

# Structure of claws and toes of two tropidurid lizard species of Restinga from Southeastern Brazil: adaptations to the vertical use of the habitat

## Estructura de garras y dedos en dos lagartos tropidúridos de Restinga, sureste de Brasil: adaptaciones al uso vertical del hábitat

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### ABSTRACT

*Tropidurus torquatus* and *Liolaemus lutzae*, found in a restinga habitat, show some morphological differences associated with differential microhabitats use. There were made measurements of the snout-vent length, length and width of the largest toe of hand and foot, and length, width, height and curvature of the claws. We counted the number of adhesive lamellae of the largest toe of each member. *T. torquatus* has larger toes, greater number of adhesive lamellae and higher and more curve claws than *L. lutzae*. No significant differences in toe and claw widths were found. These results suggest that the differences found in the morphology of toes and claws of these two species would be associated with the differential microhabitat use. *T. torquatus* has morphological adaptations that allow it to use the microhabitat both vertically or horizontally, while *L. lutzae* use it only horizontally.

**Key words:** Tropiduridae, ecomorphology, lizard, claw, microhabitat use.

### RESUMEN

*Tropidurus torquatus* y *Liolaemus lutzae* hallados en un hábitat de restinga, muestran algunas diferencias morfológicas asociadas a el uso diferencial de microhábitats. Se realizaron mediciones de la longitud "snout-vent", longitud y ancho del dedo mayor de la mano y el pie y, longitud, ancho, altura y curvatura de las garras. Se contó el número de lamelas adhesivas del dedo mayor de cada miembro. *T. torquatus* posee dedos más grandes, mayor número de lamelas adhesivas y garras más altas y curvadas que *L. lutzae*. No se hallaron diferencias significativas en los anchos de dedos y garras. Estos resultados sugieren que las diferencias encontradas en la morfología de dedos y garras de estas dos especies estarían asociadas con el uso diferencial del microhábitat. *T. torquatus* posee adaptaciones que le permiten utilizar el microhábitat tanto vertical como horizontalmente, mientras que *L. lutzae* solamente lo utiliza en forma horizontal.

**Palabras clave:** Tropiduridae, ecomorfología, lagartija, garra, uso de microhábitat.

### INTRODUCTION

Several specific works exist on different groups of lizards, where aspects such as morphology, foraging strategies, differentiated use of microhabitats and share of resources are analyzed (e.g., MacArthur & Pianka 1966, Pianka 1973, 1986, Pough 1973, Huey & Pianka 1981, Araújo 1984, 1991, Vitt 1990, 1991, Colli et al. 1992, 1997, Teixeira-Filho et al. 1993, 1995,

1996, 2001, Losos et al. 1993, Van Damme et al. 1997, Zani 2000, Kohlsdorf et al. 2001). Studies about relationships among ecology and morphology (ecomorphology) in animals can explain some points of natural selection based on partitioning of resources like space and food in a community. The interest in developing studies in this area is increasing every day, because such analyses allow a better understanding of the ecological, behavioural and morphologi-

cal coevolution of the species to be studied (Williams 1972, 1983, Moermond 1979, Pounds 1988, Vitt 1991, Colli et al. 1992).

Nowadays, studies linking phylogenetics to ecomorphology of lizards have been undertaken, as well as studies that seek to correlate morphology and clinging performance of these animals in different substrata (Van Damme et al. 1997, Zani 2000, Kohlsdorf et al. 2001, Teixeira-Filho et al. 2001). These studies contribute to a better understanding of the ecomorphological differences found in these animal groups.

Zani (2000) studied 13 families of lizards, analyzing them both from phylogenetic and of the morphological points of view. This and other recent studies have demonstrated that the ability of the lizards for clinging links intimately with a physical problem: the height of the point of gravity (Losos & Sinervo 1989, Sinervo & Losos 1991, Losos et al. 1993, Van Damme et al. 1997). The higher the point of gravity, more difficult it becomes for the animal to stabilize its clinging function to a substratum, and the lower the point of gravity, the larger the stability for species that present some degree of vertical use of the habitat (Losos et al. 1993, Van Damme et al. 1997). Animals considered arboreal tend to possess longer toes and shorter and more curve claws (Colli et al. 1992, Vrcibradic & Rocha 1996, Zani 2000, Teixeira-Filho et al. 2001), unlike species restricted to terrestrial habitat.

Claw curvature is an important parameter related to animal behaviour and feeding strategy. Methods have been described elsewhere that estimate curvatures taking into account the geometric features and considering reference points along the claw and in some cases at the inner part of it (Zani 2000). There are, nevertheless, at least two important remarks regarding the uncertainty about the use of this method: first, it is based on trigonometric relationships of inner angles which leads to first-order approximation, and its estimation is very dependent on curvature pattern. Second, it has a certain dependence on arbitrary choice of reference points to establish a trigonometric relationship.

In the Restinga da Barra de Maricá, in Rio de Janeiro State, there occur nine species of lizards, belonging to four families (Araújo 1991). Among them there are two tropidurids

(*Tropidurus torquatus* Wied, 1820 and *Liolaemus lutzae* Mertens, 1938), that differ strongly in microhabitat use. *Tropidurus torquatus* occurs in the area of dunes and it uses habitat vertically and horizontally to the same degree (Araújo 1991, Teixeira-Filho et al. 1996, 2001, Fialho et al. 2000). *Liolaemus lutzae* only occurs in the beach area, being exclusively a terrestrial species (Araújo 1991, Rocha 1991). The dunes and the beach area differ strongly in the composition of the vegetal community. The vegetation of dunes varies from shrubby to arboreal, while in the beach area it is herbaceous (Henriques et al. 1984). It is important to point out that several studies have already been carried out in the area (e.g., Rocha 1988, 1991, 1993, Fialho 1990, Machado & Rocha-Barbosa 1991, Rocha-Barbosa & Mandarim-de-Lacerda 1991, Fernandes & Rocha-Barbosa 1992, Rocha-Barbosa et al. 1993, 1998, Teixeira-Filho et al. 1996, 2001, Ribas et al. 1998, Fialho et al. 2000), but information on the ecomorphology of these lizards is still quite scarce.

In this study, we tested the hypothesis if lizards *Tropidurus torquatus* and *Liolaemus lutzae* present morphological differences concerning their claws and toes structures, since the microhabitat use for these species occurs in contrasting ways.

#### MATERIAL AND METHODS

We used only adult animals (18 *Liolaemus lutzae*; 24 *Tropidurus torquatus*), males and females. The specimens are deposited in the collections of the Departments of Zoology and Ecology of the Universidade do Estado do Rio de Janeiro, and were previously collected in Restinga da Barra de Maricá. This restinga is a coastal area comprising a sand ridge covered by vegetation that varies from herbaceous (in the beach area) to shrubby (in the primary and secondary dunes) (Henriques et al. 1984, Silva and Somner 1984), located approximately 38 km east of the city of Rio de Janeiro, Brazil (22°57' S, 43°50' W).

We measured the snout-vent length (SVL), the length and width of the largest toe of the forelimb (LLTF and WLTF, respectively), the length and width of the largest toe of the hindlimb (LLTH and WLTH, respectively) and the claw length (CL) of these toes, using a vernier

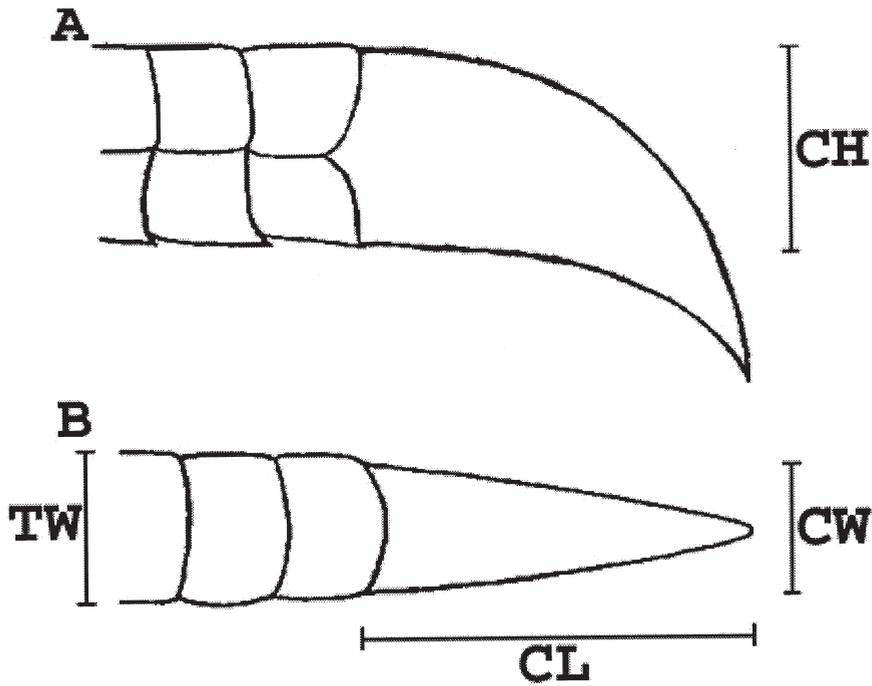


Fig.1: Morphometric marks used on the claws and toes of *Tropidurus torquatus* and *Liolaemus lutzae*: (A) lateral view; (B) dorsal view; CH = claw height; CL = claw length; CW = claw width; TW = toe width.

Marcas morfométricas usadas en garras y dedos de *Tropidurus torquatus* y *Liolaemus lutzae*: (A) vista lateral; (B) vista dorsal; CH = altura de la garra; CL = longitud de la garra; CW = ancho de la garra; TW = ancho del dedo.

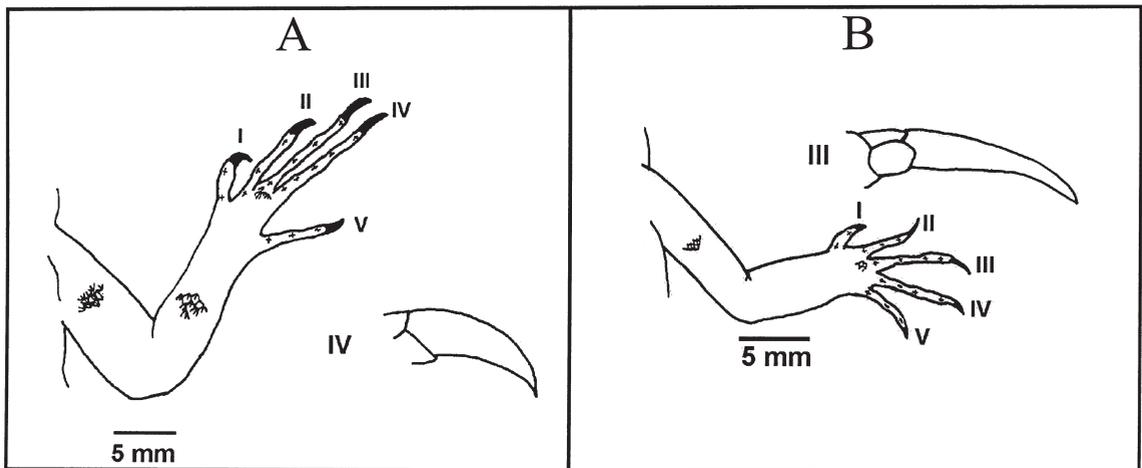


Fig. 2: Schematic drawing of forelimbs of (A) *Tropidurus torquatus* and (B) *Liolaemus lutzae*. Claws of the largest fingers from each species are in detail.

Esquema de los miembros anteriores de (A) *Tropidurus torquatus* y (B) *Liolaemus lutzae*. Las garras de los dedos más grandes de cada especie son en detalle.

caliper with precision of 0.05 mm. The claw width (CW) and claw height (CH) of both toes were measured at their basis (the point where the last scale ends) using a micrometer with precision of 0.01 mm (Fig. 1) shows the morphometric measurements used for claws and toes. According to Teixeira-Filho et al. (2001), the largest toe of the forelimb (LTF) of *T. torquatus* in Barra de Maricá is the fourth, while in *L. lutzae* is the third. For both species, the largest toe of hindlimb (LTH) is the fourth (Teixeira-Filho et al. 2001). Figure 2 shows the claws of these fingers in detail.

Curvature measurements were based on Zani (2000) method that use a geometric relation of linear segments defined at the inner part of the claw. Claws were digitalized from a scanned image taken from a light box. Amplifications of the images were applied maintaining a unit scaling factor. In addition, the adhesive lamella number of the largest toes was counted under stereoscopic microscope.

Differences in LLTF, LLTH, WLTF, WLTH, CL, CW, CH and adhesive lamella number between the two species were tested by analysis of covariance (ANCOVA, Zar 1999), using the SVL as covariate. Differences among claw curvature was tested by test function – F followed by Student t-tests.

## RESULTS

The data showed a significant difference in the heights of the claws among the species, both for claws of the forelimbs (ANCOVA,  $F = 3.784$ ,  $df = 27$ ,  $P = 0.036$ ) and for the hindlimbs (ANCOVA,  $F = 6.762$ ,  $df = 27$ ,  $P = 0.004$ ) with *Tropidurus torquatus* tending to have higher claws than those of *Liolaemus lutzae* (Table 1).

Although *T. torquatus* has somewhat wider claws than those of *L. lutzae* (Table 1), these differences were not statistically significant

TABLE 1

Averages, standard deviations (SD) and ranges of claw and toe measurements of *Tropidurus torquatus* and *Liolaemus lutzae* from Restinga da Barra de Maricá, Rio de Janeiro: SVL = snout-vent length; F = forelimb; H = hindlimb; CL = claw length; CH = claw height; CW = claw width;

CC = claw curvature; LLTF = length of the largest toe of the forelimb; LLTH = length of the largest toe of the hindlimb; WLTF = width of the largest toe of the forelimb; WLTH = width of the largest toe of the hindlimb. Measurements are in mm. Numbers in parentheses indicate sample sizes

Medias, desviaciones estándar (SD) y rangos de las medidas de garras y dedos de *Tropidurus torquatus* y *Liolaemus lutzae* de la Restinga da Barra de Maricá, Río de Janeiro: SVL = distancia desde el hocico al origen de la cloaca; F = miembro anterior; H = miembro posterior; CL = longitud de la garra; CH = altura de la garra; CW = anchura de la garra; CC = curvatura de la garra; LLTF = longitud del dedo más grande del miembro anterior; LLTH = longitud del dedo más grande del miembro posterior; WLTF = anchura del dedo más grande del miembro anterior; WLTH = anchura del dedo más grande del miembro posterior. Las medidas están en mm. Los números entre paréntesis indican los tamaños de muestra

Measure	<i>T. torquatus</i>		<i>L. lutzae</i>		
	Average $\pm$ SD	Range	Average $\pm$ SD	Range	
SVL	73.44 $\pm$ 9.50 (21)	55.00 - 88.95	68.42 $\pm$ 7.66 (17)	54.45 - 79.55	
CL	F	1.52 $\pm$ 0.42 (24)	0.75 - 2.40	1.74 $\pm$ 0.41 (18)	0.95 - 2.55
	H	1.96 $\pm$ 0.54 (24)	1.05 - 3.20	2.38 $\pm$ 0.50 (18)	1.65 - 3.30
CH	F	0.47 $\pm$ 0.11 (20)	0.33 - 0.73	0.42 $\pm$ 0.03 (11)	0.40 - 0.49
	H	0.56 $\pm$ 0.14 (20)	0.36 - 0.86	0.47 $\pm$ 0.03 (11)	0.45 - 0.55
CW	F	0.21 $\pm$ 0.04 (20)	0.15 - 0.29	0.18 $\pm$ 0.03 (11)	0.14 - 0.23
	H	0.28 $\pm$ 0.06 (21)	0.19 - 0.36	0.24 $\pm$ 0.05 (11)	0.17 - 0.32
CC	F	87.35 $\pm$ 9.22 (05)	71.06 - 93.70	71.99 $\pm$ 20.10 (04)	52.28 - 94.13
	H	73.62 $\pm$ 11.40 (05)	60.28 - 90.70	40.22 $\pm$ 20.62 (04)	21.26 - 64.16
LLT	F	8.14 $\pm$ 0.89 (20)	6.40 - 9.75	6.53 $\pm$ 0.91 (12)	4.65 - 7.80
LLTH		14.11 $\pm$ 1.63 (21)	11.25 - 16.75	10.46 $\pm$ 1.39 (12)	8.05 - 12.75
WLTF		0.27 $\pm$ 0.06 (21)	0.16 - 0.38	0.24 $\pm$ 0.03 (11)	0.20 - 0.30
WLTH		0.35 $\pm$ 0.11 (21)	0.19 - 0.61	0.29 $\pm$ 0.04 (11)	0.24 - 0.34

(ANCOVA, claw of the forelimb,  $F = 2.219$ ,  $df = 27$ ,  $P = 0.128$ ; claw of the hindlimb,  $F = 0.766$ ,  $df = 28$ ,  $P = 0.474$ ).

*Liolaemus lutzae* had longer claws in both members (Table 1), however, the claws of the forelimbs did not differ significantly in length to those of *T. torquatus* (ANCOVA,  $F = 2.492$ ,  $df = 38$ ,  $P = 0.096$ ), while the claws of the hindlimbs showed a significant difference in this variable (ANCOVA,  $F = 3.537$ ,  $df = 38$ ,  $P = 0.039$ ) (Table 1). In relation to the curvature of the claws of the forelimbs and hindlimbs (Table 1), *T. torquatus* exhibited curver claws than *L. lutzae*, in both cases (forelimb,  $P < 0,000768$ ; hindlimb,  $P < 0,000294$ ).

The data showed a significant difference among the species with relationship to the length of the toes, *T. torquatus* toes tending to be significantly larger than *L. lutzae* (Table 1), both in the forelimb (ANCOVA,  $F = 9.928$ ,  $df = 27$ ,  $P < 0.001$ ) and in the hindlimb (ANCOVA,  $F = 25.313$ ,  $df = 29$ ,  $P < 0.001$ ). As with width, there was no significant difference in both toes (ANCOVA, WLTF:  $F = 0.465$ ,  $df = 28$ ,  $P = 0.633$ ; WLTH:  $F = 1.618$ ,  $df = 28$ ,  $P = 0.216$ ).

The number of adhesive lamellae differed significantly among the species, both in LTF (ANCOVA,  $F = 23.735$ ,  $df = 21$ ,  $P < 0.001$ ) and in LTH (ANCOVA,  $F = 5.488$ ,  $df = 21$ ,  $P = 0.012$ ). *Tropidurus torquatus* presented an average of  $23.0 \pm 1.69$  adhesive lamellae in LTF and  $30.65 \pm 2.43$  in LTH, while *L. lutzae* presented averages of  $18.88 \pm 0.99$  and  $26.12 \pm 2.37$ , respectively.

## DISCUSSION

Several structures present in the forelimbs and hindlimbs of lizards (e.g., hooks, claws and adhesive toe pads) aid them to climb and cling to different substrata to counteract the effect of the gravity (Zani 2000). As well, morphological specializations allow these animals to expand their ecological niches, improving their performance in the microhabitats used by them (Melville & Swain 2000).

In the literature, several studies that relate morphological modifications with the differentiated use of microhabitats exist (Lundelius 1957, Collette 1961, Williams 1983, Pounds 1988, Vitt et al. 1997, Kohlsdorf et al. 2001,

Teixeira-Filho et al. 2001, Schulte et al. 2004). These studies proposed that lizards that use open areas have longer hindlimbs than those considered arboreal. Teixeira-Filho et al. (2001) studying the ecomorphological relationship of six species of lizards of the Restinga da Barra de Maricá (among them *Tropidurus torquatus* and *Liolaemus lutzae*), discussed other morphologic aspects, such as variations in the size of the toes and proportional variations of the claws in relation to the toes in those species of lizards.

The analysis of our results showed that between the two studied tropidurids, *T. torquatus* and *L. lutzae*, the first species presented toes of the forelimbs and hindlimbs longer than the second, which is in agreement with studies by Colli et al. (1992) and Vrcibradic & Rocha (1996). Besides possessing longer toes, *T. torquatus* also possesses a larger number of adhesive lamellae. The fact that *T. torquatus* has longer toes and a larger number of lamella compared to *L. lutzae* suggests that this animal has a larger contact surface and a better grip with the rough substratum, making it more capable in the vertical use of the habitat. *Liolaemus lutzae*, however, uses the habitat only in a horizontal way, and this would explain the smallest length of the toes and smaller lamella number in relation to *T. torquatus*. However, when we compared the width of the toes of the forelimb and hind limb, we did not find a significant difference among the species.

Zani (2000) in a study with 13 different families of lizards, showed that animals that use flat substrata possess wider toes and they have larger number of adhesive lamella than those that use rough substrata, such as sand, logs and rocks. Mahendra (1941) verified that just the existence of adhesive toe pads in the palms of the paws would not allow to lizards to stick to rough surfaces. It would be the action of these toe pads, associated with the type of claws of those animals that would allow them to climb better in these substrata. Our results, however, suggest that the width of the toes of those animals (that used a rough substratum) is not a decisive morphological variable to explain an improvement of clinging performance, as it is seen in animals that used flat substrata. Therefore, this lead us to conclude that, in some way, our results end up being in partial agreement with the studies accomplished by Zani (2000)

and Mahendra (1941), regarding the width of toes and the number of adhesive lamella.

With relationship to the height of the claws, *T. torquatus* was shown to possess higher claws in both members in relation to *L. lutzae*. Higher claws are probably more resistant to break than lower ones when subject to vertical forces, as occurs when the lizard is climbing or positioned vertically. The largest height of the claws may avoid them to be broken easily due to the weight of the animal in such situation. This information is in agreement with Zani (2000). This author, however, proposed that arboreal lizards, besides having higher claws, also have shorter toes. Our results are not in agreement with this proposition because *T. torquatus*, in spite of possessing higher claws, has relatively longer toes than *L. lutzae*. We believed that this happens because *T. torquatus* is not strictly an arboreal lizard, using the habitat horizontally as much as vertically. So, *T. torquatus* would have a relatively differentiated morphological adaptation of the animals that use the habitat strictly in a vertical way, because this larger length of the toe increases the contact surface with the substratum, improving their performance during a race from a vegetation thicket to another.

If we take in consideration that an animal creeper (as *T. torquatus*) uses the claws as structures of vertical suspension that act as hooks, we will see that the curvature of the claw is much more important for it to accomplish this function than its width. So, the fact that both species of lizards use the habitat horizontally and just *T. torquatus* uses it vertically, would explain the inexistence of differences with relationship to the widths of the claws and the largest curvature of the claws of *T. torquatus*.

With relation to the length of the claws, our results showed that there were differences only in the length of the claw of hindlimb, being larger in *L. lutzae* than in *T. torquatus*. These data reinforce the idea that in *L. lutzae*, the fact of the claws being longer in the hind limb, and being also less curved and lower, would allow to this lizard to have an increase of the contact surface with the sand, giving a better impulse to flee from potential predators and in the excavation of burrows.

Although the morphological divergences found in both species might be only a result of their phylogenetic history (see Garland & Adolph 1994), we believe that they are a reflex of the

differentiated habitat use. Nevertheless, further studies regarding the phylogenetic influence are needed in order to enlighten this point.

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