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Thermoregulation of the European Pond Turtle, *Emys orbicularis*, in Central Italy

CORINNE DI TRANI[1] AND MARCO A.L. ZUFFI[2,3]

[1]*Parc Zoologique et Botanique de Mulhouse, 51 rue du Jardin Zoologique, 68100 Mulhouse, France;*
[2]*Museo di Storia Naturale e del Territorio, University of Pisa, via Roma 103, 56011 Calci (PI), Italy [Fax: 039-50-937778];*
[3]*Corresponding Author for Reprint Requests*

Thermoregulation in reptiles is a behavioral and physiological strategy principally evolved to achieve desired body temperatures with respect to varying ambient temperatures (see Avery, 1982 and Huey, 1982, for a comprehensive review). In temperate regions, where daily environmental temperatures may be low, heliothermy is an important behavior of most reptilian taxa serving to elevate body temperatures above ambient levels.

Little is known about the thermal ecology of the European pond turtle, *Emys orbicularis*, in Italy (Di Trani, 1989). The range of temperatures of the species' activity has been studied in the laboratory (Cherchi, 1958), but preference for sites where trophic and basking activities can take place has been only partially explored (Capula et al., 1994; Gariboldi and Zuffi, 1994). Reports exist on certain North American emydids by Woolverton (1961), Gibbons (1970), Berry (1975), Waters (1975), Ernst (1986), and Hammond et al. (1988); on a northern African species by Meek (1983); and on European populations of *Emys orbicularis* by Aniola and Kusniak (1969), Servan (1983), Servan and Pieau (1984), Servan et al. (1989), and Naulleau (1991). Boyer (1965) described the relationships between the biological and physical factors of the environment in different species of non-European turtles. Lebboroni and Chelazzi (1991) studied behavior patterns of the European pond turtle in Italy. Nevertheless, little is known about the preferred optimal temperatures of *E. orbicularis* in the field, whether this species thermoregulates actively, under what thermal conditions basking occurs, and how local environmental features may influence the activity of a given population. The present work has been aimed at understanding thermoregulation of *E. orbicularis* in Italy.

Materials and Methods. — Observations of daily activities in turtles were made in 1986 (187 hrs in May–June and August–September) and 1988 (123 hrs in April–July and September) along the Scoglietto–Collelungo canal, in the northwestern Parco Naturale della Maremma, Grosseto, central Italy. Terrestrial vegetation is typical Mediterranean *maquis*. The canal receives drainage waters from the area, but the former connection of the canal with the sea is now closed. Emergent aquatic vegetation in the canal consists mainly of reeds (*Phragmites australis*).

We performed observations from sunrise to sunset, grouping all records in 1-hr intervals. We studied turtles along 825 m of the canal, which averages 4–5 m wide. We subdivided the canal into 33 sectors, each 25 m in length, and classified emergent reeds into three density categories: A) "sparse vegetation," where the distance between two adjacent reeds was greater than 20 cm, covered about 28.6% of the area of 2.5 sectors (62.5 m length, 7.6% of the study canal); B) "intermediate vegetation," where distance between reeds ranged from 10 to 20 cm, covered about 42.9% of the area of 16.5 sectors (412 m length, 50.0% of the area); and C) "thick vegetation," where inter-reed distance was less than 10 cm, covered 71.4% of the area of 14 sectors (350 m length, 42.4% of the area).

We trapped animals along the same side of the canal each year using three methods: a floating trap (Lagler, 1943), hand net collecting, or hand catching. We marked each individual with shell notches (Stubbs et al., 1984), and also numbered it with a bright red marker for short-term recognition. We considered only numbered specimens for thermal ecology analysis. With a Dyalit electronic thermistor (accuracy ±0.1°C), we measured shaded air (at 10 cm), ground, water (at 5 cm depth), and body (cloacal) temperatures of each turtle captured. We also designated all turtles as either "mobile" or "stationary" when caught. We distinguished "movement" from "basking" (sleeping or resting on land or in water). Selected parameters of both years (temperatures, habitat preference, activity) were relatively homogeneous. Only water

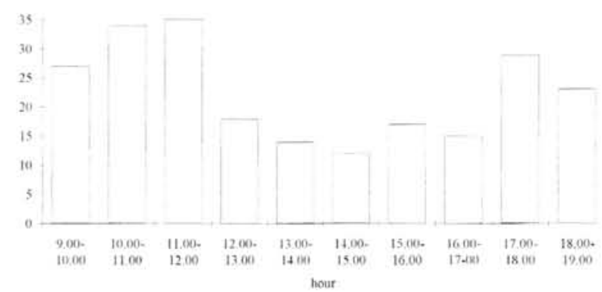

Figure 1A. Hourly frequency of observations in 1986 and 1988 ($n=224$).

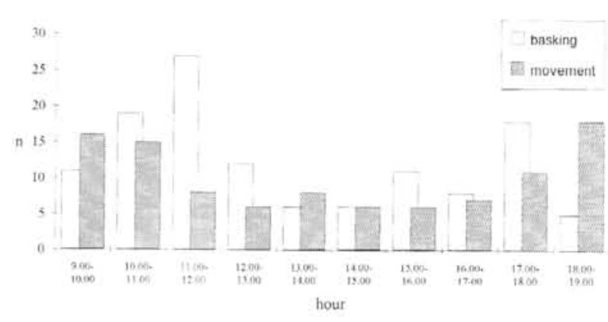

Figure 1B. Hourly frequency of basking vs. movement. Open bars = basking, shaded bars = movement.

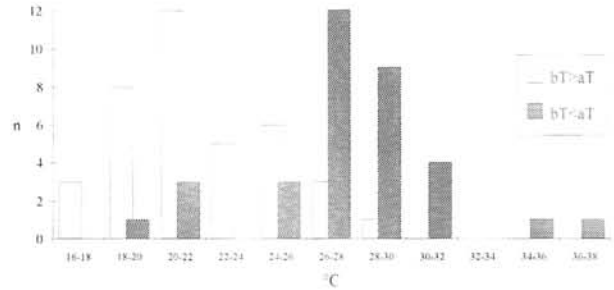

Figure 2. Frequency of body–ambient temperature differences. Open bars = bodyT greater than ambientT ($n = 38$); shaded bars = bodyT less than ambientT ($n = 34$).

temperatures differed slightly with respect to years (Student t-test = 1.7, $p < 0.05$).

In our analyses, we pooled all ecological and behavioral data in both years. All statistical tests (using Statgraphics 4.0; Statgraphics, 1986) were two-tailed, with α set at 0.05, and we used parametric or nonparametric statistics depending on the type of data set (Armitage, 1979; Siegel, 1980, Sokal and Rohlf, 1981).

Results. — The hourly number of observed turtles ($n = 224$) was distributed following a bimodal pattern, with about 42.9% of observations ($n = 96$) from 0900 to 1200 hrs and 23.2% between 1700 to 1900 hrs ($n = 52$) ($\chi^2_{9,18.59} = 28.6$, 8 df, $p < 0.001$; Fig. 1A). Different hourly frequencies of basking (mode at 1100–1200 hrs) vs. movement (mode at 1700–1800 hrs; $n = 123$ and 101, respectively), were not statistically different (Kolmogorov-Smirnov test, $D_{max} = 0.137$, $p > 0.05$; Fig. 1B), suggesting a tendency for turtles to move early in the morning from emergence to basking points and in the afternoon from basking points to night refuges.

Body temperatures in °C (mean ± SE, range; 24.88 ± 0.36, 18.5–31, $n = 80$) were not significantly different from ambient (airT, 24.59 ± 0.48, 17–36, $n = 80$; waterT, 25.31 ± 0.54, 18–36, $n = 60$) (Student $t_{water\text{-}body} = 0.78$, $p = 0.43$; Student $t_{air\text{-}body} = 0.78$, $p = 0.43$). Body and ambient (water and land) temperatures showed a high positive correlation ($y_{land} = 0.80x + 0.61$, $r = 0.78$, $r^2 = 62.3\%$, $F_{land; 1,15} = 26.4$, $p < 0.001$; $y_{water} = 0.68x + 1.01$, $r = 0.86$, $r^2 = 74.8\%$, $F_{water; 1,57} = 171.9$, $p < 0.001$). Body and ambient temperatures did not vary significantly among reed categories (ANOVA, $F_{bodyT; 2,77} = 0.331$, $p = 0.72$; ANOVA, $F_{airT; 2,77} = 0.105$, $p = 0.9$). Below the air temperature range of 24–26°C we found a large proportion of basking turtles with body temperatures significantly higher than that of the air, above this range we found a high proportion of basking turtles with body temperatures significantly lower than that of the air (Kolmogorov-Smirnov test, $D_{max} = 0.689$, $p < 0.001$; Fig. 2) (see also Boyer, 1965). Plotting the difference "bodyT–airT" vs. airT it was shown that consistent differences did exist: the negative regression explained that many specimens increase or decrease their bodyT to reach an optimal thermal range of activity ($y = -0.46 + 11.65x$, $r = -0.66$, $r^2 = 43.9\%$, $F_{1,78} = 61.07$, $p < 0.001$). The comparison of airT frequency of distribution among the three reed categories showed a significant presence of turtles in the B category below 24–26°C and in the C category above 24–26°C ($\chi^2 = 55.4$, 14 df, $p < 0.001$; Fig. 3). No significant presence of turtles was found in the A category below or above the 24–26°C interval.

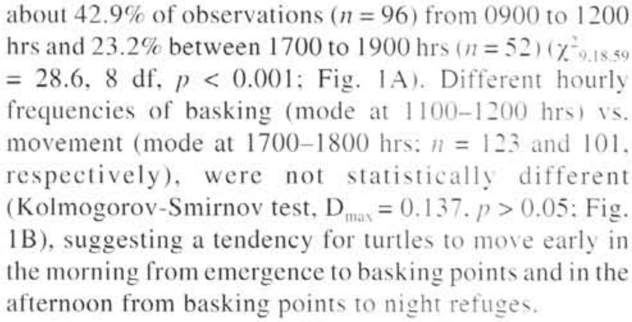

Figure 3. Different use of aquatic vegetation as a function of air temperatures. Open bars = A, sparse vegetation; shaded bars = B, intermediate vegetation; black bars = C, thick vegetation.

Discussion. — The *Emys orbicularis* population displayed, on average, a bimodal pattern of activity. At the study site turtle presence in reed areas was frequently associated with feeding activity, mainly during the mid-day hours (Di Trani, 1989); the presence of pond turtles in high density vegetation areas at air temperatures greater than 24–26°C and in intermediate density vegetation areas at air temperatures lower than 24–26°C (Fig. 3) could be considered a pattern of thermoregulation seeking thermoconformity. This is conceptually similar to the "shuttling" behavior of many desert lizards (Bradshaw, 1986). Movement and thermoregulation did not seem to be dependent on a particular range of temperatures (Boyer, 1965; Shealy, 1976), and basking behavior was probably mainly dependent upon solar radiation (Auth 1975; Waters, 1975; Obbard and Brooks, 1979).

Behavioral basking may have had the secondary purpose of reducing carapacial algal growth (Boyer, 1965; Meek, 1983). Basking facilitates turtles reaching temperatures at which digestion proceeds rapidly (Cagle, 1950) and digestive enzymatic activity is increased (Sturbaum, 1982). The high positive correlation of cloacal–ambient temperatures (Obbard and Brooks, 1979), the significant distribution of body–ambient temperature differences vs. airT (Fig. 2) and the high negative correlation among body–ambient temperature differences vs. airT led us to conclude that *E. orbicularis*, at least in the population studied, was not a stable thermoconformer (*sensu* Bradshaw, 1986). The body and ambient thermal values found were similar to those of *Mauremys caspica* (Meek, 1983) and *Clemmys insculpta* (Ernst, 1986), the strategy adopted being apparently limited heliothermy with a high degree of thermoconformity with ambient temperatures (Edgren and Edgren, 1955; Meek, 1983). The temperature range of 24–26°C may be considered the target zone for daily activities. The observations on habitat use confirmed that the density of aquatic vegetation played a fundamental role in determining the presence or abundance of *Emys orbicularis* (Zuffi and Gariboldi, in prep.).

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Dietary Overlap in Three Sympatric Congeneric Freshwater Turtles (*Pseudemys*) in Florida

KAREN A. BJORNDAL[1,2], ALAN B. BOLTEN[1,2], CYNTHIA J. LAGUEUX[3], AND DALE R. JACKSON[4]

[1]*Archie Carr Center for Sea Turtle Research, University of Florida, Gainesville, Florida 32611 USA [Fax: 352-392-9166; E-mail: kab@zoo.ufl.edu]*; [2]*Department of Zoology, University of Florida, Gainesville, Florida 32611 USA*; [3]*Department of Wildlife Ecology and Conservation, University of Florida, Gainesville, Florida 32611 USA*; [4]*Florida Natural Areas Inventory, The Nature Conservancy, 1018 Thomasville Road, Suite 200-C, Tallahassee, Florida 32303 USA*

Florida has one of the highest species diversities of freshwater emydid turtles in the western hemisphere (Jackson, 1988), and many of these species, particularly in the genus *Pseudemys*, are known to be primarily