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Activity patterns and habitat preference of eastern Hermann's tortoise (*Testudo hermanni boettgeri*) in Serbia

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Abstract: We analyzed variation in the distribution of eastern Hermann's tortoise (*Testudo hermanni boettgeri*) in a complex landscape consisting of both natural and human-altered habitats in a temperate climate region in Serbia. Our results indicated nonrandom distribution of tortoises within different habitat types with large and medium effect size for year and activity pattern, respectively. Additionally, the tortoises expressed relatively weak preference for habitats modified by human activity (e.g., vineyards, orchards, or gardens). The results suggested that these tortoises preferred some particular habitats more than others when performing specific activities. They also did not exhibit the same distribution pattern among habitats over consequent years. In other words, they were not randomly distributed among habitat types with regard to specific activity or year. The information on preferences in complex habitat systems is important for the conservation management of eastern Hermann's tortoise and should be considered when planning activities related to sustainable development within the region of study.

Key words: Activity patterns, habitat type, *Testudo hermanni boettgeri*, complex environment

1. Introduction

Tortoises inhabit a wide variety of habitats and show diverse activity patterns, dispersal abilities, and home ranges, with variability occurring from species to populations, age classes, sex, and seasons (Pough et al., 2004). Among three tortoise species occurring in Europe (*Testudo hermanni*, *T. graeca*, and *T. marginata*), Hermann's tortoise has the largest regional distribution area (Gasc et al., 1997; Sillero et al., 2014): the western subspecies, *T. hermanni hermanni*, inhabits parts of the Italian Peninsula, Sardinia, Sicily, Corsica, Provence, the Balearic islands, and the Massif of Alberes, while the eastern subspecies, *T. hermanni boettgeri*, occupies parts of the Balkan Peninsula, including a number of islands in the eastern Mediterranean region (Fritz et al., 2006) and European Thrace in Turkey (Türkozan et al., 2005). Hermann's tortoise has a regular activity break in winter, which is shorter in the semiarid Mediterranean part of the distribution area (October/November to February/March) (Willemsen, 1991; Huot-Daubremont and Grenot, 1997) than in more temperate climate areas (October to March/April) (Haxhiu, 1995; Mazzotti et al., 2002). In summer, Hermann's tortoises in the Mediterranean area have bimodal daily activity while in the temperate region they tend to be active throughout the day (Cruce and Răducan, 1976; Hailey et al., 1984; Meek, 1988), except in extremely high daily temperatures (Willemsen, 1990; also Stojadinović and Crnobrnja-Isailović's unpublished data).

It is obvious that activity patterns of Hermann's tortoises are constrained by local habitat composition in some parts of the distribution area. The preferred habitat for *T. hermanni* is described as "open patchy evergreen Mediterranean oak forest" (van Dijk et al., 2004), but a number of studies suggested spatial variation in habitat preferences within the distribution range of the species (Wright et al., 1987; Longepierre et al., 2001; Corti and Zuffi, 2003; Rugiero and Luiselli, 2006; Corti et al., 2013; Rozylowicz and Popescu, 2013; Berardo et al., 2015): in the western part of the distribution area, Hermann's tortoises were frequently recorded in maquis with *Pinus* sp. and *Quercus* sp.; in coastal heathland, coastal forests, and coastal dunes; and in inland temperate grasslands, shrubs, and forests dominated by *Quercus* sp., *Carpinus* sp., and rarely *Fagus* sp. Artificial habitats such as pastureland and rural gardens are considered marginal (van Dijk et al., 2004). Few studies have been done so far in the eastern

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part of the species range (Cruce and Răducan, 1976; Rozylowicz and Dobre, 2010; Rozylowicz and Popescu, 2013), but they suggested that complex habitat matrices harbor relatively dense tortoise populations due to (still) low human impact, e.g., modest alteration of primary habitats (traditional farming).

Hermann's tortoise is considered Near Threatened due to its fragile population status in many places, e.g., declining population size (Rozylowicz and Dobre, 2010). Habitat fragmentation and degradation is at the top of the list of threatening factors that jeopardize the species (Swingland and Klemens, 1989; Fernández-Chacón et al., 2011), although overexploitation cannot be neglected (Türkozan and Kiremit, 2007; Ljubisavljević et al., 2011; Celse et al., 2014). In the eastern part of the distribution range, most of the countries are currently facing transitions whereby economic development in the area could come into the conflict with the conservation of indigenous wildlife because of conversion of pristine habitats into intensively exploited agricultural land (Rozylowicz and Dobre, 2010; Celse et al., 2014). It is possible to reach a compromise if ecological preferences of wild species are identified.

In line with this, we analyzed one population located in the Republic of Serbia where habitat loss, fragmentation, and degradation are considered to be far less intense than in the western part of the species' area (Celse et al., 2014; Ljubisavljević et al., 2014). Our aim was to check following assumptions: first, that eastern Hermann's tortoises in this part of the distribution range prefer specific habitats for specific activities; second, that significant correlations occur between ambient temperatures and variables selected for the study; third, that there are sex- or age-specific preferences for a particular habitat type. Additionally, we compared the habitat preference of Hermann's tortoises in our study area with literature data to check for regional variations in the eastern part of the species range.

2. Materials and methods

2.1. The study site

Regular monitoring of Hermann's tortoises took place every year in spring and summer from 2010 to 2014 in the area around the village of Kunovica, which administratively belongs to Niška Banja County, a suburban part of the city of Niš. It is a hilly landscape with elevations ranging from 309 to 621 m above sea level, dominated by oak woodlands of *Quercetum farnetto-cerris* (Ranđelović et al., 1996). The field site of 23 ha is part of the Jelašnica Gorge nature reserve and is situated between Jelašnica and Kunovica villages. The district of Kunovica represents a mixture of pristine and rather abandoned human-altered habitats, where forests, pastures and fields, and agricultural land occupy 58%, 16%, and 25% of the total space, respectively (Turnšek, 2006). More details on the field locality were presented by Stojadinović et al. (2013). The two important prerequisites for the choice of study population were adequate population density (Stojadinović et al., 2013) and easy access to the field site.

2.2. Field procedures

The temporal dynamics of monitoring included two visits per year, always in the last week of May (considered to be spring in the analysis) and in the third week of July (considered as summer). On every visit, researchers spent 7 consecutive days searching for tortoises using a visual encounter survey method. They recorded activity of Hermann's tortoises from 0800 to 1900 hours on a daily basis. Data collection exclusively occurred within the same experimental area (see Figure 1), with eight people involved in the fieldwork and organized in two teams. Every team was led by one experienced tortoise biologist (DS and JCI) so we considered the sampling effort to be homogeneous throughout the monitoring days. The methodology for general recognition of age/sex (male, female, immature) of the tortoises, as well as a technique of individual marking by shell notching applied in this study, were described by Stojadinović et al. (2013).

Data on diurnal and seasonal activity patterns were collected following the procedure described by Crnobrnja-Isailović et al. (2007), with modifications: only sex, age, season, year, activity pattern, and habitat type were recorded and the list of habitat types was different (see next paragraph). Researchers recorded both the time of encounters and the activity performed by each tortoise, as well as the type of habitat where the individual was spotted. Moreover, in order to avoid pseudoreplication only first records of individual tortoises during the whole study period were included in the analysis (Rugiero and Luiselli, 2006).

Habitat types were defined following Rozylowicz and Popescu (2013) with modifications: forest was defined as a closed canopy area larger than 100 m^2; open habitat encompassed grassland patches wider than 10 m; forest edge comprised every strip of grassland within the forest narrower than 10 m or an open surface less than 5 m distant from the forest line; human-modified habitat included all kinds of agricultural land present in the area of study such as vineyards, orchards, and gardens; a path referred to a local narrow unpaved road that partly represents the borderline of the area of study. We also included in the analysis data on substrate temperature (Ts) and air temperature measured at 5 cm (Ta5) and 60 cm (Ta60) above the ground at the capture sites of individual tortoises. Ambient temperature was measured with a Dostmann digital Einstich-Thermometer TFA with ± 0.1 °C precision.

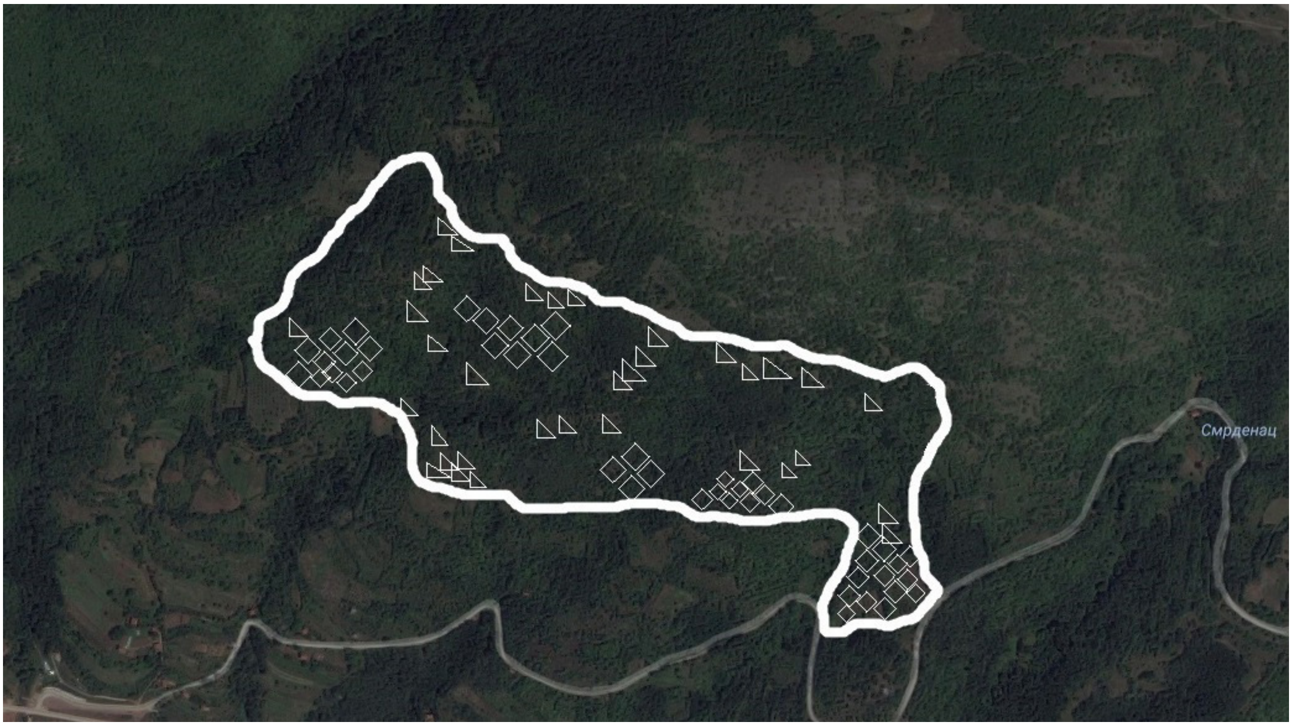

Figure 1. The study area. The map was constructed with Google Earth. The white line borders the area where monitoring was conducted. Triangles mark the position of open habitat or grassland. Squares mark the position of human-modified habitat. Surface without symbols represents forest.

2.3. Statistical analyses

To analyze the habitat specificity of Hermann's tortoises, data matrices were constructed using the following variables: sex/age group (1 – adult male, 2 – adult female, 3 – immature); year (1 – 2010, 2 – 2011, 3 – 2012, 4 – 2013, 5 – 2014); season (1 – spring, i.e. the last week of May, 2 – summer, i.e. the third week of July); type of activity (1 – basking, 2 – hiding, 3 – moving, 4 – feeding, 5 – reproductive activities including chasing, mating, egg laying, or fighting between males), and type of habitat (1 – forest, 2 – open habitat or grassland, 3 – forest edge, 4 – humanly modified habitat, 5 – local unpaved road). The described habitat types within the experimental area occurred in proportions equal to those reported for the overall district of Kunovica (see Section 2.1). Departure of frequencies from random distribution was tested using the Shapiro–Wilk test.

We tested the first and third assumption (i.e. that Hermann's tortoises prefer particular habitats when performing specific activities and there are sex- or age-specific preferences for a particular habitat type) by calculating the strength of the association among nominal variables (habitat type, sex/age group, year, season, and type of activity) using the chi-square test and then Cramer's V as an indicator of small, medium, or large strength of association (effect size) (Cohen, 1977).

The second assumption was tested by analyzing variables with major interaction effects against ambient temperatures recorded at capture spots of adult tortoises. Normal distribution of ambient temperatures was confirmed by the Kolmogorov–Smirnov test for continuous data. We tested three variables (activity type, habitat type, and year) with major interaction effects against ambient temperatures recorded at capture spots of adult tortoises. We accordingly performed factorial ANOVA with ambient temperatures Ts (Ta5 and Ta60) as dependent variables and variables showing significant interactions in the previous analyses as factors.

All analyses were performed using Statistica 5.0 and SPSS 15.0 software.

3. Results

During the 5 years of monitoring 449 individuals were marked. Among them, 389 (86%) were adults and 63 (14%) were immature (Shapiro–Wilk $W = 0.41$, $P < 0.001$). In the adult subgroup, females outnumbered males (male:female = 0.56; Shapiro–Wilk $W = 0.61$, $P < 0.001$). Calculation of the chi-square test and then Cramer's V values for pairs of nominal variables (habitat type, sex/age group, year, season, and type of activity) revealed seven significant associations, but four of them had small effects (Table 1) and therefore were not considered in the discussion. For

Table 1. Strength of departure from randomness when considering significantly nonrandom distribution of tortoises in regard to sex/age groups, seasons, years, habitat types, and activity types analyzed in this study. df = degrees of freedom; P = significance.

Pairs of variables	χ^2 test				
	Pearson χ^2	df	P	Cramer's V	Size effect
Sex/age type × year	17.826	8	0.023	0.140	Small
Sex/age type × season	45.268	2	0.000	0.316	Medium
Year × season	10.709	4	0.030	0.154	Small
Year × habitat type	116.923	16	0.000	0.255	Large
Season × activity pattern	18.300	4	0.001	0.202	Small
Season × habitat type	27.737	4	0.000	0.249	Small
Activity pattern × habitat type	51.754	16	0.000	0.170	Medium

example, the distribution of three main sex/age groups among habitat types or with regard to activity patterns was random ($P > 0.10$ in all cases). In contrast, their distribution among years was nonrandom ($P < 0.05$, Table 1), but the significance of those interactions was small (Cramer's V = 0.140 for df = 2, Table 1).

Three interactions of paired variables had large or medium effects: the distribution of sex/age groups with regard to season (V = 0.316; medium effect size), and the distribution of tortoises among habitat types with regard to year (Cramer's V = 0.255; large effect size) and activity type (Cramer's V = 0.170, medium effect size) (Table 1).

The frequency of occurrence of three sex/age groups in two seasons indicated the predominant occurrence of adult females in the spring (70% in comparison to 30% in summer). In contrast, most of the adult males were detected in the summer (63% in comparison to 37% in spring). Occurrence of immature individuals was almost equal in spring and summer (43% and 57%, respectively).

In general, records were not randomly distributed among habitat types (forest – 111 individuals, grassland – 116 individuals, forest edge – 92 individuals, human-altered habitats – 53 individuals, and the path – 77 individuals; $\chi^2 = 29.61$, df = 4, $P < 0.001$). There were significant differences between observed and expected frequencies of records on the basis of relative presence of three main habitat types within the experimental area (in forested habitat 25% observed vs. 58% expected, difference test P = 0.0000; on grassland 26% observed vs. 16% expected, difference test P = 0.0001; in human-altered habitats 19% observed vs. 25% expected, difference test P = 0.015).

The frequencies of the recorded distribution of all tortoises in different habitat types with regard to year or activity pattern, which departed significantly from randomness with medium or large effect size, are presented in Figures 2 and 3, respectively. In 2010 most of the records occurred at the forest edge, in 2011 on the grassland, in 2012 in the forest, in 2013 again at the forest edge, and in 2014 most of the records were noted in the forest and the grassland (Figure 2). Basking individuals were recorded most frequently at the forest edge, while hiding was the most common activity on the grassland. Moving was the most frequently recorded behavior in the forest and on the path. Feeding was mostly seen in tortoises occurring on the path. Reproduction-related activities were the most frequently recorded events in the forest (see Figure 3).

The sample of temperature data in total included 353 records collected over 5 consecutive years. Most of these records or 295 (84%) were related to adult tortoises, 18 (5%) were of subadult ones, and 40 (11%) were of juvenile tortoises. Only data collected from the sample of adults were subjected to further analysis due to the small sample of ambient temperatures taken for subadult and juvenile tortoises. Over the years of study and among the habitats, ambient temperatures at spots selected by tortoises were similar, except Ta60, which differed over the years (Table 2). On the contrary, ambient temperatures were different for specific combinations of year and habitat type (Table 2). Additionally, adult tortoises performed all activities under similar ambient temperatures (Table 3 – variation of all three ambient temperatures showed $P > 0.10$ for factor 'activity type'), but Ta5 and Ta60 were not similar in different habitats. Variation of ambient temperatures was not significantly different among interactions between activity patterns and habitat types (Table 3).

4. Discussion

In this study we have analyzed data on the eastern Hermann's tortoise population in an environment consisting of both pristine and human-altered habitats. There was no evidence that tortoises exclusively chose specific habitat for performing specific activity, but rather

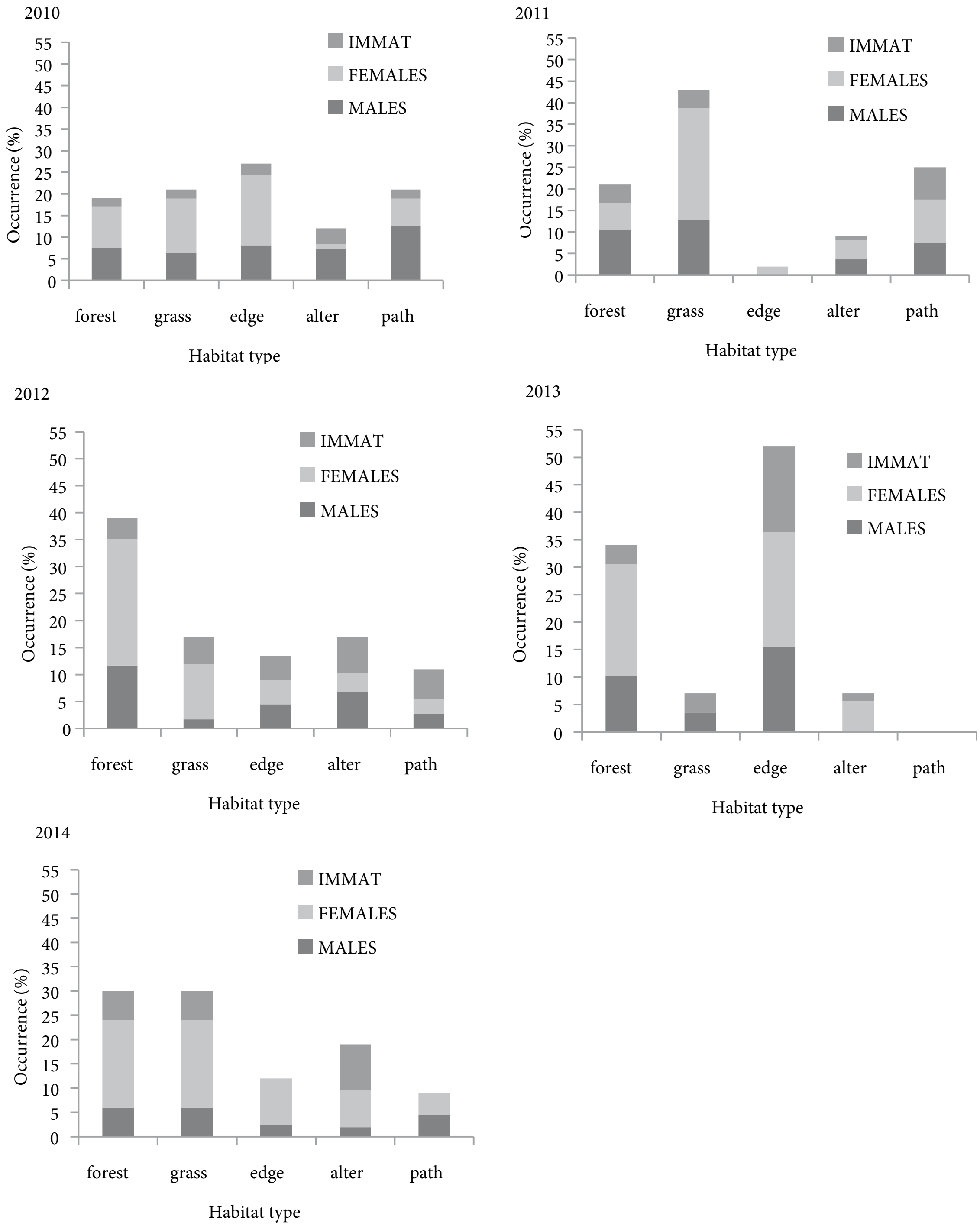

Figure 2. Percent of occurrence of tortoises in specific habitat types in consecutive years. For description of habitat types, see Section 2.2.

that certain particularities exist in their habitat preferences and activity patterns in the mixed landscape of oak forests, meadows, gardens, orchards, and vineyards. Our study site represents a habitat system dominated by deciduous and mostly oak forest, but during the 5 consecutive years the tortoises were mostly not recorded in the forested habitat type; moreover, the frequency of their occurrence in the same habitat varied significantly among the years of study (Table 1; Figure 2). Additionally, the frequencies of performing defined activity types were significantly

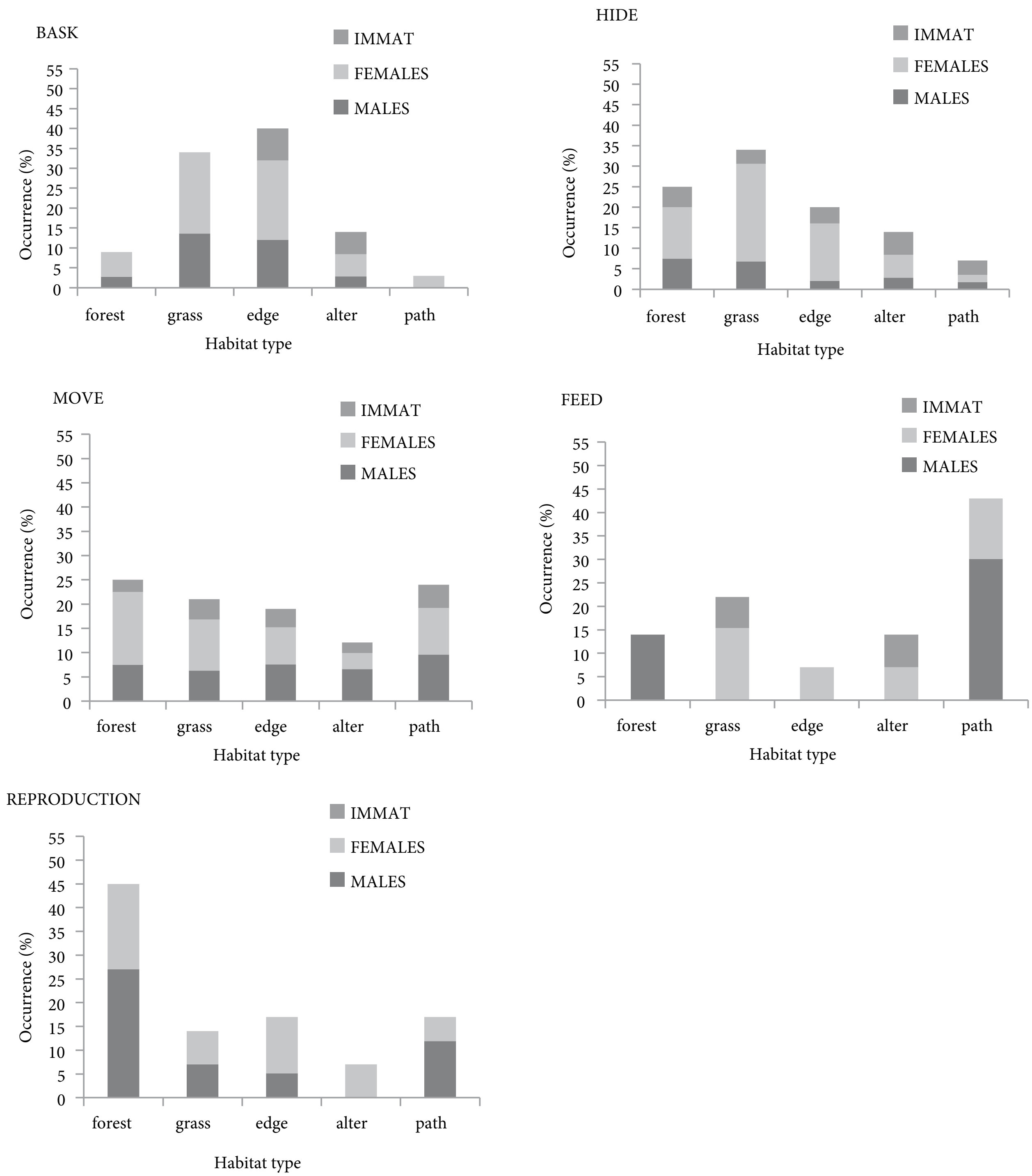

Figure 3. Percent of occurrence of tortoises performing specific activities in specific habitat types. For description of activity types, see Section 2.3.

different among the habitats (see Table 1 and Figure 3). This indicates that eastern Hermann's tortoises, at least in this part of the species area, require a heterogeneous environment, or in other words a complex habitat system.

Our analysis of ambient temperatures at spots "used" by the adult tortoises suggested that they probably actively maintain a suitable range of environmental temperatures in their closest surroundings by moving between different habitat types: Ts and Ta5 at occupied spots were not significantly different over the years of study or among the habitats where they were detected (see Table 2, factors 'year' and 'habitat type' for Ts and Ta5), while Ta60 differed

Table 2. Factorial ANOVA on ambient temperatures recorded at capture spot of individual adult tortoises with year and habitat type as factor variables. Significant effects are bolded. Ts = ground surface temperature, Ta5 = air temperature at 5 cm from the ground surface, Ta60 = air temperature at 60 cm from the ground surface.

Factor	df	MS	F	P
Factorial ANOVA for Ts				
Year	3	18.48	0.94	0.424
Habitat type	3	44.39	2.24	0.083
Year × habitat type	**15**	**47.31**	**2.39**	**0.003**
Error	271	19.77		
Factorial ANOVA for Ta5				
Year	3	19.95	1.03	0.380
Habitat type	3	36.42	1.88	0.133
Year × habitat type	**15**	**44.69**	**2.31**	**0.004**
Error	271	19.38		
Factorial ANOVA for Ta60				
Year	3	37.47	2.06	0.105
Habitat type	**3**	**52.73**	**2.90**	**0.035**
Year × habitat type	**15**	**42.75**	**2.35**	**0.003**
Error	271	18.16		

Table 3. Factorial ANOVA on ambient temperatures recorded at capture spot of individual adult tortoises with activity type and habitat type as factor variables. Significant effects are bolded. Ts = ground surface temperature, Ta5 = air temperature at 5 cm from the ground surface, Ta60 = air temperature at 60 cm from the ground surface.

Factor	df	MS	F	P
Factorial ANOVA for Ts				
Activity type	3	34.75	1.69	0.169
Habitat type	3	53.52	2.61	0.052
Activity type × habitat type	15	24.72	1.20	0.268
Error	271	20.53		
Factorial ANOVA for Ta5				
Activity type	3	24.92	1.26	0.288
Habitat type	**3**	**72.18**	**3.65**	**0.013**
Activity type × habitat type	15	26.94	1.36	0.166
Error	271	19.77		
Factorial ANOVA for Ta60				
Activity type	3	27.87	1.48	0.222
Habitat type	**3**	**71.24**	**3.77**	**0.011**
Activity type × habitat type	15	28.14	1.49	0.108
Error	271	18.89		

among habitat types. All activities were performed under similar ground temperatures, while air temperatures differed among habitat types (Table 3, factors 'activity type' and 'habitat type').

Unequal numbers of males, females, and immature individuals in the overall sample could not impact the nonrandom associations between activity patterns and habitat types as the three sex/age groups were randomly distributed among habitats. However, the absence of sex/age-specific habitat requirements in the analyzed sample cannot be interpreted as the absence of a need for a complex habitat system. It is rather confirmation that the entire population should have more than one habitat type at its disposal for successful overcoming of negative effects of environmental variation.

To a certain extent, our results resemble the general conclusions that arose from the research conducted in southwestern Romania (Rozylowicz and Popescu, 2013). Both studies confirmed significantly different frequency of occurrence of tortoises among analyzed habitat types. We detected a relatively weak preference of Hermann's tortoises toward habitats modified by humans (e.g., vineyards, orchards, or gardens), which was also indicated elsewhere (e.g., van Dijk et al., 2004; Rozylowicz and Popescu, 2013; Couturier et al., 2014). Those authors also underlined the necessity of having more than one particular habitat type in the tortoise reserve, which is in accordance with our findings, illustrated by the nonrandom occurrence of tortoises performing certain activities in certain habitats.

Due to the relatively low number of ecologically oriented studies on the eastern Hermann's tortoise in this part of the range, the outcomes of our relatively short-term monitoring also could serve as an argument for promoting habitat protection in local traditional farming systems. Our results strongly suggest that in East Europe landscapes already modified by humans need promotion of carefully planned and monitored traditional land use so that the protection of Hermann's tortoise can be realized (see, for example, Anadón et al., 2007). Due to the prolonged existence of extensive cultural practices and to the relatively abandoned countryside (see Rozylowicz and Popescu, 2013) East Europe still has relatively pristine habitats or complex habitat systems that could be comfortable for Hermann's tortoises, at least because of the wide array of suitable thermal environments. Moreover, preserving a spatially heterogeneous environment for eastern Hermann's tortoises is a prerequisite for minimizing the harmful effects of climate change, whose deteriorating impact should not necessarily be restricted only to the Mediterranean part of the distribution area (Fernández-Chacón et al., 2011).

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