Acta Hydrobiol., **37** (1995), 4, 213–224. Kraków, December 1995

Life cycles of selected species of mayflies (Ephemeroptera) of the Wołosatka and Terebowiec streams (The Bieszczady National Park, south-eastern Poland)

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(Received 7 November 1994, Accepted 29 May 1995)

Abstract – The life cycles of nine species of mayflies were elaborated on basis of collected material. A winter cycle with one generation a year was found for all the investigated species of the genus *Rhithrogena* (*R. carpatoalpina*, *R. puytoraci*, *R. gorganica*, and *R. wolosatkae*). The remaining species analyzed had in this period summer cycles with one generation (*Ephemerella ignita*), winter cycles with one generation (*Baetis muticus*, *Habroleptoides confusa*) or a winter cycle with two generations a year (*Baetis rhodani*).

Key words: mayflies, life cycles, running waters.

Cykle życiowe wybranych gatunków jętek (Ephemeroptera) potoków Wołosatka i Terebowiec (Bieszczadzki Park Narodowy, południowo-wschodnia Polska). Opracowano cykle życiowe 9 gatunków jętek. U wszystkich badanych gatunków z rodzaju *Rhithrogena* (*R. carpatoalpina*, *R. puytoraci*, *R. gorganica*, *R. wolosatkae*) stwierdzono cykl zimowy z jednym pokoleniem w roku. Pozostałe gatunki miały w tym okresie cykle letnie z jednym pokoleniem (*Ephemerella ignita*), cykle zimowe z jednym pokoleniem (*Baetis muticus*, *Habroleptoides confusa*) lub cykl zimowy z dwoma pokoleniami w roku (*Baetis rhodani*).

1. Introduction

The mayflies of the Carpathian streams of Poland and Czechoslovakia were investigated by Sowa (1975) and Landa (1969). In these works the information about the course of the life cycle can usually be found with a description of particular species. For many species these data are very superficial, being most often based on scarce material. Rare species (Sowa 1992) and those described in recent years have no precise descriptions of their life cycle.

The aim of the present work was to determine the life cycles of nine species of mayflies, including species with a limited range of occurrence and endangered ones.

2. Study area, material, and methods

The samples were taken from four stations from the two montane streams Wołosatka (Stations 1, 2 and 3) and Terebowiec (Station 4) flowing across the area of the Bieszczady National Park (Polish Eastern Carpathians) (fig. 1). The material was collected within the period from 13 June 1985 to 16 June 1986 (the Wołosatka Stream) and from 10 January to 21 November 1986 (the Terebowiec Stream). Stations 1 and 2 were shaded by beeches and alders at the bank. The bottom

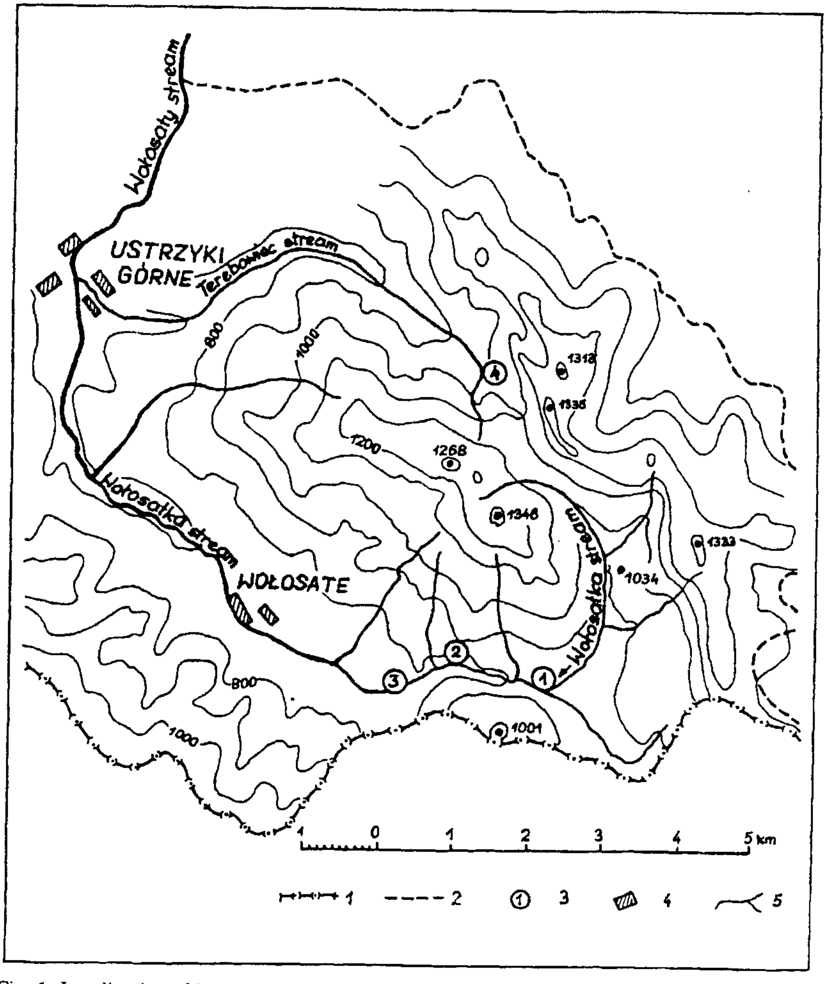

Fig. 1. Localization of investigated stations: 1 — state frontier, 2 — borders of the Bieszczady National Park, 3 — stations, 4 — buildings, 5 — streams.

consisted of large stones, and in some places sections with gravel occurred. Station 3 was only partly shaded by alders and the bottom was more varied, with more shallower places and those with gravel. Station 4 was intensively shaded by beech forest and large stones prevailed on the bottom. The remaining hydrographic data of the stations are given in Table I.

Table I. Hydrographic and hydrological characteristics of investigated stations.

Station	Altitude	Distance from springs (km)	Gradient (‰)	Width (m)	Depth (m)	Current velocity (m s^{-1})
Wołosatka Stream						
1	825	4.1	21	2.5–6	0.3–0.8	1.5
2	775	6.0	19	1.5–6	0.3–0.8	1.5
3	750	7.0	12	5–9	0.2–0.7	1.2
Terebowiec Stream						
4	900	1.7	85	1.5–4	0.1–0.3	1.5

Qualitative and quantitative samples were taken. A bottom scraper with 0.33 mm mesh net was used for catching the mayflies larvae. Adult mayflies were collected using an entomological net. The larvae were divided into size classes on the basis of their body length measured from the anterior head margin to the posterior margin of the tenth abdomen tergite.

3. Results

3.1. *Rhithrogena carpatoalpina* Kłonowska, Olechowska, Sartori et Weichselbaumer and *Rhithrogena puytoraci* Sowa et Degrange

Both the species from the *semicolorata* group were distinguished mainly on the basis of the structure of eggs because morphological features permit the distinction only of large larvae, hence the necessity of tracing the life cycles of the two species in the jointly treated material. On the basis of the morphology of mature eggs originating from the females caught, it can be stated that both species were present at Stations 2 and 3, whereas at Station 4 probably only *R. carpatoalpina* occurred and not very numerously. In the Wołosatka Stream emergence of imagines of both the discussed species was observed from May to the beginning of September (fig. 2). The females of *R. carpatoalpina* appeared earlier, i.e. from May to the end of June, and those of *R. puytoraci* from June to mid-August. The male larvae caught in late summer probably also belonged to *R. puytoraci*. The number of nymphs developing or fully developed gradually decreased in the period from August to early September, and in mid-September in the collected material there were no countable larvae in either of the discussed species. The larvae hatched from the eggs probably developed relatively slowly and remained in the smallest classes for a longer period, which could have caused their being mistakenly classified as *Rhithrogena iridina* (Kol.). In the autumn–winter period the larvae grew quite rapidly so that in April some of them were of considerable size. The material from the Terebowiec Stream was much scarcer and permitted only

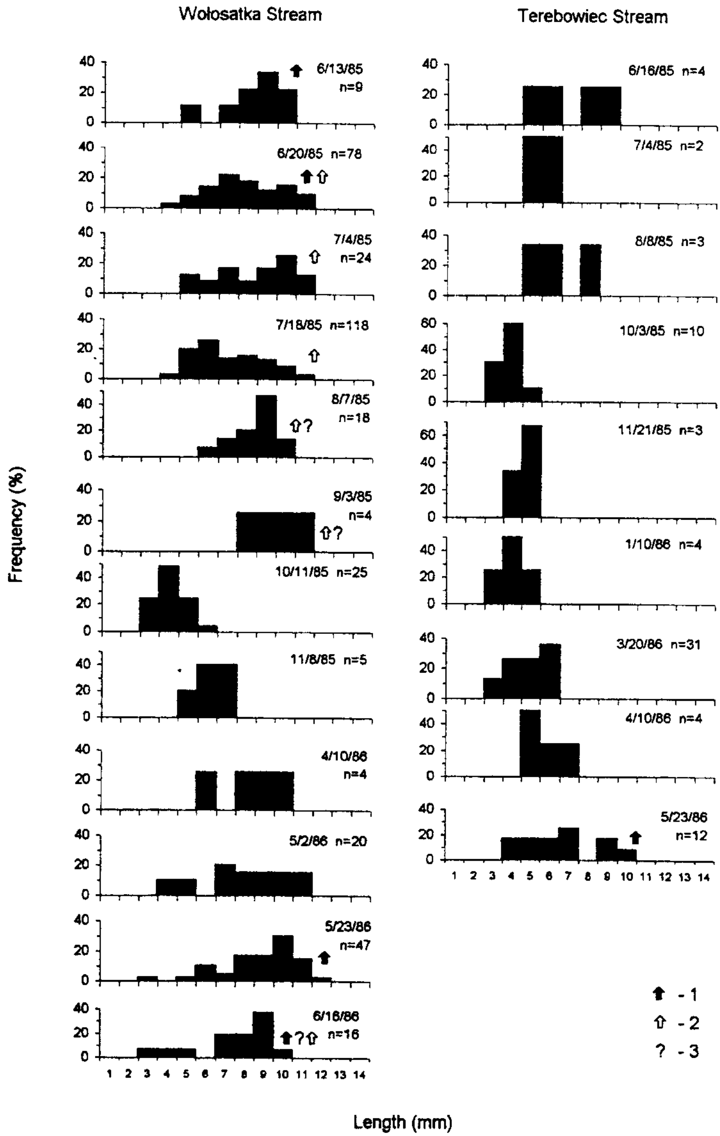

Fig. 2. Size classes frequency of larvae of *Rhithrogena carpatoalpina* Kłonowska, Olechowska, Sartori, Weichselbaumer and *Rhithrogena puytoraci* Sowa, Degrange (sampling data — month/day/year): 1 — *R. carpatoalpina* subimago emergence, 2 — *R. puytoraci* subimago emergence, 3 — uncertainty concerning emerging species.

a hypothetical description of the life cycle (fig. 2). Emergence of adult individuals belonging to *R. carpatoalpina* was observed only in May. Probably the emergence period lasted until August, which could be indicated by the size of the larvae in June and in August. As at Stations 2 and 3 in the Wołosatka Stream there were no larvae of this species in September, perhaps for of the same reasons. *R. carpatoalpina* and *R. puytoraci* are winter species with one generation a year (univoltine winter cycles).

3.2. *Rhithrogena wolosatkae* Kłonowska

The material for elaborating the life cycle of this species originated from Stations 1 and 2. Emergence took place in May and June (fig. 3). The young larvae hatch very quickly and grow all summer and autumn. In the winter the larvae also grow quite intensively and are almost ready to emerge in the spring. This is a winter species with one generation a year (univoltine winter cycle).

3.3. *Rhithrogena gorganica* Klap.

The course of the life cycle of *R. gorganica* was described on the basis of the material from Station 4, situated in the vicinity of the lower line of the species occurrence, hence the number of the larvae caught was small (fig. 3). Emergence was observed in May, and probably lasted from the beginning of that month to the beginning of June. In 1987 at a higher situated station the emergence of *R. gorganica* took place from May to the end of June. The young larvae of the next generation appeared at Station 4 in June and grew systematically during the next months, and in the winter ones, too. In late winter the larvae reached a considerable size — up to 9 mm. *R. gorganica* is a typical univoltine winter species.

3.4. *Baetis rhodani* (Pict.)

The material which was used for elaborating the life cycle of *B. rhodani* originated from Station 3 in the Wołosatka Stream. Emergence of *B. rhodani* was observed from mid-June to early July, and then from August to mid-September, and single individuals in November (fig. 4). The specimens emerging in autumn laid eggs from which the larvae hatched rapidly. The growth of the larvae was inhibited in the winter, this being indicated by the distribution of the size classes in spring. After the spring warming there began an intensive growth of the larvae and adult imagines appeared in June. A considerable percentage share of the smallest larvae (2–3 mm), probably originating from the eggs laid in spring, were found in mid-July. These larvae grew quickly and were ready to emerge in autumn. It may be concluded that *B. rhodani* in the Wołosatka Stream during 1985–1986 had two generations a year (bivoltine winter cycle).

3.5. *Baetis muticus* (L.)

The life cycle of this species was observed at Station 3 in the Wołosatka Stream. Emergence took place from mid-June to the beginning of September (fig. 4). From mid-September small larvae with a very small growth in the autumn–winter period dominated in the collected material, this being evidenced by the size of the larvae in April. The rate of larval growth increased slightly in spring, while in the summer the successive classes of larvae gradually reached emergence maturity. The absence of larvae from the first size class in the period of emergence of adult

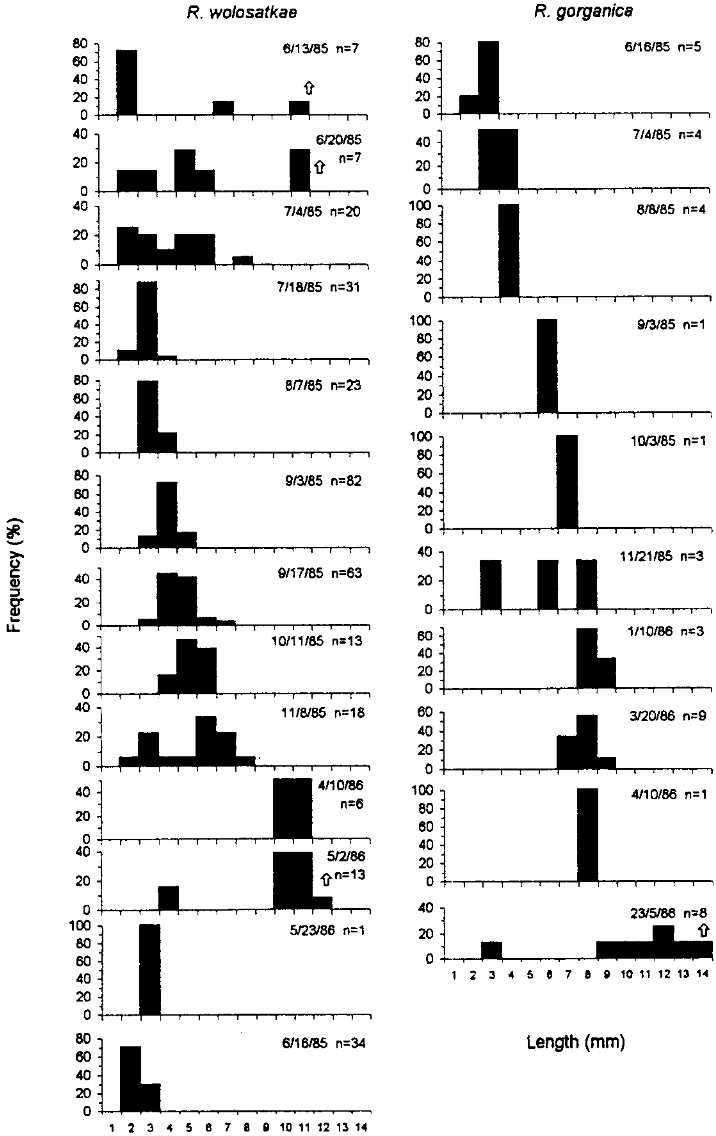

Fig. 3. Size classes frequency of larvae of *Rhithrogena wolosatkae* Kłonowska in the Wołosatka Stream and *Rhithrogena gorganica* Klap. in the Terebowiec Stream (sampling data — month/day/year; subimago emergences indicated with arrows).

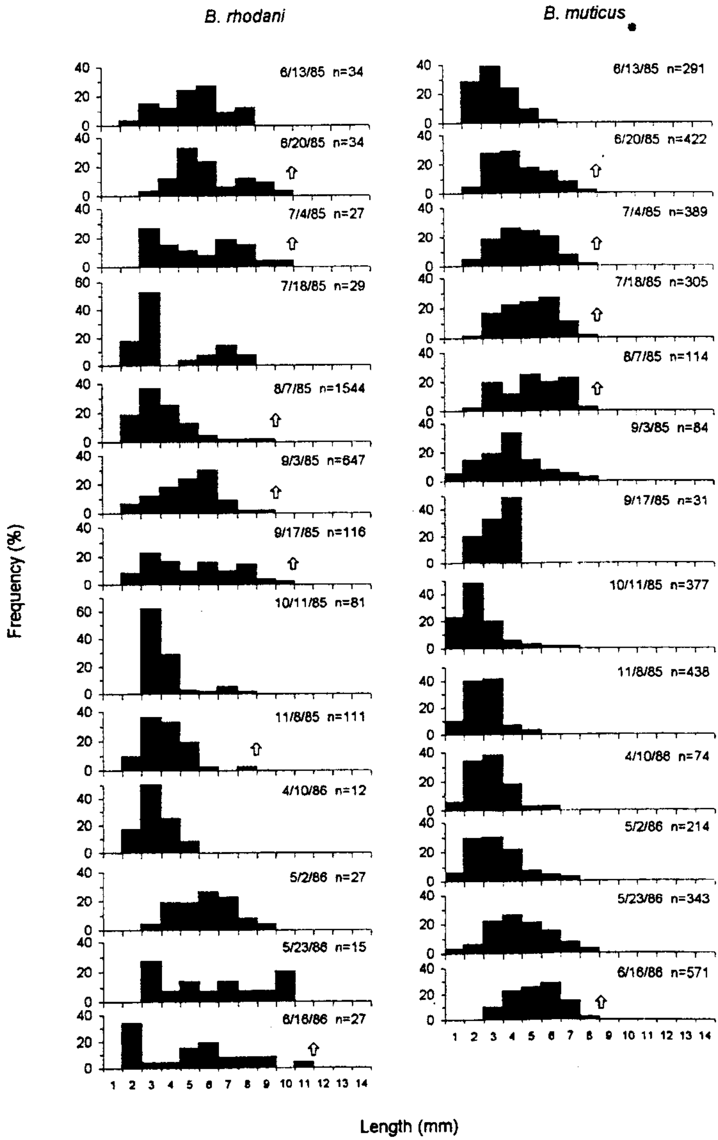

Fig. 4. Size classes frequency of larvae of *Baetis rhodani* (Pict.) and *Baetis muticus* (L.) in the Wołosatka Stream (sampling data — month/day/year; subimago emergences indicated with arrows).

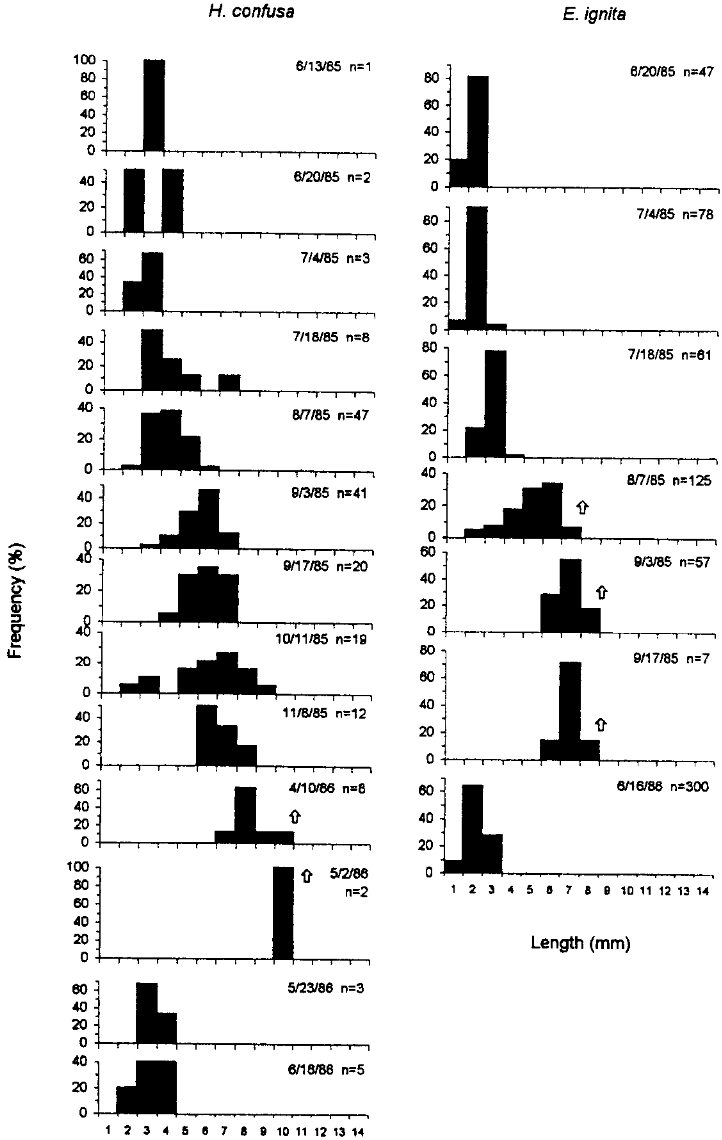

Fig. 5. Size classes frequency of larvae of *Habroleptoides confusa* Sartori et Jacob and *Ephemerella ignita* (Poda) in the Wołosatka Stream (sampling data — month/day/year; subimago emergences indicated with arrows).

individuals and the appearance of a greater number of 1 mm larvae only at the beginning of September may be evidence of the protraction of embryonic development in summer. Moreover, from the distribution of the size classes of the larvae in the spring of both years it may be concluded that some of the eggs survived the winter. It seems that in the years 1985–1986 *B. muticus* had one generation (univoltine winter cycle).

3.6. *Habroleptoides confusa* Sartori et Jacob

The small material collected in the Wołosatka Stream at Stations 2 and 3 permitted only an approximate description of the life cycle of this species. Emergence of *H. confusa* occurred early in spring and lasted until the beginning of May (fig. 5). The young larvae hatched out of the eggs laid in spring were caught in late May. The gradually appearing small numbers of young larvae from May to mid-July and their increased number in August seems to result from the varied length of the period the embryonic development of the eggs. Growth of the larvae in June and July was slow. It was more rapid in autumn and continued in winter. This species had one generation a year (univoltine winter cycle).

3.7. *Ephemerella ignita* (Poda)

The diagram presenting the life cycle of *E. ignita* concerns the material from Station 3 in the Wołosatka Stream (fig. 5). Emergence took place from the beginning of August to mid-September. In this period the number of smaller larvae rapidly decreased and individuals ready to emerge decidedly predominated. The first juvenile larvae appeared only in mid-June, which clearly demonstrates the winter survival of *E. ignita* in the form of eggs. The larvae grew fast in June and July. This species had a univoltine summer cycle.

4. Discussion

The occurrence of 38 species of mayflies was found in the streams of the Bieszczady National Park (Kukuła 1991). Most of them are winter species with one generation a year — univoltine winter species (Sowa 1975, Clifford 1982). Species with summer cycles are more numerous in lower sections of the streams. A similar distribution of species with winter and summer cycles is typical of many Carpathian running waters (Sowa 1975).

The life cycles of *R. carpatoalpina* and *R. puytoraci* had not hitherto been precisely described, although some of literature data concerning *Rhithrogena ferruginea* Navàs, and even *Rhithrogena semicolorata* (Curt.) may refer to *R. puytoraci* or *R. carpatoalpina*. Clifford (1982) claims that *R. semicolorata* has most often one generation a year. According to Kłonowska et al. (1978) *R. carpatoalpina* is a univoltine winter species, similarly as *R. puytoraci* (Sowa and Degrange 1987). The data from the Wołosatka and Terebowiec streams show similar courses of the life cycles of both species, allowing them to be included with the univoltine winter species.

Kłonowska (1987) classes *R. wolosatkae* with the univoltine winter species on the basis of observations of the emergence of subimagines. *R. wolosatkae*, replacing the related species *Rhithrogena circumtatrica* Sowa et Soldan absent in the Bieszczady Mountains, has a life cycle similar to that of the above-mentioned species. Sowa (1975) described the life cycle of the population of *R. circumtatrica*

(= *hybrida* sensu Sowa) from the Olszowy Stream from a station situated at an altitude of 780 m. The author found a distinct growth of the larvae also in winter and a very short period of emergence lasting from late April to late May. On the other hand, in the streams of the Tatra Mountains at an altitude of about 1000 m the emergence of *R. circumtatrica* is delayed and protracted up to two months (Sowa 1975). It seems that the life cycle of *R. wolosatkae* had a similar course as that of *R. circumtatrica* from the stations situated higher, i.e. a univoltine winter cycle.

The life cycle of *R. gorganica*, endemic in the Carpathian Mountains, with its centre of occurrence in the East Carpathians, has hitherto rarely been described. Sowa (1975) gives a description of the life cycle of this species that does not differ from that presented above. *R. gorganica* is probably a cold-stenothermic species, connected with waters with small annual temperature fluctuations. Its sites in the Wołosatka and Terebowiec streams are therefore located in the higher areas (about 1000 m), in intensively shaded places, not far from the spring zone (Kukuła 1991). The conditions prevailing here enable systematic growth of the larvae within the whole year.

B. rhodani is one of the best known species of mayflies, with regard to their life cycle. Humpesch (1979), on the basis of 2.5-year investigations in streams in Austria suggests the possibility of changing the number of generations in the year in a given flow depending on the climatic conditions. Bengtsson (1988) found two generations in the annual life cycle of *B. rhodani* in two streams in Denmark. In more favourable conditions *B. rhodani* can have even 3 generations in one year. Such a type of life cycle was found by Rosillon (1986) in a Belgian stream. In the Wielka Puszcza Stream in the Beskid Mały Mountains (southern Poland), in its upper section only one generation was found, but in its middle and lower sections three generations (Sowa 1965). Sowa (1975), elaborating the life cycle of *B. rhodani* according to material from the River Raba, found two generations a year at the stations situated at an altitude of about 350 m. The first generation from the autumn larvae, growing fairly rapidly in winter, had adult nymphs much larger than the second generation. In the lower river course *B. rhodani* had one, i.e. only a winter generation within the year, but in summer it underwent a long period of quiescence in the stage of an egg or of the youngest larvae, descending to the deeper layers of the bottom (Sowa 1975). For the population of *B. rhodani*, a similar cycle as at Station 3 in the Bieszczady Mountains was described in a stream in the Apennines, where two generations a year were found — a bivoltine winter cycle (Ghetti et al. 1979). Weichselbaumer (1984) measured limiting temperature for the emergence of three species of mayflies in the Piburger Bach stream in the Alps. *B. rhodani* emerged there even at a temperature of 5 °C. In the light of the above presented information the late beginning of emergence of *B. rhodani* in the Wołosatka and Terebowiec streams is striking. At all the stations and on all the sampling dates the emergence of this species is documented only as beginning from June. On the earlier dates no nymphs ready to emerge were found, although most authors (among others Müller-Liebenau 1969, Sowa 1975) report that this is one of the earliest emerging species of mayflies in Europe. Perhaps the lack of mature larvae in the collected material was caused by the few emergences in early spring and these larvae did not get into the collected samples.

Within the years 1985–1986 *B. muticus* had one generation (univoltine winter cycle). Sowa (1975) and Landa (1969) reported that *B. muticus* has two generations a year. The data of Clifford (1982) report bivoltine life cycles of *B. muticus* in most of the investigated water bodies. In one only case did Clifford (1982) determine a life cycle of this species as a univoltine summer cycle, but he does not mention a univoltine winter cycle. The univoltine winter cycle of this species in the Bieszczady Mountains may result from the low water temperatures preventing the appearance of a second generation during the year.

Clifford (1982) reports *H. confusa* (= *H. modesta* (Hagen)) as an entirely univoltine winter species, similarly as Ghetti et al. (1979) and Landa (1969). The life cycle of this species in the River Raba described by Sowa (1975) had a course almost identical to that in the Wołosatka Stream. Landa (1969) and Sowa (1975) would seem to be correct in remarking that the growth rate of the larvae of this species does not greatly depend on water temperature. Both at stations located in higher situated sections of streams (the Apennines, the Tatra Mountains, the Bieszczady Mountains) and at those situated lower (the River Raba) the course of the life cycle is also very similar.

E. ignita is one of the most frequently studied species of mayfly, with regard to the life cycle. Clifford (1982) reports that *E. ignita* has a mainly univoltine summer cycle, although other ways of realizing the life cycle were also found (among others a univoltine winter cycle, Rosillon 1986). Elliot (1978), Jażdżewska (1980) and Hefti and Tomka (1988) emphasize the great effect of water temperature on the time of emergence and the growth rate of the larvae. In the higher situated areas univoltine summer cycles dominate (as was the case in the Wołosatka Stream), whereas in lowland streams larvae may be present throughout the year. The moment of appearance of the youngest larvae also depends on the place of occurrence of the species. In the upper section of the River Raba the first larvae appeared only in June and in the lower one in May. The period of emergence in higher situated regions was delayed by nearly a month (Sowa 1975).

Acknowledgements – The author would like to express his gratitude to the staff of the Bieszczady National Park, and particularly to Tomasz Winnicki, M.Sc. for their help with the organization of the field investigations.

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