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REPRODUCTION AND POPULATION TRAITS OF *Clyomys laticeps* (THOMAS, 1909) (RODENTIA: ECHIMYIDAE)

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Abstract: Echimyidae encompasses the highest rodent species richness within Caviomorpha, thus presenting different evolutionary histories. However, information regarding species' biology, behavior, and ecology is still scarce for this group, precluding investigations of the role of phylogenetic and ecological factors on diversity. We investigated the reproduction and population traits of the semi-fossorial echimyid *Clyomys laticeps*. *Clyomys laticeps* individuals were captured through a capture-mark-recapture approach in the Cerrado domain at Serra de Caldas Novas State Park, state of Goiás, Brazil, from August 2018 to February 2020. The species presented a 1:1 sex ratio and sexual monomorphism in body mass, which probably reflected a dispersal behavior in both sexes or a weak competition for mates in the population. *Clyomys laticeps* reproduces year-round, and females are predominantly monotocous, with long gestation lengths, which likely contributes to low density and a lack of seasonal population fluctuations within a year.

Keywords: breeding; litter size; population size; sex ratio; sexual monomorphism

The echimyid rodents (Rodentia, Echimyidae) present 117 recognized species distributed in Central and South America (Mammal Diversity Database 2024), occurring in all Brazilian biomes and encompassing a variety of ecomorphological adaptations (Fabre *et al.* 2017). Despite the high species richness and ecological diversity of echimyids, information regarding their species behavior, ecology, and reproductive patterns is still scarce (Wolff & Sherman 2008, Ebensperger & Hayes 2016), especially from wild populations. Indeed, Wolff (2003) noted that to improve confidence in laboratory results, we should also document this in the field. Hence, long-term studies with periodical sampling from free-living populations are needed to fully understand echimyid behavior and reproductive activity.

Overall, there is evidence that echimyids can reproduce throughout the year, thus presenting non-seasonal reproduction (Roberts *et al.* 1988, Luchesi *et al.* 2019, Silva & Mancina 2023). In captivity, gestation takes approximately 60-100 days (Weir 1973, Roberts *et al.* 1988, Luchesi *et al.* 2019). Each female produces three or more litters per year, ranging from one to three precocious pups in most species studied to date (Roberts 1988, Ebensperger & Hayes 2016, Silva & Mancina 2023). Adler (2011) reported low density for most species, probably due to reduced fecundity. Although these natural history data are essential for understanding population dynamics, little is known about most burrowing echimyids, such as *Carterodon sulcidens*, *Clyomys laticeps* and *Euryzygomatomys spinosus* (Tavares *et al.* 2019).

Clyomys laticeps is a semi-fossorial echimyid distributed along the Cerrado domain and the Paraguayan Chaco (Bezerra *et al.* 2016). This species occupies subterranean galleries, although it may also forage aboveground. Recent studies

suggest solitary behavior and an herbivorous diet (Ferrando *et al.* 2019, Luchesi *et al.* 2022, Ferrando *et al.* 2023). A few anecdotal studies have addressed the reproductive behavior of this rodent, with scant information suggesting small litter size and seasonal reproduction (Vieira 1997, Patton *et al.* 2015). To fulfill this gap, we investigated whether individuals presented sexual dimorphism in body mass and provided data on the adult sex ratio, population size, seasonality of reproduction, and number of litters and pups produced by *C. laticeps* females.

The study was conducted at a Cerrado grassland site at Serra de Caldas Novas State Park (PESCaN) (17º 48' 28.1'' S, 48° 42' 09.7'' W, *datum* WGS84), state of Goiás, Brazil, from August 2018 to February 2020. The climate is characterized by two seasons: a dry season (April-September) and a wet season (October-March) (Silva *et al.* 2008). As rainfall started later in 2019, we considered October 2019 as a dry season (AMAT 2020). The trapping procedures of this study were part of a research project on the social behavior of *C. laticeps* approved by the Sistema de Autorização e Informação em Biodiversidade (No: 62336-2) and the Ethics Committee on the Use of Animals of the Federal University of Uberlândia, Brazil (No: 001/19), and were consistent with the guidelines for animal research provided by the National Advice of Control and Animal Experimentation (CONCEA 2018) and the American Society of Mammalogists (Sikes & Animal Care and Use Committee of the American Society of Mammalogists 2016).

Clyomys laticeps individuals were captured bimonthly through a capture-mark-recapture approach from August 2018 to February 2020, using a 120 m x 140 m trapping grid composed of eight transects equidistant 20 m, each with seven trapping points equidistant 20 m. Sherman traps (43 x 12.5 x 14.5 cm) were set every 40 m within each transect, alternating between four and three traps per transect (N = 28 traps). Moreover, traps were set in active burrows (*e.g.*, freshly excavated soil, with remnants of freshly consumed fruits, fresh feces) within the trapping grid (see Malizia 1998). The traps were baited with a mixture of peanut butter, banana and oats, and were checked every morning for ≥ 5 consecutive nights (maximum of 10). Each individual was marked with a numbered ear tag, and sex, body mass, age class (pup < 100 g; juvenile 100 - 200 g, adult > 200 g, Ferrando *et al.* 2019), and reproductive status of females (pregnant, lactating, or receptive to copulation visualized by the presence of perforated vagina) were recorded. Additionally, individuals were captured using Sherman traps set at the entrance of active burrows along the Cerrado grassland site next to the trapping grid (encompassing a total area of 11 ha – including the trapping grid area) to increase the sample size for the analysis of sexual size dimorphism. These traps were set in May and June 2018, February, August and October 2019, and February and August 2020.

Sex ratio and population size were estimated using the longitudinal capture-mark-recapture dataset (August 2018 – February 2020). The adult sex ratio (ASR) was calculated based on the proportion of males in the adult population (*i.e.*, $ASR = N_{male} / (N_{male} + N_{female})$) (Ancona *et al.* 2017), and significance was tested with a binomial test. The population size was estimated using the minimum number of individuals known to be alive (MNKA) between intervals (in this study, two months) (Krebs 1966). To minimize sampling bias, we included only individuals captured within the first five nights of the trapping session. Moreover, we considered those adults captured only once as transients and those captured more than once in the trapping grid as residents (Galindo-Leal 1997, Malizia 1998). Sexual size dimorphism was estimated considering all the adults (except lactating and/or pregnant females). The mean body mass (used as a proxy of the body size) of males and females was compared with a t-test. All analyses were performed in R version 3.6.3 (R Core Team 2020), and in the absence of a normal distribution of data, permutation tests were performed with 1,000 iterations.

Fifty-three individuals were captured, with 31 individuals captured outside and 22 individuals inside the trapping grid (Females: 18 adults and 15 juveniles and pups; Males: 10 adults and 10 juveniles and pups) through a sampling effort of > 5,900 trap-nights within an 11ha area. From these 22 captured in bimonthly trapping sessions, 18 individuals were captured in traps placed in active burrows, with a total sampling effort of 4,344 trap-nights (Adults: 15 = 7 males and 8 females; Juveniles and pups: 7 = 5 females and 2 males). Seven adults were classified as residents (2 males; 5 females), those captured longer than 5 months within the grid, and eight as transients (5 males; 3 females). In December 2018, the maximum population size was apparently reached, since it remained constant from that month

onward. Hence, after this moment, the monthly population size within the grid varied from six to nine individuals, including all age classes and transient and resident individuals, indicating low population density (range: 3 – 5 individuals/ha). From December 2018 onward, all the residents remained inside the trapping grid, leading to a constant population size until February 2020 (Figure 1). Transients and young individuals accounted for small and regular variations in population size throughout the study period (Figure 1). Although unequal sampling effort could affect population estimates (Jolly & Dicko 1983), the nearly constant number of individuals captured throughout the study, irrespective of the sampling effort and of the lack of correlation between sampling effort and the number of captures (Correlation permutation test: p = 0.53), argue against the occurrence of significant sampling bias.

Population attributes have important implications for species mating systems and sexual selection patterns (Tschol *et al.* 2024). The proportion of males in the adult population was 0.5, indicating that the sex ratio was not significantly different from 1:1 (binomial test p = 1). The lack of a biased sex ratio may reflect similar survival and recruitment rates for both sexes, possibly because both sexes seem to disperse equally in the population (Ferrando 2022). Mean (± SD) body mass of adult *C. laticeps* was 291.88 ± 38.34 g, and individuals lacked sexual dimorphism (adult males: 300.73 ± 38.89 g; adult females: 284.93 ± 37.84 g; t test: t = -1.02; p = 0.31). Sexual monomorphism seems to be common in echimyid species (Ebensperger & Hayes 2016), as it has already been reported for body size, cranial size and shape measures among several species of this family (Monteiro *et al.* 1999, Bezerra & Oliveira 2010, Raidan *et al.* 2019), suggesting that it may be a phylogenetically conserved trait.

Previous studies have shown that sexual monomorphism may evolve in species presenting soft intra-sexual mate competition, as selective pressures for increased body size may not translate into increased reproductive success (Cooper *et al.* 2011). As previously demonstrated for craniodental measures (Bezerra & Oliveira 2010), *C. laticeps* appears to follow the same pattern as the other echimyid rodents. Irrespective of the causes of sexual monomorphism in this species, this pattern may shape the species' mating system (McEachern *et al.* 2009). Similar body size can impair the monopolization of females by males, favoring a condition where females could mate with several males (Cooper *et al.* 2011), as evidenced by molecular data demonstrating that most males and females share their partners (Ferrando 2022). Multiple

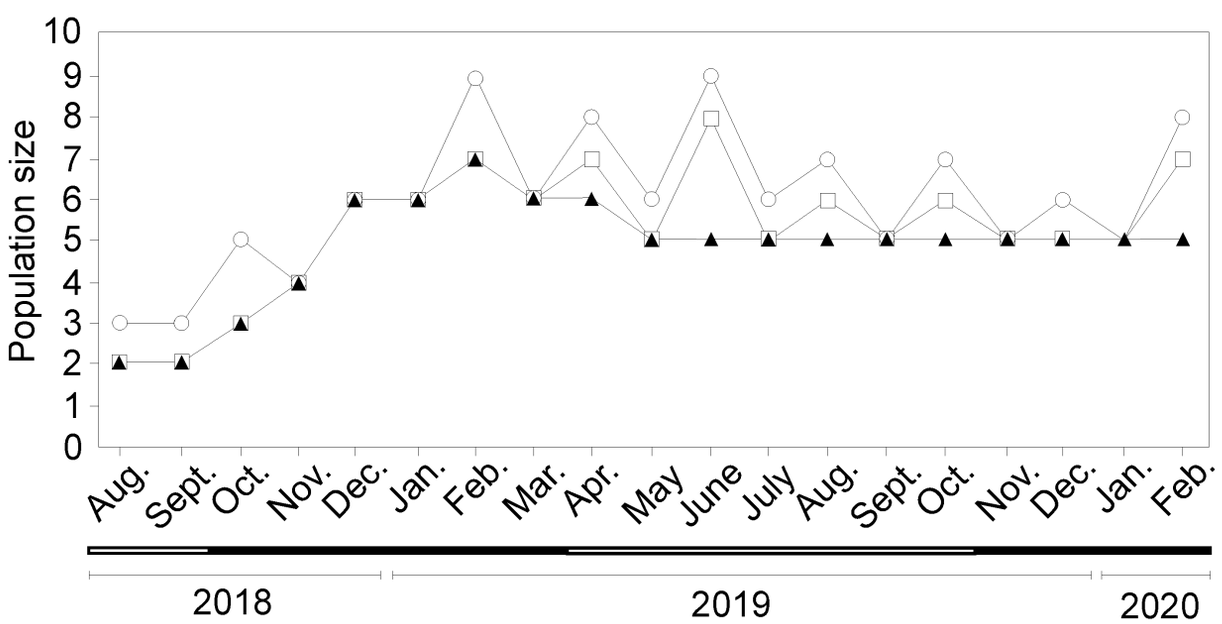

Figure 1. Monthly estimates of population size (Minimum number of individuals known to be alive -MNKA) of *Clyomys laticeps* (Rodentia, Echimyidae) on a 1.7 ha grid at Serra de Caldas Novas State Park, state of Goiás, Brazil. Open circles: all captured individuals. Open squares: adults. Black triangles: adult residents. On the x axis line: open line: dry season, full line: wet season.

Table 1. Pregnant females, numbers of pups (< 100 g, P) and numbers of juveniles (100 - 200 g, J) of *Clyomys laticeps* (Rodentia, Echimyidae) captured during the study from 2018 to 2020 at Serra de Caldas Novas State Park, state of Goiás, Brazil. F = pregnant females (differentiated by number).Different uppercase letters (a and b) indicate different gestations by the same female. * indicates pups and juveniles from F1 and F3. of = Offspring.

	Pregnant females			Number of youngs		
Year/month	**2018**	**2019**	**2020**	**2018**	**2019**	**2020**
January						
February		F5			2 P 1 J* ($F3_{of}$)	2 P 1 J
March			F2			1 P* ($F1_{of}$)
April					1 P	
May				2 J		
June		F1[a]				
July				1 J		
August		F1[a] F3[b] F6			3 P 3 J	1 P* ($F1_{of}$) 1 J
September						
October	F3[a]	F4		1 P* ($F3_{of}$)	1 P* ($F1_{of}$) 3 J	
November						
December	F3[a]				1 J* ($F3_{of}$)	

partners may also be favored by the occurrence of transient adults within the population (Ferrando *et al*. 2019).

The leaner (probably the youngest) *C. laticeps* individual captured weighed 47 g (female), and the heaviest individuals weighed 360 g (non-reproductive female) and 356 g (male). We have evidence that males may have live more than four years, as one adult male was captured in April 2016 (already an adult) and again in August 2019. This result is in agreement with that reported for *Proechimys semispinosus* in the wild (3-5 years; Oaks *et al*. 2008); nevertheless, a larger sample size and longer study time are necessary to determine the lifespan of *C. laticeps*. Pregnant females (N = 6), as well as young individuals (pup and juveniles; N = 25), were captured throughout the study period, regardless of season (Table 1), thus indicating continuous and asynchronous reproduction. Year-round reproduction has been observed in several echimyids, such as *Thrinomys yonenagae* (Luchesi *et al*. 2019), *Thrichomys apereoides* (Roberts *et al*. 1988) and *Capromys pilorides* (Silva & Mancina 2023).

Kinship data revealed that females predominantly produce only a single young per litter, suggesting the occurrence of monotocy in *C. laticeps* (Ferrando 2022). Most caviomorphs produce small litters, in many cases ranging from one to three pups (Ebensperger & Hayes 2016). Although monotocy is usually rare, especially within solitary rodents, it seems to be associated with species with precocial newborns (Lukas & Clutton-Brock 2020), such as *C. laticeps* (Freitas 2013, Ferrando *et al*. 2019) and several caviomorphs that seem to trade-off offspring number versus offspring size. In our study system, pups accounted for 12.65 % of the female body mass by the end of gestation, as observed by female weight loss after giving birth (N = 2; one lost 62 g and the other lost 40 g). Kinship data indicated that females may produce young from two to three times during one-year intervals (Ferrando 2022), with a minimum interval between pregnancies of four months (see F1 and F3 in Table 1). Moreover, gestation length is likely longer than two months (at least from June 2018-August 2018 for F1 and October 2018-December 2018 for F3 in Table 1). This result agrees with previous studies suggesting long gestation lengths among echimyids (~ 100 days; Roberts *et al*. 1988, Luchesi *et al*. 2019).

Among caviomorphs, the description of reproduction has been restricted to a few species, and most studies have been performed in captivity (Patton *et al*. 2015, Ebensperger & Hayes 2016, Tavares *et al*. 2019). The observed reproductive

attributes suggest a slow life history for *C. laticeps* and may contribute to the reduced density reported for this species and other echimyids (Adler 2011). The present data provide insights into the forces driving the evolution of sexual selection patterns, mating and social systems, and behavioral strategies of individuals within a population (McPherson & Chenoweth 2012, Ebensperger & Hayes 2016). Future studies should compare reproduction and population attributes among echimyid rodents and explore the role of phylogenetic and ecological factors on diversity.

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