

Clutch size in the small-sized lizard *Eurolophosaurus nanuzae* (Tropiduridae): does it vary along the geographic distribution of the species?

Conrado A. B. Galdino^{1,2} & Monique Van Sluys²

1. Departamento de Biologia, Universidade Federal do Ceará, Campus do Pici, Bloco 906, 60455-760 Fortaleza, CE, Brazil. (galdinoc@gmail.com)

2. Departamento de Ecologia, Instituto de Biologia Roberto Alcântara Gomes, Universidade do Estado do Rio de Janeiro, Rua São Francisco Xavier, 524, Maracanã, 20550-019 Rio de Janeiro, RJ, Brazil. (vansluys@uerj.br)

ABSTRACT. We studied life history traits of females of the lizard *Eurolophosaurus nanuzae* (Rodrigues, 1981), an endemic species of rock outcrop habitats in southeastern Brazil. During October 2002 and 2003 we sampled three populations in sites that encompass the meridional portion of the geographic range of the species. Clutch size varied from one to three eggs, with most females carrying two eggs. Clutch size did not vary among populations, but was correlated to female body size. Only larger females produced clutches of three eggs. Females of the small-sized *E. nanuzae* produce eggs as large as those of medium-sized tropidurids, thus investing a considerable amount of energy to produce clutches resulting in high values of relative clutch mass.

KEYWORDS. Life history, interpopulational variation, Squamata.

RESUMO. Tamanho da ninhada no lagarto *Eurolophosaurus nanuzae* (Tropiduridae): há variação ao longo da distribuição geográfica da espécie? No presente trabalho estudamos alguns aspectos da história de vida de fêmeas de *Eurolophosaurus nanuzae* (Rodrigues, 1981), endêmica dos campos rupestres da cadeia do Espinhaço, sudeste do Brasil. Durante outubro de 2002 e outubro de 2003 amostramos três populações em áreas cuja disposição geográfica engloba a parte meridional da distribuição da espécie. O tamanho da postura variou de um a três ovos, sendo que a maioria das fêmeas produziu uma ninhada de dois ovos. O número de ovos não variou entre as populações mas foi relacionado ao tamanho corporal das fêmeas (apenas as fêmeas maiores produziram uma postura de três ovos). As fêmeas de *E. nanuzae* produzem ovos de volume equiparável a espécies de médio tamanho corporal, resultando em elevados valores de massa relativa de postura.

PALAVRAS-CHAVE. História de vida, variação interpopulacional, Squamata.

In lizards, differences in growth rates, fecundity, mortality, and sizes of adults and hatchlings occur among populations within the geographic range of a species (e.g. JAMES & SHINE, 1988; NIEWIAROWSKI, 1994; RADER, 2006; KIEFER *et al.*, 2008) as a result of microevolution (DUNHAM & MILES, 1985).

Clutch size is known to vary between lizards from temperate and tropical regions (RAND, 1982), from seasonal and non-seasonal environments (JAMES & SHINE, 1988) and also among populations of a species (e.g. KIEFER *et al.*, 2008). Such variations arise as responses to local environmental conditions (FERGUSON *et al.*, 1990; SHINE & ELPHICK, 2001), but may also result from evolutionary processes (TINKLE & BALLINGER, 1972; SHINE & GEER, 1991). Hence, one might expect that life history traits of species with broad geographic ranges will vary in response to different environments along their distribution or to genetic dissimilarities among distinct populations (NIEWIAROWSKI, 1994).

In Tropidurid lizards, clutch size often ranges from one to 14 eggs and, within a species, larger females typically produce larger clutches (VAN SLUYS, 1993; VAN SLUYS *et al.*, 2002; WIEDERHECKER *et al.*, 2002). However, *Tropidurus torquatus* Wied-Neuwied, 1820 from coastal populations seems to be an exception because clutch size is not related to female body size (KIEFER *et al.*, 2008). Nonetheless, data on geographic differences in life history traits for tropidurids are still needed (but see KIEFER *et al.*, 2008).

The genus *Eurolophosaurus* Frost, Rodrigues, Grant & Titus, 2001 comprises at least three species of small to medium-sized lizards: *E. amathites* (Rodrigues,

1984), *E. divaricatus* (Rodrigues, 1986) and *E. nanuzae* (Rodrigues, 1981). *Eurolophosaurus nanuzae* is endemic to areas of rocky meadows along the Espinhaço mountain range above 900 m elevation known as *Campos Rupestres* (RODRIGUES, 1981), whereas *E. amathites* and *E. divaricatus* occur in association with sandy areas close to the banks of the São Francisco river (PASSONI *et al.*, 2008). Previous information on reproduction for the genus is restricted to one population of *E. nanuzae* (GALDINO *et al.*, 2003). These lizards reproduce seasonally, females have a mean clutch size of two eggs (one to three), and there is no association between females' body size and clutch size (GALDINO *et al.*, 2003). Herein we present data on clutch size, clutch volume and relative clutch mass of females from three different populations of *E. nanuzae*, encompassing most of its meridional geographic range.

MATERIAL AND METHODS

Field work was conducted in three localities above 800 m elevation along the Espinhaço mountain range (Fig. 1): Diamantina (18°25'S, 43°60'W), Serra do Cipó (19°12'S, 43°40'W) and Serro (18°36'S, 43°23'W). These localities encompass the meridional portion of the geographic distribution of *E. nanuzae* (PASSONI *et al.*, 2008). In all areas, the habitat is dominated by vegetation associated to rocky habitats forming the *Campos Rupestres* physiognomy (GIULIETTI *et al.*, 2000). At the *Campos Rupestres* predominant plant families are Poaceae, Eriocaulaceae, Velloziaceae and Melastomataceae (GIULIETTI *et al.*, 1987). Climate is markedly seasonal, with the rainy season occurring

between October and April and the dry season between May and September (NIMER, 1972). Serra do Cipó is the southern limit of occurrence of *E. nanuzae*, Serro is located ca. 60 km to the north and Diamantina is the northernmost locality sampled (Fig. 1). Nevertheless, Diamantina is located ca. 480 km to the south of the northern limit of the species' distribution.

Females were sampled during the reproductive season (October, GALDINO *et al.*, 2003) of 2002 in Diamantina and Serra do Cipó, and 2003 in Serro. Sampling effort was the same in all locations (4 days). Lizards were caught by noosing or by hand. After capture, individuals were killed and fixed with 10% formalin. All animals were measured with a caliper (nearest 0.1 mm) for the snout-vent-length (SVL) and dissected for gonadal inspection. Clutch size was estimated by counting the number of vitellogenic follicles or oviductal eggs. Follicles were considered vitellogenic when they were yellow and larger than 2.0 mm in diameter (GALDINO *et al.*, 2003). Eggs were weighted with an electronic scale (to nearest 0.001 g) and measured in their length and width within one month after collection. Their volumes were estimated as the volume of a prolate spheroid: $4/3\pi ab^2$ where "a" is the half egg length and "b" the half egg width. Specimens are deposited in Museu Nacional do Rio de Janeiro, Rio de Janeiro (MNRJ).

To test for the association of female SVL with clutch size (number of eggs) and between the clutch size and clutch volume we used Spearman rank correlation. Simple linear regression was used to evaluate the relation between females' SVL and clutch volume and, between female SVL and clutch mass (all \log_{10} transformed). We compared clutch size among populations using Kruskal-Wallis test (ZAR, 1999). Relative clutch mass (RCM) was estimated following VITT & CONGDON (1978): $RCM = CM / FTM$, where CM = clutch mass and FTM = female total mass including clutch mass. Statistical analyses were performed using R (R DEVELOPMENT CORE TEAM, 2009).

RESULTS

We collected 58 females: 18 in Serra do Cipó, 19 in Serro, and 21 in Diamantina. Female body size varied from 35.8 to 60.2 mm (mean 46.6 ± 5.8 mm) in Serra do Cipó, from 42 to 54.6 mm (47.4 ± 3.8 mm) in Serro, and from 35.6 to 55.8 mm (48.2 ± 5.6 mm) in Diamantina. Females' body size did not differ among sites (Kruskal-Wallis $p = 0.14$) (Fig. 2). From these females, six were reproductive in Serra do Cipó, 17 in Diamantina, and 14 in Serro. Reproductive females averaged 47.8 ± 5.20 mm in body size (SVL). Nine females, three in each locality, had evidence of producing more than one clutch simultaneously (mean SVL = 54.1 ± 2.5 mm).

Clutch size varied from one to three eggs. From the 37 mature females, three (8.11%) had one vitellogenic follicle and/or egg, 27 (78.4%) two vitellogenic follicles and/or eggs and five (13.5%) three eggs. There was no difference in clutch size among populations (Kruskal-Wallis $H=3.74$; $p=0.15$). Mean clutch size was 2.01 ± 0.69 with a modal value of two eggs. Females carrying eggs were found in Serra do Cipó ($n=7$) and in Diamantina ($n=6$), but not in Serro. Due to the small sample size of ovigerous females for each population, and because we found no variation in clutch size among populations, we pooled the data from all populations for the following analysis. Clutch size was associated with female body size ($r_s=0.47$; $p=0.004$; $n=34$) (Fig. 3). No female smaller than 54.0 mm had clutches with three eggs. Mean egg volume was 519.05 ± 95.86 mm³, and mean clutch volume was 1014.88 ± 211.45 mm³. We found no association between clutch size and egg volume ($r_s=0.19$; $p=0.54$; $n=12$). Neither clutch mass (1.06 ± 0.23 g) nor clutch volume was related to females' SVL ($F_{1,10}=3.66$, $p=0.08$ and $F_{1,10}=0.65$, $p=0.44$, respectively). Mean relative clutch mass was 0.24 ± 0.05 ranging from 0.17 to 0.31.

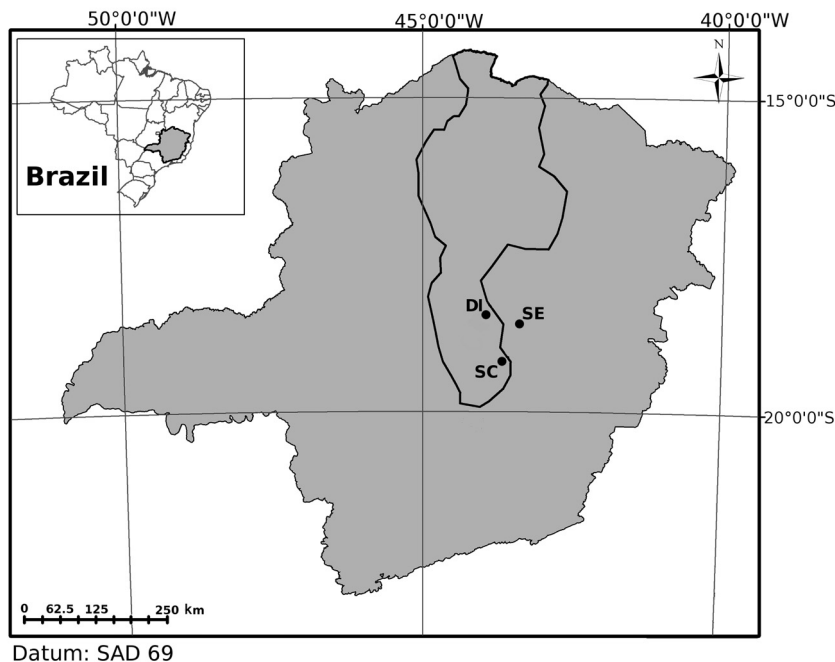


Figure 1. Studied localities at Espinhaço mountain range, Southeastern Brazil (DI, Diamantina; SE, Serro; SC, Serra do Cipó; dark line, limits of Espinhaço mountain range).

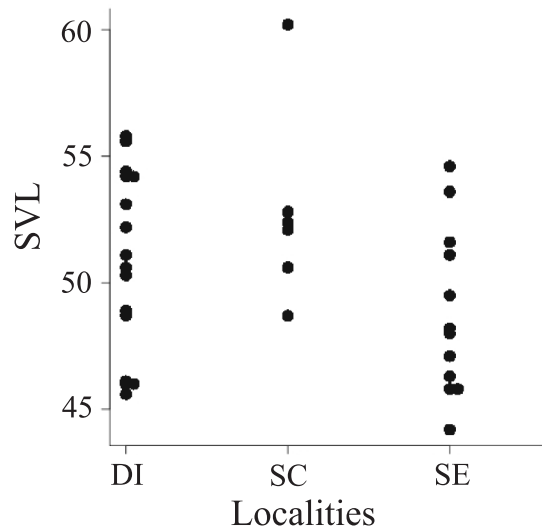


Figure 2. Distribution of females *Eurolophosaurus nanuzae* (Rodrigues, 1981) body size (SVL) in Diamantina (DI), Serro (SE) and Serra do Cipó (SC) state of Minas Gerais, MG.

DISCUSSION

Despite the near invariable clutch size in *E. nanuzae*, this trait was associated to female body size and only larger (older) females were able to produce clutches with three eggs.

Life history traits in lizards are expected to vary geographically in species with broad geographic distributions as a result of local selective forces (QUALLS & SHINE, 1997, 1998; SHINE & DOWNES, 1999; SVENSSON & SINERVO, 2000). Nonetheless, clutch size did not vary among populations of *E. nanuzae*. Small-sized lizards have small clutches in general and a relatively invariant clutch may emerge as a result of a small variance in clutch size (SHINE & GEER, 1991). However, clutch size was related to female body size when data were pooled from all three populations. This result suggests a biological trend for larger females of *E. nanuzae* to produce larger clutches. Only females larger than 54.0 mm produced clutches of three eggs, despite the low frequency of these large females. In an extensive study on the reproduction of *E. nanuzae* at Serra do Cipó, GALDINO *et al.* (2003) found no association between clutch size and females' body size, albeit larger females produced clutches of three eggs. Therefore, females' body size affected their fecundity. The adjustment of clutch size to female body size is a pattern commonly found in lizards (DU *et al.*, 2005). In animals with indeterminate growth, body size is correlated with age, thus the larger *E. nanuzae* females should be the eldest. Because the major cost of reproduction for female lizards is the decrease in their chances of survival and in later reproduction (OLSSON *et al.*, 2001; SVENSSON *et al.*, 2002), and because the energy investment to produce eggs seems to be high for females of *E. nanuzae* (*e.g.* voluminous eggs and high RCM), we suggest that younger females of *E. nanuzae* might benefit from an increased survival by having a clutch of one or two eggs. Therefore, the largest (eldest) females benefit from a high investment in current reproduction inasmuch as their chances of future reproduction decrease. Since in several

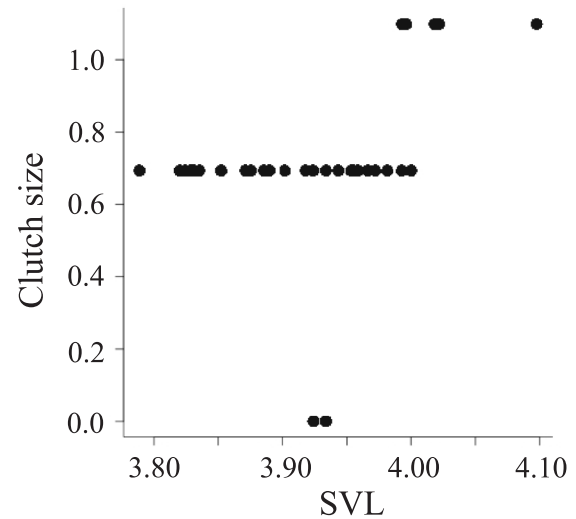


Figure 3. Association between clutch size and female body size (SVL), both log transformed, for *Eurolophosaurus nanuzae* (Rodrigues, 1981) from three populations from southeastern Brazil.

small-sized lizards the probability of surviving to another reproduction is inversely related to fecundity (TINKLE, 1969), we believe this might be the case in *E. nanuzae*.

Clutch volume was not associated with female body size. Probably, females of *E. nanuzae* produced an optimal-sized egg (and/or maternal investment per offspring) in consequence of limitations of their small body size. The lack of an inverse relation between egg volume and clutch size may also constitute an evidence of an optimal egg size for *E. nanuzae*. Egg volume in *E. nanuzae* is high even when compared to larger tropidurids. As an example, females *T. hispidus* Spix, 1825 and *T. torquatus* averaged eggs with similar volumes despite their larger body sizes (VITT, 1993; KIEFER *et al.*, 2008). The Relative Clutch Mass of *E. nanuzae* is also high when compared to other tropidurids (see KIEFER *et al.*, 2008, tab. IV), indicating a considerable high energy allocation in the production of offspring by females. Indeed, *E. nanuzae* has low rates of locomotion during activity (Mara C. Kiefer, pers. comm.) and uses crypsis as its primary defense strategy (GALDINO *et al.*, 2006), behaviors associated with larger RCM (VITT & CONGDON, 1978). Therefore, the production of larger individual offspring may constitute a trait increasing the fitness of *E. nanuzae*.

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