

SHORT COMMUNICATION

# Notes on the postcranial osteology of the sand lizard *Liolaemus azarai* (Squamata: Liolaemidae)

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**Palavras-chave:** Argentina, características osteológicas, esqueleto, Paraguai, variação.

The liolaemid lizard genus *Liolaemus* Wiegmann, 1834 comprises more than 235 species described and is widely distributed in southern South America (Avila *et al.* 2010, Lobo *et al.* 2010, Breitman *et al.* 2013). It is one of three genera of Liolaemidae. *Liolaemus* differs osteologically from *Ctenoblepharys* Tschudi, 1845 and *Phymaturus* Gravenhorst, 1837 in several characters. The lateral borders of orbitonasal fenestra are formed by down growths of the frontals. The supratemporal is enclosed in a groove on the ventral surface of the paraoccipital process of parietal. The dentary extends beyond the posterior lingual process of coronoid. The anterior process of the angular is reduced or absent, and the posterior coracoid fenestra is present (Etheridge 1995).

Osteological studies of the diverse genus *Liolaemus* are scarce. The cranial osteology of *L. lutzae*, *L. signifer*, and *L. occipitalis* was described by Fabián-Beurmann and Vieira (1980) and Simões-Lópes and Krause (1988). Keller and Krause (1986) provided a description of the appendicular skeleton of *L. occipitalis*, and da Silva and Verrastro (2007) reported on the postcranial axial skeleton of *L. arambarensis*. In his phylogenetic analysis of the *L. wiegmanni* Group, Etheridge (2000) reported a sequence of morphological transformations that facilitate subterranean breathing; these include changes in the sternum and interclavicle. Recently, Lobo and Abdala (2001) identified 35 osteological characters of *Liolaemus* that they considered to be variable and phylogenetically informative. We examined 23 postcranial skeletal characters of *Liolaemus azarai* Avila, 2003 and the distribution of each of these in *Liolaemus* to provide more information about morphological variation in the genus.

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*Liolaemus azarai* is a small lizard (54.3 and 48.7 mm snout-vent length in males and females, respectively) that inhabits sandy dunes in northeastern Argentina and on Yacyretá Island (Paraguay) (Álvarez *et al.* 2003, Avila 2003). This lizard is a member of the *L. wiegmannii* Group, which also includes *L. arambarensis* Verrastro, Veronese, Bujes and Dias Filho, 2003; *L. cuyumhue* Avila, Morando, Pérez and Sites, 2009; *L. lutzae* Mertens, 1938; *L. multimaculatus* (Duméril and Bibrón, 1837); *L. occipitalis* Boulenger, 1885; *L. rabinoi* (Ceí, 1974); *L. riojanus* Ceí, 1979; *L. salinicola* Laurent, 1986; *L. scapularis* Laurent, 1982; and *L. wiegmannii* (Duméril and Bibrón, 1837).

We examined skeletons of seven adult and juvenile specimens of *Liolaemus azarai* that were cleared and double-stained following the methodology of Dingerkus and Uhler (1977). The specimens examined are deposited in the herpetological collection of the Universidad Nacional del Nordeste (UNNEC; Appendix I).

Of the 23 postcranial skeleton characters that we examined, 17 were proposed by Lobo and Abdala (2001) and six others were extracted from the literature, as follow: number of sternal and xiphisternal ribs (Etheridge 1965, Torres-Carvajal 2004); shape of sternum and extent of medial process of interclavicle (Etheridge 2000); and condition of cartilaginous ends of Cervical Ribs V and VI (da Silva and Verrastro 2007). Measurements were made with digital calipers (precision 0.01 mm) and seven ratios were calculated from the morphometric data. Illustrations were prepared with the aid of a stereomicroscope equipped with a camera lucida.

The postcranial skeletal characters examined and their corresponding states in *Liolaemus azarai* are listed in Tables 1 and 2 and depicted in Figures 1–3.

Six osteological features characterizing *Liolaemus azarai* were described in most of 24

species analyzed by Lobo and Abdala (2001). These include presence/absence of the following features: Cervical Rib III; clavicle fenestra; posterior process of sternum; single, median sternal fontanelle; anteriorly oriented pubis; and expansion of free end of hypoischium. In *L. azarai*, 10 morphological characters do not vary, and six others vary as follow (Table 1): (1) cartilaginous distal ends of Cervical Ribs V (entire/divided, 5/2 specimens); (2) cartilaginous distal ends of Cervical Rib VI (entire/divided, 3/4); (3) number of sternal ribs (2/3, 4/3 specimens); (4) number of xiphisternal ribs (2/3, 3/4 specimens); (5) number of postxiphisternal (3/4, 2/5 specimens); and (6) length of the median process of the interclavicle (long/short, 3/4).

The ranges and means of the seven morphometric features (lateral process of interclavicle length/skull length; maximum diameter of coracoid fenestra/maximum diameter of scapular fenestra; hypoischium length/skull length; uneven xiphisternal rod length/skull length; clavicle length/ skull length; clavicle width/ skull length; sternum width/ sternum length) recorded for *Liolaemus azarai* fall within the variation expected for the genus (fide Lobo and Abdala 2001).

Our findings complement the current knowledge about the osteological variation in *Liolaemus* and these character states may include in a data matrix to future phylogenetic studies.

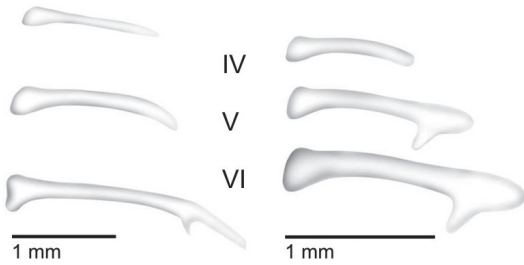
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**Table 1.** Character states of postcranial skeleton of *Liolaemus* species including *L. azarai*. Sources: Keller and Krause 1986, Etheridge 1995, 2000, Lobo and Abdala 2001, da Silva and Verrastro 2007, this study.

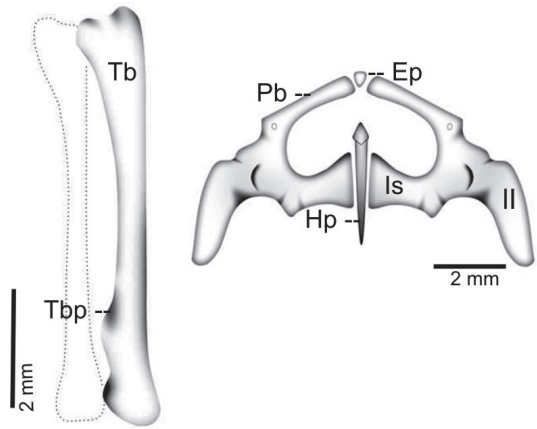
Characters	Character states	Species
Cervical Rib III	Absent	<b>L. azarai</b> , <i>L. arambarensis</i> , <i>L. bibronii</i> , <i>L. bitaeniatus</i> , <i>L. boulengeri</i> , <i>L. cf. silvanae</i> , <i>L. grosseorum</i> , <i>L. koslowskyi</i> , <i>L. lemniscatus</i> , <i>L. magellanicus</i> , <i>L. neuquensis</i> , <i>L. pictus</i> , <i>L. pseudoanomalus</i> , <i>L. tenuis</i>
	Present	<i>L. kingii</i>
	Variable (present/absent)	<i>L. buergeri</i> , <i>L. chacoensis</i> , <i>L. chiliensis</i> , <i>L. nigroviridis</i>
Cervical Rib IV, cartilaginous end	Entire	<i>L. arambarensis</i> , <i>L. lemniscatus</i> , <i>L. tenuis</i>
	Divided	<i>L. bitaeniatus</i> , <i>L. cf. silvanae</i> , <i>L. neuquensis</i> , <i>L. pictus</i>
	Variable (entire/divided)	<b>L. azarai</b> , <i>L. boulengeri</i> , <i>L. bibronii</i> , <i>L. buergeri</i> , <i>L. chacoensis</i> , <i>L. chiliensis</i> , <i>L. grosseorum</i> , <i>L. kingii</i> , <i>L. koslowskyi</i> , <i>L. magellanicus</i> , <i>L. nigroviridis</i> , <i>L. pseudoanomalus</i>
Cervical Rib V, cartilaginous end	Divided	<i>L. arambarensis</i>
	Variable (entire/divided)	<b>L. azarai</b>
Cervical Rib VI, cartilaginous end	Divided	<i>L. arambarensis</i>
	Variable (entire/divided)	<b>L. azarai</b>
Sternal ribs, number	3	<i>L. arambarensis</i> , <i>L. occipitalis</i>
	2 or 3	<b>L. azarai</b>
Xiphisternal ribs, number	2	<i>L. arambarensis</i> , <i>L. occipitalis</i>
	2 or 3	<b>L. azarai</b>
Elongated postxiphisternal ribs, range	5–7	<i>L. kingii</i> and <i>L. lineomaculatus</i> Groups
	3–5	<i>L. chiliensis</i> Group
	2–5	<i>L. signifer</i> Group
	3 or 4	<i>L. wiegmanni</i> Group: <b>L. azarai</b> , <i>L. salincola</i>
Sternal fontanelle	Variable (divided or absent)	<i>L. riojanus</i> , <i>L. multimaculatus</i> , <i>L. occipitalis</i> , <i>L. salinicola</i> , <i>L. scapularis</i> , <i>L. arambarensis</i> <i>L. wiegmanni</i> Group: <b>L. azarai</b> , <i>L. wiegmanni</i> , <i>L. lutzae</i> .
	Single, median	<i>L. kingii</i> , <i>L. archeforus</i> , <i>L. lineomaculatus</i> , <i>L. chiliensis</i> , <i>L. signifer</i> and <i>L. boulengeri</i> Groups.
Sternum shape	Wider than long	<b>L. azarai</b> , <i>L. multimaculatus</i> , <i>L. occipitalis</i> , <i>L. riojanus</i> , <i>L. salinicola</i> , <i>L. scapularis</i>
	As wide as long	<i>L. lutzae</i> and <i>L. wiegmanni</i>

Table 1. Continued.

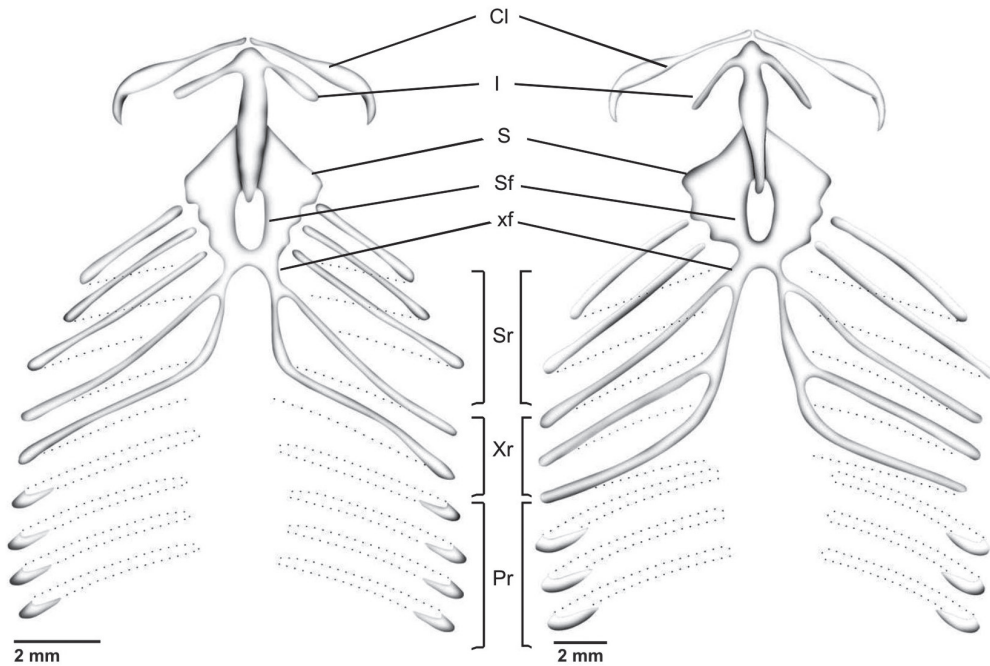
Posterior process of sternum	Variable (absent/present)	<i>L. pictus</i> , <i>L. tenuis</i> <i>L. wiegmanni</i> Group: <b><i>L. azarai</i></b> , <i>L. arambarensis</i> .
	Absent	<i>L. kingii</i> , <i>L. archeforus</i> , <i>L. lineomaculatus</i> , <i>L. chiliensis</i> , <i>L. signifer</i> and <i>L. boulengeri</i> Groups.
Clavicle	Variable (fenestrated/ not fenestrated)	<i>L. tenuis</i> , <i>L. koslowskyi</i> <i>L. wiegmanni</i> Group: <b><i>L. azarai</i></b> , <i>L. arambarensis</i> , <i>L. occipitalis</i> .
	Not fenestrated	<i>L. lineomaculatus</i> , <i>L. chiliensis</i> , <i>L. signifer</i> and <i>L. boulengeri</i> Groups.
Median process of interclavicle	Variable (Not reaching/reaching level of anteromost pair of sternal ribs)	<b><i>L. azarai</i></b> , <i>L. lutzae</i> , <i>L. wiegmanni</i> , <i>L. salinicola</i>
	Not reaching level of anteromost pair of sternal ribs	<i>L. occipitalis</i> <i>L. riojanus</i> , <i>L. multimaculatus</i> , <i>L. scapularis</i> , <i>L. arambarensis</i>
Free end of hypischium	Expanded	<i>L. tenuis</i> , <i>L. kingii</i> <b><i>L. azarai</i></b> , <i>L. buergeri</i> , <i>L. chacoensis</i> , <i>L. chiliensis</i> , <i>L. cf. silvanae</i> , <i>L. koslowskyi</i> , <i>L. lemniscatus</i> , <i>L. magellanicus</i> , <i>L. neuquensis</i> , <i>L. pictus</i>
	Not expanded	<i>L. bibronii</i> , <i>L. boulengeri</i> , <i>L. grosseorum</i> , <i>L. nigroviridis</i> , <i>L. pseudoanomalus</i>
Pubis orientation	Perpendicular to vertebral column	<i>L. pseudoanomalus</i> <i>L. wiegmanni</i> Group: <b><i>L. azarai</i></b> , <i>L. occipitalis</i>
	Forward	<i>L. kingii</i> , <i>L. archeforus</i> , <i>L. lineomaculatus</i> , <i>L. chiliensis</i> , <i>L. signifer</i> and <i>L. boulengeri</i> Groups.
Bladelike process of the tibia	Present	<i>L. montanus</i> Group: including <b><i>L. azarai</i></b>
	Absent	<i>L. kingii</i> , <i>L. archeforus</i> , <i>L. lineomaculatus</i> , <i>L. chiliensis</i> Groups, <i>L. pseudoanomalus</i>
Caudal vertebrae without chevrons, number	1	<i>L. capillitas</i>
	2	<i>L. cf. quilmes</i> , <i>L. dorbignyi</i> , <i>L. grosseorum</i> , <i>L. salinicola</i> , <i>L. tenuis</i>
	3	<i>L. bibronii</i> , <i>L. cf. silvanae</i> , <i>L. chacoensis</i> , <i>L. chiliensis</i> , <i>L. koslowskyi</i> , <i>L. lemniscatus</i> , <i>L. orientalis</i> , <i>L. ramirezae</i>
	4	<b><i>L. azarai</i></b> , <i>L. ornatus</i>
	Variable (2/3)	<i>L. boulengeri</i> , <i>L. burgeri</i> , <i>L. kingii</i> , <i>L. magellanicus</i> , <i>L. neuquensis</i> , <i>L. nigroviridis</i> , <i>L. pictus</i>



**Figure 1.** Cartilaginous ends of cervical ribs IV–VI of *Liolaemus azarai* (UNNEC 10588, left; UNNEC 4333, right).



**Figure 3.** (A) Dorsal view of left tibia of *Liolaemus azarai* (UNNEC 10587, left). (B) Ventral view of pelvic girdle of *L. azarai* (UNNEC 9656, right). Abbreviations: Ep., epipubis; Hp, hypoischium; Il, ilium; Is, ischium; Pb, pubis; Tb, tibia; Tbp, bladelike process of the tibia.



**Figure 2.** Clavicle, interclavicle, sternum, and sternal, xiphisternal, and postxiphisternal ribs of *Liolaemus azarai* in ventral view (UNNEC 4333, left; UNNEC 9659, right). Abbreviations: Cl, clavicle; I, interclavicle; Pr, postxiphisternal ribs; S, sternum; Sf, sternal fontanelle; Sr, sternal ribs; xf, xiphisternal ribs; xr, xiphisternal rods.

**Table 2.** Ratios based on measurements of ten postcranial characters skeleton of *Liolaemus azarai*.

Morphometric ratios	Range	Mean $\pm$ SD
Lateral process of interclavicle length/skull length	0.24–0.28	0.26 $\pm$ 0.017
Maximum diameter of coracoid fenestra/maximum diameter of scapular fenestra	0.3–0.7	0.47 $\pm$ 0.13
Hypoischium length/skull length	0.34–0.5	0.43 $\pm$ 0.069
Uneven Xiphisternal rod length/skull length	0.02–0.1	0.06 $\pm$ 0.026
Clavicle length/skull length	0.25–0.4	0.32 $\pm$ 0.06
Clavicle width/skull length	0.01–0.09	0.07 $\pm$ 0.017
Sternum width/sternum length	0.75–1.12	0.9 $\pm$ 0.14

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**Appendix I.** Specimens Examined.

ARGENTINA: CORRIENTES: Isla Apipé Grande: Puerto Arazá (27°28'42" S, 56°56'34" W) 2 ♂, 21.IX.2007, V. Zaracho col. (UNNEC 09656, UNNEC 09659); ♀, 4.XII.2007, V. Zaracho col. (UNNEC 09770); 2 ♂, 20.IX.2009, V. Zaracho col. (UNNEC 10587, UNNEC 10588); San Miguel: Curuzú Laurel (27°56'11" S, 57°30'04" W) ♂, 14.III.1992, R. Aguirre col. (UNNEC 04333); Concepción: Estancia Rodeo Porá (28°33'11" S, 58°06'44" W) ♂, 13.XII.2001, R. Aguirre col. (UNNEC 07634).