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ASPECTS OF ECOLOGY AND BEHAVIOUR IN THE LIZARD *PODARCIS ERHARDII*

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Introduction

In the 40 years since it was discovered that lizards can control their body temperatures by using various behavioural patterns (COWLES & BOGERT, 1944) biologists have gathered many data on this subject both in the field and the laboratory. Unfortunately the majority of articles refer to summer months and give a limited view of the kind and flexibility of the thermoregulatory mechanisms of lizards. (HUEY ET AL., 1977).

The present article contributes to a further understanding on this subject and adds some knowledge on the flexibility of thermoregulatory behaviour in cases of rapidly changing weather conditions, a topic of which, little is known (HEATWOLE 1970). The intensity of lizard activity is correlated to temperature changes. The results are explained on the basis of thermoregulatory behaviour as well as on other specific factors since this can be established by indirect and descriptive data —like the present— although with certain limitations (HEATH 1964, HUEY ET AL 1977).

Much is known about the geographical distribution of *Podarcis erhardii,* mainly from German scientists, but very little is known on its ecology and behaviour (GRUBER 1971, GRUBER & SCHULTZE-WESTRUM 1971).

Data on its distibution and morphology can be found in ARNOLD & BURTON 1977. The subspecies present in the study area is *P.erhardii naxensis,* (ONDRIAS 1968).

Description of study area

The area where the study was carried out, lies on the island of Naxos, which is the largest of the Cyclades islands, (Fig. 1). It is situated on the eastern part of the island, 5 km south of the small village Moutsouna. Its mean altitude is ca. 120 m, it is exposed to the east and is approximately 1250 m away from the sea.

The particular biotope we worked at, lies on a hill, with 30% (19°) gradient and composed of limestone. The substrate can be considered rocky. The soil, mainly on the hollows of the rocks, is thin and clayey. The ground is covered with many stones of medium to large size. The vegetation covers almost 60-70% of the total surface (estimation by eye). The dominant plant species are *Juniperus phoenicea, Pistacia lentiscus, Olea europaea,* and *Quercus coccifera,* with *J.phoenicea* predominating. Many annual plants are present. A large population of *Urginea maritima* is also noteworthy.

Methods

The field work took place on the following dates: 19th-22nd March, 3rd-12th of April and 23rd-27th of April 1982. Additional observations were made on the 21st-23rd of August 1982.

The observer walked, with the help of a compass, on an east to west direction in parallel lines and counted all lizards that could be observed within a zone 6 m wide (3 m to the left and 3 m to the right of the observer). Due to the dense vegetation, turns and circles could not be avoided. However these lasted only a few meters. These various hindrances (trees or shrubs) were passed alternatively from the right and the left. The starting points were picked up randomly, with the only condition that each day's runs —that never exceeded six— were sufficiently apart in order to cover the study area. Each run was performed with a steady and slow walk so that the area could be surveyed sufficiently. Very few runs lasted less than 20 minutes. Most lasted around 30 min.

After the end of each run, the observer returned to the starting point where he noted the maximum and minimum temperatures from two thermometers, one placed in the sun and the other in the shade, at ground level. The duration of the run was measured with a hand watch, up to the nearest half minute.

Assumptions

1. The lizards in the study area, use as their hides, rock crevices and holes, which lie under the dense scrub vegetation *(P.lentiscus, Q.coccifera)* as well as in places covered by the lower branches of trees *(J.phoenicea, O.europaea)* which grow on the trunk almost from ground level. (Gruber & Schultze-Westrum 1971 and personal observation).

By «lizard activity» we mean that lizards are outside their refuges, either to bask or to hunt or both. Apparently the lizards can be active, inside their refuges as well (see Discussion).

2. To estimate population density, the biotope was considered to be rather uniform - regarding vegetation cover, rock cover and plant species - so that lizards might show a random distribution (but see Discussion).

Results

Time of activity and air temperature

The lizards *P.erhardii* show a different intensity of activity during the various times of day. This is also well known for other individual species (Mayhew 1968, Porter *et al.* 1973, Huey & Slatkin 1976 and Huey *et al* 1977). This fact depends on air temperature and possibly on other factors as well. It is evident here (see Fig. 2), that the highest activity is observed between 12-13 hours. There is a gradual increase from 10-13 hrs and a steep decline from 13-14 hrs which declines more and stabilises from 14-16 hrs (Data uncorrected for intensity of counting, but variation insignificant).

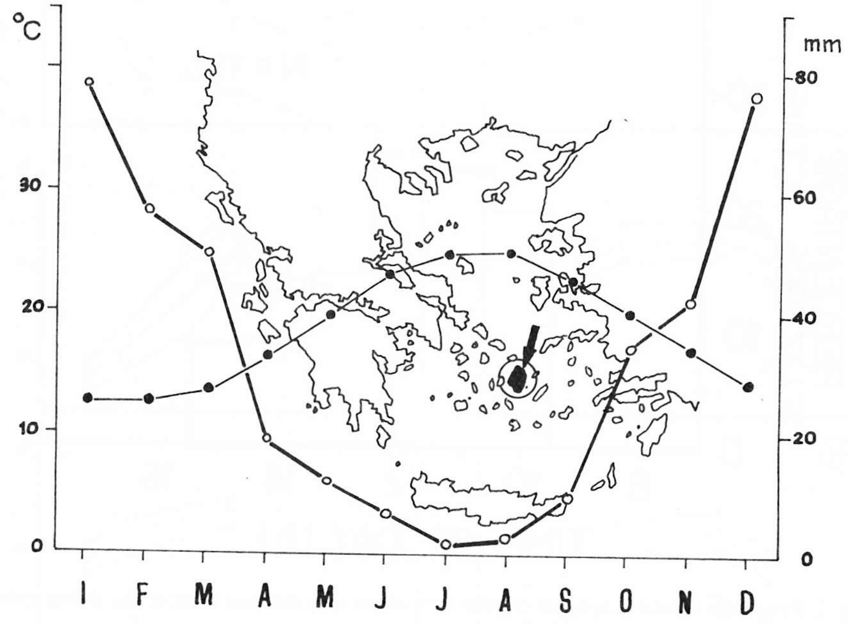

Fig. 1. Geographical location and monthly temperature - rainfall averages for Naxos island. The values are calculated from data gathered by Naxos island Meteorological Station for the years 1931-1975. For 1982 and the months of our study: March: 12.4° C/106 mm, April: 15.4° C/47 mm (Mean air temperature/total rainfall).

From the results of those runs that were made in one day and were more than 2, we tried to find with which temperatures (T_a, mean air temperature in sun) the changes of the frequency of presence (activity) of lizards were correlated. The choice of these runs was made so that the correlation coefficient could be used.

It was observed that air temperatures in shade, had no relation with the lizards'activity. As far as temperatures in sun are concerned, the following can be mentioned: For temperatures ranging between 30-32.5° C, there is a positive correlation between T_a and d (= No of liz/30 min) (Table 1). From these temperatures onwards, a negative correlation between T_a and d is observed. These correlations are shown on A, B, C, and H, fig. 3. The value of C is probably affected by non continuous but strong winds. In the remaining runs, where temperatures are less than 30-32.5° C, this positive correlation is evident, although without possibility of quantification.

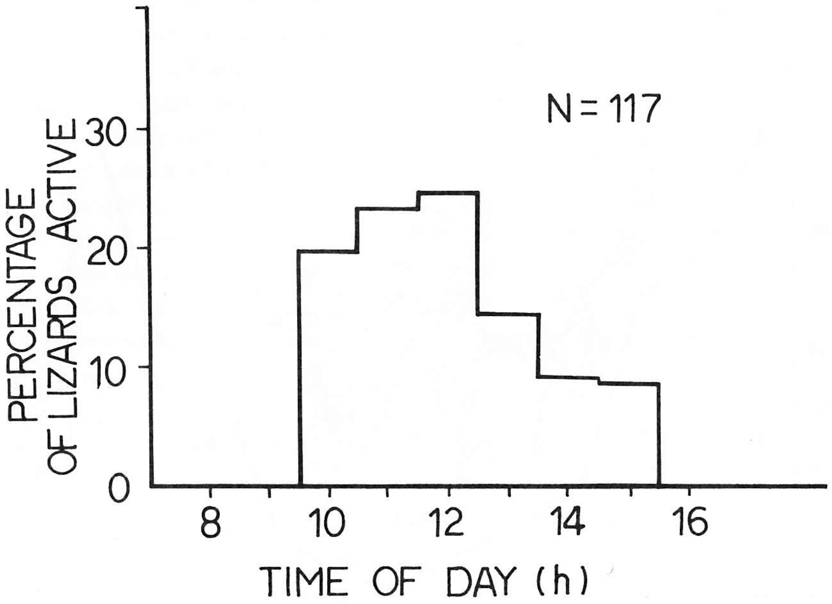

Fig. 2. Percentage of total *P. erhardii* (N) that were observed at different times of day during spring.

The negative correlation for higher temperatures can be observed in case G, fig. 3. This negative correlation is noticeable in other days too, without quantification.

The other two temperatures in sun, namely, T_a min. and $T_a$max, do not always present a correlation to lizards' activity. In cases, when a correlation is observed, it is less strong than that of T_a.

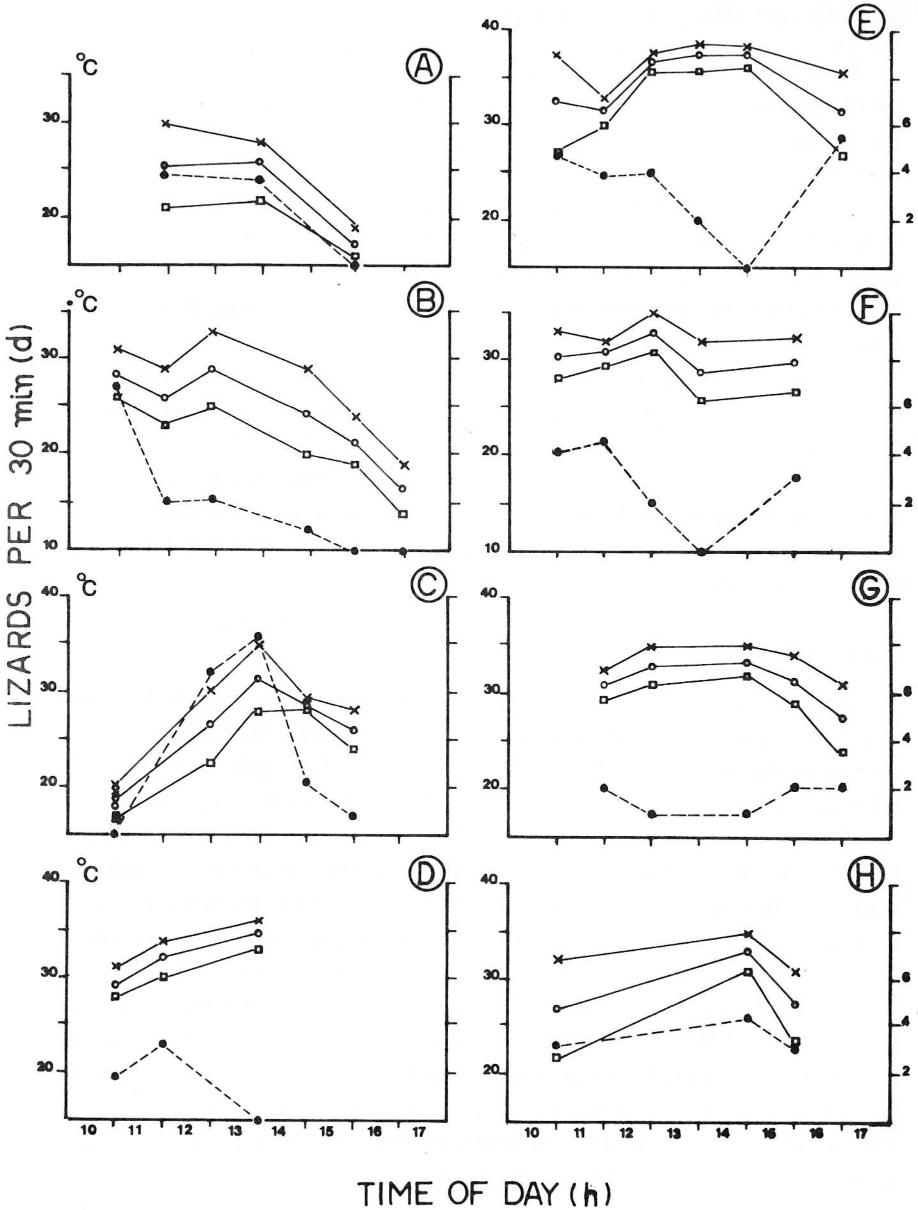

Fig. 3. Number of lizards / 30 min, observed at various times of day. The days, on which three or more runs were performed are included. Symbols: x = $T_a$max, □ = $T_a$min, o = T_a (mean), ● = lizards /30 min. and the corresponding temperatures.

Seasonal variation in time of activity

Time of activity varies seasonally. During summer a pattern well known for a lot of species is to be active early and late in the day. By avoiding acitivity at midday in summer, they avoid the hottest time of the year. A similar pattern is suggested for *P.erhardii,* by GRUBER & SCHULTZE-WESTRUM, 1971.

The short observations during summer time did not show such a pattern. Only 17 lizards were observed at various times of the day, so the number is too small to establish an activity pattern. It is presumed that lizards do not leave their hides and they confine their activities (e.g. foraging) in coverage, given an optimal temperature is retained for them.

Actually, the temperature in shade, varied between 27-33° C (almost optimal according to our previous deductions), while temperature in sun was too high for the lizards (31-41° C).

Of course, that remains just a presumption as it is known that it is hazardous to deduct thermoregulatory behaviour from such kind of data. For example, lizards might not be thermoregulating per se but following prey items that thermoregulate (HUEY ET AL, 1977).

Population density

An attempt was also made to estimate the population density by using the counts of lizards in a certain area. However the large fluctuations of weather conditions that have a significant effect on lizard activity and the limited detectability due to the dense vegetation give a high error to the estimation.

Nevertheless, we must note that the density must be higher than 4 lizards/1000 m^2. This number is derived from the following: The mean frequency during the hour of highest activity (12-13 hrs) is 3.78 lizards/30 min. From table 2, it can be seen that in 30 min, a length of 156 ± 7.5 m and respectively an area of 940.2 ± 45 m^2, is covered. Therefore the mean density is 4.02 lizards/1000 m^2.

Taking in consideration the previous sections as well as that higher frequencies than 4.01 liz/1000 m^2 were often observed, we conclude that the population density must certainly be higher than 4 lizards/1000 m^2. For example if we calculate the population density from the highest frequency observed, that is 8.3 liz/30 min, we arrive at a value of 8.5 liz/1000 m^2. According to a subjective estimation, an intermediate value would be the best approach to reality.

Basking intensity

The percentage of all lizards, observed at various times of day, that were

perched in sun when first sighted, indexes basking intensity. In the present case, this could not be measured because of the sudden and irregular, short or all day long, presence of clouds, during the observations.

So, we consider the simple presence of a lizard outside its hide to be an index of nonrandom movement towards an «appropriate» place, in terms of temperature (see Assumptions and Discussion).

Discussion

To establish thermoregulatory behaviour from descriptive field data one must assume that the behaviour of a lizard is adjusted in order to increase heat loads when ambient temperatures are low and to reduce heat loads when temperatures are high in order to avoid overheating. An attempt is made here to explain on this basis the results obtained.

Lizards thermoregulate by moving between shade and sun or other cold and hot microenvironments, in order to alter the heat flux, by regulating times of activity, in order to alter the heat load and by modifying posture in order to alter the body surface exposed to heat sources, (HUEY et al. 1977). Here, only the first two behavioural patterns are discussed since the results refer to these two. We ignore the physiological thermoregulatory mechanisms (TEMPLETON 1970, SCHMIDT-NIELSEN 1977) since they play only a minor role (BRATTSTROM 1964).

The first thing that has to be mentioned about the results, is the instability of climatic conditions and their intense alterations that predominated during field work. However, our data suggest that the daily activity of *P.erhardii* during spring, is almost identical to a typical pattern known for other species of lizards.

Although it cannot be supported quantitatively, the following observation deserves further attention: After relatively long periods with low temperatures and generally harsh conditions for lizards (i.e. rain), an increased activity is observed as soon as the conditions improve, although not to a degree that they can be considered favourable. These conditions are however the first «good» after the «hard» days. We mention characteristically, that the four highest values of presence frequency observed, that is 6.9, 7.2, 7.9 and 8.3 liz/30 min, belong to this case.

This means that activity at a certain time depends solely on the temperature of that time, only when the conditions are rather steady or slow changing, i.e. for most of the summer period. When the conditions fluctuate, activity depends also on preceding temperatures.

A factor that seriously affects lizard activity, in almost every case, is the amount of shade covering the ground. This is an indirect effect since it affects temperature.

If we consider the length of the shadow of a rod stuck in the ground, to be a measure of the shaded proportion of the ground, at various times during the day, we see that it follows a U-shaped distibution, if plotted against time of the day (Fig. 4). So, if the lizards moved randomly between sun and shade we would expect that the proportion of those being in sun to those being in shade (basking intensity index) would also follow a U-shaped distribution pattern. If we could show that this proportion follows another pattern, then this would strongly suggest that lizards move nonrandomly and apparently thermoregulating.

Although cloudy weather prevented us from measuring basking intensity, we observed that, in the mornings, most of the lizards don't leave their hides unless there is sun at the vicinity and in the afternoons they prefer to retreat to their hides soon after the vicinity around it is shaded, than to remain in shaded open places or to follow sunlit patches. If this holds true, then the counts of lizard incidence (basking and not basking individuals lumped together) are only a little biased and the pattern of activity (Fig. 2) could be interpreted as an index of selection by lizards of an optimal range of temperatures, if compared to the U shaped pattern of the shaded proportion of substrate.

We can notice the effect of this proportion by simply comparing the values in fig. 4, which are between 10-11 hrs and 13-14 hrs. There is a dramatic decline of lizard activity after 13 hrs, because the shaded portion of the ground increases rapidly from 13 to 14 hrs, although the mean temperature in sun is higher than it was during 10 to 11 hrs.

Although the total hours of activity was expected to be longer in summer than in spring, this was not a fact at all. The activity of lizards during summer was at most, half of that during spring. In summer, on runs with total duration of 373 min, performed between 7-17 hrs, only 17 lizards were observed (0,04 liz/min). In spring, on runs with total duration of 1467 min, 117 lizards were observed (0.08 liz./min), which is a statistically significant difference. Although the duration was much longer in spring, the results remain unaltered if only the first 373 min of spring observations are taken into consideration. The mean air temperatures during summer observations were: in shade: 27-33° C, from 7-10 hrs, 33-31° C, from 10-15 hrs. In sun: 31-39° C, from 7-11 hrs, 39-41° C, from 11-15 hrs and 41-36° C from 15-17 hrs.

It is obvious that although lizards could be outside their hides, during early and late in the day, even on shaded substrate, they prefer for some unclear reason to remain in coverage. This is a fact that supports in a way, the opinion expressed in

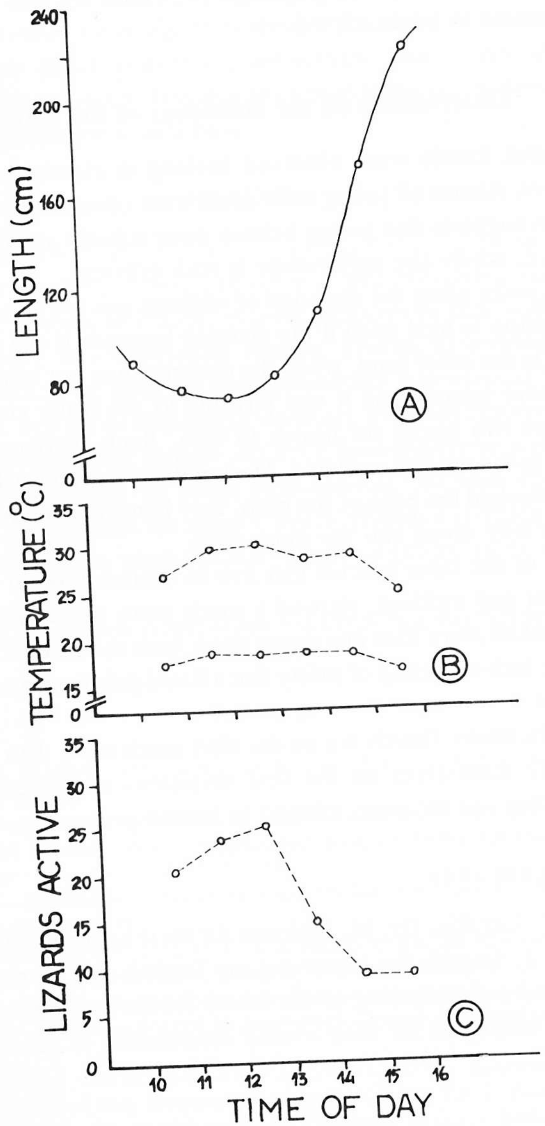

Fig. 4. A. Length of the shadow of a stick, 1.20 m long, during the day, giving a measure of proportions of shaded substrate.
B. Total averages of mean air temperature, in sun (T_a) and shade, during the observation dates.
C. Total number of lizards observed at successive hours of the day. Values uncorrected for intensity of observation runs but variation insignificant.

the paragraph before, concerning springtime. There are not enough data for a further explanation to be attempted.

Observations on the behaviour of the species

1. Only adult lizards were observed basking in clearings far enough from bushes and trees. Almost all young individuals were observed very close to bushes and trees. This suggests that young behave more timidly and dare not procceed into open space, where the only refuge is rock crevices.

2. In most cases when the direction of walking was towards a basking lizard, this would go away to hide even if the distance between it and the observer was long enough. On the other hand, when the direction was not straight to the lizard, it was much more tolerant and it was possible to get really close to it.

3. There are two places for lizards to hide. Rock crevices and vegetation. They would go to the nearest available. Most of those that chose the latter, ran and when they approached the edge of the bush, they jumped onto the outer twigs first and from there they dived into the inner parts.

4. Animals of the same species that live in another type of biotope nearby, more or less flat and rockless, showed a much more timid behaviour and they almost never basked more than one meter away from the nearest scrub. Probably this is due to the lack of feeling of safety that a lizard gets from an easy approachable rock crevice.

5. During afternoon, lizards are on the alert much more than during morning and tend to hide themselves on the first suspicious movement, while in the morning hours they are far more tolerant to human presence.

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Summary

In this work, the activity of the lizards of the species *Podarcis erhardii* is correlated with ambient temperatures (mean, min, max) in spring. Besides this, an evaluation of the method proposed for estimating the population density is made.

It is concluded that lizard activity reflects the climatic conditions and that it is

strongly correlated with mean air temperature in sun, up to 30-32.5° C. For higher temperatures it becomes inversely proportional. The temperature in shade does not seem to have any direct relation to lizard activity. Finally some data are given on the behaviour of the species. It is also attempted to document thermoregulatory behaviour using a descriptive data base.

Περίληψη

Στην εργασία αυτή συσχετίζεται η δραστηριότητα των σαυρών του είδους *Podarcis erhardii*, με τις θερμοκρασίες του περιβάλλοντος μετρημένες με διάφορους τρόπους. Εκτός από αυτό, γίνεται αξιολόγηση μιας μεθόδου που προτείνεται για μέτρηση των πληθυσμών σαυρών. Γίνεται προσπάθεια να ερμηνευτούν τα αποτελέσματα με βάση τη θερμορυθμιστική συμπεριφορά των σαυρών.

Καταλήγουμε στο ότι οι κλιματικές συνθήκες αντικατοπτρίστηκαν στις συχνότητες δραστηριότητας των σαυρών και ότι η δραστηριότητα αυτή παρουσιάζει έντονη θετική συσχέτιση με τις μέσες θερμοκρασίες του αέρα στον ήλιο, μέχρι τους 30-32.5° C και από εκεί και πάνω η σχέση γίνεται αντίστροφα ανάλογη. Οι θερμοκρασίες στη σκιά δεν παρουσιάζουν καμιά συσχέτιση με τη δραστηριότητα των ζώων.

Εκτός από τα παραπάνω γίνονται και παρατηρήσεις συμπεριφοράς του είδους.

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TABLE 1

Days of	$t_a$max		T_a(mean)		$T_a$min	
	r	p	r	p	r	p
A = 19/3	0.9932	<0.10	0.9999	<0.001	0.9796	>0.1
B = 3/4	0.8736	<0.10	0.8929	<0.05	0.8967	<0.05
C = 4/4	0.8503	<0.05	0.7634	<0.1	0.6065	>0.1
D = 10/4	—	—	Insufficient data		—	—
E = 11/4	—	—	Insufficient data		—	—
F = 12/4	—	Temperatures fluctuate between 30-32,5° C				
G = 26/4	0.8546	>0.1*	0.9694	<0.05*	0.9432	<0.1
H = 27/4	0.9708	>0.1	0.9971	<0.05	0.9972	<0.1

* = Inverse correlation

Table 1. Correlations: $T_a$max. vs. lizards / 30 min (d), T_a. vs. lizards / 30 min. (d), $T_a$min. vs. lizards / 30 min. r = correlation coefficient.

TABLE 2

Duration (min)	Distance (m)	Distance/30 min (m/30 min)
9	48.5	161.6
4	21.5	161.2
9	48	160
9	45	150
5	25	150
6	32	160
6	31.5	157.5
6	31	155
10	31	148.5
7	34.5	147.8

Mean±s.d = 156.6±7.5 m

Table 2. Durations, distances covered and values extrapolated to 30 min, from the special runs made for calculating the distance covered by the observer during the observation runs.