EPHEMEROPTERA EMERGENCE FROM A HIGH MOUNTAIN STREAM IN TYROL, AUSTRIA

Helmut Ritter

Dept. of Limnology, Inst. of Zoology, University of Innsbruck, Technikerstrasse 25, A-6020 Innsbruck, Austria

ABSTRACT

The emergence of *Baetis alpinus* and *Rhithrogena loyolaea* was investigated using emergence traps at two sampling stations on the Stocktalbach, a high mountain stream in Tyrol, Austria, from June 1981 to October 1982. The emergence period was 2 to 2.5 months with only one peak. Most subimagines of both species emerge in August. Differences in the phenology of the emergence between the two sites resulted from differences in water temperature while differences between the two species result from different larval development cycles.

In terms of biomass, calculated from a body length – dry weight regression, average emergence of *B. alpinus* was 32 mg dry weight m^{-2} (24.3–40.3) at P3 and 354.5 mg m^{-2} (285.1–423.8) at P7, while for *R. loyolaea* the figures were 298 mg dry weight m^{-2} (333.3–262.2) at P3 and 285.2 mg m^{-2} (161.5–408.9) at P7.

INTRODUCTION

The present work is part of a more extensive study of the Ephemeroptera of the Stocktalbach, a high mountain stream in Tyrol, Austria, during the years 1980–1982 (Ritter 1985). The study area is situated in the Stubaier Alps about 36 km SSW of Innsbruck at an altitude of 2200 to 2500 m above sea level (Fig. 1). The Stocktalbach rises at 2500 m and the drainage area above the study sites is about 1.5 km^2. Like any high mountain stream the Stocktalbach has a long period of snow cover, November to May, with a thickness of up to 3.5 m at several locations. Water temperature (Fig. 2) is high in summer with large fluctuations, while in winter, under snow, the temperature is between 0 and 0.5 °C.

METHODS

The study reported here was restricted to two sampling sites, P3 (2385 m above sea level) and P7 (2260 m), from June 1981 to October 1982. The two sites differ in substratum, current and water temperature, but both are characteristic of parts of the Stocktalbach. P3 and P7 differ in daily maximum temperature (18–19 °C at P7 and 12 °C at P3) and in the size of the daily fluctuations (often 10–13.5 °C at P7 and at most 5 °C at P3).

Emerging insects were collected in a tetrahedral "pyramid" trap (Mundie 1956, Schwoerbel 1977, Stummer 1980) with an edge length of *ca* 40 cm, giving a collecting area of 693 cm^2. The sides of the trap were covered with a light gauze (mesh 400 μ), and it was fixed on the substratum with iron pegs. At each sampling site 8 emergence traps were situated at random.

I.C. Campbell (ed.) Mayflies and Stoneflies, 53–59.

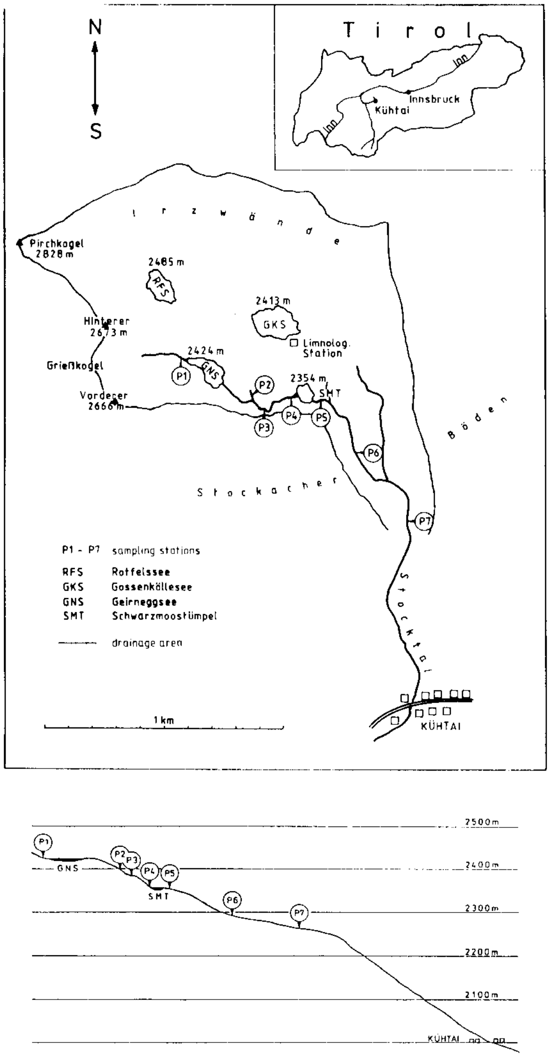

Fig. 1. Map and profile of Stocktalbach.

RESULTS AND DISCUSSION

Five species of Ephemeroptera were found in the Stocktalbach, with *Baetis alpinus* Pictet and *Rhithrogena loyolaea* Navas dominant, comprising more than 99% of the mayflies collected. *Epeorus alpicola* Eaton and *Baetis Gr. vernus* were found once and *Ecdyonurus Gr. helveticus* was found sporadically in benthic samples. Only *B. alpinus* and *R. loyolaea* were collected with the emergence traps.

Abundance and phenology

At P3 the emergence is dominated by *R. loyolaea* (1981: 85.7% and 1982: 67.7% of the Ephemeroptera), while the emergence at P7 is dominated by *B. alpinus* (1981: 89.8%, 1982: 80.2%). The total catch of Ephemeroptera in 1982 (273 individuals) was higher than in 1981 (195 individuals). At P7 both *B. alpinus* and *R. loyolaea* were more abundant in 1982 while at P3 only *B. alpinus* increased in 1982 and *R. loyolaea* was less numerous. Annual fluctuations in the emergence were also found over several years by Illies (1978, 1980).

The emergence period of the two species is very short (Fig. 3), starting in the middle of July in both years and continuing for a maximum of 2.5 months. In lowland streams the emergence period can go on for 7 months (Illies 1971, Sandrock

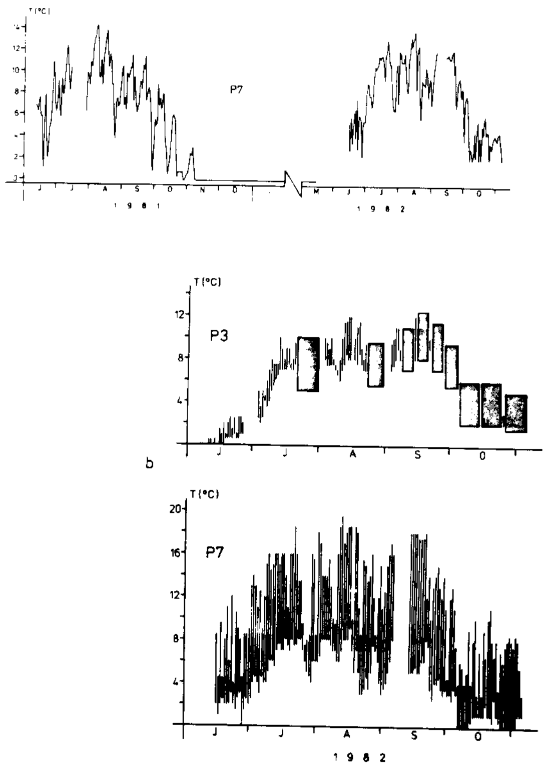

Fig. 2. Temperature of Stocktalbach: a) daily mean (min. + max./2) at P7; b) daily amplitudes of water temperature (shaded region indicates amplitude over a longer period).

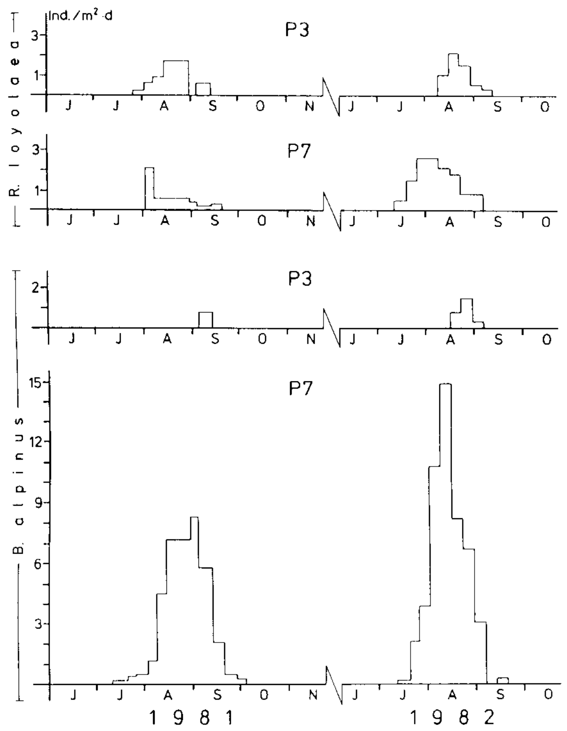

Fig. 3. Emergence during 1981 and 1982 in Stocktalbach: curve of abundance (individuals m^{-2} day^{-1}) of *B. alpinus* and *R. loyolaea* at P3 and P7.

1978, Weichselbaumer 1984). The short emergence period results from the pattern of water temperature. Many authors have noted that the water temperature has an influence on the emergence of insects (e.g. see Weichselbaumer 1984), with the influence of the input of heat on the length of the larval development being expressed in earlier or later emergence times.

To determine the temperature requirements of the larvae to complete their development to emergence after the stream is free of snow, I summed the daily means of the water temperature from this moment to the beginning of the emergence period. This sum, expressed in day-degrees, is the minimum needed after overwintering to complete development, not the requirement for development of larvae from the hatched of eggs to the subimagines. For site P7 in 1981 and 1982 and for P3 in 1982 (there was no temperature data in 1981 at P3) the data were concordant, between 300 to 320 day-degrees. This value will be reached later at P3, because the rise of the water temperature begins later and never reaches such high values as at P7 (Fig. 2), thus the later commencement of emergence at P3.

The emergence curves of *B. alpinus* and *R. loyolaea* clearly have only one peak (Fig. 3), with most subimagines of both species hatching in August. The maximum rates of *R. loyolaea* are between 1.7 and 2.6 individuals m^{-2} day^{-1} (ind m^{-2} d^{-1}). The highest rates of *B. alpinus* are low at P3 (in 1981 0.8 and in 1982 1.5 ind m^{-2} d^{-1}) and very high at P7 with 8.1 in 1981 and 14.9 ind m^{-2} d^{-1} in 1982. The real maximum in 1981 is cut off by the collecting interval of 14 days.

Lower water temperature accounts for the later commencement of emergence at P3 and also to a delayed peak at this site. The peak of *R. loyolaea* always occurs earlier than the peak of *B. alpinus*. *B. alpinus* has a univoltine and *R. loyolaea* a biannual (triannual if egg development is considered) development cycle (Ritter 1985). The larvae of *R. loyolaea* are more developed at the beginning of the summer in which they emerge,and emerge earlier than the larvae of *B. alpinus*. The length of the emergence period in 1982 is less than in 1981, and there is also an earlier emergence peak by *B. alpinus* in 1982. Both observations result from higher water temperatures in the year 1982.

Biomass

Because the subimagines were fixed with 4% Formol and preserved with 70% alcohol, the biomass was not estimated directly by weighing the captured insects, but was calculated from a body length – dry weight regression. The relationship between the body lengths of the subimagines and their dry weights is well described by the transformed power law $\ln DW = \ln a + b \ln L$. Where DW is dry weight (mg), L is body length (mm) and a and b are constants.

For *B. alpinus* Weichselbaumer (1984) calculated both constants of the equation (Table 1), by measuring the length of living subimagines, drying them at 60 °C for 48 hours and weighing them. I used these values for *B. alpinus*, not having enough material of either species for my own stu-

Table 1. Values for the body length – dry weight regression for the subimagines of *B. alpinus* (After Weichselboumer 1984) and *R. loyolaea* (ln-transformation of Fig. 5). CL_{95} = 95% confidence limits

	ln a	CL_{95}	b	CL_{95}	r	n
B. alpinus						
male	– 5.8831	0.6616	2.9904	0.3384	0.92	31
female	– 5.7470	0.7363	3.1388	0.3826	0.96	15
R. loyolaea						
male	– 5.3638	0.0228	2.9260	0.0098	*	*
female	– 4.9755	0.0358	2.9586	0.0155	*	*

* theoretical calculation (see text).

dy. For *R. loyolaea* I estimated the weights of the subimagines from the dry weights of the mature nymphs which had ceased growing. I compared the dry weights of large mature nymphs of *B. alpinus* with the dry weights of the subimagines of the same size (Fig. 4). The relationships of males and females both were clearly linear, with the

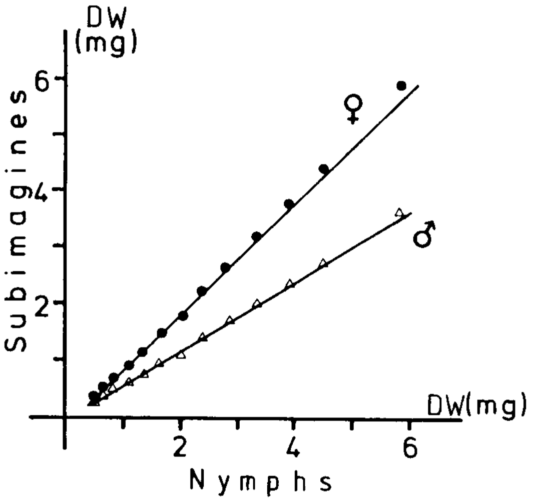

Fig. 4. Relationship between the dry weight (DW) of mature nymphs and subimagines of the same size of *B. alpinus.*

Table 2. Stocktalbach: Abundance and biomass of subimagines of *B. alpinus* and *R. loyolaea* at P3 and P7 in 1981 and 1982. DW = dry weight

Species	Abundance (ind m^{-2})				Biomass (mg m^{-2})			
	♂	♀	sum	%	♂	♀	sum	%
1981/P3								
B. alpinus	–	7	7	14.3	–	24.3	24.3	6.8
R. loyolaea	16	27	43	85.7	14.9	238.4	333.3	93.2
Total			50	100.0			357.6	100.0
1981/P7								
B. alpinus	161	110	271	89.8	145.1	140	285.1	63.8
R. loyolaea	15	16	31	10.2	60.4	101.1	161.5	36.2
Total			302	100.0			446.6	100.0
1982/P3								
B. alpinus	5	13	18	32.3	6.1	34.2	40.3	13.3
R. loyolaea	16	22	38	67.7	77.6	184.6	262.2	86.7
Total			56	100.0			302.5	100.9
1982/P7								
B. alpinus	179	171	350	80.2	177.7	246.1	423.8	50.9
R. loyolaea	45	42	87	19.8	166.8	242.1	408.9	49.1
Total			437	100.0			832.7	100.0

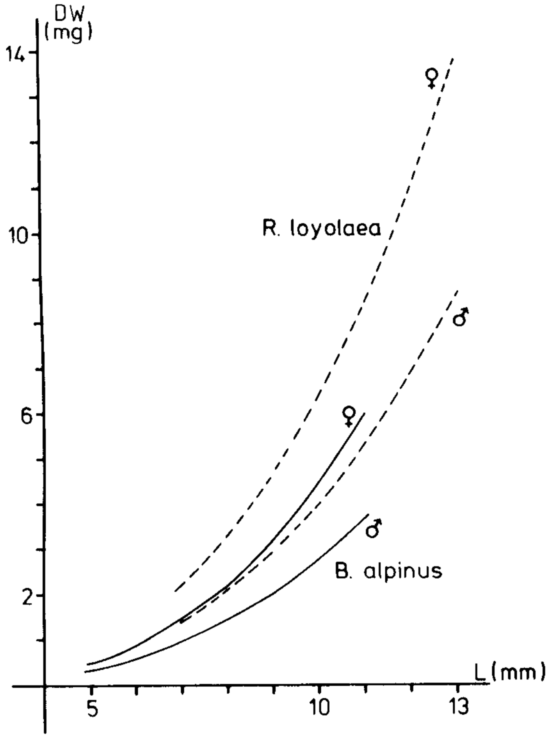

Fig. 5. Body length – dry weight – regression of the male and female subimagines of *B. alpinus* and *R. loyolaea*. L = body length, DW = dry weight

females, with their abdomens full of eggs, higher than the males and corresponding almost to the weights of the mature nymphs. Since the larvae of *R. loyolaea* go through the same moulting process to subimagines as *B. alpinus*, the same linear regression between weight of mature nymphs and weight of male and female subimagines can be used for *R. loyolaea*. With this relationship and the dry weights of the mature *Rhithrogena* larvae determined from other studies (Ritter 1985), it is possible to calculate the weights of subimagines of different sizes. *R. loyolaea* is heavier than *B. alpinus* of the same size (Fig. 5), with a greater average body length the difference in the biomass between the two species increases even more.

The numerical dominance of *R. loyolaea* at P3 is emphasized in the biomass calculations (Table 2), but the dominance of *B. alpinus* at P7 is reduced in the biomass calculations. The curves of the biomass emergence (Fig. 6) are very similar to the curves of the abundance, with small differences due to the different percentages of females in the samples.

Fecundity and natality

Fecundity is defined as the number of ripening eggs per female prior to oviposition (Elliott and Humpesch 1980, Humpesch and Elliott 1984). Natality (or potential natality) is defined as the average number of existing or developing eggs (i.e. highest possible number of descendants) per time and area (Schwerdtfeger 1968). Fecundity is related to one individual, potential natality to the whole population.

The relationship between fecundity and body length of females has been shown to be well described by a power law (Benech 1972, Britt 1962, Clifford 1970, Clifford and Boerger 1974, Elliott and Humpesch 1980, Weichselbaumer 1984)

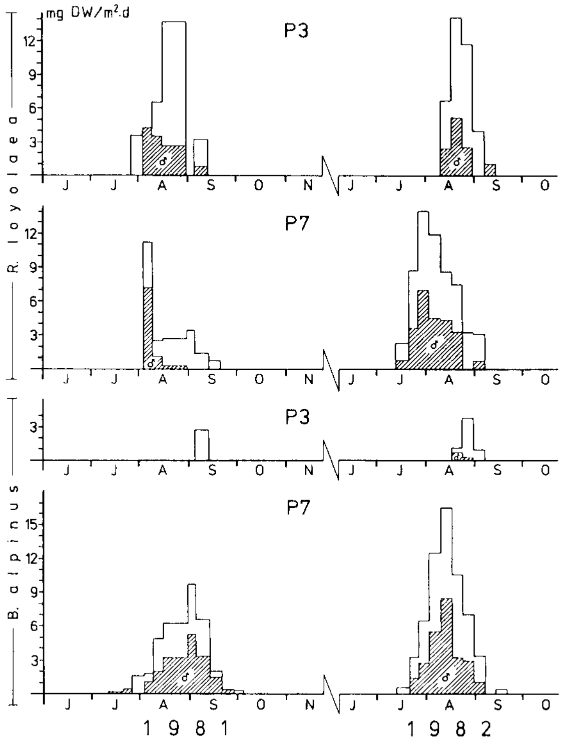

Fig. 6. Emergence during 1981 and 1982 in Stocktalbach: Curve of biomass (mg dry weight m^{-2} day^{-1}) of subimagines of *B. alpinus* and *R. loyolaea* at P3 and P7 (shaded area indicates percentage of males)

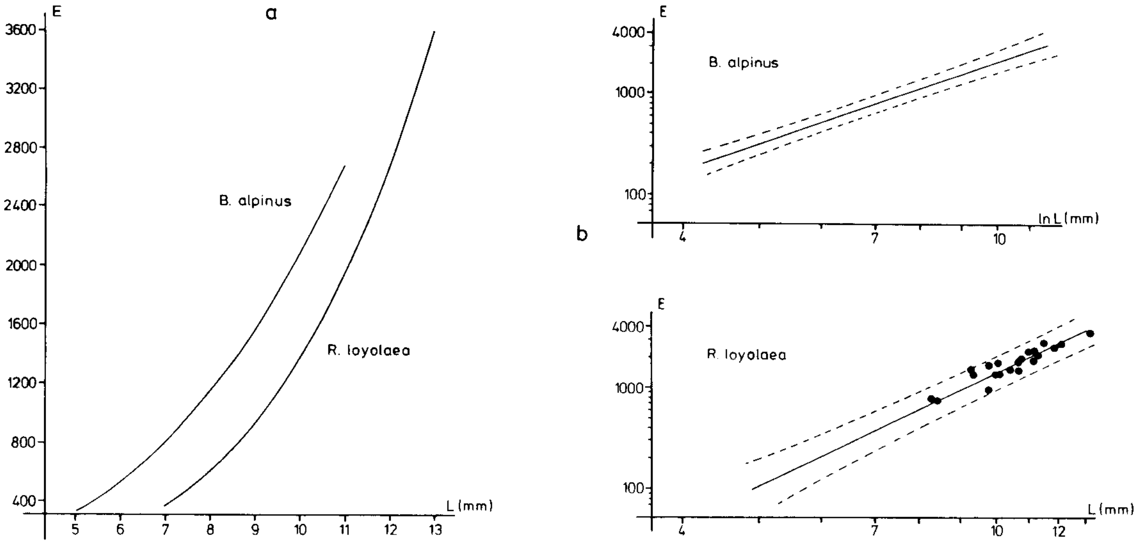

Fig. 7. Fecundity of of *B. alpinus* and *R. loyolaea*: a) relationship between body length (L) and number of eggs (E) b) in – transformation of the body length – fecundity regression (*B. alpinus* after Weichselbaumer 1984, broken line indicates 95% confidence limits)

which can be transformed to ln E = ln a + lb ln L where E is the number of eggs, L is the body length (mm), and a and b are constants. Other authors cite values between 2.66 and 3.77 for the constant b. The values for the constant b of both *B. alpinus* (2.72) and *R. loyolaea* (3.3) lie within the range of these authors.

With this relationship, and the measured lengths of the females, it is possible to calculate the theoretical number of eggs of a population, that will be developed in one year each m^2 (Table 3). The real number of eggs, which will be laid into the water and can start their development is much fewer due to predators, unfertilized eggs, etc. but this reduction cannot be determined. To estimate how much of the existing potential will develop from the egg to the subimago in nature, the potential natality of a year must be related to the emergence of the resultant generation. For the Stocktalbach we can do this only for *B. alpinus* with its univoltine development cycle. The multiannual development cycle of *R. loyolaea* could not be observed completely during the investigation period.

In 1981 the potential natality for *B. alpinus* was 11583 eggs year^{-1} m^{-2} at P3 and 73849 eggs year^{-1} m^{-2} at P7. In 1982 18 subimagines year^{-1} m^{-2} were caught at P3 and 352 at P7. Thus at P3 only one of 644 eggs completed the whole development, and at P7 one of 210.

Table 3. Stocktalbach: Potential natality (Eggs $m^{-2}\text{year}^{-1}$)

	B. alpinus	*R. loyolaea*	Total
	($E\ m^{-2}\text{year}^{-1}$)	($E\ m^{-2}\text{year}^{-1}$)	($E\ m^{-2}\ y^{-1}$)
1981			
P3	11583	65818	77401
P7	73849	21261	95110
1982			
P3	16317	43319	59636
P7	134893	50377	185270

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