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With the author's compliments

Autecological studies on *Baëtis rhodani* (PICT.) (Ephemeroptera)

By JOHS. BENGTSSON

With 8 figures and 2 tables in the text

Abstract

The autecology of *Baëtis rhodani* was investigated in two Danish lowland streams. Nymphal growth and life cycle as well as adult flight pattern, oviposition behaviour and egg hatching were studied in the field and in the laboratory.

Introduction

Elements of the autecology of *Baëtis rhodani* (PICT.) have been described in BENGTSSON, 1973, 1982 and 1984. The aim of this paper is to present the main results of these papers as well as some unpublished observations in a concise form to an international audience.

Baëtis rhodani was studied in two small lowland streams in Himmerland, Northern Jutland, Denmark. A small tributary of Halkjær å (A) and a larger tributary of Sønderup å (Haverslev bæk) (B).

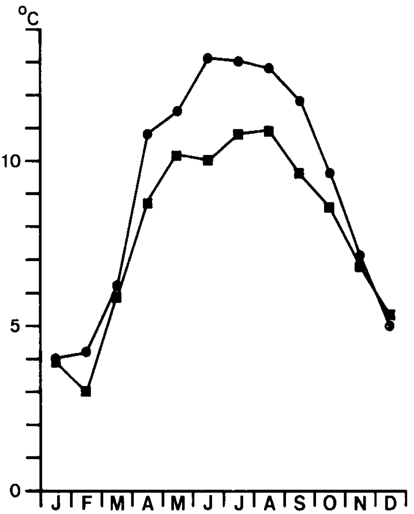

Fig. 1. Monthly mean water temperatures in locality A (■——■——■) and B (●——●——●).

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Stream A is unpolluted and no maintenance and macrophyte cutting is carried out. Stream B is slightly polluted and intense maintenance and macrophyte cutting is carried out. The mean water temperature of B exceeds that of A by about 2—3 °C in summer (Fig. 1).

Results

Nymphal growth

The body lengths (less antennae and cerci) of nymphs were measured monthly in 1970—72 (A) and in 1979—81 (B). Histograms showing the distribution on length classes at four selected times of the year are presented in Fig. 2. A total of 2058 nymphs were measured. The size distribution in the

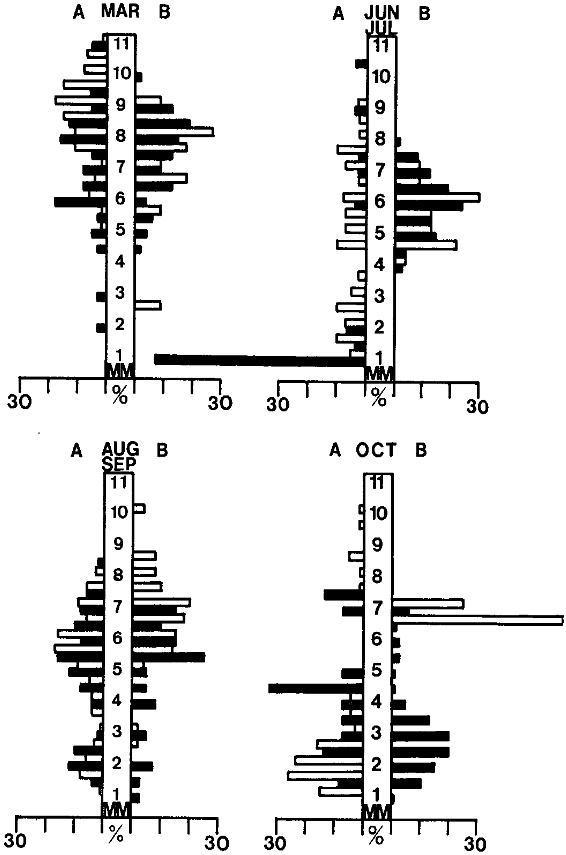

Fig. 2. Percentage distribution of length classes in a single samples of *Baëtis rhodani* nymphs at four selected times of the year in locality A (■: 1971 and □: 1972) and locality B (■: 1980 and □: 1981).

samples showed that the species has two generations per year in both localities: a slow growing overwintering generation with emergence in spring and early summer, and a rapid growing summer generation with emergence in late summer and fall.

There is some evidence from the size distributions that the nymphs are split up into two cohorts in the summer, the imagos in late summer and autumn representing the quick growing cohort. The remainder grow more slowly and emerge in stream A in the following spring together with nymphs hatched from eggs laid by the females in late summer and autumn. In locality B such large summer generation nymphs were also found just before macrophyte cutting each autumn, but after cutting only newly hatched nymphs remained. The macrophyte cutting caused a reduction in the total number of nymphs during winter, especially when it coincided with egg hatching in the autumn.

Emergence periods

Subimagines, imagines or egg masses were found from early April to early November. In locality A there was a distinct separation between the emergence of the two generations. The emergence of the winter generation took place from April to June with a maximum in May. The summer generation emerged from August to November with a maximum in September. In July no adults or egg masses were found in locality A. In locality B the emergence periods of the two generations overlapped. Maximum emergence of the winter generation was in May—June and that of the summer generation in August—September (Fig. 3).

A possible explanation for this is the different summer water temperatures. The disappearence of the large nymphs in locality B during autumn may also play a role.

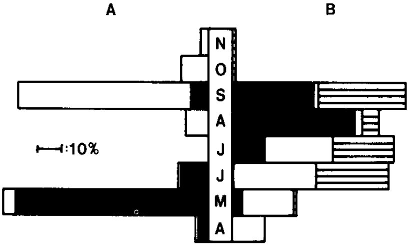

Fig. 3. Percentage distribution of *Baëtis rhodani* imagines found in locality A (black: 1971 and white: 1972) and locality B (black: 1980 and white: 1981) and egg batches found in locality B 1981 (lines).

Table 1. Mean body and wing lengths of *Baëtis rhodani* imagines.

		Winter generation				Summer generation			
Mean length (mm)		♀♀		♂♂		♀♀		♂♂	
Locality	Year	Body	Wings	Body	Wings	Body	Wings	Body	Wings
A	1971	8.4	–	10.0	–	–	–	6.3	–
A	1972	8.9	–	8.3	–	7.4	–	7.4	–
B	1980	6.3	6.3	–	–	5.8	6.8	6.3	6.1
B	1981	6.3	6.1	8.0	8.4	7.3	7.8	6.0	6.0

Size of imagines

The mean body and wing lengths of the imagines are shown in Table 1. The imagines of the summer generation were smaller than those of the winter generation from locality A (1979—72). This was to some extent also true in the imagines from locality B (1980—81). No significant difference was observed between the mean body length of females and males. Females constituted 77.8 % of the total number of imagines collected.

Emergence pattern

From August to November 1972 the summer generation imagines were so numerous that the emergence pattern could be observed in more detail. The females dominated at the beginning of the emergence period. At the end of the emergence period the sexes were about equal in numbers. The females constitute 75.9 % of the total numbers in this material. The mean body length of the two sexes increased about 1 mm at the time of maximum emergence, then fell again, although at the end of the period another rise and fall of mean body length occurred.

In accordance with the total material in this study, the body lengths of the two sexes were almost the same at the time of maximum emergence in autumn 1972 (Fig. 4).

Flight pattern

The adults usually fly near the stream. In spring at the beginning of the emergence period however subimagines and imagines were frequently found up to 250 m from the stream. Here subimagines dominated (Aprox. 60 %) (both sexes in about equal numbers). Male imagines occurred in about three times the numbers of females.

In autumn 1972, 191 imagines were captured on sticky traps suspended across stream A, using the method of Madsen et al. (1973). The results show a convincing dominance of specimens flying in the upstream direction (84.8 %). The percentages of females on both sides of the traps were almost equal (mean:

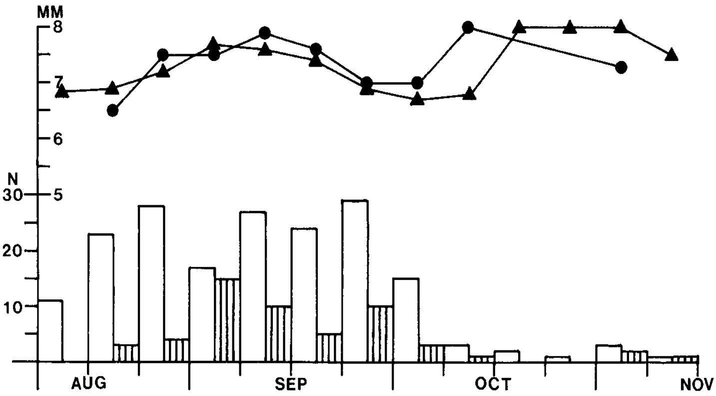

Fig. 4. Emergence pattern of *Baëtis rhodani* summer generation imagines in locality A 1972 (white: females, lines: males) and mean weekly body length (▲——▲: females, ●——●: males).

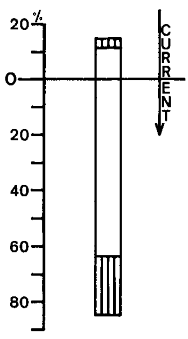

Fig. 5. The percentage distribution of *Baëtis rhodani* imagines in locality A August and September 1972 on up- and downstream facing sides of an adhesive trap (white: females, lines: males). Arrow indicates current direction.

75.6 %), which agrees with the sex-ratio in the total material of imagines found (Fig. 5).

Many females were caught in spiders' nets along the streams especially in late summer. Once stuck in the nets it was observed, that the females often released their eggs, which dropped into the water. The fate of these eggs is uncertain.

Oviposition behaviour

After mating and drift compensating upstream flight the females oviposit on partially submerged stones, macrophytes (e.g. *Berula* and *Sparganium*), poles etc. Females prefer to oviposit in areas where the stream is not exposed to the prevailing wind direction.

If the females lands on for example stones in vertical position, her head is always orientated upwards. Then she quickly turns around and goes under the water surface folding her wings along the abdomen and seeking a suitable place to oviposit. Here the female swings her abdomen from side to side while she moves slowly forwards placing arches of eggs, which finally form a flat semi-circular plate of eggs on the substrate.

The females are water-repellent and continue to oviposit even if the stone with the ovipositing females is removed from the stream bottom.

Oviposition itself was once observed to last 42 min.

Substrate preference for oviposition

The eggs are slightly ovoid, about 0.1 mm × 0.15 mm.

Newly laid eggs are ivory-white but change within a few days to light brown.

Oviposition was investigated in more detail by means of 5 cm plastic tubes placed vertically in the stream bottom. 52 % of the egg batches were placed on the downstream-facing side of the tubes, 21 % and 25 % respectively on the sides parallel to the current and 2 % on the upstream facing side of the tubes. The majority of egg batches were placed near the stream bottom (Fig. 6).

Some plastic tubes were provided with different kinds of surface to investigate the choice between different substrates for oviposition. The females prefer dark-grey plastic to white plastic, dark-grey plastic to dark-grey rubber-foam and fresh wood to old decaying wood. The females prefer wood to plastic. In conclusion, the females prefer hard, rough and dark substrates for oviposition (Fig. 7).

Stones are often removed from the streams by maintenance work and once females were observed entering the underwater-area along a partially submerged 30 cm stone with a mean of 2.3 egg batches/cm^2 stone surface and 50 already ovipositing females. Then females arriving later were able to move along the stream bed to oviposite on totally submerged stones up to 50 cm from the stone, where they descended.

In another context, frames with 12 microslides were placed in the streams. The slides were totally covered with egg batches, which amount to approx. 750 egg batches corresponding to a total of 1.5×10^6 eggs. It is supposed that the willingness of the females to oviposit on for example plastic tubes, micro slides and rubber boots is caused by lack of natural substrates removed by stream maintenance.

In England sticks were placed in the trout streams to attract oviposition-mature females of Mayflies to improve the food supply of the trout.

In Table 2 the relationship between mean body length of the females and the mean area and number of eggs in the egg batches in summer 1981 is presented. The mean area of the egg batches increased with increasing size of the females.

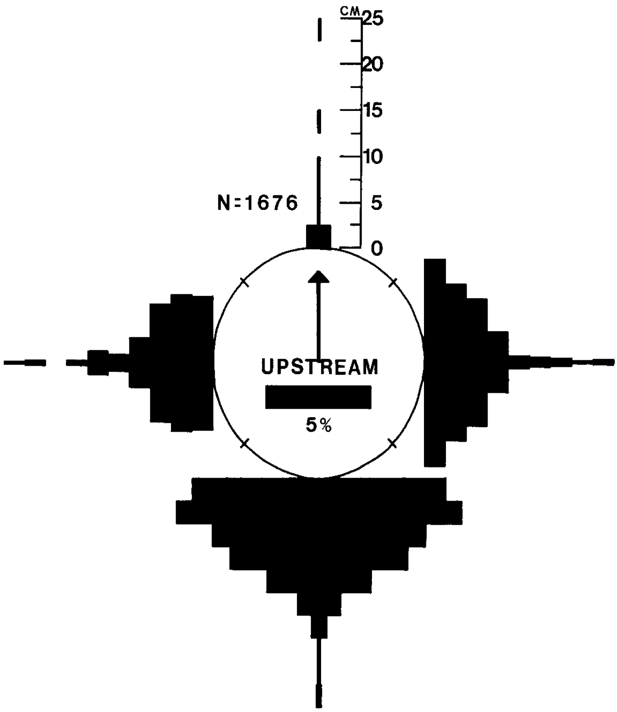

Fig. 6. Percentage distribution of *Baëtis rhodani* egg batches in locality B 1980 and 81 in relation to stream current and distance from the stream bottom on four sections of plastic tubes placed vertically in the stream. The section facing upstream is indicated with an arrow.

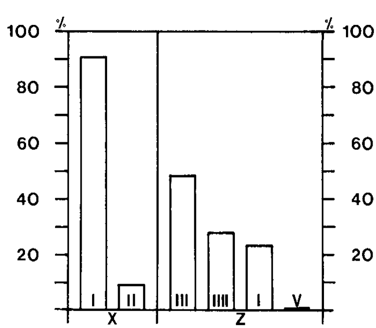

Fig. 7. Substrate preference of ovipositing *Baëtis rhodani* females. Experiment X (I: dark grey plastic, II: white plastic) Experiment Z (I: dark grey plastic, III: fresh wood, IV: decaying wood and V: dark grey rubber-foam).

Table 2. Relationships between mean female body length, mean area of egg batches and mean egg number/batch in *Baëtis rhodani*.

Year	1981	1981	1981	1974
Month	May	June	July	Sept.
Mean body length of females (mm)	7.6	6.1	6.1	–
Mean area of egg batches (mm^2)	26.4	21.2	20.5	17.6
Mean number of eggs/batch	2478	1990	1924	1652

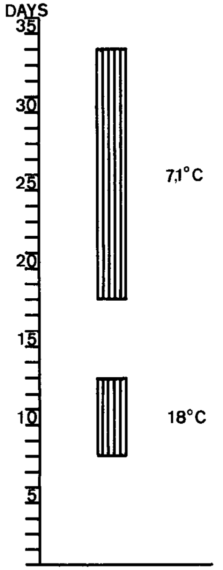

Fig. 8. Hatching periods of *Baëtis rhodani* eggs at mean water temperatures of 7.1 °C and 18 °C.

Egg hatching

The egg hatching period at 7.1 and 18 °C was investigated in laboratory experiments. At 7.1 °C the eggs hatched 18—33 days after oviposition. At 18 °C the period was 8—12 days after oviposition (Fig. 8).

Eggs with live embryos are hyaline. Just before hatching the embryos start moving to escape from the eggs. The head emerges first (slowly) then the thorax, legs and abdomen follow more quickly. Hatching lasts about two minutes at room temperature. Some of the eggs were infected with fungi before hatching. Newly hatched nymphs are whitish-hyaline with a body length of about 0.4 mm (less antennae and cerci).

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Zusammenfassung

Teile der Autökologie von *Baëtis rhodani* werden in dieser Arbeit nach Untersuchungen des Verfassers in Himmerland, Dänemark beschrieben. Auskunft über Lebenszyklus der Art, Wachstum der Larven (Fig. 2) sowohl als Emergenz (Fig. 3 und 4), Flugverhalten (Fig. 5) und Eiablage (Fig. 6 und 7) der Imagines und Ausbrüten der Eier (Fig. 8) wird gegeben.

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Address of the author:

JOHS. BENGTSSON, Napassoq, DK-3912 Maniitsoq, Greenland.