

All you can eat: predation of a giant earthworm by the Smooth-Horned Frog, *Proceratophrys cristiceps* (Müller, 1884), in the Caatinga biome

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The Caatinga is a distinctive morphoclimatic domain occupying Brazil's semiarid interior (IBGE, 2019). Covering approximately 800,000 km² across northeastern Brazil, the region is characterised by high temperatures (26–28 °C) and irregular, low annual rainfall, ranging between 500–750 mm (Leal et al., 2003). Precipitation is typically concentrated in short periods throughout the year, giving rise to temporary rivers and ponds (Leal et al., 2003). These ephemeral hydrological conditions create ideal breeding environments for various taxa, including anurans (Dayton and Fitzgerald, 2006; Caldas et al., 2019; Bonetti et al., 2020). During this brief climatic window, the energetic demands of reproductive activity also result in heightened foraging effort (Rodrigues et al., 2004).

The diet of most anurans is generally considered opportunistic (Solé and Rödder, 2010; Caldas et al., 2019; Bonetti et al., 2020; Oliveira et al., 2020), with prey composition and frequency varying in response to temporal resource availability (Giaretta et al., 1998; Oliveira et al., 2020). This dynamic is particularly evident in highly seasonal ecosystems such as the Caatinga (Santos et al., 2016; Caldas et al., 2019), where the brevity of suitable environmental conditions constrains both trophic interactions and reproductive events (Caldas et al., 2016). Consequently, the activity of predators and prey is synchronised with these fleeting ecological opportunities.

In addition to environmental seasonality, anuran diet composition is influenced by intrinsic factors such as sex and ontogenetic stage (Rodrigues et al., 2004). Diet is strongly linked to morphological, physiological, behavioural, and ecological traits, which differ between life stages and sexes (Wilbur, 1988; Díaz et al., 2020). Variation in foraging strategies (Duellman and Trueb, 1994; Wells, 2007), spatial niche use (Van-Sluys and Rocha, 1998; Rodrigues et al., 2004), and anatomical features (Wilbur, 1988) can also lead to both intra- and interspecific dietary differentiation. Such patterns reflect resource partitioning mechanisms that optimise niche exploitation and reduce competitive overlap (Woodward and Hildrew, 2002).

Proceratophrys cristiceps (Müller, 1884) is a medium-sized terrestrial anuran (snout–vent length: males 32.5–56.3 mm; females 43.3–65.0 mm) (Cruz et al., 2012), distributed across Ceará, Piauí, and from Rio Grande do Norte southwards to Bahia (Frost, 2026). It is a characteristic inhabitant of the Caatinga, where it exhibits aestivation behaviour with a short period of surface activity (Jared et al., 2019), and an explosive, rainfall-triggered breeding strategy (*sensu* Wells, 1977), usually restricted to first months of the year (Jared et al., 2019). In the *P. cristiceps* population from Contendas, reproductive activity lasts between one and two months (December–January) (Juliana Zina, pers. obs.). In this strongly seasonal environment, *P. cristiceps* is regarded as an opportunistic predator, consuming prey items that become temporarily abundant following rainfall events (Brito et al., 2012; Friedman et al., 2019; Oliveira et al., 2020). For example, the surfacing of giant earthworms after heavy rainfall, when soil saturation forces them above ground (Brown and Fragoso, 2007), creates short periods of elevated biomass availability. These events coincide with the rainfall-induced activity of *P. cristiceps* (Brito et al., 2012), thus providing an ecologically plausible opportunity for the species to exploit earthworms as a food resource.

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In Brazil, approximately 51–53 species of giant earthworms (families Rhinodrilidae and Glossoscolecidae; genera *Rhinodrilus* and *Glossoscolex*, respectively) have been documented (Brown and James, 2007), exhibiting a broad yet uneven distribution across the country. Despite their ecological relevance, these invertebrates remain markedly underrepresented in zoological collections, particularly in northeastern Brazil, where only about 40 species have been recorded from merely 35 localities (James and Brown, 2006; James et al., 2023; Silva et al., 2023).

In the present study, we report on the diet of *P. cristiceps*, with special emphasis on giant earthworms (species identification ongoing).

Material and methods

This study was conducted in the Contendas do Sincorá National Forest (FLONA), located in south-central Bahia, Brazil (13°55'15.161"S; 41°06'54.245"W; 300 m elevation), located within a scrub arboreal Caatinga region in south-central Bahia, Brazil (Fig. 1). We performed our fieldwork during the rainy season of 2024/2025 (November 2024 to April 2025), when temperatures may reach up to 43 °C (Brasil, 2006). The mean annual rainfall is approximately 596 mm, with a rainfall deficit ranging between 350–600 mm (Brasil, 2006).

We conducted active visual and acoustic searches at reproductive sites following Heyer et al. (1994). We captured three individuals of *P. cristiceps* (Fig. 2) between 24 and 25 January 2024, one day after heavy rainfall event, during which relative humidity reached 100%. The air temperature recorded during fieldwork was 27 °C on 24 January and 28 °C on 25 January, measured with a thermohygrometer.

Specimens were euthanised with a 5% lidocaine solution (50 mg/g), fixed in 10% formalin, and preserved in 70% ethanol. The specimens were deposited in the zoological collection of the Universidade Estadual do Sudoeste da Bahia (UESB), Jequié campus: MHNCHJ 1837 (♀), 1839 (♀), and 1841 (♂). Euthanasia procedures followed established ethical guidelines in herpetological research and were approved by SISBio/Ibama.

We measured snout–vent length (SVL), head width (HW), and head length (HL) using a digital calliper with a precision of 0.01 mm to assess potential correlations between morphometric variables and stomach content weight. Total stomach content weight (SCW) and body weight (TW) were recorded using a precision scale (0.0001 g) following euthanasia. Stomach contents

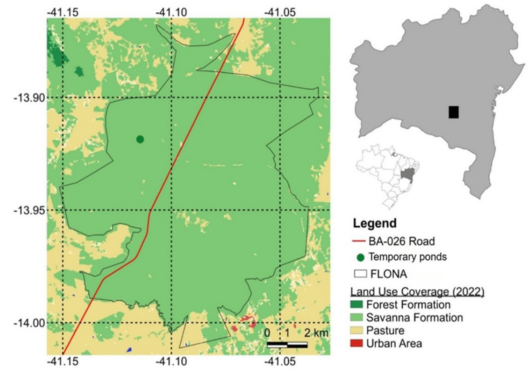


Figure 1. Map of the Contendas do Sincorá National Forest (FLONA), located in south-central Bahia, Brazil, showing land use and vegetation cover based on 2022 data (MapBiomas, 2022). The red line indicates the BA-026 road that crosses the region. Land use categories include forest formation, savanna formation, pasture, and urban areas. The green point indicates the location where the specimens were collected.



Figure 2. Individual of *Proceratophrys cristiceps* (Anura: Odontophrynidae) registered in the National Forest of Contendas do Sincorá, state of Bahia, Brazil. Photo by Vinicius Bastos.

were examined under a stereomicroscope, and prey items were identified to the lowest possible taxonomic level with the assistance of an entomologist (Dr. Ivan Cardoso, Universidade Estadual do Sudoeste da Bahia). The larger earthworm was identified by Rafaela Dudas under light microscopy at the Universidade Federal do Paraná.

Results

The females of *P. cristiceps* differed from the male in several morphometric traits, with females having

greater snout–vent length (SVL) and body weight (Table 1). Head width (HW) and length (HL), typically large in this species, were proportionally similar between sexes. However, the relative weight of stomach contents was higher in females than in males (Table 2). In one female, the stomach contained exclusively a giant earthworm (Fig. 3) (*Rhinodrilus* sp., probably *R. motucu* Righi, 1971) (Fig. 4). Whereas in the other female, in addition to the earthworm, a small amount of insect fragments was also recorded, representing less than 1% of the total stomach content weight (Table 2). More precise identification was not possible as the earthworms were still juveniles. The stomach contents of the male also included an earthworm and 16% of arthropods fragments (Coleoptera, Isoptera, Chilopoda and Scorpiones; Table 2).

Earthworms accounted for the largest proportion of stomach content weight in all specimens, ranging between 28–43% of the specimens' body weight (Table 2). The earthworms that were consumed by the females measured 29 and 31.5 cm in length, while the one consumed by the male measured 8 cm.

Discussion

According to their dietary strategies, species may be classified as generalists, opportunists, or specialists (Gerking, 1994). Generalist species do not exhibit strong preferences for particular food items (e.g., *Thoropa taophora*; Brasileiro et al., 2010), whereas specialists concentrate their foraging efforts on a specific prey type and rarely diversify their diet (e.g., *Phyllodytes edelmoi*; Araújo-Vieira et al., 2018). Opportunistic species exploit readily available food resources when preferred items are seasonally scarce or heavily exploited by competitors (Gerking, 1994). Seasonal environments, where resources are temporally limited during certain periods and abundant in others, tend to favour species capable of adopting generalist or opportunistic feeding strategies (Friedman et al., 2019; Oliveira et al., 2020). Ideally, species inhabiting environments subject to climatic variability should exhibit some degree of opportunism at certain stages of their life cycle (Gerking, 1994), as the energetic costs of maintaining a specialised diet under unstable conditions may be prohibitively high, rendering such strategies unviable from an ecophysiological perspective (Friedman et al., 2019).

A previous study of anuran communities from two Caatinga areas in the Brazilian states of Rio Grande do Norte and Ceará describes the diet of *P. cristiceps* as

Table 1. Morphometric measurements of two female and one male specimens of *Proceratophrys cristiceps* recorded in the Contendas do Sincorá National Forest, Contendas do Sincorá, State of Bahia. Abbreviations: SVL = snout–vent length; HL = head length; HW = head width; TW = total body weight; SCW = stomach contents weight.

Specimen	SVL (mm)	HL (mm)	HW (mm)	TW (g)	SCW (g)	SCW/TW
MHNCHJ1837♀	63.27	17.13	23.43	38.16	15	0.39
MHNCHJ1839♀	66.17	18.07	24.87	31.76	9.09	0.29
MHNCHJ1841♂	50.70	21.60	22.00	17.24	4.77	0.28



Figure 3. Stomach of *Proceratophrys cristiceps* (Anura: Odontophrynidae) with a giant earthworm, National Forest of Contendas do Sincorá, state of Bahia, Brazil. Photo by Natalia Nascimento.



Figure 4. *Rhinodrilus* sp. (cf. *R. motucu*) registered in the National Forest of Contendas do Sincorá, state of Bahia, Brazil. Photo by Gustavo de Abreu.

Table 2. Food items, quantity (N), and weight of each item recorded in the stomachs of *Proceratophrys cristiceps* captured in the Contendas do Sincorá National Forest, State of Bahia, Brazil. N/I = Non determined fragments of insects; nd = not determined.

Specimen	Annelida	Chilopoda	Scorpione	Coleoptera	Isoptera	N/I	Total
MHNCHJ18 37♀	1 (15 g)	-	-	-	-	-	15 g
MHNCHJ18 39♀	1 (9 g)	-	-	-	-	nd (0.09 g)	9.09 g
MHNCHJ18 41♂	1 (4 g)	1 (0.48g)	1 (0.10 g)	1 (0.17 g)	nd (0.02g)	-	4.77 g

being predominantly composed of Coleoptera and insect larvae, classifying the species as opportunistic (Caldas et al., 2019). Further research conducted on the diet of *P. cristiceps* in a shrubby Caatinga in Ceará revealed a broader and more diverse diet, primarily including Coleoptera, Gastropoda, and Formicidae (Brito et al., 2012). This supports the classification of *P. cristiceps* as both opportunistic and generalist, due to its ability to exploit a wide variety of seemingly abundant food resources in its environment (Brito et al., 2012). These findings are consistent with our observations, which are likely linked to the increased energetic demands associated with reproductive activity.

Morphological features, particularly in small predators, tend to limit prey selection, mainly due to the inability to subdue or ingest larger prey (Wilbur, 1988; Costa-Pereira et al., 2018). Although *P. cristiceps* is a medium-sized anuran, it has a proportionally large mouth (Cruz et al., 2012), enabling individuals to ingest relatively large prey. Van-Sluys et al. (2001) found a significant positive relationship between mouth size and prey quantity in the Leaf-litter Frog (*Cycloramphus parvulus*) from the Atlantic Forest in southeastern Brazil. Our observations indicate that the proportionally large mouth of *P. cristiceps* enables the ingestion of relatively large prey, at least 16–49% of its body length (28–43% of its body mass), as recorded in the present study.

Proceratophrys cristiceps is an explosive breeder (Wells, 1977) that is reproductively active only for a few days throughout the year, typically following intense rainfall events. This temporal activity pattern increases the likelihood of encountering giant earthworms (Brown and Fragoso, 2007), which emerge from the soil under similar conditions, thereby creating favourable conditions for the exploitation of this resource by explosive breeding anurans and potentially explaining their presence and dominance in the diet of

P. cristiceps. Compared to males, the diet of *P. cristiceps* females showed lower prey diversity, with a markedly higher contribution of giant earthworms. This sexual divergence likely reflects differences in ecological traits, particularly reproductive energy demands, which vary between sexes due to distinct reproductive strategies (Woolbright, 1982; Pombal Jr. and Haddad, 2005).

Additionally, in Contendas do Sincorá, females of *P. cristiceps* are typically observed only during or shortly after rainfall events. Males, in contrast, tend to be recorded over a slightly longer period in the field (Juliana Zina pers. obs.). During this time, they move between water bodies, crossing the leaf litter—the species' primary habitat (see Leite-Filho et al., 2015)—in search of temporary ponds, where they call from the margins for as long as water remains available (Juliana Zina pers. obs.). Differences in temporal activity patterns between the sexes may therefore also help to explain the dietary differences reported here. Body size differences may further influence prey composition (Toft, 1980), as may other factors such as reproductive effort, resource use, and substrate preference, which have been proposed as additional explanations for sexual dietary divergence in anurans (Ferreira et al., 2007; De-Carvalho et al., 2008; Ganci et al., 2008; Díaz et al., 2020). These findings, however, should be interpreted with caution given our small sample size, which may limit the robustness of our conclusions.

During periods of intense rainfall in the Contendas do Sincorá National Forest, it is common to observe numerous earthworms emerging from the soil. Even after these events, hundreds of worm mounds remain easily visible (Juliana Zina pers. obs.). These worms represent a temporary but abundant food resource for a variety of soil-foraging species (Vinogradov et al., 2024), including spiders (Nyffeler et al., 2017), reptiles (Strüßmann et al., 2013; Picelli et al., 2019; Mesonero et al., 2025) and amphibians (present study). Documenting such predation events may increase the likelihood of detecting prey species with strongly seasonal activity patterns that would otherwise remain rarely recorded, potentially resulting in new species records or even the discovery of undescribed taxa, especially considering that northeastern Brazil is a hotspot for new earthworm species discoveries (James et al., 2023).

Of the more than 5700 known terrestrial Oligochaeta species (Misirlioglu et al., 2023), around 19% occur in Latin America (Brown et al., 2013), although species inhabiting the Caatinga remain poorly known. In northeastern Brazil, only four species of the genus

Rhinodrilus are currently recognised (Brown and Fragoso, 2007; Silva et al., 2023). This number is likely an underestimation, as many species may exhibit strong seasonal activity and therefore escape detection during standard sampling efforts. The probable species encountered here, *R. motucu*, is widely distributed in Brazil, occurring from Mato Grosso to Sergipe (Righi, 1985). Although the species is known to produce large surface castings (Righi, 1972) and is collected and sold as fish bait in several Brazilian states (Brown and James, 2007), information on its ecology and behaviour are still scarce.

The present study provides novel and relevant information on the life history traits of an anuran species from the Caatinga biome as well as its prey, highlighting the importance of anecdotal reports describing ecological interactions. Although based on a limited sample size, this observation provides novel insights into predator-prey interactions involving poorly studied invertebrate taxa within the Caatinga. It further highlights the ecological significance of brief rainy periods, which catalyse complex trophic dynamics in an environment defined by climatic extremes. Natural history notes such as this also provide valuable opportunities to record new occurrences and potentially describe new species, helping to address critical knowledge gaps that hinder effective conservation efforts. Furthermore, conservation measures in the Caatinga are both urgent and essential, as the region is increasingly threatened by desertification driven by anthropogenic activities such as deforestation and global climate change (Santos et al., 2022).

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