GROWTH RATES AND PREY-HANDLING BEHAVIOR OF HATCHLING *HELICOPS ANGULATUS* (LINNAEUS, 1758) (SERPENTES; HYDROPSINI) IN THE ATLANTIC FOREST OF NORTHEASTERN BRAZIL

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Resumo

Helicops angulatus é uma cobra de tamanho médio com comportamento aquático, que habita rios, lagos e córregos da América tropical. O presente estudo relata o tamanho dos ovos, taxa de crescimento e comportamento de subjugação de *H. angulatus* com base em cinco recém-nascidos de uma fêmea adulta coletada durante buscas ativas em um fragmento urbano da Mata Atlântica no município de Rio Tinto, Paraíba, Nordeste do Brasil. Em média, os recém-nascidos cresceram 86 mm em comprimento e aumentaram seu peso inicial em 2,6 g no final do período de 12 meses após a postura dos ovos. Os alimentos eram recusados às vezes coincidindo com os dias anteriores às ecdises. A orientação da ingestão variou com o tamanho da presa. Peixes maiores (>41 mm) foram manipulados fora da água e ingeridos primeiramente pela cabeça, enquanto peixes relativamente menores (<30 mm) foram ingeridos tanto pela cabeça quanto pela cauda. O conhecimento sobre tamanho corporal, taxa de crescimento e comportamento alimentar em recém-nascidos pode ser importante para entender plasticidade em características ecológicas, bem como variações intra e interpopulacionais.

Palavras-chave: Tamanho dos ovos, serpente, história de vida

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Abstract

Helicops angulatus is a medium-sized snake with aquatic behavior, inhabiting rivers, lakes, and streams of tropical America. The present study reports on egg size, growth rates and prey-handling behavior of *H. angulatus* based on five newborns of an adult female collected during active searches in an urban fragment of the Atlantic Forest in the Rio Tinto municipality, Paraíba State, Northeastern Brazil. On average, siblings had grown to 86 mm in length, and increased their initial weight by 2.6 g by the end of the 12-month period after egg hatching. Food was refused at times, coinciding with the days that preceded the ecdyses. Swallowing orientation varied with prey size. Large fish (>41 mm) were manipulated out of the water and swallowed headfirst, whereas relatively small fish (<30 mm) were swallowed head- or tail-first. Knowledge on body size, growth rates and feeding behavior on newborns can be important to understand plasticity in ecological traits, as well as intra and interpopulation variations.

Keywords: Egg size, snake, life history

1. INTRODUCTION

Growth rate has profound implications for snake biology, since body size may determine feeding habits, vulnerability to predation, and reproductive output (MADSEN and SHINE, 2000). Some studies in Brazil have presented information on clutch size, hatchling and egg morphology, such as of *Crotalus durissus cascavella*, *Bothrops leucurus*, *B. erythromelas*, and *Thamnodynastes strigilis* (LIRA-DA-SILVA et al., 1994); *Oxyrhopus guibei* (PIZZATTO and MARQUES, 2002); *Tomodon dorsatus* (BIZERRA et al., 2005); O*xybelis fulgidus* (SCARTOZZONI et al., 2005); *Thamnodynastes pallidus* (SANTANA et al., 2017; MEDEIROS-DA-SILVA et al., 2019); *Spilotes sulphureus* (MORAIS et al., 2018); *Helicops leopardinus* (LIRA-DA-SILVA et al., 1994; AMARAL et al., 2019); *Tropidodryas serra* (MUSCAT et al., 2019). However, few studies followed growth rates for over a year, such as of *Eunectes murinus* (LAMONICA et al., 2007) and *Thamnodynastes* sp. (BARBOSA et al., 2006).

The genus *Helicops* Wagler, 1830 currently includes 18 species widespread in South America, of which 14 are recorded in Brazil (COSTA and BÉRNILS, 2018; MORAES-DA-SILVA et al., 2019; UETZ et al., 2020), occurring in water bodies in Amazonia, Atlantic Forest, Caatinga, Cerrado, and Pantanal (SANTANA et al., 2008; ROBERTO et al., 2009; GUEDES et al., 2014). All featuring aglyphous dentition, though some with enlarged rear teeth (ESTRELLA et al., 2011) and mostly viviparous reproductive mode, with the exceptions of *H. gomesi and H. hagmanni* that are oviparous and *H. angulatus*, exhibiting both reproductive modes (ROSSMAN, 1984; BRAZ et al., 2016). *Helicops angulatus* is a moderately sized snake (reaching on average of 700 mm total length), has nocturnal and aquatic behavior and feeds mainly on fishes and amphibians (FORD and FORD, 2002; ROBERTO et al., 2009; MORAES-DA-SILVA et al., 2019).

Information about the reproduction of *Helicops angulatus* is still scarce. The species usually lays eggs but can give birth to live young when suitable nesting sites are not accessible (ROSSMAN, 1984; FORD and FORD, 2002). Litter size can vary from two to 20 eggs (FORD and FORD, 2002; SILVA et al., 2019) and incubation time from 16 to 45 days (ROSSMAN, 1973, 1984; FORD and FORD, 2002). However, other reproductive aspects (e.g., related to body size, sexual dimorphism, reproductive cycle, fecundity)

still require investigation. This study reports on egg size, feeding behavior and early growth of *H. angulatus* based on examinations of newborns of an adult female for a period of 12 months.

2. MATERIAL AND METHODS

We captured an adult female with a clutch of five eggs on 2 November 2016 at 10 a.m., in the Gelo River (6°48'18.37"S, 35°4'26.75"W, 11 m above sea level; Datum WGS84) located in an urban fragment of the Atlantic Forest in the Rio Tinto municipality, Paraíba State, Northeastern Brazil. The female was measured and released in the location of capture the next day. In addition, all eggs were measured at their widest point using a digital caliper to the nearest 0.1 mm and weighed on a digital scale to the nearest 0.1 g. Eggs were kept buried in sand and incubated in a glass container with plant material for a period of 51 days, at the end of which all embryos hatched on 23 December 2016 between 7:30 and 8 p.m. (Fig. 1).

One hatchling was fixed in 10% formalin and preserved in 70% alcohol. This specimen was deposited in the Herpetological Collection of UFPB under collection number RF 302. The others were kept each in different translucent plastic boxes (360 × 300 × 550 mm) with water and a piece of rock for a year. They were kept in a room with constant temperature between 20 and 22 degrees Celsius, humidity approximately 60% and natural sunlight from 6 am to 5 pm. We did not determine the sex of newborns (using snake probe) to avoid possible injuries due to their small size.

The hatchlings went through ecdysis monthly and after this process we took new measurements of snout-vent length and tail length, as well as weighted them after they defecated. Snakes were provided with a fish diet including *Carassius auratus* (Cyprinidae), *Poecilia sphenops* (Poeciliidae), and *Xiphophorus helleri* (Poeciliidae). Feeding took place once a week during the first two months, and once a month afterwards, totaling 17 feeds. After one year all remaining snakes were released in the same place were the mother was captured.

Figure 1. An adult female *Helicops angulatus* (A) and a clutch of five *H. angulatus* eggs at the moment of hatching of the first offspring (B).

3. RESULTS

Measurements for the adult female were 480 mm snout-vent length (SVL), 167 mm tail length (TL), and 118 g mass (MA). The five eggs measured 43.46 ± 2.09 mm in

length and 18.30 ± 1.98 mm in width on average. All hatchlings presented the same color patterns and measured an average of 143.2 ± 7.1 mm in SVL, 67.4 ± 14.5 mm in TL, and 5.5 ± 0.7 g in mass (Table 1).

Table 1. Measurements of offspring and mother (adult) of *Helicops angulatus* on the day of hatching (23 December 2016) and after 12 months (* - 05 November 2017).

ID	SVL	TL	MA
1 (RF 302)	154	80	5.8
2	145	68	4.4
2*	195	86	7.98
3	140	47	5.3
3*	199	89	6.93
4	142	82	6.04
4*	201	103	7.31
5	135	60	6.05
5*	196	96.5	9.8
Adult	480	167	118

Abbreviations: ID, Individuals; SVL, Snout-vent length; TL, Tail length; MA, Mass. All measures are in mm except for mass (g).

Helicops angulatus newborns only started to feed from the third day after birth. They showed a considerable increase in body length in the first months of life but did not grow in body mass. Average hatchling growth was 9.41 mm in SVL, 5.41 mm in TL, and 0.17 g in mass in the first two months (which represents an increase of 6,5% in SVL, 8% in TL and 3% in mass), where feedings occurred at seven-day intervals. After their second month of life, hatchlings stopped eating frequently, and ecdyses started.

Throughout the first few months some hatchlings (individuals 2 and 5) accepted only small fishes (10 mm in length), therefore even though the growth rate was relatively constant, they did not increase significatively the body mass. However, from the fourth month on all snakes started to consume bigger fishes and thus increased in size and body mass.

During feeding, the hatchlings started to subdue and ingest large-sized fish by the head (31-41 mm in length, >1 g in mass; n= 23) and small-sized fish both by the tail and the head (19-30 mm in length, <1 g in mass; n= 38). Ingestion lasted between 1-3 minutes. When larger-sized fish (>41 mm) were offered (n= 5), the snakes kept them underwater for up to 3 minutes. However, as prey continued to move, the snakes raised their heads out of the water for a period of 2-6 minutes until the fish became immobile (Fig. 2). Next, prey was ingested by the snakes starting with the head.

After a year in captivity the hatchlings presented a mean of 197.75 mm in SVL, 93.62

Figure 2: Subjugation of prey (*Carassius auratus*) by a *Helicops angulatus* hatchling. A- Asphyxiation predation technique; B- Swallowing a fish underwater.

mm in TL, and 8.5 g in mass (see Table 1). Compared to their initial sizes, they had an average growth of 86 mm in length (which represents an increase of 60% in SVL) and an average increase of 2.6 g in weight (increase of 47% in weight) (Fig. 3).

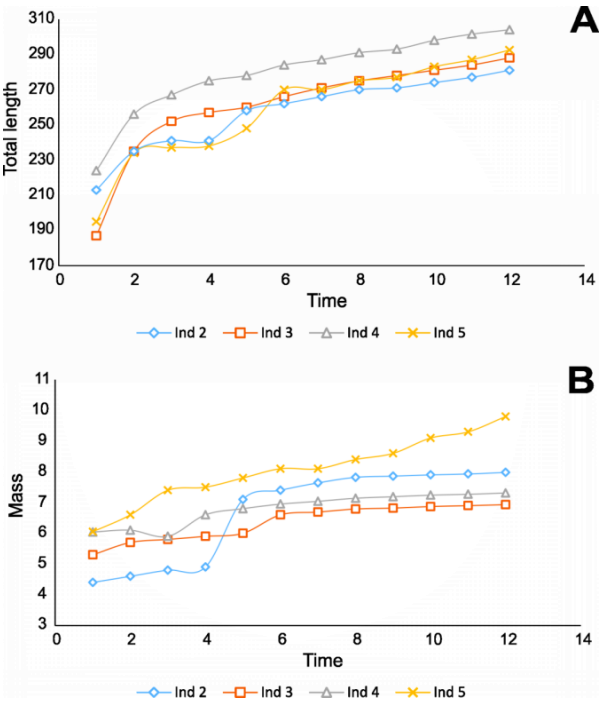

Figure 3. Growth (A) and hatchling mass (B) monitoring data of *Helicops angulatus* from December 2016 (Time 1) to November 2017 (Time 12). Mass was measured in g and total length measured in mm.

4. Discussion

Hatchlings born in captivity do not usually feed until they have reabsorbed egg yolk (XIANG and SUN, 2000; MADSEN and SHINE, 2002) which explains why the newborns fed after the third day after birth. The initial rise in length corroborates that described in Norval et al. (2007), where *Lycodon ruhstrati ruhstrati* hatchlings grew primarily in length but with a body mass reduction. Madsen and Shine (2002) also reported that water pythons (*Liasis fuscus*) grew faster without increasing their body mass, as a longer body can facilitate the ingestion of larger prey.

Differences in snake growth rate during their lifetime are closely associated with food abundance and availability, also referred to as 'silver spoon' effect, which occur especially in the first year of life (MADSEN and SHINE, 2000). We found an initial tail growth rate of 8% in *Helicops angulatus.* Another Dipsadidae, *Thamnodynastes pallidus*, presented an increase of 3% in tail lenght (MEDEIROS-DA-SILVA et al., 2019). These differences may be due to the fact that *T. pallidus* is arboreal and is born with a longer tail compared to *Helicops*'s tail. Other studies must be carried to corroborate this.

Feeding behavior related to prey size has already been observed in the aquatic snake *Natrix maura* that ingested smaller preys by the tail and larger preys by the head, even taking fish out of the water to choke it (HAILEY and DAVIES, 1986). *Helicops infrataeniatus* swallowed small preys either by head or tail-first but larger preys were mainly ingested headfirst (DE AGUIAR and DI BERNARDO, 2004), similar to our findings. In a study on sea snake's (*Aipysurus laevis*) toxin, Zimmerman et al. (1992) reported that one of the effects of snake venom is the paralysis of the prey respiratory system, causing death by asphyxiation. Estrella et al. (2011) indicated that *Helicops angulatus*, despite having an aglyphous dentition, can produce toxins from salivary excretion, which helps to subdue the prey and consequently kill it by asphyxiation.

Comparing the body size of *Helicops angulatus* newborns with the congeneric *H. leopardinus* (LIRA-DA-SILVA et al., 1994; AMARAL et al., 2019), *H. angulatus* hatchlings were born with approximately 21% larger snout-vent length, 41% longer tail and 63% heavier than that of *H. leopardinus*. Both species reach similar maximum lengths and share the same habitats in the northeast Atlantic Forest of Brazil but differ in their reproductive mode. *Helicops angulatus*

exhibits reproductive bimodality and *H. leopardinus* is viviparous (SILVA et al., 2019). The growth of hatchlings during one year in captivity reached approximately 52% of the average total length considered for adults (FORD and FORD, 2002).

Body size and growth patterns can influence important attributes of the natural history of snakes, such as vulnerability to predation, reproductive success, and the maximum size of ingestible prey (ARNOLD, 1993; MADSEN and SHINE, 2002). *Helicops angulatus* is a wide distributed species with few studied populations in Brazil and our data can contribute to future ecomorphological studies and help us elucidate taxonomic and systematic questions on their intra- and interpopulation diversity (MADSEN and SHINE, 2000).

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