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Differences in the production of mayfly larvae in partial habitats of a barbel stream

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With 9 figures and 5 tables in the text

Abstract

The barbel zone (epipotamon) of a eutrophized stream grants mayfly larvae varied living conditions differing from one another. The results of the investigation of abundance, biomass, and production of mayfly larvae in such a stream (the Jihlava — drainage area of the Morava) showed considerable differences in the population of the individual habitats. Most mayflies and their highest production can be found in the plants of the riffle parts of the stream, fewest on the stony bottom of slowly flowing stretches. The most important species from the production point of view is *Baetis buceratus*, followed by *Ephemerella ignita*. From 17 species found 7 constitute more than 97 % of all biomass and production. The total annual production was estimated to be 25.029 g/m^{-2}. Differences in the production of the individual species at partial habitats and throughout the year are discussed.

1. Introduction

In following the production of the zoobenthos of running waters we continued in the barbel zone of the Jihlava River (drainage area of the Morava, see Fig. 1). According to the classification of ILLIES-BOTOSAEANU (1963) it is the upper part of the epipotamon. Summer temperatures of water exceed 25 °C. In the water of the stretch under investigation there is a relatively high content of nutrients, due to the mineralization of the previous organic pollution and flushing from agriculture. Mean values of PO_4—P were 100 μg/l^{-1}, NH_4—N 257 μg/l^{-1} (see Table 1). In the stream even plankton algae reproduce considerably, so that in the warm season of the year the water has vegetation coloration (mainly cycloteloid diatoms and chlorococcal algae of the genus *Scenedesmus* and the species *Coelastrum microporum*). Rich are also covers of higher water plants, mainly *Ranunculus fluitans*, less frequent *Myriophyllum spicatum* (HELAN 1978). The conditions are suitable for "passive traps" and in the benthos there is a mass reproduction of larvae of Simuliidae and caddis flies of the genus *Hydropsyche*. Fish population is typical of the upper parts of barbel zones of streams.

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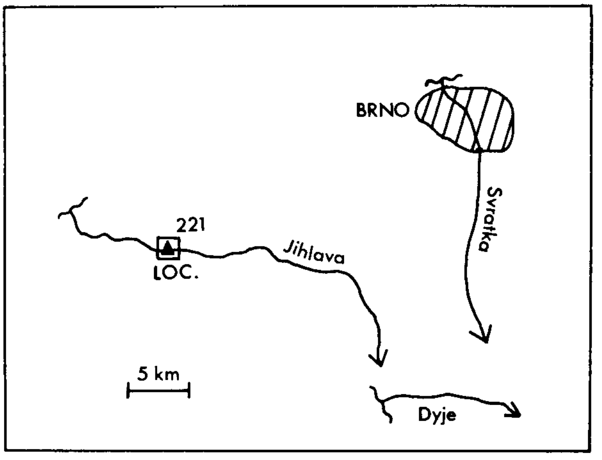

Fig. 1. Map of the station as a part of the drainage area.

The nature of the stream under investigation is evident from Fig. 2. The river bed is natural, the bottom is stony. Riffles interchange with quieter places. The average speed of the stream in riffles under average discharge rates is about 0.8 m/sec^{-1}, in quieter parts 0.3 m/sec^{-1}. Near the banks in the quiet parts there are sandy to muddy deposits with covers of *Baldingera arundinacea*. Maximum depths during average discharge rates only seldom exceed 1 m. A long-term mean discharge rate is 5 m^3/sec^{-1}, the minima measured in the period of investigation were 1 m^3/sec^{-1}.

2. Methods

Samples were taken regularly monthly from March, 1976 to March, 1977. The stream was subdivided into individual partial habitats: stones in riffles, plants in riffles, stones in quiet parts, plants in quiet parts, grasses near the banks. In all those habitats samples were taken quantitatively by means of the triangular

Table 1. Basic chemical water composition of the studied station of the Jihlava River (annual average values).

pH	8.74
Total alkalinity meq l^{-1}	1.92
Total hardness meq l^{-1}	3.52
Dissolved oxygen mg 0_2 l^{-1}	13.9
Oxygen % of saturation	124
B. O. D.$_5$ mg O_2 l^{-1}	3.96
PO_4^{3-} μg P–PO_4 l^{-1}	100
NH_4^+ μg N–NH_4 l^{-1}	257
NO_2^- μg N–NO_2 l^{-1}	64
NO_3^- mg N–NO_3 l^{-1}	5.60
Total inorganic N mg N l^{-1}	5.93

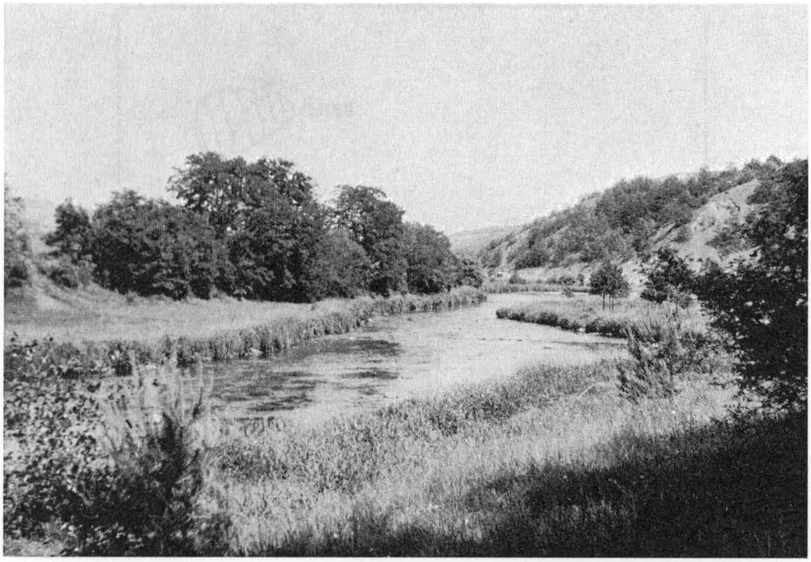

Fig. 2. Photograph of the studied stretch.

benthometer according to Kubíček (see Helan et al. 1973) with area of 0.1 m^2 (stones) or 0.05 m^2 (plants). Quantitatively, larvae of the size from 2.0 mm onwards were obtained. All were removed from the samples, weighed and measured (for details see Zelinka 1969). The weighing was carried out after drying by means of the battery centrifuge (Kubíček 1968). Production was calculated by the method according to Zelinka (Zelinka 1973; Zelinka, Marvan 1976).

In the studied stretch riffles took up 60 % of the area of the stream, quietly flowing parts 35 %, bank grasses 5 %. In this ratio the conversion to one average m^2 of the stream was carried out. The area of covers of submersion vegetation varied throughout the year: in riffles from 1 to 30 % of the area, in quiet parts from 0 to 55 %. According to actual conditions at the time of each individual sample taking the conversion is carried out to the total area of the riffles or of the quiet parts. Conversion to the so-called "corrected" metre (see Zelinka 1969) were not necessary, as the submerged area of the bottom does not practically change with the change of the discharge rate, with the exception of the spates, when samples were not taken.

I should like to thank my colleagues from the Department of Animal and Human Biology, J. E. Purkyně University, Brno, for their assistance in field work and for granting some data.

3. Results

3.1. Abundance

In the studied stretch of the Jihlava River altogether 17 mayfly species were found, all of them typical of that type of stream. Surprising was only anisolated occurrence of the species *Oligoneuriella rhenana*, which used to be frequent there in samples taken before 1970. The reason of its absence

Table 2. Average annual abundance of mayfly larvae (pcs/m^{-2}).

Taxon \ Biotop	riffle: stones	riffle: plants	riffle as a whole	quiet part: stones	quiet part: plants	quiet part as a whole	grasses near the bank	the total stream
Baetis buceratus Etn	357	1785	602	40	527	161	93	423
Baetis lutheri Müll.-Liebenau	482	646	507	42	135	61	0	326
Potamanthus luteus (L.)	206	133	199	95	36	78	62	150
Baetis fuscatus (L.)	151	208	163	52	116	81	0.8	126
Caenis macrura Steph.	69	289	101	100	118	112	61	102
Ephemerella ignita (Poda)	21	312	104	8	85	43	5	78
Ecdyonurus venosus (Fabr.)	23	5	21	4	2	3	0	14
Cloëon dipterum (L.)	0	0	0	0	44	21	113	13
Baetis rhodani (Pict.)	5	10	5	0	0	0	1.6	3
Heptagenia flava Rost.	0.8	1.6	0.9	0	0	0	0	0.5
Centroptilum luteolum (Müll.)	0	0	0	0.8	0	0.7	5	0.5
Procloëon pseudorufulum Kimm.	0	0	0	0.8	1	0.9	3	0.4
Baetis muticus (L.)	0.4	+	0.4	0	0	0	1.6	0.2
Ecdyonurus insignis (Etn)	+	0	+	0	0	0	0	+
Oligoneuriella rhenana (Imh.)	+	0	+	0	0	0	0	+
Ephemerella notata (Etn)	0	+	+	0	0	0	0	+
Ephoron virgo (Oliv.)	0	0	0	+	0	0	0	+
S	1315	3389	1703	342	1064	561	346	1236
S species	12	11	13	10	9	10	10	17

+ = < 0,1 pcs m^{-2}

could not be found out. An outline of the species found and their abundance in individual habitats follows from Table 2. The annual variation in the number of individuals of the individual species is generally sufficiently known and does not differ from hitherto information.

The most frequent are mayfly larvae in plants in the stream and in the stream in general. On the other hand, the smallest density is on the stones in tahe slowly running parts. Larvae may not like the muddy surface which occurs during low discharge rates. The decisive species in the total abundance are representatives of the genus *Baetis*, particularly *B. buceratus* and *B. lutheri*, constituting more than 60 % of the total abundance. In the grasses near the banks the prevailing species is *Cloeon dipterum*. The remaining data follow Table 2.

3.2. Biomass

The calculations of the biomass in the individual habitats and for the whole year were carried out according to the above scheme of the ratios of areas, the results being given in Table 3. Like abundance, biomass is the

Table 3. Average annual biomass of mayfly larvae (g/m^{-2}).

Biotop / Taxon	stones	riffle plants	riffle as a whole	stones	quiet part plants	quiet part as a whole	grasses near the bank	the total stream
Baetis buceratus	0.298	2.925	0.793	0.054	0.705	0.225	0.163	0.563
Ephemerella ignita	0.097	2.164	0.689	0.037	0.607	0.303	0.063	0.521
Baetis lutheri	0.571	0.960	0.619	0.045	0.305	0.101	0	0.407
Potamanthus luteus	0.351	0.198	0.328	0.505	0.216	0.387	1.119	0.388
Ecdyonurus venosus	0.527	0.004	0.456	0.099	0.066	0.091	0	0.305
Baetis fuscatus	0.177	0.271	0.193	0.051	0.114	0.077	0.001	0.143
Caenis macrura	0.046	0.238	0.081	0.089	0.143	0.116	0.033	0.091
Cloëon dipterum	0	0	0	0	0.104	0.047	0.418	0.037
Other species	0.036	0.070	0.041	0.007	0	0.004	0.060	0.030
S g/m^{-2}	2.103	6.830	3.200	0.887	2.260	1.351	1.857	2.485

highest in the plants of the riffles, then in the plants of the quiet parts, and lowest again on stones of the quiet parts. As for the individual species, the first in biomass is again *Baetis buceratus*, second, however, is *Ephemerella ignita,* thanks to its relatively high mass. This species finds the most advantageous conditions of life in the water plants and predominates there at the beginning of summer. The absolutely highest local biomass is reached by the species *Potamanthus luteus* in the grasses near the banks, as most of the big larvae gather there in the months of June and July before the emergence. Only a few species are of decisive importance in the total biomass. The first two mentioned above (see also Table 3) take up more than 43 %, the first three 60 % and the first four over 75 % of the total biomass of mayfly larvae.

Differences in the biomass of the individual habitats are considerable, like in the abundance. In both cases, however, 50 % of the total value of mayfly larvae fall to the plants in the riffles. The variation of the annual course is evident from Fig. 3.

3.3. Production

From the above data it follows that the most significant habitat in the production will be plants in the riffles, and as far as species are concerned it will be *Baetis buceratus* and *Ephemerella ignita.* The results given in Table 4 confirm it. Relatively high local production is that in the grasses near the banks, but the share calculated for the whole production of the stream is relatively low, being 11.6 %. This, however, exceeds the share of the area taken by grasses near the banks in the whole area of the stream, which is only 5 %. On the other hand, the share of the lowest local production,

Table 4. Annual production of mayfly larvae (g/m^{-2}).

Biotop / Taxon	riffle stones	riffle plants	riffle as a whole	quiet part stones	quiet part plants	quiet part as a whole	grasses near the bank	the total stream
Baetis buceratus	3.522	34.574	9.373	0.638	8.333	2.659	1.927	6.652
Ephemerella ignita	1.068	23.826	7.586	0.407	6.683	3.336	0.693	5.734
Baetis lutheri	4.786	8.045	5.188	0.377	2.556	0.847	0	3.412
Ecdyonurus venosus	5.022	0.038	4.345	0.943	0.629	0.866	0	2.907
Potamanthus luteus	2.580	1.455	2.411	3.712	1.587	2.844	8.225	2.853
Baetis fuscatus	1.981	3.032	2.161	0.571	1.276	0.863	0.011	1.601
Caenis macrura	0.597	3.089	1.052	1.155	1.856	1.506	0.428	1.181
Cloëon dipterum	0	0	0	0	1.163	0.523	4.675	0.414
Other species	0.320	0.630	0.378	0.064	0	0.055	0.560	0.273
S g/m^{-2}	19.876	74.689	32.494	7.867	24.083	13.498	16.519	25.027

Table 5. Percentual differences in the population of partial habitats by mayfly larvae.

Biotop	Abundance	Biomass	Production
Stones in the riffle	20.4	15.1	13.9
Plants in the riffle	52.4	49.0	52.2
Stones in the quiet part	5.3	6.4	5.5
Plants in the quiet part	16.5	16.2	16.8
Grasses near the bank	5.4	13.3	11.6
%	100	100	100
Riffle as a whole	65.2	50.0	52.0
Quiet part as a whole	21.5	21.0	21.6
Grasses near bank	13.3	29.0	26.4
%	100	100	100

which is on the stones of slowly running parts —5.5 %, is reverse in the ratio of surface taken up by this habitat in the total area of the stream than in the grasses near the bank (Table 5). The share of the two above main production species in the total production is almost 50 %.

The chief production period is March to August, with the peak in May and June (Fig. 3). The peaks of production of the individual species take place mostly at different times (see below). With the exception of species with the winter egg diapause mayfly larvae grow also in the cold winter season. The growth rate is, however, substantially slower (also in comparison with some species of mountain brooks, see ZELINKA 1973). The winter community consists for the most part of small larvae and there also occur the greatest losses. Those are the reasons of small winter production. Further we concentrate in detail on the production of the main species.

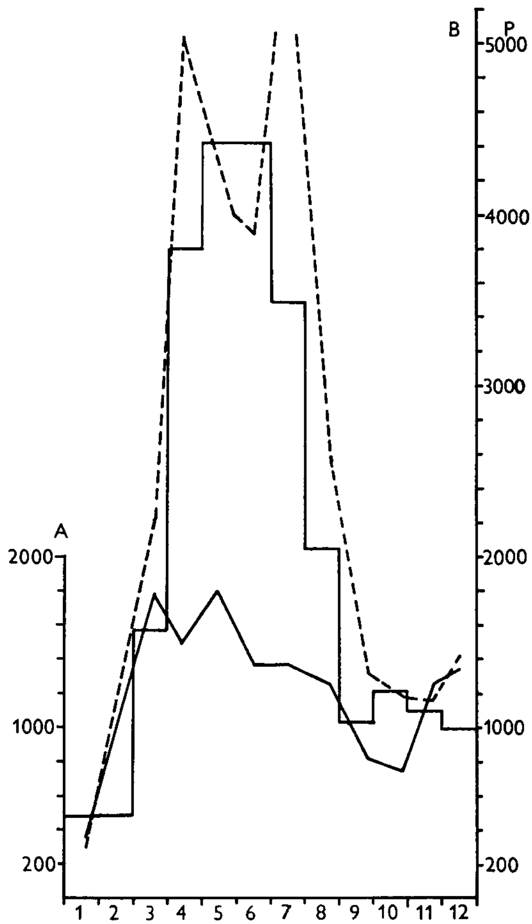

Fig. 3. Graph of the annual variation of abundance (= A — full line, pcs/m^{-2}), biomass (= B — dashed line, mg/m^{-2}) and production (= P — monthly columns, mg/m^{-2}) of mayfly larvae.

Baetis buceratus

The chief production period of this species is the latter half of spring and the beginning of summer (Fig. 4). April is the time of quick growth, the end of April (according to temperature) and mainly May is the period of emergence. From the first laid eggs new larvae appear as early as in May, the growth and emergence of this generation being spread from June to September. The whole autumn is the period of hatching of a part of eggs laid by the second generation. The growth is slow and in winter part of the larvae, particularly the big ones, perish. Further eggs are hatched at the beginning of March. The mean annual production calculated for the whole stream is 6.652 g/m^{-2}. The absolute maximum of the annual production of

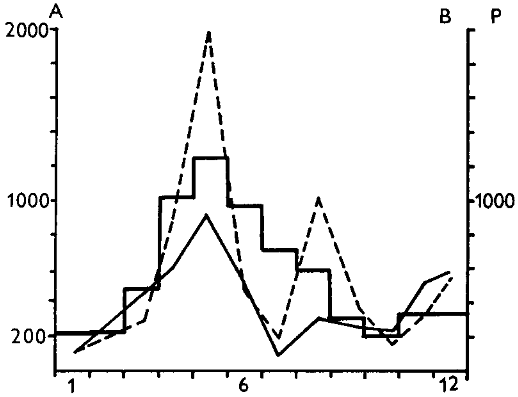

Fig. 4. Graph of the annual variation of abundance, biomass, and production of the species *Baetis buceratus* (explanations as in Fig. 3).

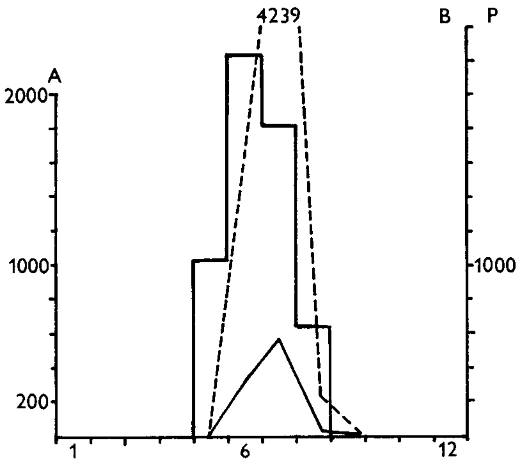

Fig. 5. Graph of the annual variation of abundance, biomass, and production of the species *Ephemerella ignita* (explanations as in Fig. 3).

all the species and all the habitats is *Baetis buceratus* in the plants of the riffles —34.574 g/m^{-2} (Table 4). The monthly maximum of production was reached in May. The P/B coefficient found is 11.82 (two generations).

Ephemerella ignita

This species is the second significant in production. The first small larvae appear towards the end of May, the growth rate is very quick with relatively small losses and during July most of them emerge. The highest production was reached in July, when the daily production rate is 74 mg/m^{-2}. Despite the fact that this production period is limited to 4

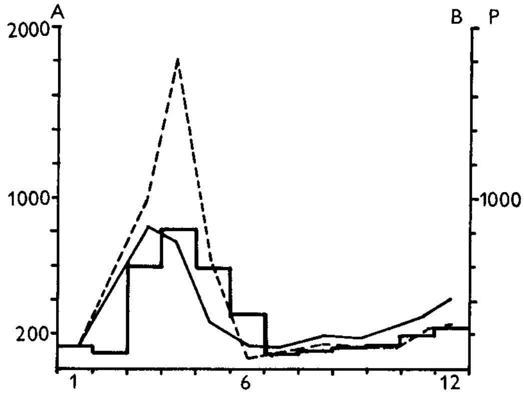

Fig. 6. Graph of the annual variation of abundance, biomass, and production of the species *Baetis lutheri* (explanations as in Fig. 3).

months, the total annual production is 5.734 g/m^{-2}, i. e. 23 % of the whole mayfly production. Like in the preceding species, the chief habitat are plants in the riffles (Table 4, Fig. 5). A high P/B coefficient — 11.01 — is probably due to small losses during the growth in the warm season of the year.

Baetis lutheri

A typical spring to pre-spring species. A quick growth of larvae starts as early as in March, at the beginning of April the increments and production reach their maximum, at the end of April and May the whole generation emerges (Fig. 6). Small larvae appear from June onwards and losses during winter are lower than in the species *Baetis buceratus* (*B. lutheri* is a more cold-adapted species). We found isolated emerging submagines also in September. The nymphae were more than $^1/_4$ smaller in that case than the spring nymphae. In our opinion a small part of the first hatched larvae mature in the same year, forming the second, weak, partial generation. This will depend also on the development of weather of that particular year. The total annual production was determined to be 3.412 g/m^{-2}, i. e. 13.6 % of the total mayfly production. The P/B coefficient = 8.38.

Ecdyonurus venosus

The abundance of larvae of this species was low, so that it was impossible to calculate the production directly. By using the P/B coefficient established for this species in the brooks of the Beskydy Mountains and in the Bítýška (Zelinka 1973; Zelinka et al. 1977) we estimated the annual production to be 2.907 g/m^{-2}, i. e. 11.6 %.

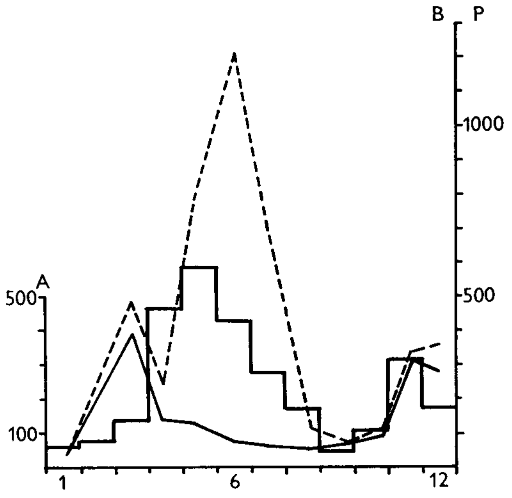

Fig. 7. Graph of the annual variation of abundance, biomass, and production of the species *Potamanthus luteus* (explanations as in Fig. 3).

Potamanthus luteus

The nature of the studied stretch of the river is not too suitable for larvae of this species, their peak being lower down the stream. Despite it its production there was significant. Small larvae exhibit rapid growth in spring, the peak taking place in May. From June to August hatching goes on and the production drops gradually (Fig. 7). As early as in August, but mainly in autumn there appear the first small larvae which grow till winter. During winter great losses are observed and in spring new small larvae appear. Small larvae are the most frequent in plants and stones of riffles, with gradual growth they move to stones in the mild stream and grown up larvae can be found mostly near the banks. The total annual production is 2.853 g/m^{-2}, i. e. 11.4 % of the total production. The P/B coefficient = 7.53.

Baetis fuscatus

This summer species forms mostly two generations in the stretch under investigation, a small part of larvae of the second generation, however, does not finish the metamorphosis. The first small larvae appear at the beginning of April, they grow relatively rapidly and in June part of them hatch. In July another generation of small larvae appears. Subimagines were found as late as in October. Due to the mixing of the two generations the production is relatively balanced throughout the warm season of the year (Fig. 8). The total production, however, is only 6.4 % of the total production of all mayfly larvae. The P/B coefficient = 11.19.

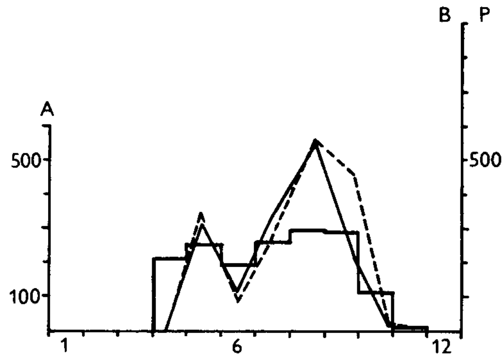

Fig. 8. Graph of the annual variation of abundance, biomass, and production of the species *Baetis fuscatus* (explanations as in Fig. 3).

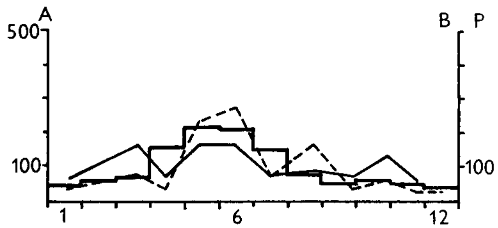

Fig. 9. Graph of the annual variation of abundance, biomass, and production of the species *Caenis macrura* (explanations as in Fig. 3).

Caenis macrura

Despite its relatively high abundance — 8.3 % — this species is of little importance for the production —4.7 %. Two generations mix and the chief production period is thus prolonged from April to August (Fig. 9). The P/B coefficient = 12.98.

Cloeon dipterum

Larvae of this species form a numerous summer population in grasses near the banks, where the abundance reaches as many as 500 individuals per m^2. Local production is relatively high, being 4.678 g/m^{-2}. $year^{-1}$. Converted to the whole year it is, however, only 0.414 g/m^{-2}, i. e. 1.7 % of the total annual production. The P/B coefficient = 11.19.

Other species

The share of the remaining 9 species found at the station is negligible for the total production; it was estimated to be about 1.1 % of total production.

4. Conclusions

The warm and eutrophized barbel stream yields more varied life conditions to mayfly larvae than, say, trout streams, where substantial differences are found only between the biocenosis in the current and that near the bank (see ZELINKA 1969, 1973). In the barbel zone even considerable differences are found in the qualitative, but mainly in the quantitative compositions of the mayfly larvae community in the individual partial habitats. Like in trout streams, only a small part of species living in the studied stretch are of important for the production: out of 17 species found 7 constitute 97 % of all biomass and production.

Conspicuously most mayfly larvae are gathered in plant covers of the riffle parts of the stream. On the other hand, fewest of them are found on the stony bottom of slowly running parts (see Tables 2—4). It is due to good trophic and shelter conditions and, on the other hand, to unfavourable covering the bottom with mud in quiet parts during low discharge rates. Differences in the individual studied habitats are considerable in this respect, as can be seen from Table 5. The share of the habitats in the total production of the stream is determined by the areas of those habitats. That share changes in the individual years, chiefly due to the extent of covers of *Ranunculus fluitans* (influenced by the spates).

The most frequent and significant species is *Baetis buceratus*, populating mainly water plants. High production rate is also due to *Ephemerella ignita* whose larvae, relatively big, grow in the warm season without great losses. The periods of the most intense growth of larvae and thus the peaks of production differ in the chief species as far the time is concerned. In the species *Baetis lutheri* it is April, in *Baetis buceratus* May, in *Ephemerella ignita* June to July. In this way the maximum food competition is partly eliminated and a totally high production of mayfly larvae lasts from April to July.

Despite the relatively high abundance of larvae (1.236 pcs/m^{-2} on the annual average) the total annual production was estimated to be only 25.027 g/m^{-2}, which, in comparison with someother streams, can be considered to be average (see ZELINKA 1977). The reason can be seen in the prevalence of small species for which the rich water plants are suitable, and in the absence or low occurrence of big species important for the production, particularly *Oligoneuriella rhenana*. About 10 km below in the same stream the representatives of big species are abundant (*Potamanthus luteus, Ephoron virgo, Oligoneuriella rhenana*) and mayfly production is higher there by as much 100 %.

In the total production of the zoobenthos of the studied stretch of the Jihlava River the main share is that of Trichoptera (*Hydropsyche*) and Simuliidae larvae, so that mayfly larvae constitute less than 10 % of the total annual production of zoobenthos. This is typical of a eutrophized stream in which higher water plants are developed and which yields sufficient drift food for the respective group of zoobenthos.

The calculations of the relations between biomass and production have again shown a relatively balanced ratio. The annual production of all mayfly larvae at the station under investigation is ten times higher than the average annual biomass. This ratio (or the above data for the individual species) seems to be a starting point for preliminary estimates of their production.

Great differences in mayfly larvae population in the individual partial habitats of this type of streams draw the attention to a parallel study of different habitats, which can be the starting point in estimating the total population and production of the stream.

Zusammenfassung

Die Barbenregion eines Flusses (Epipotamon) bietet den Ephemeropterenlarven verhältnismäßig mannigfaltige Lebensbedingungen dar. Die Untersuchung der Barbenregion des Flusses Jihlava (Fig. 1) hat große Unterschiede in der Abundanz, der Biomasse und der Produktion der Ephemeropteren in einzelnen Teilbiotopen gezeigt (Tabellen 2—4). Das Maximum der Ephemeropterenlarven ist deutlich in den Pflanzen (*Rannunculus fluitans*) der schneller strömenden Abschnitte, das Minimum auf dem steinigen Boden der langsam fließenden Abschnitte (Schlammsedimentation bei niedrigen Durchflußmengen, Tabelle 5). Die größte Produktion hat *Baetis buceratus* (26,6 %), es folgt *Ephemerella ignita* (22,9 %). Sieben von den siebzehn festgestellten Arten bilden über 97 % der gesamten Biomasse und Produktion.

Die Jahresproduktion der Ephemeropteren haben wir auf 25,029 g/m^{-2} geschätzt. Im Vergleich mit der Produktion in dem unteren Teil der Barbenregion des Jihlava-Flusses ist dies relativ wenig. Hauptsächlich in den Pflanzen sind nämlich die kleinen Arten vorherrschend, und es fehlen größere Arten, die für die Produktion wichtig sind (*Oligoneuriella rhenana*, *Ephoron virgo*). Das Verhältnis zwischen der durchschnittlichen Jahresbiomasse und Jahresproduktion ist wieder relativ gleichmäßig und schwankt überwiegend zwischen 1 : 8 bis 12.

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