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Ecology of the forest stream Lane Błoto in the Niepołomice Forest

2. Community structure, life cycles, and production of Ephemeroptera

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Abstract — The *Ephemeroptera* fauna in the stream Lane Błoto in the Niepołomice Forest has been studied by means of twice a month samplings at 5 stations from March 1978 to March 1979. In all, about 50 000 larvae have been collected comprising 19 species. The data concerning structure and dynamics of mayfly community, life cycles, and production of the dominant species have been analysed. Mayfly community at all stations has a low diversity index value, reflecting the dominance of two species: *Baetis vernus* and *Leptophlebia vespertina*. The life history of 7 most abundant species was investigated. All of the species were univoltine. Annual production of 5 of those species was 7.465 g m^{-2} $year^{-1}$.

Key words: *Ephemeroptera*, forest stream, species diversity, life cycles, biomass, production.

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1. Introduction

Mayflies occur commonly in inland flowing waters where they constitute, apart from flies, caddisflies, and stoneflies one of the most important group of water insects. The great species diversity and abundance of mayflies in unpolluted flowing waters indicates to the significance of that group in the food chain. They constitute easily available food for fish (Brittain 1979). Particular species show great differentiation as far as environmental condition requirements are concerned; accordingly, they have a distinct zonal distribution along the course of flowing waters (Sowa 1975a, Maitland 1979). Great sensitivity to organic pollution of the major part of species belonging to this group causes formation of their changed communities in the contaminated waters; in the case of heavy pollution of water they perish completely. Mayflies can, thus, be also used as biological indicators in determining the degree of water purity (Sowa 1979).

The present paper aims at determining the role of mayflies in a small lowland stream, and especially at recognizing their species diversity, abundance, life cycles, and production of the most numerous species. These chosen problems concerning mayfly ecology seem to be of great importance in understanding their role in the ecosystem of inland flowing waters.

2. Investigation area

The present investigations were carried out in the lowland stream of Lane Błoto, one of the three main affluents of the stream Drwinka. It flows across the southern part of the Niepołomice Forest. Its total length is 3500 m of which 800 m cross a wooded sector. Along the whole length of the stream 5 investigation stations were appointed. An exact description of those stations and chemical analysis of water and bottom sediments were presented in the first part of this work (Jop 1981). According to the classification of flowing waters proposed by Illies and Botosaneanu (1963) the stream Lane Błoto can be included into the type of small lowland streams in which thermic conditions and poor water yield are unfavourable for cold adapted aquatic organisms.

3. Material and method

Investigations were carried out from 15th March 1978 to 27th March 1979. The material was sampled twice a month from 5 stations located along the course of the stream. Quantitative samples from plants were collected by use of a standard bottom sampler of inlet area 625 cm^2 provided with a net of mesh diameter 0.3 mm. The fragment of the plant tuft delineated by the frame of the bottom sampler was covered from above and subsequently plants were cut off quickly at the surface of the sediment. Quantitative samples from a bottom sediments were collected by use of Morduchaj-Boltovski's tube bottom sampler of an inlet surface area of 50 cm^2, and a core 6 cm long was cut off subsequently. Semiquantitative samples from a sediments and plants were collected with a standard bottom sampler of an inlet surface area of 200 cm^2 provided with a net of mesh diameter 0.3 mm. Samples from plants were collected by use of the moving method from a projection area of 1 m^2, whereas, samples from a sediments were collected each time at their surface layer within 5 seconds. From the stream section in which production was determined about 20 quantitative and 4 to 5 semiquantitative samples were taken on each date; at other stations 4 to 5 semiquantitative samples were taken. Animals were preserved in situ in 4 per cent formalin solution. Diurnal investigations of drift were carried out on 4th May 1978 at station 3 straining 500 dm^3 water every 2 hours using a plankton net.

Three types of habitats were appointed among which significant faunistic differences could have been expected, as follows:
— sandy bottom in the current,
— bottom formed of mud, mainly in the marginal parts of the stream bed,
— vascular plants throughout the width of the stream bed.

The total number of 587 samples of both types were collected, in it 139 from sandy bottom, 193 from muddy sediments, and 255 from plants. Generally 49 178 larvae and nymphs of mayflies were found.

The larvae fixed in situ were transfered into the laboratory and together with plants and mud from the natural biotope rinsed with water and subsequently fixed again with 2.5 per cent formalin. For measurements all specimens were removed from the samples, and larvae damaged or disshaped under the influence of the fixative were eliminated. The applied technique of sampling permitted to collect also the youngest larval forms whose identification was relatively easy owing to the small number of closely allied species. The material was identified according to descriptions and identification keys (Landa 1969, Müller-Liebenau 1969, Macan 1970). The estimation of the growth of mayfly larvae was based on measurements of body length measured from the front margin of the head to the terminalmargin of the 10 tergite of the abdomen and on determination of the fresh weight of the body of the individual after previous drying of the specimens by a battery centrifuge (after Kubiček 1969). Weighing was performed with accuracy to 0.01 mg, using an automatic analytic scale of Sartorius type.

Similarly to Cianciara (1979) and Humpesch (1979) the size of wing pads of the 1st pair estimated in relation to the metathorax and the consequent segments of the larvae abdomen (fig. 1) was the adopted criterion of the developmental degree and constituted the basis for distinguishing larval developmental stages. On the basis of developmental stages and body length 11 size classes were distinguished for *Centroptilum luteolum, Baetis vernus, B. digitatus,* and *Leptophlebia vespertina,* and 14 size classes for *Heptagenia fuscogrisea.*

Males of most of the identified species were recognized in larval stage by the presence of turbinate eyes and germs of copulation organs

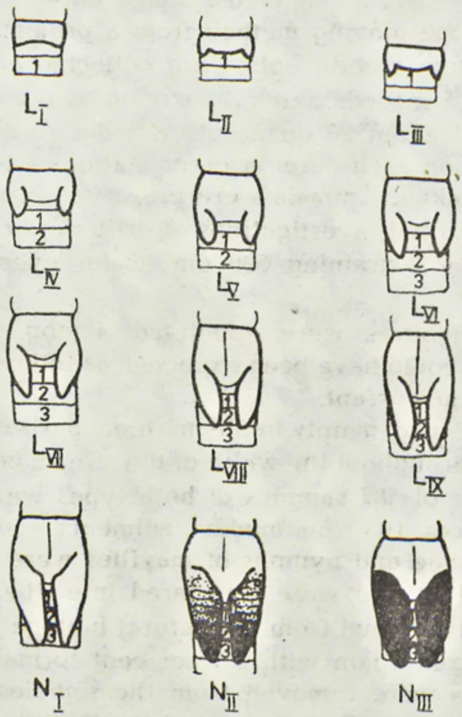


Fig. 1. Rough picture of the distinguished developmental stages of dominating species of mayflies, larvae (L_{I}—L_{IX}), nymphs (N_{I}—$N_{III}9$), 1—3 segments of the abdomen

on the ninth abdominal segment. In those species the males were distinguished from females from the L_{II} stage on. In males of *Heptagenia fuscogrisea,* apart from sexual germs, bigger asymmetric composed eyes were used. Distinction of males in that species was possible in larvae from stage L_{III} on. In the case of *Ephemera danica* and *E. vulgata* males were distinguished from females only in larvae above 8 mm long by their comparatively larger eyes and by germs of copulation organs. In the genus *Caenis* the males differed from females distinctly by their thicker basal part of the tails.

Qualitative similarity between the communities from 5 distinguished stations was arranged using the Sørensen index (Southwood 1975), whereas quantitative similarity of the communities between the stations and habitats was determined by use of the Bray-Curtis index (Clifford, Stephenson 1975).

Species diversity of mayfly communities at particular stations was calculated from semiquantitative samples as a mean value for the investigation period applying the diversity index proposed by Margalef (1957) and the Shannon-Weaver index (Lloyd et al. 1968).

Table I. Percentage participation and mean body weight of the distinguished larval stages of the dominating mayfly species in mg/indiv. and with 95 percentage of confidence limit (C.L.)

Stages	Baetis vernus			Leptophlebia vespertina			Baetis digitatus			Centroptilum luteolum			Heptagenia fuscogrisea		
	%	$\bar{x}$	± C.L.	%	$\bar{x}$	± C.L.	%	$\bar{x}$	± C.L.	%	$\bar{x}$	± C.L.	%	$\bar{x}$	± C.L.
L_0	14.6	0.0076	0.0005	8.8	0.0097	0.0007	5.9	0.0085	0.0007	3.6	0.0053	0.0005	6.9	0.0086	0.0009
L_I	19.7	0.0222	0.0016	25.3	0.0386	0.0027	13.6	0.0300	0.0021	21.4	0.0354	0.0025	3.7	0.3469	0.0243
L_{II}	16.1	0.2062	0.0143	21.5	0.0898	0.0063	23.0	0.3420	0.0242	13.6	0.0845	0.0121	5.0	0.4521	0.0316
L_{III}	9.9	0.3564	0.0214	8.1	0.3396	0.0238	22.5	0.5420	0.0380	15.2	0.2776	0.0243	10.5	0.6462	0.0542
L_{IV}	14.5	0.7045	0.0423	20.4	0.5947	0.0416	18.2	1.0862	0.0643	20.9	0.5324	0.0457	32.2	2.1180	0.1291
L_V	8.3	1.4180	0.0705	10.3	1.3406	0.0804	6.9	1.9540	0.1066	4.0	0.8390	0.0786	24.1	2.9027	0.2810
L_{VI}	4.9	2.3773	0.1189	4.2	1.8556	0.1131	4.3	2.6891	0.1613	7.2	1.7211	0.1320	12.2	4.1186	0.3750
L_{VII}	5.3	3.2116	0.1606	0.6	2.4394	0.1219	2.2	3.4502	0.1725	5.2	2.3290	0.2107	2.5	6.2345	0.4581
L_{VIII}	0.5	3.7691	0.2518	0.3	3.3732	0.1686	0.4	3.8951	0.1957	1.5	3.4568	0.2743	1.2	10.1555	0.6850
L_{IX}	3.0	3.7810	0.2812	0.1	4.2627	0.1805	1.2	4.0156	0.2066	1.5	3.9439	0.3011	0.8	13.5495	1.0205
N_I	1.4	3.8971	0.3558	0.2	4.8366	0.2117	0.7	4.2358	0.2421	3.7	4.3986	0.3820	0.6	14.1390	1.2085
N_{II}	0.5	3.9865	0.4294	0.1	6.2025	0.2481	0.2	4.4214	0.2732	1.0	5.3785	0.5482	0.1	16.0050	1.3580
N_{III}	1.3	4.8052	0.4532	0.1	6.6320	0.2749	0.9	5.0183	0.3510	1.2	5.5607	0.6132	0.2	19.3750	1.8752
Total indiv.	19 373			19 257			4 333			2 367			1 529		
Distinguished:															
♀	7 161			6 336			1 422			977			708		
♂	5 411			6 134			819			653			658		

The structure of dominance of mayflies was determined by using the Tremer formula (1969).

Knowing the dried up fresh weight of mayflies and their number calculated for 1 m^2 surface area, the monthly biomasses expressed in g fresh weight/m^2 were calculated. In calculating the biomass of mayflies, reference was made to mean weights of particular individuals for various developmental stages (Table I).

Production was calculated on the basis of the relation of weight to body length of mayflies basing upon Zelinka's method (Zelinka, Marvan 1976). The calculated values of production refer to a projected 1 m^2 of the stream since the mayflies inhabiting the bottom and vascular plants were treated in calculations globally.

4. Results

4.1. Community structure and diversity

In the collected material 19 species of mayflies belonging to 13 genera and 7 families were distinguished. Along the whole length of the stream two species: *Baetis vernus* and *Leptophlebia vespertina* dominated. Their percentage participation in the total number of larvae collected in semiquantitative samples was 71.5 per cent. In the annual cycle an evident replacement took place between *Baetis vernus,* which occurred most numerously from May till September, and *Leptophlebia vespertina* with a number maximum in October and March. The exchange between the dominating species greatly diminished the competition between them becoming simultaneously an efficient way of density regulation. In the

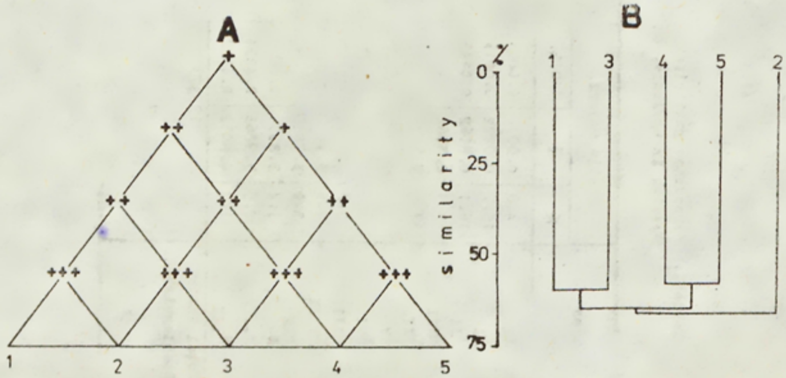
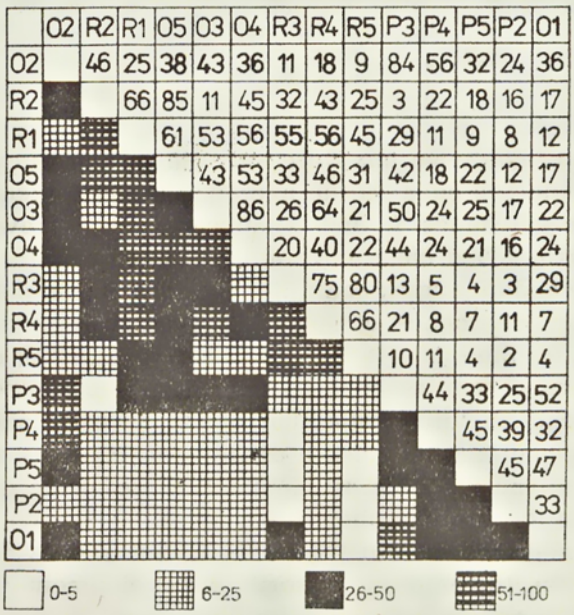


Fig. 2. Similarity of mayfly communities at stations 1—5. A — qualitative ⩾+++⩾ 80%, ++⩾ 70%, +⩾ 60%; B — quantitative

whole stream great variations in the abundance of communities took place during the year. The highest values of abundance were recorded in May and April, this being caused by the rhythm of life cycles of two dominants, *Baetis vernus* and *Leptophlebia vespertina*. At the successive stations of the stream a gradual increase in the number of species was recorded, and apart from station 2, in the density of inhabitation. A noticeable preference of the majority of species for inhabiting vascular plants was observed. Mayflies from this type of biotope constituted 82 per cent of the whole collected material.

The mayfly community of the stream Lane Błoto is represented by a low number of species. Differences in the number of species in the communities at successive stations along the course of the stream are not considerable, and as a result the neighbouring stations show a pronounced qualitative similarity. With the elongation of the distance between the stations the similarity decreases gradually (⩾ 70 per cent). The lowest similarity (⩾ 60 per cent) was found to occur between communities of mayflies from stations 1 and 5, and 2 and 5 (fig. 2A). Since a greater quantitative differentiation was expected this similarity was also calculated between all investigated stations. The values did not differ, however, significantly from the previously calculated index only station 2 (fig. 2B) was more different.



	O2	R2	R1	O5	O3	O4	R3	R4	R5	P3	P4	P5	P2	O1
O2		46	25	38	43	36	11	18	9	84	56	32	24	36
R2			66	85	11	45	32	43	25	3	22	18	16	17
R1				61	53	56	55	56	45	29	11	9	8	12
O5					43	53	33	46	31	42	18	22	12	17
O3						86	26	64	21	50	24	25	17	22
O4							20	40	22	44	24	21	16	24
R3								75	80	13	5	4	3	29
R4									66	21	8	7	11	7
R5										10	11	4	2	4
P3											44	33	25	52
P4												45	39	32
P5													45	47
P2														33
O1														

Fig. 3. Quantitative similarity of mayfly communities between distinguished habitats. O — mud with detritus, P — sandy bottom, R — submersed plants. Numbers at symbols O, P, R, denote stations

The values of the index of similarity between the habitats in the investigated stations point to the existence of two groups of mayfly communities (fig. 3). The first group is constituted by 9 communities from plants and a muddy sediment, the second group by 5 communities from a sandy bottom and sediment from station 1. Greatest similarity (80 to 86 per cent) in the first group and in the whole diagram is characteristic of communities from sediments and plants from station 3 and 4, from plants from station 2, and sediments from station 5.

During the investigation period mayfly communities from all stations had low values of the diversity indices reflecting a marked dominance of two species only: *Baetis vernus* and *Leptophlebia vespertina*. The increase in the number of species at successive stations did not influence univocally the changes of values of diversity indices. This was evidenced by their annual values:

station 1: J' = 0.54; H' = 1.30; d = 0.95
station 2: J' = 0.48; H' = 0.94; d = 0.60
station 3: J' = 0.47; H' = 1.26; d = 0.90
station 4: J' = 0.48; H' = 1.51; d = 1.23
station 5: J' = 0.52; H' = 1.65; d = 1.31

A significant decrease in the value of the diversity index at station 2 was caused by an increase of two dominating species at a simultaneous decrease in the total number of mayflies.

4.2. Life cycle

Two cohorts of *Baetis vernus* were found in an annual cycle. Females of this species laid 500 eggs on the average. In April great numbers of individuals of larval stages (L_0 and L_I) appeared; they grew quickly and the first nymphs reached emergence ability already by the end of May (fig. 4A). By the end of August again the youngest larval stages of a new cohort appeared. Emergence of subimaginal forms was recorded from the end of May till the end of November; the maximum of emergence of subimaginal forms of the first cohort started at the beginning of June and lasted till the end of July, while that of the second cohort from the middle of September till the middle of October. Nymphs of the second cohort, ready to emerge, were smaller than those of the earlier cohort. Hence, larvae of the second cohort seem not to have been in their optimal developmental condition at that time. This is also evidenced by the fact that, in winter, larvae of the majority of developmental stages which did not manage to emerge are found. In the annual cycle one generation of *Baetis digitatus* (fig. 4B) appeared only. Females of this species laid eggs in the number of 400 on the average. Apart from the spring season when an intensive growth was recorded, the growth rate of larvae of

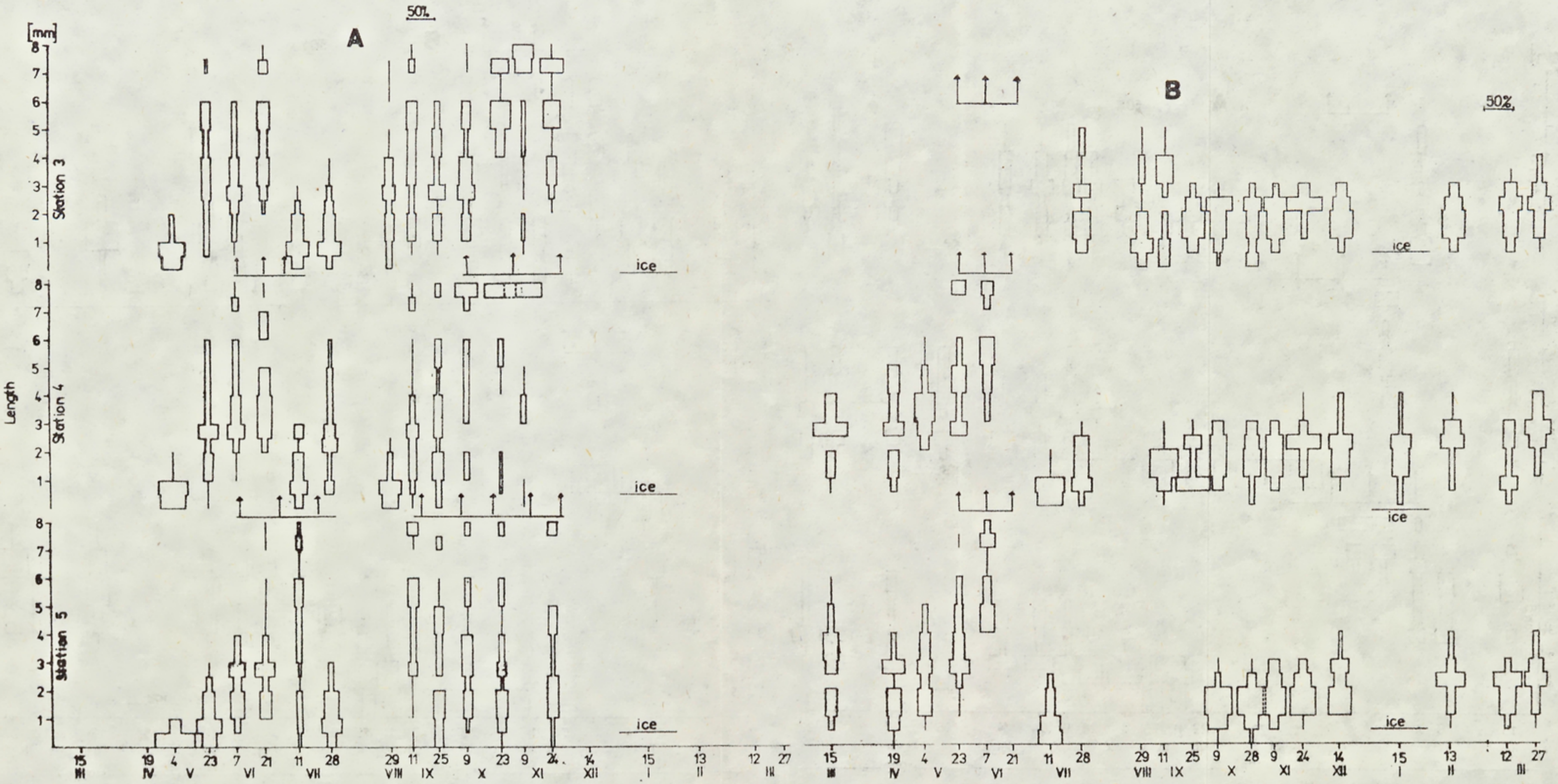


Fig. 4. Distribution of percentage participation of size groups of ***Baetis vernus*** (A) and ***Baetis digitatus*** (B) from stations 3—5. Presence of at least 100 specimens for A and 50 specimens for B at every date constituted the calculation basis. Arrows denote the period of subimago emergence

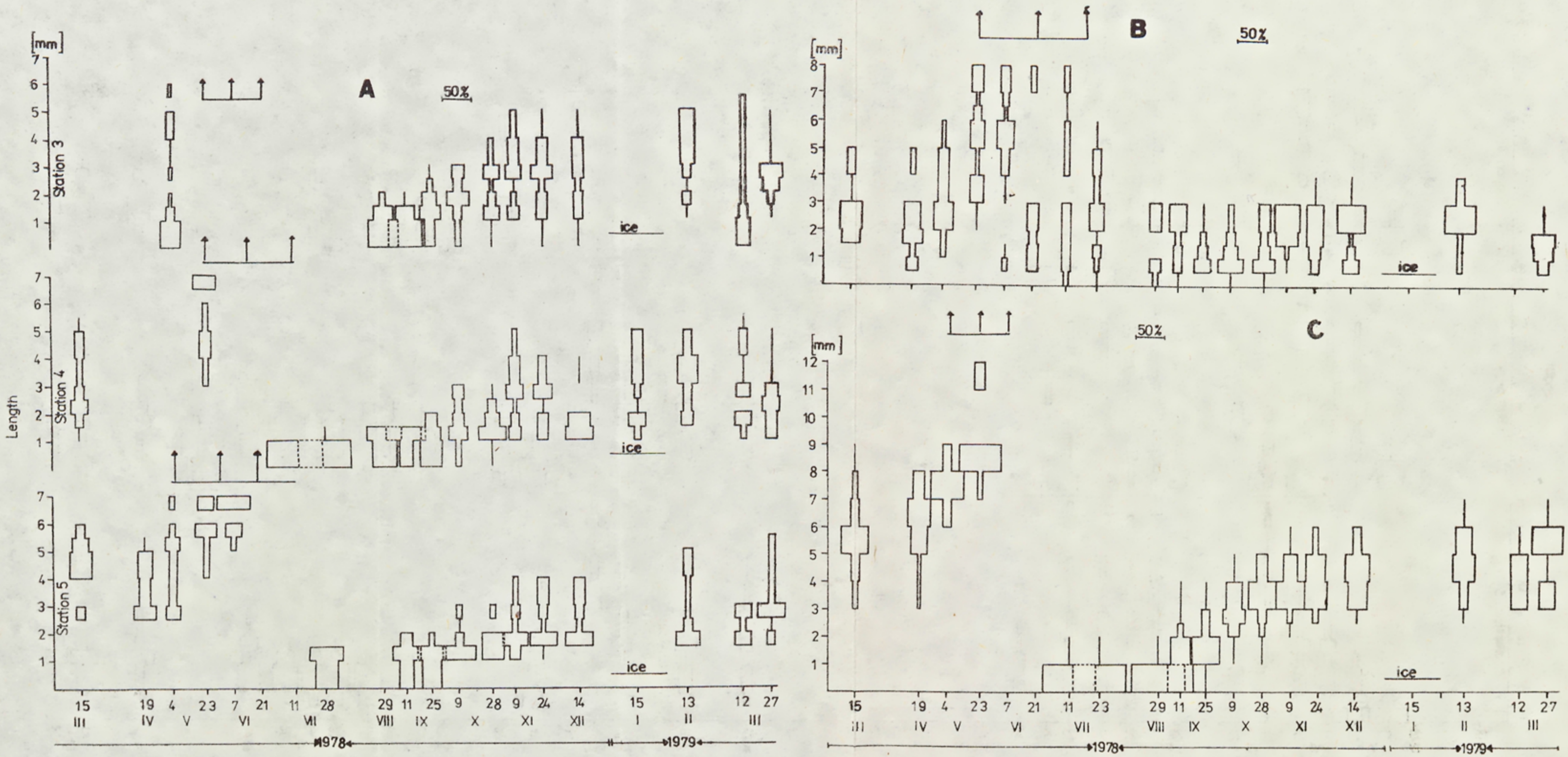


Fig. 5. Distribution of percentage participation of size groups of *Leptophlebia vespertina* (A) from stations 3—5, *Centroptilum luteolum* (B) and *Heptagenia fuscogrisea* (C) from stations 1—5. Presence of at least 100 specimens for A and 50 specimens for B and C at every date constituted the calculation basis. Arrows denote the period of subimago emergence

that species was rather regular. The period of emergence of subimaginal forms was rather very short and lasted from the end of May till the second half of June. In July numerous juvenile larvae (L_0 and L_I) appeared. In view of the short period of absence of larvae of *Baetis digitatus* it may be concluded that those species has not quiescence period in the embryonal stage. In the autumn-winter period the most numerous stages among the larvae present in the stream were L_{II}, L_{III}, and L_{IV}.

Emergence of subimaginal forms of *Leptophlebia vespertina* was observed from the beginning of May till the middle of July. Adult females laid 900 eggs on the average. The joungest larval stages (L_0) appeared already in July, so the beginning of larvae hatching took place a short time after eggs had been laid. Juvenile larvae grew at a high rate and in November already reached the length of 4 to 5 mm. At that time a great number of developmental stages was noticeable. This pointed to a prolonged hatching period of a part of eggs. From December till February an inhibition in growth of larvae of that species was observed, whereas in the final period of the winter the growth rate was considerably accelerated. Some differences in the length of the emergence period of subimagos and in the appearance of juvenile larval forms was found at three investigation stations (fig. 5A). The shortest emergence was observed at station 3, whereas, juvenile stages appeared earliest at station 4.

Centroptilum luteolum realized one generation during the year. Emergence of subimaginal forms was observed from the middle of May till the middle of July (fig. 5B). Juvenile stages (L_0 and L_I) appeared by the end of August, hence, hatching of larvae took place during a period not exceeding one month and a half following the date the eggs had been laid. During the three months preceeding emergence of imagos *Centroptilum luteolum* had the most regular growth of all the investigated species. In autumn their growth, though slowed down continued, whereas in winter months it was practically stoped.

Heptagenia fuscogrisea realized one generation in a year. Emergence of subimaginal forms was observed from the beginning of May till the first days of June (fig. 5C). In July juvenile forms of larvae (L_0) appeared. In spite of the small number of larvae of that species their fairly regular growth at successive dates of sampling, including winter, was observed.

Other more numerous species were: *Habrophlebia fusca* and *Ephemerella ignita. H. fusca* has one generation during a year. Its nymphs were present in the water of the stream from the end of May till the middle of July. The main growth took place in spring and summer. Larvae of that species were absent from samples from November till March. *E. ignita* — has also one generation during a year; it emerges from June till October; during this time grown up nymphs were found in the material. In autumn and winter juvenile larvae were not found.

4.3. Production

The production of mayflies was estimated at station 5 i.e. in the stream sector close to the mouth. The choice of that sector of the stream for that purpose was suggested by the amount of available material.

The annual mean abundance of all mayflies caught at that station was 947 specimens/m². From that number 392 specimens were larvae of *Leptophlebia vespertina* whose annual mean biomass was 0.182 g/m². *Baetis vernus* presented also a high annual mean abundance equaling 304 specimens/m² of annual mean biomass 0.461 g/m². A numerously represented species of mayflies at that station was also *Baetis digitatus* (113 specimens/m² with annual mean biomass 0.074 g/m²), *Centroptilum luteolum* (58 specimens/m² with annual mean biomass 0.048 g/m²), *Heptagenia fuscogrisea* (39 specimens/m² with annual mean biomass 0.109 g/m²), and *Ephemera vulgata* (6 specimens/m² with annual mean biomass 0.558 g/m²). Other specimens occurred sporadically (Table II) were not important in

Table II. Monthly mean number of mayfly community at station 4 for the investigation period. (Number of indiv./m^2)

Species	Months											
	IV	V	VI	VII	VIII	IX	X	XI	XII	I	II	III
Ephemera vulgata	8	6	4	5	13	4	6	5	7	6	8	3
Ephemera danica				3						4		2
Heptagenia fuscogrisea	27	14	3	72	59	55	54	47	39	36	35	29
Habrophlebia fusca	26	48	12	9								
Paraleptophlebia submarginata	11			2		5		3				
Leptophlebia vespertina	108	42	6	5	16	1244	1452	896	456	201	155	131
Leptophlebia marginata	4	6										7
Siphlonurus armatus												12
Baetis vernus	7	596	1119	754	480	323	284	47	19	14	8	3
Baetis digitatus	65	74	4	15	41	356	274	190	105	87	76	71
Baetis niger		19	29	17	15	13	24					
Centroptilum luteolum	33	28	21	12	8	5	234	121	78	69	48	39
Procloeon ornatum		5		6			3					
Cloeon dipterum						2						
Ephemerella ignita			18	36	7	8	12					
Caenis macrura		2				8	7	4				
Caenis horaria				3								
Brachycercus harrisella				5		3						
Sum	289	840	1216	944	639	2026	2350	1313	704	417	330	297

Table III. Monthly means of biomass of nine most numerous mayfly species at station 5 (g/m^2)

Taxon	Months											
	IV	V	VI	VII	VIII	IX	X	XI	XII	I	II	III
Ephemera vulgata	0.630	0.508	0.396	0.598	0.985	0.337	0.515	0.584	0.635	0.597	0.669	0.247
Heptagenia fuscogrisea	0.193	0.308	0.041	0.022	0.030	0.038	0.086	0.103	0.108	0.115	0.128	0.136
Habrophlebia fusca	0.052	0.119	0.036	0.045								
Leptophlebia vespertina	0.133	0.054	0.030	0.026	0.003	0.482	0.494	0.331	0.237	0.137	0.135	0.123
Baetis vernus	0.002	0.185	1.175	1.998	1.099	0.659	0.321	0.056	0.018	0.009	0.005	0.003
Baetis digitatus	0.071	0.191	0.018	0.032	0.089	0.126	0.101	0.085	0.050	0.045	0.044	0.043
Baetis niger		0.041	0.083	0.057	0.028	0.023	0.014					
Centroptilum luteolum	0.039	0.063	0.090	0.043	0.025	0.012	0.080	0.065	0.048	0.045	0.039	0.031
Ephemerella ignita			0.017	0.203	0.005	0.011	0.043					
Sum	1.120	1.469	1.886	3.024	2.264	1.688	1.654	1.224	1.096	0.948	1.020	0.583

the total biomass of mayflies (Table III). An intensive increase in the majority of mayfly species occurred in spring months (March — May) which influenced significantly the biomass increase.

The highest monthly production, globally for the five most numerous mayfly species equaling 1.419 g/m² (Table IV), was found in July, i.e., at the end of the period of intensive growth of all the investigated species. In the winter, the lowest values of monthly production were found; these stayed throughout on a similar level. These low values were caused by slow growth of most of the species as well as by a low participation of *Baetis vernus,* the main producer among the investigated species in the stream. Small losses and high production of that species (Table IV) were due to the fact that two cohorts developed in thermally favourable conditions and to their short period of larval development. Although the annual mean abundance of the two dominants was similar, the production of *Baetis vernus* was twice as high as that of *Leptophlebia vespertina.* A low annual production of the latter species was caused by great losses of specimens in larval development, and short period of hatching of

Table IV. Mean monthly production of most numerous mayfly species at station 5 (g/m²)

Taxon	Months												Sum
	IV	V	VI	VII	VIII	IX	X	XI	XII	I	II	III	
Leptophlebia vespertina	0.089	0.036	0.018	0.019	0.001	0.367	0.416	0.229	0.183	0.097	0.089	0.078	1.622
Baetis vernus	0.001	0.103	0.721	1.342	0.863	0.487	0.247	0.031	0.011	0.006	0.003	0.002	3.817
Centroptilum kuteolum	0.028	0.052	0.078	0.027	0.020	0.008	0.061	0.042	0.030	0.028	0.023	0.020	0.417
Baetis digitatus	0.055	0.144	0.013	0.023	0.067	0.095	0.088	0.056	0.032	0.027	0.024	0.021	0.645
Heptagenia fuscogrisea	0.155	0.245	0.025	0.008	0.024	0.028	0.055	0.067	0.072	0.084	0.097	0.104	0.964
Sum	0.328	0.580	0.855	1.419	0.975	0.985	0.867	0.425	0.328	0.242	0.236	0.225	7.465

juvenile forms in spite of the fact that larvae were present in the waters for 10 months. The production of five most numerous species constituted about 75 per cent of the total annual mayfly production at station 5. The indices of biomass rotation of the investigated species were, as follows: *Leptophlebia vespertina* 8.9, *Heptagenia fuscogrisea* 8.8, *Baetis digitatus* 8.7, *Centroptilum luteolum* 8.6, *Baetis vernus* 8.3.

5. Discussion

A great majority of the species found in the stream has a very large range of occurrence in Europe (P u t h z 1978). The group of northern--middle European species was most numerously represented.

On the basis of the species composition and dominance structure of mayfly larvae two zones of inhibitation were distinguished. In the first zone, covering the upper and middle part of the stream course, the community of mayflies is of initial character. It consists of a few species of a not fully developed dominance structure and low abundance. In the second zone, covering the more distant middle part of the stream and its lower course, the number of species and their abundance increased greatly. The increase in the number of species in that sector of the stream did not influence, however, the decrease in abundance of the two dominants. The density of inhabitation in the whole stream is, thus, achieved by a permanent increase in the number of *Baetis vernus* and *Leptophlebia vespertina* and to a small degree by the increase in the number of new species. This is evidenced also by low values of diversity indices (H' and d) and a permanently incomplete dominance structure (J) at all stations. Since the water current rate in the stream rarely exceeded 0.1 m^3/s it may be thought that this factor does not influence the differentiation of mayfly communities within the distinguished stations. This is confirmed by diurnal investigations of the drift carried out in May when only 7 mayfly larvae were caught; in it 3 specimens of *Baetis digitatus*, 2 specimens of *Leptophlebia vespertina* and 2 specimens of *Baetis vernus*. The increase in the number of species and in the total abundance in the second of the distinguished zones seems to be caused mainly by an increase in the width of the stream in comparison to the first zone, i.e. by an increase in the area available for inhabitation. In that zone the highest values of similarity of communities were found when comparing vascular plant habitats, and subsequently mud with detritus ones. It may be, supposed, that a stabilized and typical system of community structure of that kind of flows is carried out in that part of the stream.

According to Bohle (1969) *Baetis vernus* undergoes in winter a diapause in its development, the lenght of which depends on water temperature. At 0°C the diapause lasts 1 month and with the increase in temperature this period extends and the death rate of embryos increases simultaneously. In the life cycle of *Baetis vernus* in the stream Lane Błoto the youngest larval stages (L_0 and L_I) were found to occur in two different months (May and August); this may suggest that this species has two generations in a year there even though there is no distinct pause in emergence. The results of Bohle's (1969) investigations eliminate, however, the possibility of embryonal development without a longer period of quiescence as well as undergoing a diapause in *Baetis vernus* during a short summer period in high water temperature of the stream Lane Błoto. The larval hatching of that species observed by Illies (1969) in the laboratory did not proceed quickly and took from 112 to 268 days. In the stream Breitenbach during the successive years between 1969 and 1975 variations were observed in the realization of the life cycle of *Baetis vernus* (Illies, Masteller 1977), manifested in the occurrence of 1 to 3 maxima of subimago emergence caused by changes in water temperature during egg cold exposure. Since in winter relatively low temperature (0.2 to 4.0°C), approximate to those found by Illies and Masteller (1977) for the winter 1972/1973 were recorded in the water of the stream Lane Błoto it may be thought that *Baetis vernus* produced there, similarly as in the stream Breitenbach, one generation in a year consisting of two separate cohorts.

The life cycle of *Baetis digitatus* which in the stream Lane Błoto realized one generation during a year has not been investigated so far. Among the species allied to *Baetis digitatus* as far as morphology and systematics are concerned, a similar life cycle was achieved by *Baetis niger* in the lower course of the River Raba (Sowa 1975b). *Baetis niger* which shows great plasticity in its development and dependence on the environmental conditions achieves one or two generations during a year. It may be supposed that *Baetis digitatus* will behave in a similar way.

Centroptilum luteolum realized in the stream one generation during a year, but according to Sowa (1975b) and Brittain (1976) it can have sometimes two generations in a year. At that time emergence of subimaginal forms of the winter generation took place in June, and of the summer one in August; to separate these two generations is, however, difficult since continuity of emergence of that species is observed at that time (Grimeland 1966).

The life cycle of *Leptophlebia vespertina* which was the subject of previous investigations carried out, among others, by Brittain (1972, 1974, 1976), as well as the development of *Heptagenia fuscogrisea* investigated by Ulfstrand (1969) and Brittain (1974) proceeded in the stream in a similar way as in various types of waters of Scandinavia and Great Britain. In flatland, an emergence of these species was observed in May similarly as in the stream Lane Błoto, whereas, in territories situated at a higher altitude it took place in June or in July. This shift in time was caused by differences in the altitude associated with different lengths of the period of low water temperature and occurrence of ice cover. Some authors (Landa 1969, Macan 1970, Sowa 1975b) found in *Leptophlebia vespertina* an extended period of egg development in the embryonal development lasting about 3 months. That species behaved in a similar way in the stream Lane Błoto, even though the beginning of larval hatching took place a short time after the emergence of subimagos had been completed; but considerable extension of the period of occurrence of the youngest larval stages was recorded.

Habrophlebia fusca which realizes in the stream Lane Błoto one generation in a year undergoes there at the egg stage a several months long period of quiescence, possibly of diapause character; this was noticed already earlier by Landa (1969) and Macan (1970).

Ephemerella ignita realizes in the stream Lane Błoto one generation during a year. The absence of juvenile larvae in the samples from autumn and winter confirms the existing observations (Macan 1970, Bohle 1972, Sowa 1975b) on a several months long diapause in the embryonal development of that species.

Among the seven species whose life cycles were recognized in the course of investigations, and for less numerous species confirmed also by data from neighbouring territories found in literature, the prevailing species are those whose eggs undergo a complete embryonal development before winter, i.e. without a quiescence period. A quick increase in temperature in spring stimulated evidently the growth rate of larvae. Their growth finished at that time or at the beginning of summer with the emergence of subimaginal forms. Hatching of juvenile larval forms from the eggs laid during the summer took place in the major part of the species as early as the end of summer or the beginning of autumn. After a short period of growth a slow-down followed and in *Leptophlebia vespertina* and *Centroptilum luteolum* a complete inhibition of larval growth took place connected mainly with the decrease in water temperature and the shortening of day length. The winter mayfly community is here a little poorer in specific composition than the summer community, so the stream becomes more similar in this respect to smaller mountain streams, classify to the 2nd zone of longitudinal distribution of Carpathian mayflies (Sowa 1975b).

In determining the type of the life cycle of the predominant species the author has based himself upon the classification presented by Sowa (1975b), founded upon the number of generations in a year, growth rate of larvae, and the way of egg development. The development of *Baetis vernus* and of *Habrophlebia fusca* as well as of *Ephermerella ignita* was included into type B_1. This group comprises monocyclic „summer" species whose eggs laid in summer or early in autumn, in their development undergo a several months long quiescence or diapause. Larvae hatch in spring or during the summer. The development of *Baetis digitatus* and *Heptagenia fuscogrisea* was included into type B_2. To this group belong monocyclic „winter" species whose embryonal development of eggs laid in spring or in summer proceeds without a period of quiescence. Larvae grow slowly but regularly during the whole year. The development of *Leptophlebia vespertina* and *Centroptilum luteolum* was included into type B_3 in which the egg development and growth rate of larvae is similar to that in species of type B_2; in winter, however, the growth of larvae is completely inhibited in the stage of young larvae. A prevailing majority of species (7) in the stream Lane Błoto achieve their life cycle during a year; in two species only (*Ephemera danica, E. vulgata* — type A_2) a development lasting longer than a year was found, whereas polycyclic species included into group C were completely absent.

According to the results obtained in southern Moravia and northern

Slovakia the type of lowland, warm small streams is inhabited by mayflies belonging mainly to the genera: *Baetis, Cloeon,* and *Caenis.* The annual mean production amounts to the value of 10 g fresh weight/m^2 (Zelinka 1977).

The value of annual production of five most numerous species at station 5 was 7.465 g/m^2, i.e. about 75 per cent of the total production of mayflies at that station. The manifestly highest values of mayfly production were calculated for the period from June till October, i.e. the time of intensive growth of both cohorts of *Baetis vernus* whose participation in the production was 50 per cent. At that time a numerous month's mayfly community was found; its maximum, however, took place in October when the value of production was lower than during the summer. Hence, a quick growth of larvae and small losses decided about the high values of biomass and production during the spring and summer, their amount playing a minor role. The calculated value of mayfly production in the stream Lane Błoto is approximate to that which was given for this kind of stream by Zelinka (1977). It seems that favourable thermal conditions, the absence of typical beasts of prey, such as, e.g., stoneflies, and caddisflies, and the replacement between periods of high abundance of *Baetis vernus* and *Leptophlebia vespertina* are essential factors regulating the final value of mayfly production of this small stream.

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6. Polish summary

Ekologia strumienia leśnego Lane Błoto w Puszczy Niepołomickiej

2. Struktura zgrupowań, cykle życiowe i produkcja *Ephemeroptera*

Przedmiotem badań były jętki, głównie ich stadia larwalne w nizinnym strumieniu Lane Błoto, jednym z trzech głównych dopływów Drwinki. Charakterystykę terenu wraz z analizą czynników środowiskowych omówiono w oddzielnym opracowaniu (Jop 1981). Wśród zebranych 834 okazów uskrzydlonych oraz 49 178 larw i nimf oznaczono 19 gatunków należących do 13 rodzajów i 7 rodzin.

Ponieważ różnice w ilości gatunków w zgrupowaniach kolejnych stanowisk wzdłuż biegu strumienia nie są duże, sąsiadujące ze sobą stanowiska wykazują znaczne podobieństwo zarówno jakościowe (ryc. 2A), jak i ilościowe (ryc. 2B). Wartości wskaźnika podobieństwa pomiędzy siedliskami badanych stanowisk (ryc. 3) wskazują na istnienie dwóch grup zgrupowań jętek. Grupę pierwszą tworzą zgrupowania z roślin i osadów mulistych, odznaczające się dużym podobieństwem, drugą grupę o niskich wartościach wskaźnika podobieństwa tworzą zgrupowania z dna piaszczystego. Zgrupowania jętek wszystkich stanowisk miały w okresie badań niskie wartości współczynników różnorodności, odzwierciedlające zdecydowaną dominację jedynie dwóch gatunków: *Baetis vernus* i *Leptophlebia vespertina*.

Przebadano wzrost i cykle życiowe 7 gatunków jętek. Za podstawę do wyróżnienia stadiów rozwojowych przyjęto wielkość zawiązków skrzydeł w stosunku do kolejnych segmentów zatułowia (ryc. 1). Wszystkie badane gatunki mają jedno pokolenie w ciągu roku. Jedynie *Baetis vernus* tworzy dwie oddzielne kohorty (ryc. 4A). Ugrupowanie zimowe jętek jest tu nieznacznie uboższe w składzie gatunkowym od ugrupowania letniego. Do typowych gatunków „zimowych" należą *Baetis digitatus* (ryc. 4B) oraz *Heptagenia fuscogrisea* (ryc. 5C), których larwy rosną wolno lecz równomiernie w ciągu roku. Rozwój *Leptophlebia vespertina* (ryc. 5A) i *Centroptilum luteolum* (ryc. 5B) jest podobny, jednakże w okresie zimy wzrost larw tych gatunków jest całkowicie zatrzymany.

Produkcję jętek oceniano w przyujściowym odcinku strumienia na 5 stanowisku. Średnia roczna liczba wszystkich jętek złowionych na tym stanowisku wynosiła 947 okazów/m^2 (tabela II). Intensywny wzrost większości gatunków w miesiącach wiosennych wpłynął wyraźnie na wzrost biomasy dominujących gatunków (tabela III) oraz produkcji, która w lipcu, tzn. w końcowym okresie wzrostu wynosiła dla pięciu najliczniejszych gatunków 1,419 g/m^2 (tabela IV). W obliczeniach biomasy i produkcji korzystano z średnich wag pojedynczych osobników dla różnych stadiów rozwojowych (tabela I).

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