Use of cacti as heat sources by thermoregulating *Mabuya agilis* (Raddi) and *Mabuya macrorhyncha* Hoge (Lacertília, Scincidae) in two restinga habitats in southeastern Brazil

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ABSTRACT. Lizards may benefit from gain of heat from contact with the substrate via conduction. In this study, evidence that the lizards *Mabuya agilis* (Raddi, 1823) and *Mabuya macrorhyncha* Hoge, 1946 (Scincidae) inhabiting two restinga habitats in southeastern Brazil (Grussaí, Rio de Janeiro and Praia das Neves, Espírito Santo), may shift microhabitat preferences along the day, and that such shifts may be related to the use of cacti surfaces as direct sources of heat is presented. For both species, body temperature (T_b) was always significantly correlated ($p < 0,05$) with air temperature (T_a). T_b was significantly correlated ($p < 0,05$) with substrate temperature (T_s) for *M. agilis* collected on cacti, but not for specimens collected on the ground. For *M. macrorhyncha* collected on cacti, both T_a and T_s were more important in conjunction than separately, in explaining lizard T_b. Use of cacti as perches by *M. agilis* was more frequent during late afternoon when environmental temperatures are declining, but such a trend was not evident for *M. macrorhyncha*. We suggest that the use of cacti as direct heat sources may be more evident in the ground-dwelling *M. agilis* than in the scansorial *M. macrorhyncha*.

KEY WORDS. *Mabuya*, lizard, thermoregulation, cacti, heat gain by conduction, restinga habitat, Southeast Brazil

Microhabitat use may be linked to thermoregulatory behavior in lizards, since different microclimates may be available at different microhabitats; nevertheless, microclimatic characteristics of a given microhabitat may vary in time and space (e.g. HEATWOLE & TAYLOR 1987). Altitudinal, seasonal and/or hourly variations in microhabitat use patterns by lizards, related to thermoregulatory behavior, have been reported in a number of studies (e.g. RAND & RAND 1966; HEATWOLE 1970; HUEY *et al.* 1977; CHRISTIAN *et al.* 1983; HERTZ & HUEY 1981; ADOLPH 1990; ROCHA & BERGALLO 1990; GANDOLFI & ROCHA 1998). Typically, those studies refer to the microclimatic qualities of a given microhabitat type based on the air temperature and/or amount of direct insolation to which a lizard on its surface is exposed. In other words, they focus mainly on the lizard's gain of heat through direct solar radiation and through convection (but see RAND & RAND 1966; HEATWOLE 1970). However, there is a scarcity of data regarding qualities of lizard

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microhabitats as direct heat sources (i.e. lizards would benefit from a particular microhabitat by absorbing heat from its surface by conduction). In this study, we present evidences that lizards (Scincidae: *Mabuya*) inhabiting open areas in southeastern Brazil may shift microhabitat preferences along the day, and that such shifts may be related to the thermal qualities of a particular microhabitat type (i.e. cactus) as a direct source of heat via conduction.

Two species of heliophylous scincid lizards, *Mabuya agilis* (Raddi, 1823) and *Mabuya macrorhyncha* Hoge, 1946, are common in coastal areas of southeastern Brazil, where they usually occur in sympatry (e.g. ARAÚJO 1994; ROCHA & BERGALLO 1997; ROCHA 1998, 2000). The former species is mainly terrestrial, usually basking and foraging on the ground, while the latter is semiarboreal and usually basks on elevated perches, especially bromeliads (ROCHA & VRCIBRADIC 1996; VRCIBRADIC & ROCHA 1996). Field-active individuals of both species apparently regulate similar body temperatures (ROCHA & VRCIBRADIC 1996). The two species are considerably abundant in the coastal sand-dune areas (restingas) of Grussaí and Praia das Neves, where the present study was conducted. In those two areas, both *Mabuya* species (including the ground-dwelling *M. agilis*) are not uncommonly found perched on cacti (mainly *Cereus fernambucensis* and *Pilosocereus arrabidae*), which are locally abundant. Since cactuses are filled with water, they are expected to cool off more slowly than surrounding air and to retain heat for relatively long periods, constituting a potential direct source of heat for thermoregulating lizards.

In the present study, we record the patterns of microhabitat use by those two lizard species along the day, and try to assess the importance of particular microhabitats (cacti and ground) as direct sources of heat for those animals.

MATERIAL AND METHODS

Fieldwork was carried out at two areas of "restinga" habitat in southeastern Brazil: Grussaí (21°44'S; 41°02'W), in São João da Barra municipality, Rio de Janeiro state, and Praia das Neves (21°15'S; 40°58'W), in Presidente Kennedy municipality, Espírito Santo state. Restinga habitats occur in coastal areas of Brazil and are characterized by sandy, nutrient-poor soils and predominantly herbaceous and arbustive vegetation (SUGUIO & TESSLER 1984); such open xeric habitats are part of the Atlantic Forest domain (EITEN 1992). Both species of *Mabuya* are considerably abundant in both areas.

Lizards were collected during November 1999 using air rifles and rubber bands. Collections were done daily from 07:00 to 18:00 and we promptly tried to capture every lizard sighted. Using a quick-reading cloacal thermometer, we measured each lizard's cloacal temperature (T_b), as well as the air temperature (T_a) 1 cm above the substrate at the lizard's initial position and the substrate temperature (T_s), all to the nearest 0.2 °C. When more than 30 seconds elapsed between the first attempt to capture a lizard and its capture, temperature was discarded. The time at which each lizard was active when it was first sighted and the type of microhabitat it was using were also registered. At the laboratory, the animals were weighed (to the nearest 0.2 g) using a Pesola® spring balance and their snout-vent length was measured using a caliper (to the nearest 0.1 mm).

We used the air and substrate temperatures taken in each microhabitat as a measure of the lizards' thermal environment. The differences in T_b between the two species at each site were tested using a one-way analysis of variance (ANOVA) and also using an analysis of covariance (ANCOVA) using T_a as covariate.

For the subsequent analyses, we used pooled data from both study sites for each species. Temperature data were divided in two groups for each species: one comprising lizards collected on cacti and the other comprising lizards collected on the ground (for *M. agilis*) or on bromeliads (for *M. macrorhyncha*). Differences in mean T_b, T_a, and T_s between the two groups were tested using ANOVA. For each group (and for *M. macrorhyncha* collected on cacti), the relationship between lizard T_b and T_a and T_s, respectively, were analysed by simple regression analyses (Zar 1999). The relationship between lizard T_b and both environmental temperatures simultaneously was estimated by multiple regression (Zar 1999). Descriptive statistics are given as mean ± 1 SD, unless otherwise stated.

RESULTS

Overall T_b, T_a and T_s of lizards (pooled data from both localities) averaged 32.0 ± 2.6 °C (n = 35), 28.0 ± 2.4 °C (n = 35) and 28.1 ± 2.7 °C (n = 30), respectively, for *M. agilis* and 30.0 ± 3.3 °C (n = 21), 25.6 ± 2.3 °C (n = 20) and 27.9 ± 3.5 °C (n = 16), respectively, for *M. macrorhyncha.*

Mean values and ranges of T_b, T_a, and T_s for *M. agilis* collected on cacti and on the ground and for *M. macrorhyncha* collected on cacti and on bromeliads are given in table. I. Both T_b and T_a averaged higher (though not significantly so) for *M. agilis* collected on the ground compared to those collected on cacti, but mean T_s of cacti was significantly higher than that of the ground (Tab. I). For *M. macrorhyncha*, there were no differences in T_b and T_a between lizards on cacti and those on bromeliads (Tab. I).

Table I. Mean values (with range in parentheses) of T_b, T_a, and T_s for *M. agilis* collected on cacti and on the ground and for *M. macrorhyncha* collected on cacti and on bromeliads. T_s values for bromeliads were not considered since they tended to be little or no different from respective T_as. F-values (from ANOVAs) are given on the bottom row, with an asterisk indicating values significant at 0.05.

Type of substrate	T_b	T_a	T_s
M. agilis			
cactus (n =10)	30.4 ± 2.9 °C (27.0 – 35.2)	26.8 ± 2.3 °C (24.2 – 32.0)	29.5 ± 3.3 °C (25.0 – 36.4)
ground (n = 20)	32.3 ± 2.3 °C (27.2 – 35.2)	28.2 ± 2.2 °C (24.4 – 32.6)	27.3 ± 2.9 °C (22.8 – 30.0)
F-value	3.83	2.43	4.93 *
M. macrorhyncha			
cactus (n = 9)	30.0 ± 3.5 °C (25.4 – 35.2)	26.2 ± 2.7 °C (23.4 – 30.6)	28.6 ± 3.9 °C (24.4 – 35.0)
bromeliad (n = 11)	29.7 ± 3.3 °C (24.6 – 35.8)	25.0 ± 1.9 °C (21.6 – 27.6)	–
F-value	0.06	1.19	–

For *M. agilis* collected on cacti ($n = 10$), T_b was positively and significantly correlated with T_a ($r = 0.81$; $p = 0.005$) and with T_s ($r = 0.91$; $p < 0.001$). The effect of both heat sources combined explained a significant part of the variation in *M. agilis* T_b ($R^2 = 0.83$; $p < 0.005$), but only T_s explained an addittional portion of such variation ($p = 0.029$) after factoring out the effect of the other variable. For *M. agilis* collected on the ground ($n = 20$), T_b was significantly correlated with T_a ($r = 0.56$; $p < 0.05$) but not with T_s ($r = 0.32$; $p = 0.17$). The combined effect of both T_a and T_s significantly affected the variation in T_b ($R^2 = 0.32$; $p < 0.05$), but only T_a explained an addittional portion of the variation in T_b ($p = 0.035$), when the other variable was factored out.

For *M. macrorhyncha* collected on cacti ($n = 9$), T_b was positively and significantly correlated with T_a ($r = 0.84$; $p = 0.005$) and T_s ($r = 0.84$; $p < 0.005$), as well as with both heat sources combined ($R^2 = 0.72$; $p < 0.05$); however, neither T_a nor T_s showed an additive effect ($p > 0.5$).

Data on microhabitat use frequencies by the two species during the morning (07:00-10:59 h), afternoon (11:00-15:59 h) and late afternoon (16:00-18:00 h) are presented in table II. Most (86.7%) *M. agilis* collected before 11:00h were on the ground, while 85.7% of those collected after 16:00h were on cacti. For *M. macrorhyncha* there was no clear trend for the use of a particular microhabitat during each period. Mean T_a (pooled data for both species at both sites) did not differ between morning (28.0 ± 2.9°C, $n = 22$) and afternoon (26.9 ± 2.5 °C, $n = 24$) ($F_{1,44} = 1.99$; $p = 0.17$), nor between afternoon and late afternoon (25.6 ± 0.7 °C, $n = 9$) ($F_{1,31} = 2.43$; $p = 0.13$), but the difference was marginally significant between morning and and late afternoon ($F_{1,25} = 4.24$; $p = 0.05$).

Table II. Frequency of use of each microhabitat type by *M. agilis* and *M. macrorhyncha* per time period at the restinga habitats of Grussaí and Praia das Neves, Brazil (pooled data for both sites). Data include all animals collected, whether or not temperature data were taken.

Microhabitat	*M. agilis*				*M. macrorhyncha*			
	0700 – 1100	1100 – 1600	1600 – 1800	Total	0700 – 1100	1100 – 1600	1600 – 1800	Total
Soil	13	10	1	24	–	1	–	1
Cactus	1	7	6	14	4	5	2	11
Bromeliad	1	–	–	1	4	7	1	12
Other	–	–	–	–	–	1	–	1
Totals	15	17	7	39	8	14	3	25

DISCUSSION

The data suggest that cacti are used as basking sites by both species, but that its importance in thermoregulation may differ between species. For *M. agilis*, it appears that gain of heat by conduction may be more important for lizards perching on cacti than for lizards on the ground. This is also suggested by the differential use of both types of substrate according to the daily period: the lizards appear to use cacti infrequently during the morning, but quite frequently during late afternoon. It is possible that *M. agilis* may bask on the ground during early morning, when environmental temperatures are low and surfaces of cactuses have not yet warmed up. By late morning, air temperatures may already be high enough to provide suitable heat sources for the lizards via convection, so that there may be no need to thermoregulate on cacti surfaces. As the afternoon progresses and air temperatures start to decrease, lizards begin to climb on cacti, by then already warm due to hours of exposure to solar radiation. Finally, by late afternoon, air temperatures have cooled off and lizards will presumably climb on cactuses to gain heat from direct contact with their surfaces, which have become warmer than the surrounding air (and presumably better meeting the thermal requirements of the skinks).

Heat gains through conduction via direct contact with the ground may have its importance diminished in *M. agilis* also because this lizard is usually found on the leaf litter rather than on open sand [of the 24 individuals collected on the ground, only five (20.8%) were on open sand]. The litter layer prevents direct contact of the lizards with the sand, which may reach extremely high temperatures (ca. 50-60° C) during the hotter hours of the day in restingas (ROCHA 1988; FIALHO 1990). Also, air temperatures during the hottest periods are usually higher at or near the ground compared to more elevated microsites (e.g. GEIGER 1965; PORTER *et al.* 1973; STEVENSON 1985; ADOLPH 1990). Thus, the primarily terrestrial *M. agilis* is presumably exposed to relatively high T_as during much of the day, without having to be in direct contact with the sand substrate. Unlike other lizards common in restingas (*e.g. Tropidurus torquatus* and *Cnemidophorus* spp.; e.g. BERGALLO & ROCHA 1994; TEIXEIRA-FILHO *et al.* 1995, 1996), which are sometimes found on open sand away from shrub edge, *M. agilis* is a secretive species rarely leaving the edge of shrubs (VRCIBRADIC & ROCHA 1996; personal observation). Thus, although those lizards could gain heat from contact with open sand after T_as have cooled off, that would leave them exposed; using the surface temperatures of cactuses, on the other hand, may have a similar effect without requiring the lizard to leave a patch of vegetation.

The importance of cacti surfaces as heat sources for thermoregulating *M. macrorhyncha* is less clearly suggested by our data. Unlike *M. agilis*, this species usually basks on elevated perches, especially bromeliads (VRCIBRADIC & ROCHA 1996). Thus, being a naturally scansorial species, its climbing on cacti may not be particularly linked to heat gain by conduction. Also, our data suggest that *M. macrorhyncha* may perch indiscriminately on both bromeliads and cactuses during each period of the day. Nevertheless, our data for this species regarding the late afternoon period is too limited (n = 3) and is insufficient to draw any conclusions about preferential microhabitat use during this period. Moreover, the additive effect of both T_a and T_s was more important than each of them alone in explaining the variation in T_b for *M. macrorhyncha* individuals perching on cacti; this suggests that those lizards may actually benefit from the heat gain through contact with the surfaces of cactuses, even though they may use them primarily as basking sites (as they use bromeliad leaves). More data from specimens collected after 16:00 would probably help to settle this issue.

To sum up, our results suggest that microhabitat shift associated to thermoregulatory behavior may be employed by skinks (*Mabuya* spp.) in restinga areas where cacti are abundant, in order to take advantage of cactuses as heat sources. Such behavior appears more evident in the ground-dwelling *M. agilis* than in the scansorial *M. macrorhyncha*, but further data on both species (especially during late afternoon) are needed to test if they really differ in this aspect. It would be also interesting to compare T_as and T_ss randomly taken at the surfaces of cacti, ground and bromeliad leaves during each period of the day, and also to compare those with the T_as and T_ss experienced by members of both skink species taken in the field during the same day. The great abundance of both skinks and cacti makes the restingas of Grussaí and Praia das Neves excellent areas for such a study.

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