On the relation of body and shell temperatures in a freshwater turtle

Being ectothermic animals, freshwater turtles depend on environmental temperatures for thermoregulation (HUEY 1982). Thus, temperature plays a key role in determining turtle behavior, from microhabitat selection for feeding or breeding (BROW & BROOKS 1991; NIEUWOLT 1996) to the formation of population structures and geographical distribution patterns (LITZGUS et al. 1999; EWERT et al. 2005). In fact, the turtle body temperature (T_b) is a result of interaction between abiotic factors (e.g., environmental temperature, solar radiation) and the ability to use behavioral and physiological processes to control temperature fluctuations (BULTÉ & BLOUIN-DEMERS 2010).

The common behavior that freshwater turtles use to control T_b is temporary basking in selected, comfortable sites (LACHER et al. 1986; MEEK & AVERY 1988; GRAYSON & DORCAS 2004). However, little is known about the importance of thermoregulation activity in turtle behavior (DALL'ANTONIA et al. 2001) and available data on T_b for free-ranging species are primarily anecdotal.

SOUZA & MARTINS (2006) found thermoconformity in *Hydromedusa maximiliani* (MIKAN, 1820), by recording its body temperature using a cloacal thermometer. A clearly more efficient method to measure T_b internally in free-ranging turtles is the use of implanted temperature loggers which was successfully applied in the studies by e.g., EDWARDS & BLOUIN-DEMERS (2007) with *Chrysemys picta* (SCHNEIDER, 1783) and BULTÉ & BLOUIN-DEMERS (2010) with *Graptemys geographica* (LE SUEUR, 1817). However, there are important implications associated with this method: The use of implanted temperature loggers involves (i) a surgical procedure and (ii) application of a radio transmitter to locate the turtle. In contrast, implanted temperature-sensitive radio transmitters as described e.g., by OROMI et al. (2010) would offer transmission of both T_b and localization by a single device.

To avoid surgical procedures, a non-invasive alternative could be the application of external radio transmitters to monitor the shell surface temperature. This is why the

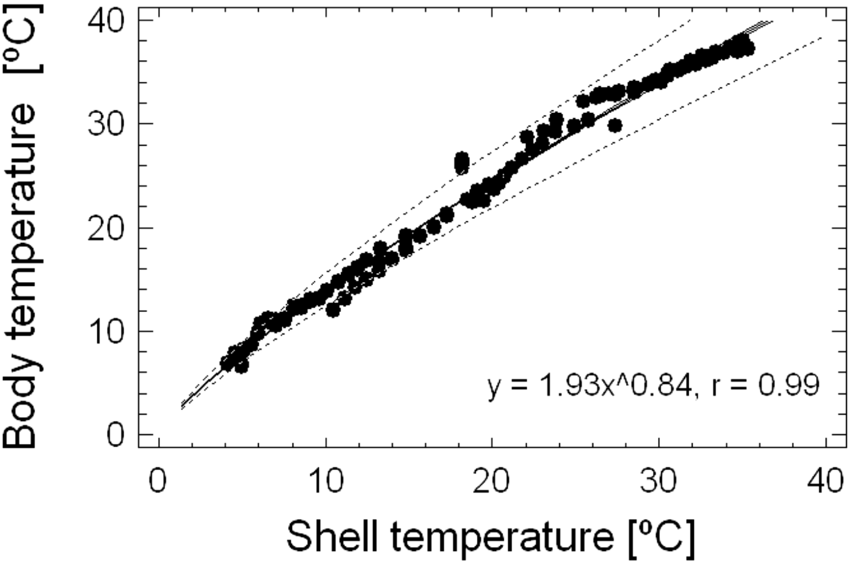

Fig. 1: Body and shell temperature relationship in the three tested individuals of *Trachemys scripta elegans* (WIED, 1838). See Table 1 for details.

authors studied the relation between internal body temperature (T_b) and shell surface temperature (T_s) in a controlled laboratory experiment with *Trachemys scripta elegans* (WIED, 1838).

Three individuals (body mass 272.2, 476.5 and 448.2 g, turtle 1, turtle 2 and turtle 3, respectively) obtained from the Catalonian Reptile and Amphibian Rehabilitation Center (CRARC) in Barcelona were subject to the experiment. The turtles were fed two hours before the beginning of the experiment in May 29, 2012. The laboratory experiment was made within two days during which the turtles were not fed. For temperature test, the turtles were simultaneously placed in a test container (24 cm x 30 cm x 36 cm, water depth 20 cm) where the gradually increased water temperature was kept constant for 15 minutes at every 1 °C step within the temperature range of 4.1 – 35.3 °C. The turtles were submerged in the water most of the time and could move freely.

Table 1: Regression model ($T_b = a*T_s^b$) between body (T_b) and shell surface temperatures (T_s) recorded from the three individuals of *Trachemys scripta elegans* (WIED, 1838).

	a	b	P-value	R^2	Body mass
Turtles 1-3	1.93	0.84	<0.0001	0.985	
Turtle 1	1.86	0.84	<0.0001	0.991	272.2 g
Turtle 2	2.13	0.82	<0.0001	0.986	476.5 g
Turtle 3	1.81	0.86	<0.0001	0.987	448.2 g

The values of T_b and T_s were recorded at the end of each 15 minutes interval of temperature constancy. Body core temperature (T_b) was measured using internal temperature-sensitive radio transmitters (SOPT-2070; Wildlife Materials, Inc., Murphysboro, Illinois, USA) implanted into the peritoneal cavity, through inguinal access next to the left hind leg, using sterile surgical techniques. Previously, the turtles were locally anesthetized with Propofol (Propovet 10 mg/ml; Esteve Laborarories, Barcelona, Spain) at a dose of 10 mg/kg intravenously in the dorsal coccygeal vein. In SOPT-2070 transmitters, an internal thermistor modulates the interval between signals transmitted depending on the ambient temperature. Therefore, prior to the implantation, each transmitter was calibrated in a water bath (range 1.3 – 35.8 °C) to obtain the empirical relationship between signal interval and temperature. The transmitter signal (frequency range: 150.025 – 150.430 MHz) was detected using a hand-held scanner Albrecht AE65H (ALAN Electronics GmbH, Lütjensee, Germany). A device (self-manufactured at the electronic lab of the University of Koblenz, Germany) connected to the scanner measured the interval between two signals (to the nearest 1 millisecond) as the surrogate of transmitter temperature (= T_b). Intervals were converted to temperature using the regression models obtained before. A digital thermometer (HD 9215, Delta OHM, Caselle di Selvazzano, Italy; precision 0.1 °C) was used to measure shell surface temperature (T_s). The relationship between T_b and T_s was described by fitting 27 regression models provided by the program package Statgraphics 5.1 (Statpoint technologies, Inc., Warrenton, Virginia, USA). The model providing the maximum R^2 was selected.

The results demonstrated a positive correlation between T_b and T_s. The multiplicative regression model ($T_b = a*T_s^b$) showed the best fit between T_b and T_s of the temperatures recorded from the three turtles (Table 1, Fig. 1). Separately, turtles 1, 2 and 3 exhibited similar results. At any time, T_b was higher than T_s and exceeded the shell = water temperature by at least 2.1 °C.

The clear relationship observed between shell and body temperatures in this freshwater turtle suggests that similar correlations apply to most species of freshwater turtle and provides an easy and useful method to study T_b variation using external transmitters without the health risks of a surgical procedure.

These preliminary results achieved under laboratory conditions encouraged the authors to apply the technique in a future study to wild turtles at natural conditions.

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REFERENCES: BROW, G. P. & BROOKS, R. J. (1991): Thermal and behavioral responses to feeding in free-ranging turtles, *Chelydra serpentina*.- Journal of Herpetology, Salt Lake City; 25: 273-278. BULTÉ, G. & BLOUIN-DEMERS, G. (2010): Implications of extreme sexual size dimorphism for thermoregulation in a freshwater turtle.- Oecologia, New York; 162: 313-322. DALL'ANTONIA, L. & LEBBORONI, M. & BENVENUTI, S. & CHELAZZI, G. (2001): Data loggers to monitor activity in wild freshwater turtles.- Ethology Ecology & Evolution, Oxon; 13: 81-88. EDWARDS, A. L. & BLOUIN-DEMERS, G. (2007): Thermoregulation as a function of thermal quality in a northern population of painted turtles, *Chrysemys picta*.- Canadian Journal of Zoology, Ottawa; 85: 526-535. EWERT, M. A. & LANG, J. W. & NELSON, C. E. (2005): Geographic variation in the pattern of temperature-dependent sex determination in the American snapping turtle (*Chelydra serpentina*).- Journal of Zoology, Hoboken; 265: 81-95. GRAYSON, K. L. & DORCAS, M. E. (2004): Seasonal temperature variation in the Painted Turtle (*Chrysemys picta*).- Herpetologica, Emporia; 60: 325-336. HUEY, R. B. (1982): Temperature, physiology, and the ecology of reptiles; pp. 25-91. In: GANS, C. & POUGH, F. H. (eds.): Biology of the Reptilia. Vol. 12, New York (Academic Press). LACHER, T. E. & ALHO, C. J. R. & PEREIRA, I. G. T. (1986): The relation between cloacal temperature and ambient temperature in five species of Brazilian turtles.- Revista Brasileira de Biologia, São Carlos; 46: 563-566. LITZGUS, J. D. & COSTANZO, J. P. & BROOKS, R. J. & LEE, R. E. (1999): Phenology and ecology of hibernation in spotted turtles (*Clemmys guttata*) near the northern limit of their range.- Canadian Journal of Zoology, Ottawa; 77: 1348-1357. MEEK, R. & AVERY, R. A. (1988): Thermoregulation in chelonians.- Herpetological Journal, London; 1: 253-259. NIEUWOLT, P. M. (1996): Movement, activity, and microhabitat selection in the western box turtle, *Terrapene ornata luteola*, in New Mexico.- Herpetologica, Emporia; 52: 487-495. OROMI, N. & SANUY, D. & SINSCH, U. (2010): Thermal ecology of natterjack toads (*Bufo calamita*) in a semiarid landscape.- Journal of Thermal Biology, London; 35: 34-40. SOUZA F. L. & MARTINS, F. I. (2006): Body temperature of free-living freshwater turtles, *Hydromedusa maximiliani* (Testudines, Chelidae).- Amphibia-Reptilia, Leiden; 27: 464-468.

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