



## Diet and morphometry of two poison frog species (Anura, Dendrobatidae) from the plateaus surrounding the Pantanal of Mato Grosso do Sul state, Brazil

Eduardo Oliveira Pacheco, Karoline Ceron, Paulo Sérgio Akieda & Diego José Santana

To cite this article: Eduardo Oliveira Pacheco, Karoline Ceron, Paulo Sérgio Akieda & Diego José Santana (2020): Diet and morphometry of two poison frog species (Anura, Dendrobatidae) from the plateaus surrounding the Pantanal of Mato Grosso do Sul state, Brazil, *Studies on Neotropical Fauna and Environment*, DOI: [10.1080/01650521.2020.1746098](https://doi.org/10.1080/01650521.2020.1746098)

To link to this article: <https://doi.org/10.1080/01650521.2020.1746098>



Published online: 13 Apr 2020.



Submit your article to this journal [↗](#)



View related articles [↗](#)



View Crossmark data [↗](#)

ORIGINAL ARTICLE



## Diet and morphometry of two poison frog species (Anura, Dendrobatidae) from the plateaus surrounding the Pantanal of Mato Grosso do Sul state, Brazil

Eduardo Oliveira Pacheco , Karoline Ceron , Paulo Sérgio Akieda and Diego José Santana 

Instituto De Biociências, Universidade Federal De Mato Grosso Do Sul, Campo Grande, Brazil

### ABSTRACT

The plateaus surrounding the Pantanal in Mato Grosso do Sul are highly threatened by land-use conversion and are home to *Ameerega berohoka* and *Ameerega picta*, two species of poison frogs renowned for their aposematic coloration and toxic skin. The species have diurnal and terrestrial habitats and are often observed among dead tree branches, leaf litter or under rocks. Herein, we investigated the diet and sexual dimorphism of body size in *A. berohoka* and *A. picta*, aiming to increase our understanding of the natural history of both species. We collected *A. berohoka* specimens from the Bonito municipality and *A. picta* from the Rio Negro Municipality and obtained 1,600 prey items organized into 12 categories. We found that formicid insects had the highest index of relative importance and were the most frequent prey category for both species. Despite prey items such as Acari and Isoptera being present in the diet of these species, the niche breadth of these species was low. We found no evidence of sexual dimorphism in body size or body shape for *A. berohoka* and *A. picta*. Based on our findings, we conclude that both species are ant specialists, as proposed for other *Ameerega* species.

### ARTICLE HISTORY

Received 21 August 2019  
Accepted 17 March 2020

### KEYWORDS

*Ameerega berohoka*;  
*Ameerega picta*; foraging;  
natural history; sexual size  
dimorphism

## Introduction

Studies about natural history of species are fundamental for understanding basic ecology (Ricklefs 1990) and provide essential information about organisms' interactions (Greene 1994). In the current scenario of loss of natural habitats, natural history plays an important role as the basis for studies about species preservation and conservation (Bastos 2007), especially those sensitive to environmental changes, such as amphibians (Duellman & Trueb 1994; Rothermel & Semlitsch 2002).

Anurans are considered opportunistic and generalist predators (Teixeira & Coutinho 2002; Santos et al. 2004) and have an important role in maintaining ecosystems and the food chain, providing a significant part of animal biomass for several animal groups (Toledo et al. 2007) and acting in the control of invertebrate populations (Attademo et al. 2005; Toledo et al. 2007; Wells 2007). Their foraging strategies (both active and sit-and-wait) are influenced by morphological traits (Biavati et al. 2004; Pacheco et al. 2017), energy demand (Grayson et al. 2005) and prey availability (Hirai 2004; López et al. 2009). Moreover, it is expected a positive relationship between the size of the anuran and the size of its prey (Sanabria et al. 2005; López et al. 2007).

Another important aspect of anuran's natural history is body size as a fundamental morphological characteristic, which is important in a physiological, ecological, and social context (Baraquet et al. 2012). Anurans usually present sexual size dimorphism (SSD), where females are usually bigger than males (Shine 1979; Liao et al. 2013). This pattern in anurans is associated with size-dependent fecundity advantage, which can drive the evolution of female body size and consequently leads to the evolution of bigger females (Han & Fu 2013). Nevertheless, several studies have also shown sexual dimorphism for body shape and have demonstrated, for instance, greater forelimbs in males, which improves their reproductive efficiency (Yu et al. 2010) and females with larger heads than males, which reduces competition for prey between sexes (Guimarães et al. 2011).

Dendrobatidae Cope, 1865 has 199 species and the genus *Ameerega* Bauer, 1986 has the most species (30 spp.) in the Colostethinae subfamily (Frost 2019) with a broad range in South America (Grant et al. 2006; Neves et al. 2017; Frost 2019). Species of this genus are diurnal and recognized for their aposematic coloration and presence of toxins in the skin (Lötters et al. 2000). This aposematic color is an important driver of sexual

selection for *Ameerega* species, where females choose to mate brighter males (Maan & Cummings 2009; Dreher & Pröhl 2014). In addition, *Ameerega* species also present parental care, which is rare in anurans (McDiarmid 1978; Lehtinen & Nussbaum 2003), that prevent the predation of their offspring and enhance dispersal by carrying out tadpoles on their backs, even for a number of days before finding a temporary pool (Wells 1980; Acioli & Neckel-Oliveira 2014; Summers & Tumulty 2014). Nevertheless, there is scarce information about the aspects of natural history for *Ameerega* species (e.g. Forti et al. 2011; Lima & Eterovick 2013; Summers & Tumulty 2014).

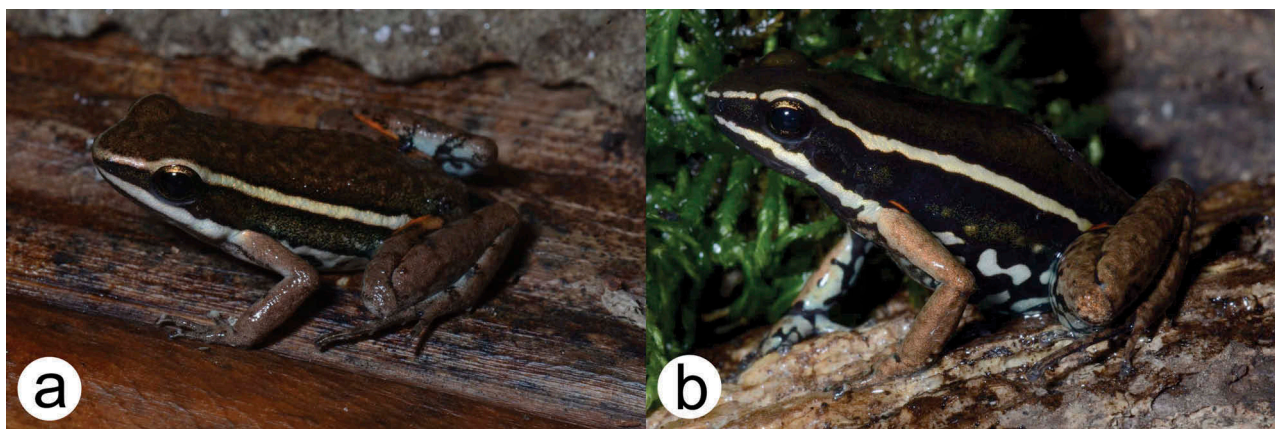
The Pantanal of Mato Grosso do Sul, Brazil is surrounded by plateaus covered by Cerrado *sensu strictu*, Cerradão, and semi-deciduous forests, which are threatened by land-use conversion, such as agriculture and cattle ranching (Scariot et al. 2005; Alho 2008). In these plateaus, two species of *Ameerega* occur in different uplands. *Ameerega berohoka* (Vaz-Silva and Maciel 2011) (Figure 1a) is restricted to Brazil and distributed in Mato Grosso, Mato Grosso do Sul and Goiás States (Frost 2019) and was recently registered in Serra de Maracaju (Sant'Anna et al. 2017). *Ameerega picta* (Tschudi, 1838) (Figure 1b) has a wider distribution in South America, occurring in Bolivia, Colombia, Peru, and Venezuela (Frost 2019). In Brazil, the species is distributed in Bodoquena and Urucum plateaus in Mato Grosso do Sul (Souza et al. 2017), eastern Amazon, and adjacent areas of Acre, Rondônia, and Mato Grosso states (Lötters et al. 2000).

Both species occur in various terrestrial microhabitats, such as dead tree branches, litter, or under rocks, and despite the close occurrence of these species in Mato Grosso do Sul state, *A. berohoka* is easily distinguished from *A. picta* by its smaller hand size,

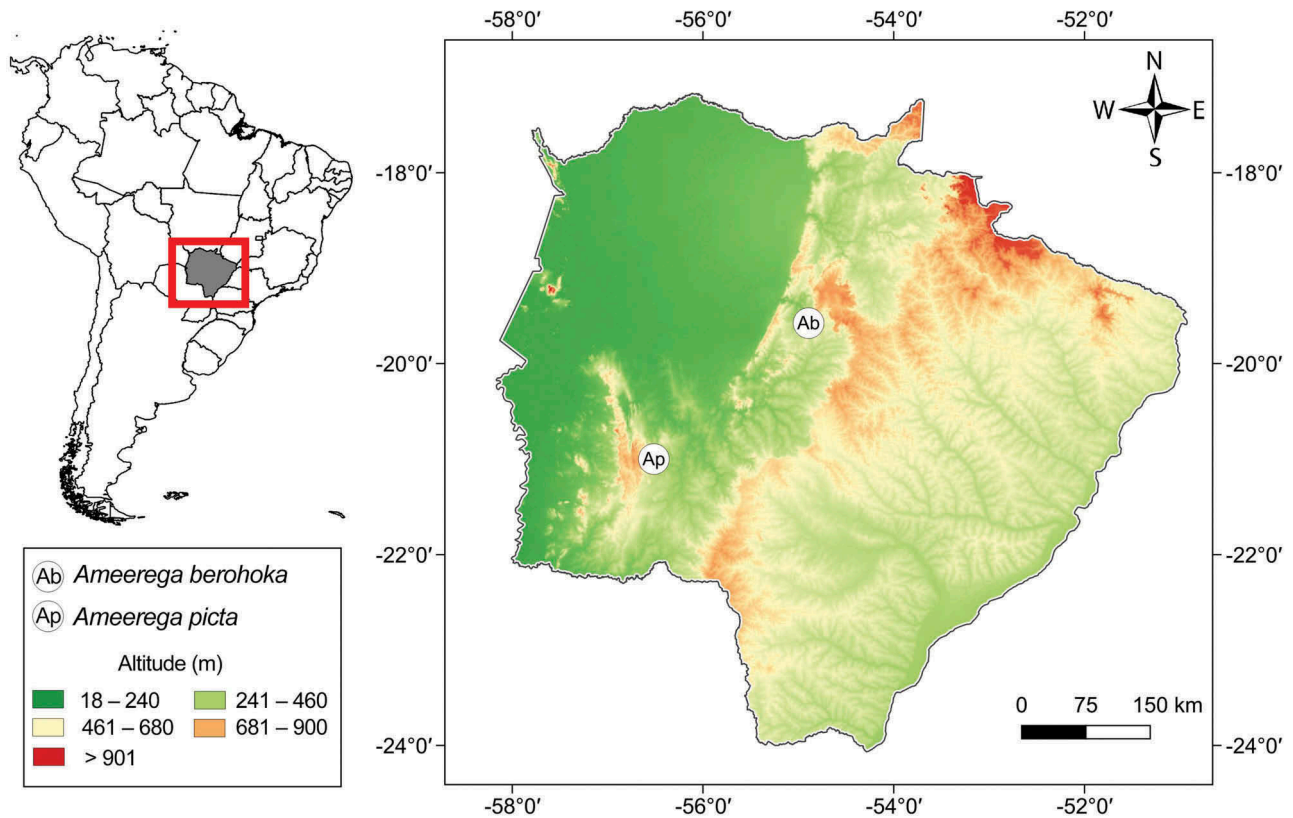
nostril shape, and irregular spots on the dorsal region (Vaz-Silva & Maciel 2011). Additionally, there is a paucity of studies that address diet or sexual dimorphism for these species, with one study reporting myrmecophagy in a population of *A. picta* from Bolivia (Mebs et al. 2010) and another describing sexual size dimorphism in a population of *A. berohoka* from the Brazilian Cerrado (Vaz-Silva & Maciel 2011). In this study, we (i) describe the diet composition of two populations of *A. berohoka* and *A. picta* and highlight their most relevant prey categories; and (ii) analyze if sexual size dimorphism is present in both species.

## Materials and methods

We captured 24 individuals (14 males and 10 females) of *Ameerega berohoka* from the Rio Peixe Waterfall (19°34'31"S, 54°53'37"W), a hillside area of the Serra de Maracaju in the Rio Negro municipality, Mato Grosso do Sul state, Brazil. For *A. picta*, we captured 22 individuals (15 males and 07 females) from the Estância Mimosa (20°58'49"S, 56°30'32"W), located in the Serra da Bodoquena, Bonito municipality, Mato Grosso do Sul state, Brazil (Figure 2). The specimens were collected during two field trips, one in April and the other in May 2016. The individuals were found and collected through visual encounter surveys (Crump & Scott 1994). The specimens were killed using topical anesthetic (lidocaine 5%) and then fixed in 10% formaldehyde before analyzing their stomach content. All individuals were considered adults, as we confirmed the development of gonads during the dissection process. The captured specimens were collected with permission from the Brazilian wildlife regulatory service (SISBIO #49080-1) and are housed at Coleção



**Figure 1.** Poison frogs from Pantanal surrounding uplands of Mato Grosso do Sul state (a) *Ameerega berohoka*, from Serra de Maracaju, in Rio Negro municipality and (b) *Ameerega picta*, from Serra da Bodoquena, in Bonito municipality.



**Figure 2.** Localization of sampling areas of (Ab) *Ameerega berohoka*, in Serra de Maracaju, Rio Negro municipality, and (Ap) *Ameerega picta*, in Serra da Bodoquena, Bonito municipality. The dark green indicates the Pantanal area in Mato Grosso do Sul state.

Zoológica of the Universidade Federal de Mato Grosso do Sul ([Appendix I](#)).

We utilized a stereomicroscope to identify the prey and classify them to the lowest possible taxonomic level. We measured prey length ( $l$ ) and width ( $w$ ) using millimeter paper placed underneath a petri dish and estimated the prey's volume ( $V$ ) from the ellipsoid formula (where  $V$  = volume,  $W$  = width, and  $L$  = length) (Griffiths & Mylotte 1987):  $V = \frac{4}{3} \pi \left(\frac{W}{2}\right)^2 \frac{L}{2}$ .

For each anuran specimen, we calculated the numerical and volumetric percentages of each prey category and the same percentages for all examined stomachs. We then calculated the Index of Relative Importance (IRI) (Pinkas et al. 1971) to determine the relative importance of each prey item in the diet using the following formula:  $IRI = (\%N + \%V)\%FO$ . This formula effectively shows the main and rare food items, where  $FO\%$  is the mean percentage of prey occurrence,  $N\%$  is the numerical percentage of prey and  $V\%$  is the volumetric percentage of prey (Krebs 1989). Higher values of IRI regarding other prey items indicate a greater importance of the prey category in the diet. To facilitate the comparison among prey categories, we calculated the IRI percentage ( $\%IRI$ ).

We also analyzed the niche breadth using Levin's Measure of Niche Breadth (Krebs 1989). This measurement permits the calculation of the diet's amplitude, particularly considering the quantitative distribution of each prey item. To facilitate comparisons with other studies, we calculated Levin's standardized measure of niche breadth (BA) according to Hurlbert (1978), which limits the value on a scale from 0 to 1 according to the following equation:  $BA = (B-1)/(n-1)$ , where  $n$  represents the number of resources (prey species) registered and  $B$  represents the Levin's measure of niche breadth. Values closer to 0 are attributed to a more specialist diet, while values closer to 1 represent a more generalist diet (Krebs 1989).

To investigate sexual dimorphism in size and shape, we only measured sexually mature individuals, which yielded 29 males and 17 females for analysis (14 males and 10 females for *A. berohoka*, and 15 males and 7 females for *A. picta*). We measured morphometric variables following Vaz-Silva and Maciel (2011) using digital calipers (nearest 0.01 mm): snout to vent length (SVL); head length (HL); head width (HW); internarinal distance (IND); eye to nostril distance (END); eye diameter (ED); tympanum diameter (TD); hand length (HAL);



thigh length (THL); tibia length (TBL); foot length (FL) (from the tip of the longest toe to the articulation of tibia–fibula and tarsus). To analyze morphometric variation in size, we defined body size as an isometric size variable (Rohlf & Bookstein 1987) following the procedure described by Somers (1986). We calculated an isometric eigenvector, defined *a priori* with values equal to  $p = 0.5$ , where  $p$  is the number of variables (Jolicoeur 1963), and obtained scores from this eigenvector, hereafter called Body Size, by post-multiplying the  $n \times p$  matrix of log10-transformed data, where  $n$  is the number of observations, by the  $p \times 1$  isometric eigenvector. To analyze morphometric variation in shape, we removed the size effect from the log10-transformed variables using Burnaby's method (Burnaby 1966). We post multiplied the  $n \times p$  matrix of the log10-transformed data by a  $p \times p$  symmetric matrix,  $L$ , defined as:  $L = I_p - V(VTV)^{-1}VT$ , where  $I_p$  is a  $p \times p$  identity matrix,  $V$  is the isometric size eigenvector defined above, and  $VT$  is the transpose of matrix  $V$  (Rohlf & Bookstein 1987). We tested for difference in body size between sexes using an analysis of variance (ANOVA) and tested for difference between sexes in Shape Variables using a Bayesian logistic regression in the *Arm* package for R (Gelman & Hill 2014). We performed all analyses in R v3.5 (R Core Team 2018). We used an  $\alpha = 0.05$ .

We state that this work and animal handling procedures were conducted with the approval of the Animal Ethics Committee from Universidade Federal

de Mato Grosso do Sul (CEUA/UFMS), protocol number 838/2017.

## Results

All the 46 analyzed stomachs from both species contained some items. We found 1,600 items, 754 in *A. berohoka* and 846 in *A. picta*, comprising 12 prey categories (11 orders and one family) and vegetal material (Table 1). For *A. berohoka*, we recorded nine prey categories and the most frequent preys were Formicidae insects (37.50%), which were present in all analyzed stomachs, representing 83.55% of ingested preys, 92.08% of total volume of stomach content and the highest index of relative importance (65.86%). Araneae, Isopoda, and Thysanoptera were the least frequent items, with a single occurrence each. Formicidae was also the most frequent item for *A. picta* (27.16%) and had the highest index of relative importance for the species (41.24%), representing 59.10% of the stomach content and 92.77% of the stomach volume. Ten prey categories were recorded and the least frequent items were Hemiptera, with a single occurrence, and Pulmonata, Ixodida, Araneae, and Isoptera, with two occurrences each. The niche breadth was 0.04 and 0.05 for *A. berohoka* and *A. picta*, respectively.

There was no sexual dimorphism in body size ( $p = 0.17$ ;  $p = 0.70$ ) or in body shape ( $p = 0.44$ ;  $p = 0.44$ ) for *A. berohoka* and *A. picta*, respectively. Average body size score for *A. berohoka* was

**Table 1.** Prey categories found in the stomachs of *Ameerega berohoka* and *Ameerega picta* in Pantanal surrounding uplands, Brazil. N = number of individuals registered (absolute number and %); F = frequency of occurrence of prey category (absolute number and %); V = volume occupied by prey item in the entire sample (in mm<sup>3</sup> and %); IRI = Index of Relative Importance. \*Except Formicidae.

Prey category	N	N%	F	F%	V (mm <sup>3</sup> )	V%	%IRI
<b><i>Ameerega berohoka</i></b>							
Acari	50	6.63	15	23.44	976.82	0.006029	1.55
Araneae	1	0.13	1	1.56	3.53	0.000022	<0.01
Coleoptera	23	3.05	12	18.75	542.30	0.003347	0.57
Formicidae	630	83.55	24	37.50	14,919,893.57	92.080104	65.86
Hemiptera	3	0.40	2	3.13	9.16	0.000057	0.01
Hymenoptera*	2	0.27	2	3.13	2.96	0.000018	<0.01
Isopoda	1	0.13	1	1.56	19.63	0.000121	<0.01
Isoptera	40	5.31	4	6.25	1,281,700.75	7.910186	0.82
Thysanoptera	1	0.13	1	1.56	0.16	0.000001	<0.01
<b><i>Ameerega picta</i></b>							
Acari	193	22.81	18	22.22	701,565.28	0.3695782	5.15
Araneae	2	0.24	2	2.47	2.58	0.0000014	<0.01
Coleoptera	32	3.78	13	16.05	7690.73	0.0040514	0.60
Diptera	5	0.59	4	4.94	138.85	0.0000731	0.02
Formicidae	500	59.10	22	27.16	176,109,222.42	92.772732	41.24
Hemiptera	1	0.12	1	1.23	2.06	0.0000011	<0.01
Hymenoptera*	12	1.42	10	12.35	70.70	0.0000372	0.17
Isoptera	91	10.76	2	2.47	13,009,880.95	6.8534866	0.43
Ixodida	2	0.24	2	2.47	0.59	0.0000003	0.01
Pulmonata	2	0.24	2	2.47	1.27	0.0000007	<0.01

**Table 2.** Morphometric measures of *A. berohoka* and *A. picta* in mm. Means  $\pm$  Standard deviation and ranges.

Measurements	<i>A. berohoka</i>		<i>A. picta</i>	
	Males (n = 14)	Females (n = 10)	Males (n = 15)	Females (n = 7)
Snout-vent length	19.10 $\pm$ 1.57 (16.07–21.89)	19.15 $\pm$ 2.06 (16.48–22.93)	23.48 $\pm$ 3.34 (18.09–32.84)	23.70 $\pm$ 3.37 (17.61–28.75)
Head length	5.36 $\pm$ 0.57 (4.41–6.26)	5.60 $\pm$ 0.79 (4.04–6.79)	5.68 $\pm$ 0.80 (4.37–7.84)	5.88 $\pm$ 1.33 (3.31–7.84)
Head width	6.31 $\pm$ 0.44 (5.76–7.19)	6.65 $\pm$ 0.56 (5.52–7.57)	6.49 $\pm$ 0.84 (5.04–8.96)	6.61 $\pm$ 0.95 (4.95–7.91)
Internarinal distance	2.14 $\pm$ 0.17 (1.86–2.51)	2.25 $\pm$ 0.19 (1.86–2.50)	2.69 $\pm$ 0.40 (2.15–3.72)	2.59 $\pm$ 0.24 (2.20–2.91)
Eye-nostril distance	2.16 $\pm$ 0.07 (2.05–2.30)	2.39 $\pm$ 0.25 (1.90–2.85)	2.60 $\pm$ 0.31 (1.75–2.94)	2.24 $\pm$ 0.33 (1.82–2.82)
Eye diameter	2.43 $\pm$ 0.22 (2.11–2.88)	2.45 $\pm$ 0.29 (2.08–3.08)	2.26 $\pm$ 0.28 (1.92–2.73)	2.26 $\pm$ 0.26 (1.71–2.40)
Tympanum diameter	1.01 $\pm$ 0.16 (0.74–1.27)	1.14 $\pm$ 0.20 (0.82–1.46)	1.64 $\pm$ 0.22 (1.11–2.08)	1.43 $\pm$ 0.23 (1.33–1.96)
Hand length	5.19 $\pm$ 0.36 (4.49–5.69)	5.45 $\pm$ 0.37 (4.59–5.65)	6.46 $\pm$ 1.30 (5.30–10.78)	6.63 $\pm$ 0.75 (5.35–7.79)
Thigh length	8.49 $\pm$ 0.84 (7.74–10.36)	8.91 $\pm$ 0.83 (8.17–10.67)	11.07 $\pm$ 1.00 (9.06–13.30)	11.38 $\pm$ 1.35 (8.22–12.35)
Tibia length	9.51 $\pm$ 0.54 (8.50–10.34)	9.99 $\pm$ 0.62 (8.76–10.35)	11.57 $\pm$ 1.25 (9.21–14.97)	11.91 $\pm$ 1.43 (8.82–13.57)
Foot length	8.71 $\pm$ 0.80 (7.28–9.97)	8.32 $\pm$ 0.85 (8.03–10.12)	10.28 $\pm$ 1.23 (8.36–13.80)	10.53 $\pm$ 1.43 (7.47–11.77)

2.25  $\pm$  0.07 (SD; range = 2.08–2.48) and for *A. picta* was 2.48  $\pm$  0.17 (SD; range = 2.07–2.86) (Table 2). Furthermore, we did not observe external morphological differences between males and females in both species, except for the presence of vocal sacs in males.

## Discussion

Our results showed ants as the most frequent prey category, with the greatest total volume of stomach content and the highest index of relative importance, ingested by *A. berohoka* and *A. picta* in the plateaus surrounding the Pantanal of Mato Grosso do Sul. Similar results have been documented for *Ameerega picta* (Ramon et al. 2010; Landgraf-Filho et al. 2019) and other populations of *Ameerega* from different biomes (Caldwell 1996; Forti et al. 2011; Lima & Eterovick 2013; Luiz et al. 2015). The niche breadth of both species was low, which is attributed to species with specialist diet and relatively limited niches (Levins 1968). Although there are no arthropod availability data in environments occupied by these populations, if we consider data on diet and niche breadth for *A. berohoka* and *A. picta* from this study, both species seem to be ant-specialists, as putatively proposed for other *Ameerega* species (Toft 1980; Caldwell 1996; Luiz et al. 2015).

Dendrobatidae is a family widely recognized for having skin toxins and aposematic coloration as its main defense mechanisms (Caldwell 1996; Darst et al. 2005). Some Dendrobatidae, including those from *Ameerega*, are diurnal active foragers, which exposes

them for longer amounts of time outside of shelter and increases their risk of predation mainly due to their diurnal habits, which could be related the bright color and skin toxins of these organisms (Toft 1980). Toxic substances in the skin of these animals are synthesized from alkaloid bases obtained exogenously (diet) from ants, mites, and other arthropods (Daly et al. 2000; Mebs 2002).

Other representative prey categories in *Ameerega* diet were Coleoptera and Isoptera. They are considered more palatable and easier to catch since they are less aggressive than ants (Juncá & Eterovick 2007). In addition, coleopterans are important protein sources for anurans, since they have more protein content than other invertebrate taxa (Anderson & Smith 1998). Coleoptera is the largest order of insects in the world and is present in most environments in Brazil (Rafael et al. 2012), presenting a high availability for consumption, and Isoptera, such as termites, are energetically valuable because they contain less sclerotized material and a higher carbohydrate content than ants (Biavati et al. 2004). Coleoptera, Isoptera, and other registered orders such as Diptera, Acari, and Araneae were also representative prey categories for other populations of *Ameerega* from different biomes (Caldwell 1996; Forti et al. 2011; Lima & Eterovick 2013; Luiz et al. 2015). Such orders and Formicidae are abundant in the litter (Sakchoowong et al. 2008), where both of the *Ameerega* species studied here usually forage, which could explain the high contribution of these prey categories to the diet of *A. berohoka* and *A. picta*. We also recorded vegetal material in the stomach contents of both

species. Anderson et al. (1999) listed some benefits for anurans to actively select plant material as dietary items, such as elimination of intestinal parasites, an additional resource of water and even nutrition resource, if digestible. However, due to the low frequency and index of relative importance, here we assume as accidentally the consumption of vegetal material by *A. berohoka* and *A. picta* (Whitaker et al. 1977).

Regarding the sexual size dimorphism of the *Ameerega* populations studied, we did not observe differences in morphometric variables, indicating that these populations do not present differences in size and shape between males and females, except for the vocal sac in males. This result opposes previous studies that reported larger body size through SVL analysis (e.g. *A. berohoka*, Vaz-Silva & Maciel 2011; *A. braccata*, Forti et al. 2013; *A. trivittata*, Acioli & Neckel-Oliveira 2014) and body shape (*A. flavopicta*, Lima & Eterovick 2013) in females. Sexual dimorphism in size for anurans, in general with males bigger than females, has been justified by sexual selection, since female fecundity is positively correlated to size (Woolbright 1983), thus allowing for bigger ovules and/or a greater number of oocytes (Crump & Kaplan 1979; Prado et al. 2000; Acioli & Neckel-Oliveira 2014) or the presence of parental care (Vaz-Ferreira & Gehrau 1975; Wells & Bard 1988). However, any pressure that affects one of the sexes may trigger a delay or acceleration of anuran growth, for example, female-male breeding age differences (Monnet & Cherry 2002), and hence the absence of sexual dimorphism in size or even males bigger than females. When sexual dimorphism in size is absent, the sexual selection in dendrobatid generally is related to the bright coloration of the males (Maan & Cummings 2009) and by the advertisement calls performed by males (Dreher & Pröhl 2014).

We also did not find evidences for external sexual dimorphism of shape in our studied *Ameerega* populations. Sexual dimorphism of shape is often observed in populations where male anurans are larger than females, which is strongly correlated to male combatting behavior and the occurrence of weaponry in males, such as spines and tusks (Shine 1979). This important trait increases the probability of defeating other males in a fight, since combatant anurans tend to be larger than noncombatant ones (Shine 1979), thus improving their reproductive success. Despite the fact that males of *A. picta* and *A. berohoka* in our study did not possess defensive or other external structures, it is common that both male and female dendrobatids provide parental care to offspring by periodically visiting nests and transporting them to

the water to complete their developmental cycle (Uetanabaro 2008; Summers & Tumulty 2014). Such shared parental care may lead females to invest less in energy intake for growth, and hence contributing to the absence of sexual dimorphism. Thus, we assume that sexual selection is also driving the absence of sexual dimorphism in both species.

## Acknowledgments

We are grateful to Estância Mimosa farm for logistic support and for allow the research in RPPN Estância Mimosa. This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Finance Code 001. KC is grateful to Fundect (Fundação de Apoio ao Desenvolvimento de Ensino, Ciência e Tecnologia do Mato Grosso do Sul) for her scholarship (# 71/700.146/2017). DJS thanks CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico) for his research fellowship (311492/2017-7).

## Disclosure statement

No potential conflict of interest was reported by the author(s).

## Funding

This work was supported by the Conselho Nacional de Desenvolvimento Científico e Tecnológico [311492/2017-7]; Coordenação de Aperfeiçoamento de Pessoal de Nível Superior [001]; Fundação de Apoio ao Desenvolvimento do Ensino, Ciência e Tecnologia do Estado de Mato Grosso do Sul (BR) [71/700.146/2017].

## ORCID

Eduardo Oliveira Pacheco  <http://orcid.org/0000-0002-7892-7936>  
 Karoline Ceron  <http://orcid.org/0000-0003-2354-3756>  
 Diego José Santana  <http://orcid.org/0000-0002-8789-3061>

## References

- Acioli ECS, Neckel-Oliveira S. 2014. Reproductive biology of *Ameerega trivittata* in an area of terra firme forest in eastern Amazonia. *Acta Amazon.* 44(4):473–480.
- Alho CJR. 2008. Biodiversity of the Pantanal: response to seasonal flooding regime ant to environmental degradation. *Bras J Biol.* 68:957–966.
- Anderson AM, Haukos DA, Anderson JT. 1999. Diet composition of three anurans from the Playa Wetlands of Northwest Texas. *Copeia.* 1999(2):515–520.
- Anderson JT, Smith LM. 1998. Protein and energy production in playas: implications for migratory bird management. *Wetlands.* 18:437–446.
- Attademo AM, Peltzer PM, Lajamanovich RC. 2005. Amphibians occurring in soybean and implications for

- biological control in Argentina. *Agric Ecosyst Environ.* 106:389–394.
- Baraquet M, Grenat PR, Salas NEY, Martino AL. 2012. Variación morfométrica y geográfica entre poblaciones de *Hypsiboas cordobae* (Anura: hylidae) en Argentina [Morphometric and geographic variation among populations of *Hypsiboas cordobae* (Anura: hylidae) in Argentina]. *Cuad Invest.* 4:147–155.
- Bastos RP. 2007. Anfíbios do Cerrado. In: Nascimento LB, Oliveira ME, editors. *Herpetologia no Brasil II*. Belo Horizonte (MG): Sociedade Brasileira de Herpetologia. p. 87–100.
- Biavati GM, Wiederhecker HC, Colli GR. 2004. Diet of *Epipedobates flavopictus* (Anura: Dendrobatidae) in a Neotropical Savana. *J Herpetol.* 38:510–518.
- Burnaby T. 1966. Growth-invariant discriminant functions and generalized distances. *Biometrics.* 22:96–110.
- Caldwell JP. 1996. The evolution of myrmecophagy and its correlates in poison frogs (family Dendrobatidae). *J Zool.* 240:75–101.
- Crump ML, Kaplan RH. 1979. Clutch energy partitioning of tropical tree frogs (Hylidae). *Copeia.* 1979(4):626–635.
- Crump ML, Scott NJJ. 1994. 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 (DC): Smithsonian Institution Press. p. 84–92.
- Daly JW, Garraffo HM, Jain P, Spande TF, Snelling RR, Jaramillo C, Rand AS. 2000. Arthropod-frog connection: decahydroquinoline and pyrrolizidine alkaloids common to microsympatric myrmicine ants and dendrobatid frogs. *J Chem Ecol.* 26:73–85.
- Darst CR, Menéndez-Guerrero PA, Coloma LA, Cannatella DC. 2005. Evolution of dietary specialization and chemical defense in poison frogs (Dendrobatidae): a comparative analysis. *Am Nat.* 165:56–69.
- Dreher CE, Pröhl H. 2014. Multiple sexual signals: calls over colors for mate attraction in an aposematic, color-diverse poison frog. *Front Ecol Evol.* 2:22.
- Duellman WE, Trueb L. 1994. *Biology of amphibians*. New York (NY): MacGraw-Hill.
- Forti LR, Mott T, Strüssmann C. 2013. Breeding biology of *Ameerega braccata* (Steindachner, 1864) (Anura: Dendrobatidae) in the Cerrado of Brazil. *J Nat Hist.* 47:2363–2371.
- Forti LR, Tisiani ASO, Mott T, Strüssmann C. 2011. Diet of *Ameerega braccata* (Steindachner, 1864) (Anura: Dendrobatidae) from Chapada dos Guimarães and Cuiabá, Mato Grosso State, Brazil. *Bras J Biol.* 71:189–196.
- Frost DR. 2019. *Amphibian species of the World 6.0*. New York (NY): American Museum of Natural History. an Online Reference; [cited 2020 Mar 13]. Available from: <https://amphibiansoftheworld.amnh.org>
- Gelman A, Hill J. 2014. *Data analysis using regression and multilevel hierarchical models*. New York (NY): Cambridge University Press.
- Grant T, Frost DR, Caldwell JP, Gagliardo R, Haddad CFB, Kok PJR, Means DB, Noonan BP, Schargel W, Wheeler WC. 2006. Phylogenetic systematics of dart-poison frogs and their relatives (Amphibia: athesphatanura: Dendrobatidae). *Bull Am Mus Nat Hist.* 299:1–262.
- Grayson KL, Cook LW, Todd MJ, Pierce D, Hopkins WA, Gatten Junior RE, Dorcas ME. 2005. Effects of prey type on specific dynamic action, growth, and mass conversion efficiencies in the horned frog, *Ceratophrys cranwelli*. *Comp Biochem Physiol.* 141:298–304.
- Greene HW. 1994. Systematics and natural history foundations for understanding and conserving biodiversity. *Am Zool.* 34:48–56.
- Griffiths RA, Mylotte VJ. 1987. Microhabitat selection and feeding relations of smooth and warty newts, *Triturus vulgaris* and *T. cristatus*, at an upland pond in mid-Wales. *Ecography.* 10:1–7.
- Guimarães TC, Figueiredo GB, Mesquita DO, Vasconcellos MM. 2011. Ecology of *Hypsiboas albopunctatus* (Anura: hylidae) in a Neotropical savanna. *J Herpetol.* 45:244–250.
- Han X, Fu J. 2013. Does life history shape sexual size dimorphism in anurans? A comparative analysis. *BMC Evol Biol.* 13(1):27.
- Hirai T. 2004. Diet composition of the Indian rice frog, *Rana limnocharis*, in the floodplain of the Kizu River, Japan. *Herpetol J.* 14:149–152.
- Hurlbert SH. 1978. The measurement of niche overlap and some relatives. *Ecology.* 59:67–77.
- Jolicoeur P. 1963. The multivariate generalization of the allometry equation. *Biometrics.* 19:497–499.
- Juncá FA, Eterovick PC. 2007. Feeding ecology of two sympatric species of Aromobatidae, *Allobates marchesianus* and *Anomaloglossus stepheni*, in central Amazon. *J Herpetol.* 41:301–308.
- Krebs CJ. 1989. *Ecological methodology*. New York (NY): Harper & Row.
- Landgraf-Filho P, Oda FH, Mise FT, Rodrigues DDJ, Uetanabaro M. 2019. Diet composition of *Ameerega picta* (Tschudi, 1838) from the Serra da Bodoquena region in central Brazil, with a summary of dietary studies on species of the genus *Ameerega* (Anura: Dendrobatidae). *Bonn Zool Bull.* 68(1):93–96.
- Lehtinen RM, Nussbaum RA. 2003. Parental care: a phylogenetic perspective. In: Jamieson BGM, editor. *Reproductive biology and phylogeny of Anura*. Enfield (NH): Science Publishers Inc. p. 343–386.
- Levins R. 1968. *Evolution in changing environments*. Princeton (NJ): Princeton University Press.
- Liao WB, Zeng Y, Yang JD. 2013. Sexual size dimorphism in anurans: roles of mating system and habitat types. *Front Zool.* 10:1–5.
- Lima NG, Eterovick PC. 2013. Natural history of *Ameerega flavopicta* (Dendrobatidae) on an Island formed by Três Marias hydroelectric reservoir in Southeastern Brazil. *J Herpetol.* 47:480–488.
- López JA, Ghirardi R, Scarabotti PA, Medrano MC. 2007. Feeding ecology of *Elachistocleis bicolor* in a riparian locality of the middle Paraná River. *Herpetol J.* 17:48–53.
- López JA, Scarabotti PA, Medrano MC, Ghirardi R. 2009. Is the red spotted green frog *Hypsiboas punctatus* (Anura: hylidae) selecting its preys? The importance of prey availability. *Rev Biol Trop.* 57:847–857.
- Lötters S, Jungfer KH, Widmer A. 2000. A new genus of aposematic poison frog (Amphibia: Anura:



- Dendrobatidae) from the upper Amazon basin, with notes on its reproductive behaviour and tadpole morphology. *Jahresh Ges Naturkd Wurt.* 156:233–243.
- Luiz LF, Contrera FAL, Neckel-Oliveira S. 2015. Diet and tadpole transportation in the poison dart frog *Ameerega trivittata* (Anura, Dendrobatidae). *Herpetol J.* 25:187–190.
- Maan ME, Cummings ME. 2009. Sexual dimorphism and directional sexual selection on aposematic signals in a poison frog. *Proc Natl Acad Sci.* 106(45):19072–19077.
- McDiarmid RW. 1978. Evolution of parental care in frogs. In: Burghardt G, Bekoff M, editors. *The development of behavior: comparative and evolutionary aspects.* New York (NY): Garland STPM Press. p. 127–147.
- Mebs D. 2002. *Venomous and poisonous animals.* Stuttgart (BW): Medpharm Scientific Published.
- Mebs D, Jansen M, Köhler G, Pogoda W, Kauert G. 2010. Myrmecophagy and alkaloid sequestration in amphibians: a study on *Ameerega picta* (Dendrobatidae) and *Elachistocleis* sp (Microhylidae) frogs. *Salamandra.* 46:11–15.
- Monnet JM, Cherry MI. 2002. Sexual size dimorphism in anurans. *Proc R Soc Lond.* 269:2301–2307.
- Neves MO, Silva LA, Akieda PS, Cabrera R, Koroiva R, Santana DJ. 2017. A new species of poison frog, genus *Ameerega* BAUER, 1986 (Anura: Dendrobatidae), from southern Amazonian rain forest. *Salamandra.* 53:485–493.
- Pacheco EO, Ferreira VG, Carvalho RMH. 2017. Diet of *Boana albopunctata* (Anura: hylidae) in an Atlantic forest fragment of southeastern Brazil. *Phyllomedusa.* 16:57–62.
- Pinkas L, Oliphant MS, Iverson ILK. 1971. Food habits of albacore bluefin, tuna and bonito in California waters. *Calif Fish Game.* 152:1–105.
- Prado CPA, Uetanabaro M, Lopes FS. 2000. Reproductive strategies of *Leptodactylus chaquensis* and *L. podicipinus* in the Pantanal. *Braz J Herpetol.* 34:135–139.
- R Core Team. (2018). R: A language and environment for statistical computing. Vienna (Austria): R Foundation for Statistical Computing; [cited 2020 Mar]. Available from: <https://www.R-project.org/>
- Rafael JA, Melo GAR, Carvalho CD, Casar AS, Constantino R. 2012. *Insetos do Brasil: diversidade e taxonomia.* Ribeirão Preto (SP): Holos.
- Ramon D, Fenker J, Calvão L, Pereira O, Marestoni T. 2010. Dieta e micro-habitat de duas espécies de anuros *Rhinella ocellata* (Bufonidae) e *Ameerega picta* (Dendrobatidae) [Internet]. Nova Xavantina-MT (Brasil): Programa de Pós-Graduação em Ecologia e Conservação, Universidade do Estado de Mato Grosso; [cited 2020 Mar 13]. Available from: <https://docplayer.com.br/8530067-Dieta-e-micro-habitat-de-duas-especies-de-anuros-rhinella-ocellata-bufonidae-e-ameerega-picta-dendrobatidae-nova-xavantina-mt-brasil.html>
- Ricklefs RE. 1990. *Ecology.* New York (NY): Freeman & Company.
- Rohlf FJ, Bookstein FL. 1987. A comment on shearing as a method for “size correction”. *Syst Zool.* 36:356–367.
- Rothermel BB, Semlitsch RD. 2002. An experimental investigation of landscape resistance of forest versus old-field habitats to emigrating juvenile amphibians. *Conserv Biol.* 16:1324–1332.
- Sakchoowong W, Jaitrong W, Ogata K, Nomura S, Chanpaisaeng J. 2008. Diversity of soil-litter insects: comparison of the Pselaphine beetles (Coleoptera: staphylinidae: pselaphinae) and the ground ants (Hymenoptera: Formicidae). *Thai J Agric Sci.* 41(1–2):11–18.
- Sanabria EA, Quiroga LB, Acosta JC. 2005. Dieta de *Leptodactylus ocellatus* (Linnaeus, 1758) (Anura: leptodactylidae) en un humedal del oeste de Argentina. *Ver Peru Biol.* 12:472–477.
- Sant’Anna AC, Rocha SB, Akieda PS, Galvão C, Neves MO. 2017. Distribution extension of *Ameerega berohoka* Vaz-Silva & Maciel, 2011 (Amphibia, Anura, Dendrobatidae): a new state record in Central Brazil. *Herpetol Notes.* 10:41–43.
- Santos EM, Almeida AV, Vasconcelos SD. 2004. Feeding habits of six anuran (Amphibia: Anura) species in a rainforest fragment in Northeastern Brazil. *Iheringia.* 94:433–438.
- Scariot A, Sousa-Silva JC, Felfili JM. 2005. Cerrado: ecologia, biodiversidade e conservação. Brasília (DF): Ministério do Meio Ambiente.
- Shine R. 1979. Sexual selection and sexual dimorphism in the Amphibia. *Copeia.* 2:297–306.
- Somers KM. 1986. Multivariate allometry and removal of size with principal components analysis. *Syst Biol.* 35:359–368.
- Souza FL, Prado CPA, Sugai JLMM, Ferreira VL, Aoki C, Filho PL, Strussmann C, Avila RW, Rodrigues DJ, Albuquerque NR, et al. 2017. Diversidade de Anfíbios do Estado de Mato Grosso do Sul, Brasil. *Iheringia* 107(supl.):e2017152. doi:10.1590/1678-4766e2017152
- Summers K, Tumulty J. 2014. Parental care, sexual selection, and mating systems in neotropical poison frogs. In: Macedo R, Machado G, editors. *Sexual selection: perspectives and models from the neotropics.* London (UK): Academic Press. p. 289–320.
- Teixeira RL, Coutinho ES. 2002. Hábito alimentar de *Proceratophrys boiei* (Wied) (Amphibia, Anura, Leptodactylidae) em Santa Teresa, Espírito Santo, sudeste do Brasil. *Bol Mus Biol Mello Leitao.* 14:13–20.
- Toft CA. 1980. Feeding ecology of thirteen syntopic species of anurans in a seasonal tropical environment. *Oecologia.* 45:131–141.
- Toledo LF, Ribeiro RS, Haddad CFB. 2007. Anurans as prey: an exploratory analysis and the size relationships between predators and their prey. *J Zool.* 271:170–177.
- Uetanabaro M. 2008. *Guia de campo dos anuros do Pantanal e planaltos de entorno.* Campo Grande (MS): Editora Universidade Federal de Mato Grosso do Sul.
- Vaz-Ferreira R, Gehrau A. 1975. Epimeletic behaviour of the common frog, *Leptodactylus ocellatus* (L.) (Amphibia, Leptodactylidae). I. Attention to the tadpole and related feeding and aggressive activities. *Physis.* 34:1–14.
- Vaz-Silva W, Maciel NM. 2011. A new cryptic species of *Ameerega* (Anura: Dendrobatidae) from Brazilian Cerrado. *Zootaxa.* 2826:57–68.
- Wells KD. 1980. Behavioral ecology and social organization of a dendrobatid frog (*Colostethus inguinalis*). *Behav Ecol Sociobiol.* 6:199–209.
- Wells KD. 2007. *The ecology and behavior of amphibians.* Chicago (IL): University Chicago Press.

Wells KD, Bard KM. 1988. Parental behavior of an aquatic-breeding tropical frog, *Leptodactylus bolivianus*. J Herpetol. 22:361–364.

Whitaker JO, Rubin D, Munsee JR. 1977. Observations on food habits of four species of spadefoot toads, genus *Scaphiopus*. Herpetologica. 33(4):468–475.

Woolbright LL. 1983. Sexual selection and size dimorphism in anuran Amphibia. Am Nat. 121:110–119.

Yu BG, Zheng RQ, Zhang Y, Liu CT. 2010. Geographic variation in body size and sexual size dimorphism in the

giant spiny frog *Paa spinosa* (David, 1875) (Anura: Ranoidae). J Nat Hist. 44:1729–1741.

## Appendix I

The reference specimens can be found at ZUFMS under numbers: *Ameerega berohoka*: Brazil: Mato Grosso do Sul state, Rio Negro municipality: ZUFMS 3763–3786. *Ameerega picta*: Brasil: Mato Grosso do Sul state, Bonito municipality: ZUFMS 3787–3808.