

with respectful regards

to
Bill & Jan Peters

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**EFFECT OF TEMPERATURE ON HATCHING
OF PARTHENOGENETIC EGGS OF
BAETIS GEMINATUS MÜLLER-LIEBENAU & HUBBARD, 1985
FROM SOUTH INDIA
(EPHEMEROPTERA: BAETIDAE)**

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Deuterokous and facultative parthenogenesis has been confirmed in *B. geminatus* by hatching from eggs of reared unmated females. Some eggs developed parthenogenetically and the hatching success ranged from 1 to 38% at constant water temperatures (range 20-40 °C). Hatching time (days after start of the experiment for 10, 50, and 90% of the eggs to hatch) decreased with increasing temperature and the relationship between the 2 variables is described by a regression equation. This represents the first demonstrated case of parthenogenesis in a South Indian *Baetis* species.

INTRODUCTION

Parthenogenesis is widely spread among various insect orders. In aquatic insects only one case has been reported in Odonata (BELLE & VAN TOL, 1990) and none in Heteroptera (SUOMALAINEN, 1962; TREMBLAY & CALTAGIRONE, 1973), but parthenogenesis has been recorded in several species of Plecoptera (HYNES, 1976), Trichoptera (ELLIOTT, 1971; MALICKY, 1973) and Diptera (HENNIG, 1973; GLOVER, 1973; TROIANO, 1978), and it occurs widely in Ephemeroptera (DEGRANGE, 1960; MINGO, 1978; BERGMAN & HILSENHOFF, 1978; HUMPESCH, 1980; GILLIES & KNOWLES, 1990). The purpose

of this paper is to report for the first time observations of parthenogenesis in a South Indian mayfly, *Baetis geminatus*, with special reference to the effect of temperature on embryonic development.

MATERIAL AND METHODS

Mature nymphs were collected from the Vaigai River at Thiruvudagam, 20 km from Madurai (long. 78°8'E; lat. 9°56'N) and reared to imagines. The female adults were held under distilled water in an embryo cup to voluntarily discharge eggs. In individuals that would not oviposit voluntarily, eggs were removed by dissection. Each cup was maintained under constant photoperiod L:D = 12:12, and aerated by a single air stone. Water temperature was recorded daily and distilled water added to replace water loss through evaporation. Eggs were incubated at constant temperatures ranging from 20° to 40°C. Time of hatching and number of nymphs hatched were recorded. Newly hatched nymphs were removed daily and counted. Unhatched eggs and eggs partly developed but not enclosed were counted at the end of the test period. Tests were terminated when no hatching occurred for 25 consecutive days.

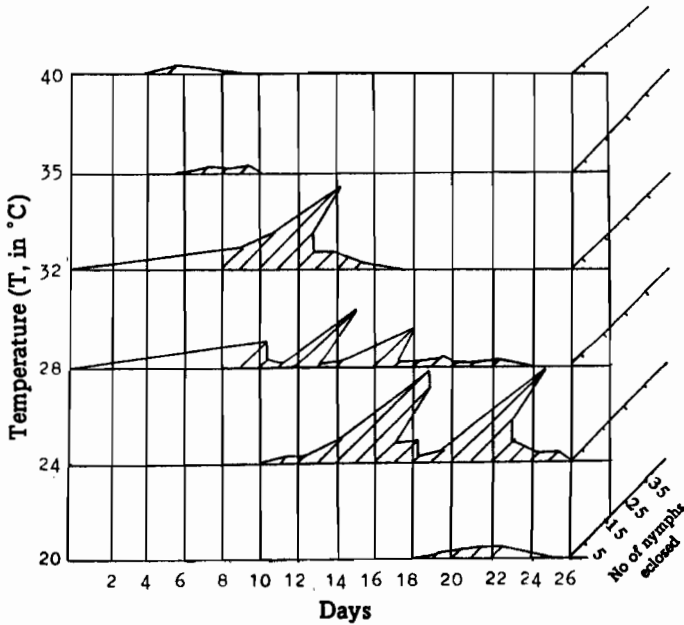


Fig. 1. Nymphal eclosion of *B. geminatus* at different temperatures.

RESULTS

Observations on development at different temperatures are summarized in Table I. Details of nymphal eclosion at different temperatures are presented in Figure 1. During the period of observation, a short series of adults was reared (52 ♂, 42 ♀, giving a sex ratio of 1.2 : 1). The correlation coefficient calculated between days of hatching and water temperature showed a significant negative correlation ($r = -0.905$) ($P < 0.01$).

The relationship between hatching time of eggs (Y) and water temperature (T) is significant and was given by the regression equation $Y = a + bT$, where a and b are constants. The regression for these two variables is represented in Figure 2. The linear regression is a good fit to the data and the F values from the variance ratio are highly significant ($P < 0.01$). The proportion (r^2) of the variance of Y due to the regression of Y on T is ≥ 0.82 . Therefore, at least 82% of the variability in the time required for hatching is accounted for by variations in temperature which is clearly the major factor affecting the time required for hatching in the laboratory.

Table I

Development of parthenogenetic eggs of *B. geminatus* at different temperatures

Temperature (°C)	No. of eggs incubated	No. (%) of larvae hatched	Developed eggs without eclosion	Undeveloped eggs
20	972	20 (2.06)	112 (11.52)	840 (86.42)
24	633	238 (37.60)	177 (27.96)	218 (34.44)
28	1237	439 (35.49)	364 (29.43)	434 (35.08)
32	928	242 (26.08)	137 (14.76)	549 (59.15)
35	793	20 (2.52)	83 (10.47)	690 (87.01)
40	1020	10 (0.97)	45 (4.37)	975 (94.66)

The percentage of eggs that hatched at test temperatures (20°-40°C) ranged from 1 to 38% (Tab. I). The counts of newly-hatched larvae were expressed as a cumulative percentage of the total number of eggs (= 100%) that hatched at each temperature. Estimates were thus made of the

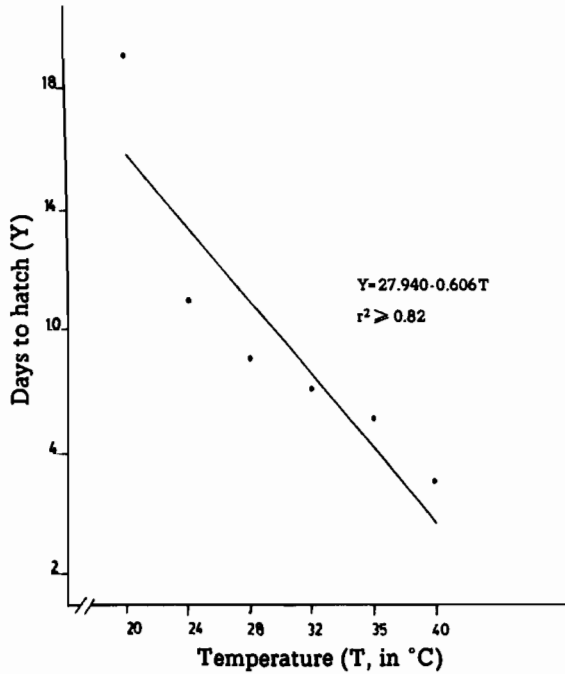


Fig. 2. Relationship between water temperature in °C (T) and days (Y) required for hatching of *B. geminatus* eggs.

actual number of days required for 10, 50 and 90% of eggs to hatch at 20°, 24°, 28°, 32°, 35°, and 40°C. Table II shows that with increasing temperature, the number of days required for 10, 50, and 90% of eggs to hatch decreases. The difference in hatching time for 50% and 90% of eggs varied from a markedly high value of 4 days at 20°C to 2 days at 40°C.

The values of the constants a and b obtained from the regression equations for 10, 50, and 90% of eggs hatched are significant ($P < 0.0025$, $P < 0.05$, and $P < 0.05$ respectively) (Tab. III, Fig. 3). Therefore, the relationship between the two variables was given in the regression equation in Figure 2.

DISCUSSION

Obligatory parthenogenesis has been demonstrated for *Ameletus ludens* (CLEMENS, 1922), *Caenis cuniana* (FROEHLICH, 1969), *C. knowlesi* (GILLIES & KNOWLES, 1990), *Cloeon triangulifer* (GIBBS,

Table II

Days required for 10, 50, and 90% of *B. geminatus* eggs to hatch at different temperatures

Temperature (°C)	Days required for hatching of		
	10%	50%	90%
20	19	21	25
24	13	14	16
28	11	15	18
32	10	11	15
35	7	10	12
40	5	7	9

1977), *Baetis hageni* and *B. macdunnoughi* (BERGMAN & HILSENHOFF, 1978). These species typically exhibit very high levels of parthenogenesis and males are either extremely rare or unknown. The adaptive value of this type is to reduce genetic variation to the minimum by adopting the evolutionary dead-end of parthenogenesis in a comparatively stable environment such as e.g. the permanent streams of equatorial rain forest. A possible consequence of this type of parthenogenesis is the lesser importance of synchrony in the emergence of adults. Unlike bisexual species, they have no need to aggregate reproduction, and a steady dribble of emergence should suffice to ensure the survival of the species (GILLIES & KNOWLES, 1990).

On the other hand, facultative parthenogenesis (sensu MINGO, 1978) or tycho-parthenogenesis (sensu HUMPECH, 1980) is the more common type of the phenomenon in mayflies and is found in species which normally reproduce sexually. The levels of parthenogenesis are typically low and arise from a small proportion of naturally occurring diploid eggs which have failed to undergo meiosis (McCAFFERTY & HUFF, 1974). This type of parthenogenesis occurs under natural conditions when a female is unable to locate a mate (MINGO, 1978).

DEGRANGE (1960) and BERGMAN & HILSENHOFF (1978) demonstrated parthenogenesis in 4 European and in 4 North American *Baetis* species respectively. Herewith the phenomenon is for the first time recorded in a South Indian member of the genus.

A change from reproduction by fertilization to parthenogenesis and the influence of the latter on the construction of a cohort requires that: (a) the females would readily oviposit when placed in contact with

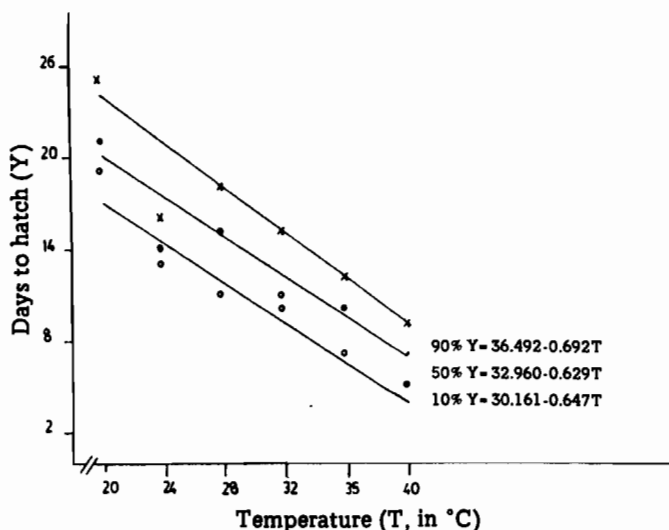


Fig. 3. Relationship between water temperature in °C (T) and days (Y) required for 10, 50, and 90% of *B. geminatus* eggs to hatch.

a water surface; (b) the unfertilised eggs must be able to develop and (c) the offspring must be able to maintain a population in the midst of or adjacent to their parental source without being eliminated by competition or hybridization (HUMPESCH, 1980). Conditions (a) and (b) are satisfied from our observations on *B. geminatus*, whereas (c) was not tested.

Since nymphs died or were preserved shortly after hatching, the

Table III

Regression ($Y = a + bT$) and correlation parameters between temperature T (°C) and days (Y) required for 10, 50, and 90% of the eggs to hatch
[C.I. = confidence interval]

Percentage hatching	a	b	95% C.I.	r ²	F	P
10%	30.161	-0.647	±0.239	0.934	56.35	<0.0025
50%	32.960	-0.629	±0.291	0.900	36.14	<0.05
90%	36.492	-0.692	±0.397	0.855	23.53	<0.05

type of parthenogenesis was estimated from mature nymphs brought from the field and reared to adults in the laboratory. These had an approximate sex ratio of 1.2 : 1. In this species, parthenogenesis is probably facultative and deuterotokous. As evidenced by the high percentage of eggs hatched in the laboratory, it is apparently not the rudimentary type mentioned by McCAFFERTY & HUFF (1974). Sporadic field observations reveal lack of synchrony in emergence of this species.

A negative correlation was obtained between water temperature and time needed for hatching of parthenogenetic eggs (Tab. I). It is also evident that with increase in temperature, the number of days required for 10, 50, and 90% of eggs to hatch decreases in our species (Tab. II). The results are in conformity with the observation on temperate parthenogenetic species of *Ecdyonurus* and *Rhithrogena* (HUMPESCH, 1980).

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