Natural history of *Xenodon matogrossensis* (Scrocchi and Cruz, 1993) (Serpentes, Dipsadidae) in the Brazilian Pantanal

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ABSTRACT

*Xenodon matogrossensis* is a neotropical snake restricted to the central part of South America, in the Pantanal wetlands and a few neighbouring areas. The available information about this species in the literature is restricted to geographical distribution, morphological variation and anecdotal information on habitat use. Here we present data on diet, sexual dimorphism and reproduction of *X. matogrossensis*. We gathered information on diet and reproduction from 72 specimens of *X. matogrossensis* deposited in scientific collections. This species feeds mainly on amphibians, but also consumes squamate eggs and other small vertebrates. Mature females are generally bigger than mature males considering body size and head width, but males have longer tail than females. The number of follicles and eggs is not related with body size in females of *X. matogrossensis*. Females showed larger follicle sizes from October to April, however females carrying eggs are found in all stations of the year. The information provided here, associated with others available in the literature can contribute to the assessment of the conservation status of this species and even to design conservation actions in case they are needed in the future.

Key words: Diet; Reproductive Biology; Reptiles; Xenodontinae.

Introduction

*Xenodon matogrossensis* (Scrocchi and Cruz, 1993) (Fig. 1) is a Neotropical snake distributed in the central part of South America, in the Pantanal wetlands and neighbouring ecoregions (Beni, Cerrado and Chaco Savannas; Scrocchi and Cruz, 1993; Giraudo, 1997; Strüssmann et al., 2011; Cabral et al., 2015). It is a member of a species group within *Xenodon* comprising six species that were previously allocated in the genus *Lystrophis* Cope, 1885 until Zaher et al. (2009) synonymized these genera based on molecular evidences. This species group contains *X. dorbignyi* (Bibron, 1854), *X. histricus* (Jan, 1863), *X. nattereri* (Steindachner, 1867), *X. matogrossensis*, *X. pulcher* (Jan, 1863), and *X. semicinctus* (Duméry, Bibron and Duméril, 1854). These species are distributed mainly in open areas of South America and are characterized by having the rostral scale conspicuously keeled (Scrocchi and Cruz, 1993; Cabral et al., 2015). *Xenodon pulcher*, *X. semicinctus*, and *X. matogrossensis* show mimetic colour patterns with coral snakes of the genus *Micrurus*, while the other species of the group show a predominantly pale ground colour with simple bands or ocelli (Cei, 1993; Giraudo, 2002).

Members of this species group are considered psamophilic, inhabiting open areas with sandy soil, and feed mainly on anurans, lizards, and squamate eggs (Orejas-Miranda, 1966; Gudynas, 1979; Williams and Scrocchi, 1994; Oliveira et al., 2001; Carreira and Lombardo, 2007; Nenda and Cacivio, 2007, Sawaya et al., 2008). Concerning reproduction, there is information only for *X. natteteri*, that probably show seasonal reproduction during the hottest months of the year (Sawaya et al., 2008). However, there is only scarce information about the natural history of *X. matogrossensis* in the literature, being
limited to notes about geographical distribution and scattered information on morphological variation and habitat use (Cabral et al., 2015; Nogueira et al., 2019). Here we present data on diet, sexual dimorphism and reproduction of *X. matogrossensis*.

**Material and methods**

We examined 72 specimens of *X. matogrossensis* deposited in the Coleção Zoológica de Referência da Universidade Federal de Mato Grosso do Sul (ZUFMSREP). All records are from Mato Grosso do Sul state (See Appendix I, for specimens examined). For each specimen we recorded the sex and the following morphological variables: (1) snout-vent length (SVL), (2) tail length (TL), (3) head length (HL), (4) head width (HW), (5) number of ventral scales (VS), and (6) number of subcaudal scales (SS). Measurements were made with a measuring tape to the nearest millimeter (SVL and TL), and the remaining variables with a dial calliper to the nearest 0.01 mm.

We made a mid-ventral incision to check gut contents and reproductive characters of the specimens. To describe the diet of *X. matogrossensis* we identified prey remains to the lowest possible taxonomic level, under a stereoscopic microscope. To describe aspects of reproductive biology, we counted and took measures of all follicles or oviductal eggs in females and recorded the length of the largest testis (mm) in males. Sexual maturity in males was determined by the presence of convoluted ductus deferens (Shine, 1982; Almeida-Santos and Salomão, 2002, Pizzatto and Marques, 2002, 2006). Females were considered mature if they had secondary vitellogenic follicles (enlarged and yellowish ovarian follicles), oviductal eggs or folded oviducts (Blackburn, 1998; Mesquita et al., 2013). Minimum size at maturity was estimated as the smallest reproductive individual of each sex. We estimated the maximum potential clutch size by counting the number of secondary vitellogenic follicles, oviductal eggs (counting only eggs, or follicles when eggs where absent), and tested if clutch size is affected by female size. We also recorded if females showed distended or folded middle oviduct macroscopically (Blackburn, 1998; Almeida-Santos et al., 2014), and if males presented turgid testes macroscopically when freshly killed (Pleguezuelos and Fahd, 2004). This data was used to infer the period of reproductive activity (Almeida-Santos et al., 2014).

The degree of sexual dimorphism (SSD index) was calculated as $1 - \frac{\text{mean adult SVL of the larger sex}}{\text{mean adult SVL of the smaller sex}}$ (Gibbons and Lovich, 1990; Shine, 1994). Positive and negative values of SSD correspond to females larger than males and vice versa, respectively. We used an analysis of variance (ANOVA) to test for sexual dimorphism in SVL and scale counts. The other morphological variables (TL, HL and HW) often vary with body length, so we used SVL as a covariate in an analysis of covariance (ANCOVA) to compare these variables between sexes. We tested for effects of body size (SVL) of females on follicles and number of eggs using regression analyses. Statistical analyses were performed with package vegan (Oksanen et al., 2013) in R software (R Core Team, 2019).

**Results**

Females of *X. matogrossensis* are significantly larger than males (ANOVA $F = 4.16, p = 0.049$; Table 1), with an SSD index of 0.15. Additional significant differences between mature males and females were
found for tail length (Fig. 2), head width and number of subcaudal scales (ANCOVA F= 23.49, p < 0.001; ANCOVA F= 5.06, p = 0.031; ANOVA F= 24.8, p < 0.001; respectively).

We found 13 females and 22 males with evidence of sexual maturity through the macroscopic analysis of the gonads. Among them, the smallest mature female and male measured 123 mm and 180 mm SVL, respectively. We failed to find a significant effect of female body size on the number of follicles ($r^2$ = 0.095, F= 3.023, p= 0.0983) or eggs ($r^2$ = 0.291, F= 1.884, p= 0.186), which varied between 1 and 9 (Fig. 3). As is possible to observe at Figure 3, one of the females was found with 9 eggs, even being much smaller (123 mm SVL) than the other mature females (between 294 and 497 mm, Table 2). Five females presented distended oviduct and secondary follicles or eggs at the same time (Table 2), what could suggest the occurrence of multiple reproductive events in short periods of time.

The seasonal size variation of follicles and testes of the mature specimens analysed showed that females have secondary vitellogenic follicles from October to April and males have large testes (> 20 mm) from July to December (Fig. 4).

The number of sexually active specimens (if females showing distended or folded middle oviduct macroscopically, and if males presenting turgid testes) was larger than that of sexually inactive specimens between September to February (Fig. 5).

Nevertheless, the distribution of body sizes throughout the year suggests that juvenile recruitment occurs from the end of the wet season (March) to the middle of the dry season (July) and in November/December.

Table 1. Summary of morphological variables of *X. matogrossensis* from Mato Grosso do Sul state, Brazil. Numbers in bold indicate significant differences (p < 0.05) between sexes (considering mature individuals).

<table>
<thead>
<tr>
<th>Morphological Variable</th>
<th>Females N= 33 Mean (Range)</th>
<th>Males N= 39 Mean (Range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>snout-vent length (mm)</td>
<td><strong>294.3</strong> (118-487)</td>
<td><strong>246.2</strong> (115-395)</td>
</tr>
<tr>
<td>tail length (mm)</td>
<td><strong>38.21</strong> (15-61)</td>
<td><strong>40.26</strong> (16-67)</td>
</tr>
<tr>
<td>head length (mm)</td>
<td>17.26 (9.12-26.30)</td>
<td>14.6 (9.80-23.48)</td>
</tr>
<tr>
<td>head width (mm)</td>
<td><strong>11.47</strong> (5.94-18.24)</td>
<td><strong>9.32</strong> (5.78-17.42)</td>
</tr>
<tr>
<td>ventral scale</td>
<td>135.5 (132-147)</td>
<td>136 (129-145)</td>
</tr>
<tr>
<td>sub-caudal scale</td>
<td><strong>26.82</strong> (23-32)</td>
<td><strong>31.08</strong> (25-42)</td>
</tr>
</tbody>
</table>

Figure 2. Variation in tail length in relation to snout-vent length in males (white dots) and females (black dots) of *Xenodon matogrossensis*.
December (Fig. 6).

Of the 72 specimens analysed, only eight had prey remains in the gut: five had frog remains, two had elongate squamate eggs and one had bones of an unidentified vertebrate. Among amphibian prey, we were able to identify *Physalaemus nattereri* (Steindachner, 1863) and *Rhinella major* (Müller and Hellmich, 1936) (one record each). We also found portions of leptodactylid prey in two individuals, as well as digits of an unidentified anuran in one specimen.

**Discussion**

Our results indicate that *X. matogrossensis* shows the typical natural history features of its species group,

**Table 2.** Summary of reproductive characteristic of mature females of *X. matogrossensis* from Mato Grosso do Sul state, Brazil. SVL: snout-vent length; FnV: non vitellogenic follicles; Sec. Fol: secondary follicles.

<table>
<thead>
<tr>
<th>SVL (mm)</th>
<th>Month</th>
<th>FnV</th>
<th>Sec.Fol</th>
<th>Egg</th>
<th>Follicle Size (mm)</th>
<th>Egg Size (mm)</th>
<th>Folded Oviduct</th>
</tr>
</thead>
<tbody>
<tr>
<td>322</td>
<td>Jan</td>
<td>19</td>
<td>0</td>
<td>5</td>
<td>-</td>
<td>17.2</td>
<td>FALSE</td>
</tr>
<tr>
<td>353</td>
<td>Jan</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>8.55</td>
<td>-</td>
<td>TRUE</td>
</tr>
<tr>
<td>366</td>
<td>Jan</td>
<td>0</td>
<td>7</td>
<td>4</td>
<td>-</td>
<td>9.55</td>
<td>TRUE</td>
</tr>
<tr>
<td>415</td>
<td>Feb</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>TRUE</td>
</tr>
<tr>
<td>441</td>
<td>Apr</td>
<td>9</td>
<td>0</td>
<td>8</td>
<td>-</td>
<td>16.53</td>
<td>FALSE</td>
</tr>
<tr>
<td>123</td>
<td>Sep</td>
<td>0</td>
<td>0</td>
<td>9</td>
<td>-</td>
<td>36.15</td>
<td>FALSE</td>
</tr>
<tr>
<td>386</td>
<td>Sep</td>
<td>34</td>
<td>14</td>
<td>0</td>
<td>5.43</td>
<td>-</td>
<td>FALSE</td>
</tr>
<tr>
<td>487</td>
<td>Jul</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>-</td>
<td>31.55</td>
<td>TRUE</td>
</tr>
<tr>
<td>294</td>
<td>Dec</td>
<td>24</td>
<td>23</td>
<td>1</td>
<td>-</td>
<td>9.38</td>
<td>TRUE</td>
</tr>
<tr>
<td>395</td>
<td>Dec</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>-</td>
<td>32.67</td>
<td>TRUE</td>
</tr>
<tr>
<td>406</td>
<td>Dec</td>
<td>0</td>
<td>0</td>
<td>8</td>
<td>-</td>
<td>23.94</td>
<td>FALSE</td>
</tr>
<tr>
<td>339</td>
<td>Nov</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>TRUE</td>
</tr>
<tr>
<td>380</td>
<td>Nov</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>-</td>
<td>22.36</td>
<td>FALSE</td>
</tr>
</tbody>
</table>
formerly assigned to *Lystrophis*: (1) they feed mainly on amphibians, although it also consumes squamate eggs and other small vertebrates; (2) occur in open areas with sandy soils; and (3) they have a seasonal reproduction (Lema *et al*., 1983; Oliveira *et al*., 2001; Carreira, 2002).

Females showed large follicle sizes from October to April, suggesting that reproduction may be more frequent during this period, even though individuals may be reproductively active throughout the year. Testes are larger in the first half of the rainy season (October to December), what could be an indicative of higher spermatogenesis activity during this period and another indicative of more reproduction events in this period. However, the lack of histological analyses of testes and a higher number of females collected along the years does not allow us to make strong conclusion about the reproductive cycle of *X. matogrossensis* here analysed (Almeida-Santos *et al*., 2014). At the Pantanal region, the period of October to April comprises the hottest and wettest months of the year when several frog species are more actives and breed (Prado *et al*., 2005). This greater availability of prey in conjunction to suitable conditions for high activities of reptiles could favour seasonal reproduction. Oliveira and Martins (2002) suggested that both the snakes and their prey may be responding to the same climatic conditions to breed and seasonal reproduction was reported for snakes from the wetland and dry plain of Pantanal, such as *Micrurus pyrrhocryptus* Cope, 1862 (Ávila *et al*., 2010), and the viviparous *Helicops leopardinus* (Schlegel, 1837) (Ávila *et al*., 2006), and *Bothrops matogrossensis* Amaral, 1925 (Monteiro *et al*., 2006).

The energetic cost of oviparity is lower when compared to viviparity (Gregory *et al*., 1999; Andrews and Mathies, 2000; Shine, 1980, 1985, 2003), and this lower energy waste might make possible multiple reproduction in the same reproductive season (Almeida-Santos *et al*., 2014). In this work five females presented distended oviduct and secondary follicles or eggs at the same time, what could suggest the occurrence of multiple reproductive events in short periods of time. Multiple reproductive events were already reported for oviparous populations of Neotropical xenodontines like *Xenodon dorbignyi* (specie closely related to *X. matogrossensis*, Oliveira *et al*., 2011), *Erythrolamprus poecilogyrus poecilogyrus* (Wied-Neuwied, 1825) (Pinto and Fernandes, 2004), *E. miliaris* (Linnaeus, 1758) (Eisfeld and Vrcibradic, 2019), and other Xenodontini species (Pizzatto *et al*., 2008). Nevertheless, the condition of show distended oviduct and secondary follicles...
or eggs at the same time can also be sometimes observed when females are ready to receive the follicles that were not ovulated (Almeida Santos et al. 2014), what require that more studies need be done to confirm our hypothesis of multiple reproductive events in *X. matogrossensis*. Sexual dimorphism in body size, as observed in *X. matogrossensis*, is commonly found in other terrestrial snakes. The tail of males accommodates the hemipenes and their associated muscles, what results in longer tail and larger number of subcaudal scales when compared with females (King, 1989). Additionally, despite females usually being bigger than males because of enhanced fecundity (Seigel and Fitch, 1984; Shine, 1993; 1994), female body size does not explain the variation in the number of follicles and eggs in *X. matogrossensis*. Considering that more than 90% of the mature females measured around 300 mm or more of SVL (Fig. 3), we believe that at this size females of *X. matogrossensis* could be considered as reproductively actives. Also, early maturation imposes a higher cost on females (Madsen and Shine, 1994) and in many species of snakes the immature eggs or early developing follicles will not be recruited and, thus, will not fully develop into eggs (Seigel and Ford, 1987).

The information on the natural history of *X. matogrossensis* provided here, associated with the information on distribution and habitat use available in the literature (Nogueira et al., 2019), can contribute to the assessment of the conservation status of this species and even to design conservation actions in case they are needed in the future.

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