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Diet of *Enyalius catenatus* (Wied, 1821) (Reptilia: Leiosauridae) from Serra Bonita Reserve, Bahia, Brazil

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Abstract. Lizards of the genus *Enyalius* are restricted to forested areas distributed throughout eastern South America, but little is known about their ecology. The aim of this study was to analyse the diet of *Enyalius catenatus* (Wied, 1821) in the Serra Bonita Reserve. Specimens were found through active search and using pitfall traps. Individuals were measured and underwent a stomach flushing procedure to retrieve stomach contents. Prey was identified to the lowest possible taxonomical level. The most numerous items retrieved from the stomachs were: Isoptera, Hymenoptera (Formicidae) and Lepidoptera larvae. Items that showed higher relative frequencies of occurrence were, respectively, Lepidoptera larvae, Isopoda and Araneae. Volumetrically, Lepidoptera larvae, Orthoptera and Isoptera reached the highest values. The Index of Relative Importance (IRI) revealed Lepidoptera larvae as the most important food item. The diet composition revealed that lizards did not actively search for aggregated food sources and that their feeding strategy could be better described as being that of a "sit-and-wait" predator.

Keywords: Foraging, lizard, Isoptera, Leiosauridae

Introduction

The Atlantic Forest is a biome with very high reptile diversity and endemism, but despite being the best studied biome in Brazil basic information about many reptiles inhabiting it is still scarce (Marques and Sazima, 2004). This is probably related to the difficulty of observing them, as several reptiles remain motionless most of the time and show low population densities (Passos et al., 2015). In Brazil, the Leiosauridae family consists out of 15 species, 10 of these belonging to the genus *Enyalius* (Costa and Bérnils, 2015). Lizards of the genus *Enyalius* (Wied, 1821) are restricted to forested areas and are distributed throughout eastern South America, mainly in the Atlantic Forest (where most species of this genus are endemic), but also with one species in the Amazon (Etheridge, 1969; Jackson, 1978; Ávila-Pires, 1995; Rodrigues et al., 2006). While the ecology of ground dwelling lizards as e g. the members of the genera *Ameiva*, *Ameivula* and *Tropidurus* has been intensively studied (Fialho et al., 2000; Van Sluys et al., 2004a; Rocha and Siqueira, 2008; Siqueira et al., 2010; Siqueira et al., 2013; Passos et al., 2015; Santos et al. 2015), little is known about the ecology of lizards living on shrubs and trees as e.g. members of the genus *Enyalius* (Van Sluys et al., 2004b).

Studied species of the genus *Enyalius* feed mainly on terrestrial arthropods (Sousa and Cruz, 2008). For *Enyalius catenatus,* Vanzolini (1972) reported a diet composed of Blattaria, larval Coleoptera, Gryllidae, Diplopoda, Chilopoda, Opiliones and Oligochaeta for 42 individuals of a population from Santa Teresa, Espírito Santo state, and Boraceia, Caraguatatuba and São Sebastião Island in São Paulo state. However, the Index of Relative Importance (a metric proposed by Pinkas et al. (1971) only one year before Vanzolini´s work was published) and frequency of each prey was not reported by this author and thus it was not possible to assess how much each prey category contributed to the diet.

Enyalius catenatus (Figure 1) is distributed in the northeastern portion of the Atlantic Forest, north of the Jequitinhonha River to the state of Rio Grande do Norte

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Figure 1. *Enyalius catenatus*, photographed in Serra Bonita.

(Porto et al., 2013). While it is mostly found in humid forests it can also occur in dryer forest enclaves as e.g. in the Chapada Diamantina (Freitas, 2011). It shows arboreal habits and is often found at a height of 3-5 meters but can also be found on the ground (Vanzolini, 1972).

In this study we aimed to assess the diet of an *Enyalius catenatus* population from a forest environment and thus gain insights into the diet of this arboreal lizard.

Material and Methods

Study Area.—The study was conducted at Serra Bonita Reserve, located in the municipalities of Camacan and Pau-Brasil, in the state of Bahia, Brazil (15°23'S; 39°33'W). The reserve has altitudinal gradients varying between 200 and 950 meters above sea level. Its vegetation consists of Dense Forests Rainforests with elements of Semideciduous Seasonal Forests in the lower areas and Moist Submontane Forests in the higher areas of the mountain. The reserve has about 50% of primary forests, while the remaining areas are composed of mosaics that include secondary forests, pastures and so called cabrucas, cocoa plantations that keep some of the original old grown trees for shading (Instituto Uiraçu, 2014).

The average monthly rainfall was 160.9 mm (23.2 – 270.8 mm) and the mean minimum air temperature was 17.2 ºC (13.5 – 20.1 ºC) and maximum 25.8 ºC (21.9 – 29.4 ºC) (Dias et al., 2014). The climate is characterized as hot and humid, without a dry season, corresponding to the Af type (tropical rainforest climate) of Köppen (1936).

Data Collection.—Data was gathered between the months of December 2009 to November 2010, during monthly fieldtrips of five days each. The specimens were found through active search and by using 100-litre pitfall traps (12 traps) (Cechin and Martins, 2000) arranged in 24 transects of 100 m each installed in the forest and in 9 transects of 50 m located near streams.

After capture, individuals were transferred to the laboratory located in the reserve headquarters, where their snout-vent length (SVL) and the mouth gape was measured using a 0.1 mm precision calliper. After the measurements, to avoid death of a representative number of specimens, we used a stomach-flushing method to obtain food items (Solé et al., 2005). A 60 ml syringe was coupled to a water pipe and then introduced through the oesophagus into the stomach of the animal. The whole content of the syringe was injected and the contents expelled by the animal collected in a container and fixed in 70% ethanol. This procedure was repeated until reaching the point when no more content was forced out. Then, a final flush was performed. After finishing the procedure the animals were kept in quarantine and released on the last day of the monthly fieldwork activity into their habitat avoiding major disruption to the specimen (Solé et al., 2005). Stomach contents were analysed and identified to the taxonomic level of Order with the aid of a stereomicroscope.

Data Analysis.—In order to calculate the volume of each prey, we measured the length and width of undigested items. Partially digested prey had their original sizes estimated from fragments using the regression formulas proposed by Hirai and Matsui (2001). The volume was measured with the following formula for ellipsoid bodies proposed by Dunham (1983):

$$V = 4/3\pi \, (L/2) \, (W/2)2$$

Where V = volume, L = length and W = width of prey.

The Index of Relative Importance (IRI) was calculated to reduce bias that may exist in the description of animal diets, using the formula below proposed by Pinkas et al. (1971):

$$IRI_t = (PO_t)(PI_t + PV_t)$$

Where PO_t is the percentage of occurrence (100 x number of stomachs containing item $_t$ / total number of stomachs), PI_t is the percentage of items (100 x total number $_t$ of individuals in all stomachs / total number of individuals of all categories in all stomachs) and PV_t is the percentage of the volume (total volume x 100 $_t$ in

Table 1. Analysed stomach contents of *Enyalius catenatus*. N is the number of items in all stomachs, N% is the relative number of each item in all the stomachs, F is the number of stomachs in which the item was found, F% is the relative number of occurrences of each item in all stomachs, V is the total volume of each item in all stomachs, V% is the relative number per item and IRI is the Index of Relative Importance of Pinkas. The three categories with the highest IRI values are highlighted in bold. The acronyms Im and Lv refer to imago and larva respectively.

Taxon	N	N%	V	V%	F	F%	IRI
Insecta							
Hemiptera	4	0.7	183.6	0.2	4	12.5	11.4
Hymenoptera Vespidae	1	0.2	21.7	>0.1	1	3.1	0.6
Hymenoptera Formicidae	28	4.8	3345.7	4.2	3	9.4	84
Hymenoptera other	2	0.3	197.2	0.3	2	6.2	3.7
Diptera	2	0.3	67.6	0.1	2	6.2	2.7
Orthoptera	**13**	**2.2**	**14863**	**18.5**	**10**	**31.3**	**646.9**
Coleoptera	12	2.1	6023	7.5	9	28.1	268.3
Lepidoptera (Im)	1	0.2	119.6	0.2	1	3.1	1
Lepidoptera (Lv)	**21**	**3.6**	**37893.7**	**47.1**	**14**	**43.8**	**2217.9**
Blattaria	1	0.2	18.9	>0.1	1	3.1	0.6
Dermaptera	1	0.2	421	0.5	1	3.1	2.2
Isoptera	**445**	**76.2**	**7831.7**	**9.7**	**3**	**9.4**	**805.6**
Myriapoda							
Diplopoda	4	0.7	2477.1	3.1	3	9.4	35.3
Chilopoda	1	0.2	100.3	0.1	1	3.1	0.9
Crustacea							
Isopoda	16	2.7	520	0.7	12	37.5	127
Arachnida							
Araneae	12	2.1	3651.5	4.5	11	34.4	226.7
Acarina	20	3.4	5.1	>0.1	1	3.1	10.7
Mollusca							
Gastropoda	5	0.9	2713	3.4	2	6.3	26.4
Total	584		80454.6				

all individuals stomachs / total volume of all categories in all stomachs).

In order to check for correlations between weight, SVL and mouth gape with volume of ingested prey and also between maximum length and width of prey items we used the Pearson Correlation Coefficient.

All analyses were performed using the software R 3.0.2 (R Core Team, 2015).

Results

We captured 36 individuals, of which 32 revealed stomach contents after applying the flushing procedure. One individual had ingested skin, probably its own. Among all captured individuals, only two revealed plant remains. The average value of SVL was 87.7 mm (± 17.0 mm, min.: 58.0 mm, max.: 123.1 mm). The gape of the mouth had an average value of 16.3 mm (± 3.8 mm, min.: 11.0 mm, max.: 23.4 mm).

The most numerous items retrieved from the stomachs were: Isoptera (N=445, N%=76.2), Hymenoptera (Formicidae) (N=28, N%=4.8) and Lepidoptera larvae (N=21, N%=3.7). Items that showed higher relative frequencies of occurrence were respectively, Lepidoptera larvae (F=14 e F%= 43.8), Isopoda (F=12 e F= 37.5) and Araneae (F=11 e F%= 34.4). Regarding volume, the Lepidoptera larvae (V= 37893.7 mm³, V%= 47.10), Orthoptera (V= 14862.98 mm³, V%= 18.47) and Isoptera (V= 7831.70 mm³, V%= 9.7) reached the highest values.

The Index of Relative Importance (IRI) showed Lepidoptera larvae (2217.9) as the most important food item, followed by Isoptera (805.6) and Orthoptera (646.9) (Table 1).

Our simple linear regression between the SVL with length, width and volume of prey, also between the width of the mouth with length, width and volume of prey (Figure 2) showed low relationship.

Discussion

Vanzolini (1972) described the diet of *Enyalius catenatus* as being composed of Blattaria, Coleoptera larvae, Gryllidae, Diplopoda, Chilopoda, Opiliones and

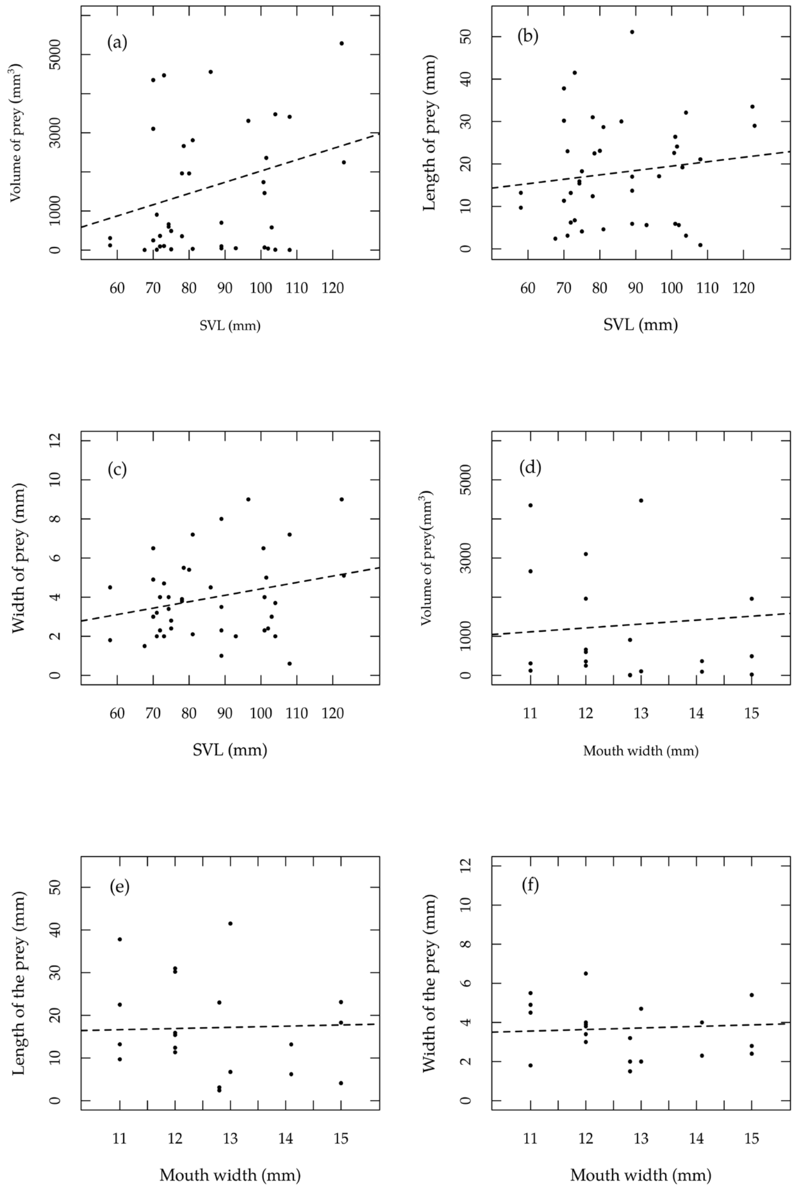

Figure 2. Simple linear regression analysis (SLR) showed low relationship between the characters studied in the species *E. catenatus*. **A**) SLR between the SVL (mm) and the volume of prey (mm³) ($R^2 = 0.0528$ ρ= 0.2163902). **B**) SLR between the SVL (mm) and length of prey (mm) ($R^2 = 0.0275$ ρ= 0.139668). **C**) SLR between SVL (mm) and width of prey (mm) ($R^2 = 0.0784$ ρ= 0.2539027). **D**) SLR between the mouth width (mm) and total prey volume (mm³) per individual ($R^2 = 0.0349$ ρ= 0.1673879). **E**) SLR between the mouth width (mm) and the length of the largest prey (mm) ($R^2 = 0.0151$ ρ= 0.0832442). **F**) SLR between the mouth width (mm) and the width of the widest prey (mm) ($R^2 = 0.0329$ ρ= 0.1366324).

Oligochaeta, without presenting data on frequencies, volumes, numerical values or the indexes of relative importance for each one of those food items. The presence of terrestrial Diplopoda in *E. catenatus* diet, in this study, corroborates the observations of Vanzolini (1972) on feeding on terrestrial species. In our study the most numerous preys were Isoptera, Formicidae and Lepidoptera larvae. These are also among the most consumed items by other species of the genus (Rautenberg and Laps, 2010; Borges et al., 2013). Our results differ partially from those found for *E. bilineatus* and *E. brasiliensis*, where the most important items were Hymenoptera, Isoptera, Isopoda and Orthoptera (Zamprogno et al., 2001; Van Sluys et al., 2004b; Teixeira et al., 2005).

The diet of *E. catenatus* resembles the diet of *E. iheringii* from an Atlantic Forest remnant in the Itajaí Valley, Santa Catarina (Rautenberg and Laps, 2010), and *E. perditus* from Atlantic Forest remnants in the Parque Estadual do Ibitipoca and Parque Estadual Nova Baden, Minas Gerais (Sousa and Cruz, 2008; Sturaro and Da Silva, 2010). For *E. catenatus* the most important items were Lepidoptera larvae, Isoptera and Orthoptera, but Araneae and Formicidae were also part of their diet. For *E. iheringii*, Coleoptera, Lepidoptera larvae and Araneae were the most important diet items. The analysis of *E. perditus* diet highlights the importance of Lepidoptera larvae, Formicidae, Araneae and Isopoda (Sousa and Cruz, 2008; Sturaro and Da Silva, 2010; Rautenberg and Laps, 2010).

Although Isoptera reached a high IRI, their frequency was low. Few individuals of *E. catenatus* preyed on many termites in a single moment. The same pattern was also observed for Hymenoptera Formicidae, another category living in aggregations.

Our simple linear regressions between the SVL with length, width and volume of prey, also between the width of the mouth with length, width and volume of prey (Figure 2) showed low relationship, meaning that larger lizards may be shifting their diets to include larger prey or excluding smaller prey. In a comparative study using data of 159 lizard species Costa et al. (2008) found that mean, minimum, maximum and prey size range were also positively linked to body size.

Reports of skin consumption by lizards are common, being mostly their own skin that is ingested after shedding (Vanzolini, 1972; Van Sluys et al., 2004b; Teixeira et al., 2005; Rautenberg and Laps, 2010). The ingestion of plant material has also been reported for other *Enyalius* species, probably representing an accidental consumption during the foraging activity and capture of preys (Zamprogno et al., 2001; Van Sluys et al., 2004b; Rautenberg and Laps, 2010).

We have not retrieved harvestmen from the lizard stomachs in this study, although the frequent presence of these arachnids has been observed in the field in the Serra Bonita reserve. Harvestmen release secretions (e. g. benzoquinone) which act as very effective chemical defences against invertebrate and vertebrate predators (Machado et al., 2005). We hypothesize that the Opiliones record by Vanzolini (1972) may have been a result of some accidental ingestion.

According to the invertebrates retrieved from the stomachs the lizards we studied did not actively search for aggregate food sources, but they were able to ingest large numbers of Isoptera and Hymenoptera Formicidae at once. Therefore, *Enyalius catenatus* can be considered a sit-and-wait predator based on its generalistic diet and by presenting cryptic coloration, characteristic of species that exhibit this foraging behaviour (Rautenberg and Laps, 2010).

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