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Contribution to the knowledge of spatial movements of adult Hermann's tortoises

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Abstract: We recorded the movements of adult Eastern Hermann's tortoises (*Testudo hermanni boettgeri*) in a local population situated in a complex forested habitat system. The average total movement range size (TMRS) calculated over three consecutive years was 4.56 ha and 7.53 ha for males and females, respectively. The largest estimated TMRS of male and female tortoises was 27 ha and 90 ha, respectively. Six females and three males (or 9% and 4%, respectively, of the overall sample) had a movement range size (MRS) greater than 10 ha. Significant differences between male and female MRS were not detected. Body size had no influence on the MRS of individuals in the sample, except on the core movement range size (CMRS) in males. Although the collected data did not enable calculation of the home range in the studied population, the results indicate that the calculated average TMRS of local Hermann tortoises is larger than the average home range in some other populations. Therefore, in the absence of information on the home range size of local adult tortoises, the MRS could be a suitable alternative for planning local species reserves.

Key words: adult tortoises; habitat system; movement range; spatial movements; *Testudo hermanni boettgeri*

INTRODUCTION

The role of dispersal (as an important aspect of life-history) in the evolution of a species is reflected in colonization and the establishment of new populations, in maintaining out-breeding (in sexual species), and in enhancing individual survival through the active choice of a more suitable environment [1]. Animal ecologists recognize two types of dispersal – dispersal in a narrow sense, and migration, which they define as "the movements of individuals away from their source" [2]. Additionally, the outcomes of dispersal may vary among individuals in the same population [3]. Those dispersing over larger distances contribute to the colonization of new space and to overall range expansion. Moreover, different dispersal capacities of males and females, if they exist, lead to sex-biased dispersal [4]. Reliable knowledge on all aspects of dispersal capacity of an endangered species is required for setting up protected areas [5,6]. The larger the dispersal, the more likely it is for individuals to frequently move beyond their refugia, if these areas do not meet the minimal required size for the species.

Hermann's tortoise is a European species with a declining population trend in many parts of its current range; its IUCN conservation status is "near threatened" and overall population trend is declining [7]. The species has been exposed to intensive anthropogenic pressure [8]. Aside from habitat fragmentation and degradation and over-collecting, new threats have been recognized in countries facing economic transition, and they include the intensification of transport with consequent road-kills [9-12], as well as application of modern agricultural practices with intensive use of agrochemicals [13]. It has become clear that the continual change in anthropogenic habitats jeopardizes the future survival of Hermann's tortoise [10]. Thus, efficient conservation of this species must include a proper design of reserves, which should be incorporated into sustainable management strategies in forestry and agriculture. Moreover, appropriate

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knowledge on the dispersal capacity of local population must be acquired.

Two subspecies of Hermann's tortoise are currently recognized: the western subspecies *T. hermanni hermanni* inhabits parts of Spain, France and Italy, while the eastern subspecies *T. hermanni boettgeri* is distributed in Croatia, Bosnia and Herzegovina, Montenegro, Albania, Serbia, FYRM, Romania, Bulgaria, Greece and Turkey [14]. We recorded the movements of Eastern Hermann's tortoises during spring and summer in the period 2010-2012, within an experimental area in southeastern Serbia. Our initial hypothesis was that during these two seasons local male Hermann's tortoises could have a larger MRS than females due to reproductive activities (e.g. active search for mates), although literature data mostly showed an equal MRS for both sexes [15-19]. Moreover, we assumed that within a gender, larger and heavier tortoises could have a larger CMRS and TMRS in comparison to smaller animals, as large individuals need to have more energy to invest in movement [20]. Our aim was to examine whether the tortoises from the analyzed population have a larger MRS than their more southern counterparts (in Spain, France, central and southern Italy, Greece), and a smaller MRS in comparison to northern populations in Romania or northern Italy [21].

MATERIAL AND METHODS

Species and study site

Analysis was conducted in the hilly area of village Kunovica (43°18'N; 22°04'E; 324 - 462 m altitude), 17 km east of the city of Niš (Fig. 1). The study area was a complex habitat system, dominated by deciduous forests of *Quercetum farnetto-cerris* [22], but partially degraded into meadows, orchards and vineyards. Most of them have been abandoned and are overgrown by primary vegetation. However, some orchards and vineyards have been actively exploited. More details on the study site are presented in [23]. Repeated records of adult *Testudo hermanni* individuals were regularly collected from 2010 to 2012 during the last week of May and third week of July within a 23-ha experimental study area. During all visits, the same number of working days and the same daily routine were dedicated to data sampling, with the same number of researchers. The reproductive activities of tortoises, including courtship and egg-laying, were recorded in both seasons.

Data collection

General information on the procedure of collecting data was previously described in [23]. Researchers recorded the geographic coordinates at spots where

Fig. 1. The study area. The map was constructed via Google Earth. The white line borders the area where monitoring was conducted. Dots – nearest human settlements (Prosek, Manastir, Jelašnica and Kunovica) which are a part of the Niška Banja community of the city of Niš

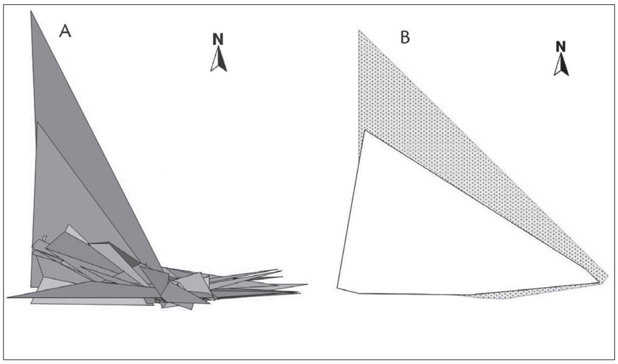

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Table 1. Descriptive statistics for the minimum convex polygon describing 50%, 95% and 100% size of the obtained movement area in adult male and female Hermann's tortoises from Kunovica.

MRS	N	M	S.E.	Min	Max
Males					
100%	27	4.56	1.37	0.02	27.41
95%	27	4.56	1.37	0.02	27.41
50%	27	0.02	0.009	0.0004	0.23
Females					
100%	41	7.53	2.54	0.04	90.07
95%	41	7.45	2.54	0.04	90.07
50%	41	0.06	0.02	0.0004	0.76

N – sample size; M – mean (ha), S.E. – standard error of mean; Min and Max – the smallest and largest MRS (ha) in a sample, respectively.

individual tortoises were located by a Garmin-E-Trex Vista handheld GPS device with 2-m precision. At first capture, the tortoises were permanently marked by shell notching and their unique numbers were recorded in individual protocols together with the data on straight carapace length (SCL) and body mass (BM) [23]. During subsequent encounters labelled individuals were recognized by their unique marks. Only adult tortoises were included in the analysis as they represent the majority (79%) of the overall sample. Tortoises recaptured less than four times were excluded from further analysis. As a polygon cannot be created with less than three input points, we considered it uninformative and therefore defined four input points as the minimum.

Statistical analyses

We calculated the hypothetical MRS of individual tortoises using Ranges 7 software [24]. This software enables different types of spatial analyses by radio tracking or GPS data, from home range or dispersal to the frequency of specific habitat use and social arrangement of individuals. Input data were the longitude and latitude coordinates of individual records – locations, transformed into decimal degrees. The minimum convex polygon (MCP) method was chosen to calculate 50%, 95% and 100% of the obtained movement area (designated as MCP50%, MCP95% and MCP100%, respectively). The normal distribution of the obtained MRS values was tested separately for males and females by Kolmogorov-Smirnov and Lilliefors tests. Since the distribution of original data was non-normal, a log10 transformation was applied. As described in [25], we checked the occurrence and direction of correlation between the MRS and the number of locations, as well as between the MRS and the timespan (one, two or three years) during which a particular tortoise was recaptured. Analysis was done by Pearson product-moment correlation, separately for males and females. General linear model (GLM) analysis was used for testing intersexual differences in variations of MRS. Multiple regression with MRS as the dependent variable and SCL and BM as predictor variables was performed separately for males and females to examine the relations between body size and hypothetical MRS. All analyses were performed using Statistica 7.0 software.

RESULTS

Movement range size (MRS) within the experimental area was calculated for 68 adult tortoises – 41 females and 27 males. An average 100% or TMRS was estimated as 4.56 ha and 7.53 ha for males and females, respectively (Table 1). The average CMRS (50%) was estimated as 0.02 ha and 0.06 ha for males and females, respectively. The maximal estimated CMRS for females was 0.76 ha and 0.23 ha for males. Minimal CMRS was the same in both sexes – 0.004 ha. The maximal TMRS of male and female tortoises was 27 ha and 90 ha, respectively. Six females and three males (or 9% and 4% of the overall sample, respectively) had TMRS larger than 10 ha. The surfaces of individual polygons created by connecting the geographic coordinates of recapture points for every tortoise analyzed

Table 2. GLM analysis of MRS in adult Hermann's tortoises from Kunovica with log10MRS as dependent variable and sex as a factor.

Effect	SS	df	MS	F	p
log_{10} (100% MRS)					
Slope	**5.19**	1	**5.19**	**9.80**	**0.003**
Sex	1.32	66	1.32	2.50	0.12
Error	34.98		0.53		
log_{10}(95%MRS)					
Slope	**4.84**	**1**	**4.84**	**9.06**	**0.004**
Sex	1.15	1	1.15	2.15	0.15
Error	35.31	66	0.54		
log_{10} (50% MRS)					
Slope	**290.43**	**1**	**290.43**	**523.20**	**0.000**
Sex	1.94	1	1.94	3.50	0.07
Error	36.64	66	0.56		

SS –sum of squares, MS – mean squares, df – degrees of freedom, F – F-ratio, p – significance.

Table 3. Multiple regression analysis performed on adult male and female Hermann's tortoises analyzed in this study, with MRS as a dependent variable and SCL and BM as independent predictor variables.

	B	S.E.$_\beta$	B	S.E.$_B$	t(23)	p
log_{10} (100% MRS)						
MALES						
Slope			-16.34	19.37	-0.84	0.41
log_{10}SCL	0.69	0.55	18.43	14.60	1.26	0.22
log_{10}BM	-0.81	0.52	-8.26	5.22	-1.58	0.13
FEMALES						
Slope			20.39	12.39	1.65	0.11
log_{10}SCL	-0.44	0.31	-11.95	8.36	-1.43	0.16
log_{10}BM	0.29	0.31	2.58	2.78	0.93	0.36
log_{10}(95% MRS)						
MALES						
Slope			-16.34	19.37	-0.84	0.41
log_{10}SCL	0.69	0.55	18.43	14.60	1.26	0.22
log_{10}BM	-0.81	0.52	-8.26	5.22	-1.58	0.13
FEMALES						
Slope			23.30	12.43	1.87	0.07
log_{10}SCL	-0.50	0.31	-13.66	8.40	-1.63	0.11
log_{10}BM	0.32	0.31	2.88	2.79	1.03	0.31
log_{10} (50% MRS)						
MALES						
Slope			-27.24	14.25	-1.91	0.07
log_{10}SCL	**1.16**	**0.53**	**23.56**	**10.76**	**2.19**	**0.04**
log_{10}BM	**-1.19**	**0.50**	**-9.19**	**3.84**	**-2.39**	**0.02**
FEMALES						
Slope			-4.41	15.62	-0.28	0.78
log_{10}SCL	-0.007	0.32	-0.24	10.54	-0.02	0.98
log_{10}BM	0.11	0.32	1.25	3.50	0.36	0.72

Parameters having statistically significant p values are bold.

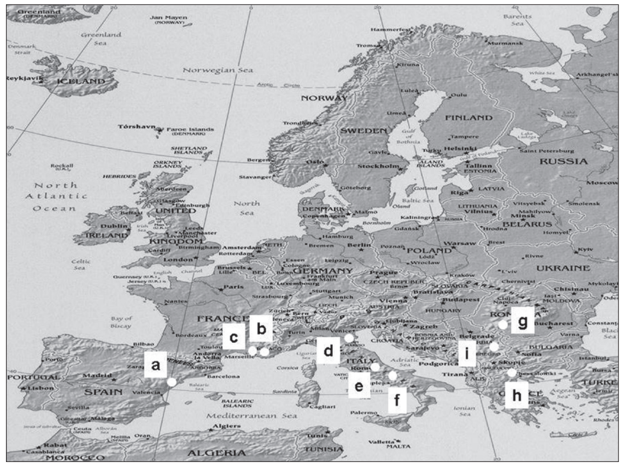

Fig. 3. Map of the localities listed in Table 4 (for a-h. see the legend for Table 4.); i – Serbia (Kunovica).

in this study are presented in Fig. 2A. The surfaces of pooled recapture points created separately for males and females are presented on Fig. 2B. There was a positive correlation between the number of locations recorded and the tortoises' MCP50% for both males (r=0.58, p=0.02) and females (r=0.37, p=0.02). The timespan between recaptures was correlated to the number of locations in females only (r=0.56, p<0.001).

The GLM analysis performed on log-transformed MRS revealed the absence of differences in variation between sexes (Table 2). Additionally, there was no relation between the body size of the females and the size of their area of activity (Table 3), while positive and negative partial correlations of SCL and BM, respectively, to the CMRS of males (p<0.05 for both relations) were detected.

Females with larger CMRS also had larger TMRS (MCP50&MCP95:Pearson r=0.55, p<0.001; MCP50&MCP100:Pearson r=0.51, p=0.001; MCP95&MCP100:Pearson r=0.98, p<0.001). Similar result was obtained for males (MCP50&MCP95:Pearson r=0.55, p=0.003; MCP50&MCP100: Pearson r=0.55, p=0.003; MCP95&MCP100:Pearson r=1.00).

The literature data presenting variations in range size in adult Hermann's tortoises across the distribution area (Fig. 3) are summarized in Table 4. The average values of range sizes at all localities in Table 4 varied from 1.2 ha to 4.6 ha in males, and from 1.8 ha to 7.5 ha in females.

Table 4. Overview of range sizes for different populations of Hermann's tortoise in Europe.

COUNTRY	LAT	LON	HABITAT	TRACKING PERIOD	100%RS	
					M_{av}	F_{av}
(a) SPAIN [18]						
Parc Natural del Delta del Ebre	40°N	00°E	Dune	Annual/ 1991-2001	2.7	1.8
(b) FRANCE [17]						
Var	43°N	06°E	Forest	Weekly/June 1998	1.2	2.1
(c) FRANCE [25]						
Massif des Maures	43°N	05°E	Forest	Annual *	1.6	2.4
(d) ITALY [21]						
Bosco de la Mesola	44°N	12°E	Forest	Annual/ April-October 1997 and May-October 1998	4.6	7.4
(e) ITALY [16]						
Central Italy	42 °N	11°E	Dry heath vegetation	Annual May 1979-April 1980	0.7	1.5
(f) ITALY [26]						
Molise	41°N	14°E	Forest	Annual 2004-2005	1.5	1.9
(g) ROMANIA [19]						
Iron Gate	44°N	21°E	Complex habitat system	Annual/2005-2008	3.0	4.2
(h) GREECE [15]						
Alyki	40°N	22°E	Dry heath vegetation	Annual	1.2	2.4
				April 1986	0.6	0.7
				May 1986	0.5	0.4
				June 1986	0.3	0.4
				July 1985	0.2	0.3
				August 1985	0.4	0.6
				August 1986	0.5	0.5
				September 1985	0.3	0.1
				October 1985	0.2	0.2

LAT – approximate latitude in degrees; LON – approximate longitude in degrees; RS – range size in hectares; Mav – mean value of RS in males; Fav – mean value of RS in females; * – no data

DISCUSSION

Our analyses showed that a longer period of recapture was accompanied by a higher number of recaptures in female tortoises. Moreover, a higher number of recaptures was related to a larger CMRS in both sexes. Therefore, we took into consideration only TMRS for analysis as it was unbiased by either the number of locations or the timespan of recording recaptures.

The TMRS value was higher in the analyzed females than in males, but overall gender differences were not statistically significant. In a number of studies on home range size in Hermann's tortoises throughout the distribution area [15-19] gender differences were not detected; however, opposite results have been reported [21,25,26]. Also, [19] reported a different extent of tortoise movements at a monthly rate, but the authors did not detect gender differences in the annual home range size when analyzing year-by-year and when performing inter-seasonal comparisons. In [15], the authors confirmed that in Alyki (northwestern Greece), at least during summer, adult Hermann's tortoises of opposite sexes had different home ranges. In [27] the authors provided more general information on the affinity toward dispersion in Hermann's tortoise; namely, some individuals utilized specific microhabitats (and consequently had small home range sizes), while others were more opportunistic and thus had even three to four times larger home ranges. In a previous study [19] it was suggested that home ranges in tortoises can be of similar size in both sexes under conditions where complex habitat systems provide access to diverse habitat types throughout the entire year and to all individuals. This explanation could also be applied to the movements of adult tortoises in our study, or at least during the mating season when our study was conducted.

In a habitat system similar to ours, the correlation between body size and range size in adult tortoises was not detected in females; however, it occurred in males to some extent [19]. The absence of correlation between body size and TMRS was confirmed in our study for the analyzed parts of spring and summer. Our results suggest that smaller males could have larger CMRS, at least during the reproductive period. Nonetheless, this could be a biased estimate since the analysis showed a dependence of male CMRS on the number of locations recorded.

The mean TMRS of adult Hermann's tortoises in our study was close to the estimate of the annual home range in a population from northern Italy [21]. The authors explained the relatively large movement areas of local Hermann's tortoises as the consequence of suboptimal environmental conditions, e.g. a forested habitat and relatively low ambient temperatures, resulting in a low population density. In contrast, the population from Kunovica was considered to be in good condition compared to some adjacent localities, e.g. it had a higher density than the population inhabiting the more open, shrubby habitat in southern Serbia [23]. Several authors [17,19,25] have claimed that the relatively high average TMRS values for Hermann's tortoises inhabiting local predominantly forested habitats with optimal conditions are due to the complex structure of the landscape.

The aim of this study was to obtain insight into the extent of movements of adult individuals within a defined study area during a particular part of the year when the expected movement of the animals is high due to reproductive activities. Although the collected data did not allow for the calculation of the home range, we acquired an indication that the movements of local tortoises could be larger than in populations from other parts of the distribution area and similar in size to the estimated home range in one of the northernmost populations. If we consider the knowledge on species dispersal as important to the planning of future conservation actions, then the results of this study could be valuable in defining the sizes of local reserves for Eastern Hermann's tortoise [28].

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