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SHORT COMMUNICATION

Neonatal growth of three species of *Xenosaurus* (Squamata: *Xenosauridae*) in captivity

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Lizards of the genus *Xenosaurus* W. Peters, 1861 are mostly crevice- or hole-dwellers, and found in cloud forest, tropical forest, pine-oak forest and xerophytic scrub in the mountains of eastern and southern Mexico (reviewed in Ballinger et al. 2000, Lemos-Espinal et al. 2012). Their conservation status is somewhat variable because of the six species of *Xenosaurus* evaluated in the IUCN Red List, two are endangered (*X. newmanorum* Taylor, 1949, *X. platyceps* King and Thompson, 1968), one is vulnerable [*X. grandis* (Gray, 1856)], two are Least Concern (*X. penai* Pérez Ramos, De la Riva and Campbell, 2000, and *X. rectocollaris* Smith and Iverson, 1993), and one data deficient (*X. phalaroanthereon* Nieto-Montes de Oca, Campbell and Flores-Villela, 2001) (IUCN 2019). The Mexican government lists three species of *Xenosaurus* as subject to special protection (Pr): *Xenosaurus grandis*, *X. newmanorum*, and *X. platyceps* (SEMARNAT 2010). Based on the Environmental Vulnerability Scores of Wilson et al. (2013), one of the nine taxa of *Xenosaurus* is at low vulnerability (*X. grandis*), two are at medium vulnerability (*X. agrenon* King and Thompson, 1968 and *X. rackhami* Stuart, 1941), and six are at high vulnerability (*X. newmanorum*, *X. penai*, *X. phalaroanthereon*, *X. platyceps*, *X. rectocollaris*, and *X. tzacualtipantecus* Woolrich-Piña and Smith, 2012). However, Johnson et al. (2017) placed the 11 species of *Xenosaurus* that they evaluated in the high vulnerability category. Given the conservation status of these lizards, we need to explore possible ways to improve their population status and to obtain a better overall understanding of their biology and ecology.

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Relatively little is known about the growth of individuals in this genus, with only three studies having examined individual growth (Lemos-Espinal et al. 2003, Zúñiga-Vega et al. 2005, Zamora-Abrego et al. 2012). Two of these studies examined growth in non-adults (Zúñiga-Vega et al. 2005, Zamora-Abrego et al. 2012), and we know of none that have investigated individual growth of Xenosaurus in captivity.

We examined the growth of captive-reared neonates of three species of Xenosaurus (X. fractus Nieto-Montes de Oca, Sánchez-Vega and Durán-Fuentes, 2018, X. grandis, and X. rectocollaris) during the first 9–10 months of life. Such information may be useful in developing a head-start program in which gravid females are brought into a lab or facility, give birth, and the neonates raised for a period of time prior to release into nature. In particular, our study will help determine the feasibility of such a strategy by establishing if levels of mortality are acceptable and whether the growth rates of neonates raised in the lab are comparable to growth in natural populations. This study will also provide basic knowledge about the growth ecology and survival rates of the lizards, especially early in ontogeny.

In spring 2016, we collected two gravid Xenosaurus grandis from Cuautlapan, municipality of Ixtaczoquitlán, Veracruz, Mexico, and two gravid X. rectocollaris from the municipality of Zapotitlán Salinas, Tehuacan Valley, Puebla, Mexico (habitats described by Zúñiga-Vega et al. 2007, Woolrich-Piña et al. 2012). At the beginning of the summer of 2016, we collected two gravid X. fractus (Nieto-Montes de Oca et al. 2018) from a pine-oak forest, at an elevation of 1900 m a.s.l., between the municipalities of Zacapoaxtla and Tlatlauquitepec, Puebla, Mexico. We transported the lizards to the Laboratorio de Ecolofisiología del ITS Zacapoaxtla where they were housed individually in plastic containers (45 × 20 × 10 cm) that contained small rocks to simulate the natural microhabitat. We provided the females with free access to water, fed them with moth larvae (Galera sp.) every third day, and kept them at a constant temperature of 20°C, because their body temperatures are similar to their microhabitat and typically range from 18–22°C (Lemos-Espinal et al. 2012). We checked containers daily in the morning and afternoon, and recorded the birth date of any neonates.

Neonates were housed individually in plastic containers (20 × 10 × 10 cm) during the study. We fed them with one moth larva (Galera sp.) daily, and provided free access to water and a constant temperature of 20°C. We measured snout–vent length (SVL; to nearest mm), total length (TL; to nearest mm), and body mass (BM; to nearest g) monthly from July–August of 2016 (depending on the date of birth) to May 2017. To analyze growth rates, we regressed measurements of SVL, BM, and TL on the age of the individual to obtain the slope of the relationship (i.e., growth rate) for each individual. We then averaged this for each species to obtain a mean growth rate (mm/d or g/d). Due to violations of the assumptions of parametric analyses (non-normal distribution and unequal variances), we used a non-parametric Kruskal-Wallis test to compare mean growth rates among species, followed by Wilcoxon pairwise comparisons.

There were differences in SVL growth rates among the three species, but they only approached statistical significance (Table 1; \(H_2 = 5.75, p = 0.056\)). Xenosaurus grandis grew slower than X. fractus (\(p = 0.0452\)) and X. rectocollaris (\(p = 0.055\)). The SVL growth rates of X. fractus and X. rectocollaris were not significantly different (\(p = 0.71\)). The three species did not differ in TL growth rate (Table 1; \(H_2 = 1.65, p = 0.44\)) or BM increase (Table 1; \(H_2 = 0.182, p = 0.91\)).

Growth rates for the captive-reared neonates of X. fractus, X. grandis, and X. rectocollaris were generally within the range of field-measured growth in yearling Xenosaurus, albeit at the lower end of the range. Field estimates of SVL growth rate in yearling X. grandis from Veracruz ranged from around 0.02–0.12 mm/d (estimated
Table 1. Mean ± 1 SE (range) of SVL growth rate, TL growth rate, and body mass (BM) increase for neonates of three species of Xenosaurus.

<table>
<thead>
<tr>
<th>Species</th>
<th>N</th>
<th>SVL growth rate (mm/d)</th>
<th>TL growth rate (mm/d)</th>
<th>BM increase (g/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>X. fractus</td>
<td>8</td>
<td>0.0291 ± 0.0026 (0.0165–0.0418)</td>
<td>0.0440 ± 0.0035 (0.0315–0.0589)</td>
<td>0.0037 ± 0.0017 (-0.00006–0.0128)</td>
</tr>
<tr>
<td>X. grandis</td>
<td>6</td>
<td>0.0235 ± 0.0012 (0.02–0.0266)</td>
<td>0.0408 ± 0.0068 (0.0251–0.0713)</td>
<td>0.0022 ± 0.0008 (-0.0006–0.0055)</td>
</tr>
<tr>
<td>X. rectocollaris</td>
<td>5</td>
<td>0.0296 ± 0.0026 (0.0205–0.0346)</td>
<td>0.0384 ± 0.0033 (0.029–0.048)</td>
<td>0.0036 ± 0.0019 (0.0013–0.0111)</td>
</tr>
</tbody>
</table>

from Figure 2 of Zúñiga-Vega et al. 2005). Field SVL growth rates in X. mendozae Nieto-Montes de Oca, García-Vázquez, Zúñiga-Vega, and Schmidt-Ballardo, 2013 from Sierra Gordo, Querétaro, Mexico, for yearlings ranged from 0.015 to 0.08 mm d⁻¹ (estimated from Figure 2 of Zamora-Abrego et al. 2012).

Because the growth rates in captivity are at the lower end of the observed growth rates in the field, we think that a “head-start” program might be successful, if it were modified to increase growth rates (e.g., change feeding rates, food type, rearing temperature). It also would be useful to have more data on the growth rates of the lizards in nature—both for the neonates/yearlings and adults because of the limited number of studies that have examined individual growth rates in Xenosaurus (X. grandis, Zúñiga-Vega et al. 2005; X. mendozae, Zamora-Abrego et al. 2012; X. newmanorum, Lemos-Espinal et al. 2003). This is particularly important given that individual growth among size classes is key to the population growth rates of some Xenosaurus populations (Zúñiga-Vega et al. 2007, Rojas-González et al. 2008, Zamora-Abrego et al. 2010). Thus, our observed survivorship rates are on par with natural survivorship estimates, but higher in X. grandis than estimated rates of 0.34–0.81 in the population studies by Zúñiga-Vega et al. (2007). However, the variation in survivorship among species suggests that there is no single husbandry technique that will maximize survivorship in all species, and that each species might need to have a specific protocol developed for any lab-based rearing program.

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