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FEEDING HABITS OF JUVENILE *CHACOPHRYS PIEROTTII* (CERATOPHRYIDAE-CERATOPHRYINAE) FROM NORTHWESTERN CÓRDOBA PROVINCE, ARGENTINA

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***Abstract*.—The Chacoan Burrowing Frog *Chacophrys pierottii* (Ceratophryidae-Ceratophryinae) is an endemic species of the Chaco region in South America. There is scarce information about the biology of the species and limited information about its post-metamorphic stages. In this work we determined the diet of juvenile *C. pierottii* and estimated the relative importance of the different prey items. We also evaluated relationships between the volume of consumed prey and three morphological features of the frogs: snout-vent length, jaw length, and jaw width. Analysis of 20 stomachs with identifiable prey from a set of 75 frogs collected showed that coleopterans and hymenopterans were the dominant prey items, although the diet also included frogs, insect larvae, dipterans, hemipterans, spiders, and scorpions. We also report cannibalism in *C. pierottii*. This species is a generalist predator similar to some other members of the subfamily. We found no associations between prey volume and the three morphological feature of predator size.**

***Resumen*.—El Escuercito Chaqueño *Chacophrys pierottii* (Ceratophryidae-Ceratophryinae) es una especie endémica de la región biogeográfica Chaqueña de América de Sur. Hay escasa información sobre aspectos de la historia natural de esta especie y es escasa la información sobre la biología de los juveniles de *C. pierottii*. En este trabajo describimos la dieta de juveniles de *C. pierottii* estimando la importancia relativa de las diferentes presas. Además correlacionamos el volumen de las presas consumidas con tres características morfológicas de los escuerzos: largo hocico-cloaca, largo y ancho de la mandíbula. El análisis de 20 estómagos con presas identificables, sobre un total de 75 estómagos, muestra que las presas dominantes en la dieta son coleópteros e himenópteros, además componen la dieta anuros, larvas de insectos, dípteros, hemípteros, arañas y escorpiones. También encontramos canibalismo en *C. pierottii*. Esta especie de anuro es un depredador generalista como lo son otros miembros de la misma subfamilia. No encontramos asociaciones entre el volumen de las presas y las tres características morfológicas analizadas, indicando que la selección del tamaño de presa no se relaciona con el tamaño del depredador.**

Key Words.—Ceratophryinae; Chacoan Burrowing Frog; *Chacophrys pierottii*; diet

INTRODUCTION

Ceratophryine frogs are endemic to South America (Perí 1991) and several species, such as *Lepidobatrachus* spp., *Chacophrys pierottii*, *Ceratophrys cranwelli*, and *Ceratophrys ornata* are endemic to the lowlands of the semiarid Chaco region in South America (Rosset 2001; Fabrezi and Lobo 2009). The Chacoan Burrowing Frog, *C. pierottii*, is distributed in areas of the Chaco region in Argentina, Paraguay, and Bolivia (Cabrera and Willink 1973; Cei 1980). Adults of *Chacophrys* as well as of *Ceratophrys* may be considered terrestrial anurans, while adults of *Lepidobatrachus* are considered aquatic (Fabrezi and Quinzio 2008).

Information concerning the natural history of the subfamily Ceratophryinae (Frost 2011) is scarce (Murphy 1976; Hulse 1978; McClanahan et al. 1983; Ruibal and Thomas 1988; Basso 1990). Several studies have described the morphology (Limeses 1965; Wild 1999; Fabrezi 2006; Fabrezi and Quinzio 2008; Mangione et al. 2011), systematics (Reig and Limeses 1963; Barrio 1970; Lynch 1982; Maxson and Ruibal 1988), and distribution (Cei 1980; Bridarolli and Di Tada 1994; Di Tada 1999; Rosset 2001; Sanabria et al. 2012) of the monotypic genus *Chacophrys*. There are also descriptions of the tadpoles and adults (Cei 1980; Gallardo 1987; Faivovich and Carrizo 1992; Norman 1994; Quinzio et al. 2006), but there is limited ecological information of juveniles and adults (O´Reilly et al. 2002; Lescano 2011).

Information on feeding habits is important to understand anuran life history. The foraging strategies used by an animal might be affected by the surrounding physical environment, but might also be limited by the animal's morphological characteristics and feeding behavior patterns (Emerson 1985; Duellman and Trueb 1994; Metzger and Herrel 2005). Variation in the diet may be reflected in morphological or anatomical features related to foraging strategies, since feeding structures and kinematics may be related to prey size (Hespenheide 1975; Huey and Pianka 1981; Van Cakenberghe et al. 2002; Metzger and Herrel 2005). In amphibians, several studies have described associations between morphological features and the type of prey consumed (Drewes and Roth 1981; Lajmanovich 1996; Parmelee 1999; Pough et al. 1998; Deban et al. 2001). In the case of Ceratophryines, their skull features, particularly of the mouth, are associated with dietary specialization on large prey (Fabrezi 2001; Fabrezi and Emerson 2003; Fabrezi and Lobo 2009).

The dietary habits of adults of the subfamily Ceratophryinae have been described for *Ceratophrys ornata* (Basso 1990), *Ceratophrys cornuta* (Duellman and Lizana 1994), and *Lepidobatrachus llanensis* (Hulse 1978). In particular, Ceratophryines are known for being top predators, and include vertebrates and siblings in their diets (Duellman and Trueb 1994). The present study on juveniles of *Chacophrys pierottii* (Fig. 1) represents the first report of the feeding habits of this species. The aims of the present work were: (1) to describe the diet of *C. pierottii* from an area of the northwestern Córdoba province, Argentina, and to estimate the relative importance of the different prey items; (2) to test for a relationship between the mean volume of consumed prey and several morphological features; and (3) compare our results with what is known for other members of the subfamily Ceratophryinae.

Figure 1. A juvenile of *Chacophrys pierottii* from the northwestern of Córdoba province. (Photographed by M. Gabriela Perotti).

Materials and Methods

Specimen collection.—We collected 75 juveniles of *Chacophrys pierottii* in February 1999 in the vicinity of the towns of L.V. Mansilla and Totoralejos (in an area between 29°51´S, 64°39´W and 29°37´S, 64°50´W), in the northwest of Córdoba province, Argentina. We detected this anuran, rarely observed in the field, in a flood plain area of the dry Chaco region. We transported individuals to the laboratory (Centro Regional de Investigaciones La Rioja-Consejo Nacional de Investigaciones Científicas y Técnicas [CRILAR-CONICET]) in aerated plastic boxes. Less than twelve hours later, we euthanized the individuals in an aqueous solution of chloretone, fixed in 10% formalin, and kept in 70% ethanol. We identified the specimens as advanced juveniles based on their size range (24.4−44.2 mm snout-vent length [SVL]; Lescano 2011) and absence of developed gonads and secondary sexual characters. Specimens analyzed in this study are housed in CRILAR-CONICET, La Rioja, Argentina (CRILAR-MGP0006; CRILAR-PT4600, PT4602, PT4606, PT4609-4610, PT4612, PT4614, PT4616, PT4618-4622, PT, 4626, PT4629, PT4634, PT4637, PT4639, and PT4654).

Diet analysis.—We removed and analyzed stomach contents under a microscope with magnification of 40-X (Olympus SZ61, Olympus Optical Co. Ltd., Tokyo, Japan). We identified each prey item to the lowest possible taxonomic level. In the case of arthropods, we used the keys of Bland and Jaques (1978).

To determine the minimum sample size of stomachs to adequately characterize the diet, we used the accumulated trophic diversity index (Hk; Hurtubia 1973) in which prey item data are taken from frogs at random: Hk = (1/N) × ($\log_2$ N! - S ($\log_2$ Ni!)), where N is the total number of prey items found in the stomach of each animal, and Ni is the total number of prey items of the taxonomic level i in each stomach. The point at which the Hk curve tended to become stable was considered the minimum suitable sample size.

The importance of each food item in the diet was quantified with the Index of Relative Importance (IRI; Pinkas 1971): IRI = % Fo (% N + % V). Percent Fo represents the number of stomachs in which a food item was found, expressed as the percentage of total number of analyzed stomachs; % N considers the number of individuals in each food category expressed as a percentage of the total individuals in all food categories; and % V represents the total volume of a food item expressed as a percentage of the overall volume of stomach contents. We calculated the volume of each prey item by the ellipsoid or cylindrical equation in accordance to the shape of the prey item. We calculated ellipsoid volume by the equation (Dunham 1983): $Ve = (4/3) \times p \times (a/2) \times (b/2)^2$, where a is the length and b is the diameter of the transverse section of the prey item. In the case of worms or other cylindrical prey items, we used the following equation: $Vc = p \times (b/2)^2 \times a$.

We estimated the trophic niche breadth for all frogs collectively by the Levins Index (B; Levins 1968): $B = 1/S\, p_i^2$, where p_i is the IRI proportion of a given item prey in the diet. To compare the niche breadth of *C. pierottii* with that of two other Ceratophryines (*Ceratophrys ornata* and *Lepidobatrachus llanensis*), we used the Standardized Levins Index (Bs; Krebs 1989): $Bs = (B - 1)/(n - 1)$, where B is the Levins Index and n is the number of prey items consumed. The Bs is independent of the number of resources available and allows a comparison between species (Hurlbert 1978; Krebs 1989). The values of Bs range from 0 to 1, with low values indicating the diets dominated by few prey items (specialist predators; Krebs 1989). To calculate the Bs values for *C. ornata* and *L. llanensis,* we used diet data from previous studies (Basso 1990 and Hulse 1978, respectively).

Morphological measurements and analysis.—To evaluate the relationship between morphology of *C. pierottii* and the mean volume of consumed prey, we used Spearman correlation. For this, we measured the SVL, jaw width (JW), and jaw length (JL) of the anuran specimens with a digital Vernier caliper (0.01 mm).

Results

Only 25 of the 75 stomachs studied contained animal content. The type of prey of five of these 25 stomach contents was not possible to identify. Therefore, the number of stomachs used for the diet analysis of *C. pierottii* was 20. This number was greater than the point at which the Hk curve tended to become stable (Hk = 16), and was thus considered a suitable sample size to characterize the diet of juvenile *C. pierottii* at the study time and place.

We identified a total of 15 taxonomic food items, corresponding to seven categories of prey items: Hymenoptera, Coleoptera, Hemiptera, Diptera, Arachnida, Anura, and insect larvae (Table 1). The Index of Relative Importance showed that the most important items in *C. pierottii* diet were Coleoptera and Hymenoptera. The remaining items in order of importance were Anura, insect larvae, Diptera, Hemiptera, and Arachnida. Numerically, the main prey items in the diet were Coleoptera (%N = 33.3%), while anurans and Hymenoptera were the most important items by volume (%V = 41.5% and

Table 1. Index of Relative Importance (IRI) and percentages of number (%N; total number of prey items = 48), frequency of occurrence (%Fo), and volume (%V) of prey items in the stomachs of *Chacophrys pierottii*.

Prey item		% N	% Fo	% V	IRI
Arachnida					
	Araneae	2.08	5	0.05	
	Scorpionidae	2.08	5	1.59	
	Total	4.16	10	1.65	58.19
Vertebrata					
	Anura	4.16	10	41.49	456.62
Insect Larvae					
	Diptera	2.08	5	0.12	
	Lepidoptera	6.25	15	4.36	
	Insect unidentified	2.08	5	0.90	
	Total	10.41	25	5.38	395.04
Hymenoptera					
	Apidae	4.16	10	33.26	
	Formicidae	8.33	20	0.13	
	unidentified	8.33	5	5.30	
	Total	20.83	35	38.70	2,083.76
Coleoptera					
	Curculionidae	14.58	25	2.46	
	Dytiscidae	2.08	5	0.08	
	Heteroceridae	4.16	10	0.08	
	Elateridae	2.08	5	0.66	
	Tenebrionidae	8.33	10	2.92	
	Coccinelidae	2.08	5	0.46	
	Total	33.33	60	6.68	2,401.07
Hemiptera					
	Pentatomidae	6.25	15	5.48	
	unidentified	2.08	5	0.06	
	Total	8.33	20	5.54	277.65
Diptera					
	unidentified	18.75	15	0.53	289.20

38.7%, respectively). For Coleoptera, Curculionidae showed the highest number, frequency, and volume. For Hymenoptera, ants were the most frequent items and bees comprised the largest component by volume. One of the two anurans found in the stomach was identified as *C. pierottii*.

Niche breadth Index (B) of *C. pierottii* was 3.34. The standardized index (Bs) showed the greatest index in *C. pierottii* (0.39), followed by *L. llanensis* (0.33) and *C. ornata* (0.02). The morphological trait measurements for the *C. pierotii* specimens varied approximately two-fold for each variable (Table 2). The correlation analyses of morphological traits (SVL, JW, or JL) and mean volume of prey showed no significant associations: $R = 0.23$, $P = 0.33$; $R = 0.10$, $P = 0.67$; and $R = 0.19$, $P = 0.41$,

Table 2. Range, mean, and standard deviation of morphological features for the 20 juvenile *C. pierottii* analyzed for stomach contents.

Morphological feature	Range	Mean	SD
Snout vent length (mm)	24.4–44.2	37.12	5.80
Jaw width (mm)	11.9–20.7	17.46	2.54
Jaw length (mm)	9.5–16.2	13.57	1.93

respectively.

Discussion

In view of the variety of prey consumed by juveniles of *C. pierottii*, the species appears to be a generalist and opportunistic predator, similar to some other members of the subfamily Ceratophryinae (Toft 1981; Basso 1990; Duellman and Lizana 1994). The diet of juvenile *C. pierottii* was composed mainly of bees, coleopterans, and anurans. The high percentage of empty stomachs and the great number of animals found at the same time suggest that specimens of *C. pierottii* in this study were collected almost immediately after coming out from their cocoons in the soil, soon after hibernation (Cei 1980), or during a local dispersal behavior as a consequence of specific environmental conditions such as previous heavy rains (Duellman and Lizana 1994; Wells 2007).

The standardized niche breath (Bs) found for *C. pierottii* supports the idea of a generalist forager. The Bs index for *L. llanensis*, also described as a generalist forager, was similar to *C. pierottii* index (Hulse 1978). Aquatic invertebrates, such as Oligochaeta and Brachypoda (= Eubrachypoda), were the most important prey items in *L. llanensis*; this species has also been described as an active carnivore and cannibal that eats other anuran species and congeners (Hulse 1978). By contrast, the low Bs found for *Ceratophrys ornata* presumably results from its more selective diet, which consists predominantly of other anurans (Basso 1990).

Regarding the foraging habits of other members of the subfamily Ceratophryinae, Duellman and Lizana (1994) reported that the larger percentages of consumed prey in *Ceratophrys cornuta* were Orthopterans and small vertebrates, whereas ants were the most abundant prey item. Wild (2001) indicated that *Ceratophrys cranwelli* feeds mainly on other anurans. Although there is no information about the foraging habits of *L. asper*, Gallardo (1987) mentioned that this Ceratophryine species may feed on vertebrates and arthropods living in the water. We observed cannibalism in *C. pierottii,* as it has been previously reported for *L. llanensis*, another member of the subfamily (Hulse 1978).

We found no significant correlation between prey volume and the three morphological variables, suggesting that selection of prey by size is not a function of predator size. This may be explained by the frogs' explosive behavior activity, possibly forcing them to fully exploit the scarce resources in a short time; explosive period of activity is a pattern commonly observed in frogs from xeric regions (Wells 2007). *Ceratophrys ornata* showed a significant correlation between maximum mouth width and volume of prey (Basso 1990). It is important to note that *C. ornata* is an active and specialist predator feeding primarily on anurans (Basso 1990) and has been described to perform particular behaviors to attract prey (Radclife et al. 1986). Given the description of diet and morphological analysis performed here for juveniles of *C. pierottii*, this species appears to be an ambush generalist forager, in agreement with that suggested for *C. cornuta* (Duellman and Lizana 1994).

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