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Seasonal influences of wind intensity on activity rates and thermoregulation of differently sized individuals of *Liolaemus lutzae* (Squamata: Liolaemidae)

Thiago Maia-Carneiro, Thiago Arnt Dorigo & Carlos Frederico Duarte Rocha

Departamento de Ecologia, Universidade do Estado do Rio de Janeiro, Rua São Francisco Xavier 524, CEP 20550-013, Rio de Janeiro, Brazil

Corresponding author: Thiago Maia-Carneiro, e-mail: tmaiacarneiro@gmail.com

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Liolaemus lutzae Mertens, 1938 (Squamata, Liolaemidae) is a lizard of relatively limited distribution (extending only approximately 200 km), which is endemic to coastal sand dunes in the state of Rio de Janeiro, southeastern Brazil (Rocha et al. 2009a, b). Individuals inhabit a narrow stretch of sand beach environment with undergrowth vegetation adapted to well drained sandy seaside soils, a place exhibiting intense solar radiation, high environmental temperatures and constant wind bursts (Rocha 1995, Rocha et al. 2009b, Maia-Carneiro et al. 2012, Maia-Carneiro & Rocha 2013a, b, c, Almeida-Santos et al. 2015). *Liolaemus lutzae* lizards utilize different substrates and structures of the beach habitat to maintain body temperatures within suitable ranges for their daily activities (Rocha 1995, Rocha et al. 2009b, Maia-Carneiro et al. 2012, Maia-Carneiro & Rocha 2013c). There are indications that lizards exposed to intense wind regimes may reduce their body temperatures and rates of movement in the environment (Fuentes & Jaksic 1979, Bujes & Verrastro 2006, Maia-Carneiro et al. 2012, Almeida-Santos et al. 2015); nevertheless, there is no information regarding the role of body sizes promoting differences in tolerances to wind. Here, we investigate the importance of body sizes of *L. lutzae* lizards to cope with intense wind regimes in the beach habitat and examine influences from wind speed on seasonal substrate temperatures (dry and rainy) with different thermal conditions.

Most '*Restinga*' (coastal sand dune ecosystems) remnants inhabited by *L. lutzae* across its distributional range in Rio de Janeiro endure a substantial decrease in their areas due to intensive habitat destruction (Rocha & Bergallo 1992, Rocha et al. 2003, 2007, 2009a, b, c, Maia-Carneiro & Rocha 2013d). Fieldwork took place in Restinga of Praia Grande (22°57' S, 42°02' W), municipality of Arraial do Cabo, state of Rio de Janeiro, southeastern Brazil. The climate in the region may vary seasonally, with greater precipitation and environmental temperatures in summer (Scarano 2002, Maia-Carneiro et al. 2012). For details regarding data collection for this study, see Maia-Carneiro et al. (2012) and Maia-Carneiro & Rocha (2013b, c).

To evaluate the occurrence of relationships of snout–vent length (SVL, mm), of body mass (g), and of substrate temperature (in °C) with wind intensity (in m/s) we performed simple linear regression analyses. We carried out the statistical analyses considering each season separately to access the influences from wind in two distinct thermal environments. We used substrate temperatures in analytical procedures because they constitute one of the main environmental heat sources for *L. lutzae* individuals in the habitat (Rocha 1995, Rocha et al. 2009b, Maia-Carneiro et al. 2012, Maia-Carneiro & Rocha 2013b, c, Almeida-Santos et al. 2015).

Measures (means, standard deviations, and minimum and maximum ranges of variation) of variables used for statistical analyses are available elsewhere (substrate temperatures and wind intensity – see Maia-Carneiro et al. 2012; SVL and body mass – see Maia-Carneiro & Rocha 2013b). The SVL of *L. lutzae* individuals was positively related to wind intensity during the dry season ($F_{[1, 131]} = 5.407$, $r^2 = 0.040$, $P = 0.022$, $N = 133$, see Fig. 1), but not during the rainy season ($F_{[1, 86]} = 0.005$, $P = 0.945$, $N = 88$). The body mass of *L. lutzae* was not significantly related to wind intensity in both seasons (dry season: $F_{[1, 131]} = 3.269$, $P = 0.073$, $N = 133$; rainy season: $F_{[1, 86]} = 0.025$, $P = 0.874$, $N = 88$). There was a negative relationship between substrate temperature and wind intensity during the dry season ($F_{[1, 131]} = 4.329$, $r^2 = 0.032$, $P = 0.039$, $N = 133$) (Fig. 2A) and during the rainy season these variables were positively related ($F_{[1, 86]} = 7.455$, $r^2 = 0.080$, $P = 0.008$, $N = 88$, see Fig. 2B).

Our data suggested that wind intensity and body size influenced the daily and seasonal (in the dry season) activity of *L. lutzae* individuals in Praia Grande. During times of strong wind bursts, mainly large lizards remained active in the beach habitat of Praia Grande in the dry season. Constant wind in the beach environment may decrease body temperatures of *L. lutzae* lizards (Maia-Carneiro et al. 2012, Almeida-Santos et al. 2015) thus affecting movement rates (Maia-Carneiro et al. 2012). As larger lizards tend to be more resistant to heat loss due to their relatively greater thermal inertia (heat conservation ability – Maia-Carneiro & Rocha 2013b), they are capable of remaining active in periods in which wind speed might induce more pronounced effects on body temperatures. Indeed, it might be advantageous for larger *L. lutzae* to remain active during periods of strong wind bursts due to decreased vulnerability of overheating produced by heat loss. Notably, during mild wind bursts in the dry season, most *L. lutzae* individuals that remained active in the beach habitat were small in size. Likely due to the comparatively divergent thermal inertia, small lizards are more susceptible to heat loss by wind action, forcing them to avoid high wind intensities, whereas the opposite occurs with larger individuals, which may benefit from advantages with respect to reduction of chances of reaching excessively high body temperatures through the exposure to high wind speeds. Body temperatures might affect metabolic and behavioural processes of high ecological relevance, as efficiency of food acquisition and digestion, locomotor performance and vulnerability to predation (Avery et al. 1982, Van Damme et al. 1991, Brown et al. 2004, Maia-Carneiro & Ro-

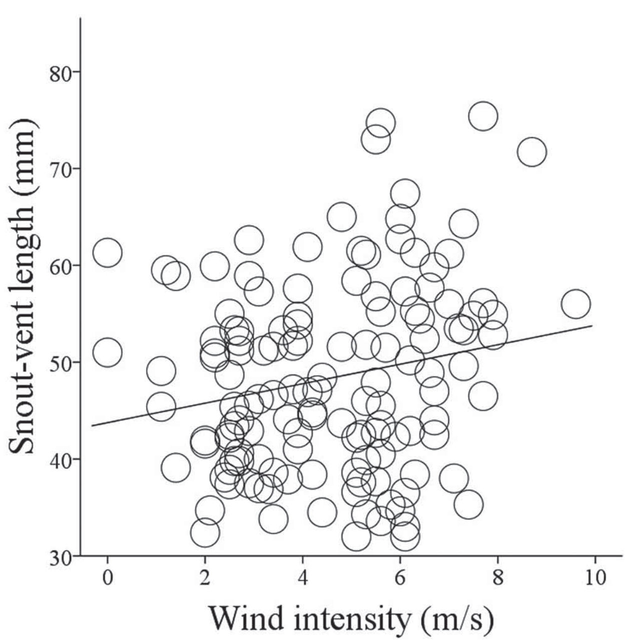

Figure 1. Relationship between snout–vent length (mm, N = 133) and wind intensity (m/s, N = 133) for *Liolaemus lutzae* in Praia Grande, municipality of Arraial do Cabo, state of Rio de Janeiro, southeastern Brazil.

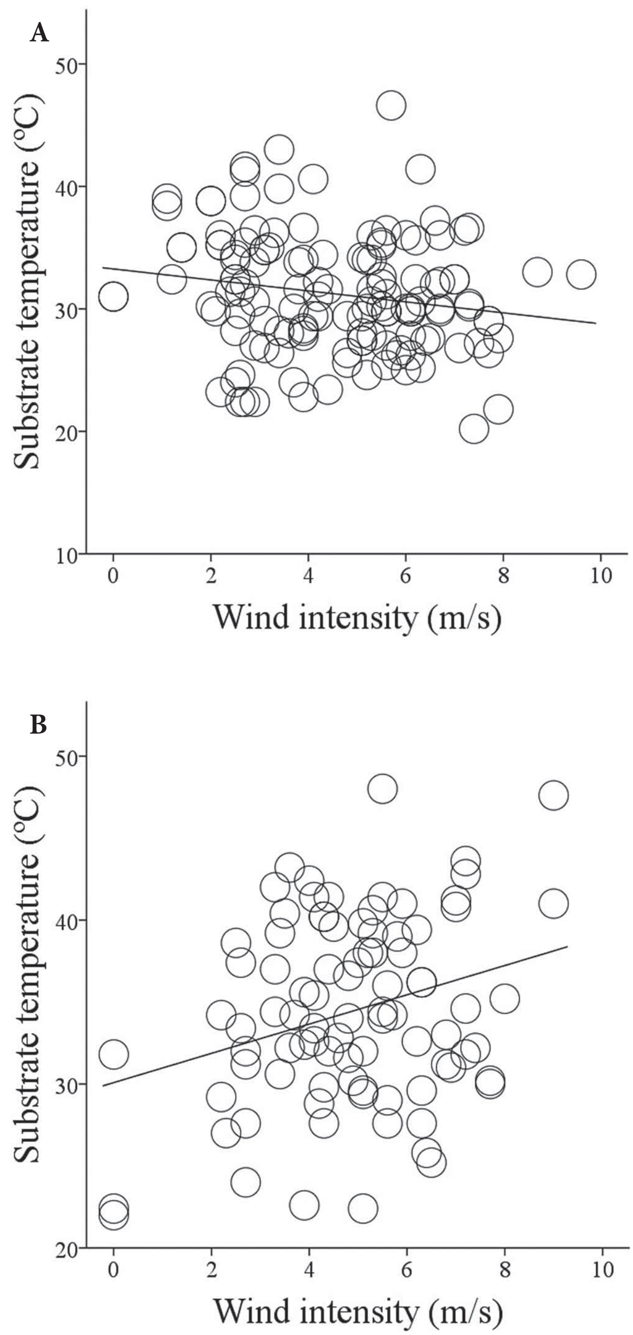

Figure 2. Relationship between substrate temperatures (°C) and wind intensity (m/s) for *Liolaemus lutzae* in Praia Grande, municipality of Arraial do Cabo, state of Rio de Janeiro, southeastern Brazil, (A) in the dry season (N = 133) and (B) in the rainy season (N = 88).

cha 2015), among others. To avoid low body temperatures small *L. lutzae* lizards supposedly increased the use of refuges (burrows and detritus – Rocha et al. 2009b, Maia-Carneiro & Rocha 2013a) during periods of strong wind bursts, whereas during periods of low wind speeds large *L. lutzae* may cope with overheating similarly (i.e., using burrows and detritus – Rocha et al. 2009b, Maia-Carneiro & Rocha 2013a), as suggested by the decreasing activity of these lizards during such periods (see Fig. 1). Body size and wind intensity may have been unrelated in the rainy season, as during this period environmental temperatures were higher than in the dry season (Maia-Carneiro et al. 2012), which may have conferred more opportunities for thermoregulation and favoured heat absorption by lizards compensating for heat loss by wind. As the rainy season encompasses almost the entire period of reproduction of *L. lutzae* (Rocha 1992), larger-bodied lizards may have remained active even under low wind intensities during this season due to reproductive compromises (i.e., the reproductive costs of staying in refuges may have been greater compared to those of remaining active). Importantly, wind intensity did not differ inter-seasonally (see Maia-Carneiro et al. 2012).

The wind caused a decrease in substrate temperatures used by *L. lutzae* during the dry season in Praia Grande. The wind might decrease body temperatures and activity rates of lizards directly by removing body heat (Maia-Carneiro et al. 2012) and indirectly by diminishing temperatures of environmental heat sources used for thermoregulation (Almeida-Santos et al. 2015; this study). During the dry season the environmental temperatures allowing heat increase for the lizards were comparatively restricted (Maia-Carneiro et al. 2012), which limited thermal resources and opportunities for thermoregulation (Maia-Carneiro & Rocha 2013c). Lizards inhabiting coastal sand dunes might be more vulnerable to heat loss caused by wind during periods of thermal constraints. This is supported by the finding that higher substrate temperatures were recorded in microhabitats used by individuals in the rainy season at increased wind intensity. During the rainy season, when more thermal resources and opportunities for heat absorption were available (Maia-Carneiro et al. 2012; Maia-Carneiro & Rocha 2013c), lizards used warmer substrates to cope with their heat loss during periods of strong wind bursts, as allowed by the comparatively higher environmental temperatures in this season (Maia-Carneiro et al. 2012), which could compensate for the heat loss from substrates altered by the wind. Therefore, wind speed might successfully remove heat from microhabitats under thermal limitations, however, when environmental temperatures are high enough they heat up microhabitats despite of the cooling effects influenced by wind. The behaviour described here highlights the ability of *L. lutzae* lizards of different sizes/age classes to deal with particular challenges imposed by variations of thermal conditions and enable individuals to be active during periods with better balance with respect to costs and benefits.

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References

Almeida-Santos, P., C. M. Militão, P. Nogueira-Costa, V. A. Menezes & C. F. D. Rocha (2015): Thermal ecology of five remaining populations of an endangered lizard (*Liolaemus lutzae*) in different restinga habitats in Brazil. – Journal of Coastal Conservation, DOI 10.1007/s11852-015-0395-7.

Avery, R. A., J. D. Bedford & C. P. Newcombe (1982): The role of thermoregulation in lizard biology: predatory efficiency in a temperate diurnal basker. – Behavioral Ecology and Sociobiology, **11**: 261–267.

Brown, J. H., J. F. Gillooly, A. P. Allen, V. M. Savage & G. B. West (2004): Toward a metabolic theory of ecology. – Ecology, **85**: 1771–1789.

Bujes, C. S. & L. Verrastro (2006): Thermal biology of *Liolaemus occipitalis* (Squamata, Tropiduridae) in the coastal sand dunes of Rio Grande do Sul, Brazil. – Brazilian Journal of Biology, **66**(3): 945–954.

Fuentes, E. R. & F. M. Jaksic (1979): Activity temperatures of eight *Liolaemus* (Iguanidae) species in central Chile. – Copeia, **1979**: 546–548.

Maia-Carneiro, T., T. A. Dorigo & C. F. D. Rocha (2012): Influences of seasonality, thermal environment and wind intensity on the thermal ecology of Brazilian sand lizards in a restinga remnant. – South American Journal of Herpetology, **7**: 241–251.

Maia-Carneiro, T. & C. F. D. Rocha (2013b): Influences of sex, ontogeny and body size onthe thermal ecology of *Liolaemus lutzae* (Squamata, Liolaemidae) in a resting remnant in southeastern Brazil. – Journal of Thermal Biology, **38**: 41–46.

Maia-Carneiro, T. & C. F. D. Rocha (2013c): Seasonal variations in behaviour of thermoregulation in juveniles and adults *Liolaemus lutzae* (Squamata, Liolaemidae) in a remnant of Brazilian restinga. – Behavioural Processes, **100**: 48–53.

Maia-Carneiro, T. & C. F. D. Rocha (2013a): The behavior of orientation of openings of burrows by *Liolaemus lutzae* (Squamata, Liolaemidae): is it influenced by environmental factors? – Journal of Natural History, **47**: 253–262.

Maia-Carneiro, T. & C. F. D. Rocha (2013d): Estimated population density of and sources of disturbance for the endemic and threatened *Liolaemus lutzae* in a remnant area of its narrow habitat in southeastern Brazil. – Salamandra, **49**: 223–226.

Maia-Carneiro, T. & C. F. D. Rocha (2015): Flight initiation distances of *Tropidurus hispidus* and *Tropidurus semitaeniatus* (Squamata, Tropiduridae) in sympatry. – Herpetological Conservation and Biology, **10**: 661–665.

Rocha, C. F. D. (1992): Reproductive and fat body cycles of the tropical sand lizard (*Liolaemus lutzae*) of southeastern Brazil. – Journal of Herpetology, **26**: 17–23.

Rocha, C. F. D., M. A. S. Alves & M. Van Sluys (2003): A biodiversidade nos grandes remanescentes florestais do Rio de Janeiro e nas restingas da Mata Atlântica. – São Carlos, Rima Editora, 160 pp.

Rocha, C. F. D., H. G. Bergallo, M. Van Sluys, M. A. S. Alves & C. E. Jamel (2007): The remnants of restinga habitats in the Brazilian Atlantic Forest of Rio de Janeiro state, Brazil: Habitat loss and risk of disappearance. – Brazilian Journal of Biology, **67**: 263–273.

Rocha, C. F. D. & H. G. Bergallo (1992): Population Decrease: the case of *Liolaemus lutzae*, an endemic lizard of Southeastern Brazil. – Ciência & Cultura, **44**: 52–54.

Rocha, C. F. D., T. C. C. Castro, A. M. G. Teixeira, C. B.M. Cruz, C. A. A. Figueiredo, C. B. A. Bohrer, C. M. Volcker, C. F. C. Sá, L. C. T. Chaves, N. C. Maciel & R. C. Villaça (2009c): Região turística dos lagos flminenses. – pp. 313–323 in: Bergallo, H. G., E. C. C. Fidalgo, C. F. D. Rocha, M. C. Uzêda, M. B. Costa, M. A. S. Alves, M. Van Sluys, M. A. Santos, T. C. C. Costa & A. C. R. Cozzolino (Orgs.): Estratégias e ações para a conservação da biodiversidade no estado do Rio de Janeiro. – Instituto Biomas, Rio de Janeiro. 344 pp.

Rocha, C. F. D. & C. C. Siqueira & C. V. Ariani (2009b): A conservação de *Liolaemus lutzae*: Lagarto endêmico das restingas do Estado do Rio de Janeiro ameaçado de extinção. – Instituto Biomas, 40 pp.

Rocha, C. F. D. & C. C. Siqueira & C. V. Ariani (2009a): The endemic and threatened lizard *Liolaemus lutzae* (Squamata: Liolaemidae): current geographic distribution and areas of occurrence with estimated population densities. – Zoologia, **26**: 454–460.

Rocha, C. F. D. (1995): Ecologia termal de *Liolaemus lutzae* (Sauria: Tropiduridae) em uma área de restinga do sudeste do Brasil. – Brazilian Journal of Biology, **55**: 481–489.

Scarano, F. R. (2002): Structure, function and floristic relationships of plant communities in stressful habitats marginal to the Brazilian Atlantic Rainforest. – Annals of Botany, 90: 517–524.

Van Damme, R., D. Bauwens, R. F. Verheyen (1991): The thermal dependence of feeding behaviour, food consumption and gut-passage time in the lizard *Lacerta vivipara* Jacquin. Functional Ecology, **5**: 507–517.