Phyllomedusa 11(1):21–27, 2012

ISSN 1519-1397

Thermal ecology of the lizard *Sceloporus gadoviae* (Squamata: Phrynosomatidae) in a semiarid region of southern Puebla, Mexico

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Abstract

Thermal ecology of the lizard *Sceloporus gadoviae* (Squamata: Phrynosomatidae) in a semiarid region of southern Puebla, Mexico. We studied the thermal ecology of the lizard *Sceloporus gadoviae* from Puebla, Mexico. Mean body temperature (T_b) was 31.5 ± 0.3°C. A multiple regression suggested that T_b was affected by substrate temperature and solar insolation, and minimally affected by ambient temperature (T_a), sex, and body size. However, body temperature was higher in females than males, and higher in gravid females than non-gravid females. We also found significant differences in T_bs of lizards occupying microhabitats with different insolation (sunny, overcast day, and shade). Results suggest that variation in T_b of *S. gadoviae* can be explained by reproductive condition, microhabitat use, and variation in substrate temperature of microhabitats occupied by these lizards.

Keywords: body temperature, reproductive condition, Tehuacan, thermoregulation.

Received 30 June 2010.
Accepted 5 June 2012.
Distributed June 2012.

Resumo

Ecologia térmica do lagarto *Sceloporus gadoviae* (Squamata: Phrynosomatidae) em uma região semi-árida do sul de Puebla, México. Estudamos a ecologia térmica do lagarto *Sceloporus gadoviae* de Puebla, México. A temperatura corporal média (T_b) foi de 31.5 ± 0.3°C. Uma regressão múltipla sugeriu que T_b foi afetada pela temperatura do substrato e insolação, e minimamente afetada pela temperatura do ar (T_a), sexo e tamanho do corpo. No entanto, a temperatura corporal foi mais elevada em fêmeas do que em machos e em fêmeas ovígeras do que em fêmeas não-ovígeras. Também encontramos diferenças significativas nas T_bs de lagartos que ocupam micro-habitats com diferentes graus de insolação (ensolarado, nublado e sombreado). Os resultados sugerem que a variação na T_b de *S. gadoviae* pode ser explicada pela condição reprodutiva, uso de micro-habitats e variação na temperatura do substrato dos micro-habitats ocupados por esses lagartos.

Palavras-chave: condição reprodutiva, Tehuacan, temperatura corporal, termorregulação.

Introduction

Although environmental temperatures change in space and time, organisms can regulate their temperature by behavior, morphology, and physiology. Lizards use behavior and physiology to avoid lethal temperatures and maintain an adequate body temperature, despite oscillation in environmental temperature (Angilletta 2009). The thermal ecology of lizards can be influenced by daily, seasonal, and geographical variation in environmental temperatures (Ballinger *et al.* 1970, Brown 1996, Angilletta *et al.* 1999, Fernández *et al.* 2011), microhabitat use (Beuchat 1986, Gillis 1991, Smith *et al.* 1993), and the reproductive condition of females (Vrcibradic and Rocha 2004). These factors are important considerations in attempting to understand how the climate change might affect the future distributions of lizards. A recent study suggested the potential for major, negative impacts of climate change on the abundance and distribution of Mexican lizards of the genus *Sceloporus* (Sinervo *et al.* 2010). To predict such changes, we need more information on temperature relationships of these lizards.

Body temperature and temperature relationships *Sceloporus* are well studied, with information on numerous species having been published (Table 1). Herein, we report some aspects of the thermal ecology of *Sceloporus gadoviae* from Zapotitlán Salinas, Puebla, Mexico. In particular, we consider the effects of environmental temperatures, sex, reproductive condition, and microhabitat on body temperature.

Materials and Methods

We conducted the study in the semiarid Zapotitlán Salinas Valley (18°19' N, 97°29' W; 1530 m elevation), in Puebla, Mexico, from October 1998 to September 1999. The mean annual temperature and precipitation are 21°C and 400 mm, respectively. The valley is situated in the Biosphere Reserve of Tehuacan-Cuicatlán. Plant species include some cacti (*Nebouxbamia tetetzo, Cephalocereus* spp.), mesquite trees (*Prosopis laevigata*), "pata de elefante" trees (*Beucarnea gracilis*), and other plants (*Myrtillocactus geometrizans, Echinocactus viznaga,* and *Holocantha stewartii*) (Valiente-Banuet *et al.* 2009).

Sceloporus gadoviae is distributed along the Río Salado, where it is confined to rock and hilltop cliffs, and slopes covered with boulders (Woolrich-Piña *et al.* 2005). Observations were conducted between 08:00 h and 18:00 h along 3 km of haphazardly chosen transects paralleling the river. We captured lizards monthly by hand

Table 1. Mean ± SE activity body temperature (T_b), air temperature (T_a) and susbstrate temperature (T_s) from lizards of the genus *Sceloporus* in Mexico.

Species	T_b (°C)	T_a (°C)	T_s (°C)	Location	Elevation (m)	Sources
S. aeneus	28.3 ± 0.4 *N* = 111	—	—	Milpa Alta-Ajusco, D.F.	2800	Andrews *et al.* 1999
S. aeneus	31.5 ± 0.5 *N* = 116	—	—	Calimaya, Mexico	2700	Trujillo-Cornejo 2001
S. bicanthalis	30.7 ± 0.3 *N* = 88	—	—	Zoquiapan, Mexico	3200	Andrews *et al.* 1999
S. bicanthalis	27.1 ± 0.4 *N* = 77	—	—	Nevado de Toluca, Mexico	4100	Andrews *et al.* 1999
S. bicanthalis	31.6 ± 0.4 *N* = 150	—	—	Nopalillo, Hidalgo	2900	Trujillo-Cornejo 2001
S. bicanthalis	31.6 ± 0.4 *N* = 104	—	—	Cuicatlán, Oaxaca	2700	Trujillo-Cornejo 2001
S. gadoviae	31.5 ± 0.3 *N* = 157	27.2 ± 0.3 *N* = 157	28.6 ± 0.4 *N* = 157	Zapotitlán Salinas, Puebla	1530	This study
S. gadoviae	35.1 ± 0.1 *N* = 258	27.0 ± 0.2 *N* = 258	28.8 ± 0.1 *N* = 258	Cañón del Zopilote, Guerrero	600	Lemos-Espinal *et al.* 1997a
S. grammicus	31.6 ± 0.1 *N* = 293	13.1 ± 0.9 *N* = 293	—	Laguna, Iztaccíhuatl, Puebla	3700	Lemos-Espinal and Ballinger 1995
S. grammicus	31.2 ± 0.2 *N* = 245	5.7 ± 0.5 *N* = 245	—	Paredón, Iztaccíhuatl, Puebla	4400	Lemos-Espinal and Ballinger 1995
S. grammicus	31.4 ± 0.1 *N* = 147	20.0 ± 0.2 *N* = 147	20.7 ± 0.3 *N* = 147	Core, Mexico City	2240	Woolrich-Piña *et al.* 2006
S. grammicus disparilis	30.5 ± 0.5 *N* = 65	—	—	La Michilía, Durango	2480	Ortega-Rubio *et al.* 1984
S. grammicus disparilis	25.4 ± 0.3 *N* = 38	—	—	La Goma, Durango	1100	Bogert 1949
S. horridus	36.8 ± 0.4 *N* = 14	25.4 ± 0.8 *N* = 14	29.5 ± 0.4 *N* = 14	Zitlala, Guerrero	1250	Lemos-Espinal *et al.* 1997d
S. horridus	35.7 ± 0.4 *N* = 15	27.9 ± 0.9 *N* = 15	30.1 ± 0.9 *N* = 15	Zacatepec, Morelos	900	Lemos-Espinal *et al.* 1993
S. jarrovi	31.6 ± 0.2 *N* = 148	29.3 ± 0.2 *N* = 148	29.6 ± 0.2 *N* = 148	Durango	1425	Gadsden and Estrada-Rodríguez 2007
S. merriami	33.6 ± 0.8 *N* = 11	—	—	Las Delicias, Coahuila	1500	Bogert 1949
S. mucronatus	29.4 ± 0.7 *N* = 104	16.4 ± 0.4 *N* = 104	20.6 ± 0.5 *N* = 104	Ajusco, D.F.	3400	Lemos-Espinal *et al.* 1997b
S. ochotoranae	34.1 ± 0.8 *N* = 34	27.0 ± 0.7 *N* = 34	29.2 ± 0.9 *N* = 34	Cañón del Zopilote, Guerrero	600	Lemos-Espinal *et al.* 1997c

Table 1. *Continued.*

Species	T_b (°C)	T_a (°C)	T_s (°C)	Location	Elevation (m)	Sources
S. ochotoranae	34.1 ± 0.2 *N* = 57	23.2 ± 0.3 *N* = 57	28.1 ± 0.5 *N* = 57	Zitlala, Guerrero	1250	Lemos-Espinal *et al.* 1997c
S. poinsettii	34.2 ± 0.4 *N* = 19	—	—	La Goma, Durango	1100	Bogert 1949
S. scalaris	31.2 ± 0.5 *N* = 90	—	—	La Michilía, Durango	2480	Ortega-Rubio *et al.* 1984
S. spinosus	33.5 ± 0.9 *N* = 8	23.1 ± 0.9 *N* = 8	25.8 ± 1.3 *N* = 8	Arcos del Sitio, Mexico	2300	Lemos-Espinal *et al.* 1997d
S. undulatus consobrinus	34.8 ± 0.2 *N* = 44	—	—	Chihuahua, Chihuahua	1400	Bogert 1949
S. undulatus speari	35.2 ± 0.2 *N* = 102	—	—	Juárez, Chihuahua	1280	Lemos-Espinal *et al.* 2003
S. variabilis	36.9 ± 0.2 *N* = 38	—	—	Palictla, San Luis Potosí	150	Bogert 1949

or noose. Once captured, we recorded sex, reproductive condition in females (by abdominal palpation), snout-vent length (SVL, to nearest 1 mm), body mass (to nearest 0.2 g, using a spring balance), and body (T_b; cloacal temperature), air (T_a; bulb in the shade, 3.0 cm above the substrate occupied by the lizard), and substrate temperatures (T_s; bulb to the shade on the substrate occupied by the lizard) with a Shultetheis quick-reading thermometer (interval 0–50°C, 0.2°C precision). We also recorded each lizard's insolation, as follows: (1) completely exposed to sun; (2) in shade; and (3) on an overcast day. Lizards that needed a major effort to capture (>1 min) were excluded from temperature records. Captured lizards were marked by toe-clipping to guarantee that T_b measurements were obtained only once for each lizard.

We used a multiple regression analysis to evaluate the influence of ambient temperatures (T_a, T_s), insolation (i), sex, SVL, and body mass on T_b. To compare T_bs between males and females, and between gravid and non gravid females, in different conditions of exposure to sun, we used analyses of covariance (ANCOVA) with T_s as the covariate.

Results

Mean T_b for *Sceloporus gadoviae* at this site was 31.5 ± 0.3°C (range 19.2–40.2°C; *N* = 157). The T_a and T_s at sites of capture averaged 27.2 ± 0.3ºC (*N* = 157) and 28.6 ± 0.4°C (*N* = 157), respectively. Multiple regression resulted in the equation: $T_b = 13.70 + 0.02T_a + 0.53T_s + 0.34i + 0.03sex + 0.07SVL – 0.17mass$ ($r^2 = 0.42$, $p < 0.01$), suggesting that T_b was affected by substrate temperature and insolation, and minimally affected by T_a, sex, and body size.

Mean T_bs for males, gravid females, and non-gravid females averaged 31.8 ± 0.5°C (range 19.2–38.4°C, *N* = 72); 33.3 ± 0.7°C (20.4–36.8°C, *N* = 24), and 30.6 ± 0.5°C (22.2–40.2°C, *N* = 61), respectively. Body temperatures were significantly different between males and females (ANCOVA, $F_{1,156} = 6.27$, $P < 0.01$), as well as between gravid and non-gravid females (ANCOVA, $F_{1,85} = 5.74$, $P < 0.01$). Both female and male T_bs were correlated with T_s ($r^2 = 0.42$, $p < 0.05$, $N = 86$; $r^2 = 0.31$, $p < 0.05$, $N = 71$; respectively) and there also were significant correlations between T_b and T_s for both gravid ($r^2 = 0.33$, $p < 0.05$, $N = 26$) and non-gravid females ($r^2 = 0.55$, $p < 0.05$, $N = 60$).

Significant differences were found between T_bs of the lizards under sunny and overcast conditons (ANCOVA, $F_{1,87} = 10.87$, $p < 0.05$), and between shade and cloudy conditions (ANCOVA, $F_{1,98} = 7.72$, $p < 0.05$). T_bs were positively correlated with T_s under different microhabitat conditions: sun ($T_b = 25.28 + 0.26T_s$, $r^2 = 0.18$, $p < 0.05$, $N = 57$), shade (T_b $15.21 + 0.57T_s$, $r^2 = 0.36$, $p < 0.05$, $N = 66$) and overcast days (T_b $9.90 + 0.72T_s$, $r^2 = 0.64$, $p < 0.05$, $N = 32$; Figure 1).

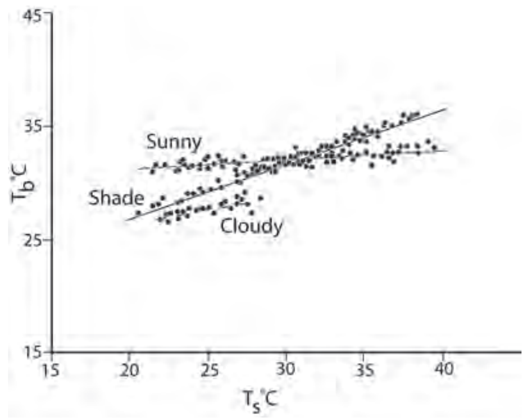

Figure 1. Relationship between T_s in different levels of insolation and body temperature (T_b) for *Sceloporus gadoviae.*

Discussion

The mean body temperature of *Sceloporus gadoviae* at Zapotitlán Salinas was lower than that of other population of the same species inhabiting another semiarid region, Cañón del Zopilote, Guerrero (Lemos-Espinal *et al.* 1997a). Differences in body temperature between these two populations may be due to altitudinal-related differences in weather conditions among sites (600 m elevation, 27.8°C mean annual temperature, 730 mm annual rainfall in Cañon del Zopilote vs. 1530 m elevation 21°C mean annual temperature, 400 mm annual rainfall in Zapotitlán Salinas). Geographic variation in thermal environment may influence the availability of thermally appropiate microhabitats for the lizards (Beaupre 1995, Ibargüengoytia *et al.* 2008).

Sceloporus gadoviae maintained higher T_bs in sunny microhabitats (i.e., fully exposed to sun) than in shaded microhabitats or on overcast days. Our results suggest that full exposure to sun may be necessary for *S. gadoviae* to maintain a high T_b, possibly shuttling between sun and shade (beneath rocks and in crevices) to maintain their T_b, as is known to occur in other lizards (e.g., Middendorf and Simon 1988, Castilla and Bauwens 1991, Sartorius *et al.* 2002).

Male *Sceloporus gadoviae* at this locality had a higher mean T_b than females. In contrast, Lemos-Espinal *et al.* (1997a) did not find a significant difference in T_b between males and females, but did find significant differences in the environmental temperatures at the site of capture of males and females. Within *Sceloporus,* males with higher mean T_bs than in females have been reported for *S. scalaris* and *S .mucronatus* (Lemos-Espinal *et al.* 1997b, Smith *et al.* 1993), with lower mean T_b in *S. undulatus erythrocheilus* (Gillis 1991) and no difference in mean T_b between males and females in a number of other species (e.g., Vial 1984, Guyer and Linder 1985, Lemos-Espinal and Ballinger 1995, Lemos-Espinal *et al.* 1997c, 2001, 2003). Possible explanations for the differences in mean T_b between and within sexes may include habitat partitioning for basking, activity at different times, or behavior.

Gravid females had higher T_b than non-gravid females. In the Guerrero population, there was no difference in T_b between gravid and non-gravid females (Lemos-Espinal *et al.* 1997a). Differences in T_b between gravid and non-gravid females may reflect thermoregulatory strategies of the former to optimize embryonic development (Beuchat 1988, Andrews *et al.* 1999).

Acknowledgments

We thank the people of Zapotitlán Salinas for their support in the field. Funding was provided by the Dirección General de Apoyo al Personal Académico (DGAPA-UNAM), project nos. IN 208398, IN 216199, IN 200102, IN 221707; PAPCA 2003 "Procesos espaciales en la diversidad local y regional de los ensambles de reptiles del Valle de Tehuacan-Cuicatlan y el Norte del Desierto Chihuahuense"; PAPCA 2007 "Organización ecológica del ensamble de lagartijas en el Valle de Zapotitlán Salinas, Puebla, México" and CONABIO project no. CP002.

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