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Benthic macroinvertebrates in acidified streams of the Świętokrzyski National Park (central Poland)

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Abstract — In running waters of the Świętokrzyski National Park the benthic macroinvertebrate fauna is low in abundance and species diversity. In acidified streams its degradation can be seen. In the period 1986—1988 strongly acidified streams (pH 4—5, 2—4.1 mg Al dm^{-3}), which are the most numerous, only Plecoptera, Diptera, and Trichoptera were found: in sectors with pH < 4 only the caddis fly *Limnephilus coenosus* was found. Ecological analysis of Trichoptera was carried out. Some information about seasonal changes in density are given.

Key words: acidified streams, Świętokrzyskie Mts, National Parks, benthic macroinvertebrates, caddis flies.

1. Introduction

Chemical investigations of the aquatic environment of the Świętokrzyski National Park (Piechocki 1986, Wróbel, Szczęsny in press) revealed considerable acidification of its streams. The pH values of the water of the upper reaches usually varied from 4.4—5.4, and occasionally below 4 (Wróbel, Szczęsny in press). Great amounts of ionic aluminium (toxic to animals) were present in these waters. Thus, there was an urgent need to study the consequences of acidification of the environment in the invertebrate fauna of running waters in the Park. The investigation was begun in 1986 and to a great degree made use of recently published results of faunistic and ecological studies which had been carried out in this area, as well as in others by workers of Łódź University a few years earlier (Kittel et al. 1980, Wiedeńska 1982, Jażdżewska 1984, Kittel 1984).

2. Study area

The Świętokrzyski National Park (fig. 1) covers the highest ridge of the Świętokrzyskie Mts (central Poland), i.e. the Łysogóry range, part of the Klonowy Ridge, and the afforested part of the Wilkowska Valley, which divides these two ridges. The highest elevations of the Łysogóry Mts are: Mt Łysica, alt. 612 m, in the western and Mt Łysa Góra, alt. 594 m, in the eastern part. The highest elevation of the Klonowy Ridge does not exceed 430 m.

The slopes of the ridges are of low gradient (10—20%) and covered by fir forest with an admixture of beech. The line which divides forest from cropland is in general the border of the National Park.

The geological substratum of the Świętokrzyskie Mts is composed of metamorphic sedimentary Paleozoic rocks with low calcium content: Cambrian quartzite sandstones (the Łysogóry Mts) and differentieted Lower Devonian sandstones (the Klonowy Ridge). On them were formed brown soils and podzols which turned into lithogenic soils in peak areas. The bottom of the Wilkowska Valley is covered with impermeable loamy soils originating from Gottland-Ordowice argillaceous schist (S t r z e m s k i 1967). For this reason the valley forms a marsch and the gravelly--stony bottom of the streams flowing there is covered with black deposits.

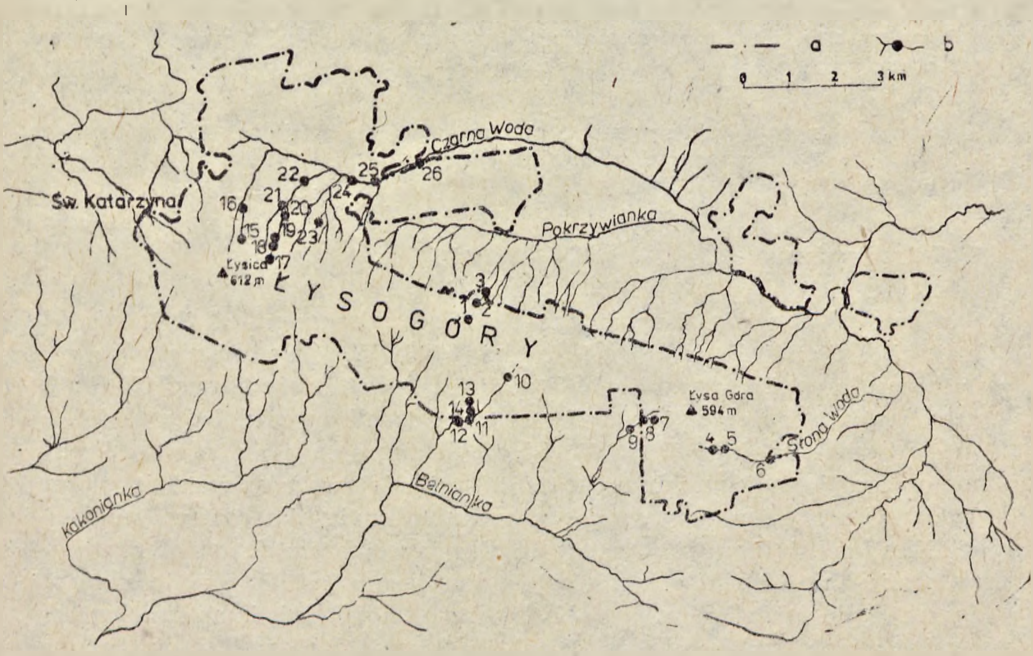

Fig. 1. Drainage network of the Łysogóry Mts. a — border of the Świętokrzyski National Park; b — sampling stations

Czarna Woda, the largest stream of the Świętokrzyski National Park, flows eastwards through the Wilkowska Valley, draining the northern slopes of Mt Łysica. The Pokrzywianka stream (a tributary of the River Kamienna) with its tributaries the Czarna Woda and Słupianka streams drains the northern and eastern slopes of the Łysogóry Mts. The southern and western slopes of the ridge are drained by the tributaries of the Lubrzanka and Belnianka streams (the River Nida basin). Numerous springs of various yield chiefly occur at the foot of the Łysogóry Mts at the border of quartzite-sandstone and impermeable shale layers.

Chemically, the waters of the springs and streams of the Świętokrzyski National Park represent the calcium-bicarbonate type at low and medium water levels, but during periods of high water their character changes into the calcium-sulphate type (Wróbel, Szczęsny in press). These waters are characterized by small amounts of dissolved mineral compounds and their conductivity is low (38.3—66.2 μS cm^{-1}). They have a low alkalinity (below 0.50 meq dm^{-3}) with low levels of calcium and magnesium. The geological substratum is built of hard rocks which are resistant to weathering and poor in basic compounds. Acid rain and the usually shallow cycling of waters which feed the stream

Table 1. Characteristics of the sampling sites on the streams of the Świętokrzyski National Park. a-altitude m; b-distance of the station from spring km; c-max.stream width m; d-mean depth of stream cm; e-max. current velocity m sek -1; f-main component of substratus; g-immediate surrounding of stream bed; s-spring; n-beginning of stream; LTB-left tributary of the Belnianka stream; RTP-right tributary of the Podłysica streaa

Station, Stream	a	b	c	d	e	f	g
1.Dębno	396	s	<0.4	<0.15	<0.3	rock chips, sand	bushes, coniferous forest
2.Dębno	360	0.3	<0.6	<0.2	0.6	rock chips, gravel	bushes, coniferous forest
3.Dębno	340	0.47	0.4-0.7	<0.25	0.5	stones, gravel	coniferous forest
4.Stona Woda	490	n	<0.4	<0.2	0.2	medium stones	mixed forest
5.Stona Woda	470	0.2	0.4-0.6	<0.2	0.4	rock chips, stones	mixed forest
6.Stona Woda	410	1.0	0.7-1.3	0.1-0.3	0.7	medium stones	mixed forest
7.LTB	468	s	<1.0	<0.15	<0.2	rock chips, gravel	mixed forest
8.Belnianka	465	0.5	0.3-0.6	0.1-0.2	0.4	medium stones	mixed forest
9.Belnianka	442	0.9	0.4-0.7	0.1-0.3	0.6	small stones, sand	meadows
10.Podłysica	500	n	<0.4	<0.2	0.3	rock chips, stones	mixed forest
11.Podłysica	385	1.5	0.6-1.0	0.1-0.2	0.5	medium stones	mixed forest
12.Podłysica	370	2.0	0.6-1.0	0.2-0.3	0.7	medium stones	bushes, cropland
13.RTP	410	0.03	<0.5	<0.2	0.3	small stones	mixed forest
14.RTP	390	0.2	0.5-0.8	<0.2	0.4	small stones, sand	mixed forest
15.Łysiczka	380	s	<0.7	<0.2	<0.2	medium stones	mixed forest
16.Łysiczka	327	0.8	0.5-0.8	0.2-0.3	0.5	medium stones	mixed forest
17.Czarny Potok	455	s	<0.4	0.15	0.2	rock chips	mixed forest
18.Czarny Potok	385	0.4	0.4-0.6	0.1-0.2	0.4	large stones	mixed forest
19.Czarny Potok	350	0.9	0.5-0.8	0.1-0.3	0.6	large stones	mixed forest
20.Czarny Potok	325	1.3	0.5-1.0	0.2-0.3	0.7	medium stones	mixed forest
21.Czarny Potok	317	1.5	0.7-1.0	0.2-0.3	0.6	medium stones	mixed forest
22.Czarny Potok	305	1.8	0.4-1.0	0.2-0.4	0.4	small stones, sand	bushes, meadows
23.Złota Woda	330	0.7	0.6-1.0	0.2-0.3	0.6	medium stones	mixed forest
24.Czarna Woda	282	3.5	1.0-1.5	0.2-0.5	0.5	stones, gravel	mixed forest
25.Czarna Woda	278	4.1	1.2-1.5	0.2-0.5	0.7	small stones, gravel	single trees, bushes
26.Czarna Woda	272	5.1	1.3-1.8	0.2-0.6	0.7	small stones, sand	single trees, bushes

network lead to the prevailing acid reaction of the water. During periods of low discharge (i.e. in a season of low precipitation, e.g. late summer/early autumn) the water usually slightly exceeds pH 5.2 while in periods of increased water discharge it falls below pH 5. With decreased pH values the content of aluminium increases even to 4.0 mg dm^{-3} (W r ó b e l unpubl.).

The annual precipitation amounts to about 800 mm in the Łysogóry Mts, exceeding the average in central Poland by about 200—300 mm.

The investigations were carried out at 26 stations (fig. 1, Table I) on the following streams: Dębno (Stations 1—3), Słona Woda (4—6), Belnianka (8—9) and its left tributary — LTB (7), Podłysica (10—12), right tributary of the Podłysica — RTP (13—14), Łysiczka (15—16), Czarny Potok (17—22), Złota Woda (23), and Czarna Woda (24—26) in the Wilkowska Valley. Only Stations 9 and 12 lie outside the forest, i.e. outside the National Park among meadows.

3. Material and method

Five or six replicate bottom samples were collected with a bottom sampler (2.5 dm^2) at Stations 1, 3, 5, 6, 8—12, 16—18, 20, and 25 on each sampling occasion. At the remaining 12 stations qualitative samples comprising many small samples from a total area of 0.5—1 m^2 were collected. Altogether, 146 quantitative and 18 qualitative samples was taken from 1986—1988. The sampling dates are given in Table II. Prior to the main sampling period, caddis flies were collected at Station 25 on 7. September 1984.

4. Results

4.1. Composition of the fauna

In samples from the streams of the Świętokrzyski National Park, nearly 17 000 individuals (Table III) of aquatic macroivertebrates were collected. They represented most of the taxonomic groups settling the stream environment. About 95% of individuals collected were aquatic insects, chiefly from the two orders Plecoptera and Diptera. Plecoptera were most abundant, this being a rare phenomenon, since in streams with stony bottoms Diptera usually prevail over other taxonomic groups of insects and frequently over all other groups of invertebrates.

Moreover, the very low variety of stonefly species is striking. They were represented almost entirely (99.7% of individuals) by two families — Leuctridae (*Leuctra* spp.), which prevail numerically, and Nemuridae (*Nemoura* spp., *Protonemura* spp., and *Nemurella picteti* K l a p.).

Table II. Dates of sampling collected in streams of the Świętokrzyski National Park. LTB - left tributary of the Belnianka stream; RTP - right tributary of the Podłysica stream

Station, Stream	12-13.VI. 1986	24-26.II. 1986	9.IV. 1987	11.VI. 1987	10.VIII. 1987	22.III. 1988	18.V. 1988	6.VI. 1988	23.VI. 1988	28.VII. 1988	11.X. 1988
1. Dębno	♦	♦									
2. Dębno				♦		♦					
3. Dębno	♦	♦									
4. Słona Woda	♦	♦									
5. Słona Woda		♦		♦							
6. Słona Woda	♦	♦	♦	♦							♦
7. LTB				♦							
8. Belnianka				♦							
9. Belnianka				♦							
10. Podłysica	♦	♦		♦							
11. Podłysica	♦	♦		♦		♦	♦	♦			
12. Podłysica				♦			♦				
13. RTP								♦			
14. RTP								♦		♦	
15. Łysicrka	♦										
16. Łysicrka	♦	♦									
17. Czarny Potok	♦										
18. Czarny Potok	♦	♦									
19. Czarny Potok											
20. Czarny Potok	♦	♦									
21. Czarny Potok					♦						
22. Czarny Potok					♦						
23. Złota Woda	♦							♦			
24. Czarna Woda					♦						
25. Czarna Woda	♦	♦		♦							
26. Czarna Woda									♦	♦	

Diptera consisted mostly of Chironomidae and Simuliidae. Of the Chironomidae larvae the representatives of Tanypodinae, Corynoneurinae, Orthocladiinae (incl. Diamesinae), and Chironominae (Chironomini and Tanytarsini) were observed. Of Simuliidae, which were not identified as to species, pupae of the genera *Eusimulium* and *Odagmia* were observed.

With regard to numbers, Trichoptera held the third place. Basically, they were found at every station, though in small quantities. Of 31 species (Table IV) found in the Łysogóry streams only eight were represented by at least 50 individuals (i.e. not less than 3% of the specimens collected in 1938). The most numerous and most frequently encountered were *Chaetopteryx villosa*, *Plectrocnemia conspersa*, and *Wormaldia occipitalis*. The larva of the first named is a case-building detritivore. It is a species commonly encountered in the streams of central and northern Europe but does not occur in the Carpathians.

P. conspersa larvae are net-spinning predators which possess high ecological tolerance.

W. occipitalis larvae are net-spinning microfilterers feeding on fine organic matter. This is an oligostenothermic species.

Fairly numerous but infrequently found is the tube-case-making detrivore *Limnephilus coenosus*. In the Łysogóry Mts it settles the upper sectors of streams with varying discharges and without distinctly

Table III. Benthic invertebrates collected in streams of the Świętokrzyski National Park in the period 1986-1988. LTB - left tributary of the Bełmianka stream; RTP - right tributary of the Podłysica stream; ZW - Złota Woda stream

Taxa	Streams	Dębno			Słona Woda			LTB	Bełmianka		Podłysica			RTP		Łysiczka		Czarny Potok						ZW	Czarna Woda			Sum	%
	Stations	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26		
	Min. pH	4.8	5.7	5.7	3.3	4.1	4.2	5.0	4.3	4.6	3.8	5.2	5.2	5.7	6.5	5.0	5.1	4.0	4.2	6.4	5.1	6.0		5.4	5.3	5.3	6.0		
Trichadida																													
Dugesia gonocephala (Dug.)			16	79								11	1															107	0.63
Gastropoda																													
Bythinella austriaca Fr.								1																				1	0.01
Lamellibranchiata																													
Pisidium spp.																21				1					1	1		24	0.14
Oligochaeta (total)																													3.67
Nais spp.											4			9												65	190	268	
Stylodrilus heringianus Cl.		8		1		1	7	1		2		7	1	1			34		5		20			2				90	
Enchytraeidae n.det.		3	3	7	5	5	35		2	2	150	8	3			1	11	3	6		13					9		266	
Hydracarina n.det.		5	2		1	3	7			1	1	1	1				4				20						21	67	0.39
Amphipoda																													
Gammarus fossarum Koch.							1							430						15								446	2.63
Ostracoda n.det.			2											2														4	0.02
Ephemeroptera (total)												2		25						4		2			4	41	49	121	0.71
Plecoptera (total)																													42.3
Nemoura spp.		60	105	52		42	286		12	4	141	197	142	15	40	16	1	114	47		50		1	30	4	76	205	1640	
Nemurella picteti Klap.		120		5		36	72	19	27	23		7	2			39	8	21	109		30		7	20		10	103	660	
Protonemura spp.			196	501	5		466					4		5	20	5	1			2			11		3	5	20	1244	
Leuctra spp.		36	424	133		101	656	8	18	5	5	635	23	10	44	2	155	165	83	14	199	25	18	160	89	127	465	3810	
Diura bicaudata (L.)															10					4								14	
Siphonoperla sp.							6					5																11	
Odonata n.det.																	2				1		3			1		7	0.04
Coleoptera n.det.		1	6	15	2	7	9			2	29	7	2		17		11	2	2		24			4		28	156	315	1.85
Megaloptera																													
Sialis sp.																			2							24	4	30	0.18
Trichoptera (total)		69	192	103	134	66	107	8	5	14	44	42	5	65	59	27	159	17	26	81	105	191	55	39	61	125	139	1938	11.4
Diptera (total)																													36.1
Tipulidae n.det.				1		2	1				1	1	1				1				1							9	
Limoniidae n.det.		4	8	9			3				8	5					6		3									46	
Psychodidae n.det.		2																										2	
Simuliidae n.det.			30	140			985	5		7	1	291	6	1	12		3		1	40	160	100	40	15	15	14	80	1947	
Chironomidae n.det.		7	50	34		31	689	17	1	90	173	192	37	17	295	1	290	52	116	160	570	150	50	18	65	210	721	4026	
Dixidae n.det.				2			1								11													14	
Ceratopogonidae n.det.												1	1				4		1		1						7	15	
Tabanidae n.det.												1				1			1									3	
Empididae n.det.							18					7	2		2		1				5			1		7	19	62	
Total																												16987	100.0

developed springs. For example, in the upper sector of the Słona Woda stream (Station 4), with a low discharge of very acid water (pH 3.3—3.8), almost the only inhabitants are larvae of this species. It is an acidophilous species colonizing stagnant waters, chiefly dystrophic marshes and peat bogs.

Table IV. Caddis flies (Trichopteral collected in streams of the Świętokrzyski National Park in 1984 and 1986-1988. LTB - left tributary of the Belnianka stream; RTP - - right tributary of the Podłysica stream; ZW - Złota Woda stream

Taxa	Streams	Dębno			Słona Woda			LTB Belnianka			Podłysica			RTP		Łysiczka		Czarny Potok						ZW	Czarna Woda			Sum	%
	Stations	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26		
	Min. pH	4.8	5.7	5.7	3.3	4.1	4.2	5.0	4.3	4.6	3.8	5.2	5.2	5.7	6.5	5.0	5.1	4.0	4.2	6.4	5.1	6.9		5.4	5.3	5.3	6.0		
1. Rhyacophila fasciata Hag.			5	4															1					1	1	7	10	29	1.5
2. - obliterata McL.							18															1		2	8	1	3	33	1.7
3. - tristis Pict.			8																									8	0.41
Rhyacophila spp. juv.			10	9																	2				5	2	7	35	1.81
4. Ptilocolepus granulatus (Pict.)							13																					13	0.67
5. Hydroptila sp.																											6	6	0.31
6. Wormaldia occipitalis (Pict.)			129	54								2		2	9					31	38	30		15				319	16
7. Polycentropus flavomaculatus (Pict.)																	1						1		23	41	8	74	3.82
8. Plectrocnemia conspersa (Curt.)			6			46	42	7	4	7	34	19	2		6		46	17	25	5	35	64	24	2	7	1		399	20.6
9. Hydropsyche pellucidula (Curt.)																											2	2	0.1
10. - saxonica McL.																									4	35	8	47	2.43
Hydropsyche spp. juv. (saxonica ?)																											67	67	3.46
11. Lithax obscurus (Hag.)																					3	8						11	0.57
12. Silo pallipes (Fabr.)														3						3	2	2				2	1	13	0.67
13. Grumotia irrorata (Curt.)		3	6	13										1	4	2				2								31	1.6
14. Lianephiles cognatus Curt.					134	19					10																	163	8.41
15. Chaetopterygopsis maclachlani Stein																										1		1	0.05
16. Chaetopteryx villosa (Fabr.)		56	2	3		1	34	1	1	1				52	34	25	39			9	13	52	10	18	2	11	5	425	21.9
17. Micropterna lateralis (Steph.)																	1											1	0.05
18. Potamophylax cingulatus (Steph.)			1	9								6					7			11	4	14	7		11	7		77	3.97
19. - latipennis (Curt.)																											1	1	0.05
20. - luctuosus (Pill.)																										6		6	0.31
21. - nigricornis (Pict.)		6	4									5	3	6	2		2				1					1		30	1.55
22. - rotundipennis (Brau.)																											9	9	0.46
23. Halesus digitatus (Schr.)																						1				1	3	5	0.26
Stenoph.+Chaetopt. spp. juv.		1	4									5							15	1	8							34	1.75
24. Sericostoma personatum (Spence)			17	11								2		1	4		13			5	6	11						70	3.61
25. Odontocerum albicorne (Scop.)												3												1				4	0.21
26. Molannodes tinctus (Zett.)																							13			2	1	16	0.83
27. Beraeodes minutus (L.)																											1	1	0.05
28. Adicella filicornis (Pict.)		3																										3	0.15
29. Mystacides nigra (L.)																											1	1	0.05
30. Athripsodes albifrons (L.)																										2		2	0.1
31. Athripsodes sp. (cognatus ?)																										5	6	11	0.57
Number of species		4	9	6	1	3	4	2	2	2	2	6	2	6	6	2	7	1	2	7	8	9	5	6	7	15	15		
Number of specimens		69	192	103	134	66	107	8	5	14	44	42	5	65	59	27	159	17	26	81	105	191	55	39	61	125	139	1938	100.0

With regard to functional feeding groups (Merritt, Cummins 1978), most species (14) belong to shredders, 7 to scrapers, and 5 each to predators and collectors. But the largest percentage of collected larvae, 64.4%, consisted of collectors, 44.9% shredders, 6.4% predators, and only 2.4% scrapers. The collectors were all filterers, 2 species (24.4% of individuals) feeding only on animal food (*P. conspersa* and *Polycentropus flavomaculatus*).

4.2. Not numerous groups

In Łysogóry streams the groups represented by small numbers of individuals were: Tricladida, Mollusca, Amphipoda, and Ephemeroptera. Tricladida were found in the Dębno (Stations 2—3) and Podłysica (Stations 11—12) streams only: Mollusca in streams on the northern slope of Mt Łysica (Stations 16 and 20), in the Czarna Woda stream (Stations 11—12) streams only; Mollusca in stheams on the northern Amphipoda in RTP and in the middle course of the Czarny Potok stream (Station 19).

Ephemeroptera were basically found only in RTP, in the middle and lower course of the Czarny Potok stream (Station 19 and 22), and in the Czarna Woda (Stations 24—16). Of 121 collected individuals 88 originated from the Czarna Woda stream; all other species, with the exception of *Electrogena samalorum*, were also observed here (Table V).

No Hirudinea occurred in the investigated streams.

4.3. Density of settlement

The numbers of individuals found in the samples, calculated per 1 m², varied considerably during the period under investigation. The

Table V. Mayflies (Ephemeroptera) collected in streams of the Świętokrzyski National Park in the period 1986-1988

Species \ Station Alt. pH	11 5.2	14 6.5	19 6.4	22	24 5.3	25 5.3	26 6.3	Sum
1. Siphlonurus sp.				1				1
2. Baetis rhodani (Pict.)		8			1	6	18	33
3. Procloeon bifidud Bqlss.							2	2
4. Electrogena samalorum Landa		16	4					20
5. Paraleptophlebia cincta (Retz.)						25		25
6. - submarginata (Steph.)				2		1		3
7. Habrophlebia fusca (Curt.)	2	1			3	5		11
8. - lauta Etn.							23	23
9. Ephemera vulgata L.						2		2
10. Potamanthus luteus L.						1		1
Total								121

smallest recorded total was 38 individuals and the largest 10 096, in each case the samples being taken at the same station but during different seasons. The smallest number of animals was found in samples from spring 1987. The above-mentioned sample of 38 individuals was taken on 9 April from the Słona Woda stream (Station 6). This was during a period of run-off of meltwaters with a low pH 4.2 after a winter of unusually severe frosts and abundant snowfall. In a sample taken at this station two months later the number of animals was already 8 times greater, but in general the density of settlement of the stream bed by macroinvertebrates was poor at that time; it amounted on the average to 462 specimens m^{-2} with a minimum of 184 and a maximum of 1200.

A year earlier (12—13 June 1986), after a mild winter of scarce snowfall, an average number of 3247 individuals m^{-2} (with extreme values of 312—7208) was found in the Łysogóry streams. In autumn of the same year the mean number of individuals amounted to 3249 m^{-2} for all stations, with extreme values of 736—10 096. These were the highest numbers recorded in the three-year period of the investigation.

5. Discussion

5.1. General discussion

Very small numbers of triclads, molluscs, amphipods, and mayflies live in the streams of the Świętokrzyski National Park. No leeches were encountered in spite of the fact that Wojtas (1957) collected 45 specimens belonging to the species *Erpobdella monostriata* (Gedr.) and *Glossiphonia complanata* (L.) in 1955. At that time these two leeches lived, among other places, at Stations 11, 16, and 21. In a detailed investigation on the distribution of leeches in streams of the southern slopes of the Łysogóry Mts between 1975 and 1977, Wiedeńska (1982) found that the species *E. monostriata* appeared in samples in the vicinity of cropland 300—400 m from the forest line. A similar observation was also made by this author in a stream on the northern slope of the range (Kittel el al. 1980).

Information obtained from local residents indicates that the extinction of crayfish which used to live here in great numbers, took place about 20 years ago. Swedish data (Anon. 1982) indicate that it is the crayfish (*Astacus astacus* (L.)) as well as some other crustaceans, leeches, snails, and bivalves, that are among the benthic animals most sensitive to increased acidification. Negative consequences were already observed in populations of these animals at pH values below 6. Animals which produced calcareous skeletons experience difficulties in the assimilation

of calcium ions (M a l l e y 1980, cited according to S t e n s o n 1985) and the shells of crayfish and snails are known to soften.

The sensitivity of mayflies to acidification is somewhat differentiated. Swedish investigations (E n g b l o m, L i n g d e l l 1983) showed that mayflies of the genera *Caenis* and *Ephemera* completely disappear when the pH value of the water approximates to 5.5, though *Baetis rhodani* may still exist at pH 4.5—5.0 and *Leptophlebia marginata* even below pH 4.5. The observations conducted on the Łysogóry mayflies to a great degree confirm the above data. In the present study in strongly acidified streams with pH $<$ 5.0 no mayflies were found. Among mayflies of the Czarna Woda stream where the pH value amounted to 5.5, *B. rhodani* was fairly common and in spite of the absence of *L. marginata* in the samples Leptophlebiidae dominate here.

J a ż d ż e w s k a (1984) found only Leptophlebiidae (imagines of *L. marginata*, *L. vespertina*, and *Paraleptophlebia submarginata*) in the Świętokrzyskie Mts (the Klonowy ridge) in the vicinity of the upper, acidified (pH 3.2—4.8), sector of the Lubrzanka stream where she did not succeed in catching mayfly larvae. Thus, it is possible that also other species of this family are resistant to acidification.

The species collected in the Łysogóry streams are chiefly inhabitants of lowland streams (*Paraleptophlebia cincta* and *Habrophlebia fusca*) or lower sectors of submontane and montane streams with a low gradient (*P. submarginata*, *H. lauta*, *Potamanthus luteus*) while *B. rhodani* is found only in true montane streams (S o w a 1875). *Electrogena samalorum* is assumed to be a rheobiontic form, since larvae of this species were found in the swift current of the Czarny Potok stream (Station 19) in a sector of considerable gradient (about 60‰) and in RTP; however, detailed data concerning its ecology were not found in the available literature.

Stoneflies should be classified with groups moderately sensitive to acidification. Their response to a decreased pH value is above all manifested by a fall in the number of species and the development of a strong predominance of a few of them. When this occurs there is a general decrease in the density of settlement. In strongly acidified stream sectors only rare specimens of the genus *Nemoura* could be caught. From the imaginal material collected by K i t t e l (1984) *Nemurella picteti* and *Leuctra nigra* (O l i v.) dominated, constituting 86% of individuals.

On the basis of imaginal stages K i t t e l (1984) gives 12 species of stoneflies for upper, afforested sectors of streams: 8 of the family Nemuridae, 3 of Leuctridae, and 1 (*Diura bicaudata*) of Perlodidae. In the present study one more species of the genus *Siphonoperla* sp. (Chloroperlidae) was also found. The following comparative data may be given: in the streams of the Gorce range 57 species of stonefly

(Fiałkowski, Olechowska 1987) and on Mt. Babia Góra 56 species (Sowa, Szczęsny 1970) were found. These differences are too great to be explained only by the slight ecological differentiation of the water environment of the Łysogóry Mts and their geographical isolation.

5.2. Caddis flies, an attempt at ecological analysis

In a study on imaginal stages of caddis flies of the Świętokrzyskie Mts Riedel and Majecki (1989) found 28 species in the area of the Park and a further 24 species in neighbouring territory. Of these 28 species only 16 inhabit running waters. In the present study 3 of them were not found (*Notidobia ciliaris* (L.), *Stenophylax permistus* McL., and *Beraea pullata* (Curt.)), but the representatives of 11 other not previously recorded species were collected. Therefore, the list of caddis flies of the Świętokrzyski National Park includes 39 species (and 19 in the vicinity of the Park).

Three of eight numerously abundant species, i.e. *Plectrocnemia conspersa*, *Wormaldia occipitalis*, and *Potamophylax cingulatus*, are included in community D (Szczęsny 1986), which settles upper sectors of forest streams in the Beskidy Mts. This community is also composed of species of the genera *Rhyacophila* and *Odontocerum albicorne* small numbers of which were found in the Park. These forms constituted 46.2% of individuals found there. In the Łysica streams they were usually accompanied by *Chaetopteryx villosa*, which constituted 21.9% of individuals, thus making a total of 68.1% of all caddis larvae in the streams. It may be that these eight species form a community which corresponds with the Beskid community D.

Of the remaining abundant species, *Hydropsyche saxonica* with less numerous *Potamophylax luctuosus* and *Silo pallipes* (a total of about 6% of individuals) constitute community E which inhabits the middle courses of Beskidy streams; *Polycentropus flavomaculatus* with scarce specimens of *Hydropsyche pellucidula* are members of Beskid community G (rivers and lower sectors of large streams); scarce individuals of *Crunoetia irrorata* and *Potamophylax nigricornis* (a total of 3.1% of all individuals) are included in community C settling Beskid springs.

If it is assumed that the above-mentioned groups of species in fact form complete equivalents of communities (e.g., C′, D′, E′) in Łysogóry streams, most investigated streams are settled by populations of caddis flies with a predominance of those from community D′ and springs by species of community C′. Community E′ is developed only in the Czarna Woda stream at Station 25 below the bridge at Celiny. It may be

that the still lower sector (Station 26) with the lowland species *Potamophylax rotundipennis* begins the zone of a lowland stream.

As compared with Gorce streams settled by similar communities of caddis flies (Szczęsny 1987), the quantitative proportions between the functional groups differ slightly. In both types of stream shredders prevail but in the Gorce streams predators and scrapers appear with them, while in the Łysogóry streams shredders occur with filterers only.

It should be stressed that in the Łysogóry streams no representatives of the family Drusinae or genus *Apatania*, typical algal feeders of springs and upper sectors of streams, were found to occur. In the Łysogóry streams the number of species was half that known from the Gorce ones.

Caddis flies should be classified as a group of animals moderately sensitive to acidification, though they were represented by twice the number of species represented by stoneflies. Generally, the lower pH value of the water at a station the smaller was the number of caddis fly species living there. When the pH value fell below 5.0 the number of species decreased rapidly (Table VI). In strongly acidified sectors of

Table VI. Dependence of the number of caddis fly (Trichoptera) species upon the lowest pH value of the water at a given station in the period 1986-1988

Min. pH	Number of stations	Number of species		
		min.	max.	mean
> 6.0	4	6	15	9
5.0-5.9	12	2	15	6
4.0-4.9	7	1	4	3
3.3-3.9	2	1	2	1

streams a few individuals either of *P. conspersa* or *Limnephilus coenosus* were found. *P. conspersa* is characterized by a great resistance to acidification and a tolerance of heavy metals at high concentrations (Darlington et al. 1986). Hence, in the strongly acidified stretches its small numbers might have been caused not so much by the toxic chemical conditions of the environment as by the absence of sufficient quantities of the invertebrate animals which constitute its food.

L. coenosus is an acidophilous form settling stagnant waters, chiefly dystrophic marshes and peat bogs. The initial sectors of the Łysogóry streams with small discharge and considerable quantities of the bottom detritus which constitutes its food, provide suitable conditions for its development, in spite of very low pH values (3.3—3.8) and a large content (over 4 mg Al^{3+} dm^{-3}) of toxic aluminium. Thus, *L. coenosus* is one of the invertebrate species most resistant to acidification of the

water environment, even if brought about by strong mineral acids and not only by weak humic ones. It is worth stressing that in some countries, on account of the decline of wet and peatbog areas which constitute its natural habitat, it has been classified as an endangered species (Wichard 1979, 1986, Tobias D., W. Tobias 1984).

An advanced degradation of benthic macroinvertebrate fauna was found in the running waters of the Świętokrzyski National Park.

The extent of degradation of the fauna in a stream reflects the degree of its acidification and is more distinctly manifested in the springtime.

In the Świętokrzyski National Park slightly acidified streams are settled by small populations of species sensitive to acidification (e.g. mayflies, amphipods, and bivalves). An inventory of these localities and guidelines for their protection against acidification are urgently needed.

Analysis of ecological interactions, particularly among caddis flies, suggests that not only acidification contributes to the impoverishment of invertebrate fauna in the Świętokrzyski National Park but also the homogeneous nature of the stream bed in the Łysogóry range and the poor food resources for macroinvertebrates in the form of algae, as well as the geographical isolation of these mountains.

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7. Polish summary

Makrobezkręgowce bentosowe w kwaśnych strumieniach Świętokrzyskiego Parku Narodowego (centralna Polska)

Niniejsze badania miały na celu rozpoznanie skutków zakwaszenia środowiska w faunie bezkręgowych wód płynących Ś.P.N.

Badania przeprowadzono w latach 1986—1988 (tabela II), w następujących potokach (ryc. 1, tabela I): Dębno (1—3), Słona Woda (4—6), Belnianka z dopływem (7—9), Podłysica z dopływem (10—14), Łysiczka (15—16), Czarny Potok (17—22), Złota Woda (23) oraz Czarna Woda (24—26).

Na 26 stanowiskach pobrano 146 prób ilościowych i 18 jakościowych, w których znaleziono niemal 17 000 osobników bezkręgowców wodnych. 95% osobników przynależała do owadów, głównie z dwóch rodzin: widelnic i muchówek (tabela III). Liczebnie dominowały widelnice, które reprezentowane były niewielką liczbą (13) gatunków, niemal wyłącznie z dwóch rodzin: Leuctridae i Nemuridae. Wśród muchówek dominowały Chironomidae i Simuliidae. Trzecie miejsce pod względem liczebności osobników zajmowały Trichoptera reprezentowane przez 31 gatunków (tabela IV).

Stwierdzono daleko posuniętą degradację fauny bezkręgowych potoków S.P.N. wyrażającą się ograniczonym, do nielicznych potoków o wyższym pH wody, występowaniem bezkręgowców najbardziej wrażliwych na zakwaszenie, t.j.: mięczaków, skorupiaków, jętek (tabela IV) i całkowitym brakiem pijawek. Stwierdzono także spadek liczby gatunków chruścików wraz ze spadkiem pH (tabela VI). Ujemny wpływ niskiego odczynu wody zaznaczył się szczególnie mocno podczas tajania śniegu. Obserwowano nie tylko ustąpienie gatunków wrażliwych, ale ogólnie niską gęstość zasiedlenia bezkręgowych dna potoków w okresie wiosennym, która wynosiła średnio 462 osobn. m^{-2}, jesienią natomiast 3249 m^{-2}.

Ogólne ubóstwo fauny bezkręgowych w potokach masywu Łysogór (w ich odcinkach źródleśnych), spowodowane jest nie tylko zakwaszaniem środowiska, ale także: a — niewielkim zróżnicowanie ekologicznym siedliska (68% osobników chruścików należało do 8 gatunków; 7 z nich przynależy do jednego zgrupowania), b — niewielkimi zasobami glonów, których rozwojowi nie sprzyja niskie stężenie soli mineralnych (23% glonożerców wśród chruścików skupia zaledwie 2,4% osobników), c — izolacją geograficzną (brak wielu gatunków, m.i. przedstawicieli Drusinae i *Apatania*).

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