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THE PRODUCTION OF EPHEMEROPTERA IN RUNNING WATERS

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Abstract

Live weight was calculated for the larvae of Ephemeroptera and other zoobenthos on many localities in the catchment area of the Morava River. At monthly sampling the year-round production of the larvae was derived and the results tabulated for individual stretches in g m^{-2} $year^{-1}$. The communities were classified also saprobiologically and the effect of saprobity on the production of mayflies in the individual zones was presented in the second table. Mayflies are considered very important for fish production in running waters.

Introduction

Mayfly larvae are an important component of the biocenosis of zoobenthos of running waters. In some types of streams or in certain stretches they often have the highest abundance and sometimes also biomass of all groups of animals of the community. Representatives of mayflies can be found from spring rivulets up to big rivers. They also constitute one of the most important components of food for a number of fish species. A lot of data concerning mayfly abundance and biomass can be found in literature (such as Berg, 1948; Badcock, 1954; Illies, 1956; Sieminska, 1956; Albrecht, 1959; Peňáz *et al.*, 1968; Sedlák, 1969; Zelinka, 1969; Flösnser, 1976 and others). There is substantially less information about production. In the course of an investigation lasting several years we have obtained data concerning the production of mayflies in different types of streams which are summarised in this paper.

Method

In spite of several attempts at reducing the elaborate calculation of the production of water animals by mathematical methods trying to reduce the number of entry data (Hynes & Coleman, 1968; Hamilton, 1969; Winberg *et al.*, 1971; Zajka, 1972; Waters & Crawford, 1973; Edmondson, 1974) we have arrived at the opinion (Zelinka & Marvan, 1977) that the hitherto most reliable method is that according to Zelinka (1973). This method requires monthly quantitative samplings carried out for at least one year and measuring all the material obtained. The method is based on the individual evaluation of the share of individuals of a certain size (length = weight) class which, between the i-th and the i + 1st taking have passed to the next size class, to some of the further classes (in the case of quicker growth) and which have been eliminated from the population. The algorithm used can be expressed by means of block diagrams (for details see Zelinka and/or Zelinka & Marvan l.c.). The method is time-consuming, but it can be considered most reliable for broad clusters of cohorts. Considerable agreement between the ratios of production determined in this way and the average yearly biomass of different mayfly species indicates the possibility of using this relation (P/B coefficients) for simplifying the estimates. It was used particularly in cases of insufficient sets of individuals.

Results

Table 1 gives the summary outline of the data of mayfly production in various types of streams. The numbers express the so-called 'live weight', i.e. the weight of living larvae on drying by means of a battery centrifuge (Kubíček, 1969). The contents of water (the loss after 5 hrs of drying at 105°C) in larvae dried in that way is only 22% on the average. It ranges from 19.5% in big species up to 24.5% in small ones, such as *Baetis*. In comparing the results one must taken into consideration this difference. Caloric values have not been determined so far. According to literature data (Cummins & Wuychek, 1971; Prichodskaya, 1975; Flösnser, 1976) one can equal 1 g of dry weight of mayfly larvae to about 5 kcal. For our data 1 g of mayfly larvae equals approximately 3.9 kcal.

In the method of zoobenthos sampling used we obtained quantitatively only larvae longer than 2 mm. The egg production is expressed in the weight of nymphae. In the value there is, however, the production of larvae from the first instar (size about 0.6 mm) up to the size of 2 mm which have been eliminated from the population. Even though this concerns a large number of individuals, from the point of view of weight this value is comparatively very small with respect to the total production of the population. There are data concerning the number of eggs of some species important for production (cf., Zelinka & Marvan, 1977) and the number of small larvae up to 2 mm, but we do not know how many eggs are hatched, i.e. how much are the losses of small larvae from hatching up to the length of 2 mm. The number of small larvae eliminated from the population at this stage of development is definitely lower than 10% of the total production. But it is negligible in view of the possibilities of errors in the calculations.

The results were obtained only in the streams of Czechoslovakia, for the most part in the catchment area of the Morava-River. Thus not all types and possibilities are expressed, particularly data from streams with frequent occurrence of big burrowing larvae are missing. We were also limited by stream pollution, so that starting from barbel zones the streams have a more or less increased eutrophic level (even though they are not organically polluted). On the other hand we were able to follow the situation in polluted stretches. A brief commentary concerning the individual types of streams is given below.

Tab. 1. Production of mayfly larvae in different types of running waters. (Mean yearly values under 1 m^2 of water surface of the stream).

Classification of the watercourse	Production $g\ m^{-2}\ year^{-1}$	Main production genera of mayflies
Spring rivulet Hypocrenon	3-5	–
Trout stream Epirhithron	28	Rhithrogena – 37% Ecdyonurus –31% Baetis – 19%
Trout to grayling stream Metarhithron	35	Ecdyonurus – 32% Baetis – 22% Rhithrogena – 15% Epeorus – 10%
Grayling stream Hyporhithron	35	Ecdyonurus – 35%, Baetis – 22%, Epeorus – 10%, Habroleptoides – 8%, Rhithrogena – 5%
Upper part of the barbel zone Epipotamon	50	Baetis – 20%, Oligoneuriella up to 30%, Ecdyonurus – 15%, Potamanthus – 10%, Ephemerella – 8%
Lower part of the barbel zone Epipotamon-Metapotamon	57	Ephoron up to 45%, Potamanthus – 20%, Baetis – 10%, Caenis – 10%, Ephemerella 9%, Heptagenia – 6%
Bream zone Metapotámon	20	–
Lowland warm stream (roach zone)	10	Baetis up to 70%, Caenis – 10%, Cloeon – 10%

Spring rivulets-hypocrenon

Those rivulets are poorly populated with mayfly larvae, particularly when passing through coniferous woods. Most frequently found were the representatives of the genera *Baetis, Rhithrogena,* sometimes *Siphlonurus.* Production was not determined directly, but estimated according to the abundance of larvae in comparison with trout zones. From among the whole production of zoobenthos the share of mayflies is about 10%, the main organism being mostly *Gammarus.* Passing to the trout stream the number of mayfly larvae increases very quickly.

Trout streams-epirhithron

Based on the results obtained by the investigation of the trout streams of the Beskydy Mountains (Zelinka, 1973; Helan *et al.,* 1973) and in comparison with the abundance and biomass of mayfly larvae in further trout stream we estimate an average yearly production slightly lower than 30 g m^{-2} (data from the streams of the Beskydy Mountains: 27,15 g m^{-2}). In the conditions of the river basin of the Morava the main production species are *Rhitrogena semilocolorata*-37%, representatives of the genus *Ecdyonurus*-31%, species of the genus *Baetis,* particularly *Baetis rhodani*-19%. The share of mayflies in the total production of the macrozoobenthos is, on the average, about 22%.

A lower production of mayfly larvae can be expected in streams with great gradient and frequent torrents where the total abundance drops. Also in streams with a small gradient (plateaux) where there are numerically more frequent species of the genus *Baetis*, but the number of big larvae of the genera *Rithrogena* and *Ecdyonurus* decreases.

Trout to grayling streams - metarhithron

In those stretches of streams the conditions are similar to those in the preceding case, but for the most part we could state an increase in the total abundance of mayfly larvae. This concerns the genus *Baetis* and above all the representatives of the genus *Ecdyonurus*, while in the genus *Rhithrogena* there is a certain drop. Some other species also become more important from the production point of view: *Epeorus sylvicola*, in some places also *Habroleptoides modesta*. The yearly production here is estimated as 35 g m^{-2} on the average. Data about the total production of zoobenthos are missing. The share of mayflies will however, be similar to that in the preceding case.

Grayling streams - hyporhithron

From the production point of view the importance of the genus *Rhithrogena* is still decreasing, chiefly at the cost of the genus *Ecdyonurus*. Frequent are all the time the representatives of the genus *Baetis*, further those of *Epeorus*, often also *Habroleptoides modesta*, and in summer *Ephemerella ignita*. The total mayfly production as well as their share in the production of zoobenthos is, however, the same as in the preceding case. In the lower part of this zone the changes are somewhat greater.

The upper part of the barbel zones - epipotamon

Here the qualitative composition of the mayfly fauna starts to change conspicuously. The importance of the genus *Baetis* with more generations per year increases as well as that of *Ephemerella ignita*. The genus *Ecdyonurus* also has an important share in the production. The production of *Oligoneuriella rhenana* reaches high values as well in clean stony waters. From among further species *Potamanthus luteus* and larvae of some burrowing species must be mentioned. After caddis-flies mayflies are the main food component of zoobenthos.

Starting with the lower part of the hyporhithron an increase in the total mayfly production can be found. In the epipotamon, populated by *Oligoneuriella*, it reaches as much as 50 g m^{-2}, i.e., 500 kg per hectare per year. With the drop in the number of *Oligoneuriella* the total production decreases and if these larvae disappear then it does not, on the whole, differ from that in the grayling zones.

The lower part of barbel zones - epipotamon to metapotamon

The results of our investigation (Zahrádka, 1976) show that here the mayfly production reaches its highest values. The species *Ephoron virgo* and *Potamanthus luteus* have the greatest share in it: 45% and 20% respectively. Frequent are also the species of *Baetis* and *Ephemerella*, the importance of the genera *Heptagenia* and *Caenis* increases. Total mayfly production, measured in a stream without organic pollution (the lower stretch of the Jihlava), was 57 g m^{-2} per year. Among zoobenthos the most important from the production point of view are *Trichoptera;* in the second place *Ephemeroptera* constitute about 30% of total production.

Bream zones - metapotamon

With the progressing basic change of the bottom a decrease in mayflies can be found. The gravelly or sandy bottom in the torrential zone is only sparsely populated with mayfly larvae *(Potamanthus, Caenis, Ephoron)*, as well as the muddy sediment near the banks. Most larvae are found among the grasses near the bank *(Baetis, Cloeon*, etc.), on submerged wood *(Potamanthus, Ephemerella)*, and/or on stones near the banks, where the torrentile zone approaches the bank *(Baetis, Heptagenia, Ecdyonurus* and others). Calculated for the total area of the stream the density and thus also the productivity are relatively low. In our conditions it is estimated to reach a maximum of 20 g m^{-2} per year. Where burrowing species are present in large numbers *(Russev* 1973 - *Paligenia)*, the total production of mayflies of such a river will be higher.

Lowland warm streams (roach zone)

Besides the chief zones of running waters, as classified by Illies & Botosaneanu (1963) there are other, less important types, as lowland warm brooks, where mainly oxygen and thermal conditions do not allow life to trout and other cold-adapted organisms. Frič (1872) called such brooks aptly 'roach zones'. The brooks are often full of growing water plants. They are comparatively frequent and typical in south Moravia and south-west Slovakia, where mayflie larvae are mainly represented by the genera *Baetis, Caenis*, and *Cloeon*, sparsely by some others. (Note: In the Záhorsky potok stream in south-west Slovakia we comparatively often came across the species *Baetis tracheatus* (Keffermüller & Machel, 1967), which is the first record in Czechoslovakia). The total mayfly production in this type of streams is estimated to reach 10 g m^{-2}

per year. The main production taxa there are *Gammarus roeselii, Hirudinea,* and/or *Odonata.*

Anthropogenic effects

As stated in the introduction, the natural character of streams is nowadays considerably changed by the activity of man. These changes usually decrease the original mayfly production. As causes appear on the one hand river bed improvements and other building activities, on the other hand waste waters and increase in trophic level connected with agricultural activity.

The effects of bed improvement were not followed in detail. But according to several observations one can say that straightening of streams, particularly walling the banks and above all the bottom, results in a significant decrease in mayfly production. The building of dams will considerably influence the original biology of the mother stream. According to some literature data (Penáz *et al.,* 1968; Zelinka, 1968) deep reservoirs have a positive effect on the production of zoobenthos, including mayflies.

The negative effect of toxic waste waters is quite clear. Decaying waste waters also act negatively of they deteriorate the saprobity of the stream by at least one degree. The influence of domestic waste was studied in detail in a trout stream (Zelinka *et al.,* 1977), and experimentally in a number of further streams. The information obtained is given in Tab. 2. As 100% in that table the original natural production of the zone in question is understood, further values give the decrease (or increase) to X%. An increase in production due to a small amount of domestic waste can occur only in originally quite pure trout streams where that waste means an increase in trophic level. A transition into beta-mesosaprobity there means, however, always a sharp drop in production, as only few species of mayflies of a trout brook can adapt to changed living conditions, particularly to the drop in oxygen content (and maybe also to a change in the food offer). Out of 19 species living in oligosaprobity we found in beta-mesosaprobity the survival of only 8 of them, mainly *Baetis rhodani* and *Ephemerella ignita.* On the other hand, in the lower zones of streams the drop in the production of mayflies connected with the change of the original saprobity by 1 degree is no longer so significant, as there are many species with a broader ecological valency. In polysaprobity mayfly production does not exist at all.

Table 2. The effects of saprobity deterioration on the production of mayfly larvae/percentages/.

Saprobity Classification of water-courses	xeno-saprobity	oligo-saprobity	beta-meso-saprobity	alpha-meso-saprobity	poly-saprobity
Epirhithron	100	130	30	3	0
Hyporhithron	–	100	50	5	0
Epipotamon	–	100		20	0
Metapotamon	–	–	100	40	0

At present one can observe, in most streams, and in barbel zones practically everywhere, an increase in the trophic level. With an increase in the content of N and P also the primary production increases. How is this increase in alimentary basis reflected in the production of mayflies? The effect was followed in a trout stream (Zelinka *et al.,* 1977). In secondary oligosaprobity (sensu Zelinka, 1975, in Marvan, Rothschein, Zelinka, 1975) due to selfpurification from polysaprobity there was an increased content of N and P and, eventually, of primary production as compared with natural conditions in the streams of the Beskydy Mountains, (cf. Helan *et al.,* 1973). At practically the same qualitative composition of the biocenosis an almost triple primary production was found; in the secondary production (macrozoobenthos) the increase was 70%, out of which *Ephemeroptera* almost increased 100%. This fact requires further verification, sice it depends on the development of primary production. A decrease in the number of mayflies was noted where there was a strong development of filamentous algae. Rich periphyton of higher water plants in the barbel zones of streams (such as a.o. *Ranunculus*) meant a drop in the number of big larvae of *Oligoneuriella rhenana* (partly also *Potamanthus luteus*) which, in the total production, was not compensated by an increased number of larvae of *Baetis.*

Summary and conclusion

The paper presents a summary of results of a study of mayfly production carried out in the main types of running waters. This production (if we omit spring rivulets) is on the average estimated to amount to 200 to 570 kg per hectare per year. The data are valid for more or less natural conditions. Even thus individual differences can be expected and variation of production in the individual years appear. It is, however, interesting to note that the variation appears to a greater extent in the individual species, whereas the total mayfly production is much more balanced. As far as there is a drop in some species due to unfavourable conditions, mainly in the period of egg laying and hatching, the loss is compensated by increased abundance in other species.

The greater part of mayfly population is in all stream zones always constituted by a few species. The production of 3 to 4 dominant species constitutes, in most cases, about 80% of the whole mayfly population.

Also anthropogenic effects on the production of mayflies were followed. They are mostly negative (unsuitable bed improvement, pollution). An increase in production was found only below deep reservoirs where there was usually also an improvement in the original saprobity and in specific cases of an increase in primary production (trophic level).

Due to a hitherto low number of detailed investigations and with respect to the non-uniformity of production estimates, which can result in substantially different results, (cf., Zelinka & Marvan, 1977), it is hard to compare our results. As, however, even in *Ephemeroptera* larvae we found a comparatively constant relation between production and biomass (P/B coefficient, cf., Zelinka, 1973), we can judge from the data concerning the average yearly biomass that the above range of production is real at least under the conditions of Central Europe.

This comparatively high production and a good accessibility of mayfly larvae as fish food (Zelinka, 1971) confirm the importance of this component of zoobenthos for fish production of running waters.

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