TAXOCENES OF EPHEMEROPTERA IN UNPOLLUTED AND POLLUTED STREAMS OF THE TATRA MOUNTAINS

Andrzej Kownacki

Laboratory of Water Biology
Polish Academy of Sciences
31-016 Kraków, Poland

ABSTRACT

In the streams of the Tatra Mountains over 1550 m a.s.l. mayflies are generally lacking. At 900 to 1550 m a.s.l. *Baetis alpinus* and *Rhithrogena loyolaea* dominate in the current, and *Ameletus inopinatus* in the pools. In the submontane zone of the streams (below 900 m a.s.l.) many other species appear. In a polluted stream (1380 to 1390 m a.s.l.) below the outlet of sewage mayflies are absent. Thirty m below the sewage outlet *B. vernus* dominates from July to September (tourist season). One hundred to 500 m below the sewage outlet *B. rhodani* and *B. muticus* dominate. Single specimens of *B. alpinus* are also encountered but representatives of *Rhithrogena* are missing.

INTRODUCTION

The aim of this paper is to present the zonation, and distribution in time, of the taxocenes of Ephemeroptera in the Tatra mountain streams and to show the effect of sewage on these taxocenes.

STUDY AREAS AND METHODS

Investigations were carried out in several streams and rivers flowing down the northern slopes of the Polish High Tatra Mountains. Twenty-six sampling stations were chosen in these streams and a short description of them is given in Table 1. Year round investigations were carried out in the stream Sucha Woda and in the stream Olczyski, both of which have preserved their natural character to a great

Table 1. Physical and chemical aspects of the streams and rivers in High Tatra Mountains and Podhale Region. 2B - sewage outlet (chemical data after Bombówna 1968, 1971, 1977; Pasternak 1971).

Stream	No.	Altitude m	Gradient %0	Temperature of water °C	pH	O_2%	BOD_5 O_2 mg/L	Ammonia $N\text{-}NH_4$ mg/L	Phosphate PO_4 mg/L	Calcium Ca mg/L
Olczyski Potok	1	1070	80	3.8- 4.8	7.0-7.6	91.7- 98.5	1.76-3.36	0-0.146	0.043-0.222	16.4-20.0
	2	1000	80	3.3- 5.6	7.0-7.6	88.3- 99.5	0-2.24	0-0.111	0.018-0.192	17.1-23.5
	3	920	80	1.2- 8.8	7.2-7.6	92.3- 97.7	0.48-2.40	0-0.116	0.012-0.185	18.5-25.7
Sucha Woda[1]	1	±1700	334	1.5- 6.4	6.2-6.4	-	-	0.08	0.038	2.5
	2	±1560	210	0.5-10.7	6.3-6.8	85.4	-	0.016-0.08	0.015	2.9
	2A	1540	80	4.0- 7.5	6.4-6.8	-	-	0.04	0.026	-
	3	1460	100	1.5- 8.0	6.5-7.0	85.1	-	0.016	0.010	7.2- 7.9
	4	1330	66	0.4- 7.0	6.7-7.5	88.3	-	0.010-0.096	0.005-0.012	7.5
	5	1180	66	0.4- 9.0	6.7-7.5	87.8	-	0.010	0.021	7.5
	6	880	20	1.5-10.0	7.4-8.3	91.5	-	0	0.010	14.3
	7	775	20	0.3-15.3	7.0-8.5	96.2	-	0.024	0.010	22.2-27.2
Potok Roztoka	1	1450	200	5.5	6.5	83.5	-	0	0.004	3.6
	2	1300	80	5.0	6.5	84.9	-	0	0.009	3.9
	3	1040	66	1.7- 8.8	6.4-6.9	85.8-108.3	1.04-2.36	0-0.068	0-0.012	3.6- 4.1
Rybi Potok[2]	1	±1450	321	0.6- 7.5	6.6-6.7	81.7- 85.9	0.26-1.60	0-0.056	0-0.020	4.1- 5.1
	2A	1393	6	1.2-12.4	6.4-7.0	67.2-114.5	0.48-3.52	0-0.106	0-0.034	4.3- 5.4
	(2B)	1393	6	1.2-12.6	6.4-6.9	69.2- 90.1	2.40-9.76	0.016-1.192	0.010-0.268	4.6- 6.4
	2C	1393	6	1.2-12.4	6.5-7.1	66.2- 95.6	1.66-3.42	0.008-0.356	0.005-0.111	4.6- 6.4
	2D	1393	6	1.1-11.9	6.5-7.1	64.3- 94.0	0.48-2.88	0.008-0.176	0.003-0.082	4.6- 6.1
	2E	1380	10	0.2-12.7	6.4-7.8	69.2- 95.1	0.90-5.82	0.008-0.136	0-0.090	4.6- 6.1
	3	1150	113	1.2-10.9	6.4-7.0	67.5- 91.8	0.16-3.04	0-0.106	0-0.100	4.6- 6.4
Białka Tatrzańska	1	960	20	9.4	7.1-7.8	86.1- 94.0	1.12-1.28	0-0.072	0-0.012	17.2-22.9
	2	840	8	-	-	-	-	-	-	-
	3	780	15	13.7	7.3-7.8	88.0- 99.7	0.64-1.44	0-0.068	0-0.034	22.5-32.2
	4	620	9	15.8	7.2-7.8	90.8- 93.2	0.64-1.92	0.002-0.260	0-0.038	25.4-32.2
	5	530	8	16.5	7.2-7.8	91.1- 97.4	0.96-1.98	0.005-0.184	0-0.104	26.6-32.9

[1] Station 1 - stream joining Zmarzty Staw Lake (1787 m) with Czarny Staw Gasienicowy (1619 m) (without name); Stations 2, 3 and 4 - Czarny Potok stream; Stations 5, 6 and 7 - Sucha Woda stream; Station 8 - Cicha Woda stream.

[2] Station 1 - stream joining Czarny Staw lake (1580.5 m) with Morski Oko lake (1393 m) (without name); Stations 2A - 2E and 3 - Rybi Potok streams.

extent, and in the stream Rybi Potok into which sewage is discharged. In the Roztoka, a stream joining the lakes Czarny Staw and Morskie Oko, and in the river Białka, qualitative samples were taken several times during the spring and summer season. At each station, and on all dates, several sample were collected with a hand net covered with 0.3 mm mesh bolting cloth. In the laboratory all specimens of mayflies were sorted from the samples, identified and counted from a 2 dm^3 volume of the substratum.

VERTICAL DISTRIBUTION OF TAXOCENES OF EPHEMEROPTERA IN UNPOLLUTED AND POLLUTED STREAMS

The zonal distribution of Ephemeroptera (Fig. 1) was examined in the system of the stream Sucha Woda which is the outflow from the lake Zmarzły Staw (1787 m above sea level (a.s.l.)) and flows into the stream Poroniec (775 m a.s.l.). Above 1550 m a.s.l. mayflies do not occur, as a rule. Single individuals of *Baetis alpinus* and *Rhithrogena loyolaea* were found; they do not, however, undergo their full life cycle there. At an altitude of 1000 to 1550 m a.s.l. in the subalpine forest zone, *B. alpinus*, constituting over 50 percent of the total number of Ephemeroptera, dominate in the taxocene. *R. loyolaea* is a fairly numerous subdominant. Single specimens of *Rhithrogena hybrida* occur below 1350 m a.s.l. and of *Rhithrogena iridina* below 1200 m a.s.l., while single specimens of *Ameletus inopinatus* are found in the pools. Below 900 m a.s.l. the taxocene of Ephemeroptera changed markedly. Although *B. alpinus* still dominates along with *Baetis melanonyx* (species difficult to separate in their juvenile stages), *R. loyolaea*, *R. hybida*, and *R. iridina* occur only rarely. In addition, a whole range of new species of the genus *Baetis* (*B. rhodani*, *B. muticus*, *B. scambus*, *B. sinaicus*), *Rhithrogena* (*R. diaphana*, *R. semicolorata*), *Ecdyonurus* (*E. venosus*, *E. torrentis*), *Epeorus*, *Ephemerella* and *Habroleptoides* are found here. In contrast, the densities of Ephemeroptera are almost equal along the whole stream length, varying from 50 to 80 individuals/2 dm^3 of stones. Only at an altitude 1550 m a.s.l., in a place where springs enrich the stream is their number higher (137 individuals/2 dm^3 of stones).

In the stream Olczyski (1070 to 920 m a.s.l.) which arises from a very rich spring, the taxocene of Ephemeroptera is basically similar to that in the Sucha Woda at the same altitude. The dominant species is *B. alpinus* occurring with subdominants *R. loyolaea*, in the upper course, and *R. hybrida* and *R. iridina* in the lower. Although the density of *B. alpinus* is higher here, especially in the spring (1100 individuals/2 dm^3 of stones), the nymphs of *R. loyolaea* occur only as individual specimens (< 1 percent of the total number of Ephemeroptera). By 400 m downstream from the spring, the density of *B. alpinus* decreases markedly (253 individuals/2 dm^3 of stones) and the importance of the nymphs of *R. loyolaea* and *R. hybrida*

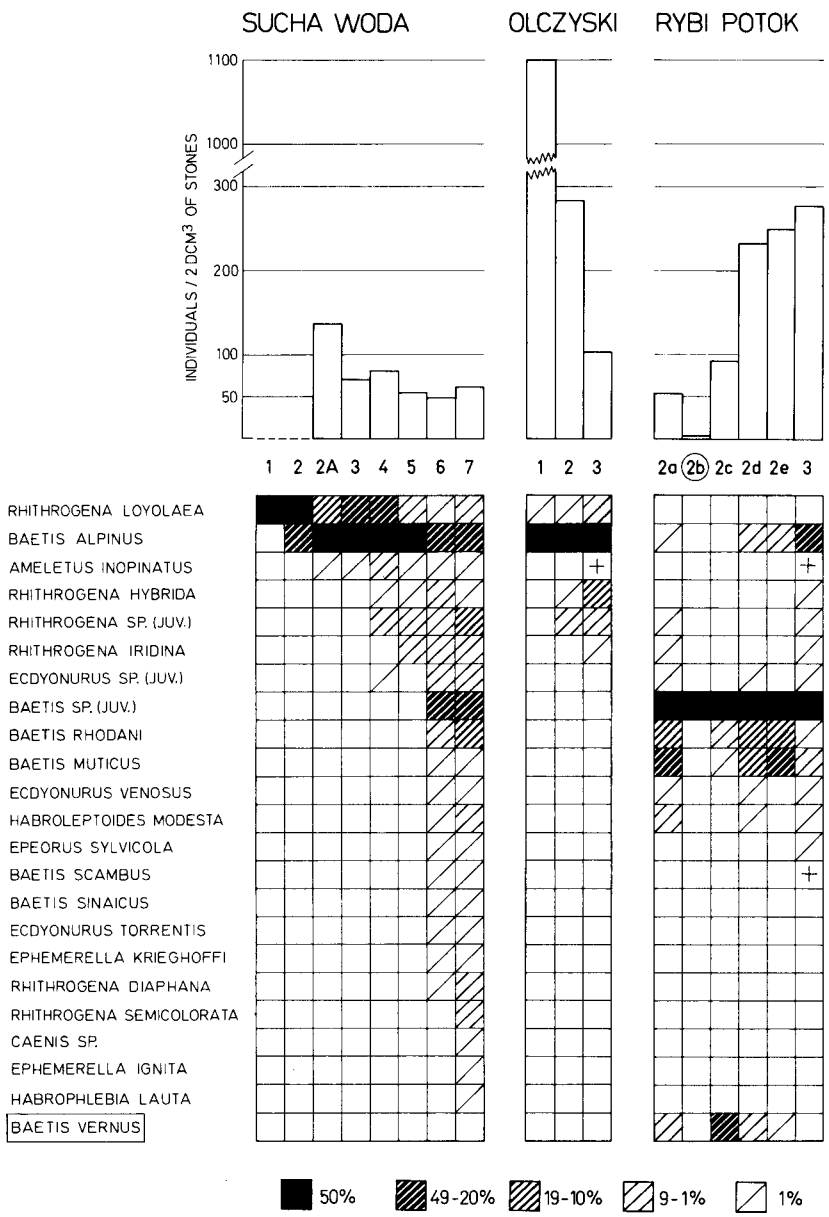

Figure 1. The altitudinal distribution of the density of Ephemeroptera and the percentage composition of the taxocenes of Ephemeroptera in unpolluted and polluted streams in High Tatra Mountains; based on the collections taken around the year. + data from the other publications, 2b is the sewage outlet.

increases in the taxocene (about 10 per cent of the total number of Ephemeroptera). By the third station, at the mouth of the valley, the density of *B. alpinus* (73 individuals/2 dm^3 of stones) is similar to the stream Sucha Woda and the subdominant species, *R. loyolaea*, *R. hybrida* and *R. iridina*, constitute 30 per cent of the total number of Ephemeroptera. No nymphs of *Ameletus* were present in the samples. They were, however, found by Sowa (1975) in the lower sector of this stream.

In other Tatra streams, the taxocenes of Ephemeroptera are similar to those discussed above (Table 2). In the stream Roztoka (1669-1030 m a.s.l.) *B. alpinus* co-dominates with *R. loyolaea* in the current and *A. inopinatus* in stagnant pools, in the upper and middle course; in the lower course, in addition to those species, *R. hybrida* and *R. iridina* dominate. *Ecdyonurus lateralis* imagines were also caught.

In the stream connecting the lakes Czarny Staw and Morskie Oko (1584-1393 m a.s.l.) *B. alpinus* and *R. loyolaea* dominate with subdominating species *R. hybrida* and *A. inopinatus*.

In the stream Rybi Potok (1393-1077 m a.s.l.), into which the sewage from the shelterhouse is discharged. A quite different taxocene of Ephemeroptera is found. Above the sewage, apart from juvenile stages of *Baetis* which dominate along the whole stream, *Baetis muticus* occurs commonly with the subdominant species *B. rhodani* and less commonly *Baetis vernus* and *Habroleptoides modesta*. *B. alpinus* and species of the genus *Rhithrogena*, so characteristic of the Tatra streams at this altitude, are rare in this stream. The total number of Ephemeroptera, however, is similar to that in other streams of the Tatra Mountains. Below the sewage discharge mayflies are almost absent. Individual juvenile specimens of the genus *Baetis* which found their way here in the drift, do not undergo their full life cycle here. By 30 m below the discharge, the total number of mayflies is the same as at the station above the discharge. *B. vernus* (missing in other streams of the Tatra) is the dominant species. Mayflies *B. alpinus*, and those of the genus *Rhithrogena*, are lacking. At a distance of 100-500 m downstream from the sewage discharge the Ephemeroptera taxocene gets more and more similar to that above the sewage discharge point. *B. rhodani* and *B. muticus* dominate again in the mayfly community and the importance of *B. vernus* gradually decreases. Individual nymphs of *B. alpinus* start to appear, although species of the genus *Rhithrogena* are still absent. However, the total number of Ephemeroptera increases markedly to about 250 individuals/2 dm^3 of stones). Only at 3200 m downstream from the sewage discharge, at an altitude of 1180 m a.s.l., does the Ephemeroptera taxocene become similar to that found in other Tetra streams. *B. alpinus* dominates, and individual specimens of *R. hybrida* and *R. iridina* are found. At the same time a number of species (*B. muticus*, *B. rhodani*, *E. venosus*, *H. modesta*) lacking in

Table 2. Distribution of the mayflies at stations in the streams and rivers in High Tatra Mountains and Podhale Region. + present, · occurs sporadically, o data according to other authors.

Stream	Olczyski			Sucha Woda								Roztoka			Rybi Potok							Białka				
Sation No.	1	2	3	1	2	2A	3	4	5	6	7	1	2	3	1	2A	(2B)	2C	2D	2E	3	1	2	3	4	5
Ephemera danica Müll.																									+	+
Rhithrogena germanica Etn.																										o
- *hercynia* Landa																								+	+	+
- *hybrida* Etn.		+	+					+	+	+	+			+							+			o		
- *loyolaea* Nav.	+	+	+	·	·	+	+	+	+			+	+	+	+											
- *semicolorata* Curt.											+													+	+	+
- *iridina* Kolenati			+					+	+	+	+			+		+					+	+	+	+	+	
- *ferruginea* Nav.																								+	+	+
- *diaphana* Nav.										+	+											+		+	+	+
Epeorus sylvicola Pict.										+	+										+			+	+	+
Ecdyonurus torrentis Kimm.										+	+													+	+	+
- *venosus* F.			o							+	o					+			+		+		+	+	+	+
- *submontanus* Landa											o															
- *lateralis* Curt.														+											+	o
- *dispar* Curt.																										+
Habroleptoides modesta Hag.										+	+					+				+	+				+	+
Habrophlebia lauta Etn.											+															
Ameletus inopinatus Etn.			o		+	+	+	+	+	+	+	+	+	+	+						+		+	o		
Siphlonurus lacustris Etn.																										o
Baetis alpinus Pict.	+	+	+		·	+	+	+	+	+	+	+	+	+	+	+			+	+	+	+	+	+	+	+
- *melanonyx* Pict.									+	+	+															
- *lutheri* M.-L.																								+	+	+
- *sinaicus* Bog.										+	+												+	+	+	+
- *rhodani* Pict.										+	+					+		+	+	+	+			+	+	+
- *vernus* Curt.																+		+	+	+	+	+			+	+
- *scambus* Etn.										+	+									+				+	+	+
- *muticus* L.										+	+					+		+	+	+	+		+	+	+	+
Centroptilum luteolum Müll.											o													o	o	+
Oligoneuriella rhenana Imm.																									+	+
Ephemerella ignita Poda.											+														+	+
- *krieghoffi* Ulm.										+	+												+	+	+	+
- *major* Klap.																									+	
Caenis sp.											+														+	+

other streams at that altitude, occur at that station. The total density of Ephemeroptera is still high.

SEASONAL CYCLES OF EPHEMEROPTERA

In the streams Olczyski, Sucha Woda, and Rybi Potok, seasonal changes in the number and structure of Ephemeroptera groups were recorded and the life cycle of the more important species investigated.

In the stream Olczyski, at all three stations, the maximum numbers of Ephemeroptera occur in the winter months, while in the summer the number is much lower. This regularity is very distinct at Station 1 (Fig. 2). The maxima observed here in November were followed by a gradual decrease, reaching the lowest value in August, whereas, maximal densities at Stations 2 and 3 take place in December.

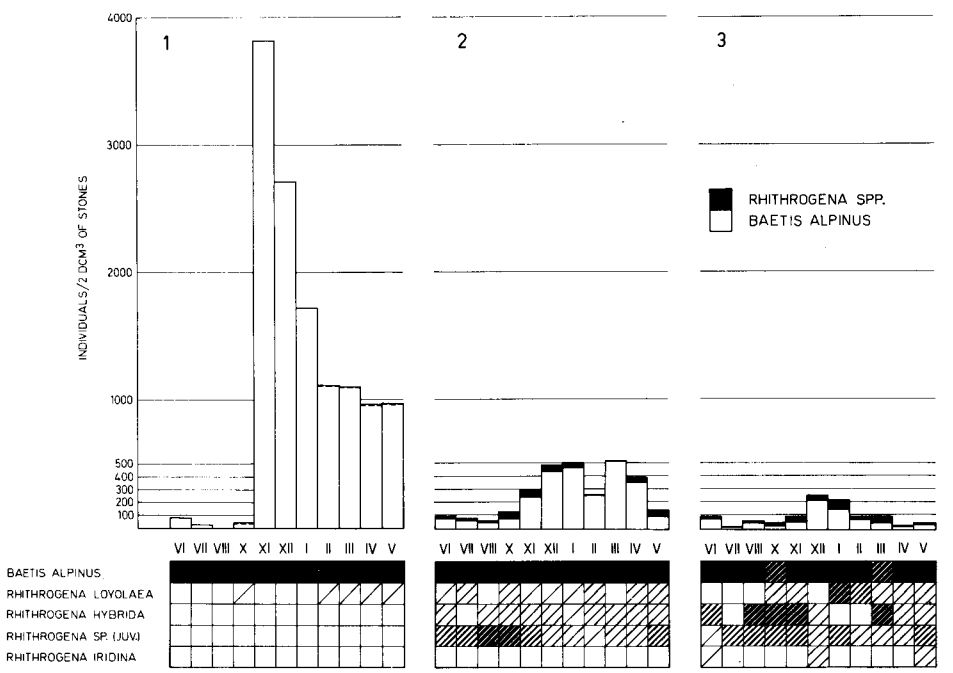

Figure 2. Annual fluctuations in the density of Ephemeroptera and the percentage composition of the taxocenes of Ephemeroptera in stream Olczyski (symbols as in Fig. 1).

At Station 1 their density is the highest of these recorded in the Tatra streams. Later the number of the individuals decreases so rapidly that it could hardly be caused by the mortality of nymphs. At Station 2 the density of Ephemeroptera remains approximately on the same level from December till March. It seems probable that the females in their compensating upstream flight, lay eggs in masses in the headwaters spring of the stream Olczyski. The juvenile forms which hatch there then drift downstream making the number of mayflies at Station 2 (400 m downstream) remain at a constant level all the winter long. At all stations in the stream Olczyski the nymphs of *B. alpinus* are the main component of the fauna of Ephemeroptera all year round. Species of the genus *Rhithrogena* are a little more numerous at Stations 2 and 3 only towards the end of summer and in autumn. The life cycle of *B. alpinus*, which dominates the total number of Ephemeroptera at these stations, was followed in this stream (Fig. 3). Individual specimens in juvenile stages (below 1 mm) appear in August, but their mass appearance takes place as late as November. During the winter and spring a gradual growth of nymphs takes place. From May on, acceleration of nymphal growth occurs, and from June till the end of August very large and pre-emergent nymphs are found. At Stations 1 and 2, this species has only one generation in a year. At Station 3, in contrast, two cohorts of *B. alpinus* or perhaps parallel occurrence of *B. melanonyx*, occurs.

In the stream Sucha Woda (Fig. 4), above 1500 m a.s.l. juvenile stages of *R. loyolaea* or *B. alpinus* are collected only in autumn and perish with the freezing of the stream. After the thaw in spring,

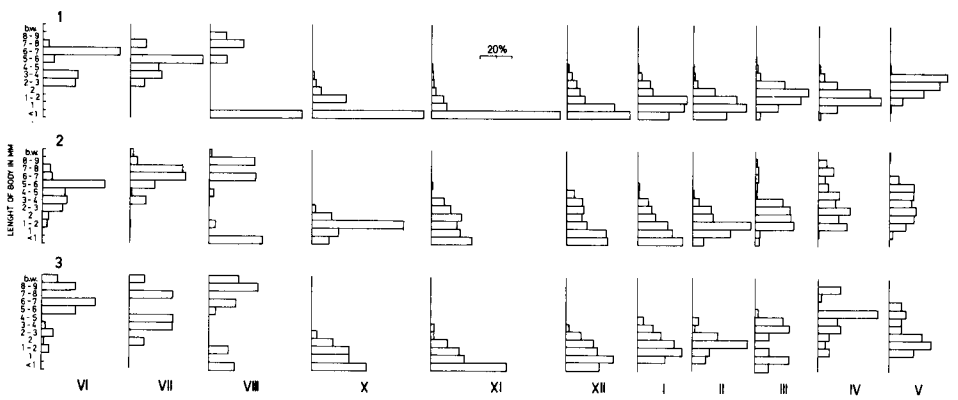

Figure 3. The percentage size-distributions of *Baetis alpinus* in approximately monthly collections from the stream Olczyski; b.w. = nymphs before emergence.

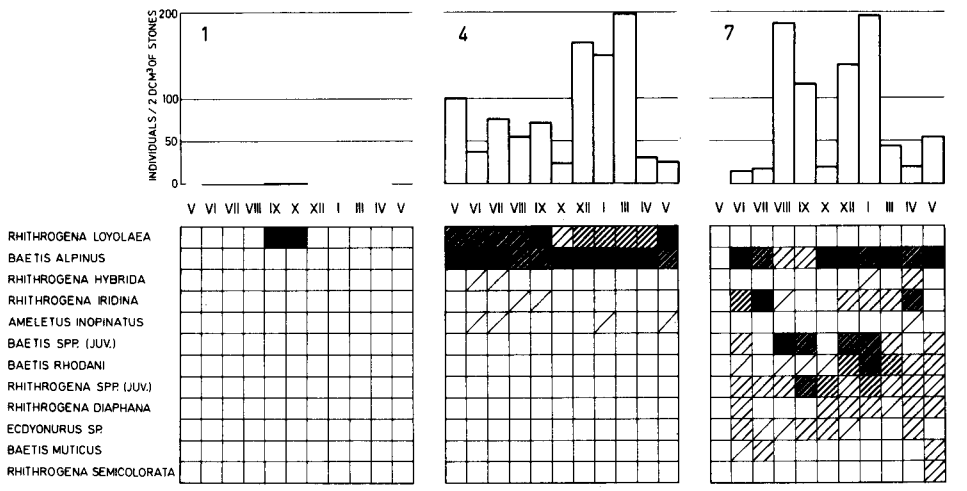

Figure 4. Annual fluctuations in the density of Ephemeroptera and the percentage composition of the taxocenes of Ephemeroptera in the stream Sucha Woda at the stations 1, 4 and 7. (Symbols as in Fig. 1).

and in summer, no representatives of the order Ephemeroptera are found. In the zone of subalpine forests, as in the stream Olczyski, *B. alpinus* dominates all year round. The importance of *Rhithrogena loyolaea* in the Ephemeroptera fauna is much greater here, especially in summer. Thus the change in the density of Ephemeroptera shows a small peak in summer and a greater one in winter. In this zone *B. alpinus* has one generation per year (Fig. 5). Juvenile stages are common in December and occur during the whole winter. Large and pre-emergent nymphs were caught from June till September; while small-and medium-sized nymphs of *R. loyolaea* occurred during the whole year in approximately the same numbers; large nymphs were found from May till December (Fig. 5). In the stream, at the foot of the Tatra Mountains, seasonal changes in Ephemeroptera are complicated. For a greater part of the year *B. alpinus* dominates along with *B. melanonyx* but at certain periods other species become dominants too.

In the stream Rybi Potok (Fig. 6) below the sewage outlet (Station 2B) individual juvenile specimens of the genus *Baetis* were found, these, however, do not undergo their full life cycles at this station. 30 m below the sewage, maximum density of Ephemeroptera occurs in spring (May, June) when a reduction in the number of

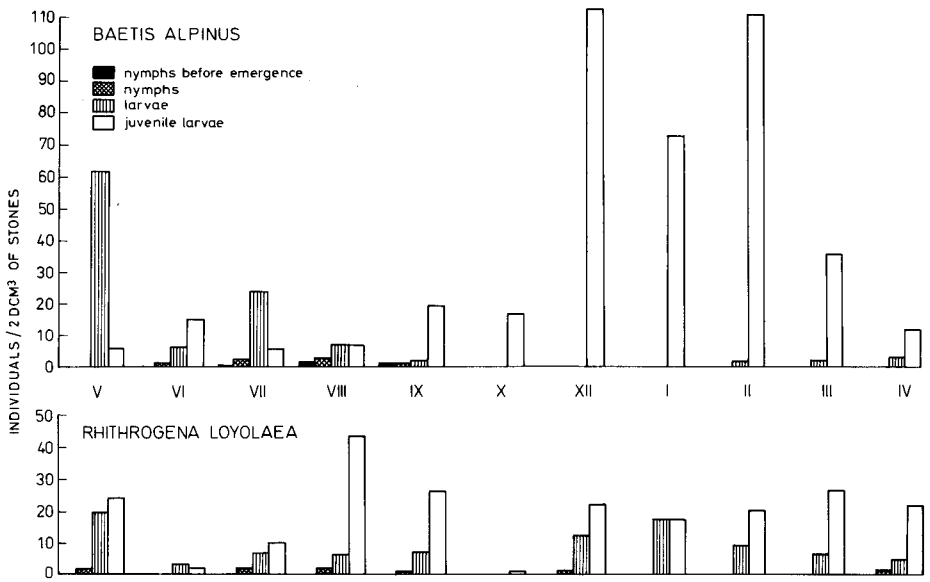

Figure 5. Annual changes of four size groups of *Baetis alpinus* and *Rhithrogena loyolaea* in the stream Sucha Woda at station 4 (data from Kownacka 1971).

tourists causes a reduction in sewage outflow. This peak is caused by juvenile stages of the genus *Baetis*. From July to December a decrease in the total number of Ephemeroptera occurs, probably related to the greater inflow of sewage. During the tourist peak (July to September) and later (October to December) *B. vernus* and *B. rhodani* dominate respectively. From January till March no mayflies were found at this station. With increasing distance from the sewage effluent (100 to 500 m) the curve representing the changes in the total number becomes similar to that for other stations. The maximum density occurs in autumn - winter months. It is interesting that *B. vernus* appeared at these stations during the tourist peak when the number of the species (*B. rhodani*, *B. muticus*) which dominated at all other periods decreased. The nymphs of *B. alpinus* too, are absent during intensive tourist traffic (July - September) at these stations. In the lower sector of the stream, about 3000 m below the sewage inflow, nymphs of *B. alpinus* are dominant all year round. Only at the beginning of September, at the end of the tourist season, does their importance in the fauna of Ephemeroptera decrease. This is caused by the biology of the species (a considerable part of juvenile stages of *Baetis* at that station are *B. alpinus*) rather than by the sewage.

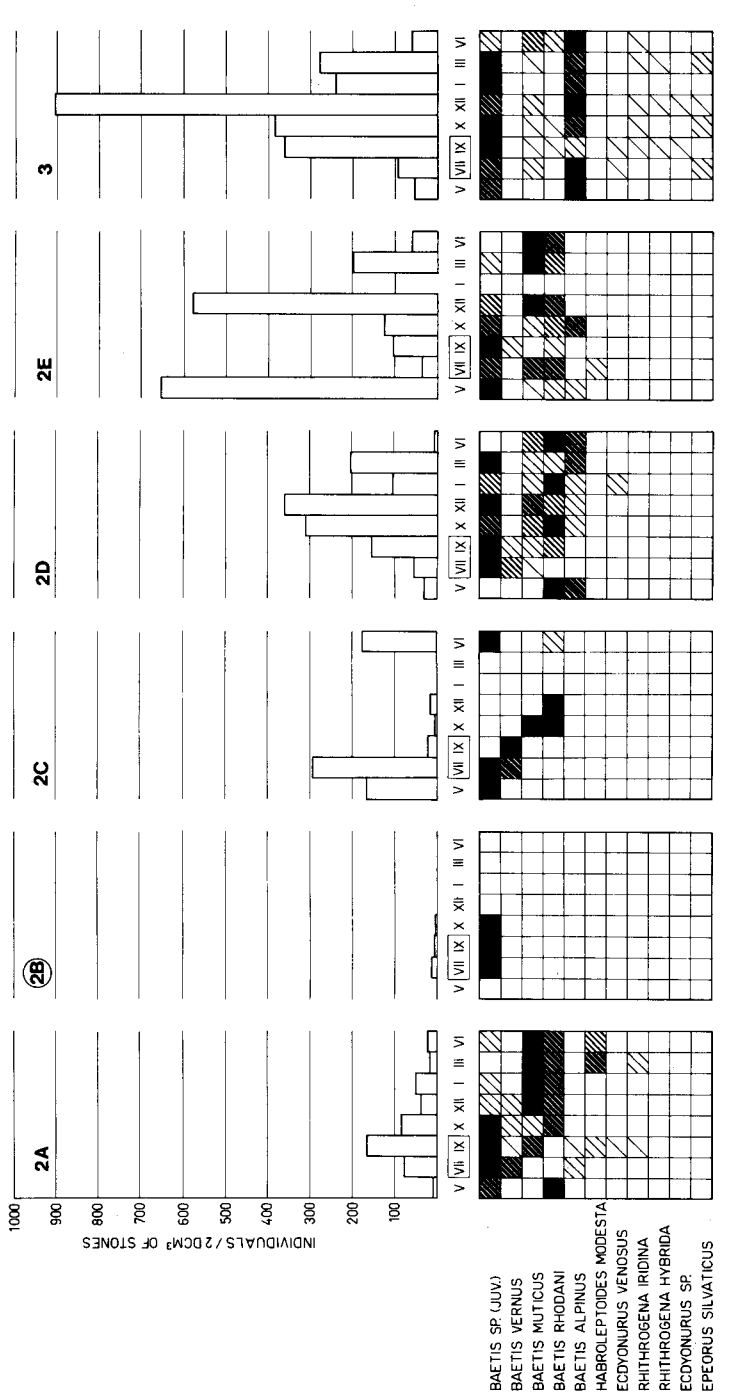

Figure 6. Annual fluctuations in the density of Ephemeroptera and the percentage composition of the taxocenes of Ephemeroptera in stream Rybi Potok (2b = sewage outlet), VII–IX is the period of increased tourist traffic (symbols as in Fig. 1).

CONCLUSIONS

Taking into consideration the species composition, the dominance structure expressed as a percentage, and the density of Ephemeroptera in the High Tatra streams and the rivers flowing at their foot, two taxocenes of Ephemeroptera, allowing defination of three zones, were distinguished.

Above 1550 m a.s.l. mayflies appear only periodically and do not form a typical taxocene. The majority of species of Ephemeroptera found in the Tatra Mountains have a one year (or longer) life cycle and require a continuous flow of water. Freezing of the streams in winter eliminates them. Sowa (1975) defines this zone as 0. But other differences, apart from lack of mayflies, between this zone of the Tatra Mountains and the rest of the Carpathians are so large that this zone should be included into the kryal (Steffan 1971, Kownacka and Kownacki 1972).

At an altitude of 900 to 1550 m a.s.l. a typical taxocene develops in which *B. alpinus* dominates with *R. loyolaea* in the upper course, and *R. hybrida* and *R. iridina*, in the lower one, as subdominants. *A. inopinatus* dominates in pools.

At an altitude of 750 to 900 m a.s.l. nymphs of *B. alpinus* and *B. melanonyx* dominate the taxocene. Numerous other species (19 species) are found simultaneously; these, however, apart from *B. rhodani*, do not reach great densities.

This distribution of the taxocenes, with small modifications, is found in all of the investigated streams of the High Tatra Mountains.

The inflow of sewage into the streams in the zone of subalpine forests causes disturbances, both in the structure and density of mayflies in the natural taxocene of Ephemeroptera. The species typical of the Tatra Mountain streams: *B. alpinus, R. hybrida* and *R. loyolaea* are absent in the polluted stream sector or occur as individual specimens, whereas many species characteristic of streams flowing at the foot of the Tatra Mountains (*B. rhodani, B. muticus, H. modesta*) occur. *B. vernus* deserves special attention. Its most intensive development took place 30 m below the sewage discharge point during the tourist peak. It was not found in other streams of the subalpine forest zone, or in streams flowing at the foot of the Tatra Mountains. Individual specimens were caught only in the lower reaches of the river Białka below 650 m a.s.l. On one occasion some individuals were caught in the river Białka at an altitude 960 m a.s.l., below the buildings at the frontier crossing at Łysa Polana, from which sewage is released into the river. In other Carpathian streams and rivers they were found only as individual specimens. They occurred more numerously only in the rivers Wilga near Cracow

(300 m a.s.l.) and Drwinka (200 m a.s.l.), (Sowa 1975). It seems probable that a more common occurrence of this species could indicate the pollution of mountain rivers and streams with sewage.

Apart from changes in the structure of the taxocene the inflow of sewage also causes some changes in the total number of Ephemeroptera. Just below the sewage discharge Ephemeroptera are eliminated from the biocenosis. By some tens of meters downstream however, a rapid increase in the density of Ephemeroptera, not reported from any other Tatra streams, takes place. An increase in density of mayflies was also noticed at a great distance (> 3000 m) from the outlet of sewage, though the structure of the taxocene was already similar to that found in unpolluted streams.

From the discussion above, taxocenes of mayflies provide a very good index in distinguishing zones in streams and rivers. They can also be useful in detecting slight pollution. On the other hand, heavy organic pollution causes a total elimination of mayflies from the biocenosis (e.g. the stream Kryniczanka - Szczęsny 1974).

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RESUME

Dans les torrents des Tatras au-dessous de 1550 m d'altitude les Ephemeroptera n'apparaissent que sporadiquement. Entre 900-1550 m d'altitude *Baetis alpinus* et *Rhithrogena loyolaea* dominent dans le courant et *Ameletus inopinatus* dans l'eau stagnante. Dans la zone du torrent en aval (au-dessous de 900 m) beaucoup de nouvelles especes apparaissent. Dans le torrent pollué (entre 1380-1390 m) au-dessous des égouts Ephemeroptera manquent. 30 m au-dessous, de juillet jusqu' a septembre (saison touristique) *B. vernus* domine. 100-500 m au-dessous des égouts *B. rhodani* et *B. muticus* dominent. On rencontre aussi quelques rares exemplaires *B. alpinus*, mais il n'y a guere de représentants de *Rhithrogena*.

ZUSSAMENFASSUNG

In Tatrabächen unter 1550 m begegnet man beinahe keine Ephemeroptera. Zwischen 900-1550 m dominieren im Strom *Baetis alpinus* und *Rhithrogena loyolaea* und im stagnierenden Wasser *Ameletus inopinatus*. In der Gebirgszone des Baches (unter 900 m) treten neue Arten auf.

In einem verunreinigten Bach (1380-1390 m) gleich unter dem Abwasserkanal befinden sich keine Ephemeroptera. 30 m unterhalb, von Juli bis September (Touristsaison) dominiert *B. vernus*. 100-500 m unterhalb des Abwasserabflusses dominieren *B. rhodani* und *B. muticus*. Einzelne Exemplare *B. alpinus* begegnet man auch, aber die Vertreter der *Rhithrogena* fehlen ganz.

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