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Natural history of the rare and endangered snake *Atractus ronnie* (Serpentes: Colubridae) in northeastern Brazil

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Abstract

Natural history of the rare and endangered snake *Atractus ronnie* (Serpentes: Colubridae) in northeastern Brazil. The habitat use, activity period, sexual dimorphism, morphological variation, reproduction and diet composition of this fossorial and nocturnal snake are reported. The snakes were captured between 2008–2014 in the Chapada do Araripe in northeastern Brazil, and were collected by active visual searches, as well as in pitfall traps with drift fences. Although females are larger than males, the males have longer tails, and scale counts differ between the sexes. Reproduction is seasonal, occurring during the rainy season. Brood sizes rang from one to four eggs. *Atractus ronnie* preys on earthworms, in addition to ants (*Crematogaster* sp.) and insect larvae.

Keywords: Cerrado, diet, sexual dimorphism, habits, reproduction.

Resumo

História natural da serpente rara e ameaçada de extinção *Atractus ronnie* (Serpentes: Colubridae) no nordeste do Brasil. O uso do habitat, período de atividade, dimorfismo sexual, variações morfológicas, reprodução e a composição da dieta desta serpente fossória e noturna são relatados. As serpentes foram capturadas entre 2008–2014 na Chapada do Araripe, nordeste do Brasil, e foram coletadas por meio de busca ativa, bem como em armadilhas de queda com cerca guias. Embora as fêmeas sejam maiores que os machos, os machos têm caudas mais longas e as contagens das escamas diferem entre os sexos. A reprodução é sazonal, ocorrendo durante a estação chuvosa. O tamanho da ninhada variou de um a quatro ovos. A principal presa de *A. ronnie* são minhocas, além de formigas (*Crematogaster* sp.) e larvas de insetos.

Palavras-chave: Cerrado, dieta, dimorfismo sexual, hábito, reprodução.

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Introduction

The Neotropical snake genus *Atractus* Wagler, 1828 is remarkably diverse, having about 150 species distributed from Panama to Argentina (Giraudo and Scrocchi 2000, Myers 2003, Passos *et al.* 2018). The descriptions of most species are based on only a few specimens (e.g., Passos and Fernandes 2008, Passos *et al.* 2010) and data on natural history are scant, owing to the secretive habits of the snakes (cryptozoic and semi-fossorial) and localized endemism. This has contributed to the small sample sizes reported by many authors (e.g., Martins and Oliveira 1993, Cisneros-Heredia 2005, Sawaya *et al.* 2008, Barbo *et al.* 2011).

Atractus ronnie Passos, Fernandes, and Borges-Nojosa, 2007 is endemic to the Caatinga Biome where it inhabits highland marshes in the Brazilian state of Ceará (Guedes *et al.* 2014). The taxon was first described for the Serra de Baturité Mountains (Passos *et al.* 2007), but the range also includes the Ibiapaba and Araripe Plateaus (Loebmann *et al.* 2009). *Atractus ronnie* is a federally threatened species, cataloged as Endangered (EN) (MMA 2014). In the Chapada do Araripe, *A. ronnie* is found only in a narrow strip of rainforest on the slopes (Ribeiro *et al.* 2012). Biological data on the species are scarce, with little information available other than the original description (Passos *et al.* 2007). Herein, we provide data on substrate use, activity period, sexual dimorphism, morphological variation, reproduction and diet of *A. ronnie* at the Chapada do Araripe in northeastern Brazil.

Materials and Methods

Study Area

The Chapada do Araripe is located in three states (Ceará, Piauí, and Pernambuco) in northeast Brazil (Lima *et al.* 2012). The altitude varies from 500–1100 m a.s.l. On the slopes, the vegetation is humid forest (tropical cloud forest) and dry forest (semideciduous forest), with Cerrado, Cerradão (xeromorphic semideciduous forest), and Carrasco phytophysiognomies at the top (Tabarelli and Santos 2004). The climate is tropical—i.e., wet and hot with a rainy season from December–May. The mean annual precipitation is 1090 mm^3 and the mean temperature is 24–26°C (IPECE 2016).

We carried out fieldwork monthly at two sites on the slopes of the Chapada do Araripe, in the municipality of Crato, Ceará state. The first site was Delvechia ranch (07°15'19" S, 39°28'12" W; datum WGS 84; 729 m a.s.l.) between March 2008 and February 2010. The second was the Ecological Trail of the Clube Recreativo Granjeiro (07°16'47.0" S, 39°26'17.7" W; datum WGS 84; 691 m a.s.l.) between September 2011 and August 2012 and January–December 2014. These sites are located in a narrow band of humid forest within the boundaries of the Araripe Environmental Protection Area (APA Araripe; Figure 1).

Data Collection

We found the snakes by active, visual-encounter searches by day and by night, and by pitfall traps with drift fences (Table 1). For specimens that we collected by active searches, we recorded the time of capture and the substrate on which the snake was first seen. We took the specimens to the Laboratório de Herpetologia da Universidade Regional do Cariri, where they were euthanized with an intraperitoneal injection of sodium thiopental 50 mg/kg as per the permits issued by the Comitê de Ética em Pesquisa of the Universidade Regional do Cariri. The specimens were fixed with 10% formalin and preserved in 70% ethanol. Voucher specimens are deposited in the Coleção Herpetológica da Universidade Regional do Cariri (URCA-H 149–158, 6203–6204, 10067, 10131–10132, 10261–10264, 10266, 10271, 10540, 10606, 10608–10609, 10656, 11019–11020) and in the Coleção Herpetológica da Universidade Federal de Pernambuco (CHUFPE 99 and 100).

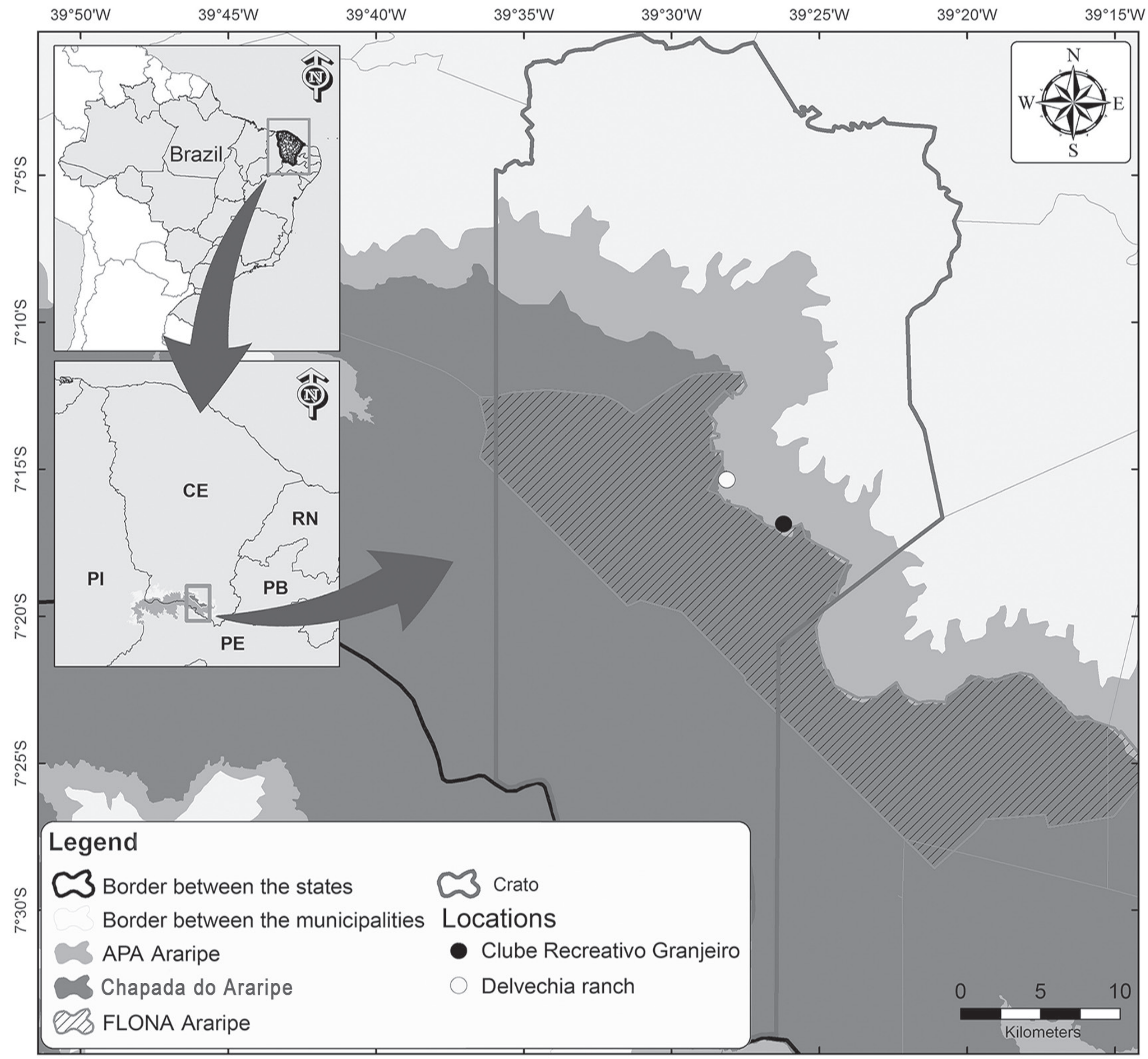

Figure 1. Study area in the Chapada do Araripe, Ceará state, northern Brazil. APA Araripe = Araripe Environmental Protection Area, FLONA Araripe = Araripe National Forest. Legend to Brazilian states: CE, Ceará; PB, Paraíba; PE, Pernambuco; PI, Piauí; RN, Rio Grande do Norte.

Data Analysis

We examined a total of 30 *Atractus ronnie* (Figure 2). For each specimen we recorded the following morphometric variables with digital calipers to the nearest 0.01 mm: snout–vent length (SVL); head length (HL); head width (HW); head height (HH); and tail length (TL). We also counted ventral and subcaudal scales and dorsal scale rows (in 3 regions of the body—i.e., counted one head length from the neck, the middle of the body and one head length from the cloaca) (Peters 1964). Males were considered reproductively active if they possessed convoluted deferent ducts (Shine 1988). Females were considered reproductively active if they possessed

Table 1. Details of sampling methods used in the collection of *Atractus ronnie* at Chapada do Araripe, northeastern Brazil between 2008 and 2014.

Locality	Period	Sampling protocol	Total days in the field	Description of the sampling method	Total effort	Number specimens collected during study
Delvechia Ranch	Mar 2008–Feb 2010	Pitfall traps with drift fences	60	5 arrays (4 buckets 20L per array) Y shape; 5 days, bi-monthly collection	1.200 buckets-day	March 2008 (*N* = 9); February 2010 (*N* = 1)
Ecological trail of the Club Recreativo Granjeiro	Sep 2011–Aug 2012	Active searches	12	1 day per mo; 1 hr per day; 4 collectors	48 hr-collector	March (*N* = 1); June (*N* = 1) in diet of *Bothrops leucurus*
	Jan–Dec 2014	Pitfall traps with drift fences	365	5 arrays (8 buckets 60L per array) straight line	14.600 buckets-day	January (*N* = 3); February (*N* = 5); May (*N* = 1); December (*N* = 2)
		Active searches	48	4 days per mo/ 3 hr per day; 2 collectors	288 hr-collector	October (*N* = 1); November (*N* = 5); December (*N* = 1)

flaccid oviducts, ovarian follicles in secondary vitellogenesis (> 4 mm long) or oviductal eggs (modified from Shine 1988); the simultaneous presence of both vitellogenic follicles and eggs was considered evidence of production of more than one clutch per season (Shine 1977, Fitch 1982). We recorded the number of eggs and/or follicles, as well as the lengths and widths of eggs, follicles, and testicles, and estimated their volumes using the ellipsoid formula: $V = (4\pi/3)(W/2)^2(L/2)$, in which W and L represent width and length, respectively (e.g., Sousa and Ávila 2015).

We calculated the sexual size dimorphism index (SSD) following Shine's (1994) method in which the mean body size of the larger sex is divided by the mean body size of the smaller sex, minus one. Positive values represent females larger than males, and negative values represent the converse (Shine 1994). We used a Mann-Whitney U test to examine intersexual differences in adult SVL, and tested sexual dimorphism in relation to HL, HW, HH, and TL using an ANCOVA with SVL as covariate. We used Student's t-test to examine dimorphism ventral and subcaudal scales in adults. To determine if there is a correlation between SVL and testicle volume and between SVL and egg volume, we used the parametric correlation of Pearson. Descriptive statistical analyses used throughout the paper include means followed by ± SD. We conducted all tests with 1.26 PAST software (Hammer *et al.* 2001), using a 5% significance level.

We dissected each specimen and analyzed stomach contents, identifying the prey to the most precise taxonomic category possible.

Results

Substrate Use and Activity Period

During active searches we observed eight individual *Atractus ronnie*. Four were inactive at 07:15 to 09:51 h and found under fallen logs (2 in November and 1 in December) or buried 10 cm deep in soil loosened by roots (1 in October). The other four were active at 19:26 and 20:22 h and found on the ground (1 in November), in leaf litter (2 in November), and under a fallen

Figure 2. *Atractus ronnie* at Chapada do Araripe, northeastern Brazil.

log in moist soil (1 in March). Twenty-one snakes were captured in pitfall traps and one individual was found in the stomach of a *Bothrops leucurus* Wagler, 1824 (Ferreira-Silva *et al.* 2015) (Table 1).

Sexual Dimorphism

There is significant sexual dimorphism in the tail and snout–vent lengths and the head width of *Atractus ronnie*. Females have a longer SVL (U = 4.20, $p < 0.001$; SSD = 0.23) and a wider head ($F_{1, 24}$ = 21.23, $p < 0.001$). However, males have longer tails ($F_{1, 24}$ = 84.06, $p < 0.001$) (Table 2). Likewise, there is sexual dimorphism in the numbers of ventral and subcaudal scales with females having more ventrals (mean = 142.1 ± 7.3; 139–155) than males (mean = 135.2 ± 3.5; 132–143; t = 8.29; $p < 0.001$), and males having more subcaudals (mean = 23.4 ± 1.1; 22–25) than females (mean = 21.2 ± 2.6; 18–21; t = 8.39; $p < 0.001$). There are three patterns of dorsal scale rows—viz., 17-17-17; 15-17-17; 15-15-15 (Table 3).

Reproduction

The smallest sexually active female was 217.1 mm SVL, whereas the smallest sexually active male was 169.4 mm SVL. We recorded four females with eggs—one in January and three in March. The clutch size varies from 1–4 eggs (mean volume ± SD = 222.7 ± 38.9; 167.6–250.3 mm^3; N = 10); there is no correlation between SVL and egg volume (r = -0.06, p = 0.9). Only one female collected in March had oviductal eggs (mean volume ± SD = 250.1 ± 16.6; 234.7–267.6 mm^3; N = 3). We collected six females with follicles in secondary vitellogenesis—one in February and five in March; the number of these follicles varied from three to seven (mean length ± SD = 7.3 ± 2.2 mm, range = 4.7–11.8 mm; mean volume ± SD = 21.1 ± 16.9 mm^3, range = 4.9–49.2 mm^3; N = 26). Egg laying is coincident with the rainy season (Figure 3). We recorded juveniles in November (N = 3) with one juvenile female having a SVL of 94 mm and two juvenile males with SVLs of 125.2 and 136.6 mm, respectively. The mean volume of the testicles of adult males was 10.1 ± 3.8 mm^3 with a range of 4.5–17.5

Table 2. Morphometrics of adult female and *male Atractus ronnie* (mean ± standard deviation; and range) and sexual dimorphism. SVL = snout–vent length, TL = tail length, HL = head length, HW = head width, HH = head height. Statistically significant results in bold.

Variable	Females (N = 11)	Males (N = 15)	Statistical results
SVL	249.1 ± 21.9; 217.1–289.2	201.8 ± 14.8; 169.4–230.0	U = 4.20, $\mathbf{p < 0.001}$
TL	23.4 ± 3.2; 18.6–29.4	26.8 ± 2.3; 22.9–31.0	$F_{1,24}$ = 84.06, $\mathbf{p < 0.001}$
HL	11.2 ± 0.8; 9.6–12.4	10.9 ± 0.6; 9.4–11.7	$F_{1,24}$ = 3.91, p = 0.06
HW	6.0 ± 0.4; 5.5–6.6	5.6 ± 0.5; 5.0–6.7	$F_{1,24}$ = 21.23, $\mathbf{p < 0.001}$
HH	4.4 ± 0.3; 3.6–4.7	4.1 ± 0.5; 3.3–5.4	$F_{1,24}$ = 9.17, p = 0.99

Table 3. Variation in the number of dorsal scale rows (DO), ventrals (VE), and subcaudals (SC) of *Atractus ronnie* from Chapada do Araripe, Serra de Baturité (Passos *et al.* 2007) and Planalto da Ibiapaba (Loebmann *et al.* 2009), northeastern Brazil.

	Baturité		**Ibiapaba**	**Araripe**	
	Males	Females	Females	Males	Females
N	14	11	1	17	13
DO	17	17	17	17-17-17 (*N* = 2) 15-17-17 (*N* = 12) 15-15-15 (*N* = 3)	17-17-17 (*N* = 5) 15-17-17 (*N* = 8)
VE	134–144	154–160	163	132–143	139–155
SC	20–25	17–20	23	22–25	18–21

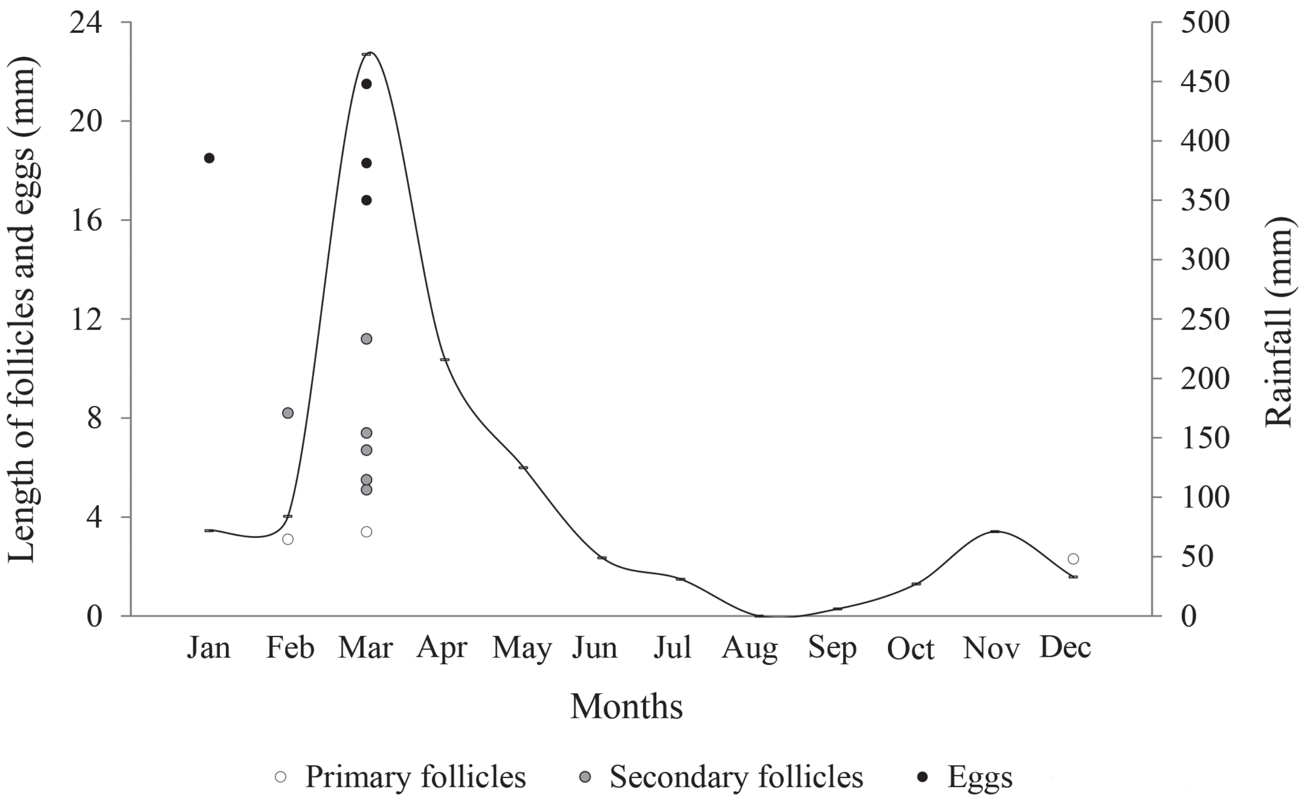

Figure 3. Variation in the length of the largest follicles and eggs of mature females of *Atractus ronnie* and mean monthly rainfall in Crato municipality, Ceará, between 2008 and 2014 (FUNCEME 2014) in the Chapada do Araripe, northeastern Brazil.

mm^3. There is no correlation between SVL and testicular volume ($p = 0.4$). The greatest testicular volume of adult males was recorded in November at 17.5 mm^3 and the least was recorded in February at 4.5 mm^3.

Diet

Of the 30 *Atractus ronnie* examined, only 12 (40%) had stomach contents. Earthworms (Oligochaeta) were the most common prey, representing 84.6% of the 13 recorded items in 11 *A. ronnie*. Most of the earthworms were decomposed, with only the bristles or small parts of the earthworms being visible; the one intact earthworm was 14.7 mm long. One snake had ingested only one ant (*Crematogaster* sp.) and one unidentified insect larvae (7.7% each of the total items).

Discussion

The seasonal variation in abundance of *Atractus ronnie* has also been observed in other species of *Atractus* (Balestrin and Di-Bernardo 2005, Resende and Nascimento 2014). Abundance in the rainy season may be related to reproductive activities when the snakes are moving near the surface of the soil (e.g., males seeking females for mating and females looking sites for thermoregulation and oviposition) (Resende and Nascimento 2014). It also may coincide with higher prey availability (Sawaya *et al.* 2008), and/or other environmental factors (e.g, increase of humidity and temperature; Lillywhite 1987, Resende and Nascimento 2014).

Species of *Atractus* have been reported as nocturnal, or diurnal and nocturnal (Martins and Oliveira 1993, 1998, Marques *et al.* 2004, Barbo *et al.* 2011, Santos-Costa *et al.* 2015, Passos *et al.* 2016). In a study on the Ibiapaba Plateau, Passos *et al.* (2007) stated that *A. ronnie* was active at various hours during the day, and were observed in the field in almost all months of the year, but the snakes were seen more frequently in the rainy season (December–April). In contrast to the observtions of Passos *et al.* (2007), we only observed *A. ronnie* to be active at night.

The sexual dimorphism in SVL and tail length observed in *Atractus ronnie* is characteristic of other species in the genus (Savage 1960, Passos *et al.* 2005, 2007, 2016, Zaher *et al.* 2005). The SSD found here was positive, and although slightly greater, resembles that of *A. reticulatus* (Boulenger, 1885) (Balestrin and Di-Bernardo 2005) and other snakes from the tribe Dipsadini (Pizzatto *et al.* 2007). Usually, females are larger than males in species in which male-male combat does not occur (Shine 1978, 1984). There is no record of male-male combat in *A. ronnie* or its congeners; thus, the pattern we report is expected. The larger size of females may be linked to their reproductive success because larger females may produce more, larger eggs; in addition, larger females may ingest larger prey thereby ensuring greater energy reserves for reproduction (Shine 1986, 1991). Males tend to have longer tails associated with the presence of muscles related to copulatory organ located in the base of the tail (Klauber 1972, King 1989). The dimorphism in snout–vent and caudal lengths also is reflected in segmental counts (Savage 1960, Passos *et al.* 2005), and this correlation is well known in other *Atractus* (Passos *et al.* 2005, 2010).

Moreover, we observed significant sexual dimorphism in head length, with females having larger heads than males. According to Pagel and Harvey (1989), the evolutionary increase in body size dimorphism usually is accompanied by an increase in the degree of dimorphism in relative head size—as we observed in *A. ronnie*. However, Shine (1991) suggested that the increase in female head size might reflect a higher food intake to support the higher energetic expenditure on reproduction by this sex. Owing to the decomposition of the stomach contents we recovered, it was not possible to compare the sizes of the prey ingested by males and females.

We found additional variation in scale counts, mostly in dorsal scales, than that reported by Passos *et al.* (2007) and Loebmann *et al.* (2009). Thus, ventral scales in *A. ronnie* should be considered 139–163 in females and 129–144 in males. The most frequent pattern (67%) of dorsal scale rows in the population of Chapada do Araripe was 15-17-17, in contrast to the findings of Passos *et al.* (2007).

At maturity, female *A. ronnie* are about 30% larger than males, which is consistent with findings for other members of the genus (Balestrin and Di-Bernardo 2005, Resende and

Nascimento 2014) except *A. potschi* Fernandes, 1995 (Passos *et al.* 2016). *Atractus ronnie* reproduces seasonally; recruitment begins at the end of the dry season preceding the rainy season (November), and secondary vitellogenesis, pregnancy, and oviposition occurs in the rainy season (January–March). Seasonal reproduction also was observed in other species of the genus, such as *A. reticulatus* in southern (Balestrin and Di-Bernardo 2005) and *A. pantostictus* Fernandes and Puorto, 1993 in southeastern Brazil (Resende and Nascimento 2014), and it has been suggested for *A. potschi* (Passos *et al.* 2016). Martins and Oliveira (1993) speculated that Amazonian populations of *A. latifrons* (Günther, 1868) and *A. torquatus* (Duméril, Bribon, and Duméril, 1854) might reproduce throughout the year. Reproductive cycles in reptiles are known to vary in response to climate stability; thus, species in seasonal environments (e.g., Caatinga and Cerrado) tend to concentrate reproduction in favorable periods, whereas species in aseasonal environments do not (Fitch 1982). According to Brown and Shine (2006) females tend to lay eggs at the rainy season, when the higher soil moisture is appropriate to embryogenesis.

We observed oviducal eggs in *Atractus ronnie* in March and juveniles with obvious umbilical scars indicating that hatching of eggs occurred recently in November. Thus, oviposition may occur in March–April, and the incubation period may extend to November. Long incubation periods were reported for congeners, such as *A. pantostictus* with 5–8 mo of incubation (Fernandes and Puorto 1993, Cardoso and Maia 2012) and *A. reticulatus* with 8 mo of incubation (Fernandes and Puorto 1993).

Testicular volumes were higher at the end of the dry season preceding the rainy season (November), thereby allowing mating period to occur during the early rainy season. Resende and Nascimento (2014) also reported that the mating period of *A. pantostictus* occurs early in the rainy season.

Clutch size in *Atractus ronnie* varies from one to four eggs, and this is associated with the small body size. Congeners with similar SVLs also have small clutch sizes—e.g., *A. pantostictus,* 3–5 eggs, mean = 378.4 mm SVL, *N* = 5: Barbo *et al.* 2011, Cardoso and Maia 2012; *A. reticulatus,* 1–3 eggs, mean = 307.8 mm SVL, *N* = 5: Balestrin and Di-Bernardo 2005, Barbo *et al.* 2011; *A. carrioni* Parker, 1930, 3–5 eggs, 363 mm SVL, *N* = 2; Passos *et al.* 2013; and *A. schach* (Boie, 1827), 5 eggs, 418 mm SVL, *N* = 1: Martins and Oliveira 1993. Larger *Atractus* have more eggs—e.g., *A. francoi* Passos, Fernandes, Bérnils, and Moura-Leite, 2010, 6 eggs, 473 mm SVL, *N* = 1: Marques *et al.* 2004; *A. gigas* Myers and Schargel, 2006, 12 eggs, 760 mm SVL, *N* = 1: Passos *et al.* 2010; *A. guentheri* (Wucherer, 1861), 6 eggs, 427 mm SVL, *N* = 1: Filadelfo *et al.* 2013; *A. major* Boulenger, 1894, 6–12 eggs, 627 mm SVL of the female with six eggs, *N* = 2: Duellman 1978, Martins and Oliveira 1993; *A. snethlageae* Cunha and Nascimento, 1983, 3–9 eggs, no available SVL: Cunha and Nascimento 1983, Martins and Oliveira 1998; and *A. torquatus,* 3–8 eggs, mean = 693 mm SVL, *N* = 3: Martins and Oliveira 1993.

Atractus ronnie feeds mostly on earthworms, as do most of its congeners (Pérez-Santos and Moreno 1990, Martins and Oliveira 1993, 1998, Balestrin *et al.* 2007, Sawaya *et al.* 2008, Barbo *et al.* 2011). Consumption of ants and insect larvae may be secondary and/or incidental. Pérez-Santos and Moreno (1990) considered ants and other arthorpods found in the stomach of *A. badius* (Boie, 1827) to be secondary ingestions, because these items also were found in the diet of intact earthworms. Martins and Oliveira (1993, 1998) and Bernarde and Abe (2010) found acari and insect remains in the hindgut of other *Atractus* [*A. latifrons, A. major, A. poeppigi* (Jan, 1862), *A. schach,* and *A. torquatus*], which prey mainly on Oligochaeta.

By way of summary, the population of *A. ronnie* at Chapada do Araripe is diurnal and sexually dimorphic, with females having larger bodies and heads than males, and males having longer tails than females. These traits are reflected in the counts of ventral and caudal scales. Three distinct patterns of dorsal scales occur in the population of *A. ronnie*—viz., 15-15-15, 15-17-17 and 17-17-17. The species reproduces seasonally in the rainy season. Members of the population are specialize on earthworms for food. The data presented should aid in the establishment of management programs for this endemic and endangered snake to assure the continued existence of its populations.

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