186.5	4.4	157.7	7.3
Pseudodiamesa branickii (Now.)		-	-	-	-	0.4	-	-
Boreoheptagyia sp. (? monticola Ser.-Tos.)	♂				x			
Potthastia gaedii (Mg.)	p	3.3	8.0	1.0	0.9	3.2	0.1	-
Potthastia longimana Kieff.		-	0.2	-	0.6	-	0.4	-
Prodiamesa olivacea (Mg.)	p	-	6.6	16.0	-	1.6	0.3	4.7
Odontomesa fulva (Kieff.)		-	6.7	0.7	-	1.6	-	-
Brillia longifurca (Kieff.)		0.3	-	-	-	-	-	-
Brillia modesta (Mg.)	♂	0.5	-	-	x	-	-	-
Paratrichocladius rufiventris (Mg.)	♂	0.7	-	-	0.7	-	-	-
Paracladius sp. (? alpicola) (Zett.)	♂				x			
Cricotopus (C.) similis Goetgh.	♂ p	3.5	-	7.7	3.2	-	-	-
Cricotopus (C.) vierriensis Goetgh.	p	-	-	-	-	-	0.4	-
Cricotopus (C.) annulator Goetgh.	♂ p	-	-	-	-	1.6	-	-
Cricotopus (Isocladius) sp.		-	1.4	-	-	-	-	-
Cricotopus spp. (non det.)	p	0.3	-	0.7	0.1	0.8	-	19.3
Cricotopus spp. + Orthocladius spp.		241.3	84.7	88.3	233.7	204.0	147.2	42.0
Orthocladius (O.) sp. I	♂ p	43.0	6.1	10.3	62.9	144.0	73.6	5.3
Orthocladius (O.) gr. rhacobius	p	-	-	-	1.4	-	-	-
Orthocladius (O.) sp. (? oblidens (Walk.))	♂				x			
Orthocladius (O.) saxicola (Kieff.)	♂ p	0.2	-	-	0.5	-	-	-
Orthocladius (O.) frigidus (Zett.)	♂ p	17.2	-	0.7	70.4	-	39.6	8.0
Orthocladius (E.) rivicola (Kieff)	♂ p	14.7	-	2.0	269.2	0.8	3.7	-
Orthocladius (E.) thienemanni (Kieff.)	♂ p [1]	-	-	-	3.5	-	-	-
Orthocladius (E.) rivulorum (Kieff.)	♂ p	12.2	11.1	0.7	59.2	4.8	1.1	-
Orthocladius (Euorthocladius) sp.	p	-	-	-	-	0.8	-	-
Tvetenia spp.		28.3	7.4	13.0	10.4	7.2	13.9	-
Tvetenia bavarica Goetgh.	p	0.3	-	-	0.4	-	-	-
Tvetenia calvescens Edw.	♂ p	-	-	0.3	0.1	-	-	-
Eukiefferiella brevicalcar (Kieff.)	♂ p	1.2	5.7	-	2.7	-	1.2	-
Eukiefferiella sp (? claripennis (Lundb.))		1.7	-	1.3	3.1	3.2	4.8	-
Eukiefferiella clypeata (Kieff.)	♂	0.5	-	-	1.5	-	-	-
Eukiefferiella coerulescens (Kieff.)	p	-	-	1.0	-	-	-	0.3
Eukiefferiella ilkleyensis (Edw.)	p	3.0	-	-	29.5	9.6	-	1.3
Eukiefferiella minor (Verr.)	p	8.6	1.4	0.7	51.8	1.6	3.7	1.3
Eukiefferiella gracei (Edw.)	♂ p	11.1	2.3	0.7	53.6	4.0	8.8	0.7
Eukiefferiella gr. gracei (juv.)		41.2	4.6	4.7	105.2	1.6	0.4	-
Rheocricotopus fuscipes (Kieff.)	♂ p				x		x	
Rheocricotopus spp.		0.2	0.6	18.0	0.1	4.3	4.8	55.7
Heterotrissocladius marcidus (Walk.)		-	-	0.7	-	0.8	-	-
Paracricotopus niger (Kieff.)	p	1.7	0.6	0.7	14.4	6.4	-	-
Nanocladius sp.		0.5	0.4	-	15.1	-	-	-
Synorthocladius semivirens (Kieff.)	♂ p	0.4	0.6	26.3	8.6	405.6	34.1	10.0
Parorthocladius nudipennis (Kieff.)	p	-	-	-	10.8	-	10.9	2.0
Parametriocnemus stylatus (Kieff.)		0.3	0.6	0.7	2.8	-	1.7	3.0
Heleniella ornaticollis (Edw.)	♂	-	4.6	1.3	0.4	0.8	0.4	0.7
Limnophyes sp.		-	-	-	-	7.2	0.3	-
Limnophyes sp. (? prolongatus Kieff.)	♂				x			
Metriocnemus sp. (? hygropetricus Kieff.)		0.2	-	11.7	-	-	0.3	-
Pharaphaenocladius sp.		-	-	7.7	-	-	-	-
Pseudosmittia sp.		0.3	-	-	0.9	-	6.6	-
Chaetocladius perennis (Mg.)	♂				x			
Krenosmittia sp.		-	-	-	-	-	0.1	2.7
Krenosmittia camptophleps (Edw.)	p				x			
Parakiefferiella sp.		-	-	-	-	-	-	2.7
Orthocladiinae gen? 1. acutilabis		-	-	-	-	-	0.4	-
Orthocladiinae gen? sp. I		-	-	-	-	-	1.5	58.7
Thienemanniella spp.	♂ p	9.6	22.9	27.6	4.6	5.4	4.6	2.7
Corynoneura spp.	♂ p	4.7	9.7	19.0	1.9	5.6	4.2	31.0
Orthocladiinae (juv.)		318.0	138.8	80.0	520.7	114.4	271.9	126.7
Polypedilum sp. (gr. pedestre)		0.8	2.9	-	21.5	-	-	-
Polypedilum sp. (gr. nubeculosum)		-	-	-	-	0.8	-	-
Polypedilum sp. (gr. breviantenatum)		-	6.3	59.7	6.8	-	1.5	30.0
Polypedilum sp. (gr. convictum)		-	-	0.6	-	-	-	2.3
Paracladopelma sp.		-	-	-	-	0.8	-	-
Microtendipes sp. (gr. chloris)		4.0	6.9	12.0	-	8.8	0.1	-
Chironomini (juv.)		1.3	11.4	69.0	6.0	33.6	1.3	16.0
Micropsectra spp.	p	3.7	12.6	248.7	9.3	64.0	33.8	345.7
Micropsectra sp. (? bidentata Goetgh.)	♂				x			
Micropsectra sp. (? atrofasciata Kieff.)	♂				x			
Micropsectra apposita (Walk.)	♂				x			
Cladotanytarsus spp.		2.5	0.6	5.7	-	5.6	-	-
Cladotanytarsus vandervulpi Edw.	♂				x			
Rheotanytarsus spp.		15.8	7.0	0.7	0.2	-	4.3	2.0
Rheotanytarsus reissi Lehm.	♂ p	-	-	-	-	-	0.7	-
Neozavrelia fuldensis Fitt.	♂ p	17.5	20.9	16.0	59.5	15.6	-	-
Stempellinella sp. (? brevis Edw.)		-	-	-	-	0.8	1.5	0.7
Tanytarsini (juv.)		9.1	13.7	40.0	4.0	25.6	13.9	33.7
COLEOPTERA		6.1	-	9.3	7.3	12.4	3.2	2.7
T O T A L		1793.6	874.1	1232.0	2473.7	1599.1	1233.1	2281.3


BW1
BW2
K2
%
RIFFLE
100
90
80
70
60
50
40
30
20
10
0
%
POOL
Chironomidae
Trichoptera
Ephemeroptera
Plecoptera
Other Diptera
Amphipoda
Other taxa
0 500 1000
No of individuals/
/2 dcm3 substrate

tified. Of the remaining groups of fauna, *Oligochaeta* (Dumnicka 1982), *Simuliidae*, and *Epididae* (Niesiołowski 1982) have been investigated in separate works. Other groups, such as *Turbelaria, Nematoda, Mollusca, Hydracarina, Ostracoda*, and of the insects *Coleoptera* and the remaining *Diptera*, were only identified to higher taxonomic units. However, the list could be extended by species from groups studied in this area by other authors: *Oligochaeta* (Kasprzak 1979), *Hydracarina* (Biesiadka 1979), *Odonata* (Mielewczyk 1978a), *Heteroptera* (Mielewczyk 1978b), *Trichoptera* (Ridel 1978), *Coleoptera* (Galewski 1979), stoneflies (Wojtas 1964), and mayflies (Sowa 1975a).

4.2. Quantitative differences and the domination structure at the different stations and in various habitats

Most species appearing more frequently and in greater numbers were usually found at all stations. Only the caddis-fly *Micrasema minimum*, and the *Chironomidae Neozavrelia fuldensis* and *Paracricotopus niger*, which were fairly numerous at stations BW1 and BW2, did not appear at K2.

Greater differences were noted in the numbers and structure of benthic invertebrates at lotic and lenitic habitats between the different stations.

In the lotic habitat *Chironomidae* constituted the main part of benthic invertebrates (fig. 2). However, at station BW1 their percentage reached 45% only, while that of other groups, caddis-flies, mayflies, and stoneflies, was considerable. The proportions observed at this station were typical for natural zoocenoses of the Carpathian stream. At stations BW2 and K2, established in the pastures, the share of *Chironomidae* rose, exceeding 70%, while that of caddis-flies decreased. At stations K2 the percentage of mayflies fell while the numbers of stoneflies rose. The greatest total number of benthic invertebrates was noted at station BW2, and the smallest at K2.

In the lenitic habitat at stations BW1 and BW2 *Chironomidae* also constituted the most numerous group, reaching 65% of the total invertebrate fauna. At station K2 the amphipods (chiefly *Gammarus fossarum*) constituted the main part of the fauna (40%), *Chironomidae* being the next group with regard to number. The greatest total number of invertebrates was found at station K2 and the smallest at station BW1.

The domination structure of invertebrate communities in the different

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Fig. 2. The numbers and percentage composition of the bottom invertebrate fauna at the different stations

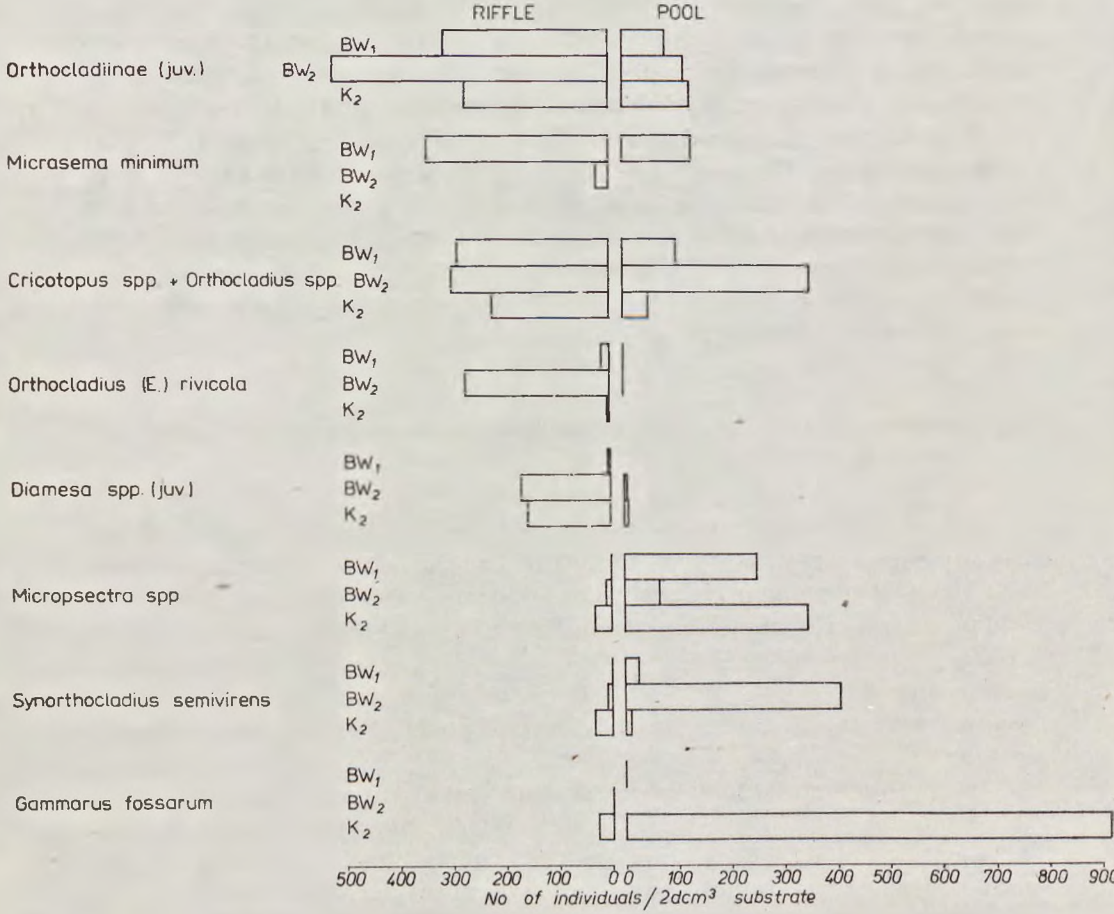

Fig. 3. The numbers of dominant species at the different stations and habitats

habitats of the stations was also analysed (fig. 3) The species and higher taxonomic units whose number exceeded 10% of the total invertebrate fauna at least one habitat were taken into consideration.

In lotic habitats, apart from unidentified young *Orthocladiinae* larvae and larvae of the genera *Cricotopus* and *Orthocladius* which appeared almost uniformly at all stations, the remaining taxa occurred in greater numbers at certain stations only. At station BW1 the caddis-fly *Micrasema minimum* predominated. *Orthocladius* (E.) *rivicola*, though encountered at all stations, was found in its greatest numbers at BW2. Similarly, mayflies of the genus *Baetis* (*B. lutheri*, *B. alpinus*, *B. rhodani*) and the larvae of *Chironomidae Eukiefferiella gracei* and *E. minor* which occurred at all stations, appeared in the greatest numbers at BW2. At K2 no taxonomic units characteristic for this station alone occurred. The larvae of the genus *Diamesa* which were among the dominants here, were also numerous at station BW2.

In lenitic habitats the formation of communities was different. In this type of stream lenitic habitats do not constitute a constant element during the year and their situation changes depending on the water level. At station BW1 *Chironomidae* larvae of the genus *Micropsectra* and the larvae of *Micrasema minimum* prevailed, though the latter were much less numerous than in the lotic habitat. At BW2 *Synorthocladius semivirens* larvae were the first dominant. At K2 there was a mass occurrence of the amphipod *Gammarus fossarum* and, similarly to station BW2, *Micropsectra* larvae were observed.

4.3. Seasonal cycles

The analysis of seasonal changes in the total numbers of the benthic invertebrates showed fairly pronounced differences between station BW1 and BW2, and station K2 (fig. 4). At BW1 the total number of the fauna rose in the winter months, then decreased and reached a minimum in the summer. A similar pattern of seasonal changes were observed at BW2, though the total numbers of the fauna in the different months were much greater than at BW1. A rapid decrease in numbers in December was brought about by the fact that at this station the stream was then covered with ice. The samples were collected in an arificial air-hole where water was scooped out with buckets for the nearby home, the biocenosis thereby being greatly damaged. At station K2 a few maxima were noted in March, July, November, and February, followed by a rapid decrease in the total number of the fauna.

The pattern of these changes was associated with the seasonal succession in the communities of invertebrate fauna and with the life cycles of the prevailing species. At station BW1 during the winter and early spring (from December to April) a community developed in which the caddis fly *Micrasema minimum* was dominant and which included young unidentified *Orthocladiinae* larvae and the larvae of the genera *Orthocladius* and *Cricotopus*. The emergence of *Micrasema minimum* imagines in May brought about a change in the community. Although unidentified, *Orthocladiinae*, chiefly young stages of species from the genera *Orthocladius* and *Cricotopus*, continued to prevail, a new important element, the mayfly larvae, appeared there. In July *Baetis* larvae appeared, but in August *Ephemerella* (chiefly *E. major*) was the only dominant. In October the community became similar to that in July with the dominance of unidentified *Orthocladiinae* and young *Baetis* larvae. From December, the gradual development of the winter community could be observed.

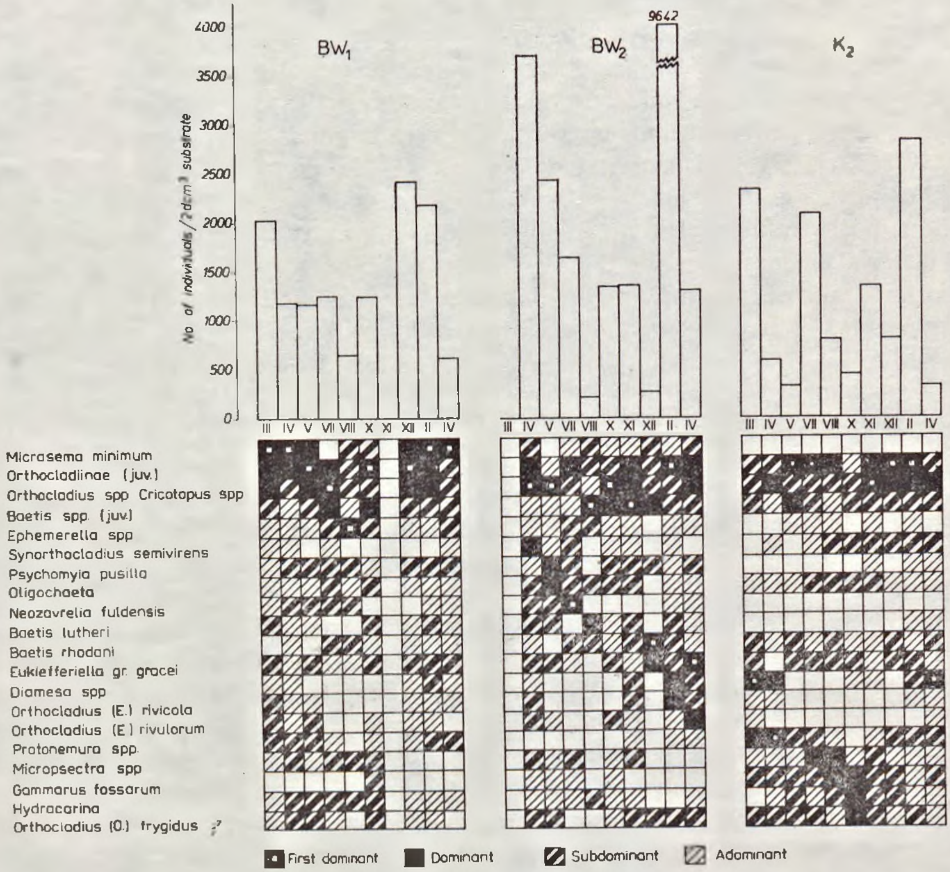

Fig. 4. Seasonal fluctuation in numbers and in the structure of benthic invertebrates at different stations

At station BW2 no such regularity could be observed. Single specimens of the caddis-fly *Micrasema minimum* were noted there, playing an inferior role in the community. Young *Orthocladiinae* larvae and larvae of the genera *Orthocladius* and *Cricotopus* which for the most part prevailed in the winter-spring period, constituted an important element of the community. In the summer and autumn (August — December) *Baetis* larvae (chiefly *B. lutheri, B. rhodani,* and young stages of *Baetis*) were an important element here. However, at this station the structure of the community was not stable. In different periods the mass occurrence of species which usually appeared as single specimens was observed. Very large numbers of *Chironomidae* larvae, *Synorthocladius semivirens* in April 1977, *Neozavrela fuldensis* in April and July 1977, *Eukiefferiella* gr. *gracei* from December 1977 to April 1978, *Orthocladius*

(E.) *rivicola* and *Diamesa* spp. in February 1978, and *Orthocladius* (E.) *rivulorum* in April 1978 can be mentioned here.

At K2 the seasonal succession of communities was different. Although, young *Orthocladiinae* larvae and the larvae of *Orthocladius* and *Cricotopus* still predominated, the structure of the community was not the same. In the spring (March-April) *Diamesa* larvae (chiefly *D. thienamanni*) and stonefly larvae of the genus *Protonemura* prevailed. From May to August, besides the young *Orthocladiinae* stages, the group of dominants was composed of mayfly larvae of the genus *Baetis* (May), *Chironomidae* larvae, *Micropsectra* (July and August), and the amphipod *Gammarus fossarum* (August). The amphipods were also the first dominants in the autumn (October). Larvae of the genera *Cricotopus* and *Orthocladius* and young *Orthocladiinae* larvae prevailed in the zoocenosis from November to February. In the spring a community with the *Diamesa* larvae as dominants again developed.

4.4. The flood

A rapid decrease in the total numbers of the fauna at station BW2 in August should be discussed in detail. It was brought about by torrential rain in the vicinity on 10th August at 11 a.m. The body of water flowing down the bare slopes formed flood wave carrying huge rocks and stones and destroying the stream biocenosis. Since at this station samples were collected on the 2nd and then on the 22nd of August, it

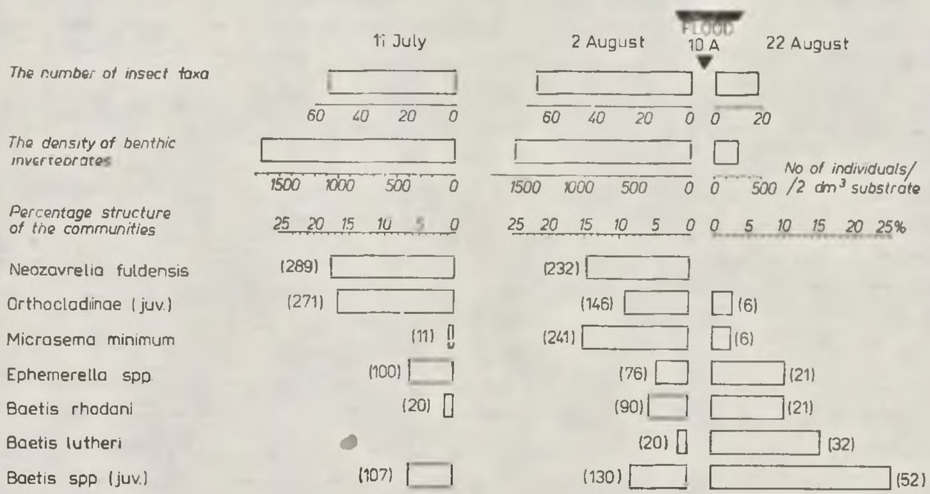

Fig. 5. The influence of the flood on the numbers and structure of benthic invertebrates (the numbers of specimens/2 dm³ of the substratum are given in brackets)

was possible to determine the influence of the flood on the development of invertebrate communities in the stream.

The flood reduced the number of taxa and the total numbers of the fauna (fig. 5). After the flood wave had passed the number of taxon units was 3.5 times decreased, falling from 66 to 18 taxa, while the total number of benthic invertebrates was reduced as much as 8 times (from 1600 to 200 specimens/2 dm^3 of the substratum). The structure of the zoocenosis was also changed. In the summer (July, August) larvae of *Chironomidae Neozavrelia fuldensis* and young stages of *Orthocladiinae* prevailed at this station. At the beginning of August the mass appearance of young larval stages of the caddis-fly *Micrasema minimum* was observed. Other species were found in smaller numbers. In the post-flood period the percentage of mayflies in the invertebrate community increased, while the number of other groups of the fauna, among them also *Chironomidae*, was rapidly reduced. The prevailing forms were then *Baetis lutheri*, *B. rhodani*, young stages of *Baetis*, and the *Ephemerella* larvae (chiefly *E. major*). It must be stressed that before the flood these species were also encountered there in great numbers (higher than after the flood), but their share in the total fauna was small, not exceeding 10%. A similar obesrvation was made in the Burns Rum stream in Pensylvania (USA) where larvae of the genus *Baetis* dominated after a sudden flood (Hoopes 1974).

5. Discussion

It is very difficult to determine the effect of intensification of the pastoral system on the bottom fauna of streams. The systematic list does not contain species or taxonomic forms characteristic for polluted waters. They are typical inhabitants of pure mountain streams.

However, fairly great differences were observed in the total number of the fauna and the structure of communities at the individual stations.

In the lotic habitat the largest numbers were found at station BW2 and the smallest at K2. This was in agreement with changes in the number of algae (Kawecka 1982) but did not correlate with the content of nutrients in the water. The greatest content of mineral nutrients was always noted at K2 (Bombówna 1982). At this station the increase in the content of nutrient substances was so high that it should rather raise and not reduce the number of algae, and consequently of the fauna. On the other hand, in the lenitic habitat the smallest total numbers of the fauna were found at station BW1 and the largest at K2. At K2 *Amphipoda* chiefly contributed to the observed increase. If it were not for them, the situation would not have differed from that in the lotic habitat. However, it seems that the development of amphipods at this station was not brought about by the inflow of nutrients but on the one hand by a marked increase in calcium content in the water (26—46 Ca mg/dm³ at station BW1; 53—66 Ca mg/dm³ at K2) and, on the other, by a reduced flow rate and greater bottom sliming. At stations BW2 and K2 in the lotic habitat a pronounced increase in the number of *Chironomidae* and a simultaneous decrease in the percentage of other groups of the fauna, especially of may flies and caddis-flies, as compared with the control station BW1, suggested the gradual eutrophocation of streams owing to the pastoral system.

The differences observed in the dominance structure of communities were still greater. *Chironomidae* larvae of the genera *Orthocladius* and *Cricotopus* and young *Orthocladiinae* larvae predominated but other prevailing species changed.

The absence of the caddis-fly *Micrasema minimum* at station K2 and its small percentage at BW2 were particularly interesting. This is a one--year species. At BW1 young larvae appeared in August. Their numbers then gradually rose until April. In April the larvae rapidly grew and in May very numerous pupae were found. In July no larvae or pupae were observed. Szczęsny (personal communication) observed a mass occurrence of this species in some Carpathian forest streams at 600—700 m above sea level. This might indicate that it is one of the indicator species for pure forest streams at this altitude. However, it is hardly possible that its absence at K2 and the reduction of its numbers at BW2 could have been brought about by the increased content of nutrients in water. A different explanation is possible here: in the streams which flow across the pastures the bottom is frequently damaged by numerous drief floods, this limiting the development of species with a one-year life cycle, especially those beginning their development in summer.

Another reason for differences in the communities at various stations can be found in the character of the bottom (fig. 1). At station K2 the bottom is composed of small stones, frequently covered with silt, even in the water current. This may explain the dominance of *Gammarus fossarum* and *Micropsectra* spp., characteristic for lenitic or poorly lotic habitats, in the summer-autumn period, while the rheophilous species *Orthocladius* (E.) *rivicola* and *Baetis lutheri* avoid this station.

The examples discussed above, based on averages from the entire period of the investigation, show differences in the number and structure of communities at the individual stations, but they do not prove conclusively that the changes were brought about by economic activity. More data can be obtained from the analysis of seasonal changes in the numbers and the dominance structure of communities at the different stations. At BW1 the changes show a regular pattern and are replicable from year to year. However, already at BW2, in spite of similar changes in the numbers of the fauna, the dominance structure is greatly disturbed. In some periods species whose percentage is later reduced occur in masses. At K2 this phenomenon was still more pronounced, the regularity of the seasonal changes of numbers and structure of the communities being disturbed. These phenomena show that the mechanisms of self-regulation in the communities have grown weaker. Owing to changes in the intensity of nutrient runoff from the pastures, certain species sometimes find better conditions of development in habitats not typical for them, but after a short period of dominance recede. Apart from increases in the nutrient content in the water, the reduction of forest areas is also responsible for the condition of zoocenoses. In the summer frequent rains bring about sudden rises in the water level in streams and destruction of the natural zoocenosis. The mass appearance of the caddis fly *Micrasema minimum* on 2nd August at station BW2 can be given as an example. The population of this station was greatly damaged by the flood of 10th August and was not regenerated. After the flood, the decreases in the total number of the fauna were much smaller at station BW1, which drained water from a forest area, than at station BW2 which received water also from open pastures.

The relatively poor literature on the effect of agriculture on invertebrate communities (Dance, Hynes 1980), especially in mountain regions, does not allow any far-going general conclusions to be drawn. Nevertheless it can be accepted that the impact of pastoral economy on the communities is chiefly expressed by the increased percentage of *Chironomidae* in the total fauna, by changes in the dominance structure, and by disturbances in the regularity of the seasonal fluctuation in the numbers and structure of the communities. In the species composition of the fauna no significant changes were noted.

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6. Polish summary

Ekosystemy potokowe na terenach pastwisk górskich (Karpaty Zachodnie)

8. Fauna bezkręgowców

Próby zbierano na trzech stanowiskach (BW1, BW2, K2) usytuowanych w potokach zbierających wodę ze zlewni o różnym stopniu intensyfikacji pasterskiej.

W badanych potokach oznaczono 162 jednostki taksonomiczne zwierząt (tabela I). Są to typowi mieszkańcy czystych górskich potoków.

Zaobserwowano natomiast dość znaczne różnice w ogólnej liczebności fauny (ryc. 2) i w udziale poszczególnych grup systematycznych na poszczególnych stanowiskach i siedliskach (ryc. 3). W siedlisku prądowym najniższą liczebność fauny stwierdzono na stanowisku K2, najwyższą na stanowisku BW2, a w siedlisku bezprądowym odpowiednio na stanowiskach BW1 i K2. Grupą dominującą na wszystkich stanowiskach i siedliskach były *Chironomidae*. Jednak na stanowisku kontrolnym BW1 w siedlisku prądowym ich udział wynosił tylko 45%, a pozostałych grup: chruścików, jętek, widelnic był znaczny, natomiast na stanowiskach usytuowanych na obszarze pastwisk (BW2, K2) znacznie wzrósł udział *Chironomidae*, osiągając ponad 70%, a zmalał udział innych grup. Na stanowisku K2 w siedlisku bezprądowym najważniejszym elementem fauny były kiełże.

Charakterystyczne są też zmiany sezonowe fauny na poszczególnych stanowiskach (ryc. 4). Na stanowisku BW1 zmiany te mają charakter uporządkowany. Ogólna ilość fauny wzrasta w miesiącach zimowych i następnie maleje, aby minimum osiągnąć w okresie letnim. Przebieg tych zmian wiąże się z sukcesją sezonową poszczególnych zespołów fauny i cyklami życiowymi gatunków dominujących. Ale już na stanowisku BW2 pomimo że zmiany liczebności są podobne, to struktura dominacji została znacznie zaburzona. Jeszcze trudniej mówić o prawidłowościach zmian sezonowych na stanowisku K2. Obserwujemy kilka maksimów: w marcu, lipcu, listopadzie i lutym, po których następuje gwałtowny spadek ogólnej liczebności fauny.

Oddzielnego omówienia wymaga raptowny spadek ogólnej liczebności fauny na stanowisku BW2 w sierpniu, spowodowany przez gwałtowny przybór wód (ryc. 5). Powódź spowodowała spadek ilości taksonów z 66 do 18 i ogólnej ilości fauny z 1600 na 200 osobników/2 dcm^3 substratu.

Reasumując, można przyjąć, że wpływ gospodarki pasterskiej na zespoły bezkręgowców wyraża się głównie przez: wzrost udziału *Chironomidae* w stosunku do całości fauny, zmiany w strukturze dominacji zespołów i zaburzenia w prawidłowości rocznych zmian liczebności i struktury zoocenoz. Nie ma większych różnic w składzie jakościowym fauny. Zmiany zespołów fauny bezkręgowców są spowodowane nie tylko przez wzrost biogenów w wodzie, ale również przez wiążące się z gospodarczą działalnością człowieka zmiany fizycznych parametrów takich jak różnice w przepływie wody, oświetlenia i temperatury, które są spowodowane wycięciem lasu. Inną przyczyną różnic pomiędzy zespołami z poszczególnych stanowisk mogą być różnice w charakterze dna (ryc. 1).

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