Vulnerability to climate change of *Anolis allisoni* in the mangrove habitats of Banco Chinchorro Islands, Mexico

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ABSTRACT

As niche specialist species, lizards from tropical environments are characterized by a low tolerance and high physiological sensitivity to temperature changes. The extent of vulnerability to thermal changes depends on the lizard's physiological plasticity to adjust the environmental changes. Herein we studied the thermal biology of *Anolis allisoni*, an endemic arboreal lizard from the tropical islands of the Banco Chinchorro Biosphere Reserve, Mexico, carried out during April and May 2012 and April 2014. We report field body (T_b) and preferred body temperatures in the laboratory (T_{pref}), operative temperatures (T_e) and restriction of hours of activity. *Anolis allisoni* showed high and identical T_b and T_{pref} (33 °C), not significantly different than the mean T_e (32.15 °C). The effectiveness of thermoregulation (E= −0.30) and the analysis of hours of restriction suggested that the high temperatures of T_e (40–62.5 °C) registered at midday (from 12:00 to 15:00) of *A. allisoni* habitat are hostile and force lizards to take refuge during a period of 3 h of their daily time of activity. The scarcity of opportunities to find alternative refuges for thermoregulation in Banco Chinchorro point out the vulnerability of *A. allisoni* and the risk of local extinction when considering future predictions of increase in global environmental temperatures.

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1. Introduction

Climate change has profoundly affected terrestrial organisms (Walther et al., 2002; Parmesan, 2006), and it is predicted that the rise in environmental temperature due to global warming in the coming decades will impact tropical species more harshly (Root et al., 2003; Angilletta, 2009; Deutsch et al., 2008). However, the direct biological consequences depend not only on the rate of climate warming but also on the physiological sensitivity to warming and on the behavioural and physiological capabilities of organisms to buffer the environmental changes (Huey and Slatkin 1976; Huey et al., 2003; Deutsch et al., 2008; Tewksbury et al. 2008). In the long term, avoidance of local extinctions will depend on the possibilities of adaptation to new thermal niche conditions (Logan et al., 2014).

Ectotherms (e.g. insects, amphibians, reptiles) constitute the vast majority of the biodiversity at tropical latitudes. However, many tropical ectotherms are thermal specialists and therefore vulnerable to even slight increases in regional temperature, which can adversely impact individual fitness and population viability. For instance, tropical and endemic lizards of tropical islands are adapted to less variable climatic conditions (Tewksbury et al., 2008) where body temperatures (T_b) are close to their critical thermal maximum (Huey et al., 2012). Therefore, lizards of tropical regions are characterized by low tolerance to high T_b, limited acclimation ability, and reduced dispersal capabilities (Janzen, 1967; Van Berkum, 1986; Addo-Bediako et al., 2000; Deutsch et al., 2008) making them vulnerable to thermally stressful changes.

Recent evidence is controversial about the possible paths of adaptive evolution of tropical lizards to global warming. Given enough time, species may shift geographically to milder thermal environments or could adjust to local conditions by behavioural and physiological plasticity, or may adapt by natural selection to changed environments, whereas a short-term behavioural change may be to retreat to a refuge during the hottest hours of the day. The shortening of the daily activity period, which in turn reduces feeding opportunities, social and reproductive behaviours,

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undermine body condition, growth and reproduction, increasing the risk of local extinction (Sinervo et al., 2010).

In a global warming scenario, lizards will have at least three main responses: dispersal, behavioural and physiological plasticity, and adaptation (Sinervo et al., 2010). For example, if environmental temperatures increase, sympatric species which occur in open habitats may invade the forest, competing and driving the forest lizard populations to extinction (Huey et al., 2009), or they could adapt to the changing environment by natural selection instead of shifting their geographic range and competing with novel sympatric species (Logan et al., 2013).

The genus *Anolis* (anoles) consists of about 400 species of small, arboreal, insectivorous lizards (Roughgarden, 1995). It is among the largest genera of vertebrates, occurring throughout the subtropical and tropical Western hemisphere, in the southern United States, Mexico, Central and South America, and about 150 species occur on the Caribbean Islands (Williams, 1969; Losos and Schneider, 2009). *Anolis allisoni*, endemic to Caribbean Islands, is the only anole occurring solely in mangrove forest habitats (Rand, 1964, 1967). *Anolis allisoni* can also be found in the upper trunks and crowns of trees in sympatry with species geographically widespread in open habitats such as *A. sagrei* and *Aspidocelis maslini*.

We hypothesize that the specialist character and the restricted distribution of *A. allisoni* make it vulnerable to rapid environmental changes. Herein, we estimate how a predicted increment of 3.2–4 °C (IPCC, 2013) in mean ambient temperature could affect the time of activity of the insular *A. allisoni* from the Banco Chinchorro Islands in Mexico. We integrate data on lizard field and preferred body temperature, quality of thermal microenvironment, and efficiency of thermoregulation (*sensu* Hertz et al., 1993), and we describe the main cooling or heat sources that these lizards use for thermoregulation.

2. Materials and methods

2.1. Study area and materials

Field work was carried out in Cayo Centro, the largest island of Banco Chinchorro atoll, Quintana Roo, Mexico (18°34′N–87°19′W) in April and May 2012, and April 2014. *Anolis allisoni* (N=34) were caught when active on the trunks of palm trees or on the branches of trees where the leaves provide small patches of sun and shade (i.e. performing any behaviour related to feeding or breeding activities) from 9:00 to 19:00 h, by hand or noose. Individuals were kept in captivity no more than 48 h, and were all released at the precise spot of capture using a GPS device (Garmin, eTrex 20).

2.2. Data collection

Body temperature (T_b, *sensu* Pough and Gans, 1982) was measured in the field in active lizards using a catheter probe TES TP-K01 (1.62 mm diameter) introduced approximately 1 cm inside the cloaca. Individuals were handled by the head to avoid heat transfer and temperature was recorded within 20 s of capture. Time of day at capture was also recorded.

The micro-environmental temperatures were recorded at capture sites in order to determine heat sources used by lizards. We measured substratum temperature (T_s), air temperature at 1 cm (T_a) and air temperature at 1 m above the ground (T_{air}). Temperatures were registered using thermocouples for substrate (TES TP-K03) and air (TES TP-K02), each instrument connected to a TES 1302 thermometer (TES Electrical Electronic Corp., Taipei, Taiwan, ± 0.03 °C).

The operative temperatures (T_e, *sensu* Hertz et al., 1993) were measured in the field using 12 plastic cylinder (PVC) physical models, 15 cm length $\times$ 5 cm diameter, sealed at the ends, distributed at a variety of microsites on vertical substrates (trees and heights above the ground) where *A. allisoni* typically perch (Rand, 1964; Schoener and Schoener, 1971; Jenssen et al., 1984). The physical models were connected to three data loggers (HOBO U12, 4 External Channel Logger) each with four thermistors, and the micro-environmental temperatures were recorded every 15 min from 9:00 to 19:00 during captures (8 days in April and May 2012 and during 7 days in April 2014). The mean of the temperatures recorded from each model every day of capture were used to obtain the mean T_e.

2.3. Laboratory experiments

Thermoregulation experiments were conducted 1–2 days after capture. Lizards were placed individually in open-top terraria (100 × 45 × 20 cm) with a thermal gradient produced by a lamp over the end of the terraria making a substratum gradient from 25° to 50 °C. Temperatures were register using ultra-thin (1 mm) catheter thermocouples fixed in the abdomen with adhesive tape. The temperature of each lizard was obtained every 1 min for 2 h by connecting the thermocouple to a TC-08 Data Acquisition Module Omega® (8-Channel USB Thermocouple).

Experiments were performed to estimate the mean and range of the T_{pref} for each individual. The set-point range (T_{set}), considered as the temperatures within the interquartile range of the observations, was also noted because of neurophysiological evidence that ectotherms regulate between upper and lower set-point temperatures rather than around a single T_b (Barber and Crawford, 1977; Firth and Turner, 1982). The interquartile range represents the natural settings comprising the hypothalamic thermostat in lizards and fishes (Hertz et al., 1993).

In order to measure the average extent to which *A. allisoni* experienced T_b outside the set-point range, the sum of the absolute values of the deviations of T_b from T_{set} of each individual was calculated (individual deviation=d_b). The values obtained for each lizard were used to estimate the mean and range of T_{pref}, T_{set}, and d_b. In addition, the index of the mean thermal quality of a habitat from an organism's perspective (d_e) was calculated as the deviation of T_e in relation to the mean T_{set} for the species. The existence of active selection of the microhabitats and the effectiveness of the thermoregulation was obtained as E=1–(Mean d_b/ Mean d_e) which integrates the average degree to which *A. allisoni* experienced T_b outside the set-point range (d_b) and the quality of thermal environment to achieve T_{pref} (d_e). Thermoregulation can be considered as effective when E is close to 1, whereas that of a thermoconformer when E is close to 0, or as that of a moderately effective thermoregulator when E is close to 0.50 (Hertz et al., 1993; Bauwens et al., 1996; Medina et al., 2009; Ibargüengoytía et al., 2010; Medina et al., 2011). Negative values of E can occur when animals actively avoid microhabitats within the set-point range for example: when predators are abundant, food is rare at such sites or when the thermal conditions are restrictive (Huey and Slatkin, 1976; Hertz et al., 1993; Gutiérrez et al., 2010).

2.4. Restriction and activity time

We estimated the restriction in hours of activity (h_r), which is considered to be the additional time a lizard would remain in its thermal refugia due to temperatures exceeding their thermal preferences (Sinervo et al., 2010). Hours of restriction were estimated as the amount of time during which the temperature of at least one of the physical models exceeded the upper bound of $T_{pref}=40.51$ °C ($T_{ei} >$ upper bound T_{pref}), because we considered as threshold for activity restriction (Kubisch et al., 2016). The activity hours were estimated as the period during which at least one

model registered a T_{ei} higher than the lowest T_b of lizards in activity (lowest activity temperature, $T_{lowest\ activity}$) and lower than the upper bound T_{pref} ($T_{lowest\ activity} < T_{ei} <$ upper bound T_{pref}). We assumed that the lowest T_b that lizards are active is 24 °C for tropical thermoregulatory species, correspond to the minimum T_b registered in the current study.

2.5. Measurements of sexual dimorphism

Morphological descriptions and assessment of sexual dimorphism were restricted to adults, and variables were chosen considering the body components that display sexual dimorphism most consistently (*sensu* Olsson et al., 2002). Snout-vent length (SVL), head length (HL), head width (HW), head height (HH), and body width at vent (WAV) were recorded. In addition, tail length (TL) and the inter-limb length (IL, between the armpits to the pelvic girdles). We measured IL on both right and left sides and used the mean in our analyses.

2.6. Statistical analyses

The sexual dimorphism was analysed using discriminant analysis to identify the morphological variables that best explained the differences between sexes. The dependence of T_b and T_{pref} of SVL and body mass was analysed by simple linear regressions. In addition, the main heat sources used by the lizards were determined by comparing the T_b with the micro-environmental temperatures at each capture site using Repeated Measures ANOVA. The difference between the T_b and T_{pref} of each individual was analysed using paired t-test, and the differences between males and females in T_b or T_{pref} were analysed with t-test. For more than two samples, we used one way analysis of variance or Repeated Measured for related samples. Assumptions of normality and variance homogeneity were tested with the one-sample Kolmogorov-Smirnov and Levene's tests, respectively. When the assumptions were violated, non-parametric, Kruskal-Wallis or Dunn's test were used. Means are given $\pm$ 1 SE.

3. Results

3.1. Capture site

The climate of Banco Chinchorro atoll is Tropical warm and sub-humid, with rainfall mainly in summer and winter (1500 mm of annual rainfall; Cabrera, 1998). The hottest months are July and August with an average of 28.3 °C, while the coldest month is December with 24.2 °C (Fig. 1). The study was performed during at the onset of the rainy season. The average environmental temperatures obtained from Banco Chinchorro weather station during the field work were similar in April-May 2012 and April 2012-April 2014, but were slightly higher in April 2014 than in May 2012 (Kruskal-Wallis, H_2=7.314, P < 0.1; Dunn's Method, $Q_{April\ 2014–May\ 2012}$=11.59, P < 0.05; $Q_{April\ 2014–April\ 2012}$=6.02, P > 0.05; $Q_{April\ 2012–May\ 2012}$=17.624, P > 0.05; $Median_{April\ 2012}$=29.73 °C, $Median_{May\ 2012}$=29.44 °C, $Median_{April\ 2014}$=29.59 °C). *Anolis allisoni* was found associated with the plant species *Cocos nucifera, Thrinax radiata, Pithecellobium keyense* and *Bursera simaruba*. *Anolis allisoni* is also sympatric with two other small, diurnal lizards *Anolis sagrei* and *Aspidoscelis maslini*.

3.2. Anolis allisoni body size and mass, sexual dimorphism and body temperature

Adult *A. allisoni* SVL and body mass ranged from 48.18 to 88.68 mm and from 1.5 to 15 g, respectively. Males of *A. allisoni*
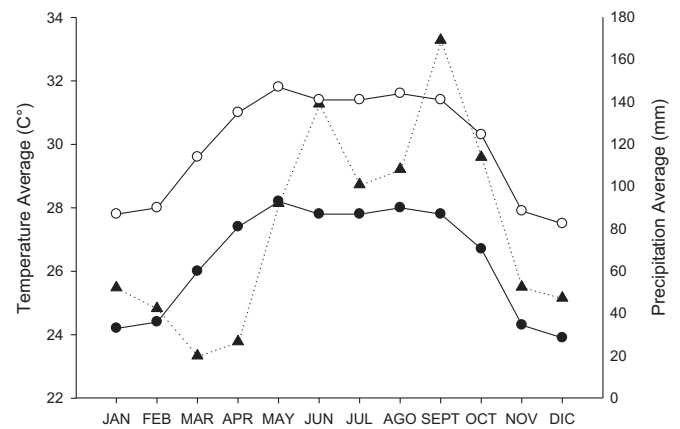
Fig. 1. Current monthly average temperature (black circles, °C), predicted monthly average temperature to the next decade based on IPCC simulations (white circles, °C; IPCC, 2013) and current monthly average precipitation (black triangles, mm) on Banco Chinchorro Islands.

had larger values for SVL (t-test, t_{29}=14.34, P < 0.001), HL and HW than females (discriminant analysis, λ=0.24, P < 0.001, N=21; Table 1).

The values of mean $\pm$ standard error of T_b, T_{pref} and T_{set} (upper and lower) of *A. allisoni* are present in Table 1. In addition T_b and T_{pref} did not show a relationship with SVL or body mass (Multiple Linear Regression, $F_{Tb\ 2,\ 24}$=0.865, P=0.44; $F_{Tpref\ 2,\ 21}$=0.316, P=0.73). Furthermore, we found no differences between males and females in T_b or T_{pref} (t-test, $t_{Tb,\ 24}$=0.36, P=0.72; Mann-Whitney U Statistic, $T_{Tpref,\ 23}$=66, P=0.68).

3.3. Determination of the main heat source used by the lizards

Anolis allisoni T_b's were higher than substrate temperature at capture sites (T_s), air temperature (T_{air}) and air temperature at 1 cm above substrate (T_a) (Repeated Measures ANOVA, $F_{3,122}$=35.72, P < 0.001; Fig. 2). In addition, the mean values of T_s, T_{air} and T_a did not show differences among them (Table 2). The T_bs showed a significant and positive relationship only with T_a (Linear Regression, $F_{1,\ 30}$=4.93, P < 0.05).

3.4. Preferred body temperature and effectiveness of temperature regulation

There were no differences between T_b and T_{pref} (Paired t-test, t_{31}= − 1.37, P > 0.17; Table 1), neither were found a significant relationship between T_b and T_{pref} (Linear Regression, $F_{1,\ 30}$=0.283, P=0.599, Fig. 3). In addition, the T_e was lower than T_{pref} and was not different from the T_b (Kruskal-Wallis, H_2=12.195, P < 0.01; Dunn's method, $Q_{Te-Tpref}$=3.49, P < 0.05, Q_{Te-Tb}=1.82, P > 0.05; $Median_{Te}$=32.15 °C). The 47% of the T_bs (N=16) were lower than the minimum-T_{set} (32.62 $\pm$ 0.30 °C), 41% were included in the set-point range (N=14; maximum-T_{set}=35.35 $\pm$ 0.31 °C, Fig. 4) and 12% (N=4) of the T_b's were higher than the maximum-T_{set}. In addition, 45% of the T_e's (N=14) were lower than the minimum-T_{set}, 45% were included in the set-point range (N=14) and 10% (N=3) of the T_e's were higher than the maximum-T_{set}. The efficiency of thermoregulation was E= − 0.30, being E= − 0.19 in females and E= − 0.48 in males (Table 1).

3.5. Empirical estimates of restriction time from T_e physical models

The average hours of restriction obtained for *A. allisoni*, were h_r=1.58, while the average hours of daily activity were 8.9 h (Fig. 5).

Table 1

Descriptive data (mean $\pm$ SE) of snout-vent length (SVL, mm), head length (HL, mm), head width (HW, mm), body, preferred temperature (T_b and T_{pref}, °C), set-point temperature range (T_{set}, lower and upper, °C), operative temperatures (T_e), and absolute values obtained from the deviations of T_b from T_{set} of each individual (d_b), index of the average thermal quality of an habitat (d_e) and the effectiveness of temperature regulation (E). Sample sizes (N) are indicated for Male and Female and for the overall data set.

	SVL	HL	HW	T_b	T_{pref}	T_{set}		T_e	d_b	d_e	E
						Lower	Upper				
Females	56.4 ± 4.0 (14)	13.9 ± 2.2 (14)	13.2 ± 0.4 (14)	32.1 ± 0.9 (12)	33.2 ± 0.6 (12)	33.0 ± 0.8 (12)	34.9 ± 1.3 (12)	31.5 ± 0.9 (180)	1.25 ± 0.6 (12)	1.05 ± 1.4 (12)	−0.19
Males	77.0 ± 7.6 (19)	24.8 ± 3.6 (19)	9.5 ± 0.8 (19)	33.6 ± 0.6 (19)	33.5 ± 0.4 (19)	32.4 ± 0.3 (19)	34.8 ± 0.4 (19)	32.5 ± 0.2 (180)	1.33 ± 0.3 (19)	0.9 ± 0.3 (19)	−0.48
Overall	68.9 ± 2.1 (33)	20.5 ± 1.1 (33)	11.7 ± 0.5 (33)	33 ± 0.4 (31)	33.8 ± 0.3 (31)	32.6 ± 0.3 (31)	35.3 ± 0.3 (31)	32.1 ± 0.8 (180)	1.62 ± 0.3 (31)	1.25 ± 0.2 (31)	−0.30
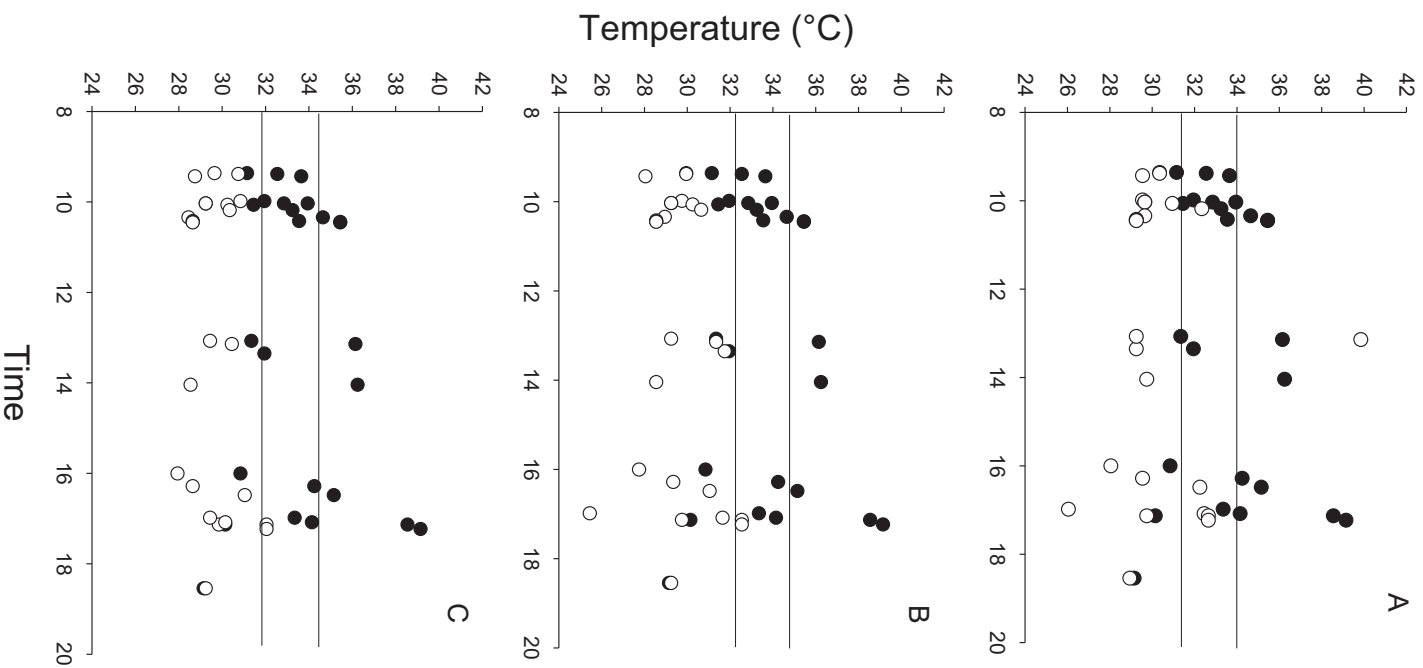
Fig. 2. Field active body temperatures (black dots, °C) and micro-environmental temperatures (white circles, °C) vs. time of day (h): substrate (T_s, panel A), air at 1 cm above substrate (T_a, panel B) and air (T_{air}, panel C) of *Anolis allisoni* of Cayo Centro in Banco Chinchorro Islands. Lines indicate the lower and upper set-point (T_{set}) for preferred body temperature.
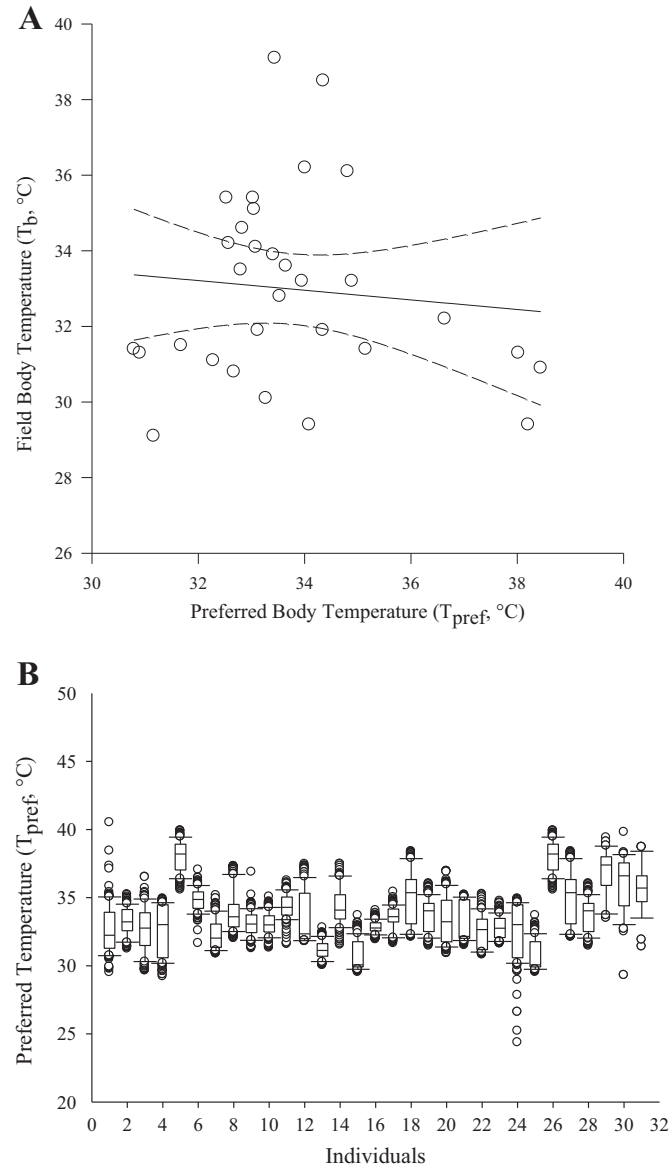
4. Discussion

Anolis allisoni showed the highest body temperature (T_b=33 °C) recorded for the genus (Brattstrom, 1965; Roughgarden et al., 1981; Hertz, 1992; Hertz et al., 1993), similar to preferred body temperature in the laboratory (T_{pref}=33.8 °C) and higher than the mean operative temperature (T_e=32.1 °C). Under hot and tropical environments, both sexes showed similar thermal eco-physiological responses, despite males being larger than females.

Table 2

Comparisons by t-test of mean ($\pm$ SE) body temperatures (T_b, °C) and the micro-environmental temperature (°C): substrate (T_s), air temperature (T_{air}) and air temperature at 1 cm above substrate (T_a).
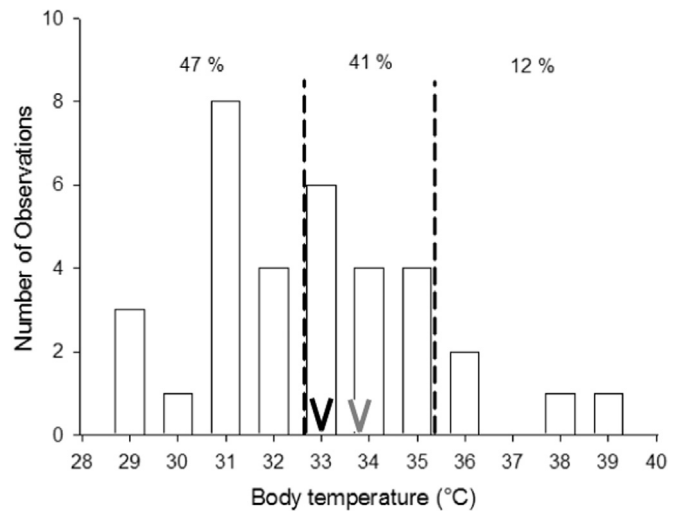
Anolis allisoni – Cayo Centro in Banco Chinchorro Islands				
	T_b	T_s	T_{air}	T_a
$T_b = 33 \pm 0.41$ (34)	–	$t = 6.85^*$	$t = 8.64^*$	$t = 9.07^*$
$T_s = 30.35 \pm 0.45$ (34)	$t = 6.85^*$	–	$t = 2.003$	$t = 2.221$
$T_{air} = 29.7 \pm 0.2$ (34)	$t = 8.64^*$	$t = 2.003$	–	$t = 0.15$
$T_a = 29.5 \pm 0.46$ (34)	$t = 9.07^*$	$t = 2.221$	$t = 0.15$	–

Sample size (N), t-value and significance (p < 0.05) are indicated (*).

Fig. 4. Distribution of field active body temperatures (T_b) at capture of *Anolis allisonii* (bars) of Cayo Centro in Banco Chinchorro Islands. The black arrow shows the mean T_b, gray arrow the mean T_{pref} and the dashed lines indicate the lower and upper set-point (T_{set}) of the preferred body temperature.
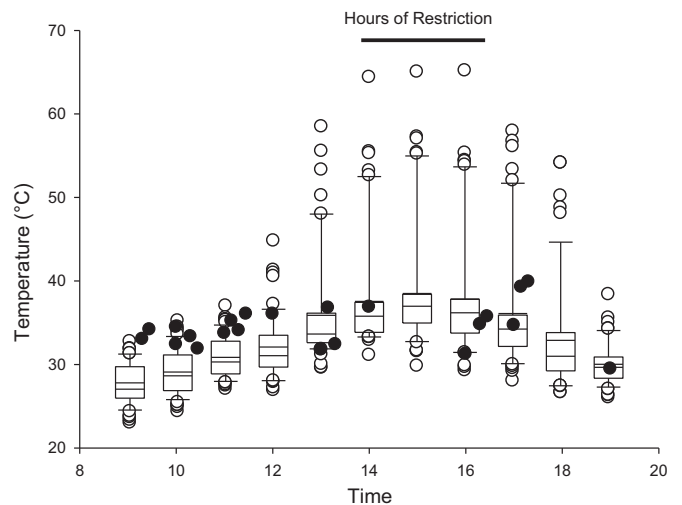

Fig. 3. Field active body temperature vs. preferred body temperature, linear regressions with 95% confidence intervals are indicated (panel A); and box plot of preferred body temperature (T_{pref}, panel B) of *Anolis allisonii* individuals of Cayo Centro in Banco Chinchorro Islands.

Fig. 5. Distribution of body temperatures (T_b, black circle) and operative temperature (T_e, white box plot) of *A. allisoni* from Cayo Centro in Banco Chinchorro Islands. The horizontal black line indicates the hours of restriction.

Anolis allisoni was found in the mangrove forest habitat of Cayo Centro in Banco Chinchorro Islands Reserve, specifically in an open-habitat forest associated mainly with the upper trunks and crowns of *Cocos nucifera*. This open-habitat forest has low understory vegetation and canopy cover, offering full sunlight and few shadow spots during the day for lizards to perch and shelter, especially at the hottest midday hours. The *A. allisoni* was found basking early in the morning and late in the afternoon when the lower operative temperatures were registered (Fig. 5). The *A. allisoni* was always using colder T_s, T_a spots compering with their T_b, suggesting that they cool by perching in the shade, losing heat to the environment by radiation (Table 2). This is especially true if we consider that the T_es, which mimic a "thermoconformer *Anolis*", reached the upper voluntary T_{set} at mid-day.

Most tropical forest ectotherms exhibit body temperatures closer or similar to environmental temperature and often operate at body temperatures close to their upper thermal limits (Kearney et al., 2009). These tropical species have been characterized as thermoconformers, because they live most of the year with body temperatures (near or above their optimal performance) approximately equalling the pattern of the thermal environment (Tewksbury et al., 2008). Accordingly, *A. allisoni* behaves as a poor thermoregulator probably because there is a credible constraint in the times of day when operative temperatures are very high (mid-day), and lizards must remain in the shade or refuges to avoid risk

of overheating. In particular, females showed to be more vulnerable because the limited capacities for thermoregulation (close to thermoconformity, E= −0.19), than males (E= −0.48), probably because the smaller body size of females limit their thermoregulation capabilities. *Anolis allisoni* basks during the morning and late in the afternoon when T_e rarely approached critically high levels ($T_{ei\ max}=65.12\ °C$, recorded in the present study, Fig. 5), in the same way as *A. cristatellus* does (a species from a desert site in Puerto Rico where the average $T_e=32.8\ °C$, was above $T_{set}=28.6–30.9\ °C$; Hertz et al., 1993). Lizards restrain activity even when this behaviour can negatively impact foraging and mating success and could therefore undermine the population dynamics of this species (Sinervo et al., 2010). Shifts in daily thermoregulatory behaviour have not been surveyed in other *Anolis* species, with the exception of *A. limifrons* from Panama which has been found to bask during the dry season less frequently than in the wet season, probably to avoid dehydration (Ballinger et al., 1970).

The high operative temperatures registered at midday (Fig. 5) in the Cayo Centro of Banco Chinchorro, significantly above mean body preferred temperature; show that *A. allisoni* has few options to evade hot spots and the physiological stress that may results from the predicted rising environmental temperatures. However, climate change projections and thermal performance of two populations of *A. allisoni* from Roatan and Cayo Menor Island in Honduras, showed that they may experience an increase in performance capacity as temperature rises over the coming century (Logan et al., 2013). In addition, the average diel operative temperature ranges of these populations will begin to converge on the peak performance by the year 2100 (Logan et al., 2013). It is notable that the peak in performance projected for 2100 for the populations of *A. allisoni* studied by Logan et al. (2013) is based on a mean operative temperature of 33 °C, while under higher T_e the performance of the populations begin to decline (see Fig. 3 in Logan et al. (2013)). In contrast, present results for *A. allisoni* populations from Cayo Centro in Banco Chinchorro, with high average T_e (32.15 °C) at present indicate that this population would be over the optimum performance in short-term temperatures with detrimental effects on activities such as locomotion, feeding, dispersion, social behaviours and reproduction, and thus affecting fitness.

The scarcity of options for behavioural thermoregulation by *A. allisoni*, is similar to the findings for *Anolis* populations from Puerto Rican forests where T_es are relatively homogeneous in space and time and represent a 'monochromatic thermal mosaic' for such forest species (Hertz, 1992). *Anolis allisoni* experience T_b and T_e above or within their set-point range, showing a very low index of d_b (1.62) and an extremely low index of d_e (1.25), similar to the populations of *A. cooki* and *A. cristatellus* restricted to xeric lowland habitats in southwestern Puerto Rico (Hertz et al., 1993).

Anolis allisoni is a thermal specialist, with preference for a narrow range of high body temperatures bounded by 2.5 °C (minimum-$T_{set}=32.62\ °C$; maximum-$T_{set}=35.35\ °C$). Accordingly, the effectiveness of thermoregulation was negative (E= −0.30) suggesting the thermal conditions are restrictive and that the ability to use behavioural thermoregulation to buffer the impacts of increasing environment temperature will be strongly contingent on the availability of shade. Thus, behavioural thermoregulation of tropical forest species would require maintenance of a position in the shade to keep cool, rather than the use of behavioural tactics to stay warm (Tewksbury et al., 2008).

In environments that are thermally "homogeneous" (e.g., tropical climates), such as Cayo Centro in Banco Chinchorro Islands, the onset of a quickly changing critical stress factor would not provide the necessary time to the *A. allisoni* population to adapt to the rapid increase of environmental temperatures predicted in the coming decades. On one hand, evolution under stressful events is more probable when events are predictable, prolonged and frequent in relation to the generation time. In addition, when individuals vary in their reaction to stress and when stress-induced strategies are favoured by natural selection during and after a stressful event, these strategies can facilitate local adaptation by favouring better adjustments, synchronization and functioning of many organismal systems (Emlen et al., 2003; Wingfield and Sapolsky, 2003; Badyaev, 2005). On the other hand, an extreme stress factor (short term) disrupts normal development and, moreover, a decrease in population viability and the likelihood of local extinction is closely associated with extreme environmental changes (Howarth, 1993; Guex, 2001; West-Eberhard, 2003).

Nevertheless, it should be noted that we based predictions on changes in the mean environment temperature alone, yet changes in temperature variability, precipitation, and cloud cover may also be important for population viability (Hare and Cree, 2010; Clusella-Trullas et al., 2011). In addition, one of the most important components of the habitat of *A. allisoni* is the particular and specific association to the trunks of mangrove forests. The mangroves forests are subject to extreme impacts like sea level rise and hurricanes, affecting their distribution and composition (Alongi, 2008). But actual fragmentation, together with climate change could accelerate the increased rates of local extinction (Alongi, 2008). The fragmentation and dehydration of vegetation are some of the consequences of increased environmental temperatures, which not only increase further restriction on the time of activity of *A. allisoni* but also a decrease the number of microenvironments where *A. allisoni* lives, affecting the population viability of this species.

Under the climate warming scenario, the thermoregulatory priority for terrestrial diurnal ectotherms will be to find an optimal balance between avoiding overheating (Kearney et al., 2009) and spending longer periods in refuges, reducing foraging time and net energy income for reproduction or other functions, with the outcome unavoidably being an increase in the risk of local extinction (Huey et al., 2010). Many desert lizards resolve this trade-off evading heat stress by retreating underground during warm periods (Porter et al., 1973; Stevenson, 1985), while others move to higher elevations or to higher latitudes, searching for lower environmental temperatures. But for insular endemics such as *A. allisoni*, the dispersal possibilities are almost nil and the avoidance of extinction will depend on the shady refuges in the yet extant forests, considering that these populations occur over extremely small geographic ranges (219 ha). It is expected that many populations of tropical forest lizards (which have greater geographic ranges) are more likely to escape warming because of the availability of topographical complexity and specifically the availability of higher latitudes and altitudes (Logan et al., 2013). *A. allisoni* from Banco Chinchorro Islands is expected to experience due global warming a rise up to 4 °C of air temperature (Fig. 1) but it is constrained from migrating to cooler areas, pointing out the vulnerability of this Island endemic species and the lower likelihood of population viability and the avoidance of local extinction during warming.

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