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Reproductive phenology and sex ratio variation of the Thumbless bat *Furipterus horrens* (Cuvier, 1828) (Furipteridae)

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ABSTRACT

Reproduction is crucial for species survival, influencing population dynamics and fitness. For female small mammals, pregnancy and lactation are energetically costly activities and thus are typically timed to coincide with the season of highest food available. Reproductive phenology of bats varies by species and geographic location and data on Neotropical bats, in particular for non-phyllostomids, is scarce. We examined the reproductive phenology and sex ratio patterns of the aerial insectivorous bat *Furipterus horrens* (Furipteridae) in the Eastern Brazilian Amazon using monitoring data collected for over 10 years in 100 iron caves distributed in the Serra dos Carajás region of northern Brazil. Annual timing of reproduction of *Furipterus horrens* was unimodal, with pregnancy rates peaking at the dry season and lactation events spanning the end of the dry season into the early rainy season. Sex ratios averaged 0.75 across years and exhibited no variation between seasons. Understanding the reproductive phenology of species such as *F. horrens* that rely on specific habitats and rocky shelters, such as caves, is key to development of monitoring programs and actions to protect their populations. Both long-term monitoring and research focusing on the natural history of Neotropical bat species are essential to the development of effective conservation strategies and programs.

KEYWORDS: Phenology, bat reproduction, lactation, natural history, pregnancy, seasonality, sex ratio

Fenologia reprodutiva e padrões de proporção sexual do morcego sem polegar *Furipterus horrens* (Cuvier, 1828) (Furipteridae)

RESUMO

A reprodução é crucial para a sobrevivência das espécies, influenciando a dinâmica populacional e a aptidão. Para mamíferos, a gestação e a lactação são atividades de alto custo energético para as fêmeas, que frequentemente ocorrem em sintonia com a estação chuvosa, período com maior oferta de alimentos. Em morcegos, a fenologia reprodutiva varia de acordo com a espécie e a geografia, mas os dados sobre morcegos Neotropicais, especialmente os não-filostomídeos, são limitados. Neste estudo, examinamos a fenologia reprodutiva e os padrões de proporção sexual da espécie de morcego insetívoro aéreo *Furipterus horrens* na Amazônia Oriental Brasileira. A pesquisa foi conduzida ao longo de 10 anos em 100 cavernas de ferro na Serra dos Carajás. *Furipterus horrens* exibiu um padrão reprodutivo unimodal, com a gestação atingindo o pico na estação seca e a lactação abrangendo as estações seca e início das chuvas. A proporção sexual entre machos e fêmeas foi semelhante, sem variação significativa entre as estações. Nosso estudo destaca a importância de entender os padrões reprodutivos, particularmente em espécies como *F. horrens* que dependem de hábitats e abrigos específicos como cavernas. As descobertas sugerem que atividades humanas, como a mineração, podem ter impacto no sucesso reprodutivo desses morcegos e na estabilidade populacional ao longo do tempo, se não forem monitoradas cuidadosamente. O monitoramento e pesquisas de longo prazo sobre a história natural e os padrões reprodutivos de espécies de morcegos menos conhecidas são essenciais para estratégias de conservação eficazes.

PALAVRAS-CHAVE: estação reprodutiva, reprodução de morcegos, lactação, história natural, gestação, sazonalidade, variação da abundância

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INTRODUCTION

Reproductive activities play a critical role in the persistence of species, directly influencing the growth trajectories of populations and ultimately the fitness of species. Pregnancy and lactation are energetically demanding process, and have been shown to require extra resources in bats (Smith 1956; Racey and Entwistle 2000; McLean and Speakman 2000). The reproductive phenology of female mammals can be adjusted to coincide with periods of high food abundance and predictability (Bronson 1985; Hau et al. 2017; Williams et al. 2017). For example, patterns of seasonal reproduction reflect seasonal variation in food availability in primates (Chmura et al. 2022; 2023), marsupials (Barros et al. 2008) and bats (Carvalho et al. 2019; Willig and Presley 2023; Bobrowiec and Tavares 2024).

Reproductive periods, as indicated by female behavior, appear to be related to seasonal patterns in precipitation that, in turn, affect the timing and abundance of food sources such as fruits, nectar, and insects in the Neotropics (Haugaasen and Peres 2005). Rainfall is probably the most reliable clue to predict timing of future availability of food (Heideman 2000) and likely triggers reproductive activities (Racey and Entwistle 2000).

Sex ratio influences the demographic dynamics of species (Schmickl and Karsai 2010). Skewed sex ratios can affect mating patterns, reproductive success, growth and stability of populations (Schmickl and Karsai 2010). Male-biased ratios can lead to heightened competition among males for mates, potentially increasing aggression and male mortality (Buck and Barnes 2003; Kappeler et al. 2023). Conversely, female-biased ratios may enhance reproductive rates, as more females are available to bear offspring, but can also result in inbreeding and reduced genetic diversity (Kappeler et al. 2023).

Bats are the second most diverse group of mammals, after rodents (Simmons 2005) and exhibit a broad range of feeding habits and foraging behaviors, use a diverse array of habitats, and occupy several different types of diurnal shelters, such as leaves, cavities in trees and rocks, natural and man-made caves, and anthropogenic structures, such as houses, tunnels and bridges (Voss et al. 2016; Lacher et al. 2019; Garbino and Tavares 2018). Knowledge of reproductive patterns for most of the Neotropical bat species are generally scarce. Based on the little data available, we know that reproductive phenology of bats varies among species (Carvalho et al. 2019; Hazard et al. 2022) and throughout the geographic distribution of species (Happold and Happold 1990; Zukal et al. 2024). Concurrently, similarities in responses to temporal patterns of forage availability in similar ecosystems may suggest some degree of phylogenetic constraints (Willig and Pressley 2023) to the reproductive patterns.

Most of what is known of reproduction and phenology in Neotropical bats is biased towards species of the Phyllostomidae family (Molinari and Soriano 2014; Carvalho et al. 2019; Hazard et al. 2022; Willig and Presley 2023; Bobrowiec and Tavares 2024). This is likely related to the more frequent use of mist nets to capture bats in the wild, a method that is selective towards phyllostomid captures (Appel et al. 2021). Data about taxa belonging to other neotropical families, including all aerial insectivorous bats, are generally associated to roost-based studies (e.g. molossids, Soares et al. 2020; vespertilionids, Wilson and Findley 1970) and often fortuitous observations (Fleming et al. 1972; Uieda et al. 1980; Tavares et al. 2012).

Here, we characterize the reproductive phenology and sex ratio patterns of the aerial insectivore bat *Furipterus horrens* (Cuvier, 1828) (Furipteridae) gleaned from a dataset of long-term monitoring studies conducted over ten years on the iron caves in Eastern Brazilian Amazonia. We assessed whether the abundance of males and females differed and if they do, whether it was influenced by seasonality, based on putative seasonal variation in the availability of prey insects. We predicted that the peak of the reproductive period, signaled by female pregnancy and lactation, would occur at the end of the dry season/beginning of the rainy season, a period in which there is generally a larger offer of insects' abundance in the tropics (Pearson and Derr 1986; Racey and Entwistle 2000; Nurul-Ain et al. 2017; Correa et al. 2021). We also expected a reduced abundance of females in the caves during the dry season, indicating movement of females to areas of greater food availability move to areas with greater food availability to fulfill the high energetic demands associated with gestation and lactation. We discuss our data under predictions of resource driven drivers of reproduction, such as seasonal patterns of precipitation.

METHODS

Study area

The reproductive data for *Furipterus horrens* was obtained from bats captured in the region known as the Serra dos Carajás, within the Itacaiúnas river basin, Eastern Amazonia, Pará state, Brazil (49°55'0" W; 6°8'49" S; Figure 1). This region comprises a set of mountain ranges 500 to 700 m a.sl. with ferruginous rocky outcrops on the plateaus (Devecchi et al. 2020). The tops of the plateaus are overlain by patches of forest and savannah-like vegetation (regionally called *canga*) embedded in a matrix of *terra-firme* forests on the slopes and lowlands (Viana et al. 2016; Devecchi et al. 2020, Silva et al. 2023). The *canga* landscape harbors a complex subterranean system with more than 1500 natural iron caves (Piló et al. 2015) and one of the largest high-grade iron ore deposits in the world under continuous mining (Poveromo 1999). The caves are in the transition zone between the forest and *canga* vegetation. The dry season extends approximately from mid-May to September and the rainy season from October to April (Figure 2) (Silva Júnior et al. 2017; Cavalcante et al. 2020). During the dry months, there is a water storage deficit in the Itacaiúnas basin, and rates of evapotranspiration exceed rainfall inputs. The average annual precipitation is ~ 2000 mm and the annual ambient temperature averages 25°C (Silva Júnior et al. 2017; Cavalcante et al. 2020).

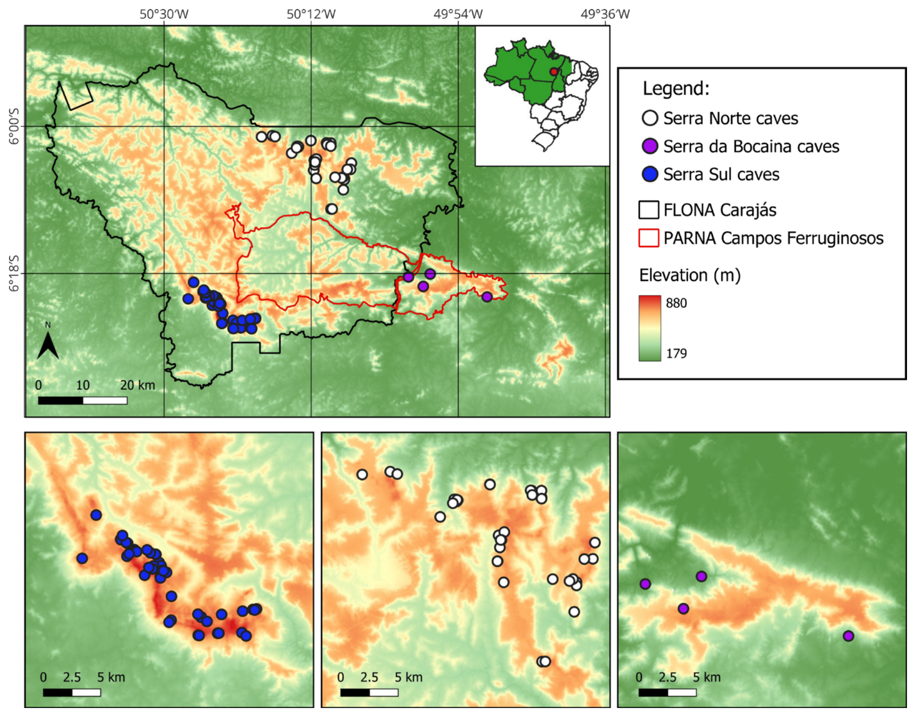

Figure 1. Map showing the study site and the monitored caves in the Carajás region, eastern Amazon, Brazil.

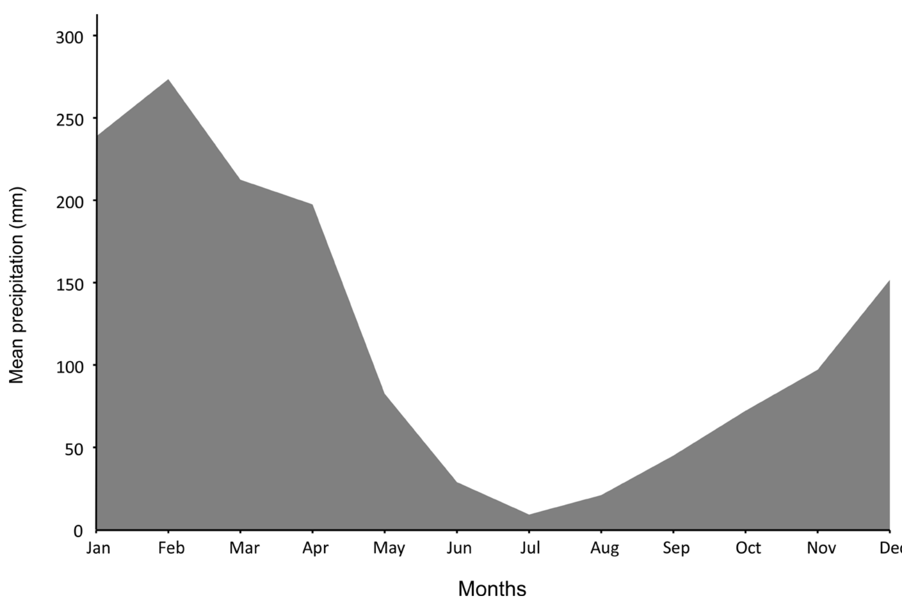

Figure 2. Monthly average rainfall between 2015 and 2022 in the Carajás region, eastern Amazon, Brazil. Source: Instituto Nacional de Meteorologia - INMET https://bdmep.inmet.gov.br.

The sampled area is comprised of three relatively isolated plateaus (Figure 1): Serra Norte, Serra Sul, located within the National Forest of Carajás (FLONA Carajás), and Serra da Bocaina, located in the Campos Ferruginosos National Park (Parque Nacional dos Campos Ferruginosos). Portions of the Serra Norte and Serra Sul have been modified by iron mining, an activity that is included in the management plans of the FLONA Carajás, which also guarantees the protection of the immediate surroundings of many caves classified as of maximum relevance for conservation (up to 250 m from the entrance) and the *terra-firme* forest surrounding the mines (de Fraga et al. 2023). In contrast, Serra da Bocaina is a fully protected area in the Parque Nacional dos Campos Ferruginosos and consequently not explored for mining, but in previous decades highly impacted by the conversion into illegal pastures (de Fraga et al. 2023).

Study species

The thumbless bat, *Furipterus horrens,* is a small Neotropical bat (body length of 33–41 mm, forearm length of 34–39 mm, and body mass of 3–4.2 g, Arroyo-Cabrales 2019) that has been considered locally rare along its broad distributional range. The species is considered monotypic, occurring from southern Central America to South America (from Nicaragua, Costa Rica, Panama, Colombia, the island of Trinidad, Venezuela, Guianas, eastern Peru, northern Bolivia, and Brazil southward into the state of Santa Catarina, Arroyo-Cabrales 2019). *Furipterus horrens* appears to be sexually dimorphic, with adult females larger than adult males, as demonstrated for some populations distributed in Brazil (Uieda et al. 1980). There is no information available on duration and timing of gestation, number of embryos, or patterns of fetal development. Neither the behaviors of parturition nor lactation have been described for this species. We speculate that at least lactation behavior differs from for other bat species because female *F. horrens* nipples are uniquely positioned in the abdominal region, close to the genitalia. The echolocation calls of *F. horrens* are characterized by pulses of downward broadband frequency-modulated sweeps of short duration, above 100 kHz (Falcão et al. 2015). The thumbless bat inhabits lowland and montane tropical and subtropical humid forests at altitudes of 200 to 3000 m, and shelters in caves, tree holes, and fallen trees (Uieda et al. 1980; Tavares et al. 2012). *Furipterus horrens* feeds on insects, and examination of stomach contents from southeastern Brazilian individuals revealed the presence of Lepidoptera and to a lesser extent Diptera and Coleoptera remnants (Fenton et al. 1999). Data on the biology and natural history of *F. horrens* are rarely reported in the literature (Uieda et al. 1980; Tavares et al. 2012; Falcão et al. 2015; Arroyo-Cabrales 2019) and this species is listed as vulnerable in the Brazilian Red List of Endangered Fauna.

Capture, handling and sampling

To gather reproductive data on *F. horrens*, we analyzed data compiled from cave bat monitoring programs conducted in the study area. This databank includes data from a 10 y monitoring period (2015-2024) of 100 caves distributed in Serra Norte (43 caves), Serra Sul (53 caves), and Serra da Bocaina (4 caves). Bats were captured over 189 nights along 40 months across the 10 years of sampling. The frequency of visits per year ranged from 2 to 11 months, with three years having between 7 and 9 months of sampling. Individuals of *F. horrens* were primarily captured with hand nets inside the caves during the day and complemented by captures conducted with ground level mist nets set inside caves or at their entrances and/or harp traps set up at the cave entrances. Harp traps were only used during the field expeditions of 2021 to 2024. In these years, harp traps were typically placed at the cave entrances between 17:00 and 20:00, and occasionally in the early morning (05:00-06:30) coincident with the return of bats to their roosts. Captured bats were placed individually in cotton bags until they were assessed for biometry and identified to species. Taxonomic identification followed the dichotomous key of Gardner (2007). Following data collection, bats were released into the cave that they were originally captured. Cave bat monitoring program permits were issued by the Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis, IBAMA, under the following numbers: #247/2013, #455/2014, #639/2015, #103/2017, #116/2018, #938/2018, #1000/2018, #104/2021.

Reproductive phenology

Captured bats were assessed for sex (male or female) and age class (adult or juvenile) and females were further evaluated for their reproductive status (pregnant and/or lactating or non-reproductive) using well-established methods as described below. Adults were differentiated from juveniles by the observation of the ossification of the epiphyses of the long arm bones (Anthony 1988; Brunet-Rossini and Wilkison 2009). Pregnancy was assessed by palpation of the abdomen to detect the presence of embryos (Racey 1988; 2009). Lactation in adult females was confirmed by the observation of hair loss around the nipples, development of the nipples (e.g., darkened and swollen nipples), and evidence of milk production (Racey 1988). Simultaneously pregnant and lactating females were included in both categories (pregnant and lactating) for analyses.

All reproductive assessments were combined and analyzed to determine the average seasonal reproductive pattern of *F. horrens*. We used the proportion of pregnant and lactating females in relation to the total number of females to identify peaks of pregnancy and lactation across months and seasons. The seasons (wet and dry) were defined by the rainfall pattern from the Instituto Nacional de Meteorologia (https://bdmep.inmet.gov.br) for the Carajás region between 2015 and 2022 (Figure 2). We defined a peak of reproduction as a period with the highest proportion of pregnant/lactating females followed by a period of a >50% decrease in proportion of pregnant/lactating females (Bobrowiec and Tavares 2024). Reproductive patterns followed four categories proposed by Durant et al. (2013): nonmodal, unimodal, bimodal, or polymodal. The nonmodal pattern exhibits no seasonal or annual peaks in either pregnancy or lactation; the unimodal pattern has a single annual peak in pregnancy followed by a peak in lactation; the bimodal pattern consists of two annual peaks of pregnancy, each followed by a peak of lactation; and the polymodal pattern is characterized by >2 peaks of pregnancy, each followed by equal numbers peaks of lactation.

Statistical analysis

All the statistical analyzes were performed using R (R Core Team 2023). We tested for differences in bat abundance between sexes and seasons (rainy and dry) using Generalized Linear Mixed-effects Models (GLMMs). We built the models with the Template Model Builder (TMB) applying Gaussian distributions with linear parameters using *glmmTMB* package (Brooks et al. 2017). We considered bat abundance per cave as a response variable (log-transformed: $\log_{10} + 1$), and sex, season, and their interactions as fixed predictor variables. GLMM incorporated the three *canga* plateaus as a random variable to explain potential spatial autocorrelations. If there were interactions between the sex and seasons, we evaluated the pairwise comparisons between sex × season categories using the *lsmeans* function from the *emmeans* package (Lenth 2025) followed by Tukey tests (HSD). The GLMM was not over/underdispersed and the presence of outliers was evaluated by the *simulaResiduals* function of the *DHARMa* package (Hartig 2017).

We assessed reproductive phenology across months using circular statistics implemented in the *circular* package (Agostinelli and Lund 2022). We used the Rayleigh uniformity test to check for the uniform distribution of the bat capture ratios of pregnant and lactating females (Morellato et al. 2010). An angle was assigned to each month, and later transformed into radians to perform the circular analysis.

RESULTS

We recorded the reproductive information of 1091 adult and 39 juvenile *F. horrens* bats. Among adults, 44.1% were females (n = 481), while among juveniles, females accounted for 23.1% of bats (n = 9). The sex ratio (adult females captures/ adult males captures) of adult bats was 0.79 individuals. We captured 598 bats during the rainy season (males = 308, females = 290) and 532 bats during the dry season (males = 332, females = 200). The GLMM showed no sex × season interaction effect (z = 0.38, p = 0.97) and no individual effect of the sex (z = -0.84, p = 0.40) and season (z = -1.13, p = 0.26; Figure 3).

Among adult females, 89 were pregnant (18.5%) and 47 were lactating (9.8%) (Table 1). Pregnancy rate of *F. horrens* peaked during the dry in during the dry season, in August (39.0% of captured females) and September (77.6%) (Table 1; Figure 4). The seasonal distribution of lactating females was concentrated at the end of the dry season and at the beginning of the rainy season (Figure 4) with elevated rates in October (50.0%), and November (72.7%) (Table 1). The pattern of distribution of pregnancies was unimodal (Rayleigh uniformity test, Z = 0.77, p < 0.001) with a single peak in the dry season followed by an initial peak in lactation at the end of the dry season and at the beginning of the rainy season.

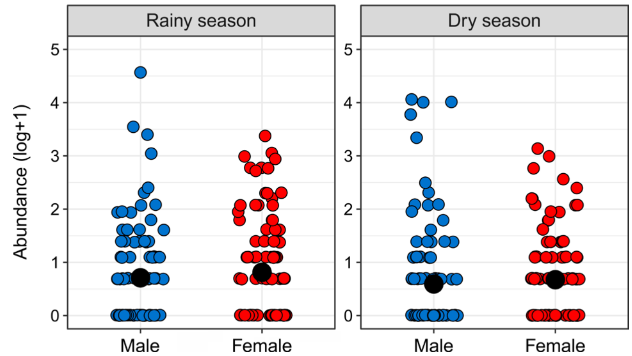

Figure 3. Relative number of adult males (blue dots) and females (red dots) of *Furipterus horrens* per season captured in 100 iron caves in the Carajás region, eastern Amazon, Brazil over the years 2015 to 2024. Black dots indicate the mean values for each sex.

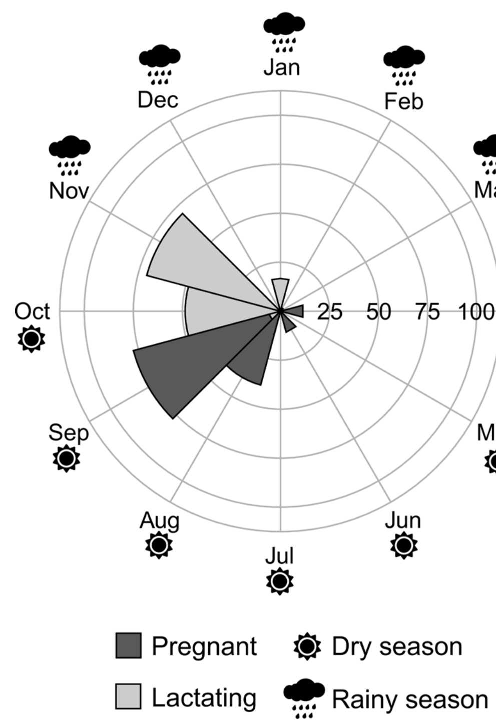

Figure 4. Distribution of pregnant and lactating females across months and seasons (rainy and dry) for *Furipterus horrens* adult females captured in 100 iron caves in the Carajás region, eastern Amazon, Brazil. The numbers in each circle ring within the graph represent capture percentages.

Table 1. Number of adult male and female Furipterus horrens bats, and the reproductive status of females, captured across different months from 2015 to 2024, in 100 iron caves in the Carajás region, eastern Amazon, Brazil.

Sex/Reproductive status	Months												Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Males	70	87	81	6	3	37	16	194	56	15	43	2	610
Females	87	55	90	17	3	18	5	118	49	6	33	0	481
Pregnant females	0	1	0	2	0	2	0	46	38	0	0	0	89
Lactating females	15	0	1	0	0	0	0	1	3	3	24	0	47

DISCUSSION

Our results indicate a pattern of unimodal reproductive phenology for *F. horrens* populations, with little interannual variation. Unimodal reproductive patterns tend to be recurrently found in animalivorous bats, as recorded in the Caribbean lowlands of Costa Rica (Durant et al. 2013), Peruvian Amazon (Willig and Presley 2023), and central Amazon (Hazard et al. 2022). Unimodal reproductive phenology has been observed in animalivorous bats such as *Phyllostomus elongatus* (É. Geoffroy, 1810), *P. hastatus* (Pallas, 1767), and *Gardnerycteris crenulatum* (É. Geoffroy, 1803) (Phyllostomidae) and aerial insectivores like *Pteronotus rubiginosus* (Wagner, 1843) (Mormoopidae) (LaVal and Fitch 1977; Hazard et al. 2022; Willig and Presley 2023; Bobrowiec and Tavares 2024). Some species of fruit and nectar feeding phyllostomid bats also have unimodal reproductive phenologies (Frankie et al. 1974; Stoner 2001; Hazard et al. 2022; Willig and Presley 2023). Quite likely, the reproductive phenology of bat species varies across their distributional range and may be bimodal in different regions of tropical forests (Willig and Presley 2023). This is certainly the case for *Rhinophylla pumilio* Peters, 1865 which has a unimodal pattern of reproduction in central Brazilian Amazon and in northwestern Peru, and a bimodal reproduction in the southern Brazilian Amazon (Hazard et al. 2022; Willig and Presley 2023; Bobrowiec and Tavares 2024).

Bat species with bimodal reproductive phenology exhibit more plastic expressions of reproductive activities and lower secondary peaks at the end of the reproductive season. This observation suggests a dependence on food availability and abundance throughout the reproductive period, which may determine whether a second reproductive attempt is undertaken (Willig and Presley 2023). The potential responsiveness to environmental conditions increases the probability of interannual variation in the reproductive patterns of populations and could explain the geographic differences in reproductive phenologies (Willig and Presley 2023). In contrast, species with unimodal reproductive phenology appear to be less likely to modify the timing of the reproductive attempts (Willig and Presley 2023). In years of low food quality or quantity, the number of pregnant females and offspring may be reduced without changes in reproductive phenology. In our study area and across 10 years, *F. horrens* exhibited low interannual variation in reproductive periods, indicating a unimodal pattern and precluding any interpretation of hidden bimodal reproductive phenology patterns.

Contrary to our prediction, pregnancies of *F. horrens* were concentrated in the dry season, with lactation peaking at the end of the dry season and at the beginning of the rainy season. A pregnant female was reported in September in Colombia and lactating females with pups were found in January and February in Brazil (Uieda et al. 1980; Arroyo-Cabrales 2019), observations that mirror our results on reproductive timing. Peaks of reproductive activity during the dry season for species exhibiting a unimodal pattern of reproduction have also been reported for the frugivorous bats *Artibeus lituratus* (Olfers, 1818), *A. obscurus* (Schinz, 1821), *Carollia perspicillata* (Linnaeus, 1758), and *R. pumilio* in central Amazon fragmented landscapes (Hazard et al. 2022), and for *A. planirostris* (Spix, 1823) and *C. benkeithi* Solari and Baker (2006) in the Peruvian Amazon (Willig and Presley 2023). In Costa Rica, the animalivorous ensemble had a single mid- to late-dry season peak (Durant et al. 2013).

The reproductive pattern in bats is related to food availability, which in turn is influenced by the seasonality of rainfall (Carvalho et al. 2019; Willig and Presley 2023; Bobrowiec and Tavares 2024). In the tropical region, insect populations are less numerous during the dry season than at other times of the year, and there is usually an insect bloom when the rains begin (Pearson and Derr 1986; Racey and Entwistle 2000; Correia et al. 2021). If the gestation period is around 60 days, as in other species of small bats (Racey 1988), starting the reproductive activities in the middle of the dry season may increase the probability that recently weaned pups will begin foraging during the rainy season, the period of greatest abundance of the insect prey (Racey and Entwistle 2000; Nurul-Ain et al. 2017). Thus, the reproductive pattern of *F. horrens* might be timed to wean the young at this time of year and to avoid weaning young at times of lowered food supply (Wilson and Findley 1970). Indeed, available data on the reproductive biology of Neotropical and Asian aerial insectivorous bats indicate that most of these species are seasonally monoestrous, with reproductive activities timed in such a way that the young are weaned around the onset of, or during, the wet season (Bernard 2002; Nurul-Ain et al. 2017).

A limitation of our results appears to be related to the method employed to assess pregnancy, palpation, which is a standard method for detecting pregnancy in bats. Palpation of the female abdomen may not be sufficiently sensitive to identify embryos during their early development stages in *Furipterus*, because this is a very small bodied bat species (3–4.2 g) with commensurately tiny-sized early developing fetuses. Therefore, we hypothesize that reproductive activity begins in July, one month before our detections of pregnancy based on palpation. However, this early onset of pregnancy does not alter the unimodal pattern found for *F. horrens*. To circumvent this limitation of accuracy of palpation to determine early pregnancy, we suggest that future studies monitor for endocrine signals of pregnancy and lactation. Although the study of hormonal data related to reproduction have been a growing field of research in wild mammals (Dillon et al. 2021), endocrine data are scarce or non-existent for most bat species (Ocampo-González et al. 2021; Krishna et al. 2024).

The capture rates sex were similar to those described for other insectivorous bats in the Amazon basin, such as *L. silvicola* d'Orbigny, 1836, *P. elongatus*, and all gleaning insectivorous species in southeast Amazonia (Bobrowiec and Tavares 2024). Contrary to our expectations, the sex ratio of *F. horrens* was not influenced by season, indicating either that neither sex relocated across the year or that they moved proportionally. During the periods of gestation and lactation, female bats are most dependent on the availability and distribution of food as compared to other periods of their annual cycle (Rocha et al. 2017). This may be reflected in a seasonal increase in foraging area in some bat species, particularly during periods of food shortages (Charles-Dominique 1991; Rocha et al. 2017; Bobrowiec and Tavares 2024). Future investigations of the movement ecology of *F. horrens* could decipher if, and to what extent, these animals alter their foraging range as a function of season, reproductive status, and both biotic and abiotic factors of the environment.

Furipterus horrens is a cave-dependent species in Carajás (Tavares et al. 2012, 2025) and caves can provide a safe and stable place for the birth of young and protection from heavy rain, heat, and many predators (Furey and Racey 2016). The caves in our study area are situated in mosaics of forested and rupestrial (*canga*) vegetation and *F. horrens* shows a preference for foraging in open habitats, including preserved *canga* areas and degraded pastures (Tavares et al. 2025). Thus, it is possible that *F. horrens* do not migrate to other caves between seasons. However, there has been recently shown that *F. horrens* travels long distances at night (2,163 ± 2,453 m) and that flight distances vary according to the landscape conditions and mediated by seasonality, with larger foraging areas and longer distances recorded in disturbed habitats during the wet season and larger areas and distances in preserved landscapes during the dry season (Tavares et al. 2025). The seasonal variation in the movement patterns is likely influenced by the spatiotemporal availability of food resources and possibly the reproductive period of females. During the dry season, females forage in preserved habitats in search of more quality food to ensure sufficient nutritional resources and sustain the high energetic demands of reproduction in this season.

CONCLUSIONS

To our knowledge, this is the first investigation of the reproductive phenology of *F. horrens*. This was made possible because of long-term monitoring of cave bat populations in the Carajás region. We recommend long-term efforts to study and monitor the biology of cave bat populations, including their reproductive phenology. This recommendation is especially, but not exclusively, for those aerial insectivores that are rarely captured with mist-nets in inventories and ecological studies (Appel et al. 2021). These types of studies hold the potential to fill knowledge gaps of the reproductive activities of a poorly known bat ensemble that includes several rare species. Further, we advocate for collection of more data on natural history of these species including data on food availability/preferences, the study of their demographics, and investigations of physiological patterns, such as reproductive hormone panels. In combination, these additional targeted investigations are necessary additions to ongoing studies to enhance and make more effective conservation programs for *F. horrens* and other species.

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