Thermoregulation of *Craugastor berkenbuschii* (Peters, 1870)

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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 *Craugastor berkenbuschii* in a remnant of tropical evergreen forest in southeastern México. Mean body temperature was 22.02 ± 1.55°C (range: 19.5-25.5°C). Body temperature was correlated with air and substrate temperature. It requires more complex studies involving other aspects of the thermal ecology, together with consideration of other biological characteristics, to purposefully conclude specific conservation strategies for this species.

THE family Craugastoridae comprises 114 species of frogs, of which 39 inhabit Mexico. The family represents 10.4% of the total Mexican amphibian fauna. Specifically the genus *Craugastor* occurs from southern Arizona to central Texas (USA) and south through tropical and subtropical habitats to northwestern Ecuador, Colombia and eastern Brazil (Frost, 2009). In Mexico the genus occurs from southeastern San Luis Potosi and northern Veracruz to northern Oaxaca, and to the Isthmus of Tehuantepec at 400-1,900 m ASL. Although these frogs are widely distributed, their ecology is still poorly known.

Craugastor berkenbuschii (Berkenbusch's Stream Frog) (Fig. 1 and 2) is endemic to Mexico. It inhabitats rocky streams in premontane and lower montane wet forests, has an insectivorous diet, and is a species with direct development (Pough et al., 2004). The frog is protected by Mexican law under the "Special Protection" category (Pr). The IUCN list the species as "Near Threatened" although it is still relatively widely distributed. It depends on areas of cloud forest habitat and thus its area of occupancy is probably not much greater than 2,000 km^2. The extent and quality of its habitat is rapidly declining, making this species close to qualifying as "Vulnerable" (Santos-Barrera & Flores-Villela, 2004).

Thermoregulation in amphibians is both behavioural (emergence, retreat, temperature selection and basking, etc.) and physiological (acclimation, evaporative cooling, etc.) (Brattstrom, 1963). Behavioural thermoregulation enables ectotherms to use thermally diverse environments and yet control temperature-sensitive physiological processes (Feder, 1982). In this paper we analyze the thermoregulation of *C. berkenbuschii* and describe the relationship of body temperature with substrate, air temperature and microhabitat for this frog.

METHODS AND MATERIALS

This study was carried out 6 km southestern of Paso del Moral locality, in municipality of Uxpanapa, Veracruz, México, (17º10´50" N, 94º35´0.8" W; 225 elev.). The climate of the study area is tropical

Figure 1. *Craugastor berkenbuschii* on the forest floor. Photograph © Uri Omar García-Vázquez. ◄

Figure 2. *Craugastor berkenbuschii* in a communal shelter hole. Photograph © Uri Omar García-Vázquez. ▲

with a mean annual temperature of 25°C and a mean annual rainfall of 2900 mm (García, 1973). Vegetation is tropical evergreen forest (Secretaría de Gobernación, 2005). We collected 21 frogs between 20:00 to 02:00 from 22 to 24 February 2009. Organisms were captured by hand and returned to their habitat after data collection. Body temperature (Tb to the nearest 0.2°C), air (Ta at 5 cm) and substrate temperatures (Ts on the site where the frog was first observed) were obtained using a Miller & Weber® (0-50 ± 0.2 °C) quick reading thermometer. We also recorded microhabitat type for each captured specimen. Snout-vent length (SVL) was measured with an electronic caliper to 0.1 mm and body mass measured using a Pesola® scale to 0.2 g.

We assessed normality and homocedasticity with Kolmogorov-Smirnov and Bartlett tests, respectively. Parametric statistical analyses were performed with JMP Statistical Software Package Version 7® (SAS, Institute Inc. 2007). We calculated residuals from the relationship of Tb to SVL to produce Tb adjusted variables which maintained variation of extrinsic factors and minimized the compounding effect of size related individual variation in SVL. We performed a multiple regression analysis to analyze the relationship among Tb, Ta, and Ts. All measurements are reported as mean ± standard deviation. Statistical significance (α) was set at 0.05.

RESULTS

The mean SVL of all frogs was 50.39 ± 11.05 (n = 21; range 30.9-69.5 mm) and the weight was 12.84 ± 8.54 (n = 21; range 2.2-29 mm). Overall mean Tb of *C. berkenbuschii* was 22.02 ± 1.55°C (19.5-25.5°C; n = 23). There was no significant relationship between SVL and Tb (y = 25.329 + 0.064 SVL, r^2 = 0.195, F = 4.387, P = 0.05) so we used the original data set on the analysis. Air temperature in the locality fluctuated between 20.6°C to 23.3°C (Ta = 22 ± 0.77°C, n = 23) and substrate temperature had an average of Ts = 20.36 ± 1.27°C, n = 23, with extremes of 19°C to 25.5°C. There was a significant relationship between Tb with both Ta and Ts (r^2 = 0.436, F = 7.349, P =

0.0043). Most frogs were found on the ground (n = 10) and among rocks (n = 8), the remainder were found on trunks (n = 3) and vegetation (n = 2).

DISCUSSION

Amphibian diversity is threatened by direct factors such as diseases, pesticides and habitat loss, and indirect factors like climate change and invasive species, which reduce their population viability, and increase their vulnerability to extinction (Semlitch, 2003). Among these risk factors, habitat loss and local environmental climate change are some of the most important factors causing tropical amphibian decline. The former creates a semi-natural landscape composed principally of forest fragments, immersed in an agricultural matrix (Saunders et al., 1991). The latter (climate change) alters the temperature and precipitation pattern and results in changes at the macro and micro climate level that may influence amphibian behaviours, such reproductive phenology, hibernation, aestivation and foraging (Blaustein et al., 2001). It could also potentially affect a frog's thermoregulatory behaviour. Some *Craugastor* species have been identified as habitat quality indicators in tropical rain forest fragments. Urbina-Cordona (2006) found that *Craugastor vulcani* is a truly forest interior/edge-avoiding species due to it requirement for living in forest fragments with high habitat quality (e.g., high leaf-litter cover, good understorey density, high relative humidity, but with lower temperatures) in order to reproduce and survive. The effect of decline factors, together with the highly specialized habitat use by *C. berkenbuschii* could lead to body/environment temperature change. Therefore, more complex studies, involving other aspects of thermal ecology of Berkenbusch´s Stream Frog, may prove useful. Such studies might include consideration of habitat composition and other biological characteristics that could aid development of specific conservation strategies for the species.

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