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Eating on the City: Diet Composition of *Leptodactylus troglodytes* Lutz, 1926 in Pedro II Municipality, Piauí, Brazil

Comendo na Cidade: Composição da Dieta de *Leptodactylus troglodytes* Lutz, 1926 no Município de Pedro II, Piauí, Brasil

Mariane da Silva Oliveira[a]; Nayla Letícia Assunção[ab]; Kássio Castro Araújo[a]; Etielle Barroso de Andrade*[a]

[a]Instituto Federal de Educação, Ciência e Tecnologia do Piauí. PI, Brasil
[b]Universidade Estadual de Santa Cruz, Programa de Pós-Graduação Stricto Sensu em Ecologia e Conservação da Biodiversidade. BA, Brasil
*E-mail: etlandrade@hotmail.com

Abstract

Knowing the species' diet becomes essential to understand the dynamics of populations in the environment and their trophic relationships with other species. In general, amphibians tend to have a generalist diet, with a few exceptions such as ant-specialist frogs. Among leptodactylids, *Leptodactylus troglodytes*, is considered a common and abundant species in the places where it occurs, but little is known about its trophic ecology, mainly in urban zones. Therefore, the present study aimed to investigate and describe the diet composition of this species in the municipality of Pedro II, Piauí state, Northeastern Brazil, besides testing the relationship between the predator's body size and prey volume. Considering anurans are one the most threatened vertebrate group we used a non-lethal method (stomach-flushing) to collect the diet of each individual sampled during the rainy season in Pedro II municipality. Overall, we found 46 prey items labeled in 11 categories, being Araneae, Hymenoptera, and Scolopendrida the most important prey items for the diet of *L. troglodytes*. As observed in other leptodactylids, our results indicate this species presents a "sit-and-wait" foraging strategy and a generalist and opportunistic pattern that eat a great diversity of prey. The present study contributes information on the feeding habits of this species in urban and anthropized areas.

Keywords: Feeding Habits. Flushing Method. Leptodactylid. Trophic Niche.

Resumo

Conhecer a dieta das espécies torna-se essencial para entender a dinâmica das populações no ambiente e suas relações tróficas com outras espécies. Em geral, os anfíbios tendem a ter uma dieta generalista, com algumas exceções, como sapos especialistas em formigas. Dentre os leptodactilídeos, Leptodactylus troglodytes, é considerada uma espécie comum e abundante nos locais onde ocorre, porém pouco se conhece sobre sua ecologia trófica, principalmente em zonas urbanas. Portanto, o presente estudo teve como objetivo investigar e descrever a composição da dieta desta espécie no município de Pedro II, estado do Piauí, Nordeste do Brasil, além de testar a relação entre o tamanho do corpo do predador e o volume da presa. Considerando que os anuros são um dos grupos de vertebrados mais ameaçados, utilizamos um método não letal (lavagem estomacal) para coletar a dieta de cada indivíduo amostrado durante a estação chuvosa no município de Pedro II. Ao todo, encontramos 46 presas incluidas em 11 categorias, sendo Araneae, Hymenoptera e Scolopendrida as presas mais importantes para a dieta de L. troglodytes. Assim como observado em outros leptodactilídeos, nossos resultados indicam que esta espécie apresenta uma estratégia de forrageamento "senta e espera" e um padrão generalista e oportunista que come uma grande diversidade de presas. O presente estudo contribui com informações sobre o hábito alimentar desta espécie em **áreas** *urbanas e antropizadas.*

Palavras-chave: *Hábitos Alimentares. Método de Lavagem. Leptodactilídeo. Nicho Trófico.*

1 Introduction

Ecological niches might be understood as conditions and resources needed for species living in different environments (BEGON; HARPER; TOWSEND, 2006). In this perspective, the diet consists of a fundamental aspect of the species' ecological niches once they might drive how communities are structured in the natural environment (SIH; CHRISTENSEN, 2001; SABAGH; CARVALHO-E-SILVA, 2008). Also, studying the diet composition might enable us to comprehend basic information about the natural history, population fluctuations, and how species interact with each other and the environment (ANDERSON; HAUKOS; ANDERSON, 1999; DIETL; ENGELS; SOLÉ, 2009).

Amphibians are one the most diverse group of vertebrates (VITT; CALDWELL, 2014) and are important components of energy flow and cycling of organic matter in ecosystems (ARAÚJO *et al*., 2007; HUCKEMBECK *et al*., 2014) because act as predators or prey in different food networks (TOLEDO; RIBEIRO; HADDAD, 2007; POUGH; JANIS; HEISER, 2008). In general, these animals are considered generalist and opportunistic predators (DUELLMAN; TRUEB, 1994), and their diet composition reflects the type of foraging strategy used (DODD, 2010). Active foragers usually eat a large amount of small, chitinous, and sedentary prey, whereas sit-and-wait foragers eat moving prey, large, and solitary, but in small amounts (PARMELEE, 1999; SCHMITZ, 2017).

Leptodactylidae is a diverse family of anurans harboring

233 species in the Neotropical regions from the extreme south of the United States to South America (FROST, 2023). Overall, it is composed of species with different morphological and ecological characteristics but have in common, for instance, long fingers, smooth tegument with granules, and hind feet adapted to jump, among others (WELLS, 2010; ANDRADE *et al*., 2022). Of that leptodactylids, 84 species belong to the genus *Leptodactylus*, of which 67 species are found in Brazil (SEGALLA *et al*., 2021), and nine occur in Piauí state (*L. fuscus*, *L. macrosternum*, *L. mystaceus*, *L. natalensis*, *L. podicipinus*, *L. pustulatus*, *L. syphax*, *L. troglodytes*, and *L. vastus*) (ROBERTO; RIBEIRO; LOEBMANN, 2013; ARAÚJO *et al*., 2020). However, ecological studies, including trophic aspects, are still scant for all *Leptodactylus* in the Piauí state.

Leptodactylus troglodytes, belonging to *L. fuscus* species group, is a widespread frog in northeastern Brazil (FROST, 2023), which vocalizes near rivulets or in rock cavities and lay its eggs in a foam nest in underground chambers (KOKUBUM *et al*., 2009). The fossorial niche might enable this species to live in urban areas too (ALMEIDA; ARZABE, 1997). Its trophic ecology is known in the Caatinga and Atlantic Forest biomes, and it is composed of invertebrates, including Coleoptera, Formicidae, Homoptera, and insect larvae, amongst others (LEITE-FILHO *et al*., 2015, 2017; CALDAS *et al*., 2019), but little is known about the prey items consumed in urban areas. Thus, the present study aimed to investigate the diet composition of *L. troglodytes* from an urban area of Pedro II municipality, Piauí state, northeastern Brazil, and tested the influence of predator size on prey selection.

2 Material and Methods

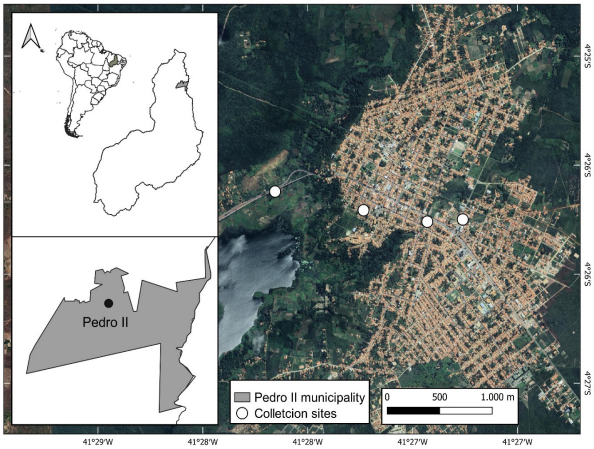
2.1 Study area

The present study was carried out in the urban perimeter of the Pedro II municipality (4°25'23'' S; 41°27'34'' W), located in the north-northeast region of Piauí state, northeastern Brazil (Figure 1). Pedro II is inserted in the Environmental Protected Area Serra da Ibiapaba (GOMES; CORTEZ, 2020) at a transitional area between Caatinga and Cerrado biomes, with predominantly plant physiognomy of Cerrado (BARROS *et al*., 2014). The climate is dry with mild temperatures (annual mean = 23.1º C) due to the high elevation (above 600 meters a.s.l.), and annual mean rainfall is about 1.000 mm (AGUIAR; GOMES, 2004).

2.2 Sampling

We sampled adult male individuals of *L. troglodytes* during the rainy season from November to December 2020 using visual and auditory searches (HEYER *et al*., 1994). The collected specimens were identified and transported in plastic bags to the Biochemistry Laboratory of the Instituto Federal do Piauí – IFPI Campus Pedro II, where we measured their snout-vent-length (SVL) with a digital caliper (0.01 mm precision). Thereafter, we used the flushing method (SOLÉ; RÖDDER, 2010) to get the diet composition of each individual (following CONCEA/MCTI Resolution No. 49, May 7, 2021). This alternative method has been applied in recent years to avoid unnecessary deaths of large numbers of animals (SOLÉ; RÖDDER, 2010; MAGESKI *et al*., 2019; OLIVEIRA-SOUZA *et al*., 2022). After these laboratory procedures, they were released close to sampling points. Two individuals found recently run over and still in good condition were collected, fixed in 10% formaldehyde, and deposited in the Biological Collection of the Federal Institute of Piauí – IFPI Campus Pedro II.

Figure 1 - Location map of the municipality of Pedro II, Piauí, northeastern Brazil, showing collection sites in the urban environment



Source: Research data.

2.3 Data analyses

In the lab, the consumed preys were analyzed under a stereomicroscope and identified to the lowest taxonomic level possible using specialized literature (TRIPLEHORN; JOHNSON, 2015). We also measured the width and length of each prey item using a digital caliper (0.01 mm precision). Thereafter, we used the ellipsoid formula (V=4/3 π(L/2)x(W/2)^2) to calculate each prey item volume (DUNHAM, 1983) and the relative importance index (IRI=(F%+N%+V%)/3) to measure the relative contribution of each prey to the species' diet composition (POWELL *et al*., 1990). We calculated the volumetric trophic niche width (Bvol) through the inverse of the Simpson index (SIMPSON, 1949).

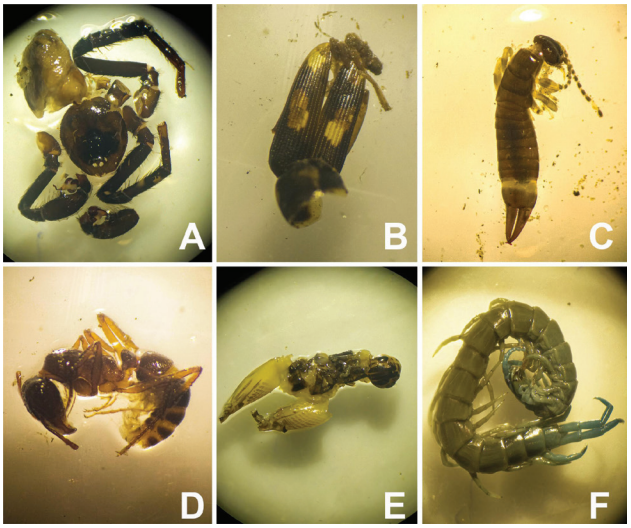
We evaluated our sampling effort using accumulated curves with 1000 randomized from an incidence matrix (GOTELLI; COLWELL, 2001). Additionally, we evaluate the prey richness through the nonparametric richness estimators Chao 2 and Jackknife 1 (MAGURRAN; MCGILL, 2011). To investigate whether the predator body size (SVL) influences the volume of prey consumed we used

the simple linear regression test with data log-transformed. All these analyzes were performed using the R packages BiodiversityR (KINDT; COE, 2005) and Vegan (OKSANEN *et al*., 2016).

3 Results and Discussion

We found 28 adult male individuals of *L. troglodytes* of which 14 had empty stomachs. A total of 46 prey items included in 11 categories were registered for this species, and the volumetric trophic niche width (Bvol) was 3.73, thus, having a generalist diet (Figure 2). The number of items per stomach ranged from one to 11 (mean = 3.29; standard deviation = 2.84) and the number of categories in each stomach ranged from one to three. Individuals of *L. troglodytes* consumed prey in three classes of arthropods (Arachnida, Chilopoda, and Insecta) and included in the following orders: Araneae, Blattodea, Coleoptera, Dermaptera, Hymenoptera, Neuroptera, Odonata, Orthoptera, Scolopendrida, and Scorpiones. The Insecta class had the greatest contribution to the diet of *L. troglodytes*, representing 72.7% of the items consumed (Table 1).

Figure 2 - Some prey items consumed by *Leptodactylus troglodytes* in the municipality of Pedro II, Piauí, northeastern Brazil. A: Araneae, B: Coleoptera, C: Dermaptera, D: Hymenoptera, E: Orthoptera, F: Scolopendrida.



Source: Research data.

The diet of *L. troglodytes* consisted mainly of Hymenoptera (N = 10; 21.74%), Araneae (N = 6; 13.04%), and Scolopendrida (N = 6; 13.04%), these categories being the most abundant. In addition, we found plant material (4.35%) and items in an advanced stage of digestion and therefore have not been identified (17.39%). Araneae (IRI = 24.4) represented the most important and volumetric prey category, representing about half of the total prey volume consumed. Scolopendrida (IRI = 15.1) and Hymenoptera (IRI = 12.4) were also important prey items for their diet composition (Table 1).

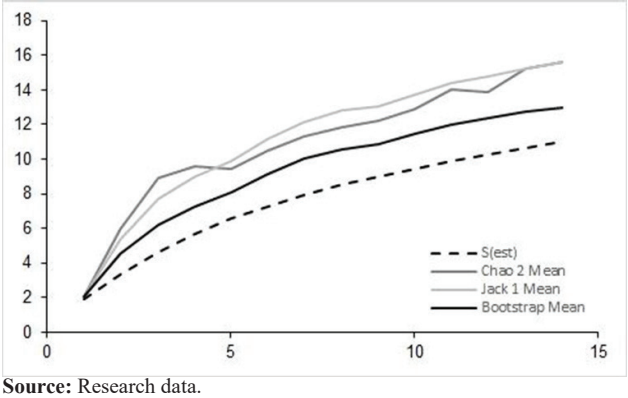
Table 1 - Absolute values and proportions (%) of frequency (F), number (N), volume (V) (in mm³) and index of relative importance (IRI) of each prey category consumed in the diet of *Leptodactylus troglodytes*. *The eggs were not identified.

Prey Categories	N	N%	V	V%	F	F%	IRI
Arachnida							
Araneae	6	13.0	3135.5	42.1	6	18.1	24.4
Scorpiones	1	2.17	309.0	4.15	1	3.03	3.12
Chilopoda							
Scolopendrida	6	13.0	1736.6	23.3	3	9.09	15.1
Insecta							
Blattodea	1	2.17	67.1	0.90	1	3.03	2.04
Coleoptera	3	6.52	137.5	1.85	3	9.09	5.82
Dermaptera	3	6.52	49.3	0.66	3	9.09	5.42
Hymenoptera	10	21.7	267.6	3.59	4	12.1	12.4
Orthoptera	1	2.17	1010.1	13.5	1	3.03	6.26
Neuroptera	2	4.35	57.0	0.77	1	3.03	2.71
Odonata	1	2.17	345.6	4.64	1	3.03	3.28
Other Items							
Plant material	2	4.35	163.2	2.19	2	6.06	4.20
Eggs*	2	4.35	5.19	0.07	1	3.03	2.48
Not identified	8	17.3	161.9	2.17	6	18.1	12.5
Total	**46**	**100**	**7446.0**	**100**	**33**	**100**	**100**

Source: Research data.

The accumulation curve showed a slight tendency towards stabilization, suggesting that the sampling effort was adequate for the prey richness, but it is possible to find other items with increased sampling effort (Figure 3). The richness estimators indicated the addition of a maximum of four new prey categories (Chao 2 = 15.6 ± 5.6; Jacknnife 1 = 15.6 ± 2.2, and Bootstrap = 13). In addition, we found a non-significant relationship between the predator body size and prey volume (r = -0.21, p-value > 0.05).

Figure 3. Prey accumulation curves for *Leptodactylus troglodytes* collected in the municipality of Pedro II, Piauí, northeastern Brazil.



Source: Research data.

As observed in other leptodactylids (e.g., PAZINATO *et al*., 2011; COSTA *et al*., 2016; JUNQUEIRA; SANTOS; SILVA, 2016; SANTANA *et al*., 2019; SOLÉ *et al*., 2019), *L. troglodytes* is a generalist and opportunist species that eat a great diversity of prey. Furthermore, the low number of prey items per individual indicates a "sit-and-wait" foraging strategy (TOFT, 1980). It might be one the reasons of our curve

accumulations do not reach asymptotes. Anuran foraging strategies represents a continuum between a sit-and-wait and actively search, in which the sit-and-wait forager consumes few items, commonly mobile and larger prey (SOLÉ; RÖDDER 2010). Such foraging strategy observed here differentiates *L. troglodytes* from other species of the *L. fuscus* species group, such as *L. bufonius*, *L. fuscus*, *L. latinasus*, and *L. mystacinus* (DURÉ; KEHR, 2004; DE-CARVALHO *et al*., 2008; JUNQUEIRA; SANTOS; SILVA, 2016; SANTANA *et al*., 2019; MONTES *et al*., 2020), in which they are considered as opportunistic and/or intermediate active foragers.

Spiders, centipedes, and ants were common prey items consumed by leptodactylids in different environments (PAZINATO *et al*., 2011; COUTO *et al*., 2018; SANTANA *et al*., 2019; MONTES *et al*., 2020). The presence of these prey categories might represent their availability in the environment as observed in other species (MANEYRO *et al*., 2004; SANTANA *et al*., 2019). Although we have not evaluated and compared here the availability of prey between the natural and urban environments, the presence of prey from the orders Araneae and Scolopendrida seems to be more related to the urban environment (SANTANA *et al*., 2019; COUTO *et al*., 2018). Furthermore, the presence of the order Scorpiones in the diet of leptodactylids (PAZINATO *et al*., 2011; COUTO *et al*., 2018; SANTANA *et al*., 2019) demonstrates that possibly these species are resistant to scorpion venom. Recently, Jared *et al*. (2020) showed that the species of *Rhinella icterica* is a voracious predator of *Tityus serrulatus*, being extremely resistant to its venom.

Leptodactylus troglodytes exhibit intraspecific differences regarding the importance of consumed prey. At temporary ponds in a Caatinga area of Paraíba state, it was observed that individuals of *L. troglodytes* eat preferentially Homoptera, Insect larvae, and Coleoptera (LEITE-FILHO *et al*., 2015), whereas in other Caatinga areas of Ceará and Pernambuco states Coleoptera, Formicidae and Insect larvae were the most consumed prey items (CALDAS *et al*., 2019). In rainforest environments preserved, Aranea and plant material had the highest importance index of prey categories (CALDAS *et al*., 2019), whereas, in an Atlantic Rainforest Urban Fragment in Paraíba state, Insect larvae and Orthoptera were the most important (LEITE-FILHO *et al*., 2017). Our result of the volumetric trophic niche width found in *L. troglodytes* was similar to other leptodactylids (FRANÇA; FACURE; GIARETTA, 2004), including the own species (LEITE-FILHO *et al*., 2015). These findings indicate this species tends to eat what is available in the environment. Due to their generalist habits, leptodactylids usually have broad trophic niches (TOFT, 1981; SOLÉ *et al*., 2019).

The frequency of plant material in the diet of *L. troglodytes* may be related to the consumption of ants belonging to the genus *Atta*. These ants are usually found carrying plant fragments to the anthill. This kind of relationship was already been reported when plants were found in the jaws of ants in the stomachs of bufonids (OLIVEIRA *et al*., 2014). In addition, these plant materials might provide physiological advantages to their digestive processes (ANDERSON; HAUKOS; ANDERSON, 1999). Although it seems to be an incidental consumption the plant material in the diet of *L. troglodytes* might be also important to its digestive processes.

The lack of relation between predator size and prey volume was already observed in other leptodactylids (SOLÉ *et al*., 2009; COUTO *et al*., 2018; SANCHES; SANTOS; COSTA-CAMPOS, 2019), assigning them opportunist behaviors. At interspecific views, predator size seems to have a more prominent influence on prey selection (VIGNOLI; LUISELLI, 2012). Additionally, in species with pronounced sexual dimorphism regarding body size, females tend to eat larger prey than males (DIAZ *et al*., 2020). Thus, as we sampled just adult male individuals with similar body sizes it was not possible to see the influence of these variables on prey selection.

4 Conclusion

Leptodactylus troglodytes had typical characteristics of a sit-and-wait predator as most leptodactylids. Additionally, this species ate a great diversity of prey items, thus, having a generalist and opportunist behavior, which might reflect the prey availability in the environments. The present study contributes information on the feeding habits of this species in urban and anthropized areas, and reinforce the importance of non-lethal methods (flushing) to dietary studies in anuran communities once these animals are one the most threatened vertebrate group.

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