

Thermal ecology of a population of *Testudo hermanni* in the Ebro Delta (NE Spain)

M. A. CARRETERO¹, A. BERTOLERO^{1,2} & G. A. LLORENTE¹

¹Department of Animal Biology (Vertebrates), Faculty of Biology, University of Barcelona. Av. Diagonal, 645. E-08028 Barcelona (Spain)

²Parc Natural del Delta de l'Ebre. Plaça 20 de maig s/n. E-43580 Deltebre (Tarragona, Spain)

Abstract: The thermal relations were analyzed in an introduced population of Hermann's Tortoise (*Testudo hermanni*) sited in a sandy area of the Ebro Delta (NE Spain). Usual techniques in thermal ecology were used. Body, air and substrate temperatures of 242 animals were recorded. Results define this species as heliotherm. The body temperatures were low (mean 27.30) with a relatively narrow range (13.40-37.20). The relation between substrate and body temperatures followed a logarithmic curve. Intraspecific and seasonal differences were registered but no evidence of thermal inertia was detected in the largest animals. Conversely, only the juveniles showed capability of thermoregulation. The adult females reached lower body temperatures than males at the same environmental temperatures. During winter, the active adults showed thermal compensation indicated by higher temperature residuals than those in other seasons. These findings are discussed in comparison to other populations taking into account the thermal environment and the species constraints.

Key words: Thermal ecology, thermoregulation, Chelonia, *Testudo hermanni*.

INTRODUCTION

Terrestrial chelonians can be interesting objects for studies on thermal ecology. First, their bodies are large and hemispherical (MEEK & AVERY, 1988) and, second, their movements are slow in comparison to other reptiles (see JAYES & ALEXANDER, 1980; MEEK & AVERY, 1988). So, on one hand, the low surface/volume relation could provide large species with thermoregulation mediated by thermal inertia. On the other hand, their low mobility would not allow them accurate behavioural thermoregulation (MEEK, 1984) and the proximity of shade would be important for preventing overheating (MEEK & AVERY, 1988).

The present paper deals with these thermal traits in an introduced population of Hermann's Tortoise (*Testudo hermanni*) in NE Spain, their intraspecific variation and the possible environmental influences.

T. hermanni is a Mediterranean species of medium size which ranges the Balkan Peninsula, Greece, Italy and some Mediterranean islands (ARNOLD & BURTON, 1978). In the Iberian Peninsula, only the relictual population of the Alberes (NE Spain-SE France) can be considered native at present (FRETEY, 1987; CHEYLAN, 1984; LLORENTE *et al.*, 1995). The thermal ecology of this species has been previously investigated (CHERCHI, 1956-1960; CHERCHI *et al.*, 1958; MEEK & INSKEEP, 1981; MEEK, 1984; PULFORD *et al.*, 1984; MARAGOU & VALAKOS, 1992) and other members of the same genus have also been studied (BANNIKOV,

1951; CLOUDSLEY-THOMPSON, 1974; LAMBERT, 1981; MEEK & JAYES, 1982; MARAGOU & VALAKOS, 1992).

MATERIAL AND METHODS

The population studied was introduced in the Parc Natural del Delta de l'Ebre (delta of the Ebro river, UTM 31TCE09) in 1987-1988 (BERTOLERO, 1991), in a group of sand islets of the Alfacs Peninsula with 5.8 Ha of total surface. 44 individuals were set free and bred successfully (BERTOLERO, 1991). The population is now estimated at more than 200.

The space around the islets lacks vegetation and it is covered or not by the sea depending on the season. When it is dry the tortoises can pass from one islet to another. The vegetation is composed of psammophile and halophile plants (CURCÓ, 1991) and a wood of White Pine (*Pinus halepensis*) which was set up in 1940-50. The climate is littoral Mediterranean, with a long dry season in summer (mean annual rainfall=548 mm, mean temperature=16.6°C; see PANAREDA & NUET, 1973).

Sampling was carried out in 1992 on sunny days without strong wind. The visits to the area depended on the transport possibilities, so it was impossible to carry out uniform prospection. Animals were active between February and November (see also BERTOLERO, 1991). Standard techniques in thermal ecology (AVERY, 1982) were used on 242 animals. Cloacal temperature (TB), air temperature (TA) 10 cm above the ground and substrate temperature (TS)

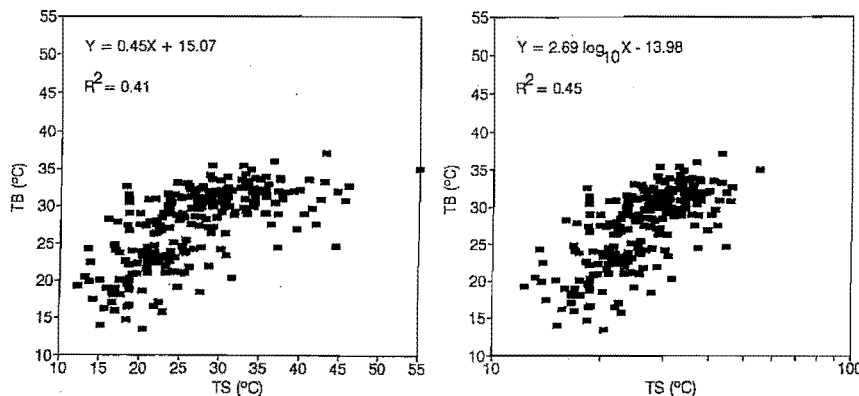


Figure 3: Linear (left) and logarithmic (right) regressions between body (TB) and substrate (TS) temperatures.

1985) predict a thermal inertia effect in ectotherms larger than 0.1-1 Kg of body mass as *T. hermanni*. However, this effect has not been detected here (see also MEEK, 1984). Probably, this is due to the more accurate behavioural thermoregulation in juveniles than in the adults (see results). Juveniles can compensate their low surface/volume relation with more availability of shade sites because of their small size. A conservative activity of juveniles at midday and in the evening, has also been reported (see HAILEY *et al.*, 1984; and LAMBERT, 1981 for *T. graeca*).

The maximum voluntary body temperatures detected here (37.20°C) is the highest detected in this species. In this kind of habitats with a reduced vegetal coverage, the sand can accumulate a great amount of caloric energy during the day (CLOUDSLEY-THOMPSON, 1991). This implies a danger of overheating and can increase TB to near the critical thermal maximum (39-42°C, see CHERCHI, 1956) and may reduce the summer activity. Tortoises are partially able to compensate for this process. While TS is lower than 28-30°C the tortoises behave as thermoconformers but above these values thermoregulation takes place (see Figure 3).

The importance of the habitat in the activity of this species has been stated previously (HAILEY *et al.*, 1984; PULFORD *et al.*, 1984). Some authors (CHELAZZI & CALZOLAI, 1986) have also shown that thermoregulatory efficiency depends on habitat familiarity. This has been suggested to be important in introduced animals (MEEK & AVERY, 1988). In this case, five years after the introduction, animals seem to

be acclimatized, since thermoregulation is even more efficient than in other localities studied (see references). The environmental conditions in summer (drought, overheating) in an extreme habitat allow *T. hermanni* in the Ebro Delta to show its capability of thermoregulation (juveniles) or its thermoconformity for high temperatures (adults). The importance of studying extreme thermal environments should be considered before defining the species constraints.

ACKNOWLEDGEMENTS

The authorities of the Parc Natural del Delta de l'Ebre facilitated the visits to the Integral Reserve and supplied transport. Marc Grau helped in several computer calculations.

REFERENCES

- AVERY, R. A. (1979): *Lizards: A study in thermoregulation*. Studies in Biology 109. E. Arnold Pub. Ltd. 56 pp.
- AVERY, R. A. (1982): Field studies of body temperatures and thermoregulation. pp. 93-166, in: C. GANS & F. H. POUGH (eds.) *Biology of the Reptilia. Vol. 12. Physiology*. C. Academic Press. London.
- ARNOLD, E. N. & BURTON, J. A. (1978): *A field guide to the reptiles and amphibians of Britain and Europe*. Collins. London.
- BANNIKOV, A. G. (1951): Material on the biology of *Testudo graeca* (in Russian). *Uchenye Zapiski Biologiske Universiteta Chernovitsky*, 1: 109-118.
- BERTOLERO, A. (1991): La reintroducción de

pooled population but, considering the classes, only the differences in females were found to be significant. So, TB-TA (but not TB-TS) residuals of females were higher in winter than in the rest of the year (ANCOVA, $F = 4.60$, $p < 0.01$, for the adjusted means).

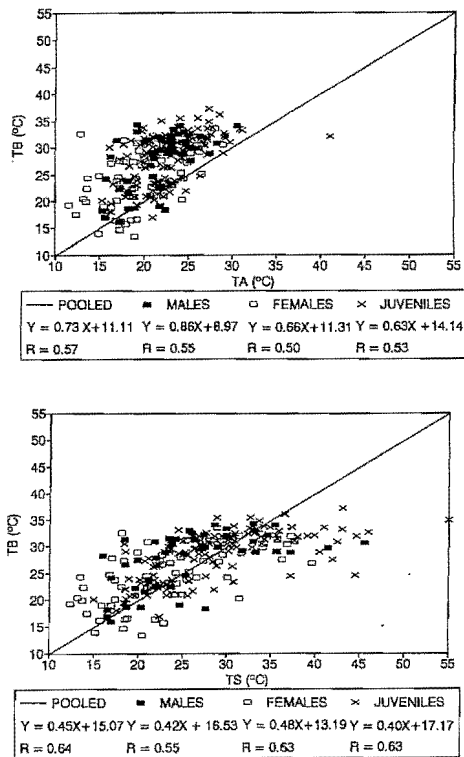


Figure 2: Relations between body (TB) and air (TA) or substrate (TS) temperatures.

The thermal relations between TB and TA or TS (Figure 2) had significant regressions in all the cases. The slopes were different (t test, $p < 0.01$) from 0 (perfect thermoregulation) and 1 (absolute thermoconformity). The only exception was the TB-TA slope of males, which was not different from 1. In females, it was different only at $p < 0.05$ level.

The TB-TA slope was higher than TB-TS slope in all the cases (parallelism tests, $p < 0.01$). No differences were found in TB-TA and TB-TS slopes either by classes or by seasons in any class.

Finally, in order to improve the adjustment in the TB-TS correlation, several non-linear regression were attempted. The logarithmic

regression provided a higher percentage of explained variance (R^2) than linear regression (Figure 3). This was not the case of the TB-TA regression.

DISCUSSION AND CONCLUSIONS

The body temperatures of *Testudo hermanni* varied between the usual limits in terrestrial chelonians and were intermediate between those of the congeneric species *T. graeca* and *T. marginata* (see MEEK, 1984; MARAGOU & VALAKOS, 1992). The moderately high values were very similar to those obtained by MARAGOU & VALAKOS (1992) who studied a population throughout the year in Greece. Other studies (MEEK, 1984; PULFORD *et al.*, 1984), carried out in spring or summer, registered higher body temperatures than these. This constancy shows the conservative character of the TB mean (AVERY, 1982) and seems to indicate a certain degree of thermal control (see below).

The intraspecific differences have been observed for the first time in this species. They cannot be due to the availability of different environmental temperatures since TB residuals (and not TB) were used. So, females reached lower body temperatures than the rest in the same thermal environment. The explanations based on the temperature for the development of the eggs in the reproductive season and/or the searching for egg sites, would need confirmation. For instance, sexual differences in the activity pattern have been detected in September (HAILEY *et al.*, 1984).

Considering the seasonal variation, the animals found in winter (all of them were females in February) reached suboptimal temperatures (lower the selected temperatures) but show evidence of thermal compensation. Although TB was the lowest one of the year, the TB-TA residual was the largest.

The slope of the regression line points out how much TB depends on the environmental temperatures, TA or TS (see HUEY & SLATKIN, 1976). The body temperature of *T. hermanni* depends more on the air than on the substrate. This confirms this species as heliotherm (AVERY, 1979) as other authors have recorded (MEEK, 1984; MARAGOU & VALAKOS, 1992). However, evidence of thermoregulation can be seen here in juveniles (and, to a lesser extent, in females) but this has not been detected by other authors.

Some models (POUGH, 1980; STEVENSON,

in the place of sight, were recorded. All three were measured in shade using a digital thermometer with a K type thermocouple (resolution 0.1°C, reading time 1'). Every tortoise was also weighed in the field with a dynamometer and its carapace length was measured.

Three work classes were distinguished: adult males (carapace length: 126-157mm), adult females (151-195mm) and juveniles (34-138mm). For the study by seasons, data were grouped as follow:

Winter = December + January + February

Spring = March + April + May

Summer = June + July + August

Autumn = September + October + November

The analysis of covariances (ANCOVA, SOKAL & ROHLF, 1981) was used to compare the TB values among groups correcting the effect of environmental temperatures.

RESULTS

The descriptive statistics of TB, TA and TS are shown in Table 1, considering the pooled population and the classes. Intraspecific variation was detected. Body temperatures of the females were lower than those of the other two classes and this difference remained when TB was corrected for TA (ANCOVA, $F = 4.86$, $p < 0.01$, for the adjusted means) and TS (ANCOVA, $F = 5.51$, $p < 0.01$, for the adjusted means). There was no significant correlation of TB either with carapace length ($R = 0.27$, $p > 0.05$) or with body weight ($R = 0.27$, $p > 0.05$).

Class	N	X	S	CV	lim(95%)	range
Pooled						
TB	242	27.30	3.25	11.89	±0.41	13.40-37.20
TA	242	21.89	3.97	18.14	±0.50	11.60-41.10
TS	242	26.81	7.30	27.23	±0.92	12.30-55.00
Males						
TB	45	27.61	5.15	18.65	±1.50	16.00-34.30
TA	45	21.65	4.19	19.35	±1.22	15.40-30.60
TS	45	26.08	7.30	27.99	±2.13	16.00-45.60
Females						
TB	74	24.89	5.20	20.89	±1.18	13.40-33.60
TA	74	20.26	3.95	19.50	±0.90	11.60-29.00
TS	74	24.16	6.78	28.06	±1.54	12.30-39.60
Juveniles						
TB	123	28.64	4.52	15.78	±0.80	17.00-37.20
TA	123	22.96	3.84	16.72	±0.68	15.30-41.10
TS	123	28.68	7.21	25.14	±1.27	15.00-55.00

Table 1: Temperatures of *Testudo hermanni* (Ebro Delta). TB = body temperature, TA = air temperature, TS = substrate temperature, N = sample, X = mean, S = standard deviation, CV = coefficient of variation.

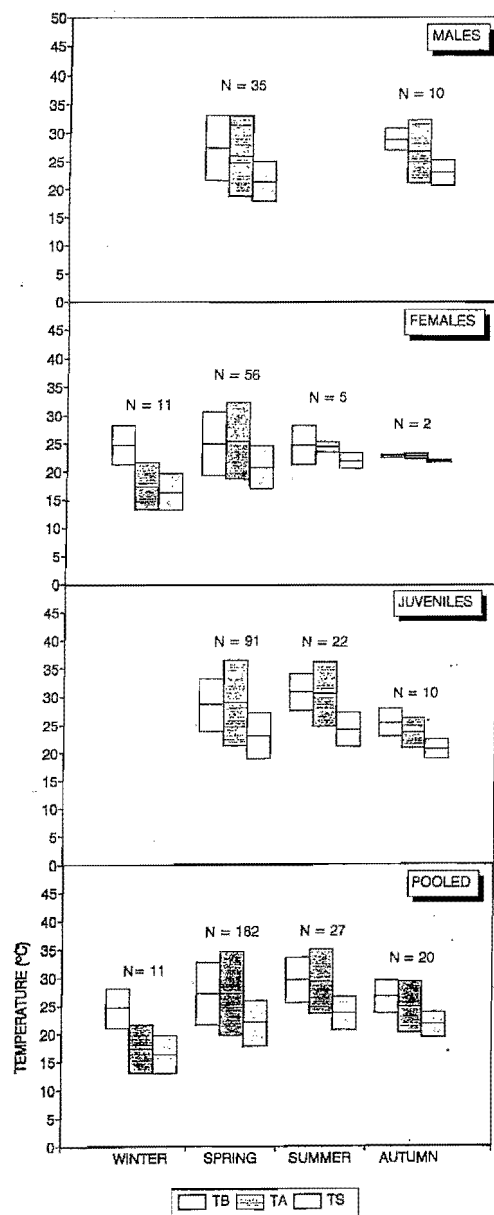


Figure 1: Seasonal variation of body (TB) and air (TA) or substrate (TS) temperatures. Horizontal lines represent mean and standard deviation intervals respectively.

The general pattern of seasonal variation consisted of higher values in summer than in the rest of year (see Figure 1). This was true for the

- Testudo hermanni* en el Parque Natural del Delta del Ebro. *Bull. Parc. Nat. Delta de l'Ebre*, 6: 22-25.
- CHELAZZI, G. & CALZOLAI, R. (1986): Thermal benefits from familiarity with the environment in a reptile. *Oecologia*, 68: 557-558.
- CHERCHI, M. (1956): Thermoregolazione in *Testudo hermanni* Gmelin. *Bolletino Musei Instituti Biologici Universita Genova*, 28: 5-46.
- CHERCHI, M. (1960): Ulteriori ricerche sulla thermoregolazione in *Testudo hermanni* Gmelin. *Bolletino Musei Instituti Biologici Universita Genova*, 30: 35-60.
- CHERCHI, M.; HOLZER, R. SORTECCI, V. & SERRATO, G. (1958): Microvariazione di temperatura in *Testudo hermanni* Gmelin. *Bolletino Musei Instituti Biologici Universita Genova*, 28: 9-77.
- CHEYLAN, M. (1984): True status and future of Hermann's Tortoise *Testudo hermanni robertmertensi* Wermuth 1952 in Western Europe. *Amphibia-Reptilia*, 5(1): 17-26.
- CLOUDSLEY-THOMPSON, J. L. (1974): Physiological thermoregulation in the spurred tortoise (*Testudo graeca* L.). *Journal of Natural History*, 8: 577-587.
- CLOUDSLEY-THOMPSON, J. L. (1991): *Ecophysiology of Desert Arthropods and Reptiles*. Springer Verlag, Berlin. 203pp.
- CURCÓ, T. (1990): La vegetació del Delta de l'Ebre (I): Les comunitats dunars (Classe Ammophiletea Br.Bl. & Tx. 1943). *Bull. Parc. Nat. Delta de l'Ebre*, 5: 9-18.
- FRETEY, J. (1987): *Guide des Reptiles de France*. Hatier, Paris. 255pp.
- HAILEY, A.; PULFORD, E. A. & STUBBS, D. (1984): Summer Activity Patterns of *Testudo hermanni* Gmelin in Greece and France. *Amphibia-Reptilia*, 5: 69-78.
- HUEY, R. B. & SLATKIN, M. (1976): Costs and benefits of lizard thermoregulation. *Quarterly Rev. Biol.*, 51: 363-384.
- JAYES, A. S. & ALEXANDER, R. M. (1980): The gaits of chelonians: walking techniques for very low speeds. *Journal of Zoology. London*, 191: 353-378.
- MEEK, R. & INSKEEP, R. (1981): Aspects of the field biology of a population Hermann's Tortoise (*Testudo hermanni*) in Southern Yugoslavia. *British Journal of Herpetology*, 6: 159-164.
- LAMBERT, M. R. K. (1981): Temperature, activity and field sighting in the Mediterranean spur-thighed or common garden tortoise *Testudo graeca*. *Biological Conservation*, 21: 39-54.
- LLORENTE, G. A.; MONTORI, A.; SANTOS, X. & CARRETERO, M. A. (1995): *Atlas dels amfibis i rèptils de Catalunya i Andorra*. Ed. El Brau, Figueres.
- MARAGOU, P. & VALAKOS, E. (1992): Contribution to the thermal ecology of *Testudo marginata* and *T. hermanni* (Chelonia: Testudinidae) in semi-captivity. *Herpetological Journal*, 2: 48-50.
- MEEK, R. (1984): Thermoregulatory behaviour in a population of Hermann's Tortoise (*Testudo hermanni*) in Southern Yugoslavia. *British Journal of Herpetology*, 6: 387-391.
- MEEK, R. & AVERY, R. A. (1988): Mini-Review: Thermoregulation in chelonians. *Herpetological Journal*, 1: 253-259.
- MEEK, R. & JAYES, A. S. (1982): Body temperatures and activity patterns of *Testudo graeca* in North West Africa. *British Journal of Herpetology*, 6: 194-197.
- PANAREDA, J. M. & NUET, J. (1973): El clima i les aigües dels Països Catalans. pp. 69-102, in: *Geografia Física dels Països Catalans*. Ed. Ketres, Barcelona.
- POUGH, F. H. (1980): The advantages of ectothermy for tetrapods. *Am. Nat.*, 115(1): 92-112.
- PULFORD, E.; HAILEY, A. & STUBBS, D. (1984): Thermal relations of *Testudo hermanni robertmertensi* Wermuth in S. France. *Amphibia-Reptilia*, 5: 37-41.
- SOKAL, R. R. & ROHLF, F. J. (1981): *Biometry*. W. H. Freeman and Company, San Francisco. 776 pp.
- STEVENSON, R. D. (1985): Body size and limits to the daily range of body temperature in terrestrial ectotherms. *Am. Nat.*, 125(1): 102-117.