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Effects of microhabitat temperature on escape behavior in the diurnal gecko, *Gonatodes albogularis* (Duméril & Bribon, 1836) (Squamata: Sauria: Sphaerodactylidae)

Die Wirkung der Mikrohabitat-Temperatur auf das Fluchtverhalten des tagaktiven Geckos *Gonatodes albogularis* (Duméril & Bribon, 1836) (Squamata: Sauria: Sphaerodactylidae)

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KURZFASSUNG

Die vorliegende Arbeit untersuchte die Wirkung der Lufttemperatur auf das Fluchtverhalten von *Gonatodes albogularis* (Duméril & Bribon, 1836) in einem tropischen Trockenwald-Relikt Kolumbiens. Die Ergebnisse zeigten negative Korrelationen zwischen der Mikrohabitat-Lufttemperatur und dem Abstand zwischen Echse und Beutegreifer zum Zeitpunkt, zu dem die Flucht ausgelöst wird sowie zwischen der Mikrohabitat-Lufttemperatur und dem Abstand der Echse zum nächstgelegenen Unterschlupf zum Zeitpunkt ihrer Erstbeobachtung.

ABSTRACT

The present study examined the effect of microhabitat air temperature on the escape behavior of *Gonatodes albogularis* (Duméril & Bribon, 1836) in a tropical dry forest relict of Colombia, South America. Results showed negative correlation between both microhabitat air temperature and distance between lizards and predators at the moment in which escape is triggered and between temperature and distance of lizards to the closest shelter.

KEYWORDS

Reptilia: Squamata: Sauria: Sphaerodactylidae: *Gonatodes albogularis*; ecology, behavior, temperature; ectotherms; predation; Colombia

INTRODUCTION

The escape behavior of ectotherm animals is strongly affected by the variables complexity of the microhabitat (Gifford et al. 2008; Pennings 1990), body size (Martín et al. 2005) and ambient temperature (Cooper 2000). Among these factors, ambient temperature takes a leading role because it is strongly linked to body temperature and, therefore, to escape ability. Optimal escape theory explains the balance between the energy costs of escape and the risk of being preyed (Ydenberg & Dill 1986; Cooper & Frederick 2007). This balance determines the moment of escape. If the distance between prey and approaching predator is short, the risk of being preyed is high and escape should start hastily. However, if this distance is large, the risk of being preyed is low and escape should start delayed, because the cost of unnecessary flight would negatively influence the energy balance of the individual and, consequently, its fitness.

Since reptiles are ectothermic vertebrates, the physiological and biochemical processes associated with their behavior depend on the ambient and finally body temperature (Bartholomew 1982; Huey 1982; Angilletta et al. 2002; Seebacher 2005). The effect of the ambient air temperature on escape behavior is more important in smaller reptiles, such as geckos which are exposed to a great number of potential predator species (Greene 1988; Martín 2002). Several studies in lizards analyzed the relationship between air temperature and the predators' approach distance (Cooper 2000; Braun et al. 2010). In accordance with the optimal escape theory, they found a negative correlation between approach distance and temperature that can be explained by the fact that small reptiles can run faster at higher temperatures and for this reason they can allow closer approximation of predators. If predators were not to attack, individuals would avoid the cost of escape. However, when temperatures are low, ectotherm animals of prey are slow and cannot allow predators to approach too close without accepting a decrease in flight success. In addition, lizards developed various alternative strategies to avoid predation such as crypsis, perching close to a shelter, or caudal autotomy (Cooper 2000; Galdino et al. 2006; Stankowich & Blumstein 2005).

Gonatodes albogularis (Dumeril & Bribon, 1836) is a small diurnal sphaerodactylid gecko that inhabits coastal habitats in South America to heights of 1,500 m a.s.l. (Rivero-Blanco 1979; Schargel 2008). This gecko is common on tree trunks, in crevices on the ground, on rocks and, less frequently, on leaf litter on the ground. It shows a remarkable sexual dimorphism, males having orange or yellow heads and dun-colored bodies, whereas females are more cryptic with a gray and brown color pattern (Ellingson 1994). Some studies reported territorial behavior in this species (Bohórquez et al. 2010). Natural predators of this gecko are larger lizards, snakes, mammals, and birds (Fitch 1973; Bello 2000).

The present study analyzed two essential components of the escape behavior of *G. albogularis* in relation to ambient air temperature. As was already demonstrated for other lizard species, hypothesis (# I) assumes that individuals allow a closer approach of potential predators at higher ambient air temperatures. This hypothesis predicts negative correlation between approach distance and temperature. Hypothesis (# II) assumes that the distance of individuals to shelters varies as a function of air temperature. This hypothesis predicts positive correlation between ambient air temperature and distance between *G. albogularis* individuals and shelters. In addition, sex-related differences in the escape behavior of this species were studied.

MATERIALS AND METHODS

Study area.— Fieldwork was carried out in one of the last relicts of tropical forest located in the south of the Córdoba Department, Colombia, South America (08°34'48.7" N, 75°42'28.4" W). This site is part of the Choco-Magdalena region, characterized as Dry Tropical Forest, with mean annual temperature of 28 °C and seasonal rains (Hernandez-Camacho et al. 1992).

Surveys.— Fieldwork was done in March and April, 2012, coinciding with the species' period of high activity (Serrano-Cardozo et al. 2007). In search of the geckos, two observers walked jointly along two parallel line transects (10 m apart, each 10 m wide, 2 km long, sampling effort 326 person hours), from 09:00 a. m. to 17:00 p. m. When an individual was found, the observers waited until the lizard showed by moving its head or tail or by other behavioral displays that it had detected at least one of the observers. After that, one observer (always the same) imitated a predator by walking slowly and at constant speed of about 1m/s in the direction of the detected individual until escape was triggered. In each case, the following spatial variables (linear distances in meters) were recorded following Bauwens & Thoen (1981) and Vanhooydonck et al. (2007): (a) approach distance (AD): distance between the lizard and the observer at the moment when escape started; (b) running distance (RD): distance between the first location of the lizard and its location at first stop after escaping; (c) end distance (ED): distance between the observer and the point at which the lizard stopped moving or the point at which the lizard went into hiding, and; (d) distance to the closest shelter (DCS): distance between the first location of the lizard and the closest shelter (crevices on the ground, rocks, trunks or leaf litter on the

Table 1: Arithmetic mean value, standard deviation (SD) and range of the analyzed variables MT – microhabitat air temperature; AD – approach distance; RD – running distance; ED – end distance and DCS – distance to the closest shelter. For definitions see Materials and Methods.

Tab 1: Mittelwert, Standardabweichung (SD) und Spannweite der untersuchten Variablen MT – Mikrohabitat-Lufttemperatur, AD – Entfernung zwischen Gecko und Beobachter zu Fluchtbeginn, RD – Entfernung zwischen der Stelle der ersten Beobachtung des Geckos und seinem ersten Halt nach der Flucht, ED – Entfernung zwischen Beobachter und der Stelle an der der Gecko seine Flucht beendete bzw. sich verkroch und DCS – Entfernung von der Stelle der ersten Beobachtung des Geckos zum nächstgelegenen Unterschlupf.

	MT (°C)	AD (m)	RD (m)	ED (m)	DCS (m)
Arithmetic mean / Mittelwert	30.57	2.26	0.36	3.96	0.64
SD	1.70	0.81	0.11	14.47	0.35
Range / Spannweite	27 - 34	0.30 - 4.5	0.12 - 0.63	0.10 - 1.40	0.10 - 2.2

ground). All measurements were done using a tape measure with 1 cm accuracy. As soon as the escape variables were measured, the individual was captured and the following data recorded (i) sex, on the basis of external features; (ii) age, classified as adult and juvenile on the basis of the minimum size at sexual maturity (30.1 mm for males and 31.7 mm for females; Serrano-Cardozo et al. 2007), and (iii) snout-vent length and tail length, using calipers with 0.1 mm accuracy. Individuals were released at their original sites to avoid pseudoreplication within transects. To exclude ontogenetic bias, only adult individuals were considered in this study.

The microhabitat air temperatures (MT) were taken at 1 cm above the surface structure where the gecko was perched, with an accuracy of 0.01 °C at the locations of the individuals' fist detection.

Statistical analysis.— For each variable, a two-sample randomization test was used to compare the data of males and females. The effect of microhabitat temperature on escape behavior was evaluated by simple randomization correlation tests between temperature (as the independent variable) and AD, RD, ED and DCS (as the dependent variables), for all individuals. In those cases in which differences between males and females were observed, separate correlation tests were run for each sex. All the analyses were performed using the null test statistics with 10,000 permutations of the software package Rundom Pro 3.14 (Jadwiszczak 2009).

RESULTS

Escape behavior data was recorded for a total of 137 adult gecko specimens, 58 females and 79 males. Table 1 presents the mean values for the variables assessed.

Comparison of male versus female mean values of behavioral variables showed significant differences in AD, RD and ED (randomization test: $p < 0.01$ in all cases; see mean values on Table 1) but not in DCS (randomization test: $p = 0.49$).

Analysis of the correlation between microhabitat temperature (MT) and behavioral variables (AD, RD, ED and DCS), using the combined data of both males and females, showed a negative relationship between MT and AD (randomization test: r = -0.89, $p < 0.01$; Fig. 1) and between MT and DCS (randomization test: r = -0.67, $p < 0.01$; Fig. 2), whereas the variables RD (randomization test: r = 0.16, $p = 0.06$) and ED (randomization test: r = 0.03, $p = 0.75$) did not show any relationship with temperature.

Different from the above combined test result, sex-specific correlation tests between MT and RD showed an effect of microhabitat temperature on the running distance (RD) for males (randomization test: r = 0. 33; p < 0.01), whereas for females, no such effect was observed (randomization test: r = 0.07, p = 0.60).

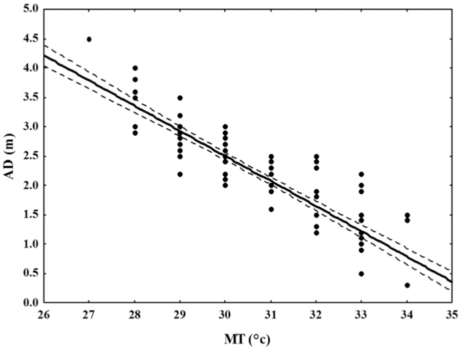

Fig. 1: Relation between AD (m) and MT (°C) for 137 specimens of *Gonatodes albogularis* (DUMÉRIL & BRIBON, 1836) studied. The distance between lizard and observer (potential predator) at the moment when escape started decreased with increasing microhabitat temperature.

Abb. 1: Zusammenhang zwischen AD (m) und MT (°C) für 137 untersuchte Individuen von *Gonatodes albogularis* (DUMÉRIL & BRIBON, 1836). Mit steigender Lufttemperatur nahm jene Entfernung zwischen Gecko und Beobachter (potentiellem Freßfeind) ab, bei der die Flucht einsetzte.

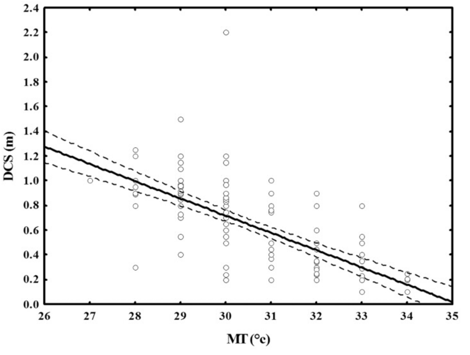

Fig. 2: Relation between MT (°C) and DCS (m) for 137 specimens of *Gonatodes albogularis* (DUMÉRIL & BRIBON, 1836) studied. The distance between the first location of the gecko and the closest shelter increased with decreasing air temperature of the microhabitat.

Abb. 2: Zusammenhang zwischen MT (°C) und DCS (m) für 137 untersuchte Individuen von *Gonatodes albogularis* (DUMÉRIL & BRIBON, 1836). Die Entfernung von der Stelle der ersten Beobachtung des Geckos zum nächstgelegenen Unterschlupf nahm mit sinkender Mikrohabitat-Temperatur zu.

DISCUSSION

The results support the optimal escape theory of YDENBERG & DILL (1986). The negative relationship observed between microhabitat temperature and approach distance suggests that, at higher temperatures, individuals allow their predators to get closer. This pattern is consistent with the fact that lizards are more active at higher temperatures, which is equivalent to an augmentation of agility, faster movements and, consequently, increased chance to escape. Delaying its escape, the lizard would minimize the costs of an unnecessary spurt, thereby increasing its fitness. However, these considerations are not universally valid for animals, considering that several species that have high energy costs of locomotion, allow a closer approach when cool, relying on crypsis (STANKOWICH & BLUMSTEIN 2005).

The present study revealed a negative relationship between ambient air temperature and distance to closest shelter. This pattern is not consistent with a strategy aiming on the reduction of predation risk, but can be interpreted as thermoregulatory or territorial behavior of these geckos. Not to overheat and to maintain the preferred body temperature under hot weather conditions, perching close to a shelter, including a regular retreat, could be a successful strategy and, in addition, would minimize predation risk. Another explanation could be related to the territorial behavior displayed by this species (BOHÓRQUEZ et al. 2010). By perching close to a shelter, irrespective of the ambient temperature, lizards could more efficiently protect their shelter from being used by competitors. The observed negative relationship between MT and DCS also means that the distance to the closest shelter increases with decreasing air temperature. Thus the gecko seems to accept the consequences of both the long distance to the shelter and reduced escape speed. This result is difficult to interpret and additional studies are required to better understand the consequences of this behavior in *G. albogularis*.

In small ectotherms, when body temperature is low, escape may not be the most effective anti-predator behavior and alternative strategies developed such as tail autotomy, discharge of chemical substances, and crypsis (Rocha 1993). Another alternative strategy is the selection of microhabitats that provide good and safe shelters. However, ectothermic organisms also must consider thermoregulatory requirements besides the benefits of shelters. For this reason, optimum microhabitats for lizards such as geckos would provide access to shelters, sites for thermoregulatory activities but also food and mates. Such optimal sites might compensate for the costs of an extended escape, not only in terms of expended energy, but also time allocated for other activities, e.g., reproduction, foraging and thermoregulation.

Hence, the patterns observed in *G. albogularis* could be indicative of the availability of an optimal microhabitat that provides adequate infrastructural requisites for thermoregulating, protecting a territory and avoiding predators.

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