

Feeding ecology of two sympatric geckos in an urban area of Northeastern Brazil

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Submitted on 2016, 31st May; revised on 2016, 11th November; accepted on 2016, 16th December
Editor: Sandra Hochsheid

Abstract. The diets of two sympatric gecko species, *Hemidactylus mabouia* and *Phyllopezus pollicaris*, were studied from an urban area of the Crato municipality, Northeastern Brazil. While the house gecko *H. mabouia* is an introduced species widely distributed in North, Central, and South America, the Brazilian gecko *P. pollicaris* is a native species distributed along the great diagonal of open formations of South America. The diets of both species were mainly composed by arthropods, Diptera was the most important item for both species, corroborating others studies with lizards in urban areas. Male and female adults of both *H. mabouia* and *P. pollicaris* use similar microhabitats which can explain the high sexual and interspecific trophic niche overlap. In these populations from an urban area of the Crato municipality, the alien *H. mabouia* seems to have not negatively affected the trophic niche of the native *P. pollicaris*.

Keywords. Trophic ecology, diet composition, Gekkota, *Hemidactylus mabouia*, invasive lizard, *Phyllopezus pollicaris*, body size.

INTRODUCTION

Gekkota is a species-rich clade of lizards with a great potential to invade new habitats, frequently introduced in anthropogenically disturbed areas and/or urban habitats (Hanley et al., 1998; Carranza and Arnold, 2006; Gamble et al., 2008). Its success in colonizing and establishing populations in new habitats is due in part to its great plasticity, which led to a wide distribution of geckos, especially *Hemidactylus*, in the old and new world (Rocha et al., 1994; Hanley et al., 1998; Vences et al., 2004; Gamble et al., 2008; Meshaka, 2011).

The tropical house gecko *Hemidactylus mabouia* is native to Africa and has successfully colonized South, Central, and North America (Rocha et al., 2011). In Brazil, *H. mabouia* is frequently found in human-altered areas, but also in pristine habitats in the Amazon, Atlantic Forest, Cerrado, and Caatinga (Vanzolini, 1978; Vanzolini et al., 1980; Araújo, 1991; Rocha et al., 2000; Rocha et al., 2002; Rocha et al., 2011; Albuquerque et al., 2013).

Several studies have demonstrated the role of *Hemidactylus* spp. in niche displacement of resident geckos by means of direct exploitative competition, indirect competition, aggression, and predation (Meshaka, 1995;

Meshaka and Moody, 1996; Meshaka, 2000; Meshaka et al., 2005; Hoskin, 2011; Hughes et al., 2015). Buildings in Brazil are colonized by many native gecko species, but the co-occurrence with *H. mabouia* caused exclusion by competition in some species, such as *Thecadactylus rapicauda* (Vitt and Zani, 1997). However, *Phyllopezus pollicaris*, a medium-sized gecko inhabiting boulder slabs in the dry formations of South America, is also frequently found in human habitations syntopic with *H. mabouia* (Vanzolini et al., 1980; Vitt, 1995; Sousa et al., 2010; Recoder et al., 2012).

Plasticity of feeding habits, associated with ecological and biological conditions, has been considered the main cause of *H. mabouia*'s invasion success (Zamprogno and Teixeira, 1998; Bonfiglio et al., 2006). Thus, diet studies can provide valuable information on the importance of prey types on the mechanism by which *Hemidactylus* geckos interact with other lizard species (Belver and Avila, 2001).

Herein, we present data on the diets of *H. mabouia* and *P. pollicaris* and test if the invasive species has affected the native lizard, considering the trophic niche, in order to answer the following questions: i) is there sexual dimorphism between *H. mabouia* and *P. pollicaris* and between species? ii) how do the diets of these two geckos differ regarding composition? iii) what are the average niche breadths and the niche overlaps between these species? iv) is niche overlap between the studied species caused by chance?

MATERIALS AND METHODS

Lizard specimens were collected from March to November 2011 in human habitations in the city of Crato (7°14'S and 39°24'W, datum WGS84), Ceará state, Northeastern Brazil. The regional climate is predominantly tropical, hot, and sub-humid (average annual temperatures vary from 24 to 26 °C). The rainy period occurs between January and May, with an average annual rainfall of 1,091 mm (IPECE, 2013).

The lizards were collected manually, humanely killed with lethal doses of 2% lidocaine, fixed in 10% formaldehyde, and preserved in 70% ethyl alcohol. The specimens were sacrificed for another study on parasitism which has been already published (Sousa et al., 2014). Snout-vent length (SVL), jaw width (JW), mouth length (ML), and head length (HL) of each lizard were measured using a digital caliper (± 0.01 mm; Table 1). Voucher specimens were deposited in the Coleção Herpetológica da Universidade Regional do Cariri - URCA.

To test for morphological variation due to the sex of each species, between adults of *H. mabouia* and *P. pollicaris* in body shape (using all morphometric variables), and between each individual variable, we performed a multivariate discriminant function analysis with residuals of morphological variables of each sampled lizard species. Residuals were obtained from a

simple linear regression following Sousa and Ávila (2015). Discriminant function analysis was executed using Statistica version 10.0 (Statsoft, 2011).

Lizards were dissected in the laboratory and their stomach contents were analyzed under a stereomicroscope. Prey items were identified and classified to the order level; length and width were measured with a digital caliper (precision 0.01mm). The percentage of lizards with empty stomachs was calculated and only lizards with identifiable items were used. The volume of each prey item was estimated by the ellipsoid formula:

$$V = \frac{4}{3}\pi\left(\frac{L}{2}\right)\left(\frac{W}{2}\right)^2,$$

where L = length and W = width. The Importance Value Index (I) was estimated by the following formula (Powell et al., 1990):

$$I = \frac{F\% + N\% + V\%}{3},$$

where F% is the relative frequency, N% is the numerical percentage, and V% is the volumetric percentage of each prey item.

Trophic niche breadth (both numerical and volumetrically) was calculated by the inverse of the Simpson's diversity index (Simpson, 1949):

$$B = 1 / \sum_{i=1}^n P_i^2,$$

where p is the numeric or volumetric proportion of prey category i and n is the number of categories (Pianka, 1973). The value of niche breadth varies from 1 to n, where the lowest values represent a more specialized diet and the highest values indicate a generalist diet. Differences in number and volume of prey items between males and females were tested by non-parametric Mann-Whitney U test using Statistica version 10.0 (Statsoft-Inc, 2011).

Trophic niche overlap between sexes and species was calculated using the Pianka's overlap index (Pianka, 1973):

$$\phi_{ik} = \frac{\sum_{j=1}^n P_{ij}P_{jk}}{\sqrt{\sum_{j=1}^n (P_{ij}^2)(P_{jk}^2)}},$$

where P_{ij} and P_{jk} are the rate consumption of prey category i, with j and k representing the compared species and sexes. Pianka's overlap index varies from zero (no overlap) to one (complete overlap). Finally, we compared the observed niche overlap values for *H. mabouia* and *P. pollicaris* against a null model (1,000 interactions) generated by the randomization algorithm 3 (RA3) (Lawlor, 1980). The use of RA3 seems adequate because it retains the niche breadth of each species, but randomizes which particular resource states are used, allowing the species to potentially use other resource states (Winemiller and Pianka, 1990). Niche overlaps and null models were calculated using EcosimR - R code for null model analysis (Gotelli and Ellison, 2013). Differences between proportions of each prey category among the two gecko species were tested by a non-parametric

Table 1. Morphometric data (mean \pm standard deviation) and results of discriminant function analysis. *Hm*= *Hemidactylus mabouia*; *Pp*= *Phyllopezus pollicaris*. M= Males; F= Females; Body Shape= pooled variables; SVL= Snout-Vent Length; JW= Jaw width; ML= Mouth length; HL= Head length; λ = Wilks' Lambda.

	Hm		Pp		Hm	Pp
	M	F	M	F	Adults	Adults
SVL	53.4 \pm 12.9	53.6 \pm 6.8	65.9 \pm 11.8	65.8 \pm 11.5	55.1 \pm 8.3	65.8 \pm 11.6
JW	9.6 \pm 2.2	9.6 \pm 1.0	11.7 \pm 2.1	11.8 \pm 2.0	9.6 \pm 1.3	11.7 \pm 2.0
ML	10.2 \pm 2.2	10.5 \pm 1.2	12.0 \pm 2.3	12.0 \pm 2.0	10.4 \pm 1.4	12.0 \pm 2.1
HL	14.2 \pm 2.5	14.6 \pm 1.4	16.7 \pm 3.0	16.8 \pm 2.6	14.5 \pm 1.7	16.7 \pm 2.7
	λ (M vs F)	P	λ (M vs F)	P	λ (<i>Hm</i> vs <i>Pp</i>)	P
Body shape	0.951	0.884	0.983	0.860	0.753	<0.0000*
SVL	0.997	0.802	0.983	0.989	0.908	0.000*
JW	0.965	0.385	0.994	0.361	0.835	0.001*
ML	1.000	0.970	0.989	0.498	0.773	0.100
HL	0.996	0.775	0.986	0.636	0.756	0.563

multivariate analysis of similarity (ANOSIM), using the Bray-Curtis similarity coefficient and 9,999 permutations in the software PAST 3.0 (Hammer et al., 2001). A similarity percentage analysis (SIMPER) was performed to determine which preys were responsible for dissimilarity in diets between the two gecko species. Data matrix for ANOSIM and SIMPER were standardized (as a percentage) to minimize the discrepancy between samples.

RESULTS

We collected 58 *H. mabouia*, 10 adult males (mean \pm standard deviation) (SVL = 56.35 \pm 9.76 mm), 21 adult females (SVL = 53.69 \pm 6.21 mm), and 27 juveniles (SVL = 30.92 \pm 5.36 mm). Of the species *P. pollicaris*, we collected 100 specimen, 38 adult males (SVL = 65.48 \pm 9.06 mm), 54 adult females (SVL = 64.58 \pm 12.62 mm), and 8 juveniles (SVL = 34.54 \pm 4.32 mm). Of these, 18 (31.03%) *H. mabouia* (2 males, 7 females, and 9 juveniles) and 45 (45%) *P. pollicaris* had empty stomachs (12 males, 27 females, and 6 juveniles).

There were no significant sexual differences in morphometric variables of both species (Table 1). On the other hand, adults of *P. pollicaris* were significantly larger than *H. mabouia* in body shape, with SVL and JW of *P. pollicaris* greater than those of *H. mabouia* (Table 1).

The diet of both species consisted of 10 arthropod prey items: Diptera, Hymenoptera, and Coleoptera were the most important items for *H. mabouia* and Diptera, Coleoptera, and Hemiptera for *P. pollicaris* (Table 2). *Hemidactylus mabouia* had numerical and volumetrically niche breadth values of 1.904 and 1.979, respectively,

which was smaller than the niche breadth of *P. pollicaris*: 4.05 and 3.036 (Table 2).

The average number of prey items per stomach (only those individuals whose stomachs were not empty) was similar for both species: 3.86 \pm 8.22 for *H. mabouia* and 3.47 \pm 4.52 for *P. pollicaris*, with no significant difference (U = 1,017.5; P = 0.387). However, the average number of prey categories per stomach was 1.54 \pm 0.61 and 1.24 \pm 0.51 for *H. mabouia* and *P. pollicaris*, respectively, and there was a significant difference (U = 769.5; P = 0.014).

Males and females of *P. pollicaris* ingested more prey items (4.26 \pm 6.02 and 3.18 \pm 3.07, respectively) than those of *H. mabouia* (2.2 \pm 2.69 and 1.68 \pm 1.21), but there were no statistical differences in prey items ingested by females of *P. pollicaris* and *H. mabouia* (U = 230.5; P = 0.836) neither between males of both species (U = 32; P = 0.081). Also, there were no significant differences in number (U = 117; P = 0.385) or volume (U = 111; P = 0.3) of the prey items between *H. mabouia* males and females, between *P. pollicaris* males and females (Number: U = 624.50; P = 0.323; Volume U = 605; P = 0.25), or in the number between adult individuals of both species (U = 995; P = 0.21). On the other hand, there was a significant difference in volume between adults of *P. pollicaris* (211.858 \pm 435.062) and *H. mabouia* and (36.749 \pm 141.807) (U = 697; P < 0.001).

Niche overlap between the sexes was 0.9159 in *H. mabouia* and 0.9526 in *P. pollicaris*; and between the two gecko species, niche overlap was 0.9094. The high niche overlap between adult individuals of both studied species could be due to chance (average overlap simulated = 0.2740; P = 0.99). There was no significant difference

Table 2. Diet composition and numerical and volumetric niche breadth of *Hemidactylus mabouia* and *Phyllopezus pollicaris* from an urban area of Crato city, Ceará state, Brazil. n= total of analyzed individuals. F = frequency of occurrence, N = number of preys, V= volume (mm³) and I = relative importance index.

Category	<i>H. mabouia</i> (n = 58)							<i>P. pollicaris</i> (n = 100)						
	F	F %	N	N%	V	V %	I	F	F %	N	N%	V	V %	I
Araneae	4	7.02	4	2.80	28.83	2.12	3.98	8	10.96	8	3.98	364.37	1.55	5.50
Blatodae	-	-	-	-	-	-	-	1	1.37	1	0.50	51.92	0.22	0.70
Coleoptera	8	14.04	13	9.09	160.26	11.78	11.64	13	17.81	51	25.37	2605.41	11.10	18.09
Diptera	24	42.11	102	71.33	936.65	68.86	60.76	26	35.62	79	39.30	11319.23	48.15	41.05
<i>H. mabouia</i> shed skin	1	1.75	3	2.10	10.45	0.77	1.54	-	-	-	-	-	-	-
Vertebrate eggshell	1	1.75	1	0.70	8.83	0.65	1.03	1	1.37	3	1.49	131.19	0.56	1.14
Hemiptera	-	-	-	-	-	-	-	8	10.96	27	13.43	6544.06	27.89	17.43
Hymenoptera	10	17.54	10	6.99	173.73	12.77	12.44	6	8.22	15	7.46	1804.91	7.69	7.79
Isoptera	1	1.75	1	0.70	3.00	0.22	0.89	-	-	-	-	-	-	-
Insect larvae	5	8.77	6	4.20	18.57	1.37	4.78	4	5.48	5	2.49	265.74	1.13	3.03
Lepidoptera	1	1.75	1	0.70	12.42	0.91	1.12	2	2.74	8	3.98	293.33	1.25	2.66
Ortoptera	2	3.51	2	1.40	7.49	0.55	1.82	4	5.48	4	1.99	83.53	0.36	2.61
Total	57	100	143	100	1360.24	100	100	73	100	201	100	23463.69	100	100
Niche breadth			1.90		1.98					4.05		3.04		
Empty stomachs	18							45						

between the proportions in prey use (ANOSIM, $R = 0.7037$; $P = 0.2035$). The results of the SIMPER analysis also showed a small dissimilarity between diet composition (32.69%), with Diptera, Hemiptera, and Coleoptera as prey groups that contribute most to dissimilarities between the two geckos, explaining 32.2, 26.7 and 11.1% of the variation.

DISCUSSION

The diets of the sympatric *H. mabouia* and *P. pollicaris* in urban habitats of Northeastern Brazil were very similar, with both species consuming 10 prey categories. Diptera, Coleoptera, Hemiptera, and Hymenoptera were the most frequently ingested preys; Diptera were the most important prey for both species. However, Hymenoptera and Coleoptera were the second most important prey for *H. mabouia* and *P. pollicaris*, respectively. These insects are commonly found in urban habitats, mainly close to streetlights (Robinson, 2005).

Food composition of urban populations of lizards may differ from that of pristine habitats (Hódar and Pleguezuelos, 1999). Moreover, the opportunistic behavior of these two gecko species, plus changes in diversity and abundance of prey, may contribute to differences between study sites (Zamprogno and Teixeira, 1998). Vitt (1995), studying the diet of *H. mabouia* and *P. pollicaris* at Caatinga habitats from Exu, found that insect larvae were

the most important prey for both species. In the coastal plain of the Espírito Santo state, Zamprogno and Teixeira (1998) found Araneae, Homoptera, and Isopoda as the most important prey for *H. mabouia*, while Apterygota, Araneae, and Orthoptera were the main items for *P. pollicaris* at Cerrado habitats in the state of Tocantins (Recoder et al., 2012). Albuquerque et al. (2013) found cannibalistic habits for *H. mabouia*, where *H. mabouia* was the most important item, followed by Formicidae and Hemiptera; for *P. pollicaris*, the most important items were Coleoptera, Araneae, and Homoptera in perianthropic environments in the state Mato Grosso do Sul. Our results corroborate the study of Bonfiglio et al. (2006), in an urban area in Rio Grande do Sul, who found that Diptera were the most important item in the diets of the two species studied here. That convergence in diet composition may be due to the fact that Diptera is often present at urban environments, mainly close to streetlights as mentioned above. In this case, perhaps geckos could act as a control of Diptera in cities.

Energetic balance in a given population of lizards can be estimated by the proportion of empty stomachs, where nocturnal lizards have a higher proportion of empty stomachs (24.1%) than diurnal lizards (10.5%); the mean percentage of empty stomachs for nocturnal geckos is 21.2% (Huey and Pianka 1981). In the present study, *H. mabouia* (31.01%) and *P. pollicaris* (42.6%) showed higher proportions of empty stomachs than stated by Huey and Pianka (1981). This may be explained by the time

when the lizards were captured, i.e., in the first hours of the night.

The lack of sexual differences in the diets of the species we studied is probably a result of similar use of space and time, which led to the use of the same prey types for both sexes and higher dietary overlap (see Rocha and Anjos, 2007). Dietary overlap was higher even when we paired both species (0.91), and the null model showed that high niche overlap between them is due to chance, indicating that the two species may eventually compete for prey. However, *P. pollicaris* presented higher prey volume and niche breadth than *H. mabouia* (probably due to its larger body) and despite the expected, *H. mabouia* was apparently not significantly affected by the trophic niche of *P. pollicaris*. Dissimilarity between the diets of these two geckos was about 30% in the present study, but this pattern can vary according to prey availability and/or greater time of colonization by *H. mabouia*. These factors can make this invasive species compete more intensely, damaging the spatial and/or trophic niche of native species (see Rodder et al., 2008; Rocha et al., 2011). Additionally, further studies are necessary to understand the role of competition for food and/or space in the coexistence of native and invader lizard species in disturbed and natural areas in Brazil.

ACKNOWLEDGMENTS

We thank the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – CAPES for providing a fellowship to JGGS, AAMT, and JAAF, the Conselho Nacional de Desenvolvimento Científico (CNPq) for a research grant to RWA (process # 303622/2015-6) and a fellowship to DAT. We also thank Sandra Hochscheid and two anonymous reviewers for their valuable suggestions. The specimens were collected under the license of the Instituto Chico Mendes de Conservação da Biodiversidade-ICMBio 29613-1.

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