

Relationship between body temperature and air temperature in stridulating male crickets, *Gryllus bimaculatus* (Orthoptera: Gryllidae)

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Body temperatures of singing male *Gryllus bimaculatus* were measured for the first time. Body temperatures were strongly correlated with ambient temperature. This indicates that, unlike some other orthopterans, larger crickets are not dependent on an elevated body temperature for efficient calling. Our results confirm that it is reasonable to use ambient temperature as an approximation of body temperature in behavioural and bio-acoustic studies.

Die liggaamstemperatuur van *Gryllus bimaculatus* kriekmannetjies is vir die eerste keer gemeet terwyl hulle gekriek het. Liggaamstemperatuur was sterk gekorreleer met omgewingstemperatuur. Dit blyk dat groot krieke nie, soos sommige ander Orthoptera, afhanklik is van 'n hoë liggaamstemperatuur vir doeltreffende stridulasie nie. Ons resultate bevestig dat omgewingstemperatuur as 'n direkte maatstaf van liggaamstemperatuur gebruik kan word tydens gedrags- of bio-akoestiese studies met krieke.

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The study of cricket communication is one of the best developed branches in the study of communication. Although crickets are popular research animals for a variety of reasons, there are also certain complicating factors in their communication which need to be understood. One of these is the fact that, unlike homeotherms, temperature can play a crucial role in the rate at which signals are produced (Walker 1975; Bennet-Clark 1989; Toms 1992). Obviously, this can create special problems for the female, since the signal she processes may differ at different ambient temperatures.

Different kinds of insect respond to temperature to different extents (Toms 1992), and have different thermoregulatory abilities (Heinrich 1974). In some katydids the thoracic temperature warms up during singing by an average of 16,6°C (Stephens & Josephson 1976). Active warm-up when singing commences suggests that these insects are dependent on high body temperatures for effective communication. In crickets, temperature measurements made by quick insertion of a hypodermic probe indicate that body temperature remains close to air temperature (Prestwich & Walker 1981). The relationship between T_a and T_b is expected to be particularly close in the small, slender tree crickets because they have a large surface area to volume ratio and sing from exposed positions (Toms 1992). However, it is worth investigating whether larger crickets (with much larger volume : surface area ratios than tree crickets) have increased body temperatures while calling. In addition, *Gryllus bimaculatus* is an extremely important experimental animal. Although a considerable amount of information is available on the stridulatory and associated behaviour of this species (e.g. Doherty 1985a, 1985b; Doherty & Huber 1983; Otte, Toms & Cade 1988), the body temperatures of singing individuals have not been published before. Considering the fact that insect stridulation may be associated with elevated

body temperature, it is most appropriate to investigate the correlation between ambient temperature and body temperature of calling males of this species. This is the first time that the body temperatures of a grylline cricket species have been measured during calling.

Body temperatures (T_b) of singing crickets were measured using a copper/constantan thermocouple (diameter 0,18 mm) implanted to a depth of ± 2 mm in the dorsal prothorax of each male. Each cricket was cooled to 4°C and the thermocouple was glued to the exoskeleton with cyano-acrylic glue. The thermocouple was connected to a Sortek BAT-12 digital thermometer (accuracy better than 0,1°C) and a chart recorder. Ambient temperature (T_a) was measured with a second thermometer of the same kind. Measurements were performed at ambient temperatures of approximately 16, 20, 25 and 29°C, these representing the normal range at which field crickets call in nature. Crickets in the laboratory did not call at ambient temperatures below 15°C. The temperature measurements used here were taken immediately before the cessation of a calling bout, when the cricket was as close to thermal equilibrium as possible. To verify that the crickets were producing normal songs and were not being affected by the thermocouple inserts, parameters of calls during our measurements were compared to published data for this species. Calling songs were tape-recorded inside a temperature-controlled sound chamber with a UHER 4000 tape recorder at a tape speed of 9,5 cm.s⁻¹ and analysed on a UNISCAN II sonagraph.

Body temperatures of stridulating crickets remained within 2°C of ambient temperature. T_b increased gradually after the inception of stridulation, reaching a maximum within 30 min (e.g. Figure 1). Cessation of calling was followed by a relatively rapid decline in T_b to within 0,5°C of T_a . The means of T_b measurements taken at each of the experimental ambient temperatures all differed significantly from T_a ,

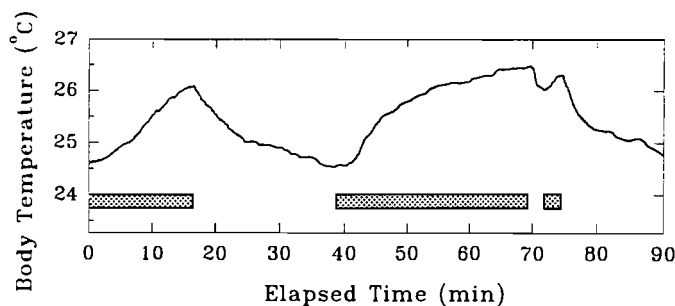


Figure 1 Trace of T_b against time for a stridulating male cricket. Shaded bars indicate stridulatory activity. $T_a = 24,8^\circ\text{C}$.

Table 1 Body-to-ambient temperature differences of stridulating *G. bimaculatus* males at different ambient temperatures. These data represent measurements taken immediately before the cessation of a stridulatory bout

Ambient temperature ($^\circ\text{C}$)	15–18	20–22,5	24–26	28–30
Sample size	4	3	4	4
Mean $T_b - T_a$ difference ($^\circ\text{C}$)	0,77	0,73	1,02	0,30
S.E.M.	0,23	0,09	0,33	0,07
Range ($^\circ\text{C}$)	0,3–1,4	0,6–0,9	0,3–1,8	0,2–0,5

($p > 0,05$). Although the data suggest smaller T_b -to- T_a differences at 30°C , no clear trend was observed and all the means fell within $1,03^\circ\text{C}$ of T_a (Table 1).

There is a very strong correlation ($r = 0,993$) of almost 1:1 between T_b and T_a in stridulating *Gryllus bimaculatus* (Figure 2). The regression equation we obtained is: $T_b = 1,96 + 0,95T_a$. The slope of the regression line implies smaller thermal gradients at 30°C than at lower temperatures, but additional data would be needed to confirm this. The constant representing the y-intercept is significantly above 0 (1-tailed t test, $p < 0,025$). Song parameters were found to be similar to published results (Table 2).

Previous inferences that the body temperature of singing *Gryllus bimaculatus* males probably approximates air temperature (e.g. Doherty 1985b) were confirmed. It is noteworthy that the y-intercept of the regression line is less than 2°C above the origin and that the mean T_b of calling males was within 1°C of mean T_a . This indicates only slight increases in body temperatures for stridulating male crickets. In other words, ambient temperature is a very good approximation of body temperature in this species. Our results therefore show that it is reasonable to use ambient temperature as a good approximation for body temperature in behavioural experiments and bio-acoustic studies.

It is interesting to note that, according to Figure 1, T_b was sometimes lower than T_a . When this occurred, the difference between T_a and T_b was not great, so some of the negative difference may be artifact, within the levels of accuracy of the electronic thermometers used.

The fact that parameters of the songs were similar to published results (Table 2), demonstrates that the crickets were producing normal songs.

These data clearly demonstrate that the energetic factors involved in sound production by large crickets are very

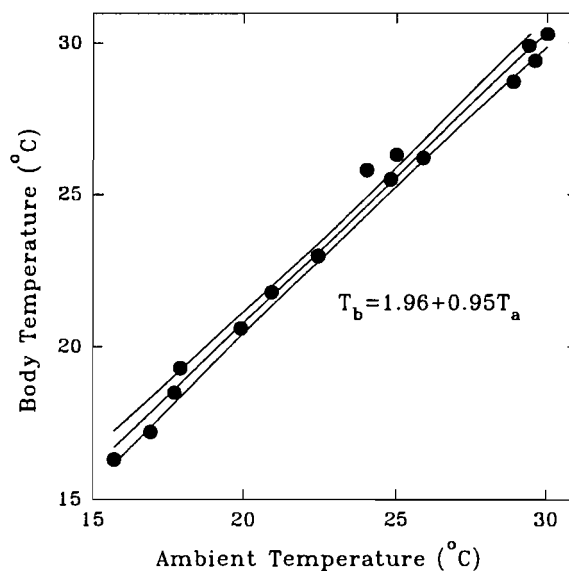


Figure 2 Linear regression showing the relationship between ambient temperature and body temperature in stridulating male *Gryllus bimaculatus*. $r = 0,993$. The 95% confidence interval is also shown.

Table 2 Comparison of call parameters of stridulating male *G. bimaculatus* derived from linear regressions obtained in this study (e.g. Figure 2) with data from recordings in the wild by Otte, *et al.* (1988). Terminology follows Bennet-Clark (1989)

Source	T_a ($^\circ\text{C}$)	Pulse period (ms)	Chirp period (ms)	# pulses	Frequency KHz
Otte, <i>et al.</i>	19	51,0	435	3	4,3
This study	20	44,5	415	4	4,7
Otte, <i>et al.</i>	26	36,6	322	4	4,7
This study	25	42,6	302	4	4,9

different from those of katydids (Stevens & Josephson 1976).

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