

## Body temperatures and exposure to sunshine of ruin lizards *Podarcis sicula* in central Italy

G. Tosini<sup>1,3</sup>, A. Foà<sup>2</sup>, R. A. Avery<sup>3</sup>

<sup>1</sup> Museo Zoologico "La Specola", Sezione del Museo di Storia Naturale, Università di Firenze, Via Romana 17, 50125 Firenze, Italy

<sup>2</sup> Dipartimento di Scienze del Comportamento Animale e dell'Uomo, Università di Pisa, Via A Volta 6, 56100 Pisa, Italy

<sup>3</sup> Department of Zoology, The University, Bristol BS8 1UG, UK (address for correspondence)

**Abstract.** Body temperatures ( $T_b$ ) of adult ruin lizards, *Podarcis sicula*, captured near Pisa (Italy) between February and November ranged from 22.4-38.5°C. There were no significant differences between sexes. Mean body temperatures in February-April and November were significantly lower than those recorded from May-October (29.0 and 32.7°C respectively). The overall relationship between  $T_b$  and soil temperature at the point of capture ( $T_s$ ) showed two components. At  $T_s < 28^\circ\text{C}$  there was a highly significant association and 98% of individuals were recorded with  $T_b > T_s$ . At  $T_s > 28^\circ\text{C}$  the association was less clear and  $T_b < T_s$  in nearly 30% of lizards. There were diel differences in exposure to sunshine at all seasons; exposure was greatest during the morning after emergence from overnight inactivity and during the late afternoon, least during the mid-day period.

### Introduction

Individuals of many lizard species are able to maintain relatively high and constant body temperatures ( $T_b$ ) using external sources of heat which are almost always derived either directly or indirectly from solar radiation (Avery, 1982; Huey, 1982). The maintenance of high  $T_b$  depends both on the thermal environment and on the thermoregulatory capabilities of the species. Behavioural thermoregulation in small diurnal lizards consists mainly of shuttling between sun and shade; the time which the animals spend in the sun in order to achieve and maintain a high  $T_b$  at lower environmental temperatures varies with thermal conditions.

This paper describes the results of a field study of  $T_b$  and frequency in sunshine in the ruin lizard *Podarcis sicula*, which is a small-medium sized lacertid; adults typically have body masses of 7-14 g. The species is widely distributed in mainland Italy, and is also found in parts of Jugoslavia and on many Mediterranean islands including Corsica, Sardinia and Sicily.

There has been a tendency to consider that thermoregulatory capacities and behaviour are fixed, species-specific characteristics, a view which is implicit in most recent taxonomic surveys of reptilian thermoregulation (Avery, 1982; Heatwole and Taylor, 1987; Lillywhite, 1987; Meek and Avery, 1989). Accumulating evidence suggests that this may not always be the case, however (e.g. Van Damme et al., 1989, 1990a, b; Adolph, 1990). There is thus justification for studying thermoregulation in an individual species from different parts of its geographical range or from different habitats. Data are currently available relating to  $T_{bs}$  of *P. sicula* from 200-550 m altitude near Florence (central Italy; Avery, 1978), from 0-70 m in Corsica (Van Damme et al., 1990a) and of individuals from Florence in the laboratory (Avery, 1978). The present paper relates to a population at sea level on the flat coastal plain to the west of Pisa, central Italy. It is part of a long-term investigation of activity cycles, rhythmical behaviour and thermoregulation in these animals.

### Material and methods

Lizards were captured from February to November 1988 in the grounds of the Field Research Station 'Arnino' of the Dipartimento di Scienze del Comportamento Animale e dell'Uomo, Pisa University. The area is of flat reclaimed marshland with a well-drained sandy soil. Body temperatures were recorded with a thermistor probe (Seac Scientific Instruments) inserted into the cloaca of lizards which had been captured with a noose. Records from lizards which needed to be chased before capture, or from lizards from which a reading could not be taken for more than 5-10 s after capture, were discarded. All lizards were handled with gloves to insulate them from human body heat, and held throughout in shade. Sex, body mass and the surface soil temperature at the point of capture ( $T_s$ ) were then recorded. Adult and subadult lizards were included in the study, but not juveniles.

Frequency in sunshine was determined by one observer walking through the study area (for more details of this, see Foá et al., 1991) along standard paths, counting the lizards observed, and determining whether they were in full sunshine or not. This was repeated every hour from sunrise to sunset for three days every month for each of the twelve months of the year ( $N=448$ ). Mean hourly frequency in sunshine was calculated as  $\Sigma s_h / \Sigma n_h$ , where  $\Sigma s_h$  was the number of lizards observed in full sunshine over three days in any one hour time interval and  $\Sigma n_h$  was the total number of lizards observed during the same interval.

### Results

#### *Body temperatures*

A total of 286  $T_{bs}$  were recorded, ranging between 22.4 and 38.5°C. Mean monthly  $T_b$  fell into two distinct groups, those from May-October (summer: overall

mean = 32.7°C) and February-April plus November (spring and autumn; overall mean = 29.0°C). The differences between these seasonal groups were significant for all adult lizards and also for males and females separately (ANOVA and GT2 tests,  $P < 0.05$ ): table 1). Monthly means did not differ significantly within seasonal groups. Within any month there were no significant differences between means for adult males, adult females or subadults ( $t$ -tests, one-way ANOVA). Dividing each day into three periods, 0700-1100 h, 1100-1500 h and 1500-1800 h did not reveal any significant differences between months (sexes combined) except that the mean  $T_b$  for 1500-1800 h in October (30.4°C) was lower than the means for this period from May-September (GT2 tests using Gabriel's approximation (Sokal and Rohlf, 1981) where appropriate); because of restricted lizard activity from February-April and in November, records were only obtained during these months for the 1100-1500 h period.

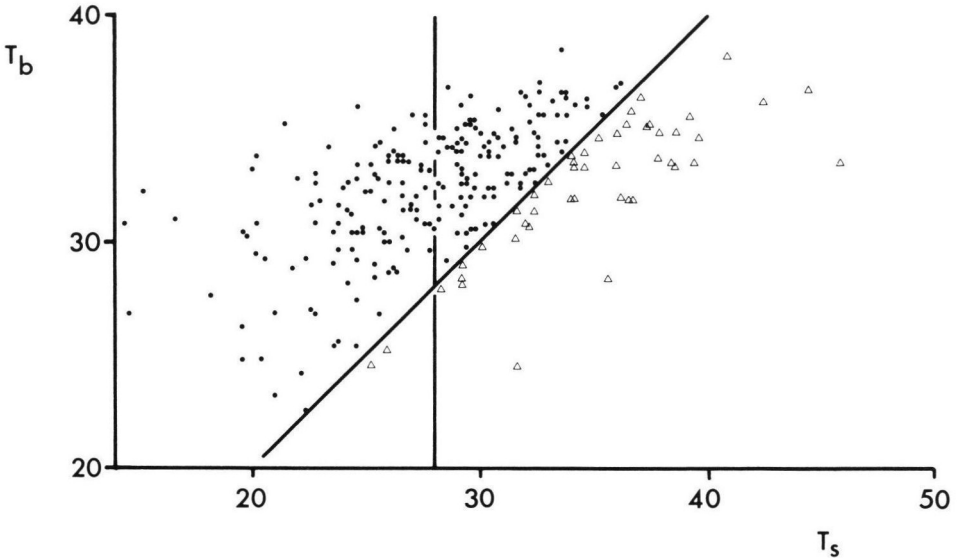
The overall relationship between  $T_b$  and  $T_s$  is shown in fig. 1. Careful inspection demonstrates that this is actually composed of two components. At  $T_s < 28^\circ\text{C}$  the association is highly significant, despite the high variance of  $T_b$  (one-way ANOVA,  $F_{1,109} = 15.7$ ,  $P < 0.001$ ); only two data points fell beneath the line of equivalence  $T_b = T_s$  (i.e. these were lizards with  $T_b < T_s$ ; triangles to the left of the line  $T_s = 28^\circ\text{C}$  in fig. 1). At  $T_s > 28^\circ\text{C}$  the variance of  $T_b$  was lower, but the relationship between  $T_b$  and  $T_s$  is less clear-cut ( $F_{1,153} = 8.8$ ,  $0.01 > P > 0.001$ ) and approximately 30% of the observations fell beneath the line of equivalence (triangles to the right of the line  $T_s = 28^\circ\text{C}$  in fig. 1).

#### *Frequency in sunshine*

There was considerable variation in recorded values for frequency in sunshine, much of it undoubtedly due to sampling error. In order to remove the effects of this error to reveal any underlying trends, the 95% confidence limits (calculated for percentages using the binomial distribution) for the overall hourly indices were determined. Any individual hourly value which lay outside these limits was designated "high frequency in sunshine" if above the mean, "low frequency in sunshine" if below it. There was a clear seasonal pattern in the distribution of high frequencies in sunshine; they were confined to the early part of activity during the morning and the late afternoon, irrespective of the length of the total active day which increased progressively through the year until June-July and decreased thereafter (fig. 2).

#### **Discussion**

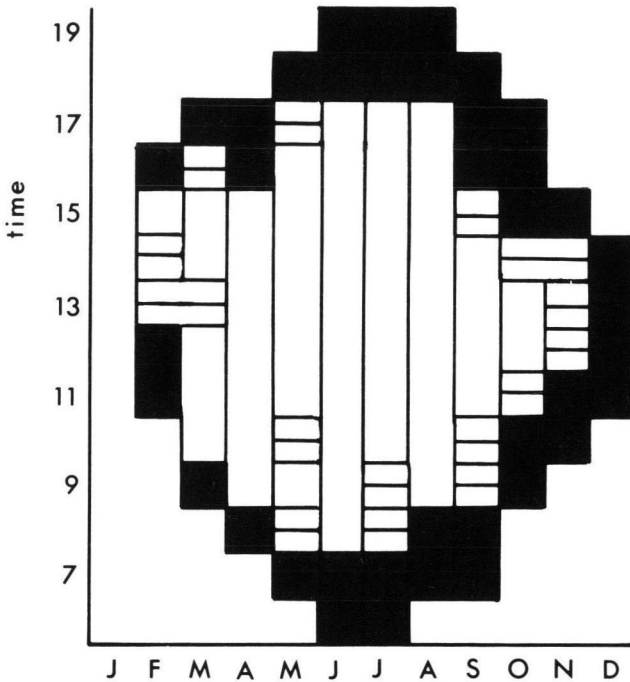
Like all *Podarcis* species which have been studied from the standpoint of thermoregulatory behaviour, *P. sicula* is a heliotherm (Avery, 1982). In a field study near Florence it was shown that individuals of this species maintained higher  $T_b$ s during the period 1330-1630 h in August than sympatric *P. muralis* (the period for comparison



**Figure 1.** *P. sicula*: overall relationship between body temperature ( $T_b$ ) and soil temperature at the point of capture ( $T_s$ ), both in °C. Circles represent lizards in which  $T_b > T_s$ , triangles represent lizards in which  $T_b < T_s$ ; the diagonal is the line of equivalence. For the significance of the vertical line at 28°C see text.

was chosen to represent times when individuals within the study populations might be expected to have achieved temperatures within the mean activity range). The standard deviation of the mean  $T_b$  during this period was lower in *P. sicula* than in *P. muralis* (fig. 2 and table 1 in Avery, 1978). In the subsequent terminology of Huey (1982), *P. sicula* is a precise thermoregulator, at any rate during times of hot weather with long periods of uninterrupted sunshine (see below). This conclusion was confirmed by a study of *P. sicula* in Corsica, which showed that relatively high  $T_b$ s were maintained throughout the day (0900-1830 h) with a lower standard deviation than that recorded in the sympatric species *P. tiliguerta*. In *P. sicula*, but not in *P. tiliguerta*, the regression of  $T_b$  on air temperature did not differ significantly from zero (Van Damme et al., 1990a). The mean  $T_b$  values recorded during predominantly sunny weather at the three sites were: Florence 33.3°C (s.d. = 3.65); Corsica 33.9°C (s.d. = 2.12); Pisa 32.7°C (s.d. = 2.02). It is clear from the standard deviations that these means do not differ significantly.

The work reported here further confirms the conclusions of Van Damme et al., (1990a) by showing (i) that there is no significant difference in the mean  $T_b$  of the two sexes, and (ii) that mean  $T_b$  does not vary during the course of the day during fine weather in summer (in contrast to *P. tiliguerta*). The present work extends available information, however, by additionally providing data on seasonal changes in body temperatures, and by relating  $T_b$ s to some aspects of behaviour.



**Figure 2.** *P. sicula*: frequency of exposure to sunshine in relation to season and time of day. Black-high frequency; horizontal hatching-average frequency; vertical hatching-low frequency. See text for definitions.

The significant seasonal trend revealed here is that overall mean  $T_{bs}$  were lower in February to April and in November than during May to October (table 1). The October mean was the lowest of the 'summer' values, however, and for the 1500-1900 h period the October mean was significantly lower than the 'summer' value. There are two possible explanations for these observations. The first is that there is a seasonal shift in the 'set points' between which the lizards thermoregulate (for a review of the 'set point' concept in relation to lizard thermoregulation, see Firth and Turner, 1982). An alternative explanation, however, is that set points do not alter but that seasonally-changing ambient temperatures and levels of solar radiation alter the fraction of time devoted to basking or other behaviour involving exposure to sunshine (Avery, 1976). This in turn will change the relative proportions of lizards which are captured at relatively low  $T_{bs}$ . This hypothesis implies that the seasonal change in recorded  $T_{bs}$  may be a statistical artefact related to the differential observability and catchability of basking versus foraging lizards. More detailed studies are clearly needed to test these hypotheses (which are not mutually exclusive).

Individual lizards in the *P. sicula* population at Pisa forage widely (see also Van Damme et al., 1990a) in an area of mostly short vegetation, with comparatively

**Table 1.** Monthly mean body temperatures and soil temperatures ( $\bar{X}$ , °C) of *P. sicula* from February to November. N = sample size, SD = standard deviation.

Month	Males			Females			Subadults			Soil temperature		
	$\bar{X}$	N	SD	$\bar{X}$	N	SD	$\bar{X}$	N	SD	$\bar{X}$	SD	maximum
February	29.1	8	2.50	26.5	2	0.42	-	-	-	19.3	3.61	25.6
March	29.3	11	4.29	28.6	8	3.09	-	-	-	22.9	3.69	28.3
April	28.9	7	2.80	29.4	6	3.03	-	-	-	25.2	6.07	33.9
May	34.7	9	1.60	32.8	19	2.24	33.2	9	3.32	29.1	4.29	39.1
June	32.9	32	3.45	33.5	3	2.29	-	-	-	29.6	4.17	36.6
July	33.2	28	2.33	33.1	13	1.40	33.6	1	-	31.1	4.70	42.8
August	32.4	22	2.93	31.7	14	3.33	33.8	3	0.85	30.3	4.76	40.9
September	34.3	12	3.51	31.9	16	3.50	32.6	13	2.19	29.7	4.70	40.0
October	32.0	16	2.48	31.7	14	2.07	31.3	10	3.50	26.6	2.65	32.5
November	29.7	6	2.08	30.2	1	-	28.4	3	0.55	16.5	2.90	21.2

limited shade. If the animals moved around this environment entirely at random, they would be expected to be mostly in direct sun. Figure 2 shows quite clearly that this is not the case; periods of extensive exposure to sunshine were concentrated at the beginning and end of the activity period, which in turn increased in total duration on a monthly basis from February to June and then decreased from July to December. During the remaining parts of their active day, the frequency of exposure to sunshine by the lizards was low. These are mostly times when environmental temperatures were high: they were indexed here as  $T_s$  at the point of capture, since air temperatures are notoriously difficult to relate to the microclimate and heat balances at the surface of a lizards (Bakken, 1989). Figure 1 shows that at comparatively high environmental temperatures ( $T_s > 28^\circ\text{C}$ ),  $T_b$  was frequently lower than  $T_s$ , suggesting lizards which have been captured in sunshine but which have recently emerged from shade. At lower environmental temperatures,  $T_b$  was almost always higher than  $T_s$ . The greater range of  $T_b$  values in the latter lizards (fig. 1) suggests that many were individuals which at the time of capture had not yet reached their activity temperature.

All the evidence thus points to a movement strategy which in summer involves exposure to sunshine during the early morning and late afternoon to periods of avoidance of direct sunshine during the middle period of the day. The latter is partly achieved by reducing movement, so that the recorded activity pattern is bimodal (Foá et al., 1991). The precise ways in which this change in thermoregulatory strategy is achieved, and how it is integrated with foraging behaviour, are currently under investigation.

**Acknowledgements.** We are most grateful to D. Bauwens and R. Van Damme for their critical and constructive comments on a draft of this manuscript.

## References

- Adolph, S. C. (1990): Influence of behavioral thermoregulation on microhabitat use by two *Sceloporus* lizards. *Ecology* **71**: 315-327.
- Avery, R. A. (1976): Thermoregulation, metabolism and social behaviour in Lacertidae. In: *Morphology and Biology of Reptiles*, p. 245-259, Bellairs, A. d'A., Cox, C. B., Eds., London etc., Academic Press.
- Avery, R. A. (1978): Activity patterns, thermoregulation and food consumption in two sympatric lizard species (*Podarcis muralis* and *P. sicula*) from central Italy. *J. Anim. Ecol.* **47**: 143-158.
- Avery, R. A. (1982): Field studies of body temperatures and thermoregulation. In: *Biology of the Reptilia 12, Physiology C, Physiological Ecology*, p. 91-166. Gans, C., Pough, F. H., Eds., London etc., Academic Press.
- Bakken, G. S. (1989): Arboreal perch properties and the operative temperature experienced by small animals. *Ecology* **70**: 922-930.
- Firth, B. T., Turner, J. S. (1982): Sensory, neural and hormonal aspects of thermoregulation. In: *Biology of the Reptilia 12, Physiology C, Physiological Ecology*, p. 213-274. Gans, C., Pough, F. H., Eds., London etc., Academic Press.
- Foá, A., Tosini, G., Avery, R. A. (1991): Seasonal and diel cycles of activity in the ruin lizards *Podarcis sicula*. *Herpetol. J.* **2**: in press.
- Heatwole, H., Taylor, J. (1987): *Ecology of Reptiles*. Chipping Norton, NSW, Beatty.
- Huey, R. B. (1982): Temperature, physiology and the ecology of Reptiles. In: *Biology of the Reptilia 12, Physiology C, Physiological Ecology*, p. 25-91. Gans, C., Pough, F. H., Eds., London etc., Academic Press.
- Lillywhite, H. B. (1987): Temperature, energetics and physiological ecology. In: *Snakes: Ecology and Evolutionary Biology*, p. 422-477. Seigel, R. A., Collins, J. T., Novak, S. S., Eds., New York etc., MacMillan.
- Meek, R., Avery, R. A. (1989): Mini review: thermoregulation in Chelonians. *Herpetol. J.* **1**: 253-259.
- Sokal, R. R., Rohlf, F. J. (1981): *Biometry*. New York, Freeman, 2nd edition.
- Van Damme, R., Bauwens, D., Castilla, A. M., Verheyen, R. F., (1989): Altitudinal variation of the thermal biology and running performance of the lizard *Podarcis tiliguerta*. *Oecologia* **80**: 516-524.
- Van Damme, R., Bauwens, D., Castilla, A. M., Verheyen, R. F. (1990a): Comparative thermal ecology of the sympatric lizards *Podarcis tiliguerta* and *Podarcis sicula*. *Acta Oecol.* **11**: 503-512.
- Van Damme, R., Bauwens, D., Verheyen, R. F. (1990b): Evolutionary rigidity of thermal physiology: the case of the cool temperate lizard *Lacerta vivipara*. *Oikos* **57**: 61-67.

*Received: March 4, 1991. Accepted: August 29, 1991*