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Body temperatures of three species of *Phrynosoma* from Puebla, Mexico

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Abstract. We report on the temperature relationships of three Mexican species of *Phrynosoma* (*P. braconnieri*, *P. orbiculare*, and *P. taurus*). Mean body temperature (T_b) was 32.72°C for *P. braconnieri*, 32.54°C for *P. orbiculare*, and 33.39°C for *P. taurus*. In *P. braconnieri* and *P. taurus*, T_b was not correlated with air or substrate temperatures, whereas in *P. orbiculare* $T_b$was positively correlated with them. Body size did not affect T_b in any of the species. Females had higher T_bs than males in *P. orbiculare*, males had higher T_bs than females in *P. braconnieri*, and males and females had similar T_bs in *P. taurus*. Most of the *Phyrnosoma* observed in our study were found in sunny microhabitats, although several were found in shaded microhabitats.

Keywords. *Phrynosoma braconnieri*, *Phrynosoma orbiculare*, *Phrynosoma taurus*, thermal ecology.

Introduction

Temperature can play an important role in the ecology and biology of reptiles. In *Phrynosoma* lizards, temperature can influence physiological performance (e.g., Prieto and Whitford, 1971). *Phrynosoma* lizards adopt a variety of thermoregulatory mechanisms, such as shuttling between sun and shade, to maintain T_bs within a certain range (Heath, 1965, 1970). Despite several reports on the body temperatures and temperature relationships of *Phrynosoma* (Table 1), we lack information on several species, especially those from Mexico. Herein, we report on observations on three species of *Phrynosoma* (*P. braconnieri*Duméril & Bocourt 1870, *P. orbiculare*(Gmelin 1789) and *P. taurus* Dugès 1873) from Mexico, two of which have not had information on their thermal ecology published before (*P. braconnieri* and *P. taurus*).

Materials and Methods

We conducted this study in Alchichica (19º24'26"N, 97º23'58"W, 2300 m elevation) and Zapotitlán Salinas Valley (18°34' N, 97°29' W, between 1530 and 2400 m elevation) in Puebla, Mexico. Mean annual temperature and precipitation are 19ºC, 21°C and 420 mm, 400 mm, respectively. In Alchichica, plant species include *Nolina parviflora*, *Yucca periculosa*, *Agave obscura*, *Hechtia roseana*, *Nolina parviflora*, *Dasylirion acrotriche*, *Distichlis spicata*, *Bouteloua hirsuta*, *Suaeda nigra*, *Opuntia robusta*, and *Mammilaria discolor*. In Zapotitlan Salinas Valley, vegetation includes*Nebouxbamia tetetzo*, *Cephalocereus* spp., *Prosopis laevigata*, *Beucarnea gracilis*, *Myrtillocactus geometrizans*, *Echinocactus viznaga,* and *Holocantha stewartii* (Rzedowski, 2006).

We captured lizards by hand. Once captured, we recorded sex, snout vent length (SVL, to nearest 1 mm), body mass (to nearest 0.2 g, using a spring balance), hour of capture, body (T_b; cloacaltemperature, to nearest 0.2°C), air (T_a; bulb inthe shade, 3.0 cm over the substrate occupied by the lizard, to nearest 0.2C), and substrate temperature (T_s; bulb to the shade on the substratum occupied by the small lizard, to nearest 0.2°C) using a quick-reading thermometer(Shultetheis, Miller and Weber Inc., interval 0-50°C, 0.2 precision). We also recorded each lizard's position with regard to solar insolation as being completely exposed to sun, in shade, or a sun/shade mosaic. Lizards that needed a major effort to capture (> 1 min.) were excluded from temperature records. We used only one observation for each lizard.

Results

P. braconnieri

Mean T_b was 32.72 ± 0.16 °C (N = 27). Mean T_a was 24.50 ± 0.22 °C (N = 27). Mean T_s was 25.70 ± 0.28 °C (N = 27). Body temperature was not significantly affected by T_a (N = 27, r^2 = 0.09, P = 0.13). Body temperature was also not affected by T_s (N = 27, r^2 = 0.002, P = 0.83). Body temperature was not affected by SVL (N = 27, r^2 = 0.04, P = 0.31).Males had a higher mean T_b than females (Table 2; $F_{1,25}$ = 14.49, P = 0.0008). However, males and females had similar mean T_as (Table 2; $F_{1,25}$ = 0.57, P = 0.46). Mean T_s also did not differ between males and females (Table 2; $F_{1,25}$ = 0.09, P = 0.76). Lizards were more frequently encountered in sunny microhabitats

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Table 1. Published reports of mean body temperatures (T_b) of *Phrynosoma* lizards.

Species	Mean T_b (°C)	Source
P. asio	32.4	Lemos-Espinal et al. (1997)
P. blainvilli	34.9	Cowles and Bogert (1944)
P. cornutum	35.7	Brattstrom (1965)
P. coronatum	34.2 – 34.9	Brattstrom (1965); Cunningham (1966)
P. douglassi	32.1	Powell and Russell (1985)
P. m'callii	36.9 – 37.4	Cowles and Bogert (1944); Brattstrom (1965)
P. modestum	20.9	Lemos-Espinal et al. (1997)
P. orbiculare	37.9	Lemos-Espinal et al. (1997)
P. platyrhinos	34.4 – 36.8	Cowles and Bogert (1944); Brattstrom (1965); Pianka and Pianka (1970); Pianka and Parker (1975)

(18; 66.7%) compared to shaded microhabitats (9; 33%). Lizards in sunny microhabitats had higher mean T_bs than those in shaded microhabitats (Table 3; $F_{1,25}$ = 12.93, P = 0.0014). However, microhabitat did not affect T_a (Table 3; $F_{1,25}$ = 0.09, P = 0.76), or T_s (Table 3; $F_{1,25}$ = 0.02, P = 0.88).

P. orbiculare

Mean T_b was 32.54 ± 0.23 °C (N = 47). Mean T_a was 24.96 ± 0.32 °C (N = 47). Mean T_s was 27.16 ± 0.40 °C (N = 47). Body temperature increased with T_a (N = 47, r^2 = 0.19, P = 0.0024; T_b = 24.87 + 0.31T_a). Body temperature also increased with T_s (N = 47, r^2 = 0.23, P = 0.0007; T_b = 25.21 + 0.27T_s). Body temperature was not affected by SVL (N = 47, r^2 = 0.01, P = 0.45). Females had higher mean T_bs than males (Table 2; $F_{1,45}$= 4.60, P = 0.038). Mean T_a did not differ between males and females (Table 2; $F_{1,45}$ = 0.36, P = 0.55). Substrate temperature also did not differ between males and females (Table 2; $F_{1,45}$ = 0.20, P = 0.66).Sunny (25; 53.2%) and shaded (20; 42.1%) microhabitats were the most used, with only 2 (4.2%) lizards using sun/shade mosaic microhabitats. Microhabitat did not affect T_b (Table 3; $F_{2,44}$ = 0.42, P = 0.66), T_a (Table 3; $F_{2,44}$ = 2.29, P = 0.11). However, mean T_s was significantly affected by microhabitat, with sunny microhabitats being the warmest (Table 3; $F_{2,44}$ = 5.37, P = 0.0082).

P. taurus. Mean T_b was 33.39 ± 0.20 °C (N = 39). Mean T_a was 26.19 ± 0.55 °C (N = 39). Mean T_s was 28.06 ± 0.42 °C (N = 39). Body temperature was not affected by T_a (N = 39, r^2 = 0.037, P = 0.24). Body temperature was not affected by T_s (N = 39, r^2 = 0.07, P = 0.10). Body temperature tended to decrease with SVL, but the relationship only approached statistical significance (N = 39, r^2 = 0.09, P = 0.064; T_b = 37.63 - 0.06SVL). Mean T_b did not differ between males and females (Table 2; $F_{1,37}$ = 0.64, P = 0.43). Mean T_as also did not differ between males and females (Table 2; $F_{1,37}$ = 0.24, P = 0.63), nor did mean Ts (Table 2; $F_{1,37}$ = 0.31, P = 0.58). More lizards were observed in sunny microhabitats (19; 48.7%), followed by shaded microhabitats (13; 33.3%). Fewer lizards were observed in shaded microhabitats (7; 17.9%). Lizards in sunny microhabitats had a lower mean T_b than those in shaded or mosaic microhabitats (Table 3; $F_{2,36}$ = 3.50, P = 0.04). However, mean T_a (Table 3; $F_{2,36}$ = 0.08, P = 0.93) and T_s (Table 3; $F_{2,36}$ = 0.07, P = 0.94) did not differ between microhabitats.

Discussion

The mean T_bs of the three species of *Phrynosoma* we studied (*P. braconnieri*, *P. orbiculare*, *P. taurus*) are fairly similar to each other (all within 1°C). The mean T_bs of the three species are also well within the range of T_bs observed in other species of *Phrynosoma* (see Table 1). In *P. braconnieri* and *P. taurus*, T_b was not correlated with T_a or T_s, whereas in *P. orbiculare*

Table 2. Mean body temperature (T_b), air temperature (T_a), and substrate temperature (T_s) of males and females of three species of *Phrynosoma*. Means are given ± 1 SE.

	T_b (°C)	T_a (°C)	T_s (°C)
P. braconnieri			
Male (N = 12)	33.27 ± 0.23 °C	24.68 ± 0.36 °C	25.6 ± 0.46 °C
Female (N = 15)	32.29 ± 0.13 °C	24.35 ± 0.27 °C	25.77 ± 0.36 °C
P. orbiculare			
Male (N = 23)	32.06 ± 0.21 °C	24.76 ± 0.37 °C	26.97 ± 0.45 °C
Female (N = 24)	33.00 ± 0.38 °C	25.15 ± 0.52 °C	27.33 ± 0.66 °C
P. taurus			
Male (N = 16)	33.20 ± 0.33 °C	25.86 ± 0.87 °C	27.78 ± 0.75 °C
Female (N = 23)	33.53 ± 0.25 °C	26.42 ± 0.72 °C	28.26 ± 0.51 °C

Table 3. Mean body temperature (T_b), air temperature (T_a), and substrate temperature (T_s) of three species of *Phrynosoma* found in sunny and shaded microhabitats. Means are given ± 1 SE.

	T_b (°C)	T_a (°C)	T_s (°C)
P. braconnieri			
Sunny (N = 18)	33.06 ± 0.17 °C	25.54 ± 0.29 °C	25.67 ± 0.36 °C
Shaded (N = 9)	32.07 ± 0.18 °C	24.4 ± 0.33 °C	25.76 ± 0.48 °C
P. orbiculare			
Sunny (N = 25)	32.34 ± 0.36 °C	25.58 ± 0.51 °C	28.29 ± 0.51 °C
Sun/Shade Mosaic (N = 2)	32.90 ± 0.30 °C	24.0 ± 1.0 °C	25.6 ± 0.20 °C
Shaded (N = 20)	32.75 ± 0.29 °C	24.28 ± 0.34 °C	25.9 ± 0.56 °C
P. taurus			
Sunny (N = 19)	32.88 ± 0.26 °C	26.20 ± 0.79 °C	27.99 ± 0.65 °C
Sun/Shade Mosaic (N = 7)	33.77 ± 0.56 °C	26.60 ± 1.30 °C	28.40 ± 0.91 °C
Shaded (N = 13)	33.94 ± 0.31 °C	25.95 ± 1.01 °C	27.98 ± 0.75 °C

T_b was positively correlated with T_a and T_s. Studies on *P. asio*, *P. douglassi brevirostre,* and *P. platyrhinos* found a positive correlation between T_b and both T_a and T_s (Pianka and Parker, 1975; Powell and Russell, 1985; Lemos-Espinal, Smith and Ballinger, 1997). Our results suggest that more variation in the effects of environmental temperatures on T_b exists among species of *Phrynosoma* than previously understood.

Body size did not significantly affect T_b in any of the three species of *Phrynosoma* we studied. Body temperature of *P. asio* was not affected by body size (Lemos-Espinal, Smith and Ballinger, 1997). These results suggest that body size does not play an important role in thermoregulation in *Phrynosoma*, at least over the range of body sizes studied. Additional studies examining the thermal ecology of hatchlings or juveniles are needed however.

The effects of sex on mean T_b differed among the three species. Females had higher T_bs than males in *P. orbiculare*, males had higher T_bs than females in *P. braconnieri*, and males and females had similar T_bs in *P. taurus*. Interestingly, in all three species, mean T_a and T_s did not differ between males and females. Male *P. asio* had higher mean T_b than females (Lemos-Espinal, Smith and Ballinger, 1997). Our results, and those for *P. asio*, suggest that the temperature relationships of males and females can differ and that these relationships can also vary among species. At this time, we can present no explanation for this variation, but these results suggest that more study of sexual differences in thermal ecology in *Phrynosoma* are warranted.

Most of the *Phyrnosoma* observed in our study were found in sunny microhabitats, although several were found in shaded microhabitats. *Phrynosoma douglassi brevirostre*were most often found in open microhabitats and rarely in shaded or mosaic microhabitats (Powell and Russell, 1985). Differences in the use of sunny and shaded microhabitats may reflect thermoregulatory behaviour, such as shuttling between these microhabitats to maintain T_b (e.g., Heath, 1965, 1970).

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