EPHEMEROPTERA OF THE RIVER DUNAJEC NEAR CZORSZTYN DAM (SOUTHERN POLAND)

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Mayfly fauna was studied in 1992-1993 when the dam on the River Dunajec near Czorsztyn was under construction, following up observations there from the 1960s to the 1980s. A continuously decreasing number of Ephemeroptera species has been observed at the Dunajec River (37 species in the 1980s compared to 22 now). There is an evident extinction of the species of various lenitic habitats (low diversity and number). Lotic stony habitats are much more inhabited, but the majority of typical species have completely disappeared and the ones that have remained are scarce. The dam is likely to accelerate negative changes in the mayfly fauna of the Dunajec River.

INTRODUCTION

Bottom invertebrate fauna including Ephemeroptera was studied in 1992-1993 near the retention dam on the Dunajec River near Czorsztyn (Southern Poland), under construction at that time. The study continued previous investigations (CISZEK & SOSIŃSKA, 1965; SOWA, 1965, 1975, 1979; DRATNAL *et al.*, 1979) and was aimed at determining the composition of bottom animal communities before the reservoir filled. It involved studying the part of the river that was to be directly impacted by the dam.

METHODS

The material was collected at three stations: 1 - Harklowa (a part of the river above the reservoir backwater); 2 - Sromowce Niżne (a part of the river below the reservoir dam); 3 - Szczawnica (a part of the river with a benthic invertebrate community characteristic of Carpathian rivers). The study was done over a one-year period (May, June, November, 1992 and March, 1993). Quantitative samples were taken with a scraper from the bottom of various habitat types (stony: lotic habitats, moderate current, rapids; stony lenitic habitats; depositions of fine substrate). Ephemeroptera density was related to 5 dm^2 of the bottom surface. Relative abundance or dominance means the percentage of specimens of a species versus the total for all species. Dominant means a species with a share of 5% or more (SOWA, 1975).

RESULTS

There has been a continuous decline in the number of Ephemeroptera species in the bottom macrofauna of the Dunajec River (Table 1). There were 24 Ephemeroptera species reported near Czorsztyn in 1965 (CISZEK & SOSIŃSKA, 1965). SOWA (1965, 1975, 1979) found 38 species here, including 13 reported for the first time in the region. What is more, there were no species characteristic of lenitic habitats (DRATNAL *et al.*, 1979). There were 5,636 Ephemeroptera larvae caught during the study, representing 22 species. The representation of the species across the stations was quite similar, with slightly less species diversity at station 1 (14 species) compared to station 2 and 3 (17 and 18 species respectively). Species have dropped out of various lenitic habitats at each station (*Baetis scambus, Centroptilum luteolum, Pseudocentroptilum pennulatum, Procleon bifidum, Cloeon cognatum, Ecdyonurus insignis, Habroleptoides confusa, Potamanthus luteus, Ephemera danica*). Besides low diversity there were low numbers of species living in these habitats. Stony lotic habitats were more diversely inhabited, although unfavourable changes within the Ephemeroptera fauna were also seen. *Rhithrogena beskidensis, R. germanica, R. podhalensis, R. carpatoalpina, R. puytoraci, Ecdyonurus dispar* completely disappeared. The remaining representatives of the family Heptageniidae occurred very infrequently and sparsely. Species from both the genus *Baetis* of the family Baetidae and the genus *Ephemerella* of the family Ephemerellidae prevailed (Tables 2, 3, 4).

At station 1 in Harklowa the greatest number of individuals (2,884) as well as the highest density on the stony substratum (136.4 individuals/5 dm^2) were observed. Station 1 and 2 were quite similar in this regard. There were 1,422 larvae caught at Sromowce Niżne (station 2), with a density of 66.4 individuals/5 dm^2, while at

Table 1. List of Ephemeroptera species reported in the Dunajec River (between Harklowa and Szczawnica) in 1965-1993.

No.	Species	Ciszek & Sosińska	Sowa 1965	Sowa 1975	Sowa 1979	Dratnal et al. 1979	occurence in 1992-1993
1	*Siphlonurus aestivalis* (Eaton)		+		+	+	
2	*Siphlonurus lacustris* (Eaton)			+			
3	*Baetis alpinus* (Pictet)		+		+	+	
4	*Baetis beskidensis* Sowa				+	+	+
5	*Baetis fuscatus* (Linnaeus)			+	+	+	+
6	*Baetis lutheri* (Müller-Liebenau)	+	+	+	+	+	+
7	*Baetis melanonyx* (Pictet)				+	+	+
8	*Baetis muticus* (Linnaeus)	+		+	+	+	+
9	*Baetis rhodani* (Pictet)	+		+	+	+	+
10	*Baetis scambus* (Eaton)	+		+	+	+	+
11	*Baetis vardarensis* Ikonomov			+	+	+	+
12	*Baetis vernus* Curtis				+	+	+
13	*Acentrella sinaica* Bogoescu		+	+	+	+	+
14	*Centroptilum luteolum* (O.F. Müller)			+	+	+	
15	*Pseudocentroptilum pennulatum* (Eaton)			+	+	+	
16	*Procloeon bifidum* (Bengtsson)				+	+	
17	*Cloeon cognatum* Stephens				+	+	
18	*Oligoneuriella rhenana* (Imhoff)	+	+	+	+	+	+
19	*Epeorus sylvicola* (Pictet)	+	+	+	+	+	+
20	*Rhithrogena beskidensis* Alba-Tercedor et Sowa			+	+	+	+
21	*Rhithrogena carpatoalpina* Kłonowska, Olechowska, Sartori et Weichselbaumer				+	+	+
22	*Rhithrogena germanica* Eaton			+	+	+	
23	*Rhithrogena podhalensis* Sowa et Soldán			+	+	+	
24	*Rhithrogena puytoraci* Sowa et Degrange				+	+	
25	*Rhithrogena semicolorata* (Curtis)	+		+	+	+	+
26	*Ecdyonurus dispar* (Curtis)			+	+	+	
27	*Ecdyonurus insignis* (Eaton)			+	+	+	
28	*Ecdyonurus torrentis* Kimmins		+	+	+	+	+
29	*Ecdyonurus venosus* (Fabricius)	+		+	+	+	+
30	*Electrogena lateralis* (Curtis)			+	+	+	+
31	*Heptagenia sulphurea* (O.F. Müller)	+			+	+	+
32	*Heptagenia coerulans* Rostock	+					
33	*Paraleptophlebia submarginata* (Stephens)			+			
34	*Leptophlebia vespertina* (Linnaeus)			+			
35	*Habroleptoides confusa* Sartori et Jacob						
36	*Habrophlebia lauta* Eaton			+	+	+	+
37	*Potamanthus luteus* (Linnaeus)	+	+		+	+	
38	*Ephemera danica* O.F. Müller	+			+	+	
39	*Ephemera lineata* Eaton	+	+	+			
40	*Ephemerella ignita* (Poda)	+	+	+	+	+	+
41	*Ephemerella mucronata* (Bengtsson)	+	+	+	+	+	+
42	*Torleya major* (Klapálek)	+		+	+	+	+
43	*Caenis beskidensis* Sowa				+	+	+
44	*Caenis horaria* (Linnaeus)				+	+	+
45	*Caenis pseudorivulorum* Keffermüller			+			
46	*Caenis macrura* Stephens	+		+			
	Total number of species	18	11	31	38	38	22

Table 2. Ephemeroptera of the Dunajec River at station 1 - Harklowa; number of individuals caught by month and by habitat; SLR - stony lotic and rapids; SMC - stony with moderate current, SLD - stony lenitic and depositional.

Species	SLR	SMC	SLD	SLR	SMC	SLD	SLR	SMC	SLD	SLR	SMC	SLD	Σ
	May			June			November			March			
Baetis beskidensis					3								3
Baetis fuscatus				591	120	10							721
Baetis lutheri	330	1	1	66	10		107	13		307	21	2	858
Baetis melanonyx										2			2
Baetis muticus	1												1
Baetis rhodani	22			3	1					3			29
Baetis vardarensis	102		1	53									156
Baetis vernus				31									31
Baetis gr. *fuscatus* juv.				462	34	3							499
Baetis gr. *lutheri* juv.	50			15	2		253	5		134	18		477
Acentrella sinaica				10									10
Oligoneuriella rhenana			2										2
Epeorus sylvicola	1												1
Ecdyonurus torrentis	1												1
Electrogena lateralis	2			3	1								6
Ephemerella ignita				56	22								78
Σ	509	1	2	1292	192	13	360	18	0	446	39	2	2874
	512			1484			378			487			

Szczawnica (station 3) the counts were 1,330 larvae and 65.9 individuals/5 dm^2 (Fig. 1). Species of the genus *Baetis* were the most common at all three stations.

The species reported, as well as their numbers, are not characteristic of this zone of the river (Table 5). According to SOWA's (1975, 1980) classification of the Ephemeroptera communities inhabiting consecutive zones of Carpathian rivers, the region in this study should have represented zone 4. It ranges from 550 to 300 m altitude and includes the middle and lower courses. On average there are 32-36 (at most 56) species living there. *Baetis vardarensis* and *Rhithrogena semicolorata* are dominant over most of the year. Other characteristic dominants are *R. germanica* and *B. beskidensis*. They are accompanied by *B.*

Table 3. Ephemeroptera of the Dunajec River at station 2 - Sromowce Niżne; number of individuals caught by month and by habitat; SLR - stony lotic and rapids; SMC - stony with moderate current, SLD - stony lenitic and depositional.

Species	SLR	SMC	SLD	SLR	SMC	SLD	SLR	SMC	SLD	SLR	SMC	SLD	Σ
	May			June			November			March			
Baetis beskidensis				8	5	3							16
Baetis fuscatus				168	56	15	39						278
Baetis lutheri	158		4	7			103			32		2	306
Baetis muticus	1												1
Baetis rhodani	19			3						2			24
Baetis vardarensis	52			1									53
Baetis gr. *fuscatus* juv.				45	24	2	93						164
Baetis gr. *lutheri* juv.	30			16		1	285			33	1		366
Acentrella sinaica				2									2
Oligoneuriella rhenana			1	2									3
Rhithrogena carpatoalpina	1												1
Ecdyonurus torrentis	5												5
Ecdyonurus venosus							1						1
Electrogena lateralis	1		1		1	2							5
Heptagenia sulphurea	3			1			12			3	1		20
Habrophlebia lauta				1									1
Ephemerella ignita				107	49	11							167
Caenis beskidensis										1			1
Caenis horaria				1									1
Σ	270	0	6	362	135	34	533	0	0	71	2	2	1415
	276			531			533			75			

fuscatus and *Caenis pseudorivulorum; B. rhodani, B. lutheri, Ecdyonurus torrentis* and *E. dispar* can also occur in large numbers. *Ephemerella ignita* and *Potamanthus luteus* can be numerous in the lower part of the zone. In the present study it was found that although *B. vardarensis* was still very common at all stations, it was *B. lutheri*, another species of the group *lutheri*, which increased in overall abundance. *B. rhodani*, which was supposed to be common and characteristic of Carpathian rivers, was actually found in small numbers (at most 2 per sample at all stations). *Rhithrogena semicolorata*, another species characteristic of the community, was almost entirely extinct (only 5 larvae caught at station 3 during the course of the study). *Rhithrogena podhalensis, R. germanica, Heptagenia coerulans*, and *Ephemera lineata*, which are very rare or critically endangered in Poland according to the «Polish Red Data Book of Animals» (SOWA, 1990, 1992), are now extinct at the localities studied. Other genera of Heptageniidae (*Ecdyonurus, Electrogena, Heptagenia*) living in lotic habitats were not numerous and only a few species were present. There were no specimens of species supposedly common and typical in lenitic habitats of the zone studied, such as *Habroleptoides confusa, Potamanthus luteus* and *Ephemera lineata. Oligoneuriella rhenana*, which lives in large numbers in rapids, was actually found in small numbers, although it occurred at all stations (a total of 18 larvae were caught). *Baetis fuscatus* and *Ephemerella ignita* were found in very large numbers at all stations. There were 2,283 *B. fuscatus* larvae caught, including 1,220 at station 1, that is, 60.8 individuals per sample. The number of *B. fuscatus* was much smaller at the other two stations (22.1 individuals per sample at station 2, and 30.7 individuals per sample at station 3). *E. ignita* was less frequent: there were 392 larvae caught (on average 18.8 individuals per sample). The high density of Ephemeroptera larvae in the stony bottom habitats observed at station 1, exceeding the densities at stations 2 and 3, resulted from the enormous numbers of these two species.

DISCUSSION

The effects of pollutants on the River Dunajec biocenoses already observed in studies from

Table 4. Ephemeroptera of the Dunajec River at station 3 - Szczawnica; number of individuals caught by month and by habitat; SLR - stony lotic and rapids; SMC - stony with moderate current, SLD - stony lenitic and depositional.

Species	SLR	SMC	SLD	SLR	SMC	SLD	SLR	SMC	SLD	SLR	SMC	SLD	Σ
	May			June			November			March			
Baetis beskidensis				14	1								15
Baetis fuscatus				74	135	107							316
Baetis lutheri	100	9	6	16		7	19			98	1		256
Baetis melanonyx				4									4
Baetis rhodani	5	16		8						5	1		35
Baetis vardarensis	39	27	5	12	4	11							98
Baetis gr. *fuscatus* juv.				7	214	84							305
Baetis gr. *lutheri* juv.	30			5	18	7	7	1		48	1		87
Acentrella sinaica				2									2
Oligoneuriella rhenana			1	7	4	2							13
Epeorus sylvicola	9	1		2									12
Rhithrogena semicolorata	1						4						5
Ecdyonurus torrentis		2											2
Ecdyonurus venosus		1	1		1								2
Electrogena lateralis				2	11	8							21
Heptagenia sulphurea	2		1			1				3			7
Ephemerella ignita				41	67	38							146
Ephemerella mucronata										1			1
Caenis beskidensis				1									1
Caenis horaria					1								1
Σ	156	56	13	195	455	265	30	1	0	155	3	0	1329
	225			915			31			158			

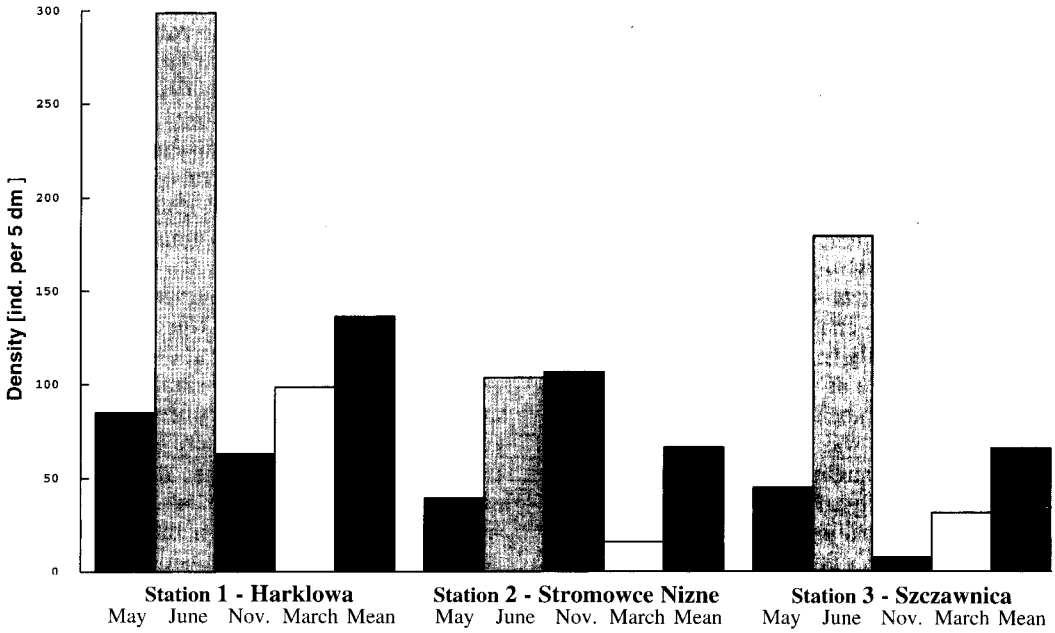

Fig. 1. Ephemeroptera of the Dunajec River between Harklowa and Szczawnica, density per 5 dm^2 stony bottom in 1992-1993.

1972-1973 (DRATNAL *et al.*, 1982) are now more and more evident. The occurrence of some Ephemeroptera species at a station depends mainly on abiotic factors such as the amount of oxygen in the water, water temperature, and the profile of the river (river channel, substratum, river gradient, etc.). Biotic factors are not decisive in the case of Ephemeroptera (HYNES, 1963; LANDA, 1984). Water pollution has reduced oxygenation. Together with additional changes in the channel bed, this has reduced both the number of species and the populations of the species that remained. Zone 4 of the Carpathian rivers, represented by the parts of the Dunajec studied here, is in particular danger, as confirmed by the disappearance of species that used to be characteristic of this zone and common in normal conditions. Good examples of this are *Rhithrogena semicolorata,* which lives in clear waters and cannot tolerate organic pollution (ELLIOTT *et al.*, 1988; HELLAWELL, 1989) or the majority of species of the family Heptageniidae, which require good supplies of oxygen (LANDA, 1984). Other species form a much smaller part of the community than would be expected from the dominance structure for this zone in other Carpathian rivers. *Baetis rhodani* is an example (SOWA, 1975). Species

Table 5. Ephemeroptera of the River Dunajec; distribution and quantitative presentation of the station: boldface are dominants.

Species	Harklowa station 1	Sromowce Nizne station 2	Szczawnica station 3
Baetis vernus	1.10		
Baetis fuscatus	**26.30**	**20.60**	**23.50**
Baetis gr. *fuscatus* juv.	**18.30**	**12.30**	**23.03**
Baetis lutheri	**28.60**	**19.90**	**19.80**
Baetis gr. *lutheri* juv.	**15.60**	**26.80**	**6.70**
Acentrella sinaica	0.40	0.15	0.23
Baetis muticus	0.03	0.05	
Habrophlebia lauta		0.08	
Rhithrogena carpatoalpina		0.05	
Ecdyonurus torrentis	0.03	0.27	0.15
Ephemerella ignita	2.90	**12.20**	**10.20**
Baetis beskidensis	0.10	1.20	1.14
Heptagenia sulphurea		1.40	0.50
Baetis vardarensis	**5.40**	2.90	**7.40**
Baetis rhodani	0.90	1.40	2.70
Electrogena lateralis	0.20	0.26	1.60
Oligoneuriella rhenana	0.07	0.20	1.00
Baetis melanonyx	0.07		0.30
Epeorus sylvicola	0.03		0.90
Caenis beskidensis		0.08	0.08
Caenis horaria		0.08	0.08
Ecdyonurus venosus		0.08	0.15
Rhithrogena semicolorata			0.45
Ephemerella mucronata			0.08
Number of species	14	17	18

dominance structures are changing. For example, there is a great abundance of *B. fuscatus* and *E. ignita*, which are particularly resistant to pollution. They dominate and constitute 60-70% of the total number of species living in very polluted waters (LANDA, 1984; ELLIOTT *et al.*, 1988). It has been observed that organic pollution can sometimes produce high density in macrofauna habitats below a source of water pollution. This is probably caused by changes in trophic conditions; the food resources of some macroinvertebrates resistant to water pollution can expand or increase so that they find good conditions there for development there (no competitors, abundance of food) (HYNES, 1963). Species replacement is another consequence of the effects of water pollution; some species are replaced by more expansive ones that take up free habitats, which then displace other species (LANDA, 1984) (e.g. *B. lutheri*, which has clearly increased its abundance in the Dunajec River).

The dam and the reservoir will inevitably hasten and aggravate the unfavorable changes within the Ephemeroptera fauna in the Dunajec. Apart from the changes that have resulted from water pollution, others will be caused by the dam itself, particularly in regard to water flow in the river bed, reduction in habitat diversity, alteration of thermal regimes and water chemistry, and the creation of barriers between macrofauna communities. It is difficult to unequivocally describe the nature and scope of these processes, which have already distorted the Ephemeroptera fauna in the Dunajec, but further unfavourable changes are inevitable.

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REFERENCES

CISZEK, H. & SOSIŃSKA, E. 1965. Mayflies (Ephemeroptera) and beetles (Coleoptera) of the River Dunajec. *In*: DRATNAL, E. & SZCZĘSNY, B. (Eds) Benthic fauna of the Dunajec River, pp. 182-186, Komitet Zagosp. Ziem Górskich PAN, Kraków.

DRATNAL, E., SOWA, R. & SZCZĘSNY, B. 1979. Zgrupowania bęzkręgowców bentosowych na odcinku Harklowa - Sromowce Niżne (Benthic invertebrate communities of the Dunajec River between Harklowa and Sromowce Niżne). Ochr. Przyr. 42: 183-215.

DRATNAL, E., SOWA, R. & SZCZĘSNY, B. 1982. Prognozy zmian w zgrupowaniach bezkręgowców wodnych (Prognosis of changes in the communities of water invertebrates). *In*: ZARZYCKI, K. (Ed.). Przyroda Pienin w obliczu zmian (Nature of the Pieniny in the face of changes), pp. 379-399, PWN, Warszawa.

ELLIOTT, J., HUMPESH, H. & MACAN, T. 1988. Larvae of the British Ephemeroptera. Fresh. Biol. Assoc., Sci. Pub., 145 p.

HELLAWELL, J. 1989. Biological indicators of frshwater pollution and environmental management. Elsevier Appl. Scien., London, New York, 546 p.

HYNES, H. 1963. The biology of polluted waters. Liverpool Univ. Press, Liverpool, 202 p.

HYNES, H. 1970. The ecology of running waters. Liverpool Univ. Press, Liverpool, 555 p.

LANDA, V. 1984. Studies on aquatic insects in Czechoslovakia with regard to changes in the quality of water in the last 20-30 years. *In*: LANDA V. *et al.* (Eds) Proc. IV-th Intern. Confer. Ephemeroptera, pp. 317-321, CSAV, Bechyne.

SOWA, R. 1965. Invertebrate water animals of the Dunajec river. *In*: STARMACH, K. (Ed.) Along the Dunajec river, pp. 41-50. XVI Limnol. Conv. in Polonia.

SOWA, R. 1975. Ecology and biogeography of mayflies (Ephemeroptera) of running waters in the Polish part of the Carpathians. 1. Distribution and quantitative analysis. Acta Hydrobiol. 7: 223-297.

SOWA, R. 1979. Le développement des Ephéméroptères de la rivière Dunajec aux environs de Pieniny. *In*: PASTERNAK, K. & SOWA, R. (Eds) Proc. Second Intern. Conf. Ephemeroptera, pp. 125-131, PWN, Warszawa-Kraków.

SOWA, R. 1980. La zoogéographie, l'écologie et la protection des Ephéméroptères en Pologne, et leur utilisation en tant que indicateurs de la pureté des eaux courantes. *In*: FLANNAGAN, J. & MARSHALL, K. (Eds) Advances in Ephemeroptera biology, pp. 141-154, Plenum Press, New York-London.

SOWA, R. 1990. Ephemeroptera-jętki. *In*: RAZOWSKI, J. (Ed.) Wykaz zwierząt Polski (A checklist of the animals of Poland), pp. 33-38, Ossolineum, Wrocław-Kraków.

SOWA, R. 1992. Jętki (Ephemeroptera). *In*: GŁOWACIŃSKI, Z. (Ed.) Czerwona lista zwierząt ginących i zagrożonych w Polsce (Polish Red Data Book of Animals), pp. 97-101, Komit. Ochr. Przyr. PAN, Kraków.