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Notes on Jumping Ability and Thermal Biology of the Enigmatic Anole *Chamaelinorops barbouri*

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By any criterion, *Chamaelinorops barbouri*, the enigmatic terrestrial anoline lizard from the mountains of Hispaniola, is remarkable. Unlike other anoles, *C. barbouri* is almost strictly terrestrial, lives in leaf litter, moves primarily by short hops, and has no stereotyped display behavior (Jenssen and Feely, 1991; Flores et al., 1994). Morphologically, *C. barbouri* possesses interzygapophysial wings that are unique among tetrapods and the function of which is poorly understood (Forsgaard, 1983). The phylogenetic relationships of *C. barbouri* are also uncertain. Williams (1969) proposed that *Chamaelinorops* is the last vestige of a pre-*Anolis* radiation and thus constitutes the sister-group to the genus *Anolis*. By contrast, recent biochemical studies suggest that *C. barbouri* arose from within *Anolis* (Wyles and Gorman, 1980; Hedges and Burnell, 1990; Hass et al., 1993; Jackman et al., in press; but see Case and Williams, 1987) and, consequently, that novel features of *C. barbouri* are relatively recently derived.

Field work in the Dominican Republic in 1989 and 1991 presented the opportunity to investigate several aspects of *Chamaelinorops* biology. The hypothesis that the vertebral structure of *C. barbouri* is an adaptation for jumping locomotion (Forsgaard, 1983) was tested by comparing its jumping ability to that of other anoles (Losos, 1990a; Losos et al., 1991). Although thermal biology of *Anolis* has been extensively studied, only data on field body temperatures are available for *C. barbouri* (Flores et al., 1994). Depending on phylogenetic relationships of *Chamaelinorops*, more extensive data on its thermal biology could shed light either on the ancestral condition for *Anolis* or the extent to which occupation of a novel microhabitat is accompanied by evolution in thermal biology.

Lizards were collected near Cabral, Provincia de Barahona, República Dominicana in August of 1989 and 1991. Jumping abilities were measured in 1991. Animals were transported to the University of California, Davis, where they were maintained for two weeks in plastic shoeboxes in which they were misted every 1–2 d and fed crickets.

Performance measurements were conducted by placing lizards on a flat board covered with a rough rubber surface 28 cm above the ground and inducing them to jump toward a pile of sticks by a tap to the tail. This procedure was repeated twice at hourly intervals; the longest jump was considered the maximum for each individual (protocol following methods in Losos [1990a]; note that some lizards in that study also were maintained in captivity prior to perfor-

mance testing). Jumping measurements were conducted at a room temperature of 30 C. We chose 30 C because four other forest anoles, which have median field body temperatures almost identical to the mean of *C. barbouri* (26.1–26.4 C vs. 26.0 C), have optimal performance temperatures for sprinting that range from 28–30 C (van Berkum, 1986; Flores et al., 1994). For comparative purposes, we report jumping capability of a similar-sized lizard, *Anolis auratus* from Barro Colorado Island, Panama. Jumping ability for *A. auratus* was measured as described above. For all lizards, snout-vent length (SVL), mass, and hindlimb length (from tip of the fourth toe to insertion of the leg into the body wall) were recorded.

For the physiological experiments in 1989, lizards were transported to the Museum of Vertebrate Zoology, University of California, Berkeley, where they were maintained in plastic shoeboxes as described above. Physiological measurements proceeded in chronological order as described below, from 22 August to 5 September, 1989. Preferred body temperature (T_p) was measured by placing lizards in a meter-long thermal gradient heated at one side by a 250 W infrared lamp and cooled by its placement within a walk-in refrigerator. Minimum and maximum temperatures on the gradient, measured by a copper lizard molded to the shape of *Anolis cristatellus*, were 16.0° and 45.3 C. We define T_p of a lizard as cloacal temperature (taken with a Bailey BAT-12 thermocouple reader) after one hour on the gradient. Critical thermal minimum (CT_{min}) was determined by cooling lizards in a refrigerator (6.1 C; methods following Spellerberg [1972]). Lizards were placed on their backs every 30 sec until they could not right themselves. Lizards took about 2–3 min to cool from room temperature to CT_{min} , at which time cloacal temperatures were recorded as above. Critical thermal maximum was determined by heating lizards under a 250 W infrared heat lamp until the loss of the righting response (following Spellerberg, 1972). In all but one case, lizards took 10–16 min to heat from room temperature to CT_{max} , at which time cloacal temperatures were taken with a Wescot thermometer. Due to its small size, one lizard took only 8.5 min to heat to CT_{max} .

Anolis auratus is slightly longer and heavier than *Chamaelinorops barbouri* and has slightly longer hindlegs, but has considerably greater jumping ability (Table 1). In comparison to 16 species of anoles for which data have previously been presented (Losos, 1990a; Losos et al., 1991), both species have relatively long hind legs for their size: based on a regression of hindlimb length vs. SVL (both variables ln-transformed) for all 18 species (data for *C. barbouri* from 1991 specimens), the hindlimbs of *C. barbouri* are 105.0% of the predicted value and those of *A. auratus* are 112.0% of the predicted value. Nonetheless, relative to its SVL, *C. barbouri* can jump only 80.6% of its expected ability, whereas *A. auratus* can jump 110.5% of expected. Based on a multiple regression including both SVL and hindlimb length as independent variables, *A. auratus* can jump 99.3% of its expected ability, but *C. barbouri* can jump only 76.4% as well as expected.

In the preferred temperature experiments, four individuals moved to the cool end of the thermal gradient and remained there, whereas the nine others chose an

TABLE 1. Morphological, physiological, and performance measurements ($\bar{x} \pm 1$ standard error).

	<i>Chamaelinorops barbouri</i>		<i>Anolis auratus</i>
	1989	1991	
N	12	10	16
SVL (mm)	35.4 \pm 0.6	38.8 \pm 0.6	40.4 \pm 0.9
Weight (g)	1.1 \pm 0.1	1.3 \pm 0.1	1.2 \pm 0.1
Hindlimb length (mm)	27.3 \pm 0.5	28.3 \pm 0.3	31.7 \pm 0.5
Jump distance (cm)		40.1 \pm 1.6	55.9 \pm 0.9

intermediate position. We report the mean T_p , both including and excluding these four lizards. Mean T_p of all 13 *C. barbouri* was 24.1 C \pm SE 0.7 (range 20.0–27.7 C). Mean of the nine lizards that regulated their temperature in the intermediate portion of the gradient was 25.2 C \pm SE 0.7 (range 22.0–27.7 C). CT_{min} of 13 lizards was 11.7 C \pm SE 0.3 (range 10.1–13.8 C) and CT_{max} of 12 lizards was 34.9 C \pm SE 0.6 (range 30.4–37.1 C).

Previous studies have found that most of the variation in jumping capability among anoles can be explained by body size and hindlimb length (Losos, 1990a; Losos et al., 1991). Indeed, the regression of jumping ability on size and hindlimb length, based on data from 16 previously studied species, perfectly predicted the jumping ability of *A. auratus*. However, the jumping ability of *C. barbouri* is 24% lower than its value predicted by this regression. Thus, the data give no support to the hypothesis (Forsgaard, 1983) that the vertebral structure of *Chamaelinorops* is related to enhanced maximal jumping abilities. In part, the relatively short jumping distance of *C. barbouri* probably results from its spindly legs and reduced limb musculature (a similar situation exists for the anolid *Polychrus gutturosus* [Losos, 1990b]).

We found that the critical thermal minimum and maximum for *C. barbouri* is similar to that for other forest-dwelling anoles (e.g., Hertz, 1979; van Berkum, 1986). In addition, like other anoles (e.g., Huey and Webster, 1976), *C. barbouri* shows a reasonably close correspondence between preferred and field body temperatures. However, *C. barbouri* is unusual in maintaining a body temperature ($\bar{x} = 26.0$) well above ambient air temperature ($\bar{x} = 22.3$) despite living in closed forest with little access to sunlit areas (Flores et al., 1994); the mechanism for this capability remains to be elucidated.

While handling lizards as part of the physiology experiments, we noticed that lizards often became immobile and adopted a vertically compressed posture. Simultaneously, the abdomen was extended downward, giving the lizard a flat and rounded appearance in profile. Subsequently, similar behavior was observed in the field. Dwarf chameleons of the genus *Brookesia*, which superficially look like *C. barbouri*, adopt a somewhat similar behavior (Raxworthy, 1991), which may serve to enhance crypticity or make ingestion by a predator difficult.

Much remains to be discovered about *C. barbouri*. Aspects of its ecology and behavior are unique among anoles (Jenssen and Feely, 1991; Flores et al., 1994) and

its unusual morphology continues to defy adaptive and functional explanation. As we have shown, however, laboratory measurements of thermal physiology are similar to other forest-dwelling anoles.

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Reproductive Activity in *Tropidurus etheridgei* in the Semi-arid Chaco of Salta, Argentina

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The timing of reproductive events in many reptiles is related to environmental factors, such as photoperiod (Clerke and Alford, 1993), temperature (particularly in temperate climates; Fitch, 1970), or rainfall (tropical environments; Barbault, 1976; Fitch, 1982; Magnusson, 1987). In some lizard assemblages, more than a single reproductive type can be found at one locality (James and Shine, 1985, 1988; Vitt, 1986, 1990; Clerke and Alford, 1993). Fitch (1982) suggested that rainfall influenced the timing of egg deposition. Vitt (1986), however, found that the timing of reproduction, even in the same habitat, is not always associated with precipitation. Dunham and Miles (1985) suggested that phylogenetic constraints and biogeographic history may play a major role in shaping reproductive patterns. Some species have broad geographical distributions and studies have demonstrated phenotypic plasticity in reproduction for such wide-ranging species (Seigel and Ford, 1991; van Marken Lichtenbelt and Albers, 1993).

Tropidurus etheridgei is a medium-sized terrestrial to arboreal lizard (male SVL = 115 mm) of the *torquatus* group (Rodrigues, 1987), distributed in the generally dry habitats from the cerrado to the chacoan region

of Brazil, Paraguay, Bolivia, and Argentina (Cei, 1993). In cerrado habitat they consume flowers and insects, predominately ants (Vitt, 1991).

Vitt (1991) described the reproductive characteristics of this species but did not include data on the length of fat body and reproductive cycles, nor document reproductive activity throughout the year. The objectives of the present study were to: (1) describe the reproductive and abdominal fat body cycles of *T. etheridgei*, (2) relate some reproductive parameters to environmental factors, and (3) compare the results obtained herein with congeneric and sympatric species.

The study site was on a ranch called "Pozo Largo" (25°05'S, 64°11'W), 8 km S and 12 km E from J. V. González, in the province of Salta, Argentina. The site is characterized by an intense rainy season (96.5% of the precipitation falls between October and April); mean annual rainfall is 553 mm (Bianchi and Yañez, 1992). Temperature and photoperiod vary seasonally, but are less pronounced as is typical of temperate-subtropical climates (Bucher, 1980). The vegetation is a dry thorn forest mainly composed by *Aspidosperma*, *Schinopsis*, and *Prosopis* species (Morello and Saravia Toledo, 1959; Bucher, 1980). The type of habitat belongs to the chacoan occidental district (Cabrera and Willink, 1980).

Lizards were obtained during dry and wet seasons over a period of 19 mo using a combination of seven drift fence pit-fall arrays and 45 pits alongside an internal path in the study area (Cruz et al., 1993). Additional individuals were obtained by hand or shooting. After killing, specimens were fixed in 10% formaldehyde and later transferred to 75% ethanol. The material was deposited in the collection of the Instituto de Herpetología, Fundación Miguel Lillo, Tucumán, Argentina.

Reproductive stages were based on occurrence of enlarged (yolked) follicles and oviductal eggs in females, and enlarged testes and epididymides in the males. The number of enlarged follicles and oviductal eggs was used to estimate clutch size. The concurrent occurrence of enlarged ovarian follicles and oviductal eggs was considered to be evidence that more than one clutch was produced each year. Abdominal fat bodies were weighed to the nearest 0.01 g. Snout-vent length (SVL), head dimensions (length, width, and height), and testes were measured with electronic vernier caliper to the nearest 0.01 mm. In most cases only the left testis was measured, except when the left tract was damaged.

Males were larger than females in SVL (Fig. 1: Males = 71.7 ± 1.1 mm, $N = 101$; females = 66.7 ± 0.79 mm, $N = 95$; $P < 0.05$). Head size (length, width, and height) also was significantly larger in males (Table 1). The relationship between head width and SVL was positive in both sexes, but the slope in males was more pronounced than in females and males had wider heads at the same SVL (Fig. 2). Adult males, (those > 55.9 mm SVL) exhibited dark brown throats and femoral patches, and older males have patches ventrally as well.

Tropidurus etheridgei was active year-round; however, during the dry season (May to September) captures were less frequent than in the wet season (October through April). Fig. 3 shows the capture frequency by