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DIET OF *CHIASMOCLEIS CORDEIROI* CARAMASCHI & PIMENTA, 2003 FROM THE ATLANTIC RAINFOREST IN SOUTHERN BAHIA, BRAZIL

Indira Maria Castro[a], Caio Vinícius de Mira-Mendes[b] and Mirco Solé*[a, c]

[a]Programa de Pós-Graduação em Zoologia, Universidade Estadual de Santa Cruz, Rodovia Jorge Amado, Km. 16, Salobrinho, CEP: 45662-900 Ilhéus, Bahia, Brasil; [b]Programa de Pós-Graduação em Sistemas Aquáticos Tropicais, Universidade Estadual de Santa Cruz, Rodovia Ilhéus-Itabuna, km 16, Salobrinho, CEP 45662-000, Ilhéus, Bahia, Brasil; [c]Herpetology Section, Zoologisches Forschungsmuseum Alexander Koenig, Adenauerallee 160, 53113 Bonn, Germany
*Corresponding author. Email: msole@uesc.br

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Abstract. We studied the diet of a *Chiasmocleis cordeiroi* population in a fragment of the Atlantic Forest in the state of Bahia, Brazil. Frogs were collected at night after an explosive breeding event and were transferred to the lab where they were measured, weighed and had their stomach contents retrieved following a stomach flushing protocol. Individuals were later released back into the pond from which they had been collected. Stomach contents were measured and identified to the lowest possible taxonomic level. The most important prey category in the diet of *C. cordeiroi* was Hymenoptera (Formicidae), as has been already observed for other microhylids. The large number of prey items in the stomach and the low niche amplitude suggest that *C. cordeiroi* is a specialist using an active foraging strategy to detect its prey.

INTRODUCTION

The diet of anuran amphibians can be influenced by several factors, such as prey availability and competition (Duellman and Trueb 1994). In their adult phase, almost all anuran species feed on invertebrates (Wells 2007). Vegetable fragments are frequently reported from stomach contents, but in most cases, this is due to accidental ingestion while capturing prey (Solé and Pelz 2007). However, some exceptions have been documented, such as *Xenohyla truncata*, which intentionally ingests small fruits (Silva and Britto-Pereira 2006).

Most anuran species are considered to be generalist predators, arthropods being the main source in their diet, but annelids, mollusks and small vertebrates can be also ingested (Solé and Rödder 2010; Solé et al. 2019; Le et al. 2020). However, diet specialization, which is frequently associated with behavioral, morphological or physiological characteristics, has been observed in several groups (Freed 1982; Solé and Rödder 2010).

Diet composition mirrors the foraging strategy of anurans, which can be classified as "sit and wait" (Duellman and Lizana 1994) and is more associated with generalist feeding, or "active foraging" (Ovaska 1991), which is more characteristic of selective feeding. Recent studies have shown that several species can be placed somewhere within the continuum between these two strategies (Caldart et al. 2011, 2012). According to Toft (1980, 1981), based on these two general dietary patterns, anurans can be differentiated into the so-called "ant specialists", which feed on highly chitinized and slow moving prey as ants, termites and mites, and the so-called "non-ant specialists", which feed on less chitinized prey. The study of amphibian diet allows us to understand their trophic position within ecosystems and the possible impacts that changes in the environment may have on their populations, serving also as a baseline for the development of conservation actions and strategies (Anderson 1991).

Chiasmocleis cordeiroi belongs to the subfamily Gastrophryninae within the family Microhylidae, which contains 688 species in 13 subfamilies (Frost 2020). It is endemic to the southern region of the state of Bahia and its type locality is the municipality of Camamu (Caramaschi and Pimenta 2003). The only available natural history data for the species are its advertisement call and its explosive breeding pattern (Forlani et al. 2013). Studies focused on other species of microhylids have revealed that they can be considered as ant and mite specialists (Erftemeijer and Boeadi 1991; Hirai and Matsui 2000; Solé et al. 2002; Silva et al. 2019).

In this study, we describe the diet of *C. cordeiroi* collected from the vicinity of its type locality and calculate the index of relative importance for each prey category found as well as the trophic niche amplitude.

MATERIALS AND METHODS

The frogs for our study were collected from a temporary pond located in an Atlantic Forest fragment (13º49'15.3"S, 39º11'52.1"W) in the Michelin Ecological Reserve (Igrap-

iúna, Bahia, Brazil). The reserve comprises a 3.096 hectare-large mosaic of forest formations interspersed with areas of banana, cacao and rubber plantations. The forest fragments have a decades-long history of intensive timber harvesting and centuries-long history of cassava cultivation. Most forest fragments are in a secondary development stage, the major part of the preserved areas being located at higher elevations (Flesher 2015). The characteristic climate of the region, according to de Köppen-Geiger, is the humid tropical Af type (Peel et al. 2007).

Chiasmocleis cordeiroi (Figure 1) is an explosive breeder. Frogs were captured manually during one single night in June 2015 between 20:00 and 23:30 during an explosive breeding event. Afterwards frogs were transferred to the Center for Biodiversity Studies of the Michelin Ecological Reserve, where they were weighed on electronic scales and had their snout vent length (SVL) and mouth width (MW) measured with a digital caliper with 0.01 mm precision. Subsequently, they were stomach flushed following the protocol proposed by Solé et al. 2005 and released into the pond, from which they had been collected. Stomach contents were stored in 70% alcohol and identified using a stereomicroscope to the lowest possible taxonomic category.

Figure 1. Adult of *Chiasmocleis cordeiroi*. Photo: Iuri Ribeiro Dias.

The length and width of the well-preserved items were measured in order to calculate the volume of ingested prey. Partially digested prey had the length of their body parts which are less prone to rapid digestion, measured e. g. elytra of beetles or ant heads. These values were used in the regression formulae proposed by Hirai and Matsui (2001) in order to estimate the approximate original length. We estimated the volume of prey using the formula of ellipsoid bodies proposed by Dunham (1983):

$$V = \frac{4\pi}{3}\frac{L}{2}\left(\frac{W}{2}\right)^2$$

Where V = volume, L = length and W = prey width.

To reduce the possible bias occurrence in the diet description, we calculated the index of relative importance (IRI) as proposed by Pinkas et al. (1970):

$$IRI_t = (PO_t)(PI_t + PV_t)$$

where PO_t is the percentage of occurrence (100 × number of stomachs that contained item t / total number of stomachs). PI_t is the percentage of individuals (100 × total number of individuals of t in all stomachs / total number of individuals of all taxa from all stomachs) and PV_t is the volumetric percentage (11 × total volume of individuals of t in all stomachs / total volume of all taxa from all stomachs).

To calculate the trophic niche amplitude we used the standardized Levin´s index (Hurlbert 1978):

$$B_A = \frac{\left(\frac{1}{\sum p_j^2}\right) - 1}{n_j - 1}$$

Where B_A = Levin's standardized index in the diet of a predator A, with an interval from 0 to 1; pj = proportion of the individuals found as resource j; n = number of individuals using resource j. All statistical analyses were performed using the R program (R Core Team 2020).

RESULTS

A total of 119 individuals (117 males and 2 females) were captured, of which 68 revealed stomach contents ranging from one to 95 items per stomach (7.69 ± 13.12). The frogs had a SVL between 17.50 mm and 24.56 mm (20.54 ± 1.41) and weighed between 0.41 g and 1.21 g (0.70 ± 0.12). Mouth width ranged from 4.70 mm to 8.18 mm (5.73 ± 0.57).

The prey categories with the highest relative frequency of occurrence in the stomachs were Hymenoptera (Formicidae) (F% = 62.50), with the species *Solenopsis virulens* (F% = 24.03) and *Nylanderia* sp. (F% = 9.61) showing the highest frequencies, followed by Acari and Isoptera, both with F% = 10.57. Hymenoptera (Formicidae) were found to have the largest relative index of importance (IRI) (IRI = 10846.25), with the species *Solenopsis virulens* (IRI = 1460.06), followed by *Nylanderia* sp. (IRI = 217.28) and *Carebara urichi* (IRI = 186.25) showing the highest values. Detailed data on the diet of *C. cordeiroi* are presented in Table 1. The niche amplitude B_A of the diet of *C. cordeiroi* was 0.02.

DISCUSSION

Ants were found to be the most consumed items in the diet of *Chiasmocleis cordeiroi*. Frogs of the genus *Chiasmocleis* have semi-fossorial habits and show an

Table 1. Prey consumed by *Chiasmocleis cordeiroi.* N = number of prey items; N% = percentage of total number; F = frequency of prey occurrence in stomachs; F% = relative frequency of prey occurrence in stomachs; V = prey volume (in mm³); V% = relative prey volume and IRI = Index of relative importance.

Prey category	N	N%	F	F%	V	V%	IRI
Arachnida							
Acari	15	2.86	11	10.57	6.24	2.25	54.01
Insecta							
Coleoptera	2	0.38	2	1.92	1.88	0.67	2.01
Diptera	1	0.19	1	0.96	0.08	0.02	0.20
Hymenoptera (Formicidae)							
Dorylinae							
Neivamyrmex sp.1	1	0.19	1	0.96	3.01	1.08	1.21
Neivamyrmex sp.2	15	2.86	3	2.88	41.14	14.84	50.97
Ectatomminae							
Gnamptogenys sp.	2	0.38	1	0.96	1.74	0.62	0.96
Formicinae							
Nylanderia guatemalensis	1	0.19	1	0.96	0.26	0.09	0.26
Nylanderia sp.	69	13.19	10	9.61	26.12	9.42	217.28
Myrmicinae							
Apterostigma pilosum	1	0.19	1	0.96	0.52	0.18	0.35
Apterostigma sp.1	4	0.76	2	1.92	4.51	1.62	4.56
Carebara urichi	92	17.59	8	7.69	18.38	6.63	186.25
Rogeria sp.	1	0.19	1	0.96	0.26	0.09	0.26
Sericomyrmex sp.1	1	0.20	1	0.96	1.57	0.56	0.73
Sericomyrmex sp.2	8	1.53	3	2.88	27.17	9.80	32.63
Solenopsis virulens	184	35.18	25	24.03	70.88	25.58	1460.06
Strumigenys sp.	13	2.48	2	1.92	2.23	0.80	6.29
Trachymyrmex sp.	1	0.19	1	0.96	11.26	4.06	4.08
Ponerinae							
Hypoponera foreli	1	0.19	1	0.96	0.1	0.03	0.21
Neoponera concava	1	0.19	1	0.96	4.42	1.59	1.70
Neoponera uridentata	3	0.57	2	1.92	12.1	4.36	9.46
Not identified	44	8.41	12	11.53	21.01	7.58	184.36
Isoptera (Termitidae)							
Nasutitermitinae							
Nasutitermes sp.	60	11.47	11	10.57	15.63	5.64	5.26
Lepidoptera (larva)	2	0.38	2	1.92	6.54	2.36	5.26
Thysanoptera	1	0.19	1	0.96	0.02	0	0.18
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explosive breeding strategy after intense rainfall. The foraging behavior of this species is unknown, but the ecology of the ant species with the highest IRI and niche amplitude can provide some insight into this behavior. Among the ants identified in the diet, *Solenopsis virulens*, *Nylanderia* sp. and *Carebara urichi* showed the highest rates of relative importance.

Solenopsis virulens is a well-known species from Brazil, Guyana and Peru (Wetterer 2011) and can be found in large colonies under the leaf litter (Kempf and Brown 1968). Ants of the genus *Nylanderia* are among the most abundant ants in the environments they occur, being more diverse in warm forest environments. Most species are generalists and form large nests, sometimes built in decaying wood and on litter (LaPolla et al. 2011). *Carebara urichi* is distributed in tropical rainforests and forests in mountainous areas in the Neotropics (Fisher et al. 2014). The ant species showing the largest IRI are also species that build their nests in the subsoil, leaf litter or in decaying wood, but they do not form ant trails.

Similar results, with ants being the most consumed prey, were found for different species of the genus as *Chiasmocleis capixaba* (Van Sluys et al. 2006), *C. albopunctata* (Araújo et al. 2009), *C. alagoanus* (Leite-Filho et al. 2017), *C. leucosticta* (Lopes et al. 2017), *C. hudsoni* and *C. shudikarensis* (Silva et al. 2019). Also, within Microhylidae, similar patterns were found for other species of this family, always revealing large frequencies of occurrence and high relative importance indices for Formicidae (Erftemeijer and Boeadi 1991; Hirai and Matsui 2000; Solé et al. 2002; Berazategui et al. 2007).

According to Scott and Aquino (2005), anuran amphibian species, which feed on such slow-moving small prey as ants, e.g. *Chiasmocleis cordeiroi*, tend to have relatively short heads, small mouths and jaws that are smaller than the head. These characteristics facilitate rapid mouth opening movements and short feeding cycles (time required to ingest the prey). The ability to

consume large quantities of prey in a short period of time has been described as "blitz-feeding" (Mo 2015).

This information suggests an active foraging behavior of *C. cordeiroi*, where individuals tend to feed on smaller and chitin-rich prey, which may live aggregated and may be less agile. The low niche amplitude ($B_A = 0.02$) is a hint that *C. cordeiroi* may be highly specialized and could be considered an "ant specialist" *sensu* Toft (1980, 1981).

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