Activity and home range of *Testudo hermanni* in Northern Italy

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Abstract. We describe the behavioral adaptations of a population of Hermann's tortoise to the climate of a northern sector of its range, and to a wooded biotope that is uncommon for the species. The activity, the home range, and the thermal relations along the daily and the yearly cycle are described. In contrast to other populations that have bimodal activity peaking in spring and in autumn, the tortoises in our study area had unimodal seasonal activity that can be related to lower summer temperatures. Home range size, 7.4 ha for females and 4.6 ha for males in our study area, was from three to seven times larger than that of all other populations. The large home range, and the low population density of the tortoises in our study area, may be due to food scarcity in the wooded habitat.

Introduction

Reptiles are conditioned by environmental factors, especially temperature that influences their metabolism and activity (Swingland and Fraizer, 1980; Meek and Jayes, 1982; Meek and Avery, 1988; Parmenter and Avery, 1990; Diaz-Paniagua et al., 1995), although most species may also control their body temperature through behavioral and physiological mechanisms (Huey, 1982; Sturbaum, 1982; Gavaud, 1987). Several studies have shown that thermal relations strongly influence the behavior and ecology of Hermann's tortoise *Testudo hermanni* (Hailey et al., 1984; Meek, 1984, 1988; Pulford et al., 1984; Chelazzi and Calzolai, 1986; Panagiota and Valakos, 1992; Carretero et al., 1995; Huot-Daubremont et al., 1996; Huot-Daubremont and Grenot, 1997; Mazzotti and Vallini, 1999). Long-term research on the movement patterns and homing behaviour of Hermann's tortoise (Chelazzi and Francisci, 1979) have shown that these tortoises stay within a stable home range, whose size varies seasonally (Calzolai and Chelazzi, 1991).

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In this paper we describe the activity, the home range, and the thermal relations along the daily and the yearly cycle in a population of Hermann's tortoises. Our study was conducted in one of the northern sectors of its European range, and in a wooded biotope that is not common for this species. Hermann's tortoises live mostly in open habitats, although wooded landscapes are also inhabited, e.g. in Italy and in Southern France. The aim of our study was to elucidate the behavioral adaptations of the tortoises to a peculiar climate and habitat.

Materials and Methods

Study area. This study was carried out in the "Bosco della Mesola" nature reserve, located within the delta of the River Po, in Nort-eastern Italy. This reserve protects a residual coastal forest, of about 1000 ha in surface, growing on ancient coastal dunes. It is a dense holm-oak coppiced wood, with mostly *Quercus ilex* and *Quercus robur* in the upper layer. Open patches of grassland, scattered throughout the wood, and ranging in size from very small to a few hectares, cover about 5% of the surface (Corbetta and Pettener, 1976; Piccoli et al., 1983; Corbetta et al., 1984).

The climate of this study area is characterized by rainy and hot summers, and dry and cold winters. During the study period, annual mean air temperature was 13.6°C, with a mean of the maximum temperatures of 19.2°C and of the minimum temperatures of 8.0°C. The warmest month was August, with a mean of 23.5°C (17.2°C mean of minimum temperatures; 29.8°C mean of maximum temperatures), and the coldest month was December with a mean of 3.6°C (−0.1°C mean of minimum temperatures; 7.4°C mean of maximum temperatures). Annual rainfall averaged 668.5 mm. The highest rainfall occurred in July (84.5 mm), and the lowest in February (4.5 mm).

The original distribution of Hermann's tortoise in Italy has been greatly reduced, particularly in the North-east where a few disjunct populations remain. The "Bosco della Mesola" hosts about 1000 Hermann's tortoises. This population is presently isolated from other neighbor populations, and it is presumably autochtonous, although during the last century specimens from other sites have been released here, a condition common to several Hermann's tortoise populations in Italy. The population structure in our study area is dominated by adults over 20 years old. The sex ratio is close to 1 : 1, and population density was estimated at 0.94 individuals/ha (Mazzotti and Vallini, 1996).

Methods. Field work was carried out from April to October 1997, and from March to October 1998. The tortoises were methodically searched for, and captured, in the two major open patches within the forest, with a surface of 37.8 ha and 37.5 ha respectively. Search was carried out for 2-7 days in each month. Each captured tortoise was marked according to Stubbs et al. (1984), and the following data were recorded: date, time (European Standard Time, one hour after Greenwich), site characteristics, weight, straight carapace length and width, body temperature, and behavior when first sighted and undisturbed. The temperature of the tortoise, and of soil at the point of capture, were measured using a digital device, with the probe inserted 3 cm into the cloaca, and 1 cm into the soil, respectively. The observed behaviors were classified in seven categories, in partial accordance with Huot-Daubremont et al. (1996): "immobile" hidden in the ground, in a hole or beneath vegetation; "quiet" not moving but uncovered under shadow; "moving" during locomotion; "basking" immobile under sun light; "feeding" browsing on vegetation; "reproduction" engaged in sexual behavior; "oviposition" nest excavation or egg laying. Air temperature was recorded hourly using a mercury thermometer located in a shaded place.

From March to October 1998, eight tortoises (3 females and 5 males) were equipped with radio transmitters, and once per each day of fieldwork their individual position was recorded using a receiver connected to Yagi antenna. Every time a radio-tracked tortoise was located, we collected the same data on temperature and behavior as for the captured tortoises. Fixes were taken weekly and were plotted on the map (1 : 1000) of the study area. We obtained 438 fixes (163 for females, 275 for males). The locations of each animal were analyzed using RANGESV software, and the distance traveled and the home range size (convex polygon) were computed (McDonald et al., 1980).

A time budget calculated simply from the behavior of the captured tortoises would be biased, because the frequency of inconspicuous behaviors such as "immobile" would certainly be underestimated, while other behaviors such as "basking" would be overestimated. To avoid such bias, we multiplied the behavior frequencies of the tortoises observed during the captures, by coefficients calculated as: ratio between the frequency of each behavior in radio-tracked tortoises, and the frequency of the same behavior in the tortoises observed during captures. Such coefficients, based on the assumption that the behavior frequency of radio-tracked tortoises was unbiased, were aimed to correct for the differential conspicuousness of each behavior. From these corrected frequencies, we calculated the diel and seasonal activity budget, by assigning to each activity a time proportional to the corrected behavioral frequencies. Seasonal activity was characterized in four periods, according to Cheylan (1981) and Hout-Daubremount and Grenot (1996): "post-hibernation" from March to April; "spring" from May to June; "summer" from July to August; and "pre-hibernation" from September to October.

Results

During the two years of study, we captured for the first time and marked 320 tortoises (155 females and 144 males), and we performed 1260 recaptures of marked individuals. The mean straight carapace length of the tortoises older than 14 years was 184.4 mm ($s = 12.1$) in females, and 162.2 mm ($s = 9.3$) in males, while their body mass averaged 1194.5 g ($s = 224.3$) and 851.8 ($s = 162.7$) g respectively.

The behaviors varied in relation to the season and to the time of day. Basking prevailed in every month (fig. 1). Active behaviors were more frequent from April to August; moving prevailed from May to July, while feeding peaked in May, and reproduction was displayed mostly in July. During post-hibernation, males were active earlier than females in the morning hours (fig. 2). During this period, the frequency of active behaviors was lower than in later periods, and the tortoises were prevalently inactive, immobile or quiet. Active

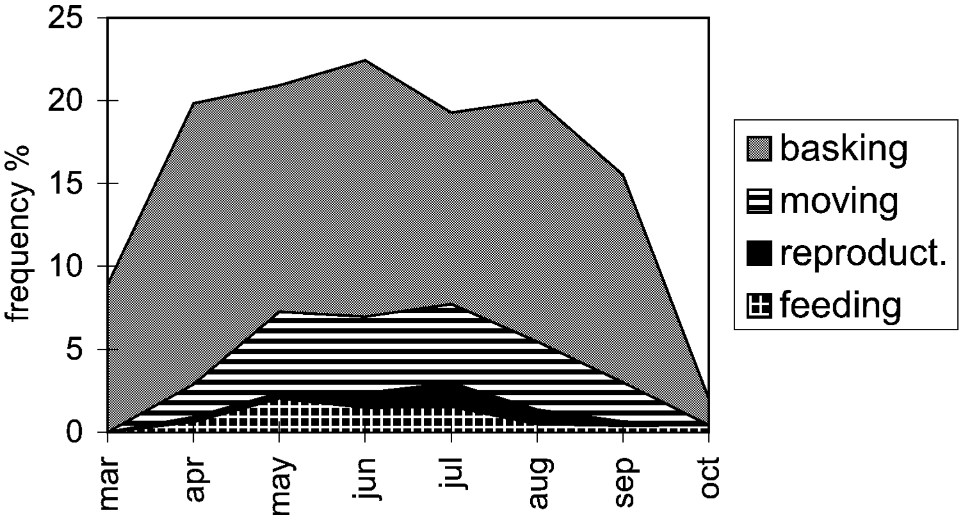

Figure 1. Monthly variation in the frequency of the main active behaviors.

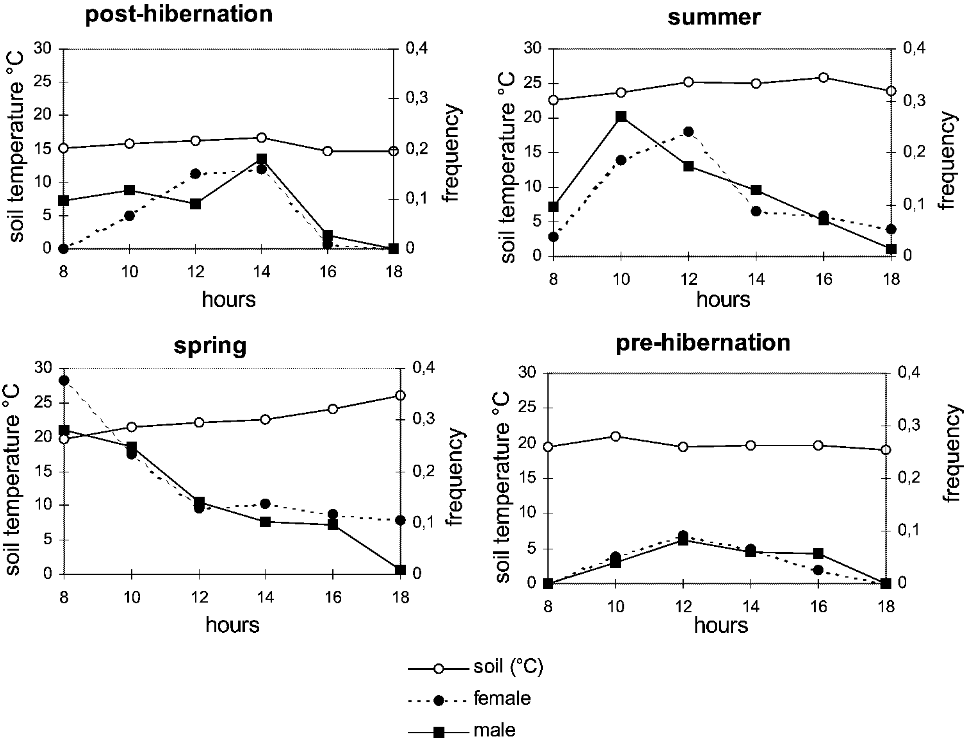

Figure 2. Daily variation in the frequency of active behaviors (moving, basking, feeding, reproduction, and oviposition) of males and of females, and soil temperature, during the four seasonal periods.

Table 1. Body temperature, and soil temperature in the four seasonal periods (mean temperature in °C ± standard deviation, number of individuals), and significance of the difference between sexes (P values, Student's t test).

	Post-hibernation	Spring	Summer	Pre-hibernation
Females	18.7 ± 6.3, 62	26.9 ± 5.6, 354	26.9 ± 4.5, 183	19.8 ± 3.3, 53
Males	19.2 ± 7.3, 80	27.8 ± 5.4, 294	27.8 ± 4.3, 330	20.8 ± 4.3, 125
Soil	13.9	21.0	24.3	18.6
Difference between sexes	$P = 0.51$	$P = 0.01$	$P = 0.05$	$P = 0.10$

behaviors peaked in spring, when the tortoises were already active in early morning, with mean soil temperature at 19.7°C, while activity slowed progressively during the day. In summer, the diel activity peaked from 9 to 10 for males with mean soil temperature at 23.6°C, and from 11 to 12 for females with temperature at 25.2°C. In pre-hibernation period, activity was low and lasted only from 10 to 16 with a mean soil temperature at about 20°C.

Body temperature was at its low during the post-hibernation period, remained high and similar during spring and summer, and declined in autumn (table 1). Body temperature of

Table 2. Body temperatures in relation to behavior (°C), mean over the entire study period.

	Immobile	Quiet	Moving	Basking	Feeding	Reproduction	Oviposition
Post-hibernation							
females	16.1	19.5	27.9	20.2			
males	14.5	17.8	24.7	24.0			
Spring							
females	25.4	26.5	28.4	25.2	30.9	29.8	32.7
males	25.0	28.1	29.4	27.2	30.9	31.0	
Summer							
females	25.1	27.5	29.6	27.6	28.4	28.2	
males	24.8	29.0	29.9	27.1	31.1	29.6	
Pre-hibernation							
females	17.8	18.9	23.0	22.8			
males	18.6	22.5	25.6	23.2			

Table 3. Distance between locations in consecutive days, and home range size.

	Daily distance (m)				Home-range size mean, min-max (in ha)
	Post-hibernation	Spring	Summer	Pre-hibernation	
Females					
mean	39.3	87.6	99.8	31.5	7.4, 1.6-10.8
s	22.7	50.6	57.6	18.2	4.3
Males					
mean	39.3	57.1	60.1	32.3	4.6, 2.1-8.0
s	17.6	25.5	26.9	14.5	2.0

males was constantly higher, by 0.5-1°C, than that of the females, but the difference was significant only for spring and summer (table 1).

Tortoise temperatures differed in relation to behavior (table 2). Immobile tortoises had the lowest temperatures, especially during post- and pre-hibernation periods. Temperature increased in the following order: quiet, basking, moving, reproducing, and feeding tortoises. The highest values were observed in the tortoises that were engaged in oviposition, with temperatures ranging from 23.1 to 37.9°C. The temperatures of males and of females were generally similar, but significantly higher temperatures were recorded for males basking during post-hibernation ($t = 2.33$, $P < 0.024$) and during spring ($t = 2.89$, $P < 0.004$), and for males feeding in summer ($t = 2.75$, $P < 0.009$).

Throughout the year, the distance between the location of a tortoise in consecutive days averaged 64.6 m ($s = 25.1$) in females and 47.2 m ($s = 10.9$) in males. The home range size was larger for the females than for the males (table 3), although the number of radio-tracked individuals is too small for a statistical test. Longer daily distances were covered in spring and summer, while movement was greatly reduced during post- and pre-hibernation periods (table 3). A significant difference was found between the distances of the post-hibernation and of the summer periods (Wilcoxon rank test $T = 2$, $P < 0.05$), of spring and pre-hibernation periods ($T = 0$, $P < 0.02$), and of summer and pre-hibernation ($T = 0$, $P < 0.02$).

During post-hibernation, 75% of females and 61% of males were found in open patches, that were mainly used in spring as well. In summer, habitat use differed with sex: less females (54%) used open patches, while more males (79%) did.

Discussion

The unimodal seasonal activity of Hermann's tortoise in our study area differed from that of all other studied populations, that have bimodal activity with peaks in spring and in autumn. The lower summer activity of the other populations can be related to high environmental temperatures (Cheylan, 1981; Hailey et al., 1984; Swingland and Stubbs, 1985; Meek, 1988; Huot-Daubremont, 1996). On the other hand, the relatively northern location, and the peculiar wooded habitat of our study area, mitigate summer temperatures and presumably determine the unimodal activity.

The tortoise body size in our study area was considerably larger, on average by 17.2% in body length for females, and by 18,4% for males than in Sicily (Tomasetti, 1997), in Tuscany (Paglione and Carbone, 1990), in France and Greece (Swingland and Stubbs, 1985). More than 90% of several thousand Hermann's tortoises measured by Willemsen and Hailey (1999) throughout Greece were smaller than in our study area. This larger size may be favorable in the relatively colder climate of our study area (Gregory, 1982). The difference in body size between females and males may be related to their differences in body temperature and in seasonal activity (Meek, 1988; Diaz-Paniagua, 1995). Females, bigger than males, require more time for warming but retain temperature longer, and this may delay the onset, and extend the end, of their daily activity.

Generally males have a higher body temperature than females, as observed also by Hailey et al. (1984), Panagiota and Valakos (1992), Carretero et al. (1995) and Huot-Daubremont (1996). In our study area these differences were statistically significant only in spring and summer and in particular during basking and feeding. The lower temperatures were observed in inactive tortoises, immobile or basking, while higher temperatures were associated with active behaviors, moving, feeding, reproduction (Sturbaum, 1982).

The home range size of Hermann's tortoise in our study area, 7.4 ha for females and 4.6 ha for males, was larger by three to seven times than home ranges of other populations studied using similar methods: 1.6 ha for females and 2.4 ha for males in a population living in a densely wooded area of Southern France (Swingland et al., 1986); 2.4 ha for females and 1.2 ha for males for adults in a coastal area of Greece (Hailey, 1989); 1.5 ha for females and 0.7 for males (Calzolai and Chelazzi, 1991); between 0.3 and 2.2 ha for tortoises in a wooded area of Southern France (Huot-Daubremont, 1996) and from 0.9 to 4.2 ha for females and from 1.7 to 3.3 ha for males (Bossuto et al., 2000) in Central Italy.

The remarkably large home range in our study area may be due to its peculiar habitat, dense oak wood with underwood producing scarce food, and with herbaceous vegetation abundant only in the small open patches. Another effect of the habitat may be the lower tortoise population density, of the order of 1 individual/ha in our study area, while in Southern France where home ranges were smaller, tortoise density was >10/ha (Stubbs and Swingland, 1985). A relatively poor habitat may determine both a low density and a large home range of the tortoises in our study area.

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