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The South-American rattlesnake *Crotalus durissus*: feeding ecology in the central region of Brazil

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Abstract: We investigated food patterns in the diet composition of 452 specimens of *Crotalus durissus* from Central Brazil. Thirty-three items were recorded corresponding to four categories: rodents (75.76%), marsupials (6.06%), unidentified mammals (9.09%) and reptiles (9.09%). Adults of both sexes and some juveniles feed mostly on mammals, specifically rodents, it is the most active and abundant prey throughout the year mainly in areas from Cerrado. In addition, we observed that in *C. durissus* there is a trend in the diet of females could be more diverse, maybe this can be associated to sexual differences involving different strategies of the feeding biology of this rattlesnake.

Keywords: diet composition, mammal specialization, lizards, Cerrado.

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Resumen: Patrones de alimentación fueron investigados en la composición de la dieta de 452 ejemplares de *Crotalus durissus* de Brasil central. Treinta y tres ítems fueron registrados, correspondientes a cuatro categorías: roedores (75.76%), marsupiales (6.6%), mamíferos no identificados (9.09%) y reptiles (9.09%). Los adultos de ambos sexos e individuos jóvenes se alimentaron básicamente de mamíferos, en específico de roedores, esta es la presa más activa y abundante durante todo el año, principalmente en las áreas de Cerrado. Además fue observado que en *C. durissus* existe una tendencia a que la dieta de las hembras sea más diversa, factor que podría estar relacionado a las diferencias sexuales que implican diferentes estrategias de alimentación en la biología de esta serpiente cascabel.

Palabras clave: composición de la dieta, especialista en mamíferos, lagartos, Cerrado.

Introduction

The rattlesnakes of the genus *Crotalus* evolved in North America and subsequently spread across Central and South America (Echevarriagaray et al. 2000; Quijada-Mascareñas et al. 2007). Currently 41 species of *Crotalus* are recognized, with greater a diversity in Mexico and the United States (Uetz et al. 2016). This genus is frequently considered as a model for studies related to ecology, due to its widespread distribution covering several habitats, including deserts, flooded areas, forest environments and open habitats (Norman, 1994; Beaupre et al. 1998; Place & Abramson, 2004).

In many species of *Crotalus* there is ontogenetic variation in diet, with juveniles feeding primarily on ectothermic prey whereas adults prefer endothermic animals as food. Moreover, there is extensive inter- and intraspecific variation in the diet of rattlesnakes. The smaller species, feed primarily on arthropods, amphibians and lizards whereas larger species feed on lizards and small mammals (Klauber 1956, 1972). For instance,

adult *Crotalus horridus* from several regions of the United States (Clark 2002) as well as *C. viridis* in southeast Idaho (Diller & Wallace 1996) feed mainly on birds and small mammals. *Crotalus vegandris* from Venezuela (Pifano & Rodriguez-Acosta 1996), *C. pricei*, and *C. lepidus* from some areas in Mexico and the United States (Holycross et al. 2002; Prival et al. 2002), feed on centipedes, lizards, and snakes. However, a divergence in the diet composition was detected in two populations of *C. lepidus* at Big Bend National Park, Texas (Beaupre 1995). In a similar way, the diet of *C. viridis oreganus* from California is more diverse when compared to *C. viridis* from British Columbia, mainly because of the greater importance of ectothermic prey (Macartney 1989).

The South-American Rattlesnake *Crotalus durissus*, is restricted to South America (Campbell & Lamar 2004) and has a discontinuous distribution (Wüster et al. 2005) from Colombia to Argentina (Vanzolini et al. 1980). Some populations exhibit considerable ecological variation, with closeby populations differing greatly from each other (Campbell & Lamar, 2004).

In Brazil, *Crotalus durissus* is widely distributed, except for the states of Acre and Espírito Santo. In addition, there are isolated populations in open areas within savannas of the Amazonian Forest (Campbell & Lamar 1989). The diet of the species is assumed to be characterized by an extreme specialization in endothermic prey; a feature that exists for only a few species of rattlesnake and which is thought to represent an ancestral trait (Clark 2002). Studies of food composition in populations from southeastern Brazil indicated that rodents and small marsupials were the prey more widely eaten by rattlesnakes (Sant'Anna & Abe 2007); however, birds (Vanzolini et al. 1980) and lizards (Santos & Germano 1996), can be considered as occasional food items in the *C. durissus* diet. In this work, we describe the feeding ecology of *Crotalus durissus* in the central region of Brazil and discuss some strategies involved in the feeding of this rattlesnake.

Material and Methods

The snakes examined represent a total of 452 individuals of *Crotalus durissus* from the central region of Brazil covering forest formations of the Amazon and Atlantic forests, Caatinga and Cerrado; identified as 213 males, 167 females and 72 neonates and juveniles. We considered specimens to be neonates when their snout-vent length was smaller than 400mm (Hoyos, 2012). The specimens are housed in the scientific collections of Instituto Butantan (IBSP), Museu de Zoologia da Universidade de São Paulo (MZUSP), and Universidade de Brasília (CHUNB). Animals kept in captivity prior to being deposited in a scientific collection were excluded from this study.

All food items were removed from the stomach and identified to the lowest possible taxonomic level. Each of the contents was deposited in a glass container with the same identification number as the specimen (voucher number). The intestinal content was determined while taking into account the type of food residue. In addition, available literature records of prey were included in this study, which analyzed the food composition for *Crotalus durissus* from southeastern Brazil (Santos & Germano 1996; Sant'Anna & Abe 2007).

Results

Thirty-three items were recorded in 30 (7%) stomachs. Approximately 52 (12%) of the intestines contained hair. Four prey categories were identified in the stomachs, the main being rodents 75.76% (Figure 2), marsupials 6.06%, followed by unidentified mammals 9.09% and reptiles 9.09% (Figure 3). The rodents were registered in almost all forest formations studied; marsupials were registered only in Cerrado sites, and lizards in areas of Caatinga and Cerrado (Figure 1) (Appendix 1). In addition, these results show a slight trend towards increased consumption of lizards in females. Evidence for ontogenetic or sexual variation was not detected (Table 1).

Overall, the diet composition of the South-American Rattlesnake *Crotalus durissus*, considering information of stomach contents identified from specimens in this study in combination with literature records (Santos & Germano 1996; Sant'Anna & Abe 2007), show a similar feeding patterns: rodents 66.05%, marsupials 3.98%, unidentified mammals 28.38% and reptiles 1.59%; in reference to the reptiles, only six specimens - four of which identified in females had reptiles in their stomach.

Discussion

Considering data to other viperids (Sawaya et al. 2008; Marques et al. 2009; Barbo et al. 2011) the frequency of individuals of *Crotalus durissus* with prey in the stomach was low.

The elapsed time between capture of the snake and its preservation probably is a reason for the low number of prey in the stomach. This is also supported by Sant'Anna & Abe 2007, where the stomach content of *C. durissus* from southeaster Brazil showed a much lower proportion than the gut content.

Approximately 90 percent of rattlesnakes of the genus *Crotalus*, exhibit ontogenetic shifts in food composition, changing from ectothermic to endothermic preys. These variations could be attributed to changes in morphological, behavioral and physiological characteristics during ontogeny (Mushinsky 1987). Alternatively a small percentage of rattlesnakes feed almost exclusively on endothermic preys, like *C. durissus* (Salomão et al. 1995; Duarte 2003), *C. horridus* and *C. molossus* (Clark 2002). Klauber (1956) gathered these three species and another, *C. basiliscus*, in the “*durissus* group”, to demonstrate this specialization.

Mammal specialization may be related to several life history strategies (Martins et al. 2002). In some species of pitvipers, it could be associated with the increased venom toxicity in juveniles; this may be a consequence of the need to immobilize larger prey such as a mammal (Andrade & Abe 1999). Furthermore, the adoption of a juvenile diet based on mammals is more profitable energetically than an ectothermic diet (Martins et al. 2002). In *Crotalus durissus* populations, the low frequency of ectothermic prey could explain such eventual facts.

Given this, behavioral and physiological changes necessary to switch from finding and consuming relatively sedentary ectotherms to finding and consuming fast, active endotherms might be costly (Clark 2002). Moreover, the microhabitat to which similar species are adapted to may not be used by local populations of reptiles that could serve as appropriate prey (Reinert 1984).

Several authors, point out the endothermic preys as a determinant element in food composition of *C. durissus*. For example, Beebe (1946) indicated that a specimen of this rattlesnake from Guyana contained a spiny rat. In populations from Uruguay, Achavál et al. (1978) reported that this rattlesnake commonly feeds on *Cavia pamparum*. Sant'Anna & Abe (2007), studying populations of southeastern Brazil, we observed that some species of rodents of the Caviidae and Muridae families followed by marsupials of the group Didelphidae, were the items most frequently consumed in this region.

In the current study, the diet composition of *C. durissus* was similar, characterized by a greater proportion of rodents. This mammals' group is terrestrial, nocturnal and dwell in open areas but they can also be found in forests (Emmons & Feer 1990; Nowak 1991). Similarly, in Cerrado endothermic prey types are rich and abundant, about 194 species of mammals are recognized, in which 51 are rodents and 17 marsupials (Marinho-Filho et al. 2002). This number has increased with the description of new species and the expansion of occurrence area of others (Bonvicino et al. 2003; Bonvicino et al. 2010).

In *C. durissus*, juveniles and adults feed predominantly on rodents (Sant'Anna & Abe 2007), a pattern attributed to the overall availability of this type of prey (Salomão et al. 1995). Field work confirmed an absence of ontogenetic variation in the diet which indicated that the juveniles of this rattlesnake could survive in dry locations with a supply

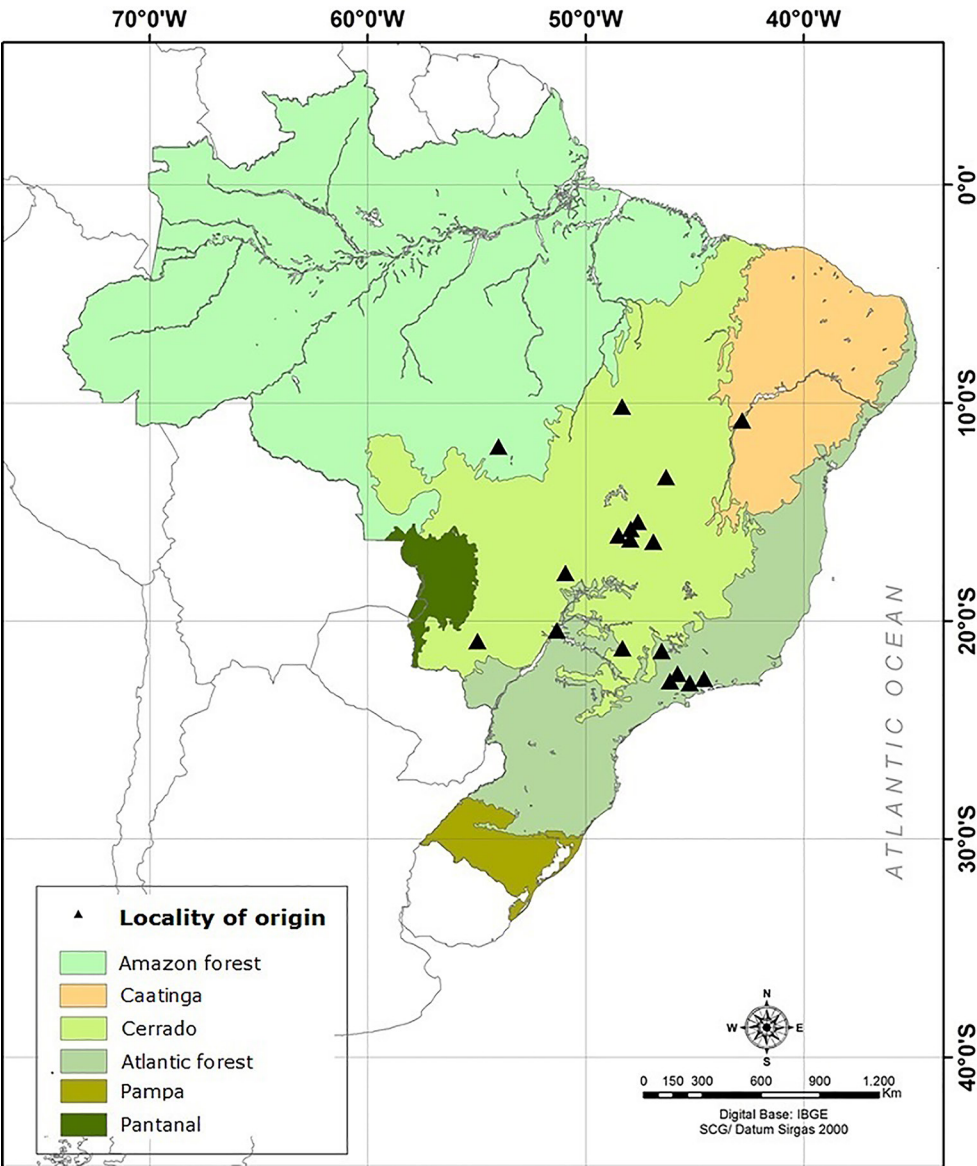


Figure 1. Geographical distribution of *Crotalus durissus* with stomach contents from Central Region of Brazil covering forest formations of Amazon and Atlantic forest, Caatinga and Cerrado.



Figure 2. Food category (rodent) of *Crotalus durissus* from Distrito Federal.



Figure 3. Food item, *Ameiva ameiva*, recorded in the stomach of a female *Crotalus durissus*. Specimen deposited in the Coleção Herpetológica da Universidade de Brasília (CHUNB 49673).

Table 1. Food composition in individual males, females, newborns and juveniles of *Crotalus durissus* from Central Region of Brazil ($n = 30$ snakes).

Categories of preys	Males	Females	Newborns/Juveniles	F	F%
Mammalia					
Not identified		3		3	9.09
Rodentia	9	10	6	25	75.76
Marsupialia					
Didelphidae	1		1	2	6.06
Reptilia					
Teiidae					
<i>Ameiva ameiva</i>		2	1	3	9.09
Total	10	15	8	33	100

of rodents (Tozetti & Martins 2008). The consumption of rodents in all age classes and both sexes is favored because this prey is the most abundant throughout the year. Yet teid lizards (*Ameiva*) (Santos & Germano 1996) can be a sporadic food item in rattlesnakes. The teid *Ameiva ameiva*, is relatively abundant in Cerrado sites (Araujo & Almeida-Santos 2012) and even near human settlements (Colli et al. 2002), usually occupying similar habitats to *Crotalus durissus*. This could be one of the reasons that this species is more frequently consumed rather than other ectothermic prey.

Additionally, some factors such as adaptations related to competition, niche utilization, foraging strategies, costs of time and energy and prey availability (Schoener 1969; Shine 1986; Shine et al. 2002), could reflect important characteristics in the understanding of feeding ecology of *C. durissus* from the central region of Brazil.

Appendix 1

Collection sites with voucher numbers of studied specimens of *Crotalus durissus* and stomach contents from Central Region of Brazil. CHUNB, Coleção Herpetológica da Universidade de Brasília; IBSP, Instituto Butantan; MZUSP, Museu de Zoologia da Universidade de São Paulo.

BAHIA: Ibiraba (MZUSP 10076) - one lizard. **DISTRITO FEDERAL:** Brasília (CHUNB 5439, 22100) - three rodents. **GOIÁS:** Alexânia (CHUNB 20432) - one unidentified mammal; Luziânia (CHUNB 20468) - one rodent; Planaltina (CHUNB 20444, 20446, 20467) - three rodents; Rio verde (CHUNB 49673, IBSP 11997) - one lizard and one marsupial; São Domingos (CHUNB 15499) - one unidentified mammal. **MINAS GERAIS:** Camanducaia (CHUNB 67995) - one rodent; Conceição dos Ouros (IBSP 68493) - one rodent; Muzambinho (CHUNB 24288) - one rodent; Unai (CHUNB 20460, 20475-76, 24379) - one lizard, one unidentified mammal and two rodents. **MATO GROSSO:** Parque Xingú (CHUNB 28739) - one rodent. **MATO GROSSO DO SUL:** Ilha Solteira (IBSP 38087) - one rodent; Sidrolândia (IBSP 23922) - one rodent. **SÃO PAULO:** Aparecida do Norte (IBSP 73254) - one rodent; Jaboticabal (IBSP 23682) - one rodent; São José do Barreiro (IBSP 71480 - 71482) - three rodents. **TOCANTINS:** Palmas (CHUNB 14690) - one rodent. In relation to three specimens from Cerrado, two of them contained two rodents respectively and the other one marsupial; for these snakes the collection sites were undetermined.

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