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SHORT COMMUNICATION

Body orientation for thermoregulation and daily activity cycle of *Mabuya macrorhyncha* (Squamata: Scincidae)

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ABSTRACT. We investigated the daily activity and thermoregulatory body orientation of *Mabuya macrorhyncha* (Hoge, 1947), a lizard species that occurs in the Brazilian Atlantic Forest. We conducted this investigation in a sandy coastal dune remnant ("restinga" ecosystem) in Grussaí, state of Rio de Janeiro, Brazil, during the summer. The daily activity cycle of the lizards started around 6:00 am and ended before 7:00 pm. This is longer than observed in other populations of *M. macrorhyncha* (approximately 7:00 am to 5:00 pm). The activity cycle of the lizards was bimodal, with the first peak between 6:00 and 11:00 am and the second from 2:00 to 7:00 pm. This contrasts with observations on other populations of this species, which revealed an unimodal pattern. The mean body temperature of *M. macrorhyncha* in Grussaí was 34.2 ± 1.5 °C, which was comparatively higher than observed in other populations of the species. The differences in the daily activity and of body temperature of these lizards between our study and previous studies on this species may reflect environmental thermal conditions. The mean air and mean substrate temperatures when individuals were active were 27.8 and 30.5 °C respectively. Lizard orientation was significantly correlated with the direction of the solar incidence, suggesting that solar radiation, and particularly behavioral adjustments that maximize exposure to the sun, are important for the thermoregulation of *M. macrorhyncha*. Circular structures at the site, such as bromeliads, offer microhabitats with different orientations to the sunlight, favoring lizard thermoregulatory behaviors.

KEY WORDS. Activity period, body temperature regulation, microhabitat, thermoregulatory behavior.

INTRODUCTION

Thermal environments affect activity patterns and body temperatures of lizards throughout their daily cycles (Huey and Slatkin 1976, Vrcibradic and Rocha 1996, Rocha and Vrcibradic 1996, Maia-Carneiro et al. 2012). Individuals control their time of activity and body temperatures by increasing and decreasing their movement rates in response to thermal conditions and by performing behavioral adjustments (Hatano et al. 2001, Rocha et al. 2009, Maia-Carneiro et al. 2012, 2017). Such adjustments include alternating between sunny and shaded microhabitats, or between sites with higher and lower environmental temperatures (Hertz 1992, Castilla et al. 1999, Maia-Carneiro and Rocha 2013). Also, individuals increase or reduce sunlight exposure on their bodies by adjusting their body posture and orientation while basking (Gandolfi and Rocha 1998, Castilla et al. 1999, Rocha et al. 2009).

Mabuya macrorhyncha (Hoge, 1947) is a diurnal lizard (Vrcibradic and Rocha 1996, Hatano et al. 2001) restricted to remnants of Brazilian Atlantic Forest. Studies on its biology have been conducted on populations in the states of Rio de Janeiro (e.g., Vrcibradic and Rocha 2002), Espírito Santo (e.g., Vrcibradic and Rocha 1995), São Paulo (Rocha and Vrcibradic 2003) and Bahia (e.g. Vrcibradic et al. 2001). Individuals are closely associated with bromeliads and use leaves of these plants as thermoregulation sites (Vrcibradic and Rocha 1996, 2002). Bromeliad leaves are arranged in spiral, which results in a circular structure that may potentially facilitates basking. In addition to bromeliads, there are also other structures with a circular shape that are used as basking sites. Here we investigated the daily activity cycle and a behavior for body temperature regulation in *M. macrorhyncha*. To this end we evaluated the daily activity cycle and the orientation of the body of this lizard with respect to the sun. More specifically, we ascertained (1) the extent and pattern of the daily activity cycle, and (2) whether individuals on plants orient their bodies randomly or follow a specific orientation.

The "restingas" are sand dune coastal ecosystems in the Atlantic Forest biome of Brazil. Relatively undisturbed restinga sites typically have diverse vegetation structures and physiognomies, including herbs, shrubs, and trees growing on sandy soils. We conducted our fieldwork at Restinga of Grussaí (21°44'S, 41°02'W), municipality of São João da Barra, state of Rio de Janeiro, southeastern Brazil. The local climate at the site is Aw in the Köppen-Geiger classification (tropical with dry winter), with annual mean temperatures between 22 and 24 °C (Alvares et al. 2013) and mean annual rainfall varying between 800 mm and 1300 mm (Cesário and Gaglianone 2008, Alvares et al. 2013).

We gathered data through time-constrained visual encounter surveys (Crump and Scott 1994) of 30 minutes each hour (14 times per day), between 6:00 am and 8:00 pm, during 14 days in December 2010 and 15 days in January 2011 (this corresponds to the summer in the Southern Hemisphere). Activity rate was considered as the number of active individuals found at different hour intervals during the day. We collected individuals manually or using an air-pressured gun. For each collected lizard, we measured the body temperature up to 30 seconds after the first sight of it, and recorded the time the individual was seen. We considered the mean body temperature (T_b) of the population as the average body temperatures of active lizards. We measured the air temperature (T_a) one centimeter above the substrate where each lizard was found and the substrate temperature (T_s) on the same microhabitat. To measure the temperature, we used a quick-reading thermometer (Miller & Weber, precision of 0.2 °C).

We searched for active perched individuals (e.g., on bromeliads or steams) to investigate their body orientation during thermoregulation, since *M. macrorhyncha* lizards frequently use the vegetation as thermoregulatory sites (Vrcibradic and Rocha 1996, 2002). We obtained this data only during the morning, when lizards were mainly basking. For each individual, we recorded (1) the cardinal direction of the sun (measured with a protractor with precision of 1°) and (2) the cardinal orientation of the lizard (with the same protractor) in the microhabitat. Fig. 1 illustrates how we collected data on the cardinal directions using a bromeliad as an example. We used circular statistics to correlate the frequencies of each orientation and direction of the sunlight. The mean vector length *r* represents the frequency of lizards' orientations and is thus a measure of dispersion of the points around the mean angle μ. Values of *r* vary from –1 (a complete negative correlation) to 1 (a complete positive correlation); r = 0 indicates absence of a correlation (Zar 1999). We estimated the significances of the mean vector lengths (*r*) by the Rayleigh's uniformity test (Z). This analysis evaluates

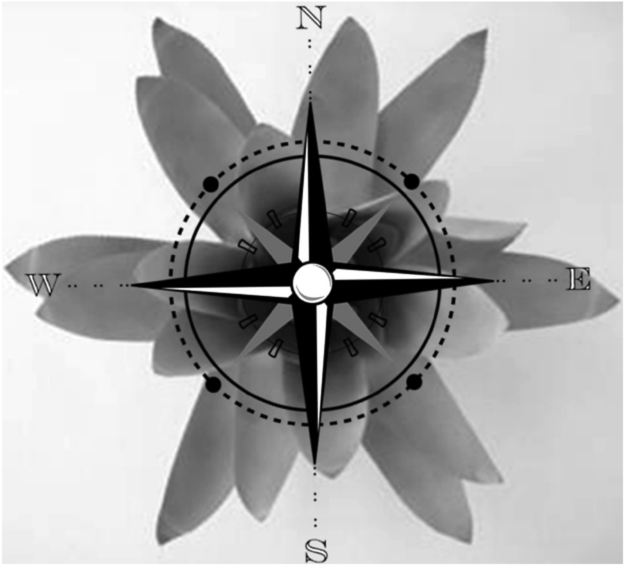

Figure 1. Illustration demonstrating how we collected the data regarding cardinal directions on bromeliads (used here for exemplification), stems, and trunks in Grussaí. We obtained the pictures of the bromeliad and of the wind rose from the World Wide Web and overlapped the second over the first for the composition of the figure.

whether the lizards were randomly oriented or not. We also performed circular-circular correlations to test whether lizards' orientations on different substrates (bromeliads, other perches, and on all types) were correlated with the direction of the sun. We present the data as average ± standard deviation (SD) or as average ± circular standard deviation (CSD). During this study, we recorded data only from adult lizards.

We collected 29 *M. macrorhyncha* lizards from Grussaí. Their activity pattern was bimodal, with peaks from 06:00 to 11:00 am and then between 2:00 and 7:00 pm, decreasing the activity during midday (from 11:00 am to 2:00 pm) (Fig. 2). Their daily activity ended close to 7:00 pm (Fig. 2). The average temperatures of active lizards were T_b = 34.2 ± 1.5 °C (range: 33.0–37.0 °C, N = 6), T_a = 27.8 ± 0.4 °C (range: 27.0–28.0 °C, N = 6) and T_s = 30.5 ± 1.4 °C (range: 28.8–32.8 °C, N = 6). We recorded 35 perched individuals oriented at the mean angle μ = 144.7° ± 13.2° (r = 0.974), and the mean angle of the sun was μ = 89.1° ± 1.53° (r = 1). The Rayleigh test and the circular-circular correlation showed that lizards were more often oriented toward the sun (Z = 33.176, $p < 0.0001$, r = 0.134, $p < 0.05$) (Fig. 3). Lizards found on bromeliads (N = 25) had a mean angle μ = 140.9° ± 11.2° and r = 0.981, whereas the sun had μ = 88.8° ± 1.7° and r = 1. The orientations of these lizards were concentrated towards the sun (Z = 24.057, $p < 0.0001$; circular-circular correlation, r = – 0.09, $p < 0.05$). Individuals on other perches (N = 10) had mean angle μ = 154.3° ± 13.1° and r = 0.974, whereas the sun had μ = 89.7° ± 0.64° and r = 1. The lizards were orientated sig-

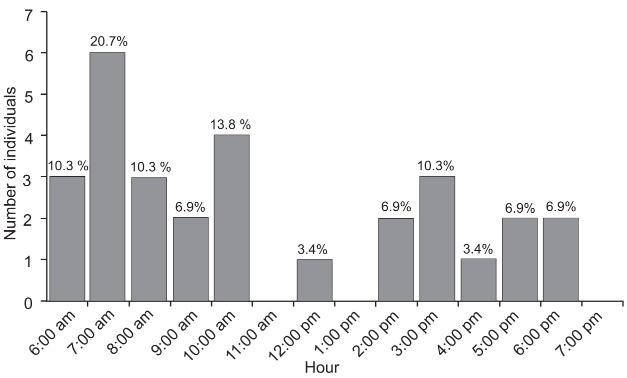

Figure 2. Daily activity cycle of *Mabuya macrorhyncha* (N = 29) in Grussaí, municipality of São João da Barra, state of Rio de Janeiro, Brazil. Frequency (%) of occurrence is shown above bars.

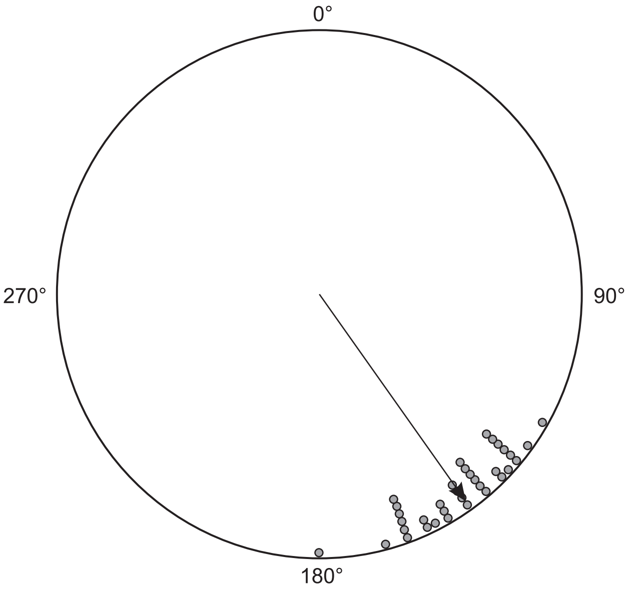

Figure 3. Cardinal orientations of *Mabuya macrorhyncha* individuals (N = 35, in degrees) at first sight on different circular-shaped substrates (mainly bromeliads) in the Restinga of Grussaí, municipality of São João da Barra, state of Rio de Janeiro, southeastern Brazil. The arrow direction represents the mean vector (μ), and its length represents the length of the mean vector (*r*).

nificantly towards the sun ($Z = 9.488$, $p < 0.0001$, circular-circular correlation, $r = 0.632$, $p < 0.05$).

The activity cycle of the lizards in our data from Grussaí was longer than recorded in the literature for other places, starting at 6:00 am and ending at approximately 7:00 pm. The following results from other studies documented shorter activity times for lizards: Barra de Maricá (Rio de Janeiro, Brazil) from 7:00 am to 4:00 pm (Vrcibradic and Rocha 1996); Jurubatiba (Rio de Janeiro, Brazil), from 08:00 to 5:00 pm (Hatano et al. 2001). The differences in the length of the activity cycles of lizards from Barra de Maricá, Jurubatiba and Grussaí might reflect the local thermal environments, including the effects of seasonality. One example of the influence of thermal variations on the activity cycle of another lizard species are populations of *Liolaemus lutzae* lizards from Barra de Maricá and Arraial do Cabo (municipalities in the state of Rio de Janeiro). Individuals of this species were active for shorter periods when environmental temperatures were high (Barra de Maricá) and for longer periods when temperatures were low (Arraial do Cabo – see discussion in Maia-Carneiro et al. 2012). It seems that in warmer days lizards may have began their activities earlier but in total they remained inactive for a longer period of time, whereas in colder days individuals start their activity later and maintain it during most of the day.

In our results, the activity cycle of *M. macrorhyncha* is bimodal. This avoids exposure to high environmental temperatures and is consistent with observations on other lizard species (Cowles and Bogert 1944, Bogert 1949, Castilla et al. 1999, Hatano et al. 2001). Individuals take shelter or use more shaded microhabitats (as leaf-litter) to avoid overheating (Mosauer 1936), which also makes them harder to detect. The extended daily activity cycle of *M. macrorhyncha* in Grussaí (see Vrcibradic and Rocha 1996 and Hatano et al. 2001 for comparisons) probably reflects the thermal properties of that environment during the summer, which is able to provide enough heat for lizard activity later during the day. This hypothesis may apply since the mean T_b in the population of Grussaí was comparatively higher than in other localities: Barra de Maricá (32.1 °C, Rocha and Vrcibradic 1996), Jurubatiba (32.7 °C, Hatano et al. 2001), and in pooled data from Grussaí and Praia das Neves (32.0 °C, Vrcibradic and Rocha 2002). However, the mean activity rates and body temperatures of *M. macrorhyncha* individuals in our data may be biased, since our sample size was small and our study went on for a shorter period of time when compared with the other studies mentioned. Further studies on the thermal ecology of different populations of *M. macrorhyncha*, including Grussaí, should be conducted in different seasons to elucidate the variations in T_b.

As expected, *M. macrorhyncha* individuals in Grussaí regulated the temperature of their bodies through exposure to sunlight radiation, selecting sites that allow fine temperature adjustments. Their body orientations significantly correlated with the direction of the sun, suggesting that solar radiation and behavioral adjustments are important for their thermoregulation. Some bromeliad species have a circular architecture that provides different heights, inclinations, and orientations for perching lizards, making it easier for them to pose according to changes in the direction of the sun. By selecting different positions and angles, the lizard may control the quantity of solar radiation intercepted by its body. Since we observed that all perching individuals were oriented towards the sun, apparently all the different perch types functioned as thermal microhabitats for thermoregulation. Beyond thermoregulation, basking on bromeliads may also provide *M. macrorhyncha* lizards with other significant advantages (e.g., improved detection of or refuge from predators and food or water availability). The basking behavior of *M. macrorhyncha* in Grussaí differed from that of its sympatric congener *Mabuya agilis*, which commonly bask on leaf-litter (Vrcibradic and Rocha 1996, 2002). Therefore, perching might be a sound strategy to avoid crowding with *M. agilis* individuals.

We noted significant differences in the correlation coefficients of lizards' positions and sun direction. We encountered a relatively weak negative correlation between individuals found on bromeliads and the direction of the sun, and a strong positive correlation was found for lizards on other perches and the position of the sun. Such apparently contrasting results occurred despite the little differences of their mean angles. It is possible that these differences derived from differences among microhabitats. Other perches might be located mainly in areas comparatively more open (e.g., shrub edges and clearings), which could facilitate the perception of the sun's position in the sky, allowing lizards to position themselves more precisely according to the incidence of sunrays. The results of this study suggest that the body orientation according to the position of the sun in the sky may be of importance for the thermoregulation of *M. macrorhyncha* individuals.

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