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THERMOREGULATION OF THE AMPHISBAENIAN *ZYGASPIS QUADRIFRONS*

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The mean selected temperature of *Zygaspis quadrifrons* in a thermal gradient was 23.1°C, similar to other amphisbaenians. Body temperatures of amphisbaenians are lower than those of other squamates, but are similar to those of fossorial snakes and lizards, apart from skinks. The precision of thermoregulation in *Z. quadrifrons* was low; body temperatures had a SD of 3.8°C and an interquartile range of 6.0°C.

INTRODUCTION

Studies of the body temperatures and thermoregulation of reptiles are heavily biased towards diurnal, heliothermic lizards (Avery, 1982). Nocturnal and fossorial lizards, and other suborders and orders of reptiles, have been neglected. Perhaps the most neglected are the fossorial reptiles of the suborder Amphisbaenia. Gatten & McClung (1981), Abe (1984) and Martin, Lopez & Salvador (1990) all reported mean body temperatures of amphisbaenians of 21-23°C, rather low for reptiles from warm climates. The aim of this study was to determine the mean and variability of selected body temperature of the tropical amphisbaenian *Zygaspis quadrifrons* from Zimbabwe. Two different thermal gradients were used to test whether body temperature was being regulated or reflected random movements of the animals within the apparatus.

METHODS

Amphisbaenians were collected from May to July 1992, under small rocks in degraded miombo woodland (mixed *Brachystegia* and *Julbernardia*) at Arcturus, 25 km east of Harare (approximately 17°50'S). The temperatures in the soil from which an amphisbaenian had been captured was measured on five occasions in July 1992. The amphisbaenians were maintained at a constant 25°C, with a 12 hr photoperiod, in stock cages with 5 cm depth of wood shavings, dampened periodically. They were fed mealworms weekly. Experiments were performed in April and May 1994.

The thermal gradient consisted of a metal floor of 183 x 45 cm, with wooden sides. It was heated from below by two electric hot plates, the whole being in a constant temperature room at 12°C, with a 12 hr photoperiod. The floor was covered by 3 cm of dry wood shavings. Substrate temperatures were measured with mercury thermometers placed next to the metal floor. The temperatures available in the gradient were mapped at 10 cm intervals on an 18 x 4 point grid. Observations on the amphisbaenians were made over two weeks in the initial configuration of the gradient (A), then for two weeks when modified by turning off one of the hot plates (gradient B).

Measurements followed a weekly routine. Amphisbaenians were placed in the gradient at about 14.00 hr on a Monday, and measurements were made at about 09.00 hr and 15.00 hr on the next four days (though some sampling occasions were missed). On Friday afternoon, the amphisbaenians were placed in 2-3 mm depth of water for 10 min to allow them to drink, then returned to the stock cages with food. They were replaced in the gradient on the following Monday. The amphisbenians were allowed a week in the stock cages between gradients A and B.

Ten adult amphisbaenians (mean mass 4.9 g, range 4.0-6.7 g) were used throughout. Each was removed from the gradient and its cloacal temperature measured to the nearest 0.5°C with a Schultheis quick-reading mercury thermometer. The amphisbaenians were placed in a plastic bucket until all ten had been measured, then they were returned to the gradient. The data are thus pooled observations from the ten animals. Statistical analysis was by Minitab

RESULTS

Substrate temperatures where amphisbaenians were captured in the field ranged from 16.4 to 27.8°C, with a mean of 23.8°C and SD of 4.4°C. These measurements were made in sandy soil, where thermal conduction between substrate and animal was probably high; see Hailey, Rose & Pulford (1987) and Daut & Andrews (1993) for the close relation between substrate and body temperatures of small reptiles buried in sand.

Substrate temperatures differed significantly between the two gradients (Mann-Whitney test, W = 6147, P = 0.0002). Maps of temperatures available in the two gradients are shown in Fig. 1. Gradient B was more difficult for thermoregulation, in terms of the area falling within the selected temperature range (found from gradient A). Ninety-two percent of body temperatures were between 19.0 and 28.5°C; 44% of substrate temperatures were in this range in gradient A, but only 24 % in gradient B.

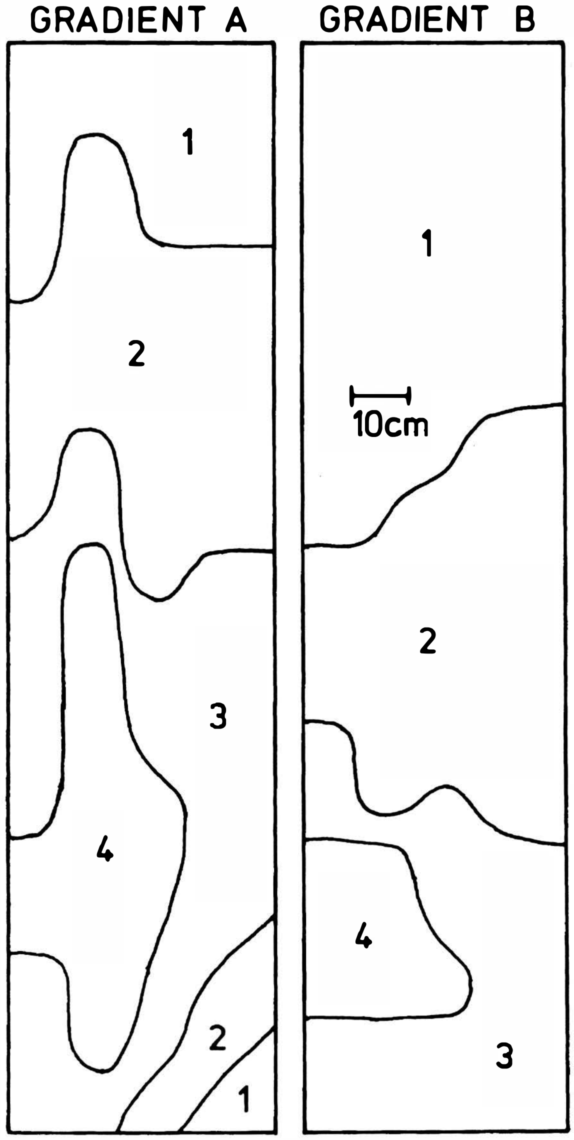

Fig. 1. Map of substrate temperatures in thermal gradients A and B. 1 = 15°C or lower, 2 = 16-20°C, 3 = 21-29°C, 4 = 30°C or greater.

One hundred and thirty body temperatures were measured in each gradient, with a mean of 23.5°C in A and 22.7°C in B. The difference between the two was not significant (Mann-Whitney test, $W = 17986.5$, $P = 0.092$), suggesting that the amphisbaenians were indeed regulating their body temperatures. The overall mean was 23.1°C, with a SD of 3.8°C and range of 15-32°C. The interquartile range (calculated to exclude the 25% lowest and the 25% highest points) of the laboratory measurements was 6.0°C, from 20.0 to 26.0°C.

DISCUSSION

Zygaspis quadrifrons had a mean selected temperature similar to those of the two species of amphisbaenians previously studied in thermal gradients, *Amphisbaena mertensi* from Brazil and *Trogonophis wiegmanni* from Tunisia (Table 1). The limited field data on both *Z. quadrifrons* and *A. mertensi* suggest that field body temperatures are similar to those selected in a thermal gradient. The only amphisbaenian studied intensively in the field is *Blanus cinereus* from Spain, which has field body temperatures similar to those of *Z. quadrifrons* and *A. mertensi* (Table 1).

The mean body temperature for the four species of amphisbaenians is thus about 22°C, rather low for reptiles from warm climates and lower than body temperatures of the other two suborders of the Squamata. Brattstrom (1965) has reviewed body temperatures of many species of snakes and lizards; the interspecific mean was 25.6°C for snakes (54 species), and 29.1°C for lizards (93 species). Is the difference between amphisbaenians and other squamates phylogenetic or ecological, due to the fossorial habit of amphisbaenians?

This question can be resolved by examining body temperatures of fossorial lizards and snakes (Table 1; habits were checked in Cogger (1986), where necessary). Several fossorial snakes and non-scincid lizards have mean field or mean selected temperatures in the range 20-24°C, similar to amphisbaenians. Two fossorial skinks, *Eremiascincus fasciolatus* and *Hemiergis decresiensis* also have mean body temperatures below 24°C. However, most fossorial skinks have mean body temperatures above 24°C; this includes other species of *Eremiascincus* and *Hemiergis*. The fossorial pygopodid *Delma fraseri* also has a high mean body temperature (Table 1).

Amphisbaenians thus do not have particularly low body temperatures compared to other fossorial reptiles. If a taxonomic distinction is to be made, it should be between fossorial skinks (and the pygopodid), and other fossorial reptiles. Skinks in general used to be thought of as having low body temperatures, but more recent data show them to be similar to heliothermic lizards (Huey, 1982). It is clear that fossorial skinks have retained high body temperatures, possibly due to a shallow depth of burrowing.

The precision of regulation in *Z. quadrifrons* was low, with a SD of 3.8°C and an interquartile range of 6.0°C. These values are similar to those for *Amphisbaenia mertensi* (SD 2.7°C; Abe, 1984), and to other reptiles normally thought of as imprecise thermoregulators. For example, the anguid *Ophisaurus apodus* had a SD of 2.7°C (Hailey, 1984), and five species of gecko had an average interquartile range of 5.0°C in the field (Huey, Niewiarowski, Kaufmann & Herron, 1989). These values can be compared with those for diurnal, heliothermic lizards. *Mabuya striata* and *Lacerta vivipara* had SD's of 1.6°Cand about 1.0°C, respectively (Patterson, 1989; Patterson & Davies, 1978). The average interquartile range for field temperatures of 13 species of diurnal lizards was 2.8°C (Huey *et al.*, 1989).

TABLE 1. (opposite) Mean selected temperatures (MST) and mean field temperatures ($\overline{\text{Tb}}$) of fossorial reptiles (°C). * Approximate.

Species	MST	$\overline{Tb}$	Reference
Amphisbaenidae			
Amphisbaena mertensi	21.4	21.1	Abe, 1984
Blanus cinereus	-	22.5	Martin et al., 1990
Trogonophis wiegmanni	22.4	-	Gatten & McClung, 1981
Zygaspis quadrifrons	23.1	23.8	This study
Anguidae			
Anguis fragilis	23	-	Spellerberg, 1976
Anniellidae			
Anniella pulchra	21	20	Brattstrom, 1965
Anniella pulchra	24.2	-	Avery, 1982
Scincidae			
Chalcides bedriagai	-	28.5	Hailey et al., 1987
Chalcides ocellatus	32*	-	Daut & Andrews, 1993
Eremiascincus fasciolatus	22.8	-	Heatwole & Taylor, 1987
Eremiascincus richardsoni	-	26.2	Pianka, 1986
Eremiascincus richardsoni	26	-	Heatwole & Taylor, 1987
Eumeces egregius	-	30*	Avery, 1982
Hemiergis decresiensis	21.2	20.3	Heatwole & Taylor, 1987
Hemiergis peronii	24.3	26.3	Heatwole & Taylor, 1987
Hemiergis quadrilineatum	26.8	-	Heatwole, 1976
Lerista bipes	-	31.2	Pianka, 1986
Lerista bougainvillii	-	30.7	Heatwole & Taylor, 1987
Lerista bougainvillii	31	-	Spellerberg, 1976
Lygosoma laterale	-	28.8	Brattstrom, 1965
Pygopodidae			
Delma fraseri	-	31.7	Pianka, 1986
Leptotyphlopidae			
Leptotyphlops dulcis	20.6	-	Avery, 1982
Typhlopidae			
Typhlops nigrescens	-	14.2	Heatwole, 1976
Uropeltidae			
Various species	-	20*	Avery, 1982
Boidae			
Charina bottae	-	23.3	Avery, 1982
Colubridae			
Carphophis amoenus	23	-	Avery, 1982

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