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Male and female reproductive cycles of *Xenosaurus rectocollaris* (Squamata: Xenosauridae) from the Tehuacan Valley, Puebla, Mexico

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Abstract. We report on the reproductive cycles of male and female *X. rectocollaris* from the Tehuacan Valley, Puebla, Mexico. Testis volume peaked in May. The smallest female with enlarged follicles was 69 mm SVL, which is the smallest size at maturity yet observed in *Xenosaurus*. Maximum follicular volume varied among months, with small peaks in April and July, and a large peak in September. Embryos were largest in July. These cycles are generally similar to those observed in previously studied *Xenosaurus*.

Keywords. Embryos, *Xenosaurus*, ovarian cycle, size at maturity, testes.

Introduction

Lizards in the genus *Xenosaurus* are viviparous (Ballinger et al., 2000b; Lemos-Espinal et al., 2012). Previous studies have found that many populations and species have relatively small mean litter sizes of 2 or 3, but some populations and species have larger mean litter sizes (Table 1). Indeed, Zamora-Abrego et al. (2007) suggested that *Xenosaurus* clusters into two groups of species: one with large litters of small offspring and one with small litters of large offspring. In addition, many species and populations show no relationship between litter size and female body size, whereas others do show such a relationship (Table 1). Observations of female size at maturity range from 90 mm SVL in *X. grandis* (Goldberg, 2009) to 117 mm SVL in *X. phalaroanthereon* (Lemos-Espinal and Smith, 2005; Table 1). These results, when taken together, suggest a considerable amount of variation in reproductive traits within and among species of *Xenosaurus* (see also Zamora-Abrego et al., 2007; Rojas-González et al., 2008).

Despite a growing body of knowledge on litter sizes and other aspects of reproduction of *Xenosaurus*, we still know little about reproductive cycles. In females, ovulation appears to occur in late summer/early fall, with well developed embryos observed from January to early and mid-summer (June–July; Ballinger et al., 2000a; Lemos-Espinal and Smith, 2005; Goldberg, 2009). Parturition occurs in summer, as early as May and as late as September in some populations (Lemos-Espinal and Rojas González, 2000; Lemos-Espinal et al., 2003a; Zamora-Abrego et al., 2007). For female reproductive cycles, the only detailed observations are for *X. grandis* (Ballinger et al., 2000a; Goldberg, 2009) and *X.*

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Table 1. Summary of *Xenosaurus* reproductive traits from previous studies. N.S. = not significant.

Species	Mean Litter Size	Relationship between SVL and Litter Size	SVL at Maturity	Reference
X. grandis	5.1–5.7	+/N.S.	90–100 mm	Ballinger et al. (2000a); Goldberg (2009)
X. g. agrenon	2.7–3.2	N.S.	97–98 mm	Lemos-Espinal et al. (2003a); Zamora-Abrego et al. (2007)
X. g. rackhami	4.5		99 mm	Zamora-Abrego et al. (2007)
X. mendozai	2.7	N.S.	92 mm	Lemos-Espinal et al. (2004)
X. newmanorum	2.6	N.S.	107 mm	Ballinger et al. (2000a)
X. phalaroanthereon	2.3		109–117 mm	Lemos-Espinal and Smith (2005); Zamora-Abrego et al. (2007)
X. platyceps	2.06–2.7	N.S.	101 mm	Ballinger et al. (2000a); Lemos-Espinal and Rojas González (2000); Rojas-González et al. (2008)
X. rectocollaris	2.6	N.S.	93 mm	Zamora-Abrego et al. (2007); Woolrich-Piña et al. (2012)

newmanorum (Ballinger et al., 2000a). Considerably less is known about male reproductive cycles. We are aware of only two published studies, both on *X. grandis* from Veracruz. Smith et al. (2000) found size at maturity to be around 95 mm SVL, with testis volume peaking in August after an increase in size during June and July, suggestive of fall mating. Goldberg (2009) found size at maturity to be around 83 mm and sperm production to occur during August and September. Here we add information on the reproductive cycles of male and female *X. rectocollaris* (Smith & Iverson, 1993) from the Tehuacan Valley, Puebla, México (Fig. 1A,B).

Materials and Methods

The study population is located in the Tehuacan Valley, Puebla, Mexico (18°18’20.49” N, 97°28’55.44” W; 2100–2400 m elevation). Woolrich-Piña et al. (2012) provided additional information on the ecology of this population. Climate corresponds to Cw (temperate with a relatively dry winter) with an environmental temperature and rainfall average of 25.4°C and 401.2 mm, respectively (García, 1988). Vegetation includes a mixture of xerophilous bushes - chaparral, shaped principally by palms (*Brahea dulcis*, *B. nitida*), yuccas (*Yucca periculosa*, *Y. oaxaquensis*), agaves (*Agave stricta*, *A. kerchovei*, *A. potatorum*, *Dasylirion acrotiche*), cacti (*Mytrocereus fulviceps*, *Echinocactus platyacanthus*), and euforbs (*Cnidosculus tehuacanensis*) (Fig. 1C).

Lizards were collected by hand from February 2003–July 2005 (see Woolrich-Piña et al., 2012). A subset of the sample (n = 60; 36 females, 24 males) was sacrificed and preserved shortly after collection (initially in 10% formalin and subsequently in 70% ethanol) and deposited in the herpetological collection of the Laboratorio de Ecología of the Unidad de Biología, Tecnología y Prototipos). We dissected lizards to obtain information on reproductive status. We measured (to nearest 0.1 mm) the length and width of each testis in males and follicles and embryos in females using dial calipers. For testes and embryos we calculated volume using the equation for a prolate spheroid, and for follicles we used the equation for a sphere. To compare testes volume and maximum follicle volume (i.e., volume of largest follicle) among months, we used non-parametric Wilcoxon/Kruskal-Wallis tests due to the unequal sample sizes among months. Due to very small sample sizes in each month, we did not statistically analyze embryo size variation. Means are given ± 1 S.E.

Results and Discussion

Males.—Testis volume showed significant variation among months (Table 2; χ^2_5 = 12.54, P = 0.0028), with the volume peaking in May and July. Our results suggest mean male testis volume peaks in early to mid-summer, and that testis volume declines by fall. This observation is relatively consistent with the testicular cycle of *X. grandis*. Smith et al. (2000) reported that

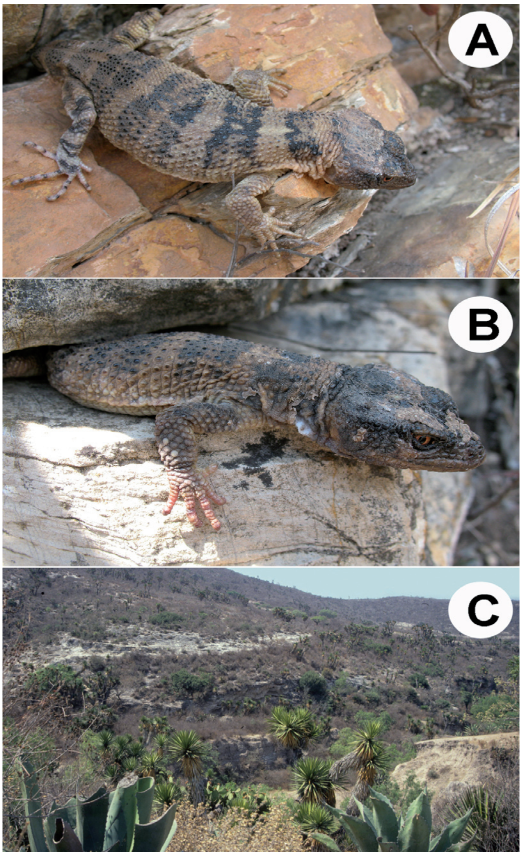

Figure 1.—(A) Female *Xenosaurus rectocollaris* from Chapulco, Puebla, Mexico. (B) Male *Xenosaurus rectocollaris* from Chapulco, Mexico. (C) Habitat of *Xenosaurus rectocollaris* near Chapulco, Puebla, México. Photos by Susy Sanoja-Sarabia.

testes started enlarging in June and July, with a peak in August, and Goldberg (2009) found that *X. grandis* show testicular recrudescence in May. All of the male reproductive cycles observed in *Xenosaurus* so far point to fall mating (this study; Smith et al., 2000; Goldberg, 2009).

Females.—The smallest female with enlarged follicles was 69 mm SVL, suggesting that females from this population mature at a smaller size than other *Xenosaurus* studied so far. All previous observations of sexual maturity (i.e., SVL of smallest reproductively active female) showed it occurring at SVLs of 90–117 mm (see Table 1).

Maximum follicular volume varied among months, with smaller peaks in April and July, and the highest values in September (Table 2; $\chi^2_5 = 11.22$, P = 0.047). Embryos were largest in July (Table 2). Non-vitellogenic follicles were observed in females from every sampled month (Table 3) and vitellogenic follicles were found in all sampled months except April, when only two females were sampled (Table 3). Embryos were observed from April–November (Table 3). Females with both embryos and vitellogenic follicles were observed in July, September, and November (Table 3).

The female reproductive cycle in this population of *X. rectocollaris* is generally similar to cycles of other *Xenosaurus* that have been examined. For example, larger embryos and obviously pregnant females were generally observed from May–August (*X. grandis*: Ballinger et al. 2000a; Goldberg, 2009; *X. newmanorum*: Ballinger et al., 2000a; *X. phalaroanthereon*: Lemos-Espinal and Smith, 2005). These observations are consistent with parturition occurring in the summer months (see Fritts, 1966; Lemos-Espinal and Rojas González, 2000; Lemos-Espinal et al., 2003a; Zamora-Abrego et al., 2007).

The presence of both embryos and vitellogenic follicles in some females suggests that they can produce litters in consecutive years, but the presence of females with only non-vitellogenic follicles in every month also suggests that some females do not reproduce every year. Goldberg (2009) found female *X. grandis* without active ovaries in every month, indicating that not all females reproduce every year. Previous studies have found variable proportions of females reproducing in each year, ranging from high (77% in *X. platyceps*: Ballinger et al., 2000a; 88% in *X. newmanorum*: Ballinger et al., 2000a; 90% in *X. phalaroanthereon*: Lemos-Espinal and Smith, 2005) to low proportions (33% in *X. newmanorum*: Lemos-Espinal et al., 2003b; 58% in *X. grandis*; Ballinger et al., 2000a). These results suggest that the frequency of reproduction varies among populations of *Xenosaurus*, and even among years (see Ballinger et al., 2000a; Lemos-Espinal et al., 2003b).

Conclusion.—Our results suggest that reproductive cycles of male and female *X. rectocollaris* are generally similar to other species of *Xenosaurus*. However, additional detailed information on reproductive cycles, especially those of males, is needed before we can conclude that these results are representative of the genus as a whole. Our results do suggest that size and possibly age at maturity may vary among species more than previously understood. Few observations address size/age at maturity in *Xenosaurus*, especially in males. Future studies should examine size at maturity in more

Table 2. Variation in testis volume (TV), maximum follicle volume (FV), and embryo volume (EV) in mm^3 in *Xenosaurus rectocollaris* from the Tehuacan Valley, Puebla, Mexico. Means are given ± 1 S.E.

Month	TV	FV	EV
February	0.0046 ± 0.0053 (N = 2)	0.0005 ± 0.0040 (N = 5)	--
March	0.0010 ± 0.0033 (N = 5)	--	--
April	--	0.046 ± 0.064 (N = 2)	0.911 (N = 1)
May	0.0259 (N = 1)	0.0008 ± 0.040 (N = 5)	0.871 ± 0.02 (N = 2)
July	0.0170 ± 0.0033 (N = 5)	0.047 ± 0.0045 (N = 4)	1.574 (N = 1)
September	0.0028 ± 0.0037 (N = 4)	0.0947 ± 0.04 (N = 5)	0.36 ± 0.18 (N = 2)
November	0.0074 ± 0.0028 (N = 7)	0.0022 ± 0.037 (N = 6)	0.65 (N = 1)

Table 3. Monthly variation in the reproductive status of adult (SVL ≥ 69 mm) female *Xenosaurus rectocollaris* from the Tehuacan Valley, Puebla, Mexico. Abbreviations for counts include non-vitellogenic follicles (NVF), vitellogenic follicles (VF), and embryos (E).

Month	NVF	VF	E	NVF + VF	NVF + E	VF + E	NVF + VF + E
February	3	2	0	0	0	0	0
April	1	0	0	0	1	0	0
May	3	0	2	2	0	0	1
July	2	0	1	1	0	2	0
September	3	1	0	0	0	2	0
November	3	0	0	0	0	2	0

populations and species, which may provide more information to allow for a better understanding of why it appears to vary among populations and species.

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