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Density, production and life cycle of *Brachycentrus subnubilus* Curtis (Trichoptera: Brachycentridae) in a lowland river, Central Poland

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Abstract

The annual mean density of *Brachycentrus subnubilus* a trichopteran species with a univoltine life-cycle was 572 ind. m^{-2}. It constituted of only 2.1% of the total macrozoobenthos abundance, while this species in terms of biomass exceeded 11.9% of the total benthic biomass. Production of *Brachycentrus subnubilus* was estimated by size-frequency method was 26.56 g wet weight m^{-2} and the turnover ratio was 5.7.

Introduction

The distribution of *Brachycentrus subnubilus* Curtis in Europe is wide (Botasaneanu & Malicky, 1978). This species occurs in large numbers in middle and lower parts of the rivers in Central Poland. In the Widawka River, larvae of *B. subnubilus* are the numerically dominant caddis larvae (Kopytek & Majecki, 1986) and play an important role in the circulation of nutrients. While the biology, life-history, ovipositional behaviour and description of the larva of *B. subnubilus* occurring in the streams and rivers of England are reported from time to time (Hanna, 1961; Barnard, 1978; Gunn, 1985), that of *B. subnubilus* occurring in the rivers of Poland has not. This species is abundant in the Widawka River and forms the food of many species of fishes (Grzybkowska, 1988; Przybylski, 1988). The production and life cycle of the larvae of *B. subnubilus* was investigated.

Study area

The Widawka River is a tributary of the Warta River (Odra Basin). The river is 109 km long with a slope of 1.3 % in the upper course and 0.5% in the lower course. The area of its drainage basin is 2440 km^2 (Penczak, 1969). During 1970, the natural character of the river was changed by very intense development of industry and urbanisation of its neighbourhood areas. This has resulted in the entry of water inputs from the coal mine in Bełchatów into the Widawka River (Figure 1).

The investigated reach of the Widawka River was located in the fifth stream order section, close to the bridge at Chociw (52° 33′N, 18° 58′W – Figure 1). At this site, the width of the river was 28 m and maximum depth 0.9 m. The current velocity in the middle part of the river fluctuated between 0.6–1.2 m s^{-1}, while in the marginal zone it was 0.4 m s^{-1}. At this stretch, the river crossed agricultural fields and the banks were covered by willow (*Salix* sp.) and alder trees (*Alnus glutinosa*). Water temperatures at the mine were relatively constant (12.2–15.3 °C) and at the sampling site had little effect on river water temperature, but prevented the river from freezing during winter. The annual mean water temperature was 10.0 °C.

Based on the four major microhabitats present in this area of the river, four sampling locations were established and the percentages of each were evaluated. The first sampling location was situated close to the right river bank and had a stony bottom. This type of bottom was characteristic of 20% of the bot-

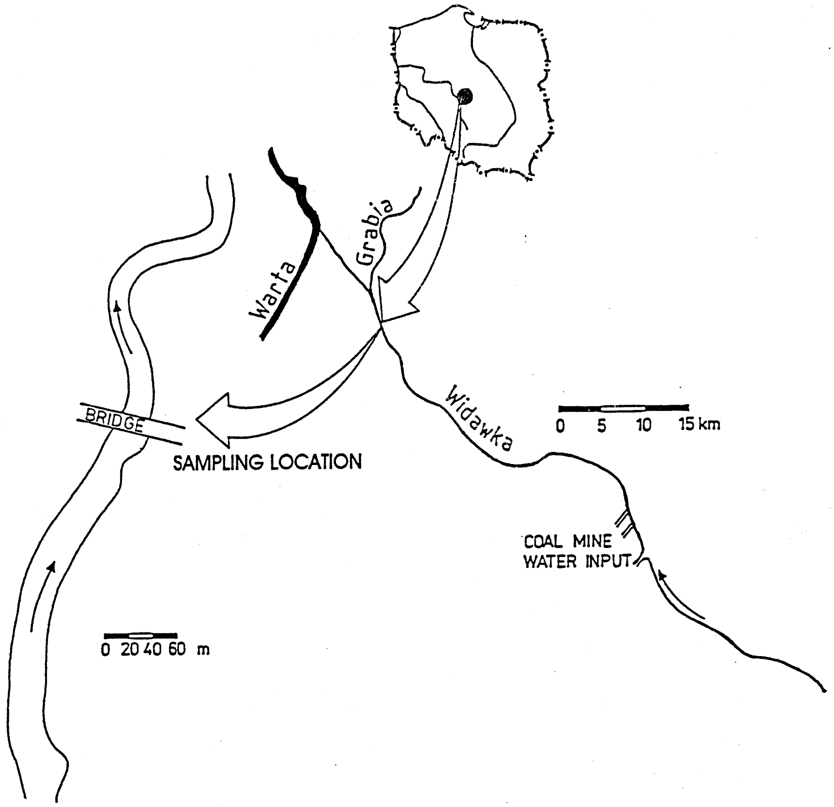

Figure 1. Location of sampling site in the Widawka River.

tom of the investigated stretch. The second location was in the left river bank in the middle part of the river. It had a gravel-stony bottom with scattered aquatic plants (50%). Silty-sandy bottom covered by aquatic macrophytes and forming 10% of the bottom was characteristic of the third sampling location. In the fourth sampling location gravel-stony bottom with a fast current was apparent and this type of substratum formed 20% of the studied river stretch. For a detailed description of the study area, see Grzybkowska et al. (1996).

Material and methods

Benthic samples at the four sampling sites were collected in the Widawka River every month from April 1984 to March 1985. At each of these sites, a sample of ten sampling units were taken randomly with a 10 cm^2 tubular sampler. The sampler was pushed into the sediment to a depth of 15 cm and also through vegetation if it was present. The macroinvertebrates were hand-sorted in the laboratory, counted and preserved in 10% formaldehyde. The data was recalculated for 1 m^2 of the total stream bed area taking into account the proportion of sampling sites. For biomass and density 95% confidence limits (95% C.L.) were calculated (Elliott, 1977).

The size frequency method of Hynes & Coleman (1968) as modified by Hamilton (1969) and Benke (1979) was used to estimate the annual production of *B. subnubilus*. The body length of larvae was measured from the anterior edge of pronotum to tip of abdomen with an accuracy of 0.1 mm and individuals were grouped into 10 mm length classes following the description of Cushman et al. (1978). All larvae of *B. subnubilus* as well as other invertebrates were weighed with an accuracy of 0.1 mg. For the *B. subnubilus* larvae the length–weight relationship was established following the equation:

$$W = aL^b, \tag{1}$$

where W = weight; L = length; a and b are coefficient constants.

The above relationship was presented in curvilinear and linear form.

The dry weight for the investigated species was established to be 15% of the wet weight and this allowed for the weight loss of larvae stored in formaldehyde (see Dermott & Paterson, 1974).

Results

The body lengths of *B. subnubilus* were found to be different in the different months of their collection. Based on the head width of larvae, Gunn (1985) has described 5 size-ranges in *B. subnubilus*. Presently, considering the body lengths of larvae of *B. subnubilus* in the different months of the study period, the length-range of the larvae in different instars was established: I instar – <2.1 mm; II instar – 2.1–3.2 mm; III instar – 2.7–5.1 mm; IV instar – 3.3–7.8 mm and V instar – 4.9 12.2 mm. The length-frequency distribution in the larvae of *B. subnubilus* (Figure 2) clearly indicated that the I instar larvae were totally absent in the collections, probably because their bodies were too small to be noticed. The smallest larvae (3 mm) as observed presently were noticed in May and June 1984, while larvae of 4.5 mm were recorded only in May 1984. During June, larvae of the size-range of 6–9 mm were predominant. Although their density decreased in July, they were still present. In August, a larval size-class of 6 and 9 mm was recorded, but their density remained very low. High density of larvae of 11 mm size-class was recorded in September and during this month the larval population had a size of 9–13 mm. During October, only 10–11 mm size-class larvae were observed, while in the winter months (November 1984 to February 1985) 10–14 mm size class larvae were predominant. However, the population of the larvae of size-class 13 mm remained significantly high in January 1985. In March 1985, only larvae of the last instar were recorded. On the whole, in May 1984, II, III and IV instar larvae were noticed. In June, II, III, IV and V instars were found, while in July, IV and V instar larvae were present. From September 1984 to March 1985, only the V instar larvae were observed. No pupae were found. From Figure 3 it is clearly evident that, during winter months there was no significant changes in the length of larvae, thus suggesting the reduced metabolic rates due to low temperature.

Over the investigated year the total benthic density was 25 090 ind. m^{-2} ($\overset{X}{\div}$ 1.6) while the biomass (wet weight) amounted to 39.344 g m^{-2} ($\overset{X}{\div}$ 1.4). The highest population density of *B. subnubilus* larvae was recorded in June 1984, while the lowest density was observed in March 1985.

Figure 3 depicts the curvilinear relationship between wet weight and body length of *B. subnubilus*. The relationship is expressed by the equation W = 0.110e0.480L, while in the linear form it was found to be W = −229 + 0.480L. The percentage of the total variation in W is expressed by the regression (r^2) is 91.3% ($P<0.001$).

The annual mean density of *B. subnubilus* was 572 ind. m^{-2} $\bar{X} \overset{X}{\div} 1.9$ 95% C.L.), which comprised only 2.1% of the total macrobenthos abundance. The calculated annual mean biomass of the larvae was 4.683 g wet weight m^{-2} and 0.937 g dry weight m^{-2}, respectively. The biomass of larvae exceeded the biomass of total benthic organisms by 11.9%. The production of larvae in an annual period amounted to 26.56 g wet weight m^{-2}, while the P/B ratio remained 5.67.

Discussion

Based on biomass, Grzybkowska et al. (1996) have described *B. subnubilus* as a subdominant form in the macrobenthic community of the Widawka River. The nature of the bottom and the vegetation appears to influence the abundance of the species. In river Frome, Dorset *B. subnubilus* tended to prefer sites beneath submerged macrophytes (Gunn, 1985). Presently, the stony-sandy substratum with submerged macrophytes in the Widawka River appear to be a suitable substratum for the occurrence of *B. subnubilus*. A precise determination of the life cycle, only on the basis of changes in the length of the larvae, creates difficulties because of differences in body length caused by the sex of individuals. Those which will become males are the smallest and those which are going to form the females are the largest (Gunn, 1985). This means that a larva of 5 mm length could be classified as larva of either the III, IV or V instars. According to present results, it could be said that, similarly to other caddis fly species occurring in Europe, the life cycle of *B. subnubilus* is univoltine. This is made clear by the presence of early instars only in May and June and last instars in autumn and winter months. Majecki (unpublished data) observed large number of flying adults of this species in the middle of April. A relatively short

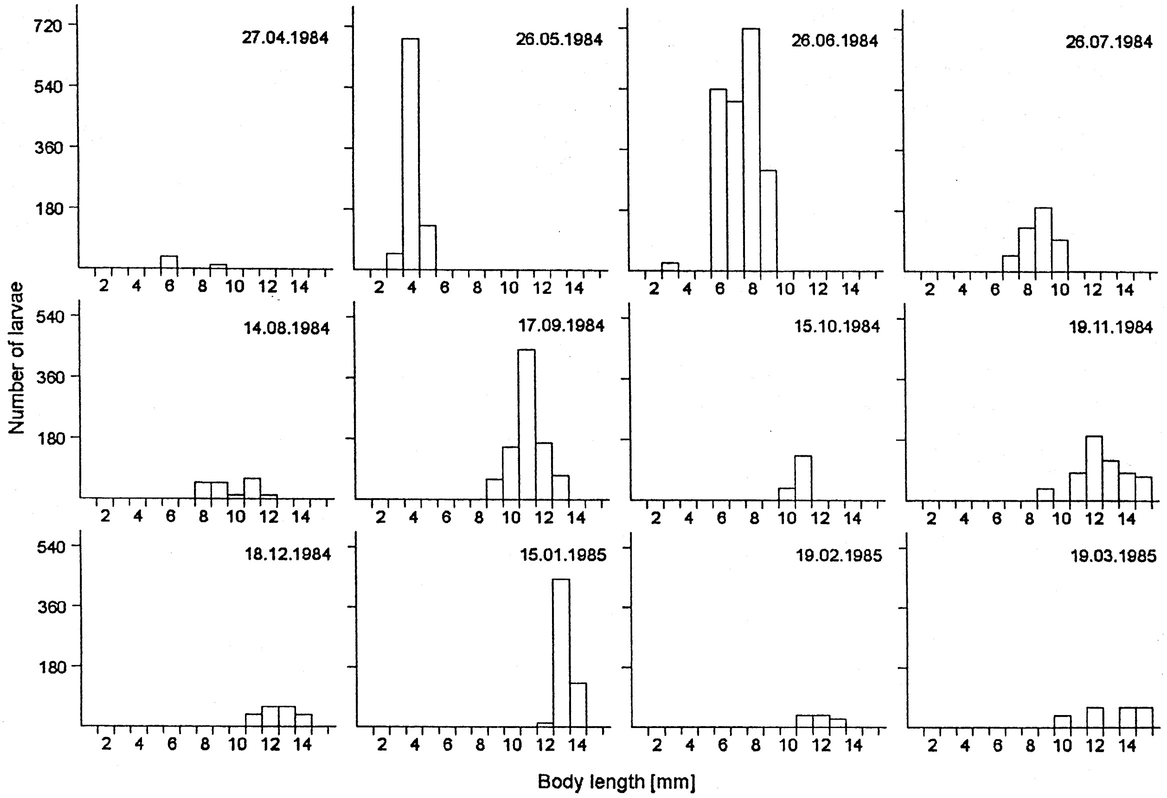

Figure 2. Size-frequency distribution of *B. subnubilus.*

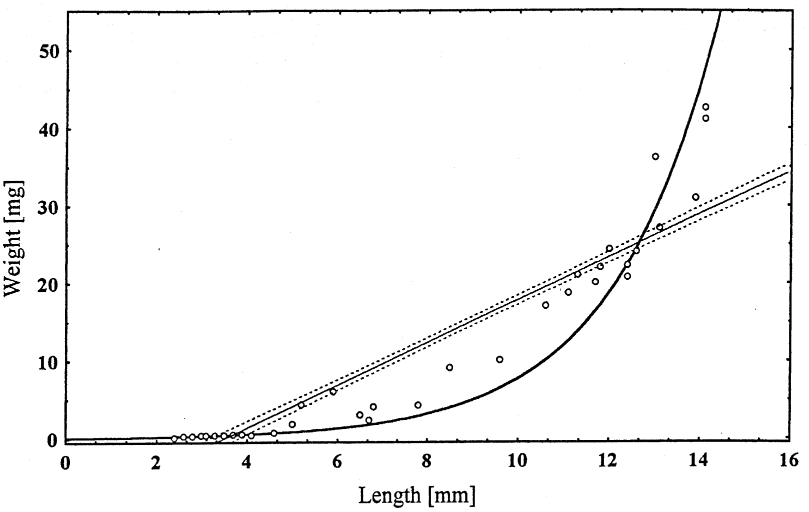

Figure 3. Curvilinear and linear relationship between wet weight and body length of *B. subnubilus.*

period of adult flight, short period of egg-laying and its development has been observed by Gunn (1985) in the Frome River. According to Gunn (1985), the first adults occurred at the beginning of April and the maximum egg-laying at the beginning of May. The successive events of adult flight, egg-laying and fast development of the larvae lead to the synchronisation of the whole life-cycle of the species and it manifests itself with the similarity of larval instars occurring in particular months. Similar synchronization of *B. subnubilus* development was observed by Andrewald (1996) in the Danube River. Synchronous development could be treated as an adaptation of the life-cycle to periodical negative environmental factors or this could be the influence of maximisation by some larval instars of periodical positive factors. Because of this, the synchronous development of species living in temporary waters or the species exploits large amounts of food periodically. An environment typical of *B. subnubilus* larvae is characterised by stability and predictability of changes. One of the factors which could influence the synchronisation of the life-cycle of the *B. subnubilus* is the amount of food available. During spring and summer, a great number of early instars of macrobenthic groups (Chironomidae and Oligochaetes) dominated in the water column (Grzybkowska et al., 1987). These drifting organisms form the food source for *B. subnubilus*. Such a food supply would promote, particularly the fast growth of larvae. This is evident by the presence of larvae of 9 mm length (V instar) in July. Anderwald (1996) found that *B. subnubilus* larvae have density dependent growth. A increase in final body weight corelated with a decrease of density observed by the latter author indicated the role of food and concurrence by specimens in food resources.

The turnover ratio for *B. subnubilus* as observed falls within the range of P:B ratios reported for trichopterans of inland waters by Waters (4.4–5.8; 1977), Benke & Wallace (4.2–5.5; 1980), Resh (5.8; 1977), Benke et al. (5.0; 1984), and Gaines et al. (4.1–6.5; 1992). The present value is slightly higher than those observed by Smock et al. (3.7–5.0; 1985) and MacFarlane & Waters (4.4; 1982). The absence or low density of early instars is due to both lower efficiency in sampling these stages and a short amount of time spent in the early instars.

Similarly, the production value is comparable to some of the previous estimates for caddis flies in rurming waters (MacFarlane & Waters, 1982; Mortensen & Simonsen, 1983; Freeman & Wallace, 1984), but the value is considerably lower as compared to the values recorded by Ross & Wallace (1983), Krueger & Waters (1983) and Benke et al. (1984). On the other hand, the highest value was reported by Krueger & Waters (1983) for *B. americanus* and *B. occidentalis*. The results obtained by the said authors are strongly dependent on the physicochemical parameters of the water inhabited by populations of both the species *Brachycentrus*.

The Hynes and Coleman method used in this paper, was described as analogous to the removal-sumation method used for actual cohorts (Waters, 1977; Benke, 1984). It shows a tendency to overestimate the annual production. This overestimation of about 10% is often found when the size of larvae reflects not only the larval instar but also the determinant sex of the adults (Waters & Crawford, 1973). On the other hand, underestimated values of annual production could be the result of hand picking and samples being taken from a wide spectrum of microhabitats and not only from those habitats particularly preferred by the larvae of the investigated species (Resh, 1977). Larvae of *B. subnubilus* are especially common on aquatic plants, but only 10% of the samples originate from the aquatic macrophytes. Another reason for the low value of the annual production could be the absence of I instar larvae in the analysed material. Benke & Wallace (1980) have also reported low production early instars of five trichopterans amounting to less than 5% of the total production.

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