Thermal ecology of *Pseudoeurycea leprosa* (Caudata: Plethodontidae) from Sierra del Ajusco

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ABSTRACT - Many physiological and behavioural processes are temperature dependent in ectothermic organisms. In this study, we evaluated the influence of environmental temperature on the thermoregulation of *Pseudoeurycea leprosa* in a pine forest of Mexico. Mean body temperature was 29.7 ± 13.24°C. Body temperature was correlated with air and substrate temperature. Further study involving more complex aspects of the thermal ecology, together with other biological characteristics, may help to make specific conservation strategies for *P. leprosa*.

Sierra del Ajusco is located within the Transmexican-Volcanic Belt. This region is one of the most important morphotectonic provinces in Mexico because it is located at the transition between the Neartic and Neotropical biogeographic regions, resulting in great biological diversity (Rzedowsky, 1998). This biodiversity has been subjected to fires, pests, deforestation, erosion and clandestine hunting for many years which has led to the decrease in populations of some species (Granados-Sánchez et al., 2004).

Mexico has 373 species of amphibians, with the salamanders of the family Plethodontidae representing 30 % of the total (Liner, 2007). Additionally, Mexico hosts 40 % of all described species of salamanders in the world (Parra-Olea et al., 2005b).

The genus *Pseudoeurycea* (Taylor, 1944) is one of the most diverse neotropical salamander groups. Species in the genus inhabit pine-oak forests at elevations higher than 2,000 m (Parra-Olea et al., 2004), and represent 12 % of the Mexican amphibian fauna. The genus includes 45 species which occur from northern Mexico to western Guatemala. Of these 41 are endemic to Mexico, one to Guatemala, and three occur in both countries (Windfield-Pérez et al., 2007). Although these salamanders are the most abundant vertebrates in many upland habitats, their ecology is poorly known (Lynch et al., 1983). Studies on *Pseudoeurycea* include analyses of its geographic distribution (Windfield-Pérez et al., 2007), taxonomy (Lynch et al., 1983; Adler, 1996; Pérez-Ramos and Saldaña-De la Riva, 2003; Parra-Olea et al., 2005a), climate change effects (Parra-Olea et al., 2005b), helminth parasites (Falcón-Ordaz et al., 2007) and ecology (Bille, 2000; García-Vázquez et al., 2006).

Pseudoeurycea leprosa (Cope, 1869) (front cover, this issue) is a terrestrial species associated with pine, pine-oak, and fir forests along the Transmexican-Volcanic Belt at the southern end of the Sierra Madre Oriental (Parra-Olea et al., 2005b). Bille (2000) studied some aspects of microhabitat use and more recently García-Vázquez et al. (2006) made an extensive study of ecological aspects of this species. Nevertheless no studies of its thermal biology have previously been completed.

In this paper we analyze the thermal profile of *Pseudoeurycea leprosa* and describe the relationship of body temperature to substrate temperature. We also record microhabitat use by this salamander.

METHODS AND MATERIALS

This study was carried out in Ejido Magdalena Petlatalco, Delegación Magdalena Contreras, Sierra del Ajusco, Mexico, Distrito Federal (19.2209° N, 99.2856° W) from 3,500 to 3,930 m. The climate of the study area is temperate semi-humid (Cw) with a mean annual temperature of 7.5-13.5°C and a mean annual rainfall of 1340 mm, less than 5% of which occurs in winter (García, 1973). The vegetation is pine forest (*Pinus hartwegii*) and grassland (*Muhlenbergia quadridentada*, *Festuca hephaestophila* and *Festuca amplissima*) (Álvarez del Castillo, 1989).

We collected 24 salamanders between 09:00 and 14:00 from January-August 2007. Animals were captured by hand and returned to their habitat after taking measurements.

Body temperatures (cloacal = T_b to the nearest 0.2°C), and substrate temperature (Ts on substrate where the salamander was first observed) were obtained using a Miller & Weber (0-50 ± 0.2°C) quick reading thermometer. Snout-vent length (SVL) was measured to the nearest mm with an electronic caliper at the site of capture.

We assessed normality and homoscedasticity with Kolmogorov-Smirnov and Bartlett tests respectively. We calculated residuals from the relationship of T_b to SVL to produce T_b adjusted variables which maintain variation of extrinsic factors and minimize the compounding effect of size related to individual variation in SVL.

We performed non-parametric statistical analysis with JMP statistical software package, Version 7 (SAS, Institute Inc. 2007). A Kruskal-Wallis analysis of variance was used to evaluate body temperature differences among age classes (adult, juveniles and hatchlings). We performed a Spearman rank correlation (r^s) to test the relationship between body (T_b), SVL and substrate temperatures (T_s). All measurements are reported as mean ± standard deviation. Statistical significance was < 0.05.

RESULTS

The mean SVL of all salamanders was 29.7 ± 13.24 (n = 24; range 17.17-60 mm) and the mean body temperature was 12.86 ± 3.77°C (range: 8-18°C). The SVL for adults was 54.33 ± 6.65 mm (n = 3; range 47-60 mm), for juveniles 28.3 ± 8.88 mm (n = 9; range 17.17-40.5 mm) and for hatchlings 20.96 ± 3.23 mm (n = 7; range 17.2-27 mm). Body temperature of adults (n = 4) was 13.85 ± 3.32°C, (range 8.9-16°C), for juveniles it was of 10.5 ± 3.59°C (n = 9; 8-18°C), and for hatchlings 14.53 ± 3.31°C (n = 9; range 9-18°C). There was no statistical significance between body temperatures of the size classes (H = 5.0024, df = 2, P = 0.082, Fig. 1). As a result, we combined temperature values for subsequent analyses.

Substrate temperature recorded during this study was 10.39 ± 3.37°C (range 6-16°C). There was a significant correlation between body and substrate temperature (r^s = 0.4563, P = 0.0376). Most salamanders were found under tree trunks (n = 22, 91.6 %), meanwhile the remainder were found under stones (n = 2, 8.3 %).

DISCUSSION

Thermoregulation in amphibians is behaviourial (emergence, retreat, selection of temperature, basking etc.) and physiological (acclimation, evaporative cooling etc.) (Brattstrom, 1963). Behaviourial thermoregulation enables ectotherms to use thermally diverse environments and yet control temperature-sensitive physiological processes (Feder, 1982). However, terrestrial salamanders from the Temperate Zone are exceptional because they exhibit seldom behaviourial thermoregulation in the field (Brattstrom, 1979) or do not thermoregulate in a manner that is conspicuous to biologists (Feder & Lynch, 1982).

Our results show that *P. leprosa* frequently occur beneath tree trunks as found by Bogert (1952) for other terrestrial salamanders. The hydric requirements of this secretive terrestrial salamander may also restrict it to microhabitats with high humidity and thermal homogeneity such as tree trunks which have a low thermal heterogeneity that may promote the apparent rarity of behaviourial thermoregulation in these organisms (Tracy, 1976). Consequently, salamanders have a narrow relationship with wet microhabitats which results in similar body and substrate temperatures. Our study suggests that body temperature of *P. leprosa* maintains a strong and positive correlation with substrate temperature in Sierra del Ajusco.

This study emphasizes the extent to which thermoregulation is related to microhabitat used. It

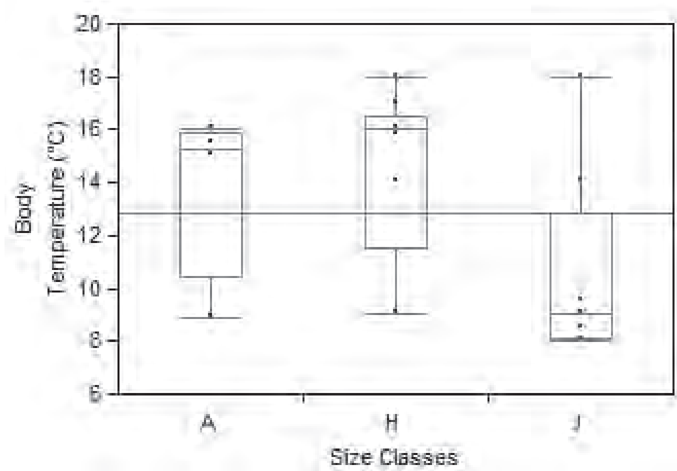

Figure 1. Comparison between body temperature and age classes in *Pseudoeurycea leprosa* in Sierra del Ajusco, Mexico. Adult (A), Juvenile (J) and Hatchling (H) age classes. Horizontal line across the graph is the mean for all animals sampled. Boxes indicate the standard deviation. The horizontal line inside the box is the mean of each sample. Vertical lines are the maximum and minimum values and any points outside the boxes are extreme values.

shows that more detailed studies involving other aspects of the thermal ecology of *P. leprosa* and consideration of habitat composition and other biological characteristics will be necessary for developing specific conservation strategies.

ACKNOWLEDGEMENTS

Field work was supported by grant Universidad Nacional Autónoma de Mexico SDEI-PTID-02 (Manejo de Ecosistemas y Desarrollo Humano). We thank Gamaliel Castañeda for providing helpful comments to the manuscript and I. Solano-Zavaleta, C. Duifhuis-Rivera and J. Maceda-Cruz for their help in the field work.

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