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RESEARCH ARTICLE

Use of microhabitat and activity patterns of two lizard species from a seasonal dry forest in northern Colombia

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Abstract

In this work, the microhabitat use and activity patterns of two lizard species with sympatric distribution were evaluated in a dry forest fragment within the department of Sucre, northern Colombia. Data was collected in May, June, September and October of 2017, using the active search method limited by time (7:00 and 19:00 hours). Substrates used, spatial distribution and time of capture were recorded for individuals of the species *Loxopholis rugiceps* (Cope, 1869) and *Lepidoblepharis sanctaemartae* (Ruthven, 1916). Complementarily, environmental and physical parameters were recorded, which allowed us to characterise the microhabitats of the species. A total of 276 lizards were recorded, 177 belonging to the species *Loxopholis rugiceps* and 99 to *Lepidoblepharis sanctaemartae*. The results showed similar resource use by the two species for the spatial dimension, with both exploiting different terrestrial elements mainly from the interior forest, followed by the riverbed stream and forest edge. Differences were found in the daily activity patterns between species, with individuals of *L. sanctaemartae* more frequently recorded in the morning hours and *L. rugiceps* in the afternoon hours. The activity patterns did not differ by age groups: juveniles and adults. Both species were more frequently found in the litter substrate within the forest, followed by rocks and bare ground. Our results indicate that both species are tolerant to matrix conditions, however, they require internal forest conditions to exploit food resources and refuge.

Keywords
ecological niche, habitat loss, litter substrate, spatial distribution, Squamata

Introduction

Microhabitat is defined as a finer scale in the landscape relevant to an individual, which is usually associated with its foraging, perch or refuge sites; while activity is determined as the frequency of active individuals in a particular range of daily hours (Carretero and Llorente 1993; Pianka 1986). Information about the use of microhabitats and activity of a given species helps analyse its natural history and ecophysiological characteristics (Adolph 1990). For ectothermic vertebrates like reptiles, habitat use and activity may be correlated with their physiology capacities and its ecology (Huey 1991). Since abiotic factors such as temperature and humidity vary between microhabitats and throughout the day, they affect the performance and behaviour of these organisms (Grover 1996; Hatano et al. 2001).

Daily variations in activity and microhabitat use represent important thermoregulatory factors for lizards (Carretero and Llorente 1993). The time interval in which these organisms are active is related to the type of climate, intensity of sunlight, duration of photoperiod, temperature of the environment and the activity time of their prey (Hatano et al. 2001), while lizard microhabitats are directly influenced by microclimatic factors, as well as by food availability and refuge (Huey 1991). Both aspects of lizard's ecological niches (space and time) can be influenced by other factors such as intra and interspecific coexistence and seasonal variation in environmental conditions (Salzburg 1984; Paulissen 1988). Intraspecific categories such as sex and age are associated with effects on body size such as thermal inertia, which can cause juvenile lizards to lose heat more quickly than adults, also with reproductive states or ontogenetic changes in energy demand; aspects that can decide resource use (Belver and Avila 2010). On the other hand, interspecific resource partitioning has been reported in tropical populations mainly in relation to spatial niche dimensions (Vitt and Zani 1996), but temporal segregation can also occur between terrestrial lizards coexisting in variable environments (Pianka 1986).

Currently, the dry tropical forest is one of the most degraded and threatened ecosystems, with little knowledge available about it (García et al. 2014). In Colombia, there is approximately 8% of the original coverage and only 5% is protected by reserves (García et al. 2014). The gradual fragmentation that this ecosystem has been suffering is associated with the replacement of extensive natural areas by activities such as agriculture, mining and livestock (Rodríguez et al. 2012). Such activity affects reptile communities that inhabit these ecosystems, reducing population sizes, changing community dynamics and altering activity patterns; all of which are consequences of the change or complete disappearance of their habitat (Carvajal-Cogollo and Urbina-Cardona 2008; Jaramillo and Cortés 2017). In this sense, it has been shown that edge effects can modify habitat suitability for many lizards as a result of forest loss (Urbina-Cardona et al. 2006;

Carvajal-Cogollo and Urbina-Cardona 2015), however, some species with greater ecological tolerance may be favoured by the resulting microclimatic changes (Urbina-Cardona et al. 2006).

In the dry forest assemblages of Colombia, small, terrestrial and diurnal lizards constitute a dominant ecomorphological group, including species with a large number of individuals in their populations that dispute for microhabitats offered by the heterogeneous substrates of the forest floor and exploit similar food resources (Carvajal-Cogollo and Urbina-Cardona 2015; Medina-Rangel and Cárdenas-Árevalo 2015; Rojas-Murcia et al. 2016). *Lepidoblepharis sanctaemartae* (Ruthven, 1916) and *Loxopholis rugiceps* (= *Leposoma rugiceps*) (Cope, 1869) belong to said ecomorphological group and, according to Medina-Rangel and Cárdenas-Árevalo (2015), these small lizards explore a smaller number of microhabitats compared to larger species, presenting higher overlap in trophic niche and lower overlap in spacial niche (microhabitat). Ecologically similar species are known to diverge in at least one of the three niche dimensions: spatial, temporal and trophic (Pianka 1973). Furthermore, these dimensions are not independent, so complex relationships are expected between the three that allow the species to coexist and provide intraspecific subgroups within a population (Pianka 1986). In this regard, we believe that the spatial and temporal segregation mechanisms can be decisive for populations of these two small terrestrial lizards in the dry forest, both at an interspecific and intraspecific level (ontogeny).

Therefore, the goal of the present work was to evaluate the microhabitat use and activity patterns of *Lepidoblepharis sanctaemartae* and *Loxopholis rugiceps* in a dry forest in the municipality of Colosó, Sucre (Colombia) and determine if there is similar resource use in the spatial and temporal niche dimensions between species and within species.

Materials and methods

Sampling site

The present work was carried out along a preserved fragment of dry forest, in the vicinity of the Primates Meteorological Station, of the Corporación Autónoma Regional de Sucre-CARSUCRE located in the Serrania de Coraza-Montes de María, municipality of Colosó, Sucre, Colombia (9°29'53.70"N, 75°21'57.82"W at 209 masl). The study area is framed within the dry forest biome and has a characteristic mountain landscape, which is crossed by the main channel of El Sereno stream. The annual average temperature is 26.8 °C and relative humidity is 77%, with rainfall fluctuating between 1000 and 2000 mm and annual average rainfall of 1114 mm (Aguilera 2005; Galvis 2009). The rainfall regime is of the monomodal type, characterised by a period of low precipitation from mid-November to March and a rainy period that starts in the month of April and extends until November, between the months of June and July there is a period of low precipitation and high temperatures known as Veranillo de San Juan (Galvis 2009).

Field work

Five field trips were made in the months of May, June, September and October of 2017, each one with a duration of 4 days. In active search limited by time, data of individuals of the species *Loxopholis rugiceps* and *Lepidoblepharis sanctaemartae* were registered, through the technique of systematic surveys by visual encounters (Crump and Scott 2001). The samplings were conducted by four people between 7:00 to 19:00 h; precautions were taken not to oversample the sites during data collection, during the course of which we carry out manual captures of lizards at different points in the study area.

The sex and state of maturity of all captured individuals were determined from secondary morphological characters, such as the presence of reddish ventral coloration in adult males of *Loxopholis rugiceps* and throat with orange coloration in males of *Lepidoblepharis sanctaemartae*. The presence of eggs in gravid females was also recorded for each specie. Additionally, the following two morphometric measurements were taken with a Stanley digital caliper: total length (TL): measured as the straight line distance from the tip of snout to the tip of tail and the length of the tail (LT): measured from tip of tail to cloacal opening. When individuals presented broken tails they were not included in morphometric comparisons. For each individual also we recorded time of capture, temperature of the substrate at the exact location of capture with an infrared thermometer Ir5d Thermoworks, relative humidity and ambient temperature was measured 1 cm above ground with a BioTemp thermohygrometer (0.1 °C / 1% RH). The pluviometric data were obtained from the CARSUCRE Primatological station during the months in which we were surveying the lizards. We recorded the type of substrate (litter, bare ground, trunk, rock, grass), the distance of the individuals to the nearest tree and the nearest rock with a tape measure, in the same way, the forest place where the individuals were captured was characterised as: riverbed stream (Rs), interior of the forest (If) and outside-edge of the forest (Ef). Rs is characterised by presenting areas with incidence of solar radiation and rocks as the main substrate. If it is located at a distance greater than 20 m from the physical edge, and presents a continuous vegetation cover and substrate dominated by leaf litter as a characteristic element of deciduous forests, in the low strata there is little solar radiation. Ef is constituted by the external matrix and the forested layer of the edge, being located up to 20 m inside the forest starting from the physical edge. In Ef the substrate is usually heterogeneous and includes elements such as litter, rocks, bare ground and grassland, moreover it has open areas with grasslands, scattered trees and high incidence of light. The habitat types If and Ef were delimited following Urbina-Cardona et al. (2006). After data collection, the lizards were released in the same place where they were found.

Data analysis

X^2 homogeneity tests were conducted to reject or approve the null hypothesis of similar use of substrates (litter, rocks, bare ground, fallen trunks and grass) by the

species, the calculation of the expected values was based on the premise that all substrates and subdivisions of the habitat had the same probabilities of being occupied. In order to determine the hours of highest and lowest activity of the individuals, additional comparisons were made using Chi-square for data of the activity pattern of the two species in each hourly interval. To prove if there are differences related to the distance from capture point of individuals of both species to the physical elements that provide refuge and food sources such as rocks and trees, the distances from each record point to the nearest tree or rock were compared using the Mann Whitney test, using the same procedure, substrate temperatures of individuals of both species were compared. To evaluate the morphometric variation of the individuals of the evaluated species, a t-student test was applied for comparisons between sexes. We used PAST 2.17 to perform all statistical analyses (Hammer et al. 2001).

Results

After 230 man/hours of sampling effort, 276 records of lizards were taken, 177 belonging to the species *Loxopholis rugiceps* and 99 to *Lepidoblepharis sanctaemartae* (Fig. 1). Body dimensions were similar for males and females of the species *L. rugiceps*; whereas for *L. sanctaemartae* the total length was greater in females, being these differences significant ($t = 43.72$, $p < 0.001$), individuals of both sexes were not differentiated in relation to the length of the tail (Table 1).

Regarding the use of substrates *Loxopholis rugiceps* was found associated with leaf litter (87.01%) $\chi^2 = 368.11$, $df = 3$, $p < 0.001$, followed by rocks (11.30%), bare ground (1.13%) and fallen trunks (0.56%). Similarly for the species *Lepidoblepharis sanctaemartae*, leaf litter substrates was the most important (79.80%) $\chi^2 = 225.70$, $df = 4$, $p < 0.001$, followed by rocks (13.13%), bare ground (3.03%), fallen trunks (3.03%) and grass (1.01%). The average values of the environmental parameters recorded in the field during each lizard record were air temperature $\bar{x} = 29.36 \pm 1.92$ °C (min: 25.8 – max: 36.7), substrate temperature, leaf litter: $\bar{x} = 26.47 \pm 0.98$ °C (min: 23.8 – max: 29.2), rock: $\bar{x} = 26.69 \pm 1.11$ °C (min: 24.8 – max: 29) and relative humidity $\bar{x} = 52.68 \pm 10.02$% (min: 35 – max: 86).

The activity pattern observed for the two species shows significant differences in terms of the frequency of active individuals throughout the day ($\chi^2 = 32.82$, $df = 11$, $p < 0.001$), individuals of *Loxopholis rugiceps* were recorded more frequently in the afternoon hours, while *Lepidoblepharis sanctaemartae* showed higher records in the morning hours (Fig. 2); Juveniles and adults of the two species do not differ in their activity patterns. Juveniles and adults of the two species do not differ in their activity patterns, significance for *L. rugiceps* ($\chi^2 = 17.28$, $df = 10$, $p = 0.068$) and for *L. sanctaemartae* ($\chi^2 = 19.12$, $df = 11$, $p = 0.058$).

The evaluated species are not distributed differentially in the zones of the forest ($\chi^2 = 1.97$, $df = 2$, $p = 0.37$), both lizard species were found predominantly in the interior of the forest. Juveniles of *L. sanctaemartae* were recorded exclusively inside the forest, while adults were present in the three sampled zones (Table 2). For

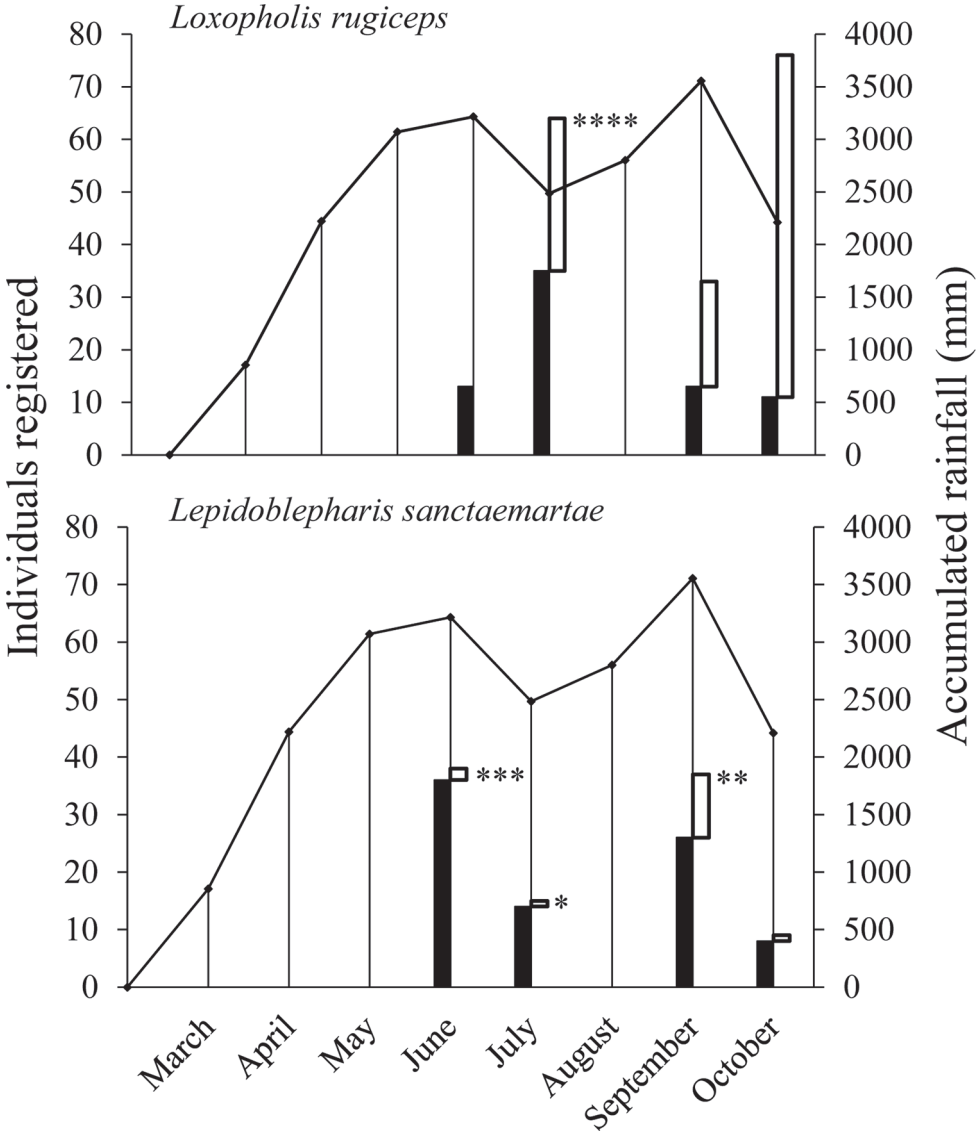

Figure 1. Monthly rainfall and number of individuals registered for *Loxopholis rugiceps* and *Lepidoblepharis sanctaemartae* recorded in Colosó, northern Colombia, in 2017. Filled bars: adult individuals and empty bars: juvenile individuals. Asterisks are used to indicate records of gravid females in the samplings within the following frequency ranges * = 1–2, ** = 3–5, *** = 6–10, **** = 11–15.

L. rugiceps these differences between maturity stages did not occur. Both species were recorded in areas of edge and outside of the forest, between low grasslands and leaf litter during the days when rains were frequent.

The location of the two species in relation to the nearest tree (Mann Whitney, U = 8735, p = 0.96) and the nearest rock (Mann Whitney, U = 8623, p = 0.82) was

Table 1. Mean (range) of the morphometric measurements taken in adult individuals of the species *Loxopholis rugiceps* and *Lepidoblepharis sanctaemartae*, recorded in Colosó, northern Colombia. The significance of the differences is indicated with an asterisk (t-student), based on a p-value of 0.01.

Measures (mm)	Species	
	Loxopholis rugiceps	
	Females (n = 43)	Males (n = 18)
TL	102.62 (52.77–141.37)	103.05 (75.39–130.27)
LT	64.29 (17.25–96.10)	66.43 (36.89–88.93)
	Lepidoblepharis sanctaemartae	
	Females (n = 36)	Males (n = 26)
TL	41.16 (34.80–49.25)	35.36 (21.31–45.00) *
LT	19.14 (11.98–31.15)	16.89 (9.10–31.46)

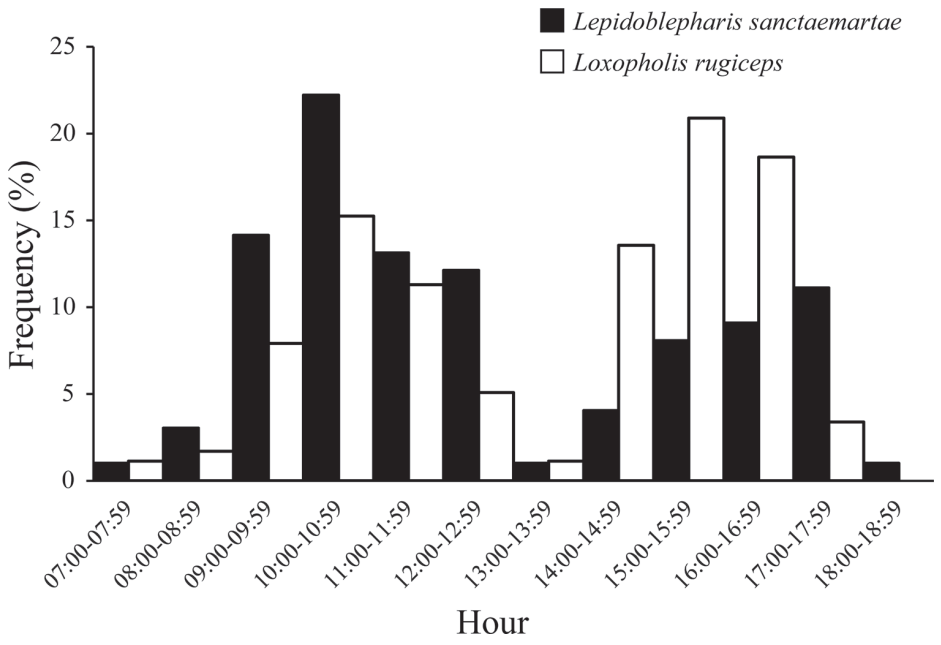

Figure 2. Activity pattern observed for *Loxopholis rugiceps* (N = 177) and *Lepidoblepharis sanctaemartae* (N = 99) in each hourly interval at a dry forest fragment located in Colosó, northern Colombia

similar. The average distance with respect to a tree and respect to a rock where the records of *L. rugiceps* were obtained were $\bar{x}$ = 3.04 ± 2.20 m (min: 0 – max: 10) and $\bar{x}$ = 1.51 ± 1.81 m (min: 0 – max: 8.1) respectively, and for *L. sanctaemartae* were $\bar{x}$ = 2.90 ± 1.68 m (min: 0.2 – max: 7.1) tree and $\bar{x}$ = 1.55 ± 2.13 m (min: 0 – max: 10) rock. Individuals of both species experienced similar average substrate temperatures (Mann Whitney, U = 7526, p = 0.06), the average substrate temperatures for *L. rugiceps* $\bar{x}$ = 26.42 ± 1.04 °C (min: 24.2 – max: 29.7) and for *L. sanctaemartae* $\bar{x}$ = 26.65 ± 1.03 °C (min: 24.8 – max: 30).

Table 2. Spatial distribution of the records of lizards in three subdivisions of the dry forest in Colosó, northern Colombia. Ef: Edge of the forest, If: Interior of the forest, Rs: Riverbed stream.

	Ef	Rs	If
L. rugiceps			
Juveniles	6	19	80
Adults	3	17	52
Total	9	36	132
Significance		$X^2 = 0.93$, df = 2, p = 0.62	
L. sanctaemartae			
Juveniles	0	0	14
Adults	3	15	67
Total	3	15	81
Significance		$X^2 = 3.62$, df = 2, p = 0.16	

Discussion

In this study, a pattern of bimodal activity was found for the populations of *L. sanctaemartae* and *L. rugiceps*, with results showing that the frequency of active individuals does decline in midday hours, as occurs for several species of the genus *Tropidurus* (Hatano et al. 2001). High temperatures during the midday hours are a factor that influences negatively the activity of tiny lizard species, because the body temperatures in this organism's ectotherms reflect the thermal environmental variations, so performance is rapidly affected given the lower thermal inertia of their bodies compared to larger lizards (Hatano et al. 2001; Huey et al. 2009). For lizards that predominantly inhabit forests, as the studied species, the buffer effect of canopy cover can regulate the thermal landscape available to them during the daytime, allowing them to perform optimally and preventing critical thermal limits (Huey et al. 2009). Even so, certain species are inactive for certain hours, which is characterised as a heat-avoidance behaviour and has been described for small leaf litter lizards from neotropical rainforests (Vitt and Zani 1996; Vitt et al. 2005).

The two lizard species in this study show differences in their activity peaks throughout the day, with the activity of *L. sanctaemartae* being more frequent in the morning hours and more frequent for *L. rugiceps* in the afternoon hours; such differences in activity time may favour less overlap in other dimensions of the ecological niche of the two species when resources are scarce (Pianka 1973, 1986). Juveniles of both species were observed active during the peak hours, and there were no intraspecific differences in time of activity in relation to adult individuals, as previously reported for *Liolaemus koslowskyi* (Belver and Avila 2010). In the study area, as well as in other localities within the dry forest of the Colombian Caribbean, the studied species coexist with other lizard species such as *Gonatodes albogularis* and *Gymnophthalmus speciosus*. Furthermore, they present little overlap of spatial and trophic niche dimensions, as reported by Medina-Rangel and Cárdenas-Árevalo (2015), which would favour activity without competition between these species in a particular ecological scenario with resource scarcity.

Herein, *L. sanctaemartae* and *L. rugiceps* were found to be homogeneously distributed within the available thermal and structural landscape. These results agree with prior studies that have shown that most dry forest lizards are not spatially associated to the same areas or microhabitats (Carvajal-Cogollo and Urbina-Cardona 2015; Rojas-Murcia et al. 2016; Jaramillo and Cortés 2017). The differential use of substrates by lizards is explained by the ecological differences that they provide for food, refuge or thermoregulation (Huey 1991). In the present study, both species showed preferences for leaf litter substrate, however, they exploited other surfaces less frequently. The presence of trees favours leaf litter availability and indirectly favours the occurrence of prey and refuge for the small lizard species like gekkonids and gymnophthalmids (Scott 1976; Vitt et al. 2005). Particularly, Isoptera and chelicerates represent common prey items for *L. sanctaemartae* and *L. rugiceps*, which explode among the leaf litter during active foraging at different times of the day (Medina-Rangel and Cárdenas-Árevalo 2015).

The existence of spatial overlap in microhabitat use suggests that resource partitioning for the two species does not occur in this niche dimension. In relation to this aspect, Medina-Rangel and Cárdenas-Árevalo (2015) reported that the two species evaluated in the present work show trophic niche overlap in the swampy complex of Zapatosa, and did not find high levels of overlap in the microhabitat they used. This differs from what was found herein, where the two species exploit the different microhabitats available in a similar manner. General trends indicate that the spatial niche dimension has been particularly important for the coexistence of ecomorphologically similar lizard species from assemblages in Neotropical regions (Vitt and Zani 1996; Santos et al. 2015). However, closely related species of small leaf litter lizards have shown similar microhabitat or substrate use, even when some species occur in a greater number of habitats than others (Vitt et al. 2005). The spatial distribution of the age groups of *L. sanctaemartae* (Table 2) suggests that juveniles and adults present different habitat use patterns, which could be associated with the ontogenetic characteristics of the species, given that they explore or are distributed in different zones during the different stages of their development or growth (Salvador 1988).

On the other hand, Rojas-Murcia et al. (2016) found that *L. sanctaemartae* is found exclusively in forest areas since there are suitable conditions for its establishment. Our records indicate that this species is distributed in areas such as the forest interior and forest exterior between low grass and litter when rains were frequent (Table 2). It is worth mentioning that this species is distributed in open areas such as savannas and even in urban areas, being associated with litter substrates (Atencia-Gándara Obs. pers.). In the present work, females of *L. sanctaemartae* have greater body sizes; however, in the evaluated population no size differences were found between sexes for *L. rugiceps*. For lizards, a larger size of females is commonly associated with volumetric demands for eggs and reproductive success, while a larger size of males is related to high pressure of sexual selection, very frequent antagonistic encounters with other males, as well as reproductive success (Carothers 1984).

Gravid females of *Loxopholis rugiceps* were registered in July, when low rainfall occurred; while in September and August a higher frequency of juveniles and no gravid females was recorded (Figure 1). This is consistent with the seasonal reproductive pattern reported by Telford (1971) from a population in Panama, where the breeding season extended from May to November, with a recruitment period from September to November. For *L. sanctaemartae*, more records were obtained during the months with higher rainfall (June and September), and gravid females of this species were not only recorded during one of the sampling months. In conclusion, individuals of *L. sanctaemartae* and *L. rugiceps* are homogeneously distributed within the habitat they use, both species are tolerant to matrix conditions; however, they require internal forest conditions to exploit food resources and refuge. Furthermore, differences in activity time may be important for the coexistence of the lizard populations studied. Nevertheless, it is necessary to understand the effect of seasonality on the population dynamics of these species in the dry forest.

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