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Aspects of thermal ecology of the meadow lizard (*Darevskia praticola*)

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Abstract. We studied the thermal biology of the meadow lizard (*Darevskia praticola*) in the peripheral part of its distribution range (westernmost edge of the distribution area). We assessed whether these lizards actively thermoregulate, estimated the accuracy and effectiveness of thermoregulation, and evaluated the thermal quality of the habitat using the standard thermal parameters: body (T_b), preferred (T_pref) with set-point range (T_set) and operative temperatures (T_e). T_set of the meadow lizard under controlled laboratory conditions was between 27.8°C and 31.4°C. In the field T_b and T_e averaged 29.0°C and 26.1°C, respectively. A large proportion of T_es fell below the T_set range of the meadow lizard, and lizard T_bs were substantially closer to the species' T_set range. Obtained values of thermoregulatory indices suggested that the meadow lizard thermoregulated actively, with a rather high accuracy ($\overline{d}_\mathrm{b} = 0.8$) and effectiveness ($E = 0.8$ and $\overline{d}_\mathrm{e} - \overline{d}_\mathrm{b} = 2.6$), and that their habitat at this locality was thermally favourable during the spring. Our results suggest that thermal requirements of the meadow lizard resemble those of alpine lacertids, while their T_bs and T_set are lower than in most lacertid lizards. Further thermoregulation studies could be an important step in predicting the impact of the global climate change on the meadow lizard and the risks of local extinctions of its peripheral populations.

Keywords: field body temperatures, Lacertidae, peripheral populations, preferred temperatures, thermoregulation.

Introduction

Reptiles thermoregulate in response to different temperatures, which enables them to gather and process food, avoid predators and reproduce, indirectly influencing their fitness by affecting physiological, reproductive and ecological performance (Huey, 1982; Adolph and Porter, 1993; Angilletta, 2009). Many studies have shown that lizards are able to regulate their body temperature in relation to different environmental conditions by changing behaviour, activity times and selection of suitable microhabitats, which alters the rates of heating and cooling (Bauwens, Hertz and Castilla, 1996; Díaz and Cabezas-Díaz, 2004; Ortega and Pérez-Mellado, 2016).

According to Arnold (1987), European lacertid lizards do not differ much regarding feeding ecology, foraging strategies, activity patterns and thermoregulatory behaviour. However, given that there are noticeable differences in the size and geographical position of their ranges, some researchers consider that various lacertid lizards use the thermal components of their environment differently (Monasterio et al., 2009; Osojnik et al., 2013; Ortega, Mencía and Pérez-Mellado, 2016a; Sagonas et al., 2017). Their thermoregulation activities respond to the environment but are also dependent on the species physiology (Huey, 1982; Angilletta, 2009). For example, the ecophysiology of the genus *Iberolacerta*, that seems to be restricted to the mountain tops after the last glaciation, suggests that these lizards are more adapted to the cold climatic conditions than most *Podarcis* species, that have a preference for higher temperatures (Crochet et al., 2004; Monasterio et al., 2009; Ortega, Mencía and Pérez-Mellado, 2016a,b). Because of their ectothermic physiology, the distribution of reptiles is highly dependent on environmental temperatures (Huey, 1982; Vitt and Caldwell, 2009),

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although habitat humidity also influences their activity and distribution (Daltry et al., 1998; Ferreira, Santos and Carretero, 2016; Carneiro et al., 2017). The influence of environmental temperatures might be different at the edges of the species area, because populations usually become smaller and more fragmented as the species approach their ecological limits, which may be followed by increased genetic isolation and the loss of ability for local adaptation and range expansion (Bridle and Vines, 2007; Sexton et al., 2009).

The meadow lizard (*Darevskia praticola* Eversmann, 1834) is a small lacertid species with a snout-to-vent length (SVL) usually less than 65 mm (Arnold, 2004). It has a disjunctive distribution range (Agasyan et al., 2009; Sillero et al., 2014) divided in two subranges: eastern (Caucasus) and western (Eastern and South-eastern Europe). The western part of the range is located in the South-eastern Europe (territory of Romania, Serbia, Bulgaria, Northern Greece and European part of Turkey) where the lizard reaches its western distribution limit near the Ibar river valley in Central Serbia (Urošević et al., 2015). Its distribution in this part of the range is quite patchy (Beshkov and Nanev, 2006; Cogălniceanu et al., 2013; Urošević et al., 2015). Contrary to most members of the genus, that are saxicolous, the meadow lizard is a ground dwelling species, mostly living in and around broad-leaved woodlands, but can also be found in meadows with lush vegetation (Arnold, 2004; Agasyan et al., 2009). It is currently listed as Near Threatened (NT) on the IUCN's European Red List of Reptiles (Cox and Temple, 2009). Although being considered as a thermophilic species by Covaciu-Marcov et al. (2009a) the meadow lizard can usually be found in rather moist and shaded places in comparison to other small lacertids (Arnold, 1987, 2004; Strijbosch, Helmer and Scholte, 1989; Darevsky 1997; Covaciu-Marcov et al., 2009b). Moreover, its diurnal activity can be halted during particularly warm days (author's pers. obs.). These facts suggest that the meadow lizard may have certain thermal constraints. These constraints may be an extra restrictive factor for the suitable habitats of the species, especially due to climate change (Sinervo et al., 2010; Huey et al., 2012; Meiri et al., 2013) that is predicted to alter the temperature and humidity patterns of habitats (making them hotter and drier). This would affect the species' response to the altered habitat suitability. While some species have the potential to change their range and adapt, these changes may be detrimental for species with limited dispersal ability or physiologically imposed constraints (Araújo, Thuiller and Pearson, 2006; Sinervo et al., 2010; Le Galliard et al., 2012; Ortega, Mencía and Pérez-Mellado, 2016a).

Since the knowledge on lizard thermoregulatory behaviour in peripheral habitats could be an important step in predicting the risks of local extinctions (Sinervo et al., 2010; Foufopoulos, Kilpatrick and Ives, 2011; Lara-Reséndiz et al., 2015) we investigated the thermoregulatory strategy of the meadow lizard and its local temperature requirements in the peripheral part of the distribution range. The study locality is set at the westernmost edge of the species range, and it differs from the central habitats of the distribution in this area (eastern Serbia and south-western Romania). Main differences can be found by comparing the patterns of two major climatic variables for the region – mean annual temperatures and annual precipitation, obtained from the BioClim variables dataset (Fick and Hijmans, 2017). This locality shows higher mean annual temperatures and lower amounts of annual precipitation. Another quite significant difference is the intense habitat fragmentation caused by human activity, observable from Vegetation Continuous Fields (VCF) that represents the forest vegetation cover (Sexton et al., 2013). This habitat alteration is a result of the close proximity to the biggest city in Serbia, and expansion of adjacent villages and agricultural fields. Also, the lack of old oak trees, compared to the more preserved habitats found in eastern

Serbia shows a historically more intense human influence at this locality (author's pers. obs.).

In the study we applied the experimental protocol designed by Hertz, Huey and Stevenson (1993), which has been widely used in studies of thermal ecology of lizards to determine whether they actively thermoregulate, to estimate accuracy and effectiveness of thermoregulation, and to evaluate the thermal quality of the habitat (Díaz, 1997; Monasterio et al., 2009; Pafilis et al., 2016; Sagonas et al., 2017). Our goals were: (1) to determine whether these lizards actively thermoregulate; (2) to estimate accuracy and effectiveness of the meadow lizard thermoregulation; (3) to evaluate the thermal quality of this peripheral habitat. To the best of our knowledge these are the first data on the thermal ecology of the meadow lizard and the genus *Darevskia* in general.

Materials and methods

Field procedures

Field sampling was conducted during three consecutive sunny days in April of 2015 (15th to 17th) from 09:00 to 17:00 CET covering the daily activity period of the species (based on experience from previous visits to the locality).

The study area was a part of an oak forest (approximately 1 ha in surface) at the slopes of Avala mountain, near Belgrade, Serbia (N44°40′52.5″ E20°33′00.3″, 230 m altitude). The studied area was clearly separated from the surrounding area by natural depressions made by two streams, and a small artificial lake at the bottom. The dominant vegetation comprises thermophilic oak community *Quercetum frainetto-cerris*. The substrate was uniform in the form of forest litter with the emergence of herbaceous vegetation during the spring. A small artificial lake supports a moderate diversity of local batrachofauna (Tomašević et al., 2008). The reptile community of the broader area includes, besides *D. praticola*, the following species: *Ablepharus kitaibelii*, *Anguis fragilis*, *Dolichophis caspius*, *Emys orbicularis*, *Lacerta viridis*, *Natrix natrix*, *Natrix tessellata*, *Podarcis muralis* and *Zamenis longissimus*.

Temperature analyses

The protocol designed by Hertz, Huey and Stevenson (1993) requires three sets of temperature data: T_b – body temperatures of field active animals, T_e – environmental operative temperatures (temperatures of models that simulate the thermal responses of non-thermoregulating animals) and T_pref – preferred body temperatures (a range of temperatures selected by lizards in a laboratory thermal gradient in the absence of other ecological constraints) that are usually described using a set-point range – T_set. Data on T_b and T_e values were simultaneously collected in the field to provide the same general temperature conditions for both lizards and models, enabling their later comparison.

Body temperatures

Active adult meadow lizards were captured by noose or by hand ($n = 53$) and sexed on the basis of body shape, size of femoral pores and presence/absence of hemipenises. Additionally, SVL and weight of the studied lizards were measured. Body temperature (T_b) was measured at the cloaca within 10 s upon capture (following Vasconcelos, Santos and Carretero, 2012), using a Dostmann digital Einstich-Thermometer TFA with an accuracy of ±0.1°C.

Operative temperatures

Data on operative temperatures were obtained using unpainted hollow copper cylinders (length = 5 cm, diameter = 1 cm) closed at both ends with synthetic material plugs, except for a small hole in one of them that allowed the tip of an electronic digital thermometer to be inserted. These copper models have been used to provide estimates of operative temperatures available to lizards (Díaz, 1997; Monasterio et al., 2009; Zamora-Camacho et al., 2013). We placed 30 copper models at randomly selected intervals along transects at the study area in a way that their 'ventral' surface was in contact with the substrate. Each sampling day there was a new scatter of models. Temperatures from all models were registered at hourly intervals. At each sampling, we recorded the time of day, temperature of the model, and its exposure to sunlight (sunny, mixed shade or shade). As the exposure of our models changed during the day due to the nature of the forest habitat, we recorded the exposure at every hour, and later grouped them accordingly for the analyses.

Preferred body temperatures

Due to logistic constraints we were not able to perform the experiment on preferred body temperatures simultaneously with the field procedure. Therefore, we used data from the experiment done a year earlier at the beginning of June 2014 where the lizards were collected from the same local population subjected to the previously described field experiment. Following the procedure described in Carretero, Roig and Llorente (2005) and Veríssimo and Carretero (2009) we only captured adult males ($N = 19$). They were housed in individual cages (for no more than three days) before the experiment, with water and food provided *ad libitum*. SVL and weight of analysed lizards were measured just before the experiment. Each lizard was individually exposed to a photo-thermal gradient between (~20-45°C) produced by a 150 W infrared reflector bulb fixed at one end of the terrarium (150 × 50 × 50 cm) (Veríssimo and Carretero, 2009). The bulbs were switched on at 07:00 h, lizards were put into experimental terraria at 08:00 h and the first measurements were made at 09:00 h allowing them one hour to acclimatise (Carretero, Roig and Llorente, 2005). Preferred body temperature (T_{pref}) measurements were taken hourly from 09:00 to 17:00 h by inserting a tip of an electronic digital thermometer in the cloaca, within 10 s of catching the individual, to minimize the heat transfer from the researcher's hand (Veríssimo and Carretero, 2009). The thermal gradient was monitored hourly during the experiment at three points in the terrarium (on both sides and in the middle). Set-point temperature ranges (T_{set}) were estimated for each lizard as the central 50% of all T_{b} selected in the thermogradient (Hertz, Huey and Stevenson, 1993). After the experiments, lizards were released unharmed at their capture sites.

Indices of thermoregulation

Lizards' thermoregulatory ability was estimated from the indices of thermoregulation proposed by Hertz, Huey and Stevenson (1993): $\overline{d}_{\mathrm{b}}$, $\overline{d}_{\mathrm{e}}$ and E. Accuracy of thermoregulation ($\overline{d}_{\mathrm{b}}$), computed as the mean of the absolute deviations of T_{b} values from the nearest limit of T_{set} ($d_{\mathrm{b}} = [T_{\mathrm{b}} -$ upper limit of $T_{\mathrm{set}}]$ for T_{b}s above T_{set}, $d_{\mathrm{b}} =$ [lower limit of $T_{\mathrm{set}} - T_{\mathrm{b}}$] for T_{b}s below T_{set}, and $d_{\mathrm{b}} = 0$ for T_{b}s within T_{set}), which means the lower the $\overline{d}_{\mathrm{b}}$, the higher the accuracy. Thermal quality of the habitat ($\overline{d}_{\mathrm{e}}$), was calculated similarly as above but for T_{e} values. Accordingly, lower $\overline{d}_{\mathrm{e}}$ implies a higher thermal quality. Effectiveness of thermoregulation was calculated by the following equation: $E = 1 - (\overline{d}_{\mathrm{b}}/\overline{d}_{\mathrm{e}})$. When lizards thermoregulate carefully ($\overline{d}_{\mathrm{b}} \ll \overline{d}_{\mathrm{e}}$) this value will approach one, and when lizards do not thermoregulate and select microhabitats randomly in their environment (thermoconform), $\overline{d}_{\mathrm{b}}$, will be similar to $\overline{d}_{\mathrm{e}}$, and E will approach zero. An additional index of the effectiveness of thermoregulation ($\overline{d}_{\mathrm{e}} - \overline{d}_{\mathrm{b}}$) proposed by Blouin-Demers and Weatherhead (2001) avoids the problem when different $\overline{d}_{\mathrm{b}}/\overline{d}_{\mathrm{e}}$ combinations may lead to the same E. The magnitude of the difference ($\overline{d}_{\mathrm{e}} - \overline{d}_{\mathrm{b}}$) is a measure of how much an animal departs from thermoconformity. When animals actively thermoregulate the index has positive values, the value is zero when animals completely thermoconform, and negative values describe animals that avoid thermally favourable habitats (see Blouin-Demers and Weatherhead, 2001, 2002).

Statistical analyses

All data were tested for normality and because parametric assumptions were not met, we performed non-parametric tests. We used the Mann-Whitney U test to assess the differences in body length (SVL) and T_{b} between males and females. To determine if there were differences in T_{e} between models differently exposed to sunlight we used the Kruskal-Wallis test. We also performed the Kruskal-Wallis test to determine whether there were differences in T_{b}, T_{e} and T_{pref} between different hourly intervals. All statistical analyses were carried out in Statistica 6.0 software.

Results

The comparison of SVL values between males and females indicated a significant difference ($Z = -4.067$, $P < 0.001$), with males (SVL = 48.4 ± 2.2 mm, $N = 39$) being smaller than females (SVL = 53.8 ± 3.6 mm, $N = 13$), as described in Arnold (2004).

There was no significant difference between males and females in their T_{b}s ($Z = -0.589$, $P = 0.556$), and they achieved similar body temperatures in the field (mean T_{b} for males = 28.8°C, $N = 40$, and mean T_{b} for females = 29.3°C, $N = 13$), so we used a pooled sample of T_{b}s in further analyses. In the field, T_{b} ranged from 22.3°C to 33.1°C with a mean of 29.0 ± 2.7°C (mean ± SD), and T_{e} ranged from 15.9°C to 45.2°C with a mean of 26.1 ± 4.8°C (table 1, fig. 1). T_{pref} values of the meadow lizard under controlled laboratory conditions ranged from 22.1°C to 35.4°C, with a mean of 29.6 ± 2.8 (table 1, fig. 1). Set-point-range calculated as the interquartile 50% from all preferred temperatures was between 27.8°C and 31.4°C, with a mean of 29.6 ± 2.3 (fig. 2). A large proportion of T_{e} (67%) fell below the T_{set} range of the meadow lizard (fig. 2), while the 57% of T_{b} readings fell within the T_{set} (fig. 2). Lizards' T_{b}s were substantially closer to the species' T_{set} range, with mean deviations of T_{b} from T_{set}

Table 1. Thermal parameters used for assessing the meadow lizard thermoregulation. Body (T_{b}), preferred (T_{pref}) and operative temperatures (T_{e}), deviation of T_{b} from T_{set} ($\overline{d}_{\mathrm{b}}$) and deviation of T_{e} from T_{set} ($\overline{d}_{\mathrm{e}}$), with two indices for the effectiveness of thermoregulation ($\overline{d}_{\mathrm{e}} - \overline{d}_{\mathrm{b}}$ and E). Mean ± standard deviation, range (in parenthesis) and sample size (N).

T_{b} (°C)	T_{pref} (°C)	T_{e} (°C)	d_{b}	d_{e}	$d_{\mathrm{e}} - d_{\mathrm{b}}$	E
29.0 ± 2.7 (22.3-33.1) $N = 53$	29.6 ± 2.8 (22.1-35.4) $N = 19$	26.1 ± 4.8 (15.9-45.2) $N = 778$ (30)	0.8 ± 1.5 (0.0-13.8) $N = 53$	3.4 ± 3.0 (0.0-5.5) $N = 778$	2.6	0.8

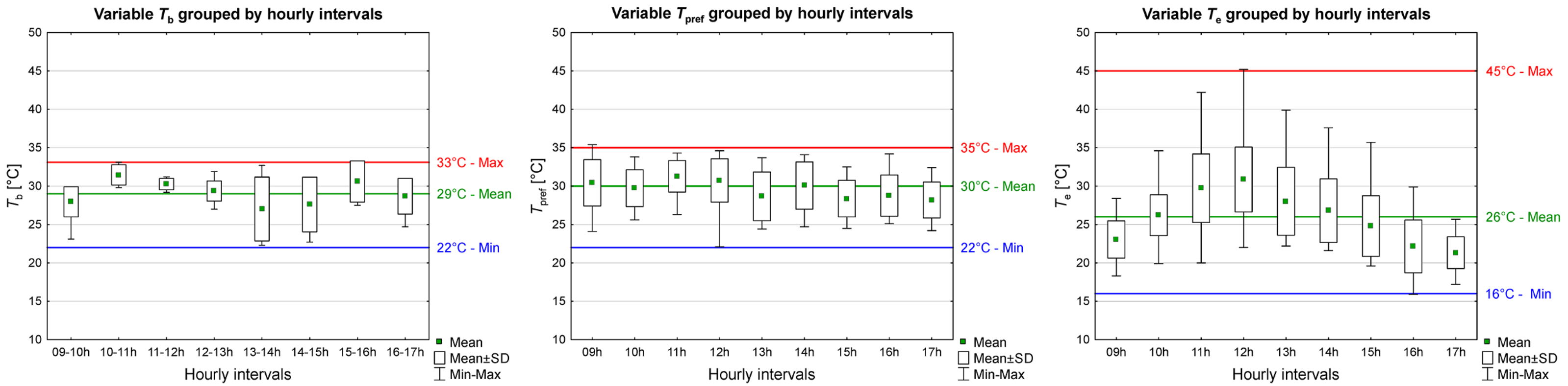

Figure 1. Variation of mean T_b, T_{pref} and T_e grouped by hourly intervals, with minimum, mean and maximum values for each temperature group.

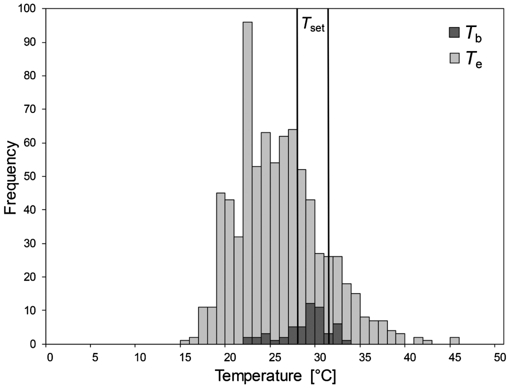

Figure 2. Frequency of mean body temperatures in the field (T_b, dark grey) and mean operative temperatures (T_e, light grey). Vertical black lines indicate the set-point range temperatures (T_{set}).

($\overline{d}_b = 0.8$), than were T_e, with mean deviations of T_e from T_{set} ($\overline{d}_e = 3.4$) (table 1). These values were used to estimate two indices of the effectiveness of thermoregulation: $E = 0.8$ (see in Hertz, Huey and Stevenson, 1993), and $\overline{d}_e - \overline{d}_b = 2.6$ (Blouin-Demers and Weatherhead, 2001) (table 1).

Kruskal-Wallis test ($P < 0.001$) showed that the T_es were significantly different between different exposures. As expected, the temperatures of the models were highest under sunny exposure (31.1 ± 5.1°C), followed by mixed shade (26.9 ± 3.8°C) and lowest temperatures were in the shade (22.9 ± 3.0°C). It is also important to note that these values come from a randomised sample of models with changing exposures during the day (total of 778 readings) 137 (18%) measures were from the sunny exposure, 335 (43%) from mixed shade and 306 (39%) from shade, indicating a predominance of mixed shade and shade in this habitat.

Kruskal-Wallis test was significant for T_b ($P < 0.05$) and T_{pref} ($P < 0.05$), and highly significant for T_e ($P < 0.001$) showing that these temperatures were different for different hourly intervals. The sample sizes of T_b, T_e and T_{pref} hourly intervals were: T_b – 09-10 h: $N = 10$, 10-11 h: $N = 7$, 11-12 h: $N = 5$, 12-13 h: $N = 10$, 13-14 h: $N = 7$, 14-15 h: $N = 6$, 15-16 h: $N = 3$, 16-17 h: $N = 5$; T_e – 09 h: $N = 88$, 10 h: $N = 89$, 11 h: $N = 90$, 12 h: $N = 90$, 13 h: $N = 90$, 14 h: $N = 90$, 15 h: $N = 90$, 16 h: $N = 90$, 17 h: $N = 61$, and for T_{pref} all hourly sample sizes were $N = 19$. Multiple Comparisons p values (2-tailed) test showed that the significant difference in temperature was between time intervals 09-10 h and 10-11 h for T_b, between almost all hourly intervals for T_e, and between 11 h and those at 15 h and 17 h for T_{pref}. Figure 1 provides a visual comparison of hourly variations of mean T_b, T_{pref} and T_e and the differences in their minimum, mean and maximum values.

Discussion

Our study shows that the meadow lizard actively thermoregulates in this peripheral habitat, with a moderate precision of thermoregulation, and that it has a low and wide set-point temperature range. The habitat at this locality had a high thermal quality without temperature extremes but was still challenging, with a large proportion of T_es below the T_{set}, so the lizards had to thermoregulate both effectively and accurately to maintain their T_bs close to the T_{set}. It is important to note that the thermoregulatory pattern and T_bs were observed in spring, and that they may change during the year, as the seasonality showed to be an important factor affecting body temperatures of temperate species of lizards (Díaz and Cabezas-Díaz, 2004; Ortega and Pérez-Mellado, 2016).

In terms of thermoregulation, a lizard could be a heliotherm or a thigmotherm, that is, collecting energy mostly by direct exposure to the solar radiation or by direct contact with the substrate, respectively (Garrick, 2008). However, thermoregulation is a dynamic process and these two categories should be seen just as opposite strategies at the ends of a continuum (see in Pough et al., 2004). Thigmothermy has been recognized as a potentially suitable strategy for small lizards, for diurnal species living in forest habitats, as well as for nocturnal species such as geckos (Vitt et al., 1998; Belliure and Carrascal, 2002; Garrick, 2008). Moreover, forests buffer the effect of the surrounding climate and create their own microclimate conditions (lower maximum temperatures, higher minimum temperatures and higher relative humidity in comparison to adjacent open habitats) (Renaud et al., 2011; Gaudio et al., 2017). This enables the forest living species to be less dependent on local climate patterns. Therefore, some forest lizards seem to be relatively passive to ambient temperatures and they behave as thermoconformers (Huey and Webster, 1976; Rummery et al., 1995; Kohlsdorf and Navas, 2006). Having this in mind, combined with rare observations of meadow lizards basking (author's pers. obs.) and their limited access to direct solar radiation, one could assume that the meadow lizard behaves as a thermoconformer that is mostly dependent on the substrate temperature. Contrary to this presumption, values of thermoregulatory indices obtained in this study suggest that the meadow lizard actively thermoregulates. Indices proposed by Hertz, Huey and Stevenson (1993) quantify aspects of the thermal interaction between an ectotherm and its environment and enable comparisons among studies.

Because of the lack of data for the *Darevskia* genus, we compared the thermal biology of the meadow lizard to other European lacertid species. The mean T_b of the meadow lizard (29.0°C) is close to the lower limit of mean field body temperatures reported for 53 lacertid species (27-40°C) (Castilla, Van Damme and Bauwens, 1999), resembling to that of alpine species such as *Iberolacerta cyreni*, *Iberolacerta galani* and *Iberolacerta bonnali* (29.3°C, 30.9°C and 30.9°C, respectively) (Monasterio et al., 2009; Ortega, Mencía and Pérez-Mellado, 2016a,b). The mean T_set for the meadow lizard in the laboratory (29.6°C) is 2°C lower than mean set-point temperatures reported for 15 species of *Podarcis* lizards (ranging from 31.7°C to 35.5°C) (Kapsalas et al., 2016). Moreover, its set-point range (27.8-31.4°C) falls completely below that of *P. muralis* (31.9-36.5°C from Central Spain; 31.3-34.0°C from Peloponnese, Greece; reported by Bauwens et al., 1995 and Sagonas et al., 2017, respectively) which is the only small lacertid found in syntopy with the meadow lizard at its western distribution limit. The set-point temperature range of the meadow lizard is most comparable to that of the *Iberolacerta bonnali*, a cold adapted alpine lizard, with a set-point range of 29.2-32.8°C (Ortega, Mencía and Pérez-Mellado, 2016b). It is interesting to note that even though it set-point temperature range is low, it is also wide (3.6°C), which is also comparable to that of *Iberolacerta bonnali*, unlike other *Iberolacerta* species that show a low but narrow set-point range (Monasterio et al., 2009; Ortega, Mencía and Pérez-Mellado, 2016a). These similarities, in T_bs and T_set, between a temperate forest lizard and alpine lizards may be a result of cooler, shaded forest habitats of the meadow lizard and moderate temperatures during spring at this particular locality.

The meadow lizard proved to be an active and effective thermoregulator, able to achieve body temperatures close to the T_set, with 57% of T_b readings being within the T_set. A wider range of T_b and T_pref (table 1, fig. 1 and fig. 2) in comparison to some other lacertids (Kapsalas et al., 2016; Pafilis et al., 2016; Sagonas et al., 2017) shows a moderate precision of thermoregulation (Hertz, Huey and Stevenson, 1993). Its $\overline{d}_\mathrm{b}$ index was low (0.8), indicating a high accuracy in thermoregulation (Hertz, Huey and Stevenson, 1993). Both indices of thermoregulation effectiveness, with high value of $E = 0.8$, and positive value of $\overline{d}_\mathrm{e} - \overline{d}_\mathrm{b} = 2.6$, show that the meadow lizard is an effective thermoregulator (Hertz, Huey and Stevenson, 1993; Blouin-Demers and Weatherhead, 2001). Compared to other lacertids with E indices ranging from low to high values, e.g. from $E = 0.52$ in *Iberolacerta cyreni* (Monasterio et al., 2009) and $E = 0.63$ in *Podarcis melisellensis* (for more *Podarcis* species see in Pafilis et al., 2016) to $E = 0.95$ in *Iberolacerta bonnali* (Ortega, Mencía and Pérez-Mellado, 2016b) and $E = 0.96$ in

Podarcis siculus (Kapsalas et al., 2016) its effectiveness of thermoregulation showed to be moderately high.

Habitat T_es were 67% of the time below the T_{set} of the species, but the habitat was sufficiently thermally heterogeneous to enable behavioural thermoregulation (fig. 1). In comparison to $\overline{d}_e$ values reported for other lacertid habitats, ranging from 3.0 to 11.0 (Pafilis et al., 2016), a low $\overline{d}_e = 3.4$ indicates a high thermal quality of the habitat, where lizards can easily achieve body temperatures within T_{set}. The importance of the thermal habitat is pivotal for an easy and affordable thermoregulation (Sagonas et al., 2013; Sagonas, Valakos and Pafilis 2013; Gómez Alés, Acosta and Laspiur, 2017).

We considered the possible effects of the predicted climate change in Europe on the habitat suitability for the meadow lizard. Even though the increase in temperature is predicted to have positive effects on lizards in Europe, for some of those species it will also cause a shift in the southern range limits towards the north. Besides the rise of temperature, the decrease of rainfall is predicted for southern and central parts of Europe (Araújo, Thuiller and Pearson, 2006; Le Galliard et al., 2012). These two changes combined may affect the meadow lizard range to retract in a similar way that it is predicted for species with restricted ranges and species distributed in humid and cold habitats (Foufopoulos, Kilpatrick and Ives, 2011; Le Galliard et al., 2012; Ortega, Mencía and Pérez-Mellado, 2016a). Meadow lizard predominantly lives in humid habitats, and as our research shows it prefers moderate environmental temperatures. This implies that the aridification and the rising temperatures of its habitats may render them unsuitable. With meadow lizards' thermal constraints and patchy distribution, our hypothesis is that the climate change will have a negative effect on this peripheral population, as these lizards will neither have the capacity to adapt to their altered habitat, nor the suitable space to move in intensively human impacted landscape, such as at our studied locality.

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