

The relationship between body mass and snout–vent length in three species of *Mabuya* from eastern Brazil

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Little information exists on the allometric relationship between body mass and snout-vent length (SVL) in lizards, in spite of the relevance of that relationship for the understanding of morphological and ecological parameters. In this study we analyzed the mass-SVL relationship for three Brazilian scincid species (*Mabuya agilis*, *M. macrorhyncha* and *M. frenata*). Our results were indicative of negative allometry for both sexes in all three species, suggesting a general tendency for a relative reduction in bulk as the animal grows. The slopes and intercepts of the regression line did not differ between the sexes in any of the species, except *M. macrorhyncha*, in which the intercepts differed (suggesting that females would tend to be relatively less robust than males). When the analyses were repeated including juvenile individuals (previously excluded from the data set), the regression for *M. agilis* tended towards isometry, though it did not change for the remaining species. The results of the present study differ from those found for other Scincidae (including the congener *M. heathi*), which generally tended towards isometry or positive allometry. We also indicate that mass-SVL regressions may give different results for the same lizard species, depending on whether immature specimens are included or not in the analyses.

Key words: allometry, growth, Scincidae, Brazil

INTRODUCTION

As in other organisms, the allometric relationship between body mass and linear dimensions is an important issue in understanding some parameters of morphology and ecology in squamatan reptiles (Kaufman & Gibbons, 1975; Anderson & Vitt, 1990; Guyer & Donnelly, 1990; White & Anderson, 1994; Rocha-Barbosa et al., 2000). Despite its relevance, studies providing data on such relationships are relatively scarce when we consider the number of living lizard species (Greer & Whitaker, 2002). For example, among the more than 1200 known species of skinks, there are analyses addressing such relationships for only four species, one from North America (*Eumeces laticeps*; Vitt & Cooper, 1985), one from South America (*Mabuya heathi*; Vitt, 1995), one from New Zealand (*Oligosoma grande*; Greer & Whitaker, 2002) and one from Australia (*Eulamprus quoyii*; Schwarzkopf, 2005).

In the present study, we analyse the relationship between body mass and snout–vent length (SVL) for three species of *Mabuya* from eastern Brazil (*Mabuya agilis*, *M. macrorhyncha* and *M. frenata*). All these species are reported to be sexually dimorphic, with females attaining greater sizes than males (Rocha & Vrcibradic, 1999; Vrcibradic & Rocha, 1998b; 2002b), as in most other species in the family Scincidae (see Fitch, 1981). The three species of *Mabuya* under study are all superficially similar in terms of general body plan and colour pattern, though they have some significant morphological and meristic differences that led Rodrigues (2000) to place each of them in a different phenetic group. They also have some ecological differences: *M. agilis* is primarily terrestrial, whereas *M. macrorhyncha* and *M. frenata* are

scansorial (Gallardo, 1968; Vrcibradic & Rocha, 1996, 1998a). *M. macrorhyncha* has a relatively depressed body plan compared to the other two species (Vrcibradic & Rocha, 1996, pers. obs.). Considering these interspecific variations, it would be instructive to learn about the trends of the relationship between body mass and snout–vent length that emerge for these congeneric species.

MATERIALS AND METHODS

Individuals of *Mabuya macrorhyncha* and *M. agilis* used in the present study had been collected in several localities (mostly restinga habitats) along the coastal lowlands of southeastern Brazil. The localities ranged from Prado, Bahia State to Grumari, Rio de Janeiro State (i.e. between latitudes 17° and 23°S) for *M. agilis*, and from Trancoso, Bahia State to Queimada Grande island, São Paulo State (i.e. between latitudes 16°30' and 24°30'S) for *M. macrorhyncha*. Most of the animals of these two species had originally been collected for previous studies on various aspects of their ecology (Rocha & Vrcibradic, 1996, 1999, 2003; Vrcibradic & Rocha, 1996, 2002a,b; Vrcibradic et al., 2000; Rocha et al., 2002). The sample of *M. frenata* was composed entirely of individuals from Valinhos (22°56'S, 46°55'W), São Paulo State, which had also been previously collected for other studies (Vrcibradic & Rocha 1998a,b; Vrcibradic et al., 1999). The lizards had their SVL measured with callipers (to the nearest 0.1mm) and were weighed in an electronic balance (to the nearest 0.001g) before fixation.

For our analyses we included only individuals with $SVL \geq 50$ mm, in order to avoid the possible effects of allometric differences between juveniles and adults in our

Table 1. Means \pm one standard deviation and ranges for snout-vent length (SVL) and body mass of males and females of the three study species of *Mabuya* from Brazil.

Species (n)	Mean SVL, mm (range)	Mean body mass, g (range)
<i>M. agilis</i>		
Males (68)	65.8 \pm 5.4 (50.1–75.8)	6.26 \pm 1.55 (3.01–9.37)
Females (33)	69.7 \pm 7.9 (53.7–88.1)	6.58 \pm 1.94 (2.78–11.05)
<i>M. frenata</i>		
Males (79)	69.6 \pm 5.1 (51.3–79.0)	6.59 \pm 1.31 (2.50–9.04)
Females (55)	74.3 \pm 8.9 (51.5–91.0)	7.79 \pm 2.49 (2.55–13.87)
<i>M. macrorhyncha</i>		
Males (86)	64.4 \pm 5.8 (50.2–73.7)	5.41 \pm 1.38 (2.49–8.11)
Females (36)	65.8 \pm 7.2 (52.9–78.6)	5.26 \pm 1.61 (2.92–9.40)

results, and to make the samples more homogeneous. We also excluded from our analyses pregnant females with relatively well-developed embryos, in order to eliminate the effects of pregnancy on female body mass. We thus considered only females with oviductal ova/embryos smaller than 4 mm in diameter (stage 3 of Rocha & Vrcibradic, 1999) or with no oviductal ova (stages 1–2 of Rocha & Vrcibradic, 1999).

The mass–SVL relationship was calculated for each sex in each species using simple regression analyses of the log-transformed data. The slopes and intercepts of the mass–SVL regressions were compared between males and females of each species using Student’s t-test, following Zar (1999, p. 360). Statistical analyses were performed with the software Primer for Biostatistics 4.0.

The regression analyses were redone for each *Mabuya* species after adding all specimens with SVL < 50 mm (including unsexed juveniles) to the samples. This was done in order to assess to what extent the results of the regressions are altered by including juveniles in the samples.

RESULTS

In all three *Mabuya* species, females attain greater absolute lengths and masses than males (Table 1). Nevertheless, mean SVL did not differ significantly between sexes in *M. macrorhyncha* and mean body mass was significantly higher for females only in *M. frenata*, with no significant intersexual differences in the other two species (Table 1). The relationship between body mass and SVL (both log-transformed) was highly significant for both sexes in all three species (Figs 1–3).

The slopes of the regressions varied among the three *Mabuya* species from 2.58 to 2.69 in males, from 2.42 to 2.70 in females and from 2.38 to 2.62 in samples of both sexes combined (Table 2). The 95% confidence intervals did not, in any case, include the slope indicative of isometry (3.00), and indicated negative allometry for the

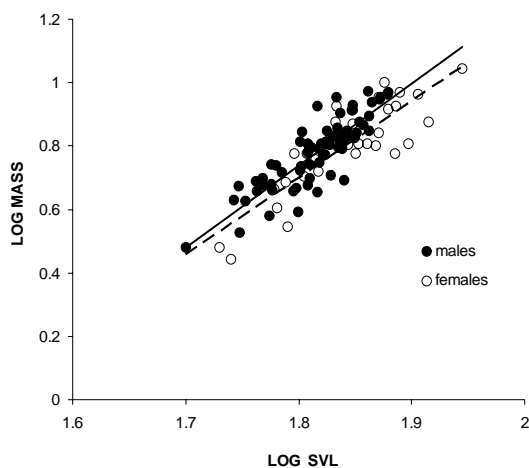


Fig. 1. Regression of log mass on log SVL for *Mabuya agilis* males ($r^2=0.73$, $P<0.001$, $n=68$; regression equation: $\log \text{mass}=2.58\log\text{SVL}-3.91$) and females ($r^2=0.73$, $P<0.001$, $n=33$; regression equation: $\log \text{mass}=2.42\log\text{SVL}-0.65$).

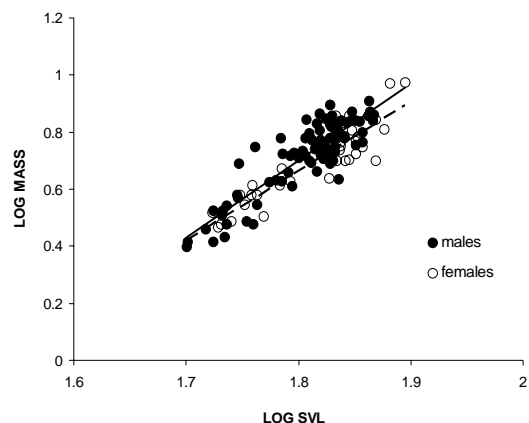


Fig. 2. Regression of log mass on log SVL for *Mabuya macrorhyncha* males ($r^2=0.78$, $P<0.001$, $n=86$; regression equation: $\log \text{mass}=2.69\log\text{SVL}-4.13$) and for females ($r^2=0.82$, $P<0.001$, $n=36$; regression equation: $\log \text{mass}=2.43\log\text{SVL}-3.71$).

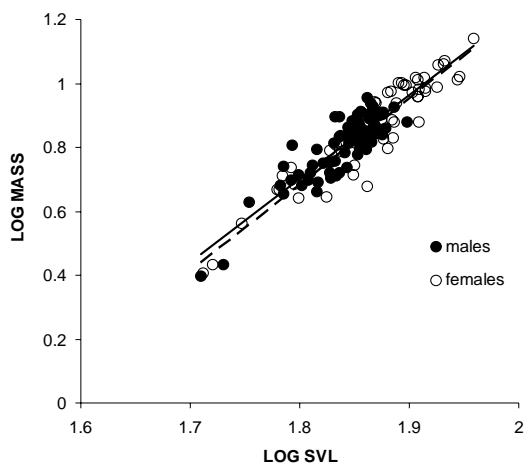


Fig. 3. Regression of log mass on log SVL for *Mabuya frenata* males ($r^2=0.76$, $P<0.001$, $n=79$; regression equation: $\log \text{mass}=2.61\log\text{SVL}-4.00$) and for females ($r^2=0.88$, $P<0.001$, $n=55$; regression equation: $\log \text{mass}=2.70\log\text{SVL}-4.17$).

Table 2. Values for slopes and confidence intervals (CI) of the log mass–log SVL regression for three species of *Mabuya* from Brazil (n = sample size), excluding individuals <50 mm. Also shown are values of t and P for between-sex comparisons of slopes and intercepts of regressions (statistically significant P -values are marked with an asterisk).

Species (n)	Slope	CI	t_{slope}	P_{slope}	$t_{\text{intercept}}$	$P_{\text{intercept}}$
<i>M. agilis</i>						
Males (68)	2.58	±0.19	0.076	0.940	1.035	0.303
Females (33)	2.42	±0.26				
Total (101)	2.38	±0.15				
<i>M. macrorhyncha</i>						
Males (86)	2.69	±0.16	0.135	0.893	2.123	0.036*
Females (36)	2.43	±0.20				
Total (122)	2.55	±0.13				
<i>M. frenata</i>						
Males (79)	2.61	±0.17	0.045	0.964	0.952	0.343
Females (55)	2.70	±0.14				
Total (134)	2.62	±0.10				

mass–SVL relationship in males and females of all three species, as well as for both sexes combined. Thus, these species apparently tend to decrease in relative body mass as they grow longer. The slopes of the log mass–log SVL regressions did not differ between sexes in any of the species ($P > 0.5$ in all cases; Table 2), indicating that both males and females tend to decrease in relative body mass at similar rates. The intercepts, however, differed statistically between males and females of *M. macrorhyncha* (Table 2), suggesting that in this species males tend to be somewhat bulkier than females at a given SVL.

When the analyses were redone after adding specimens smaller than 50 mm SVL to the samples, the tendency for negative allometry remained for both *M. macrorhyncha* and *M. frenata*, but not for *M. agilis* (Table 3). In the latter species, the slope (3.06) and confidence interval (±0.06) were indicative of isometry.

DISCUSSION

In spite of their morphological and ecological differences, the three study species of *Mabuya* all presented a similar

Table 3. Values for slopes and confidence intervals (CI) of the log mass–log SVL regression for three species of *Mabuya* from Brazil (n = sample size), including individuals <50 mm. Also shown are the regression equations for each species.

Species (n)	Slope	CI	Regression equation
<i>M. agilis</i> (124)	3.06	±0.06	3.06 log SVL–4.80
<i>M. macrorhyncha</i> (135)	2.78	±0.08	2.78 log SVL–9.94
<i>M. frenata</i> (137)	2.65	±0.08	2.65 log SVL–9.40

tendency for negative allometry regarding the body mass–SVL relationship. The results of the present study contrast with those of Vitt (1995), which indicated isometry for the congeneric *M. heathi* (based on a sample of both sexes combined). Part of the difference between our results and those of Vitt (1995) may be due to the fact that he used individuals of all sizes (i.e. both adults and juveniles) in his analyses. Indeed, when we included juveniles in our sample of *M. agilis*, the tendency changed towards isometry. Moreover, Vitt (1995) presumably included pregnant females in his sample. This latter point is interesting to consider since, although Vitt (1995) did not find a significant difference between male and female *M. heathi* in either slopes or intercepts of the regressions (which is why he chose to present the values for both sexes pooled), the P -value (0.051) was very close to statistical significance. Thus, a possible effect of the presence of pregnant females in his results should not be completely ruled out.

Our results are more directly comparable to those of Schwarzkopf (2005), Greer & Whitaker (2002) and Vitt & Cooper (1985), who also performed analyses excluding juveniles from their samples. Results of body mass–SVL regression analyses performed by Greer and Whitaker (2002) on sexable individuals of the New Zealand skink *Oligosoma grande* showed a tendency for isometry in both males and females (including gravid ones). Vitt & Cooper (1985), on the other hand, found negative allometry for males and isometry for females among sexually mature individuals of the highly dimorphic North American skink *Eumeces laticeps* (a species in which males are the larger sex, unlike *Oligosoma grande* and *Mabuya* spp.). Finally, Schwarzkopf (2005) found positive allometry for males and negative allometry for females (even

when gravid ones were included in the sample) in *Eulamprus quoyii*, a species that is not sexually dimorphic in SVL. In the present study, the three *Mabuya* species have shown the same tendency (i.e. negative allometry in both sexes), in contrast to the other aforementioned scincid species. These results indicate that mass and length relationships vary among different genera and species within the family Scincidae.

After the inclusion of individuals smaller than 50 mm SVL, the regression analyses yielded different results for one of the species (*M. agilis*), indicating a tendency for isometry instead of negative allometry. The tendency for negative allometry remained for the other two species, but it should be noted that the samples of individuals under 50 mm SVL were smaller for those species (13 for *M. macrorhyncha* and only three for *M. frenata*) than for *M. agilis* (23), so that the effects of their inclusion in the original samples were probably less significant. Thus, it is possible that a larger sample of young specimens could result in a different allometric pattern for *M. macrorhyncha* and *M. frenata* as well. Greer and Whitaker (2002) found that the inclusion of unsexed individuals (mainly juveniles) in their analyses changed the tendency of the mass–length relationship in *Oligosoma grande* from isometry to slight positive allometry. Vitt & Cooper (1985) found that the slopes and intercepts of the mass–SVL regressions differed between adult males and females of *Eumeces laticeps*, though no differences had been found before immature individuals were excluded from the samples. All these cases indicate that different allometric patterns may emerge from analyses of mass–length relationships in a given lizard species, depending on whether young individuals are included or not in samples. We thus suggest that future studies assessing the relationships between body mass and linear dimensions in lizards should include separate analyses for samples including animals of all sizes and for samples not including juvenile individuals. We also argue against the inclusion of gravid females in such studies, as the mass of clutches/broods added to the original body mass of females is likely to obscure actual allometric trends in the animals and produce female-biased results.

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REFERENCES

- Anderson, R.A. & Vitt, L.J. (1990). Sexual versus alternative causes of sexual dimorphism in teiid lizards. *Oecologia* 84, 145–157.
- Fitch, H.S. (1981). Sexual size differences in reptiles. *University of Kansas Museum of Natural History, Miscellaneous Publications* 70, 1–72.
- Gallardo, J.M. (1968). Las especies argentinas del género *Mabuya* (Scincidae, Sauria). *Revista del Museo Argentino de Ciencias Naturales Bernardino Rivadavia, Zoología* 9, 177–196.
- Greer, A.E. & Whitaker, T. (2002). The relationship between mass and snout–vent length in the New Zealand tor-inhabiting skink *Oligosoma grande*. *Herpetological Review* 33, 170–171.
- Guyer, C. & Donnelly, M.A. (1990). Length–mass relationships among an assemblage of tropical snakes in Costa Rica. *Journal of Tropical Ecology* 6, 65–76.
- Kaufman, G.A. & Gibbons, J.W. (1975). Weight–length relationships in thirteen species of snakes in the southeastern United States. *Herpetologica* 31, 31–37.
- Rocha, C.F.D. and Vrcibradic, D. (1996). Thermal ecology of two sympatric skinks (*Mabuya agilis* and *Mabuya macrorhyncha*) in Brazilian restinga habitat. *Australian Journal of Ecology* 21, 110–113.
- Rocha, C.F.D. & Vrcibradic, D. (1999). Reproductive traits of two sympatric viviparous skinks (*Mabuya macrorhyncha* and *Mabuya agilis*) in a Brazilian restinga habitat. *Herpetological Journal* 9, 43–53.
- Rocha, C.F.D. & Vrcibradic, D. (2003). Nematode assemblages of some of some insular and continental lizard hosts of the genus *Mabuya* Fitzinger (Reptilia, Scincidae) along the eastern Brazilian coast. *Revista Brasileira de Zoologia* 20, 755–759.
- Rocha, C.F.D., Vrcibradic, D., Teixeira, R.L. & Cuzzuol, M.G.T. (2002). Interpopulational variation in litter size of the skink *Mabuya agilis* in southeastern Brazil. *Copeia* 2002, 857–864.
- Rocha-Barbosa, O., Salomão, M.G., Puerto, G., Ferreira, I.L.L. & Mandarim-de-Lacerda, C.A. (2000). Allometry and ecology of *Oxyrhopus guibei* Hoge and Romano, 1977 (Serpentes; Colubridae). *Biomedical Research* 11, 259–264.
- Rodrigues, M.T. (2000). A new species of *Mabuya* (Squamata: Scincidae) from the semiarid caatingas of northeastern Brazil. *Papéis Avulsos de Zoologia, São Paulo* 41, 313–328.
- Schwarzkopf, L. (2005). Sexual dimorphism in body shape without sexual dimorphism in body size in water skinks (*Eulamprus quoyii*). *Herpetologica* 61, 116–123.
- Vitt, L.J. (1995). The ecology of tropical lizards in the caatinga of northeast Brazil. *Occasional Papers of the Oklahoma Museum of Natural History* 1, 1–29.
- Vitt, L.J. & Cooper, W.E. (1985). The evolution of sexual dimorphism in the skink *Eumeces laticeps*: an example of sexual selection. *Canadian Journal of Zoology* 63, 995–1002.
- Vrcibradic, D. & Rocha, C.F.D. (1996). Ecological differences in tropical sympatric skinks (*Mabuya agilis*

- and *Mabuya macrorhyncha*) in southeastern Brazil. *Journal of Herpetology* 30, 60–67.
- Vrcibradic, D. & Rocha, C.F.D. (1998a). Ecology of the skink *Mabuya frenata* in an area of rock outcrops in southeastern Brazil. *Journal of Herpetology* 32, 229–237.
- Vrcibradic, D. & Rocha, C.F.D. (1998b). Reproductive cycle and life-history traits of the viviparous skink *Mabuya frenata* in southeastern Brazil. *Copeia* 1998, 612–619.
- Vrcibradic, D., Rocha, C.F.D., Ribas, S.C. & Vicente, J.J. (1999). Nematodes infecting the skink *Mabuya frenata* in Valinhos, São Paulo State, southeastern Brazil. *Amphibia–Reptilia* 20, 333–339.
- Vrcibradic, D. & Rocha, C.F.D. (2002a). Use of cacti as heat sources by thermoregulating *Mabuya agilis* (Raddi) and *Mabuya macrorhyncha* Hoge (Lacertilia, Scincidae) in southeastern Brazil. *Revista Brasileira de Zoologia* 19, 77–83.
- Vrcibradic, D. & Rocha, C.F.D. (2002b). Ecology of *Mabuya agilis* (Raddi) (Lacertilia, Scincidae) at the restinga of Grumari, Rio de Janeiro, southeastern Brazil. *Revista Brasileira de Zoologia* 19 (Suppl. 2), 19–29.
- Vrcibradic, D., Cunha-Barros, M., Vicente, J.J., Galdino, C.A.B., Hatano, F.H., Van Sluys, M. & Rocha, C.F.D. (2000). Nematode infection patterns in four sympatric lizards from a restinga habitat (Jurubatiba) in Rio de Janeiro state, southeastern Brazil. *Amphibia–Reptilia* 21, 307–316.
- White, T.D. & Anderson, R.A. (1994). Locomotor patterns and costs as related to body size and form in teiid lizards. *Journal of Zoology* 233, 107–128.
- Zar, J. (1999). *Biostatistical Analysis*. New Jersey: Prentice Hall.

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