

Diet and first report of batracophagy in *Leptodactylus podicipinus* (Anura: Leptodactylidae)

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ABSTRACT

In this study, we describe the diet of *Leptodactylus podicipinus* in South Pantanal. We analysed the stomach content of 30 individuals collected in September 2017 in the Miranda sub-region, Mato Grosso do Sul. We identified 19 prey categories to Order level, out of which Coleoptera was the most representative group and the most important prey category, followed by Orthoptera and Hemiptera. We recorded a post-metamorphic individual of *Rhinella schneideri* in the diet of *L. podicipinus*, the first record of batracophagy for this species. Our results provide evidence for the opportunistic and generalist feeding behaviour of *L. podicipinus*.

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Knowledge on species feeding habits is crucial for the studies of a community's natural history, interactions and energy flux through the ecosystems [1]. Amphibians play important roles in the food webs of ecosystems because they represent a link between terrestrial and aquatic environments [2,3]. The diet of anurans is generally based on arthropods [4] and is influenced by factors such as prey availability [5,6], habitat changes [7], body size [8–10], seasonality [11,12], hunting strategy [13–16] and evolutionary factors [17]. Although anurans' diet consists basically of insects [1], it can also include vertebrates, as bats [18,19], fishes [20], snakes [21] and other anurans [batracophagy: 14,22–28].

Leptodactylus podicipinus (Cope, 1862) is a widely distributed leptodactylid frog, occupying open formations of Paraguay, Argentina, Bolivia, northwestern Uruguay, and central Brazil [29]. This species is considered small (females 30–54 mm SVL, males 24–43 mm SVL) and is characterized by its light coloured belly with dark spots and a stripe extending from either under midportion of the eye or posterior corner of the eye [30].

The Pantanal is one of the largest wetlands in the world and has a marked seasonal flood. It is subdivided into different sub-regions, according to the magnitude and frequency of floods, the soil and the vegetation, among others [31]. These floods pulses can alter the dynamic of resources and the structure of communities

[32], modifying ecological process, as well as the diet composition of anurans. Although the Pantanal is an environment with predominance of flooded areas, which is an important environmental feature for amphibians, it is one of the least studied Brazilian regions [33]. Thus, the objective of our study was to evaluate the diet of *L. podicipinus* in south Pantanal, Midwest Brazil.

The diet of *Leptodactylus podicipinus* was studied by analysing the stomach contents of 30 individuals ($N = 15$ males and 15 females) captured in Base de Estudos do Pantanal (BEP, 19°34'37"S and 57°00'42"W) of the Universidade Federal de Mato Grosso do Sul (UFMS), in the Miranda sub-region [sensu 34], Corumbá, state of Mato Grosso do Sul, Brazil, in September 2017. We collected individuals by visual encounter surveys [35] along swamps available in the area.

The specimens were euthanized using topical anaesthetic (xylocaine 5%) and then fixed with 10% formaldehyde before analysing the stomach content. We removed stomachs through a small abdominal incision and stored the contents in separate vials. We preserved the frog individuals in 70% alcohol. The captured specimens were collected under the permission of Brazilian wildlife regulatory service (SISBIO#56729-1) and housed at Coleção Zoológica de Referência da Universidade Federal de Mato Grosso do Sul (ZUFMS AMP 07800–07829).

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We analysed the stomach content under a stereomicroscope, and identified each item to order level. We standardized prey identification to order level (e.g. Araneae, Coleoptera, Diptera), because it was the lowest taxonomic level possible considering the prey fragmentation level. After measuring the length and width of each prey, we estimated their volumes using the formula of the ellipsoid:

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

where, V = volume, W = width and L = length [36]. For each item (prey category) we calculated the number, volume, and frequency of occurrence in both absolute and percentage values. We then calculated the Index of Relative Importance (IRI) to determine the relative importance of each prey item in the diet using the following formula, according to Pinkas et al. [37]:

$$IRI = (\%N + \%P)\%FO$$

where $\%N$ is equal to the relative number of each prey item per sample set, $\%P$ is equal to the mass percentage of each prey item in the sample set and $\%FO$ represents the relative frequency of occurrence on the entire samples [38]. Higher IRI values indicate a greater importance of the prey category in the diet.

We also analysed the niche breadth using Levin's Measure of Niche Breadth (B) [38]. This measure allows calculation of the amplitude of the diet, particularly considering the quantitative distribution of each prey item. In order to allow comparisons with other studies, we calculated Levin's standardized measure of niche breadth (BA) after Hurlbert [39], which limits the value on a scale from 0 to 1, according to the following equation:

$$BA = \frac{B - 1}{(n - 1)}$$

where n represents the number of resources (prey species) registered. Values closer to 0 are attributed to specialist diets, while values closer to 1 represent generalist diets [38]. We performed all analyses using the software R, version 3.2 [40].

We found 19 prey categories, out of which Coleoptera was the most representative group ($N = 37.01\%$, $V = 26.64\%$) and the most important prey category ($IRI = 1009.6$). Based on the IRI and frequency values, Orthoptera were the second most representative prey category, followed by Hemiptera [Table 1]. Anura, Coleoptera larvae, Collembola, Isoptera, Lepidoptera larvae, Mantodea, Odonata and Thysanura were the least frequent items, with a single occurrence. All stomachs evaluated had contents. The Levin's niche breadth of the species was 0.1.

We also recorded the first case of batracophagy for this species. The stomach content of an adult *L. podicipinus* male (CRC = 32.25 mm, mass = 3.4 g, ZUFMS AMP 07820) presented a post-metamorphic *Rhinella*

Table 1. Prey categories found in the stomachs of *Leptodactylus podicipinus* in Pantanal, Midwest Brazil. N = Percentage of the number individuals registered; V = Percentage of volume occupied by prey item in entire sample (in mm³); F = Percentage of frequency of occurrence of prey category; IRI = Index of Relative Importance.

Prey category	N (%)	V (%)	F (%)	IRI
Annelidae	3.1	1.7	3.4	8.7
Anura	0.8	5.4	1.7	5.9
Acari	1.6	0.0	3.4	3.4
Araneae	3.1	2.9	5.1	14.2
Blattaria	2.4	5.6	3.4	16.7
Coleoptera	37.0	26.6	23.7	1009.7
Coleoptera larvae	1.6	2.7	1.7	5.9
Collembola	1.6	0.0	1.7	1.7
Diptera	6.3	0.6	6.8	10.3
Hemiptera	14.2	10.9	11.9	157.14
Hymenoptera	9.4	1.5	10.2	24.6
Isoptera	0.8	0.2	1.7	1.9
Lepidoptera larvae	0.8	2.5	1.7	3.7
Mantodea	0.8	0.4	1.7	2.0
NI	4.7	1.6	8.5	16.2
Odonata	0.8	4.3	1.7	5.1
Odonata larvae	3.9	7.6	6.8	36.8
Orthoptera	6.3	24.7	3.4	158.9
Thysanura	0.8	0.7	1.7	2.3

schneideri (Werner, 1894) (CRC = 11.52 mm, mass = 0.2 g, ZUFMS AMP 07830), shown in Figure 1.

The number of prey categories that we registered in the diet of *L. podicipinus* ($N = 19$) was lower than the number of prey categories observed for this species in a study conducted in Pantanal of Abobral ($N = 24$) [11], and higher than another study conducted in rice fields in Pantanal of Miranda ($N = 18$) [7]. However, the higher number of prey orders registered by Rodrigues et al. [11] was influenced by the numbers of habitats sampled, which increases the diversity of available preys. In our study, we sampled only one habitat.

Species of the *Leptodactylus* genus are considered sit-and-wait generalist predators, consuming few food items that are large and mobile [41], as shown in the present study by the great abundance of coleopterans in the diet. Coleoptera is the largest order of insects in the world and Brazil [42]. The richness and abundance of this order is influenced by vegetation formations and soil moisture [42], which may explain the high IRI of this order in the diet composition of *L. podicipinus*. Likewise, this pattern can be attributed to differences in prey availability, since diet composition is determined by the arthropods availability in the environment occupied by the population [13,43,44]. This was also observed by Rodrigues et al. [11] and Piatti and Souza [7] for Pantanal, where Coleoptera was the most important order in the diet of *L. podicipinus* during both the wet and the dry season.

The presence of vertebrates in the diet of anurans is mainly restricted to large species, as previously reported for several *Ceratophrys*, *Leptodactylus*, *Lithobates* and *Rhinella* species [22,45–47]. However, this is the first report of batracophagy in the small-sized species *Leptodactylus podicipinus*. Although it is rare, small anurans can also prey other anurans [e.g. 48]. During the



Figure 1. The post-metamorphic *Rhinella schneideri* (left – ZUFMS-AMP07830) preyed by an adult male of *Leptodactylus podicipinus* (right – ZUFMS-AMP07820) in Pantanal, Midwest Brazil.
Note: Scale bar = 1 cm.

night of the fieldwork, we observed a high density of post-metamorphic *R. schneideri* active in the area sampled. The feeding strategy of sit-and-wait may offer possible advantages in situations of high population density or scarce food resources, such as obtaining energy while decreasing intraspecific competition [45,49]. Although the bufotoxin secreted by *R. schneideri* during all life stages causes nausea, vomiting, and even paralysis and death in potential predators [50], these aspects do not seem to have prevented the predation by *L. podicipinus*. Rodrigues et al. [11], suggesting that *Leptodactylus podicipinus* is an opportunistic predator. The post-metamorphic of *R. schneideri* in the stomach of *L. podicipinus* detected in our study may provide further evidence of this type of feeding behaviour.

In this sense, reports on the natural history and diet of anurans emphasize the importance of conducting studies in different habitats to understand the feeding patterns of widely distributed species [6], such as *L. podicipinus*. In the Pantanal of Miranda, the diet of *L. podicipinus* essentially consisted of invertebrates, particularly of Coleoptera. However, studies of food availability are imperative to verify if this result is influenced by prey availability or if it is species-specific preference. To the best of our knowledge, this is the first report of batracophagy in *L. podicipinus*.

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References

- [1] Duellman WE, Trueb L. Biology of amphibians. Baltimore (MD): John Hopkins University Press; 1994.
- [2] Duré MI, Kehr AI, Schaefer EF. Niche overlap and resource partitioning among five sympatric bufonids (Anura, Bufonidae) from northeastern Argentina. *Phyllomedusa*. 2009;8:27–39.
- [3] Machado IF, Menegucci RC, Mendes HF, et al. Polyphenism: defensive color behaviour of *Phasmahyla guttata* (A. Lutz, 1924) (Amphibia, Anura, Hylidae). *Herpetol. Notes*. 2015;8:467–470.
- [4] Vitt LJ, Caldwell JP. Resource utilization and guild structure of small vertebrates in the Amazon forest leaf litter. *J Zool*. 1994;234:463–476.
- [5] Vaz-Silva W, Frota JG, Prates-Júnior PH, et al. Dieta de *Lysapsus laevis* Parker, 1935 (Anura: Hylidae) do médio rio Tapajós, Pará, Brasil. *Comun Mus de Ciênc Tecnol*. 2005;18:3–12.

- [6] Pacheco EO, Ferreira VG, Carvalho RMH. Diet of *Boana albopunctata* (Anura: Hylidae) in an Atlantic Forest fragment of southeastern Brazil. *Phyllomedusa*. 2017;16:57–62.
- [7] Piatti L, Souza FL. Diet and resource partitioning among anurans in irrigated rice fields in Pantanal, Brazil. *Braz J Biol*. 2011;71:1–9.
- [8] Lima AP. The effects of size on the diets of six sympatric species of postmetamorphic litter anurans in Central Amazonia. *J Herpetol*. 1998;32:392–399.
- [9] Sabagh LT, Ferreira VL, Rocha CFD. Living together, sometimes feeding in a similar way: the case of the syntopic hylid frogs *Hypsiboas raniceps* and *Scinax acuminatus* (Anura: Hylidae) in the Pantanal of Miranda, Mato Grosso do Sul State, Brazil. *Braz J Biol*. 2010;70:955–959.
- [10] Sugai JLMM, Terra JS, Ferreira VL. Diet of *Leptodactylus fuscus* (Amphibia: Anura: Leptodactylidae) in the Pantanal of Miranda river, Brazil. *Biota Neotrop*. 2012;12:99–104.
- [11] Rodrigues DJ, Uetanabaro M, Prado CPA. Seasonal and ontogenetic variation in diet composition of *Leptodactylus podicipinus* (Anura, Leptodactylidae) in the southern Pantanal, Brazil. *Rev Esp Herp*. 2004;18:19–28.
- [12] Maragno FP, Souza FL. Diet of *Rhinella scitula* (Anura, Bufonidae) in the Cerrado, Brazil: the importance of seasons and body size. *Rev Mex Biodivers*. 2011;82:879–886.
- [13] Toft C. Feeding ecology of Panamanian litter anurans: patterns in diet and foraging mode. *J Herpetol*. 1981;15:139–144.
- [14] Maneyro R, Naya DE, Rosa I, et al. Diet of the South American frog *Leptodactylus ocellatus* (Anura, Leptodactylidae) in Uruguay. *Iheringia, Sér Zool*. 2004;94:57–61.
- [15] Camera BF, Krinski D, Calvo IA. Diet of the Neotropical frog *Leptodactylus mystaceus* (Anura: Leptodactylidae). *Herpetol Notes*. 2014;7:31–36.
- [16] Oliveira M, Gottschalk MS, Loebmann D, et al. Diet composition and niche overlap in two sympatric species of *Physalaemus* (Anura, Leptodactylidae, Leiuperinae) in coastal subtemperate wetlands. *Herpetol Notes*. 2015;8:173–177.
- [17] Wells KD. The ecology and behavior of amphibians. Chicago (IL). University of Chicago Press; 2007.
- [18] Castro IJ, Silva CR, Costa AJS, et al. Predação oportunista de *Artibeus planirostris* (Spix, 1823) e *Carollia perspicillata* (Linnaeus, 1758) (Chiroptera, Phyllostomidae) por marsupiais e anuro na APA do Rio Curiaú, Amapá, Brasil. *Acta Amaz*. 2011;41:171–174.
- [19] Leite-Filho E, Feijó A, Rocha PA. Opportunistic predation on bats trapped in mist nets by *Leptodactylus vastus* (Anura: Leptodactylidae). *Biotemas*. 2014;27:205–208.
- [20] Teixeira R, Vrcibradic D. Diet of *Leptodactylus ocellatus* (Anura; Leptodactylidae) from coastal lagoons of southeastern Brazil. *Cuad Herpetol*. 2003;17:113–120.
- [21] Fonseca E, Lanna F, Carvalho R, et al. Predation on *Sibynomorphus neuwiedi* (Serpentes: Dipsadidae) by *Leptodactylus labyrinthicus* (Anura: Leptodactylidae) in southeastern Brazil. *Herpetol Notes*. 2012;5:167–168.
- [22] Cardoso AJ, Sazima I. Batracophagy in the adult and larval phases of the pepper frog *Leptodactylus labyrinthicus* (Spix, 1824). Anura, Leptodactylidae. *Ciênc Cult*. 1977;29:1130–1132.
- [23] Silva WR, Giaretta AA, Facure KG. On the natural history of the South American pepper frog, *Leptodactylus labyrinthicus* (Spix, 1824) (Anura: Leptodactylidae). *J Nat Hist*. 2005;39:555–566.
- [24] Pirani RM, Silva ET, Feio RN. Tadpole cannibalism in *Leptodactylus cunicularius* Sazima & Bokermann, 1978 (Anura, Leptodactylidae) at a temporary stream in South-eastern Brazil. *Herpetol Notes*. 2010;3:359–360.
- [25] Santana DO, Rocha SM, Silva IRS, et al. Predation of *Leptodactylus latrans* (Anura, Leptodactylidae) and *Hypsiboas albomarginatus* (Anura, Hylidae) by *Leptodactylus vastus* (Anura, Leptodactylidae) in north-eastern Brazil. *Herpetol Notes*. 2012;5:449–450.
- [26] Maffei F, Nascimento BTM, Bernarde PS. Cannibalism in the Smith Frog, *Hypsiboas faber* (Wied-Neuwied, 1821), in Southern Brazil. *Reptiles Amphib*. 2014;21:133–135.
- [27] Sousa JC, Baía RRJ, Costa-Campos CE. *Rhinella major* (Anura: Bufonidae) and *Leptodactylus macrosternum* (Anura: Leptodactylidae): predation and cannibalism by *Leptodactylus macrosternum*. *Cuad Herpetol*. 2016;30:25–27.
- [28] Thomas M, Beirne C, Bailey E, et al. Attempted predation of the toad *Rhinella marina* (Linnaeus, 1758) (Amphibia: Bufonidae) by *Leptodactylus rhodonotus* (Günther, 1868) (Amphibia: Leptodactylidae) in southeast Peru. *Herpetol Notes*. 2017;10:533–534.
- [29] Frost DR. Amphibian species of the world: an online reference. Version 6.0. New York (NY): Am. Mus. Nat. Hist; 2017.
- [30] Heyer WR. Variation within the *Leptodactylus podicipinus-wagneri* complex of frogs (Amphibia: Leptodactylidae). Washington (WA): Smithsonian Institution Press; 1994.
- [31] Hamilton SK. Hydrological controls of ecological structure and function in the Pantanal wetland (Brazil). In: McClain M, editor. The ecohydrology of South American rivers and wetlands. Manaus (AM): Int. Assoc. Hydrol. Sci; 2002. p. 133–158.
- [32] Martins CA, Roque FO, Santos BA, et al. What shapes the phylogenetic structure of anuran communities in a seasonal environment? The influence of determinism at regional scale to stochasticity or antagonistic forces at local scale. *PLoS ONE*. 2015;10:1–14.
- [33] Souza FL, Prado CPA, Sugai JLMM, et al. Diversity of amphibians of the state of Mato Grosso do Sul, Brasil. *Iheringia, Sér Zool*. 2017;107:1–10.
- [34] Silva JSV, Abdon MM. Delimitation of the Brazilian Pantanal and its sub-regions. *Pesq Agropec Bras*. 1998;33:1703–1711.
- [35] Crump ML, Scott NJJ. Visual encounter surveys. In: Heyer WR, Donnelly MA, McDiarmid RW, Hayek LC, Foster MS, editors. Measuring and monitoring biological diversity: standard methods for amphibians. Washington (WA): Smithsonian Institution Press; 1994. p. 84–92.
- [36] Griffiths RA, Mylotte VJ. Microhabitat selection and feeding relations of smooth and warty newts, *Triturus vulgaris* and *T. cristatus*, at an upland pond in mid-Wales. *Ecography*. 1987;10:1–7.
- [37] Pinkas L, Oliphant MS, Iverson ZL. Food habits of albacore bluefin, tuna and bonito in California waters. *Calif Dep Fish Game, La Jolla*. 1971;152:1–105.
- [38] Krebs CJ. Ecological methodology. New York (NY): Harper & Row; 1999. p. 620.
- [39] Hurlbert SH. The measurement of niche overlap and some relatives. *Ecology*. 1978;59:67–77.
- [40] R Core Team. R: A language and environment for statistical computing. Version 3.2. Vienna: R Foundation for Statistical Computing; 2017.
- [41] Solé M, Rödder D. Dietary assessments of adult amphibians. In: Dodd CK Jr., editor. Amphibian ecology and conservation: a handbook of techniques. Oxford (NY): Oxford University Press; 2010. p. 167–184.

- [42] Rafael JA, Melo GAR, Carvalho CD, et al. Insects of Brasil: diversity and taxonomy. Ribeirão Preto (SP): Holos; 2012. p. 795.
- [43] Das I. Folivory and seasonal changes in diet in *Rana hexadactyla* (Anura: Ranidae). *J Zool.* 1996;238:785–794.
- [44] López JA, Ghirardi R, Scarabotti PA, et al. Feeding ecology of *Elachistocleis bicolor* in a riparian locality of the middle Paraná River. *Herpetol J.* 2007;17:48–53.
- [45] Toledo LF, Ribeiro RS, Haddad CFB. Anurans as prey: an exploratory analysis and size relationships between predators and their prey. *J Zool.* 2007;271:170–177.
- [46] Leivas PT, Leivas FWT, Moura MO. Diet and trophic niche of *Lithobates catesbeianus* (Amphibia: Anura). *Zoologia.* 2012;29:405–412.
- [47] Schalk CM, Montaña CG, Klemish JL, et al. On the diet of the frogs of the Ceratophryidae: synopsis and new contributions. *South Am J Herpetol.* 2014;9:90–105.
- [48] Mendes CVM, Ruas DS, Solé M. Predation attempt of *Trachycephalus mesophaeus* (Hylidae) by *Leptodactylus cf. latrans* (Leptodactylidae). *Herpetol Notes.* 2012;5:163–164.
- [49] Pizzatto L, Shine R. The behavioral ecology of cannibalism in cane toads (*Bufo marinus*). *Behav Ecol Sociobiol.* 2008;63:123–133.
- [50] Norman DR. Anfíbios y reptiles del Chaco Paraguayo – Tomo I. Amphibians and Reptiles of the Paraguayan Chaco – Volume 1. San José: University of Texas Press; 1994. p. 281.