

CONTRIBUTION TO THE THERMAL ECOLOGY OF *TESTUDO MARGINATA* AND *T. HERMANNI* (CHELONIA: TESTUDINIDAE) IN SEMI-CAPTIVITY

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ABSTRACT

Data on the thermal ecology of *Testudo marginata* and *T. hermanni* are presented. The two species are eurythermic and thermoconformers. There are no differences in the thermal relations between the species.

INTRODUCTION

The majority of studies on the thermal ecology of the Reptilia concern mainly lizards, and relatively few deal with chelonians (Meek and Avery, 1988). In chelonians, thermoregulatory behaviour has been observed in all the three major life forms: terrestrial, semi-aquatic and marine (Avery, 1982). The study of chelonians' thermal relations are interesting for several reasons, such as their hemispherical shape, the very large size that some species reach and the fact that the terrestrial forms move only very slowly (Meek and Avery, 1988).

In Greece there are three terrestrial species: *Testudo graeca*, which is widespread and is found in N. Africa, the Mediterranean region, Asia Minor, Middle East and Anatolia; *T. hermanni*, which is distributed in the Balkan peninsula, southern Italy, eastern Spain and southern France; and *T. marginata*, the largest of the European species. This has a restricted distribution to the south of Mount Olympus in Greece, and Sardinia as an effect of human introduction during the past 100 years (Keymar and Weissinger, 1987). There are ecological data on the population structure, activity and thermal ecology of *T. graeca* and *T. hermanni*. However, these data are restricted to spring and summer in northern Greece.

In this work we present initial data on the thermal ecology of *T. marginata* and *T. hermanni*, which are sympatric in southern Greece, under semi-captive conditions.

METHODS

The measurements and the observations were carried out in a 150m² yard in Hymmitus mountain (Attika, Greece) from February to November 1989. The proportion of basking and shaded areas during the day was similar to the proportion in the natural habitat. Moreover the animals had the opportunity to move into suitable night-time retreats. A total of 245 body temperature measurements were taken from four (two males and two females) individuals of *T. marginata* and four (two males and two females) of *T. hermanni*. The specimens were collected from the neighbouring area and were of similar size.

Body temperatures were measured inserting an electronic thermometer into the cloaca. Then, the air temperature was measured 15 cm above the animal and the substrate temperature at the place where they were found. Also, their behaviour (basking, active, hidden) was observed and their sex was confirmed.

RESULTS

THERMOREGULATION

Average cloacal (T_b) temperatures of active male and female animals for both species are given in Table 1. There is no significant difference between their body temperatures (*T. marginata* $t = 0.77, P > 0.05$; *T. hermanni* $t = 0.78, P > 0.05$).

Species	Male			Female		
	T _b °C	S.D.	N	T _b °C	S.D.	N
<i>T. marginata</i>	25.5	6.1	74	24.7	6.6	72
<i>T. hermanni</i>	27.2	4.9	55	26.3	5.8	44

TABLE 1. Descriptive statistics for body (T_b) temperatures of the two sexes of *T. marginata* and *T. hermanni*. N: number of measurements.

Species	T _b °C			T _a °C			T _s °C			N
	\bar{x}	S.D.	Range	\bar{x}	S.D.	Range	\bar{x}	S.D.	Range	
<i>T. marginata</i>	25.0	6.5	8.0-34.7	21.9	5.9	8.4-35.2	22.4	6.2	7.9-40.2	146
<i>T. hermanni</i>	26.5	5.7	14.7-33.3	23.4	5.3	14.4-35.0	24.3	5.5	17.1-38.3	99

TABLE 2. Descriptive statistics for body (T_b), air (T_a) and substrate (T_s) temperatures of *T. marginata* and *T. hermanni*. \bar{x} : mean values. N: number of measurements.

Average cloacal (Tb), air (Ta) and substrate (Ts) temperatures of active animals for both species are given in Table 2. There is no significant difference between the body temperatures of the two species ($t = 2.19, P > 0.01$). The mean annual body temperature when the animals are active is higher than the mean annual air temperature for both species. (*T. marginata* $t = 3.57, P < 0.05$; *T. hermanni* $t = 4.70, P < 0.05$).

In Fig. 1 the mean monthly temperatures (body, air, substrate) are given for the two species when active. There is a significant difference in body temperature among the months (*T. marginata* ANOVA $F = 37.14, P < 0.05$; *T. hermanni* $F = 12.03, P < 0.05$). Using ANOVA and *t*-tests, we found that there are no significant differences in the body temperatures of *T. marginata* during the months March, April, May ($F = 3.36, P > 0.05$), June, July, August ($F = 3.18, P > 0.05$), November and February ($t = 0.49, P > 0.05$). There is a significant difference between October and November ($t = 3.55, P < 0.05$). The corresponding data for *T. hermanni* are similar; March, April, May ($F = 1.79, P > 0.05$); June, July, August ($F = 2.8, P > 0.05$). There is no significant difference between October and February, the beginning and the end of the hibernation period ($t = 0.41, P > 0.05$). Therefore the data for every group of months are pooled and given in Table 3.

T. marginata was active between body temperatures of 8°C to 34.7°C. At lower temperatures the animals were inactive, whereas at temperatures higher than 35°C they retreated into the shade and continued their activity. There was no significant difference between their body temperatures when the animals basked or moved (*T. marginata* $t = 0.30, P > 0.05$; *T. hermanni* $t = 0.19, P > 0.05$).

The body temperatures of the *T. hermanni* individuals when active ranged between 14.7°C and 33.3°C. Regarding the upper limit, the behaviour of *T. hermanni* was the same as *T. marginata*. Below the lower limit *T. hermanni* hibernated buried in the soil.

There is a positive correlation between Tb versus Ta and Tb versus Ts when *T. marginata* is active (Tb v. Ta: $y = 5.27 + 0.9x, r = 0.81, P < 0.05$; Tb v. Ts: $y = 5.75 + 0.85x, r = 0.82, P < 0.05$ Fig.2). These slopes are not different from a value of one. (Tb v. Ta: $t = 1.89, P > 0.05$; Tb v. Ts: $t = 2.86, P > 0.05$).

Moreover, there is a positive correlation between Tb and Ta and Tb and Ts when *T. hermanni* is active (Tb v. Ta: $y = 5.46 + 0.9x, r = 0.83, P < 0.05$; Tb v. Ts: $y = 6.86 + 0.81x, r = 0.58, P < 0.05$ (Fig.3). These slopes are not

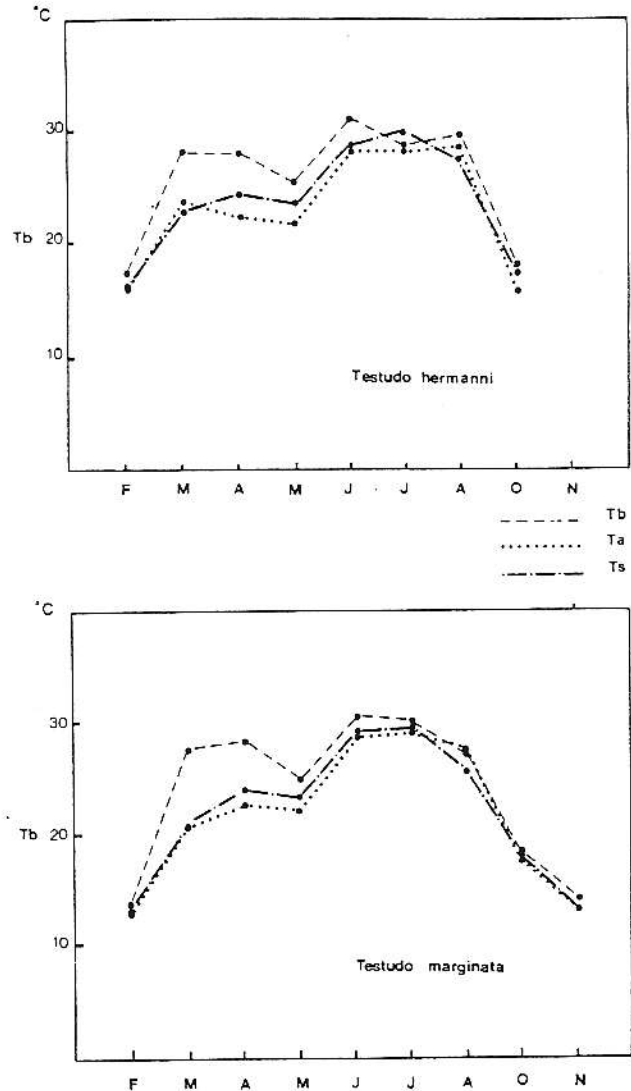


Fig. 1. Mean monthly body (Tb), air (Ta) and substrate temperatures (Ts) of *T. hermanni* and *T. marginata*.

different from a value of one (Tb v. Ta: $t = 1.41, P > 0.05$; Tb v. Ts: $t = 2.87, P > 0.05$).

ACTIVITY PERIOD

In spring, most of the *T. marginata* individuals are active throughout the day but there is also a high percentage of observations of inactive animals in the sun. In summer, the animals are active during the

Season	Tb°C		\bar{x}	Ta°C		Ts°C		N
	\bar{x}	S.D.		\bar{x}	S.D.	\bar{x}	S.D.	
<i>T. marginata</i>								
Spring	26.9	4.7	21.8	4.2	22.7	4.7	76	
Summer	30.0	2.3	28.8	3.2	28.7	4.2	34	
Autumn	18.8	1.8	17.5	1.5	18.1	1.5	20	
Winter	13.6	3.0	13.6	2.9	13.1	3.2	16	
<i>T. hermanni</i>								
Spring	27.0	5.3	22.6	4.1	23.9	4.5	56	
Summer	30.0	2.3	28.5	3.0	28.7	3.8	28	
before/after hibernation	18.2	2.9	19.4	2.2	17.4	3.5	15	

TABLE 3. Mean body, air and substrate temperatures of *T. marginata* (top), and *T. hermanni* (bottom) among the seasons.

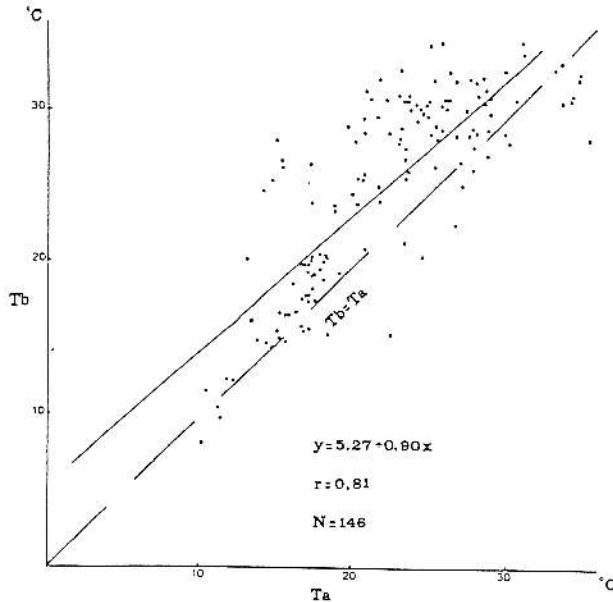


Fig. 2. Relationship between body temperature (T_b), and air temperature (T_a) in *T. marginata*.

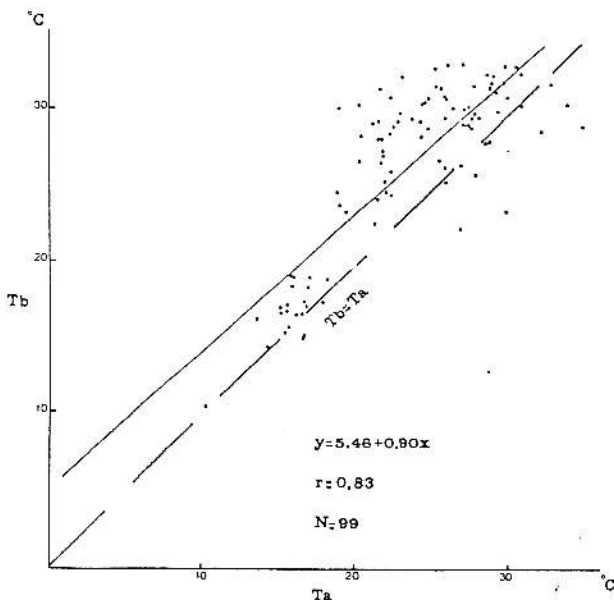


Fig. 3. Relationship between body temperature (T_b), and air temperature (T_a) in *T. hermanni*.

morning and late afternoon. Inbetween, the animals were inactive. In fall, they are active from 10.00hr to 16.00hr. The same applies to *T. hermanni*. In winter the *T. hermanni* individuals hibernate buried in the soil. On the contrary, the individuals of *T. marginata* are active, depending on the weather conditions, and are never buried.

DISCUSSION

Spellerberg (1982) states that active body temperatures of Testudinidae range from 14°C to 38°C, with an average around 30°C. From our results it seems that body temperatures of *T. hermanni* vary between these limits but *T. marginata* can be active in lower body temperatures as well. Hailey *et al.* (1984) state that in French populations of *T. hermanni*, summer activity

occurred in body temperatures between 20°C and 35°C, mostly around 30°C. Meek (1988) gives for *T. hermanni* in Yugoslavia, summer body temperatures from 21°C to 34°C and in autumn from 16°C to 33°C. It is interesting that maximum body temperatures of 34°C-35°C have been measured in all the populations studied so far, except during cooler autumn weather (Meek and Avery, 1988).

Our results indicate that the two species behave mainly as thermoconformers. This is because (1) the slopes of the curves T_b v. T_a do not differ from one (Huey and Slatkin, 1976), and (2) even though the mean annual air temperature is lower than the mean annual body temperature, the mean monthly body temperatures of the specimens are similar to the corresponding air temperatures (Fig. 1) apart from those taken in the spring months.

Eurythermy and thermoconformity are good strategies for reptile species which are distributed in a climate where the environmental temperatures fluctuate widely (Huey, 1982), such as in Mediterranean ecosystems. Also, lower body-active temperatures enable the species to be active during the cool period of the year (Huey and Slatkin, 1976). These hypotheses are in agreement with our results.

The daily activity of reptiles depends on their thermal ecology (Huey, 1982). Consequently the two species regulate their activity period when the conditions are favourable for the maintenance of preferred levels of body temperatures. Therefore they avoid the midday high summer temperatures and are active in the morning and late in the afternoon. During the cooler seasons they are active in the warmer part of the day.

In conclusion, the two species seem to have the same thermal requirements apart from the fact that *T. marginata* can be active at lower body temperatures and appears to adopt a more opportunistic behaviour through the winter. The wider distribution of *T. hermanni* in northern regions seems to be related to its ability to hibernate in the soil and to thus avoid extremely low winter temperatures.

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