The Activity and Thermal Biology of the Fossorial Reptile, *Diplometopon zarudnyi* (Amphisbaenia: Trogonophiidae) in Central Saudi Arabia

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Abstract .- The nocturnal activity of the fossorial amphisbaenid *Diplometopon zarudnyi* was studied in the field and its thermal selection and tolerance were determined in the laboratory. During the study period (summer) the animals commenced activity at 20.00 hrs (ground temperature 30-32°C) and finish their foraging between 3.00 to 4.00 hrs (ground temperature 28-26°C) before the break of dawn. The mean activity temperature determined in the field was 31.5°C, which was usually 0.5 to 1°C higher than the ground temperature. The mean selected body temperatures in a gradient during day and night were 26.4°C (range 15-38°C) and 26.3°C (range 14-38°C) respectively. The Critical Thermal Maximum was 47.6°C and the Critical Thermal Minimum was 7°C. *D. zarudnyi* tolerates a wide range of temperatures while maintaining its mean body temperature within a narrow range. The role of Selected Body Temperature is discussed in relation to metabolism.

Key words.- Amphisbaenia, Trogonophiidae, fossorial reptile, *Diplometopon zarudnyi*, Saudi Arabia, Central Arabia, activity, thermal preference, thermal tolerance.

Introduction

The amphisbaenian family Trogonophiidae is represented in central Arabia by the single species *Diplometopon zarudnyi* (Al-Sadoon, 1988). The range of this species extends to northern Arabia and the coastal Arabian Gulf (Arnold, 1986). *D. zarudnyi* is an oscillating digger, commonly found burrowing in low sand dunes in open terrain and in sub-surface soils of date palm farms. This amphisbaenian is a nocturnal forager, sometimes occupying ant and termite tunnels.

In this study the nocturnal activity of *D. zarudnyi* was studied in the field, and its thermal selection and temperature tolerance were determined in the laboratory. A comparison of results of this study has been made with the results of other species from different geographical habitats.

Material and Methods

Several field trips were made during the summer season (July-August.) to habitats of *D. zarudnyi* located around Riyadh city (Thummama and Dilam). Nocturnal activity of the animals was observed during the activity period. Rechargeable fluorescent lanterns were employed to illuminate the area being studied. When tracks appeared on the sand surface, they were followed up to the location of the animal, which was either dug out of its subsurface position by hand or using a small hand shovel. Soil temperature (T_s), air temperature (T_a) and cloacal body temperature (T_b) were taken within 15 seconds of capture by a quick reading cloacal thermometer (Millar and Weber Co.,
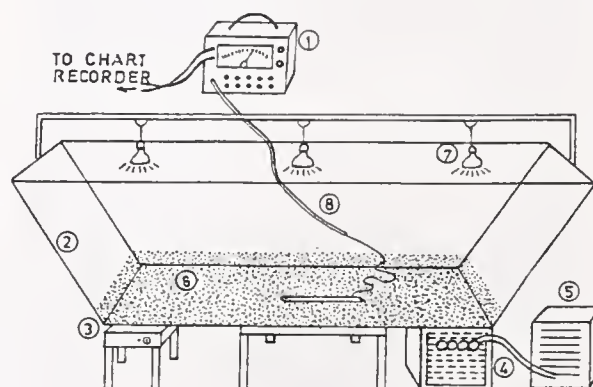

Figure 2. Setup used to measure the selected body temperature: (1) Telethermometer, (2) Thermal gradient, (3) Thermostat heater, (4) Cooling coil in water bath, (5) Refrigerant machine, (6) 10 cm thick sand layer, (7) 100 W heating bulb, (8) Thermistor probe.

U.S.A). Air and ground temperature were also monitored every hour from dusk to dawn.

Thirty *D. zarudnyi* (adult animals of both sexes) were used in the laboratory study (mean mass = 7.63 g, SD ± 2.54; mean SVL=182 mm, SD ± 13.4; mean VTL=14 mm, SD ± 2.0). They were collected from various locations around Riyadh city. They were maintained for short periods in Plexiglass boxes filled with 10 cm of clean sand. The sand was sprinkled periodically with water. Mealworms and water were available *ad lib*. The laboratory temperature was 23 ± 1.5°C.

The Selected Body Temperature (SBT) of ten amphisbaenians was determined in a metal thermal
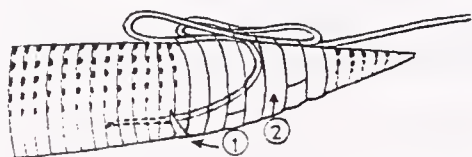
Figure 2. Method employed to tie the thermistor; the probe (1) inserted inside the animal's cloaca and looped to be held on the tail (2) with bands of adhesive tape.

gradient which measured 200 x 25 x 40 cm (Fig.1). Sand was spread evenly to a depth of 10 cm on the base of the gradient. A temperature gradient from 10-50°C was achieved by fitting a thermostatic hot plate below one end and by placing an insulated ice container constantly frozen by an immersion refrigerant coil on the other end. The surface sand at the cool end was sprinkled with water intermittently to prevent desiccation. The gradient was illuminated by two 100 watt bulbs suspended 80 cm from the surface of the sand controlled by an electronic timer to maintain the photoperiod. The animals were left in the gradient for one day prior to the start of the experiment for acclimation.

The cloacal body temperature (T_b) was monitored with high sensitivity probes (Model 511; Yellow Springs Inc.). The probes were connected to a multichannel YSI Telethermometer, and an Omniscribe Houston Instruments continuous chart recorder. The flexible tip of the pre-calibrated probe was inserted for 1 cm into the cloaca and held in place with 3-4 mm bands of adhesive tape (Fig.2). The probes remained in place even when the animal burrowed below the sand. Twenty four hour continuous recording of T_b was obtained for three days on each animal and one measurement for each hour was recorded.

These instruments were also used to measure the Critical Thermal Maximum (CTMax) and the Critical Thermal Minimum (CTMin). CTMax is the arithmetic mean of the collective thermal points at which locomotor activity becomes disorganized and the animal loses its ability to escape from conditions that will promptly lead to its death. CTMin is the low temperature that produces cold narcosis and prevents locomotion (Pough and Gans, 1982). A sheet metal box (25 X 20 cm) filled with a layer of sand and kept above a thermostat heater was employed to measure CTMax. For CTMin, a Plexiglass box (25 X 15 cm) with a layer of sand held inside a larger insulated box surrounded by ice cubes was employed. Twenty different animals (10 for each category) were used. Each animal was gradually heated or cooled inside the experimental chambers (1°C increase or decrease per

minute). The probe remained inserted in the cloaca and the body temperature was monitored continuously while the test chamber sand was gradually heated or cooled.

To determine the CTMax and CTMin, the amphisbaenian was observed until the animal lost its righting response when it was turned on its back. During the CTMin experiments, after initial cooling (9.5°C), the animal lost its ability to right itself but, after its belly was touched by a fine paint brush, the animal exhibited a wave of convulsions down the body. Further cooling led to total loss of all responses, and the temperature at which this occurred was designated as the CTMin. All but one experimental animal survived after returning to room temperature. After 10 days, the animals which were used for CTMax experiments were used to measure CTMin. The CTMin of these animals was compared to that of the first group.

Statistical analysis was performed using GLM procedure of Minitab package (version 8.2). Two-way analysis of variance (ANOVA) with interaction (unbalanced) was used for data analysis (P=<0.05).

Results

The nocturnal activity of the animals is clearly defined during summer nights. Emergence for foraging activity begins at 22.00 hrs when the air temperature is 30-32 °C and the ground temperature is 32-34°C. The foraging activity subsides between 03.00 to 04.00 hrs when the air temperature is 28-26°C and the ground temperature is 27-25°C. After this the animals move deeper into the sand surface (presumably to their burrows or refuges) and no kind of activity is observed during the daylight hours.

The animals were active between adjacently located shrubby small sand dunes. Most of these sand dunes hosted colonies of ant and termite mounds. Movement is typically a combination of sub-surface and surface locomotion. Undisturbed movement of the animal over the surface of the sand was observed only two instances. On the rest of the occasions the animals were tracked by their impressions in the sand. The animals move just below the surface of the sand for two or three meters by piercing and wiggling by strong head and body movement (probably in search of termites). After that they come out on the surface and effortlessly glide on the sand surface for several meters by fast subsequent spring action. This was done by making an `S' shape of the body and flicking forward. Consequently this kind of activity leaves a distinct pattern of tracks on the sand surface which
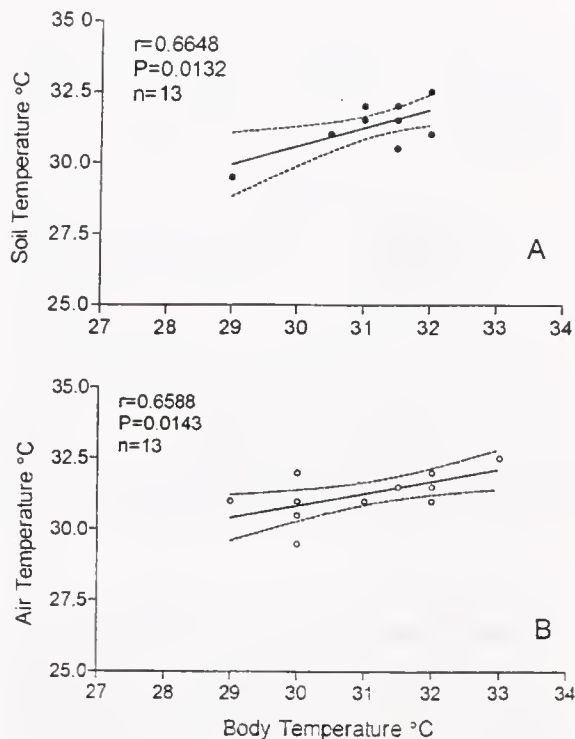
Figure 3. A. Relationship between body temperature (Tb) and soil temperature (Ts). B. Relationship between body temperature (Tb) and air temperature (Ta). (The regression line, significance value and sample size are as indicated).

Figure 4. Representation of body temperature selection (%) by *Diplometopon zarudnyi* in the thermal gradient during day and night periods.

can be easily differentiated between the tracks of other animals of the habitat.

The mean field body temperature for the active animals captured was 31.5°C (range 29.5 - 32.5°C; n=13). Regression analysis showed a significant difference between the T_b - T_a and T_b - T_s (P<0.05; Fig. 3). The mean selected temperatures in the gradient during the day and night were 26.4°C (SD ± 5.2) and 26.3 °C (SD ± 5.7) respectively; the temperatures selected during day ranged between 15 and 38°C and between 14 and 38°C during the night (Fig.4). About ninety percent of *D. zarudnyi* selected temperatures between 23 and 36°C during the day and between 21 and 36°C during the night. Temperature selected did not differ significantly between day and night (F=0.14, P=0.705). However, individuals differed significantly in temperatures selected (F=127.37, P=0.001). Also, there was a highly significant interaction between individuals and the time of day (F=7.72, P=0.001). The average hourly temperature pattern of *D. zarudnyi* showed a gradual increase of body temperature (in the gradient) and reached its highest level just before the end of the dark period (Fig.5), and a
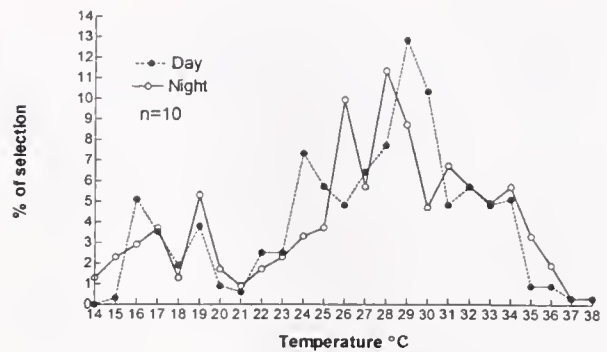
gradual decrease of body temperature to its lowest value by the end of the light period.

During the CTMax trials, animals below the soil surface emerged when the sand temperature reached 40°C. The CTMax was 47.6°C. During the CTMin trials, the animals lost the righting reflex at 9.4°C (SD±1) and CTMin was 7°C (SD±0.6). The second group of animals used in measuring CTMin lost the righting reflex at 11.3°C (SD±1.1) and CTMin was reached at 9.5°C (SD±0.5).

Discussion

D. zarudnyi come out of their refuges at night when the air temperature and the soil surface temperature are favorable. By employing two kinds of locomotion the task of foraging is accomplished. They expend vigorous efforts on their foraging activity, since they have to accomplish it in a short duration; multiple tracks crossing each other were observed for a single animal in a wide area, giving a false impression of many animals being active. This lead to many dead ends while following the leads of the tracks.

Previous reports (gradient studies) assumed that the body temperatures of amphisbaenians are equal to soil temperatures, since readings were obtained from the soil surrounding the animals. For a more accurate evaluation, here, we recorded body temperatures direct and continuously in the thermal gradient.

The selected mean temperature in the gradient (26°C) measured in this study explains the Metabolic rate-Temperature curve (M-T curve) reported for *D. zarudnyi*; in which both the adults (mean wt.6.34 g) and sub-adults (mean wt.3.15 g) showed stable O_2 consumption rates between 25-30°C (Al-Sadoon, 1986).
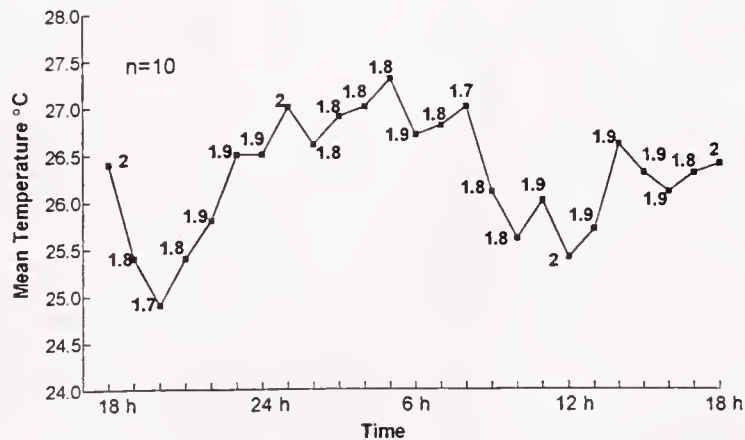
Figure 5. Mean selected body temperature pattern of *Diplometopon zarudnyi* in the thermal gradient during 24 hours. Numbers at each point indicate the SEM.

The body temperature for active *D. zarudnyi* are higher in the field than in the laboratory because the animals were deprived of food during the experiment, and also may be the result of confinement to a limited space in the gradient. Van Berkum (1980) demonstrated that the SBT is lower in lizards with decreased food consumption. It is recommended to measure metabolism during the post absorptive state of digestion, so as to minimize any contribution of specific dynamic action (Eckert and Randall, 1983).

As *D. zarudnyi* is fossorial, the low mean selected temperature (26°C) could extend activity and stabilize body metabolism in the sub-surface habitat. The present results supplement the previous published reports of lower temperature selection in amphisbaenians. Avery (1982) noted that many fossorial snakes, amphisbaenians, sea snakes, fresh water and marine turtles, appear not to thermoregulate and that many select low temperatures. Evidence of thermoregulation in *Amphisbaena mertensi* was reported by Abe (1984); mean field body temperature and preferred temperature in the gradient was 21.1°C and 21.4°C respectively. Also, Martin et. al. (1990) reported marked field thermoregulation in *Blanus cinereus* and it selected low field body temperatures. Gatten and McClung (1981) reported the low mean body temperature for *Trogonophis weigmanni* in a range of 21.7°C to 23.4°C. A field study of *Bipes biporus* demonstrated that this worm lizard can thermoregulate if necessary, by vertical and horizontal changes in substrate positioning (Papenfuss, 1982). More recently, Diaz-Paniagua et al., (1995) during a field study of seasonal and diel activity of *Blanus cinereus*, reported an activity range of ground temperatures between

13.4 -27.8°C which is low and as well clearly indicates thermoregulation.

The low temperature selection of *D. zarudnyi* is also in line with the observations made on other burrowing species of reptiles. Bury and Bolgooyen (1976) determined the thermal preferendum of the legless burrowing lizard *Anniella pulchra* to be 24-25°C. Clark (1968) reported five subterranean species of small snakes to select lower temperatures than surface dwelling species. Burrowing snakes of the family Uropeltidae also appear to select a low body temperatures between 18°C and 20°C (Gans,1973). Low selected body temperatures were also reported for *Anguis fragilis* (Gregory, 1980).

A previous study showed that *D. zarudnyi* had no endogenous circadian rhythm and no periodicity in alternating light and darkness although it was more active at high temperatures (Cloudsley-Thompson, 1979). The finding in the present study wherein *Diplometopon* showed no significant difference between day and night time temperature selection is consistent with the lack of an endogenous circadian rhythm in temperatures selected in day and night. However, in the present results there is a highly significant difference among individuals. This is probably due to individual differences in body weight, health status, age and sex of the animals tested.

In the gradient *D. zarudnyi* elevated its body temperature slightly in the second half of the night, a time when they were seen to forage actively in the field. In contrast, *T. wiegmanni* tested in a thermal gradient showed elevated temperatures in the afternoon and early evening (Gatten and McClung, 1981). Foraging activity at dawn and in early morning also is reported

for *Agamodon anguliceps* from Somalia; the animals were located in the top 2-3 inches of the soil at dawn, appearing to have moved upwards during the night. As temperatures rose, most animals disappeared from the top 6-12 inches of the ground (Gans and Pandit, 1965).

The CTMax value for *Diplometopon* is similar to that of certain terrestrial lizards of Central Arabia, but the CTMin was higher than that reported for most other sympatric lizards (Al-Johany, 1986). The relatively high CTMin might be related to the subterranean temperatures encountered by *Diplometopon* which seldom fall below freezing, unlike the surface temperatures which may drop below 0 °C. The 2.5 °C increase in the CTMin for animals that had experienced the CTMax might be attributed to a short-time heat-hardening effect (see Maness and Hutchison, 1980).

Prior to this study there was no data available on the field thermal ecology of *D. zarudnyi*. By the combined result of the field and laboratory study it is now confirmed that the animal is a thigmotherm but not in its strict sense. Since it was observed that the animal manages (probably by metabolic activity) to keep its body temperature a degree or half higher than the ground temperature.

Acknowledgments

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