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Diet of the Neotropical frog *Leptodactylus mystaceus* (Anura: Leptodactylidae)

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Abstract. *Leptodactylus mystaceus* is distributed throughout Brazil and no information is available about its diet. Here, we analyzed the diet of *L. mystaceus* from Novo Progresso, Pará, Brazil. We extracted the stomachs of 25 specimens. For each prey category, we calculated the frequency (Fi%), volume (Vi%) and Feeding Index (IAi). Among the specimens analyzed, seven (28%) had empty stomachs and the other ingested eight prey categories (Araneae, Blattodea, Coleoptera, Dermaptera, Diptera adults, Diptera larva, Formicidae, and Lepidoptera), and large amounts of plant material. This suggests that *L. mystaceus* is a generalist species and Dermaptera was the most representative component of its diet.

Key words. Alimentary importance; Feeding Index; Dermaptera; feeding; food items; amphibians.

Introduction

L. mystaceus is a large species (47 - 50 mm snout-vent length in adults) of the *Leptodactylus fuscus* group, and is distributed throughout Brazil, occurring from Roraima to Paraná (Caramaschi et al., 2008; Affonso et al., 2011). This species can be found in open areas or at forest edges in São Paulo (Toledo et al., 2005). However, studies in the Amazon recorded this species only at the edges and/or inside forest formations (Bernarde, 2007; Bernarde and Macedo, 2008; Bernarde et al., 2013).

Studies on biological factors that influence frog populations are still scarce in Brazil (Pazinato et al., 2011; Pinheiro et al., 2012). Accordingly, knowing the diet of an anuran can help understand its feeding ecology (Duellman and Trueb, 1994; Teixeira and Vrcibradic, 2003). The diet of anurans is generally based on arthropods (Vitt and Caldwell, 1994) and is influenced by factors such as prey availability (Vaz-Silva et al., 2005), environmental changes (Solé et al., 2009), body size (Lima, 1998; Batista et al., 2011; Sugai et al., 2012), seasonality (Maragno and Souza, 2011), and hunting strategy (Manyero et al., 2004).

Data on diet of anurans can help to understand life history, identify environmental conditions and consequences of habitat alterations (e.g., different stages of deforestation), prey species distribution (Parker and Goldstein, 2004), and reasons for population fluctuations (Lips et al., 2005). Information on the diet of a species can also help to devise conservation strategies (Batista et al., 2011). Therefore, in this paper we analyzed the diet of *L. mystaceus* from Novo Progresso, southwestern Pará, northern Brazil.

Materials and Methods

For the diet analysis, we used 25 specimens of *L. mystaceus* (5 males, 13 females, and 7 juveniles), which were deposited in the Museum of Zoology of Tangará da Serra (MZT 1610-1634), Center for Research, Studies and Agro-Environmental (CPEDA), Mato Grosso State University, Tangará da Serra.

We collected anurans from 19:00 h to 22:00 h during the dry and rainy seasons (September 2011 – February 2012) around the farmhouse of the Florentino farm, in Novo Progresso, Pará, Brazil (-55.389167°, -7.129167°, 235 m a.s.l; DATUM= WGS84), which has been deforestated for over 15 years (Fig. 1). We used the Visual Encounter Survey as a sampling technique (Heyer et al., 1994). Specimens were killed with 5% Xylocaine, fixed in 10% formalin, and preserved in 70%

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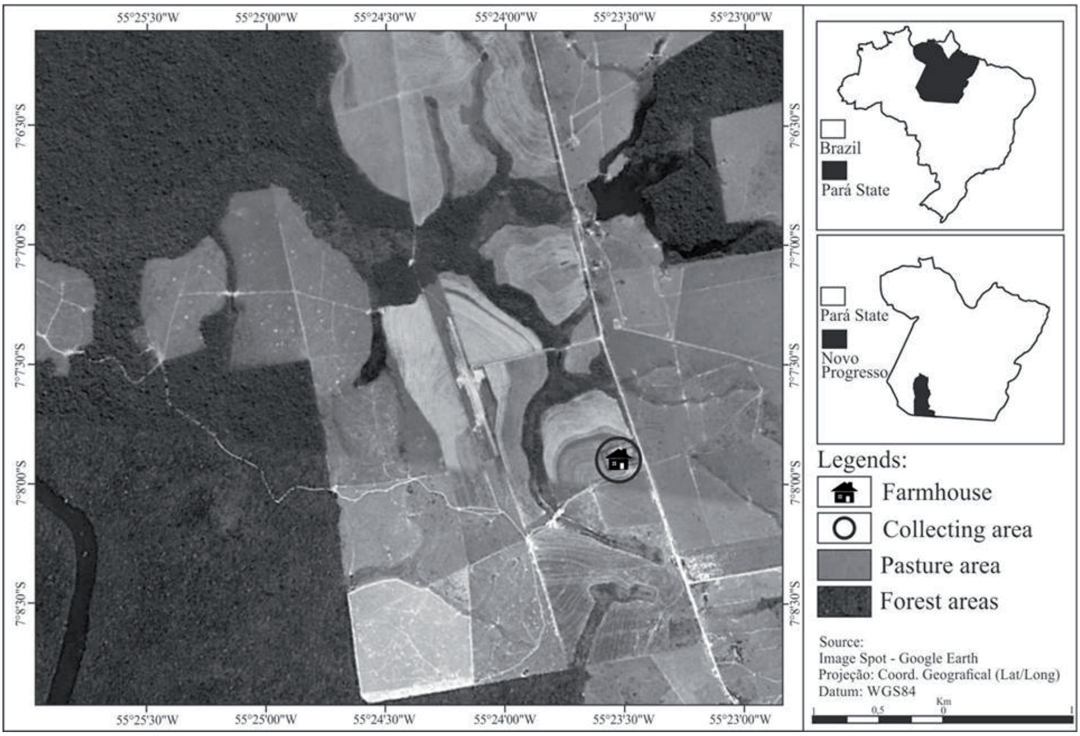

Figure 1. Location of sampling sites in Novo Progresso, Pará, Brazil.

ethanol. We extracted the stomachs through a ventral longitudinal incision and identified the prey categories at the order level, except for Formicidae, using a stereoscopic microscope. For each prey category, we calculated the Frequency of occurrence (Fi%) using the formula below (Bowen, 1983): Fi= 100ni/n, where Fi= frequency of occurrence of the *i* food item in the sample, ni= number of stomachs in which the *i* item was found, and n= total number of stomachs with food in the sample. The volume (Vi%) was calculated according to Hynes (1950): V%= Vi/(Vi1+Vi2+...Vin), where V%= volume of a given prey item (Vi) and Vi1+Vi2+...Vin are the total volume of prey items. To calculate the volume, we used four microscopy slides placed on a graph paper (Fig. 2). We calculated the Feeding Index (IAi) of each item (Kawakami and Vazzoler, 1980), according to the formula IAi = Fi*Vi / Σ(Fi*Vi), where Fi = frequency of occurrence (%) of a given item, and Vi = volume (%) of the given item.

We obtained measurements of snout-vent length (SVL) and the size of the jaw (J) using a caliper (to the nearest 0.1 mm). We use linear regression to test whether the amount of prey items and volume are related to SVL and/or J using the software Statistica 7.0. In the linear regression that related the size of the jaw with the number and volume of ingested food items, we used the values of residues obtained from regression between body size and jaw size of frogs. This was done to remove the effect of body size in the analysis.

Results

Of the 25 specimens collected, seven (28%) had empty stomachs. We found eight prey categories in the other 18 specimens (Araneae, Blattodea, Coleoptera, Dermaptera, Diptera (adults), Diptera (larva), Formicidae, and Lepidoptera), and plant material. The greatest diversity of ingested material was found in individuals containing up to four categories of food in their stomachs (plant material, Dermaptera, Araneae and Blattodea or plant material, Dermaptera, Formicidae and Coleoptera).

Dermaptera and Coleoptera were the most relevant categories in the diet of *L. mystaceus*, if we do not consider plant material. Both the frequency of occurrence and volume of these two categories were high (exceeding 60% combined), resulting in a large accumulated importance (approximately 90%, Table

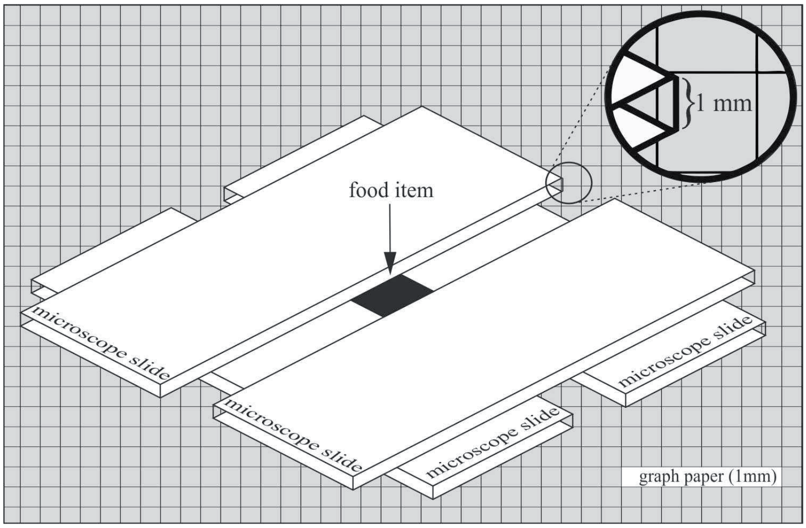

Figure 2. Method used to calculate the volume (mm^3) of each food item in the diet of *Leptodactylus mystaceus*.

1; Fig. 3 and 4). When we consider plant material, the values would be greatly changed, making it the most important item (Table 1).

Among the 25 specimens analyzed, the snout-vent length (SVL) varied from 14.11 mm to 47.98 mm (females= 46.03±2.49; males= 43.13±7.37; juveniles= 20.73±3.59). Neither the number of prey items (R^2= 0.0; $F_{1,23}$= 0.0; P = 0.97556), nor the total volume (R^2= 0.04; $F_{1, 23}$= 1.19; P= 0.28636) were significantly related to size (SVL). The same pattern was observed when we related jaw with volume (R^2= 0.03; $F_{1, 23}$= 0.26; P= 0.61) and number of prey items (R^2= 0.02; $F_{1, 23}$= 0.51; P= 0.47).

Discussion

Due to the diversity of prey items, *L. mystaceus* can be characterized as a generalist predator, as most anurans (Santos et al., 2004). According Toft (1981), this may be related to food capture strategy of leptodactylids that are sit-and-wait predators. This behavior results in the predation many arthropods (Toft, 1981). There is no information about the diet of *L. mystaceus*. However studies show that Coleoptera is the most frequent category ingested by members of this genus (Solé et al., 2009; Batista et al., 2011; González-Duran et al., 2011; Pazinato et al., 2011; Sugai et al., 2012).

Few studies report Dermapterans in the diet of anurans (e.g., *Leptodactylus podicipinus* (Rodrigues et al., 2004), *Physalaemus* cf. *cicada* and *Incilus nebuliver* (Santana and Juncá, 2007), *Leptodactylus latrans* (Solé et al., 2009), *Rhinella schneideri* (Batista et al., 2011), and *Rhinella scitula* (Maragno and Souza, 2011)). Furthermore, we note that the values of Dermaptera reported in these studies are much smaller than those found by us. Additionally, this is the first study to report Dermaptera as the main item in the diet of a *Leptodactylus*. Dermapterans are terrestrial, usually hide under bark, branches, cracks, between stones or soil during the day, are most active at night, and may be attracted to light sources (Costa-Lima, 1938). Considering that samplings occurred in the surroundings of a farmhouse, a location with lights that can attract insects, including Dermapterans, this could also have attracted individuals of *L. mystaceus* to this area due to the greater availability of prey.

When we consider plant material, this item becomes the most important category. The ingestion of plants is common in many anurans (Batista et al., 2011; Maragno and Souza, 2011; Pazinato et al., 2011; Sabagh et al., 2012), although its reason is still unknown. There are three hypotheses to explain such behavior. This material could 1) help to eliminate intestinal parasites and exoskeletons of arthropods (Anderson et al., 1999); 2) serve as an additional resource of water and nutrients (Anderson et al., 1999; Santos et al., 2004); or 3) be accidentally ingested during food capture (Whittaker et al., 1977).

The intentional ingestion of plant material has been described in some species, as in *Xenohyla truncata* (Silva

Table 1. Frequency (% Fi), Volume (Vi%) and Feeding Index (IAi) of each food category found in *Leptodactylus mystaceus* in Novo Progresso, Pará.

Category	WITHOUT plant material			WITH plant material		
	F_i%	V*i*%	NVI	F_i%	V*i*%	NVI
Plant Material	-	-	-	88.88	40.21	69.41
Dermaptera	44.44	36.06	60.83	44.44	21.55	18.60
Coleoptera	27.77	28.18	29.71	27.77	16.84	9.08
Araneae	11.11	6.96	2.93	11.11	4.16	0.89
Formicidae	11.11	2.12	0.89	11.11	1.26	0.27
Diptera	5.55	10.00	2.10	5.55	5.98	0.64
Lepidoptera	5.55	9.39	1.98	5.55	5.61	0.60
Larvae/Diptera	5.55	4.84	1.02	5.55	2.89	0.31
Blattodea	5.55	2.42	0.51	5.55	1.44	0.15

et al., 1989), *Euphlyctis hexadactylus* (Das, 1996), and *Rhinella icterica* (Benício et al., 2011). Due to ingestion of plant material, Lajmanovich (1994) considered *Rhinella schneideri* as an omnivorous species. We believe that the ingestion of plant material is intentional in *L. mystaceus*, due to its high frequency and volume, even higher than that reported by other studies.

The total volume and amount of prey categories were not related to body size. Solé et al. (2009) also found no relationship between volume and SVL in *L. latrans*. Díaz-Páez and Ortiz (2003) argue that the absence of this relationship indicates that small and large individuals can ingest prey of similar size, being somewhat selective in their choices. As in our study, *L.*

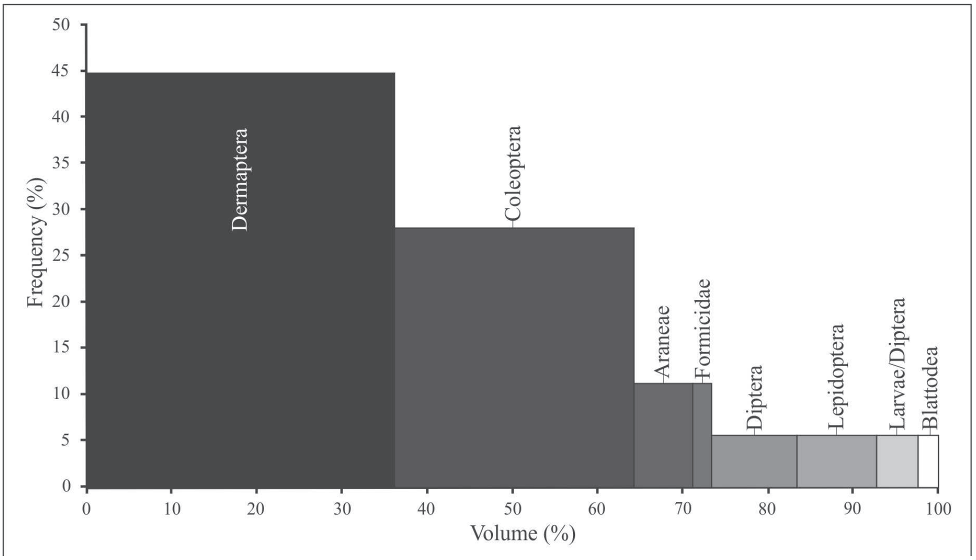

Figure 3. Relationship between percent frequency (%) and volume (mm³) of items in the diet of *Leptodactylus mystaceus*.

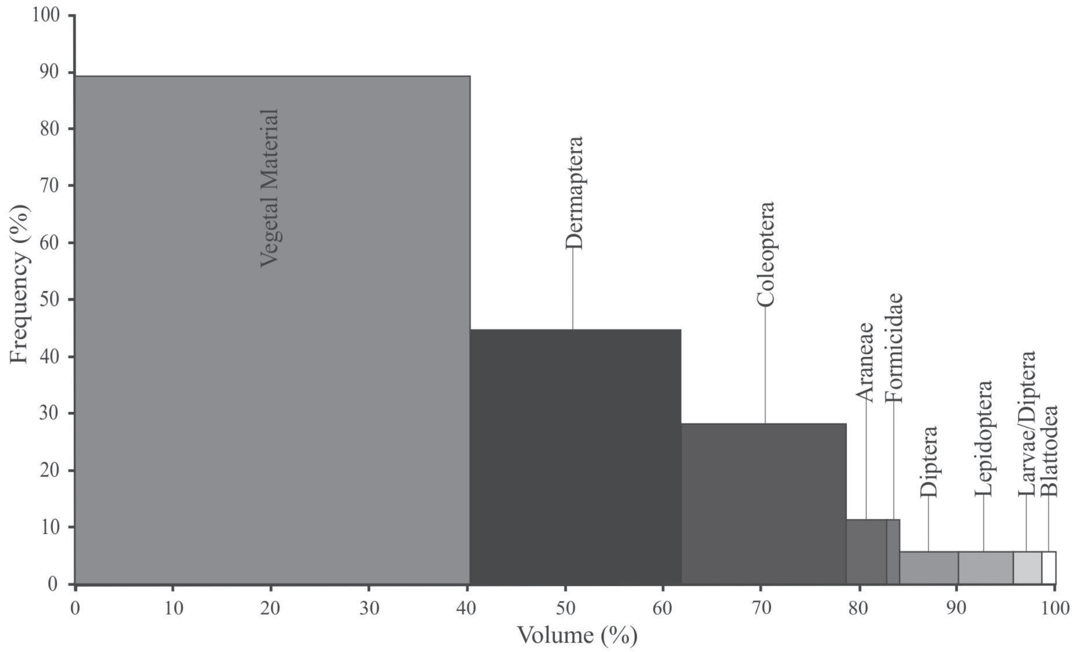

Figure 4. Relationship between percent frequency (%) and volume (mm^3) of items found in the diet of *Leptodactylus mystaceus*, considering plant material as a food item.

mystaceus also showed no variation in the diet, which could favor competition among individuals of different sizes. And thus, larger frogs would have an advantage in prey capture because they are more experienced in foraging than smaller, younger frogs.

We collected the specimens of *L. mystaceus* in an altered environment. However, studies conducted in southwestern Amazonia showed that *L. mystaceus* are sensitive to changes in the environment, and are not found in open areas (Bernarde, 2007; Bernarde and Macedo, 2008; Bernarde et al., 2013). Despite the fact that this species is easily affected by environmental change, such as in microhabitat availability (Tocher, 1998), hydric resources (Zimmerman and Bierregaard 1986), gradients of temperature and humidity (Haddad and Prado, 2005), and prey availability (Vaz-Silva et al., 2005), we found that *L. mystaceus* seem to have adapt to these adverse conditions, including deforestation, a fact not yet reported for this species in Amazon region.

We emphasize that more studies should be conducted in order to answer whether this species is strongly affected by human action or just a change in habitat use. The comparison of the diet of *L. mystaceus* from different forest formations can clarify this issue.

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