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RESEARCH ARTICLE

Diet and observations on natural history of *Gabohyla pauloalvini* (Bokermann 1973) (Amphibia: Hylidae), a poorly known species from cacao agroforestry in southern Bahia, Brazil

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Abstract

Gabohyla pauloalvini is a small Neotropical hylid, known only from three localities besides its type locality. Knowledge about its natural history is scarce and we present the first data about its diet. We conducted our fieldwork during the rainy period between November and December of the years 2014 and 2015. Thirty-eight *G. pauloalvini* individuals, collected in a semi-permanent pond inside a "cabruca" (cacao plantation shaded by trees), municipality of Ilhéus, Bahia, Brazil, were stomach-flushed. All stomach contents were identified to the lower taxonomic category as possible. The Index of Relative Importance (IRI) revealed that Formicidae was the most important prey category for *G. pauloalvini*. We assume that *G. pauloalvini* is an ant specialist. Diet records for others species of the tribe Sphaenorhynchini showed mainly ants as prey items, which reinforces an ecological synapomorphy for this tribe. Beyond diet, we also reported observations of possible parental care performed by *G. pauloalvini* females.

Keywords Anura · Endemic species · Feeding habits · Formicidae · Hileia baiana · Neotropical fauna

Introduction

Amphibians play a key role in the trophic relationships of aquatic and terrestrial ecosystems, acting both as predators and as preys of a variety of organisms (Toledo et al. 2007; Caldart et al. 2011; Gaiarsa et al. 2012). Anuran amphibians are generally portrayed as generalist sit-and-wait predators, feeding mainly on invertebrates (Rodrigues et al. 2004; López et al. 2009; Solé et al. 2009). However, several exceptions have been reported as a fruit eating tree frog (Da Silva and Britto-Pereira 2006) and other species feeding on small vertebrates (Duellman and Lizana 1994; Cicort-Lucaciu et al. 2011). Other feeding strategies as active foraging or a specialization in certain types of preys have also been reported (e.g. Rödel and Braun 1999; Solé et al. 2002; Berazategui et al. 2007; Araujo-Vieira et al. 2018b).

The tribe Sphaenorhynchini comprises 15 small Neotropical hylids, three of them are distributed through the Amazon Basin and 12 can be found within the boundaries of the Brazilian Atlantic Forest domain (Araujo-Vieira et al. 2015; 2018a; 2019; 2020). *Gabohyla pauloalvini* (Bokermann 1973) is the earliest species to diverge in the tribe being sister of all other species of Sphaenorhynchini (Araujo-Vieira

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et al. 2019). In a recent total evidence phylogenetic analysis Araujo-Vieira et al. (2020) erected a new monotypic genus for this species.

Gabohyla pauloalvini was described from specimens collected in the experimental fields of the Cacao Research Center (CEPLAC), Ilhéus, Bahia (Bokermann 1973). It remained known only from this single occurrence until recently, when the species was rediscovered in the municipalities of Una (Freitas et al. 2009) and Almadina (Dias et al. 2017), both in the state of Bahia, and Linhares in the state of Espírito Santo (Almeida et al. 2011). Due to the difficulty of being found in the field, many aspects of the natural history of *G. pauloalvini* remain unknown. So far, the available information is based on the dissection of a single museum exemplar with ants in its stomach (Araujo-Vieira et al. 2019). The aim of our study was to analyze the diet composition of a population of *G. pauloalvini* from a "cabruca" five kilometer distant from the type locality in southern Bahia.

Methods

Study area

The study was carried out in a "cabruca" area inside the campus of the Universidade Estadual de Santa Cruz, Ilhéus, Bahia, Brazil (− 14.795478 °S, − 39.172511° W; 34 m elev.). Southern Bahia is located within the Hiléia Baiana, a region largely recognized as an endemism center within the Central Corridor of the Brazilian Atlantic Forest (Carnaval and Moritz 2008). In this region, the cacao tree grows in a traditional system called "cabrucas" in which the wide-branching cacao trees thrive in the shadow of old-grown Atlantic forest trees or introduced trees as *Spondias mombin* (Anacardiaceae), *Artocarpus heterophyllus* (Moraceae) or legumes of the genus *Erythrina* (Piasentin et al. 2014). These "cabrucas" function as ecological corridors between preserved areas, harboring species from open formations as well as from forest environments (Argôlo 2004; Cassano et al. 2009; Delabie et al. 2011). Thanks to these characteristics, this agroforestry system has contributed to maintaining natural ecological relations similar to a tropical forest (Faria et al. 2007).

Sampling

Individuals of *G. pauloalvini* were captured through active search on a semi-permanent pond during two rainy periods between November and December 2014 and November and December 2015. The snout vent length (SVL) was measured in all specimens. Once the frogs had been measured, they were stomach flushed following Solé et al. (2005). The retrieved stomach contents were stored in 70% ethanol in individual vials. All frogs were released the same night of capture at the same pond they had been previously caught. Subsequent samplings were only performed after an interval of at least 3 days. It cannot be excluded that the same individual was resampled several times on different days. This was inevitable since individuals had to be kept alive as our license covered only the stomach flushing procedure.

Analysis

Measurements were used to verify possible allometric correlations (Simple Linear Regression). Stomach contents were identified to the lowest possible taxonomic level and according the state of conservation of the specimens (e.g., many ants were named at the genus level since only fragments were available for identification). The volumes of intact preys were measured from their length and width according to the formula for ellipsoid bodies (Dunham 1983): $V = (4/3)\pi\ (L/2)\ (W/2)^2$ where L represents the length of the prey and W its width. Partially digested preys had their original sizes estimated through regression calculations as proposed by Hirai and Matsui (2001) and then, their volume was estimated.

The Index of Relative Importance (IRI) (Pinkas et al. 1971) was calculated for all prey categories by the following formula: $IRI = (\%N + \%V)\%FO$ where N% is the numerical percentage of prey, V% is the volumetric percentage of prey and FO% is the mean percentage of prey occurrence (Pacheco et al. 2020). As IRI results in a value with no maximum limit, quantitative results were transformed into percentages (IRI%) in order to facilitate interpretation (López et al. 2007).

Results

We measured 38 individuals (34 males and 4 females). SVL ranged from 18 to 23.7 mm (mean = 20.4 mm, SD = 1.4 mm). A total of 69 food items were retrieved, distributed across eight prey taxa (Table 1). The prey taxon with the highest relative frequency and also the most abundant was Formicidae (F = 73.9%, n = 51), followed by non-formicid Hymenoptera (F = 10.1%, n = 7), Araneae (F = 4.3%, n = 3) and Coleoptera (F = 4.3%, n = 3), Diptera (F = 2.9%, n = 2), Chilopoda (F = 1.4%, n = 1), Hemiptera (F = 1.4%, n = 1) and Lepidoptera (F = 1.4%, n = 1). Formicidae was the taxon with the higher IRI% in the diet of *G. pauloalvini*, followed by other Hymenoptera (Table 1). The relative importance of all other categories was below 1% and the prey categories with the largest volumes were Formicidae, non-formicid Hymenoptera and Chilopoda. Most of the identified ants found in *G. pauloalvini* stomachs are associated to arboreal habitats (80%, n = 12 taxa) (Table 2).

Table 1 Prey composition of the diet of *Gabohyla pauloalvini* from a cacao plantation in the municipality of Ilhéus (Bahia, Brazil)

Categories	Volume (%)	Volume (mm^3)	Frequency (%)	Number of prey	IRI%
Arachnida					
Araneae	1.2	2.4	4.3	3	0.3
Chilopoda					
Scolopendra sp.	7.8	16.1	1.4	1	0.3
Coleoptera	2.2	4.6	4.3	3	0.8
Diptera	1.9	4	3	2	0.1
Hymenoptera					
Formicidae	65.7	136.2	74	51	93
Non-Formicidae	20.6	42.8	10.1	7	5.3
Hemiptera	0.5	1.1	1.4	1	0.1
Lepidoptera	–	–	1.4	1	–
Total	**100.0**		**100.0**	**69**	**100.0**

Table 2 Checklist of ants found in *Gabohyla pauloalvini* stomachs

Ants	Arboreal	Epigeous	Litter	References
Rogeria subarmata	X	X	X	Delabie et al. (2007), Gibernau et al. (2007), Santos et al. (2010)
Brachymyrmex sp.	X	X	X	Delabie et al. (2007)
Camponotus sp.1	X			Delabie et al. (2007)
Camponotus sp.2	X			Delabie et al. (2007)
Cephalotes minutus (Fabricius 1804)	X			Neves et al. (2010)
Linepithema sp.	X			Medeiros et al. (1995)
Nesomyrmex asper (Mayr 1887)	X	X		Delabie et al. (2007)
Nylanderia sp.1	X	X		Dambros et al. (2018)
Nylanderia sp.2	X	X		Dambros et al. (2018)
Procryptocerus hylaeus (Kempf 1951)	X			Dambros et al. (2018)
Pseudomyrmex gracilis (Fabricius 1804)	X			Delabie et al. (2007), Dambros et al. (2018)
Pseudomyrmex oculatus (Smith 1855)	X			Delabie et al. (2007)
Pseudomyrmex rochai (Forel 1912)	X			Dambros et al. (2018)
Pseudomyrmex simplex (Smith 1877)	X	X		Delabie et al. (2007), Ennis and Philpott (2017)
Solenopsis sp.			X	Delabie et al. (2007)

All specimens of *G. pauloalvini* were found on shrubby vegetation, both in the center and at the edges of the pond. Individuals were captured about 1 m above the pond at sites used for calling. Spawn was found on cacao leaves between 0.55 to 1.70 m height, located vertically above the water surface. We observed in five spawnings the presence of at least one adult female sitting next to them (Fig. 1), denoting a possible parental care of the eggs.

Discussion

Gabohyla pauloalvini appears to be a specialist predator for Hymenoptera (84% of retrieved items), with Formicidae as the main preys (up to 74% of the retrieved food items). Similar as reported in the literature, all individuals of *G. pauloalvini* were captured on shrubby vegetation in the interior and on the margins of a semi-permanent pond (see Bokermann 1973). The occurrence of other items in the diet of *G. pauloalvini* suggests also opportunistic predation.

All *G. pauloalvini* individuals have been found on branches on pond perimeters, while until today no specimen has been found on the floating vegetation or in the water. These observations are quite contrasting with what is already known for other species of Sphaenorhynchini, which are commonly found using the surface vegetation or partially submerged by water (Lutz and Lutz 1938; Bokermann 1973; Cruz and Peixoto 1980; Araujo-Vieira et al. 2019).

The majority of Sphaenorhynchini deposit their eggs on aquatic vegetation, with exception of *G. pauloalvini*, and optionally *Sphaenorhynchus carneus* (Cope 1868) (Bokermann 1973; Crump 1974; Araujo-Vieira et al. 2019).

Fig. 1 Adults of *Gabohyla pauloalvini* possibly displaying a parental care behaviour with the spawnings

There is no information about the occurrence of parental care in the tribe Sphaenorhynchini. Our observations suggest the occurrence of parental care in *G. pauloalvini*, which would represent the first species in the tribe to display such a kind of behavior. This fact might improve the perception of behavioral displaying in *Sphaenorhynchus* lineages and clarify more ecological details about the early evolutionary divergence of *G. pauloalvini* (Araujo-Vieira et al. 2019).

Regarding diet, Duellman (1978) reports the presence of ants (n = 2) in the stomach content of an individual of *Sphaenorhynchus lacteus* and the presence of the same prey type in six specimens of *S. carneus*, suggesting a trend of specialization in the tribe. More recently, Teixeira and Ferreira (2010) found ants to be the most frequent diet item in 88 individuals of *Sphaenorhynchus planicola* (Lutz and Lutz 1938).

So far, *G. pauloalvini* has been considered a myrmecophagical species based on the analysis of one single museum specimen (MNRJ 4323) (Araujo-Vieira et al. 2019). Here we confirm this assumption by examining a larger number of specimens, which reinforces myrmecophagy as an evident characteristic for the Sphaenorhynchini tribe (sensu Araujo-Vieira et al. 2020). The fact that most of the identified ants found in *G. pauloalvini* stomachs are associated to arboreal habitats suggests that *G. pauloalvini* individuals ambush ants foraging on vegetation. Although the information now available for *G. pauloalvini* suggests a strong preference for Formicidae for the whole tribe, more information about the diet of *S. carneus* and *S. lacteus*, as well as for other species, is still needed (Araujo-Vieira et al. 2019).

Although the hypothesis of phylogenetic maintenance deserves to be clarified by studying other *Sphaenorhynchus* species, a probable ecological influence of the average size of the individuals on their diet cannot be excluded. Active foragers within the anurans tend to choose Formicidae as main items of their diet (Toft 1980, 1981). In addition, an ontogenetic shift in the diet of the species is known, even for *Sphaenorhynchus*. In the Atlantic Forest of the state of Espirito Santo, individuals of *G. planicola* smaller than 26 m (SVL) were observed feeding on ants, whereas larger ones fed on a large variety of preys (Teixeira and Ferreira 2010). These data corroborate our results, since the studied population of *G. pauloalvini* showed a SVL of less than 26 mm (mean 20.4 mm).

Anuran communities in "cabrucas" seem to be structured in food guilds, where resource partitioning may be slightly driven by microhabitat used by the species (Teixeira and Vrcibradic 2004; Solé et al. 2009; Lima et al. 2010; Oliveira et al. 2018). Studies with other species strongly support this hypothesis. Solé et al. (2009) indicated feeding preference for Lepidoptera caterpillars in *Leptodactylus latrans* (Steffen 1815) (Leptodactylidae) from the same "cabruca" in Ilhéus. In the same phytophysiognomy *Ololygon argyreornata* (Miranda-Ribeiro 1926) (Hylidae) showed Isopoda as the most important food category of its diet, while the Phyllomedusidae *Pithecopus rohdei* (Mertens 1926) and *Phyllomedusa*

burmeisteri Boulenger (1882) have Araneae as their most important preys (Teixeira and Vrcibradic 2004; Lima et al. 2010). *Gabohyla pauloalvini*, in turn, is also a feeding habits specialist, preying mostly on arboreal ants. The fact that the diet patterns of anuran species inhabiting "cabrucas" diverge, provides indications that diet guilds are maintained in such cocoa plantations, contributing to the co-occurrence of a range of specialized frog predators in a single environment, which is an interesting aspect of the contribution of agroforestry to biotic conservation (Wanger et al. 2020).

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