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# 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 $T_b$s 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.

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**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 $T_b$s 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 $T_b$s 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 $T_b$s 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 $T_b$s 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 $T_b$s of the lizards under sunny and overcast conditons (ANCOVA, $F_{1,87} = 10.87$, $p < 0.05$), and between shade and cloudy conditions (ANCOVA, $F_{1,98} = 7.72$, $p < 0.05$). $T_b$s 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).

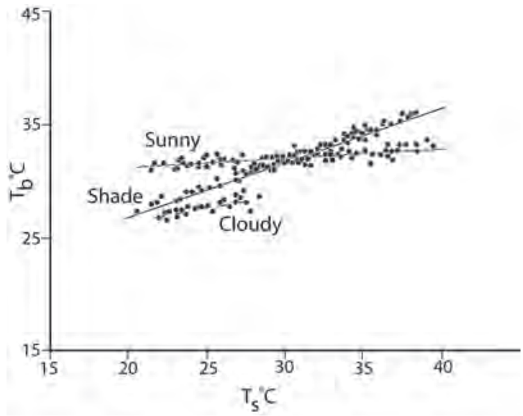


**Figure 1.** Relationship between $T_s$ in different levels of insolation and body temperature ($T_b$) for *Sceloporus gadoviae.*

## 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 $T_b$s 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 $T_b$s 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).

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