http://dx.doi.org/10.5380/abp.v51i0.86448

Acta Biológica Paranaense

Original Articles (Artigos Originais)

Reproduction of *Artibeus lituratus* and *Sturnira lilium* (Chiroptera: Phyllostomidae) in a Semideciduous Seasonal Forest fragment in southern Brazil

Reprodução de Artibeus lituratus *e* Sturnira lilium *(Chiroptera: Phyllostomidae) em um fragmento de Floresta Estacional Semidecidual no Sul do Brasil*

Mateus Rocha Ribas[1]
Sara Cristina Batista[2]
Jean M. Freitag Kramer[3]
José Marcelo Rocha Aranha[4]

Received 06/20/2022 | Accepted 11/14/2022 | Published 11/23/2022 | Edited by Fernando Passos

ABSTRACT

Here we evaluate the reproduction and changes in abundance among different reproductive stages for *Artibeus lituratus* (Olfers, 1818) and *Sturnira lilium* (E. Geoffroy, 1810) in a Semideciduous Seasonal Forest fragment at southern Brazil. Bats were identified according with sex and reproductive stages based on secondary characters, as follows: young bats (1); males with descending testes (2); males with abdominal testes (3); non-pregnant females (4); lactating females (5); pregnant females (6); pregnant-lactating females (7); post-lactation females (8). Abundance was explored monthly in each reproductive stage considering rainy (October to March) and dry (April to September) season. Bat abundance changed over the months and between species, with August and June with highest abundance for *A. lituratus* and February, June and September for *S. lilium*. Both species showed a pattern of bimodal polyestry, with first pregnancy occurring at the end of dry season and second in the middle of rainy season. The data

1 Laboratório de Ecologia de Vertebrados, Universidade Federal do Paraná (UFPR), Setor Palotina, PR, Brasil. E-mail: mateusribas07@gmail.com. ORCID: https://orcid.org/0000-0002-9060-1031. 2 Laboratório de Ecologia de Vertebrados, Universidade Federal do Paraná (UFPR), Setor Palotina, PR, Brasil. E-mail: bsaracristina@gmail.com. ORCID: https://orcid.org/0000-0001-5989-2398. 3 Laboratório de Ecologia e Biogeografia de Plantas, Departamento de Biodiversidade, Setor Palotina, Universidade Federal do Paraná, Rua Pioneiro, 2153, Jardim Dallas, CEP 85950 000, Palotina, Paraná, Brasil. E-mail: jeanfreitagkramer@gmail.com. ORCID: https://orcid.org/0000-0001-9167-9319. 4 Laboratório de Ecologia de Vertebrados, Universidade Federal do Paraná (UFPR), Setor Palotina, PR, Brasil. E-mail: jmaranha@ufpr.br ORCID: https://orcid.org/0000-0002-3082-3441.

here presented contribute to understand reproductive biology and abundance changes over one year for *A. lituratus* and *S. lilium* in a Semideciduous Seasonal Forest fragment, reducing knowledge gap about reproduction patterns of these species.

Keywords: Reproductive stage, Atlantic Forest, Neotropical bats, Fragmented tropical landscape, Chiropterofauna

RESUMO

Avaliamos a reprodução e mudanças na abundância entre diferentes estágios reprodutivos para *Artibeus lituratus* (Olfers, 1818) e *Sturnira lilium* (E. Geoffroy, 1810) em um fragmento de Floresta Estacional Semidecidual no sul do Brasil. Os morcegos foram identificados de acordo com o sexo e estágio reprodutivo com base em caracteres secundários, como segue: jovens (1); machos com testículos descendentes (2); machos com testículos abdominais (3); fêmeas não grávidas (4); fêmeas lactantes (5); fêmeas grávidas (6); fêmeas grávidas e lactantes (7); fêmeas pós-lactantes (8). Abundância foi explorada mensalmente para cada estágio reprodutivo, considerando a estação chuvosa (outubro a março) e seca (abril a setembro). A abundância dos morcegos variou ao longo dos meses e entre as espécies, com agosto e junho com a maior abundância para *A. lituratus* e fevereiro, junho e setembro para *S. lilium*. Ambas as espécies apresentaram um padrão reprodutivo de poliestria bimodal, com a primeira gravidez ocorrendo no fim da estação seca e a segunda no meio da estação chuvosa. Os dados aqui apresentados contribuem para o entendimento da biologia reprodutiva e mudanças na abundância ao longo de um ano para *A. lituratus* e *S. lilium* em um fragmento florestal, reduzindo a lacuna de conhecimento sobre os padrões de reprodução dessas espécies.

Palavras-chave: Estágio reprodutivo, Mata Atlântica, Morcegos neotropicais, Paisagem tropical fragmentada, Quiropterofauna

Introduction

Bats are mammals that exhibit great variation in reproductive strategies, such as changes in gestation time, number of pregnancies per year, presence or absence of postpartum estrus and presence or absence of reproductive synchrony (Tamsitt & Valdivieso, 1963; Fleming et al., 1972; Happold & Happold, 1990; Esbérard et al., 2006; Godoy et al., 2014). Thus, four main reproductive strategies are recognized for bats in the Neotropical Region (Fleming et al., 1972): seasonal monoestry (1), with only one pregnancy per year in a given season (Zortéa, 2003); seasonal polyestry (2), with two annual pregnancies and frequency presenting two peaks in a rapid succession (Bernard, 2002); extensive reproductive period followed by a short period of inactivity (3), with more than one progeny per year in different pregnancies (Willig, 1985); and continuous or non-seasonal polyestry (4), with pregnancy in different months over a year and reproduction all year round (Trajano, 1984). Bats reproductive strategies variation along different areas are connected with endogenous and exogenous factors (Willig, 1985; Klose et al., 2006; Lima & Fabián, 2016), such as resource availability, which is directly affected by environmental conditions, such as temperature and precipitation (Tamsitt & Valdivieso, 1963). According to Durant et al. (2013), reproductive phenologies of populations are strongly molded by environmental variation because the phenomenon of natural selection tends to favor individuals that time energetically demanding portions of their life cycle to correspond with periods of high resource availability. Phyllostomidae family is endemic to Neotropical Region and recognized as the most abundant and diverse family of bats in Brazil (Gardner, 2008; Pellón et al., 2021). Generally, the individuals of this family present a reproductive pattern of seasonal polyestry, with two reproduction peaks

per year (Fleming et al., 1972; Taddei, 1976). More specifically, the species *Artibeus lituratus* (Olfers, 1818) and *Sturnira lilium* (E. Geoffroy, 1810) belong to the Stenodermatinae subfamily which have a predominant frugivorous diet and are widely distributed across Brazil (Zortéa, 2007). *Artibeus lituratus* is one of the most common species in urban environments (Pacheco et al., 2010), mainly because of their diverse diet, which can consume exotic fruits (Novaes & Nobre, 2009; Laurindo & Vizentin-Bugoni, 2020). *Sturnira lilium* is also commonly found in altered environments, such as urban habitats, showing a varied frugivorous diet (Zortéa, 2007; Pacheco et al., 2010). However, both species can be also found in conserved environments or large forest areas (Sekiama et al., 2001; Bernard, 2002; Reis et al., 2003; Camargo et al., 2009).

Most of the frugivorous bats are seasonally polyestrous, but reproductive pattern of *A. lituratus* and *S. lilium* varies throughout their geographic distribution area, with *A. lituratus* presenting records of seasonal polyestry (Fleming et al., 1972; Ortêncio-Filho et al., 2007), continuous polyestry (Taddei, 1976; Trajano, 1984) and monoestry (Duarte & Talamoni, 2010). *Sturnira lilium* presents records of seasonal polyestry in most studies throughout their distribution area (Fleming et al., 1972; Bernard, 2002; Marinho-Filho, 2003), and some records of continuous polyestry (Godoy et al., 2014).

Information about reproductive biology of Brazilian bats is spatially fragmented and not consistent, resulting in a knowledge gap, even for common species (Bernard, 2002; Marinho-Filho, 2003). Thus, studies in regions with knowledge and information lacks, such as some parts of Semideciduous Seasonal Forest, are essential to better understanding the reproductive biology of these species and improve management strategies to bats conservation. Semideciduous Seasonal Forest is a typical formation of interior areas within the Atlantic Forest biome, which has been severely reduced and fragmented in recent decades especially due to the expansion of agricultural fields, urbanization and timber extraction (Ribeiro et al., 2009; Joly et al., 2014; Haddad et al., 2015; Dettke et al., 2018; Silva et al. 2019), directly affecting bats communities (Brändel et al., 2020).

In this context, here we evaluated the reproduction of two common Brazilian bats: *Artibeus lituratus* and *Sturnira lilium* in an Atlantic Forest fragment at southern Brazil. More specifically, we explored changes in *A. lituratus* and *S. lilium* abundance over the months of one year (1); changes in abundance according with reproductive stages (2); and the influence or effect of climatic variables on bats abundance (3). We expected changes in abundance of both species over the months and among reproductive stages in order to investigate a possible reproductive pattern in *A. lituratus* and *S. lilium*. We also hypothesized an effect of climatic variables, such as temperature and precipitation on species abundance along the year.

Material and methods

Study site

Bat species were collected in a forest fragment in southern Brazil (Fig. 1). The fragment is a state-protected area called São Camilo State Park (hereafter SCSP) located in Palotina municipality (24°8'57" S; 53°54'38" W), Paraná State, with approximately 385 hectares (ha). The region is part of Semideciduous Seasonal Atlantic Forest and the forest fragment is inserted in a highly fragmented landscape, surrounded by agricultural fields, characterized by the presence of agricultural crops with short phenological cycles such as soybean and corn (Ribas et al., 2020).

Climate of the region, according to Köppen's classification, is subtropical mesothermic (Cfa) characterized by hot summers and occasional frosts during the winter, with rainy season concentrated in the summer (Alvares et al., 2013). The highest temperatures and precipitations occur from October to March (IAP, 2006).

Sampling design and species reproductive classification

Species were collected monthly in four consecutive nights of third quarter or in new moon of each month between September 2016 and August 2017, totaling 12 months of sampling. Eight mist nets (12 x 2.5 m) were distributed in trails, in a transition area between forest fragment and agricultural crops by a riparian vegetation and an open area near a lake (i.e., forest edge habitats). Nets were opened after sunset and checked every 20 minutes for six hours. Captured bats were placed in cotton bags and taken to the field base for screening and identification. Species were tagged with numbered metal rings for identification when recaptured and to compare their reproductive stage. After that, bats were released in the same place where they are captured.

At least one specimen of each bat species was selected as material testimony, under the licence of the Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio Licence #43560-2). The procedures were approved by the Ethical Committee on the Use of Animals of Universidade Federal do Paraná, Palotina Sector (CEUA n° 39/2014). The specimens captured as material testimony were deposited in the Museu de História Natural Capão da Imbuia, in Curitiba, Paraná, Brazil. Although other species of *Artibeus* (*Artibeus fimbriatus* Gray, 1838 and *Artibeus planirostris* (Spix, 1823)) were captured as well, only *A. lituratus* were considered for this manuscript.

Bats were identified based on the keys developed by Gardner (2008) and Miranda et al. (2011). The specimens were also classified according to their sex and reproductive stages. The identification of reproductive stages was based on secondary characters of males and females, and the classifications were performed according to Trajano (1984) with modifications for male classification. Young bats were identified through the ossification level of wing epiphyses. Males individuals were classified according to

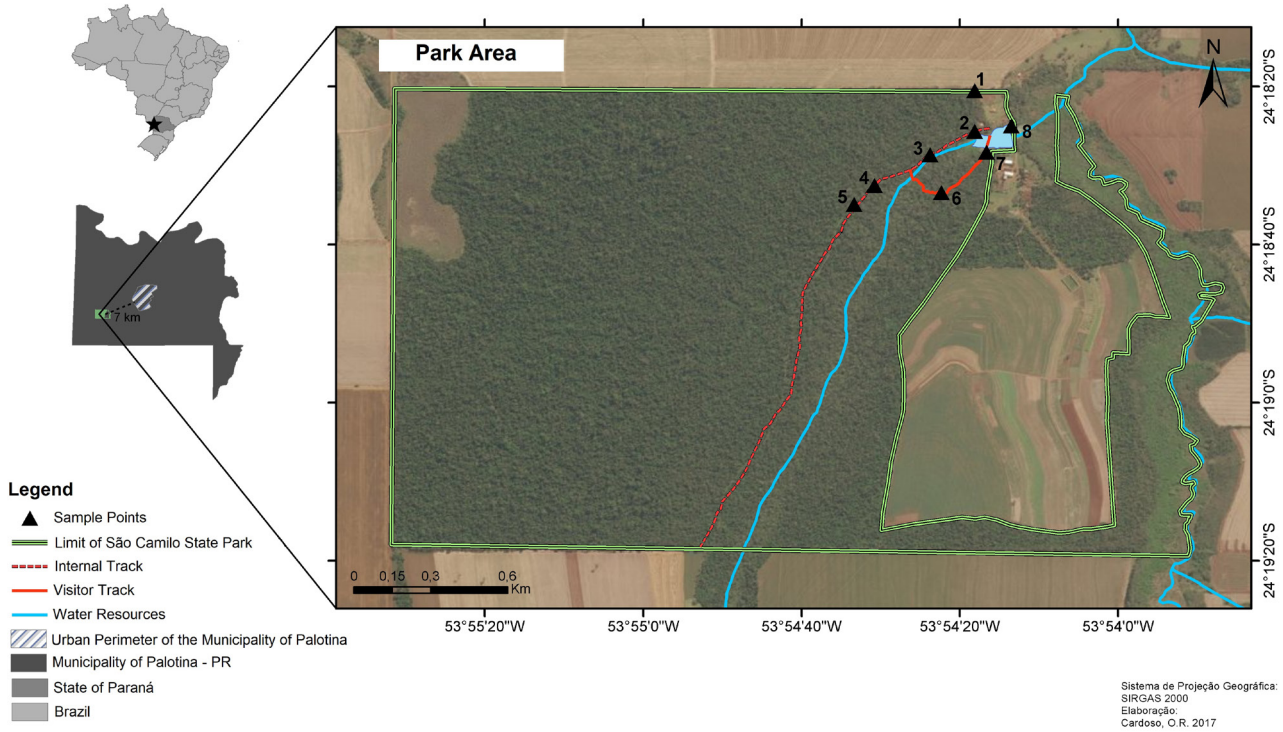

Figure 1. Location of the São Camilo State Park (24°8'57'' S; 53°54'38'' W), municipality of Palotina, state of Paraná in southern Brazil and the location of the mist nets used for the captures of the bats (triangle).

testes position into two reproductive categories: (1) males with descending or external testes, when testes are positioned in the scrotum, and (2) males with internal or abdominal testes, when testes are not detected externally. Females individuals were classified into five reproductive categories: (1) non-pregnant, when they presented no pregnancy or lactation; (2) lactating, when the female was secreting milk; (3) pregnant, when they had a detectable fetus by probing the abdomen; (4) post-lactation, when they presented slight pigmentation of the skin and almost total absence of hair around the breasts, indicating recent lactation and (5) pregnant-lactating, a condition that indicate postpartum estrus.

Sampling effort was calculated according to Straube & Bianconi (2002) proposal. We measured the number of captured individuals (i.e., abundance) of *A. lituratus* and *S. lilium*. Abundance was measured monthly for each species and considering two climatic periods: rainy and dry. October to March was defined as the rainy season and April to September as dry season.

Statistical analysis

To perform exploratory analysis and investigate data distribution, bat species abundance and their reproductive stages were compiled and organized monthly from September 2016 to August 2017. Boxplots were used to visualize and compare the abundance according to each reproductive stage for *A. lituratus* and *S. lilium*, whereas barplots were used to visualize and investigate species abundance in each reproductive stage monthly during rainy and dry season. Plots were executed using 'ggplot2' package in R statistical environment (Wickham, 2016; R Core Team 2021).

Generalized linear models (GLMs) were used to verify the effect of climatic variables on species abundance along the months and seasons. Climatic variables were obtained locally at Palotina from SIMEPAR database (2018). We used three climatic variables for each month: average monthly temperature, obtained by the mean between maximum mean temperature and minimum mean temperature; accumulated monthly precipitation, measured as the total rainfall; and average monthly relative humidity, measured as the relative air humidity in percentage (%). Previous of GLMs performance, we calculated correlation among temperature, precipitation and humidity, which were not considered as correlated variables ($r = \leq 0.42$). Abundance of *A. lituratus* and *S. lilium* were considered as response variable in the models, and climatic variables (temperature, precipitation and humidity) and seasons (rainy and dry) as explanatory variables (Crawley, 2015). Models were fitted with a Poisson error distribution (family = poisson), which is recommended for counts as response variable and executed using GLMs function from 'stats' base package in R (R Core Team 2021).

Akaike Information Criteria for small samples (AICc) were used to select the best parsimonious model given the dataset (Burnham & Anderson 2002). To provide an indication of model goodness-of-fit, we estimated pseudo-R^2 values for GLMs using the function nagelkerke from 'rcompanion' package in R (Mangiafico 2021; R Core Team 2021). AICc scores and model comparisons were obtained using the function AICctab from 'bbmle' package (Bolker 2020). All analyses were conducted in R environment version 4.0.5 (R Core Team 2021).

Results

Bats abundance and reproduction stages

A total of 278 individuals were recorded (152 *Artibeus lituratus* and 126 *Sturnira lilium*), with a sampling effort of 69,120 m^2 h. Different reproductive stages and change in species abundance were registered over the months and seasons (Fig. 2 and 3). August was the month with

highest abundance of *A. lituratus* (29 individuals) both for female and male individuals, followed by June (25 individuals) and April (18 individuals), whereas for *S. lilium*, February was the month with highest abundance (20 individuals) both for female and male individuals, followed by September and June (18 individuals; Fig 2 and 3).

For A. *lituratus*, seven of the 152 recorded individuals were juvenile females and 145 were adults, of which 82 were females and 63 were males, with a female to male ratio of 0.77:1. Juveniles were captured in April and June. Males with descending testes were found in all months, with higher numbers in August, followed by April and June. Pregnant females were found with highest abundance in October and August, whereas lactating females were found in November, February, March and April. One pregnant-lactating female was captured in December. Post-lactating females were found in November, December and April. Non-pregnant females were captured in every month, except April and November, with highest counts in June and August (Fig 2 and 3).

For *S. lilium*, 14 of the 126 captured individuals were young (11 females and 3 males) and 112 were adults, of which 79 were females and 33 males, with a female to male ratio of 0.42:1. Two peaks of young individuals were observed, with the first being recorded between January to March and the second between May to July. Males with abdominal testes were more frequent in September, January, February and July, whereas males with descending testes in May and June. Pregnant or lactating females were captured in all months, except for June and July and their

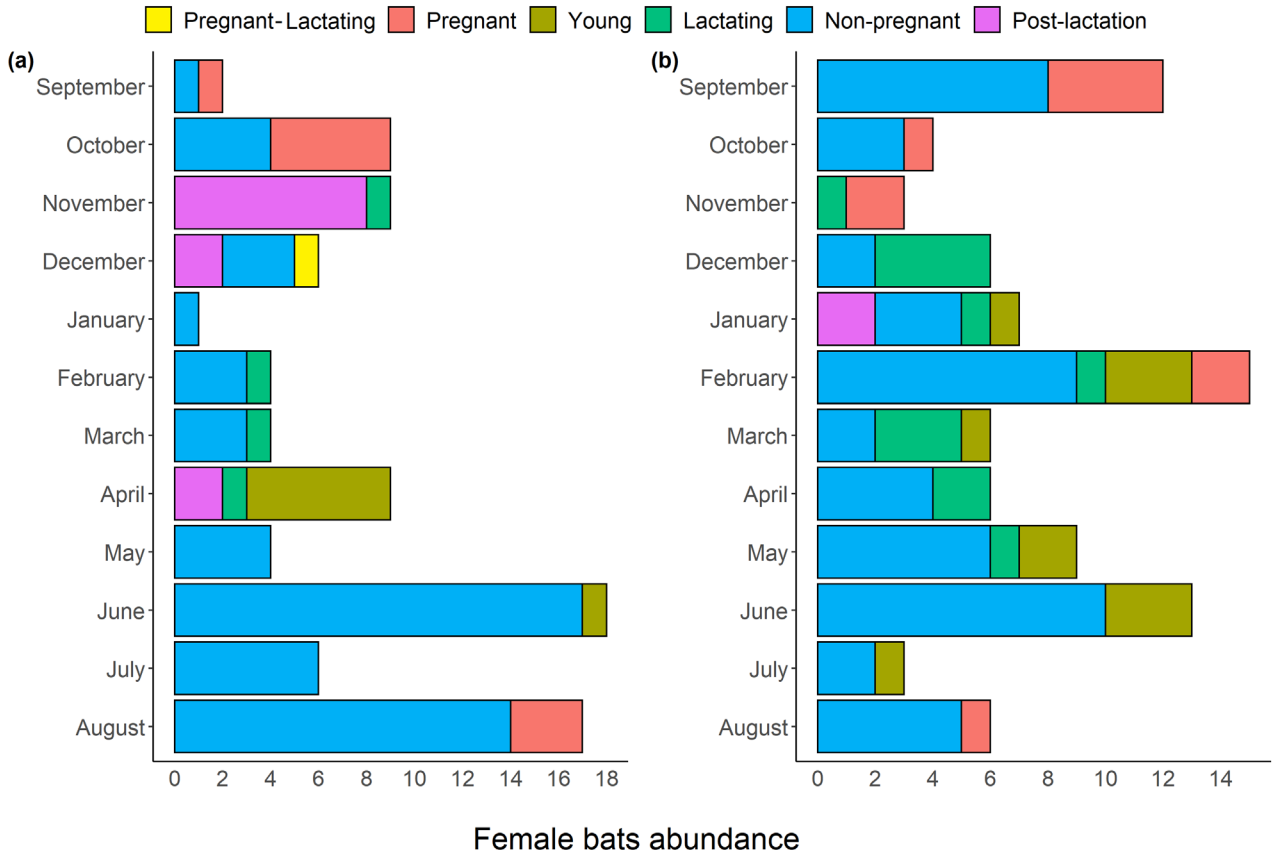

Figure 2. Female bats species abundance along the months between September 2016 to August 2017 and distribution in each reproductive stage for *Artibeus lituratus* (a) and *Sturnira lilium* (b) in São Camilo State Park, municipality of Palotina, state of Paraná, Brazil. Reproductive stages were represented by different colors.

frequency showed two peaks. Pregnant females were found with highest abundance in September whereas lactating females in December and March, forming two lactating peaks. Post-lactating females were found only in January with 2 individuals. Non-pregnant females were captured in all months, expect November, with highest counts in June, February and September (Fig 2 and 3).

Regarding *A. lituratus* recaptured bats, two of nine recaptured bats were females and seven males. All two females were non-pregnant at capture (February and March) and at the recapture (August). Six males were captured and recaptured in the same condition (descending testes), and one bat that was captured in November with abdominal testes was recaptured in February with descending testes. Regarding *S. lilium* recaptured bats, one of the six recaptured bats was male and five were females. A female that was captured in September, apparently non-pregnant, was lactating when recaptured in December. One pregnant and two lactating females were recaptured without signs of post-lactation after five and three months respectively.

The reproductive stage with highest abundance for both species was non-pregnant females (Fig 4). Considering the abundance of *A. lituratus* females per season, 13 individuals were in a lactating or post-lactation stage and six were pregnant during the rainy season (October 2016 to March 2017). Similar results were found for *S. lilium* females, where 12 individuals were lactating or post-lactation stage and five were pregnant during the rainy season. Males with descending testes for both species were captured mainly in the dry season.

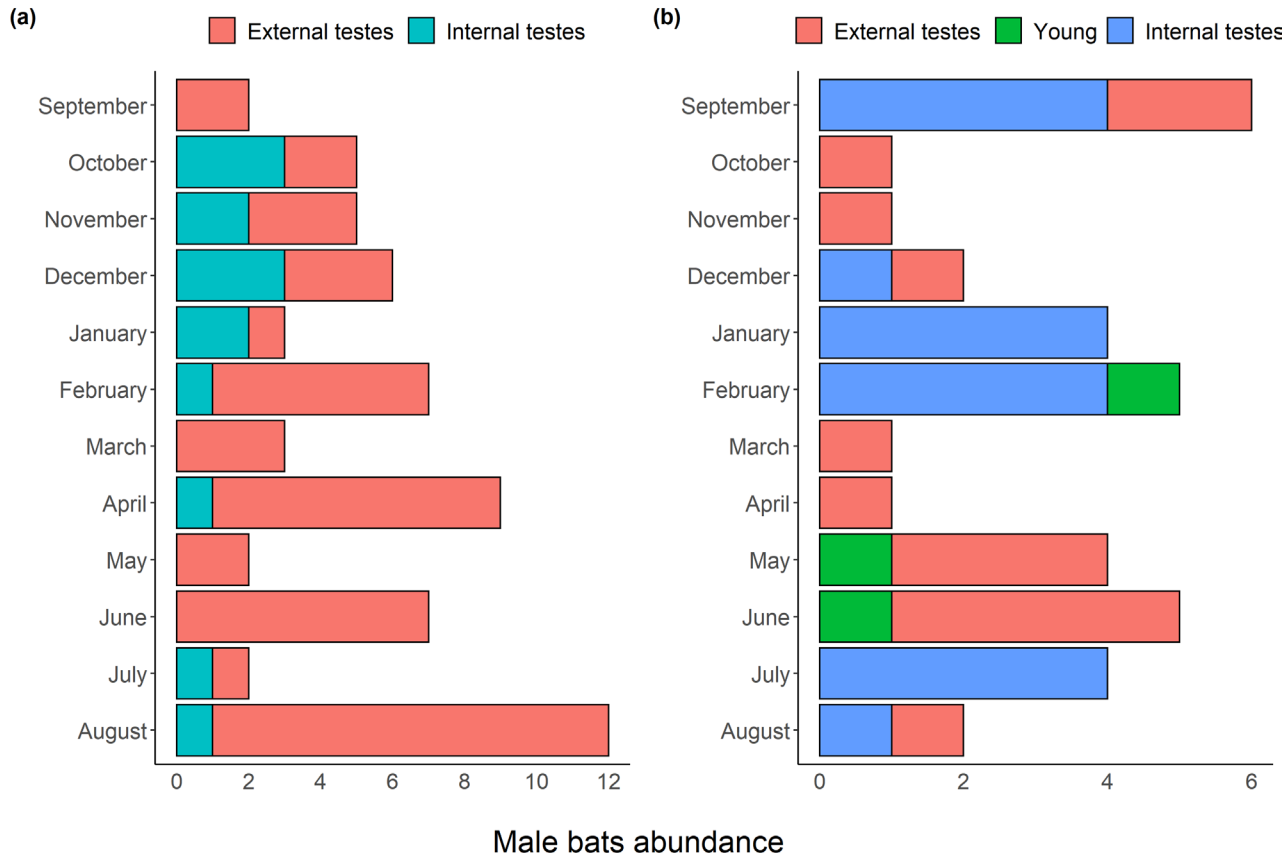

Figure 3. Male bats species abundance along the months between September 2016 to August 2017 and distribution in each reproductive stage for *Artibeus lituratus* (a) and *Sturnira lilium* (b) in São Camilo State Park, municipality of Palotina, state of Paraná, Brazil. Reproductive stages were represented by different colors.

Influence of climatic variables on bat abundance

Our GLMs indicated a potentially influence of temperature, precipitation, humidity and season (rainy and dry) on bats species abundance. For *Artibeus lituratus*, the best selected models were the effect of temperature followed by the effect of season on bat abundance, whereas for *Sturnira lilium*, was the effect of precipitation followed by the effect of season (Table 1). All performed models and explained variance (pseudo-R^2) are shown in Table 1.

Discussion

The results obtained here demonstrate a descriptive data about reproduction pattern of *A. lituratus* and *S. lilium* bats in a Semideciduous Seasonal Forest fragment at southern Brazil. As expected, we found changes in *A. lituratus* and *S. lilium* abundance over the months and among reproductive stages, demonstrating a polyestry pattern for both species. Moreover, we also registered an effect of climatic variables on bats abundance during the sampling period.

Bats abundance and reproduction stages

Both recorded bat species are common and abundant in the study area. Females of *A. lituratus* and *S. lilium* at reproductive stages were found at the end of dry season and throughout rainy season. Considering gestation time of these species, which length at least three months (Taddei, 1976), the birth of bats from females that

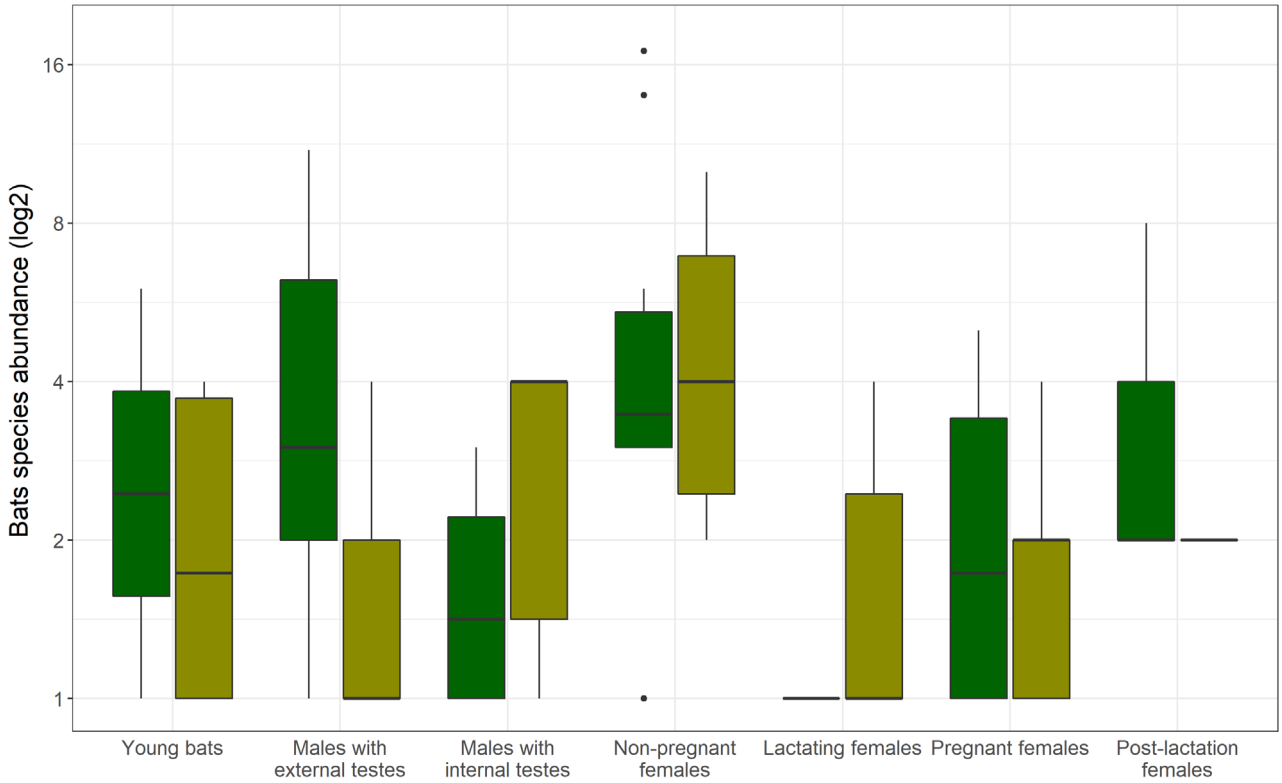

Figure 4. Bat species abundance in each reproductive stage for *Artibeus lituratus* (dark green bars) and *Sturnira lilium* (dark yellow bars) in São Camilo State Park, municipality of Palotina, state of Paraná, Brazil. Axis Y was transformed into a log scale to reduce dimensions and improve graphics looks.

were pregnant at the end of dry season (August to September) occurs at the beginning of rainy season (October and November). Energy demand in females along reproductive stages increases and lactation is the stage that requires more energy, which need a high availability of food resources (Gittleman & Thompson, 1988; Korine et al., 2004). Moreover, bats that consume fruits, pollen, or nectar can have two pregnancy peaks, which one in the end of dry season and another in the middle of rainy season, concentrating births on rainy season (Durant et al., 2013). Females of both species recorded here have this same reproductive strategy, as found in other regions along their geographical distribution (Estrada & Coates-Estrada, 2001; Ortêncio-Filho et al., 2007; Duarte & Talamoni, 2010; Kaku-Oliveira et al., 2010; Passos et al., 2013). Higher abundance of young bats sampled in the dry season (April and June for *A. lituratus* and May to July for *S. lilium*) and in the end of rainy season (January to March for *S. lilium*) demonstrate that births can occurred more often in the rainy season.

Biased sex ratio for females is commonly reported in other annual studies with bats of family Phyllostomidae and can be explained by their social habit (Zortéa, 2003; Mello et al., 2009; Kaku-Oliveira et al. 2010). These species form harems with only one adult male in each group (Morrison, 1980). In addition, males live in smaller areas than females, and females have greater mobility, thus, the probability of capturing females is higher (Mello & Fernandez, 2000; Zortéa, 2003). Moreover, long-term studies and

Table 1. Generalized linear regressions models performed between bats abundance, climatic variables and seasons in the studied forest fragment.

Response variable	Explanatory variable	AICc	df	Δ AICc	Weight	pseudo R^2
Artibeus lituratus	Temperature	102.2	2	0.0	0.50	0.41
	Season	103.5	2	1.3	0.26	0.35
	Temperature + Season	105.9	3	3.7	0.08	0.41
	Precipitation + Season	106.5	3	4.3	0.05	0.38
	Humidity + Season	107.1	3	4.9	0.04	0.35
	Precipitation	108.3	2	6.1	0.02	0.03
	Humidity	108.6	2	6.4	0.02	0.004
Sturnira lilium	Precipitation	73.6	2	0.0	0.56	0.38
	Precipitation + season	75.9	3	2.3	0.17	0.44
	Season	77.2	2	3.7	0.09	0.15
	Humidity	77.7	2	4.2	0.07	0.12
	Temperature	78.3	2	4.8	0.05	0.07
	Humidity + Season	79.5	3	6.0	0.02	0.24
	Temperature + Season	80.5	3	7.0	0.01	0.18

Where: AICc = Akaike's information criterion; df = degrees of freedom; Δ AICc = AICc difference from the best model; weight = Akaike weights of the model; pseudo-R^2 = explained variance for GLM (Nagelkerke pseudo r-squared) from Cragg & Uhler. All performed models are exhibited and models were ranked based on the lowest to highest AICc value.

with larger number of samples usually finds a sex ratio of 1:1 for *A. lituratus* and *S. lilium* (Estrada & Coates-Estrada, 2001; Godoy et al., 2014).

Atlantic Forest biome has a great latitude extension with tropical and subtropical regions depending of latitude, with variations in their climatic conditions, affecting seasonality and plant species phenology (Marques & Oliveira, 2004; Ribeiro et al., 2009; Cantidio & Souza, 2019). Plant flowering in this biome presents a pattern dependent of seasonality (Morellato et al., 2000; Mikich & Silva, 2001; Pereira et al., 2008). However, fruiting process does not follow a clear pattern and can shows peaks in the dry season (Morellato & Leitão-Filho, 1996; Mikich & Silva, 2001), or in rainy season (Marques & Oliveira, 2004; Liebsch & Mikich, 2009) or even all over the year (Morellato et al., 2000).

Studies evaluating phenology of the main chiropterochoric fruit families on fragments of Semideciduous Seasonal Forest in southern Brazil indicate a pattern and a relation between Piperaceae plants species fruitification and bats abundance, with greater availability of fruits between October and March (Lima & Reis, 2004; Sartore & Reis, 2015). Preferences for fruits of genera *Piper*, *Cecropia*, *Ficus* and *Solanum* are well recorded for diet of *A. lituratus* and *S. lilium* (Charles-Dominique, 1986, Silva et al. 2008, Andrade et al. 2013, Parolin et al. 2016; Parolin et al. 2021). Rainy season has a greater availability of these chiropterochoric fruits, and this environmental factor can explain concentration of births during this period. Relationship of birth rate and nutrient availability during dry to rainy season transition and in the rainy season was recorded for genera *Sturnira* and *Artibeus* bats species in Costa Rica, where the author found correspondence of lactation peaks with fruit abundance (Dinerstein, 1986). However, we recommended phenological studies in SCSP to better understand the influence of food resources and fruiting in bats species abundance.

The presence of a pregnant-lactating female indicates an estrus soon after delivering, confirming polyestry pattern for *A. lituratus* species in the study site. Our recorded bats did not have two pregnancy peaks, however, they had two slightly pronounced peaks of lactating females, indicating a possible bimodal polyestry pattern. Some studies confirm polyestry on *A. lituratus*, mainly fitting to bimodal polyestry pattern (Fleming et al., 1972; Estrada & Coates-Estrada, 2001; Ortêncio-Filho et al., 2007; Kaku-Oliveira et al., 2010; Castillo-Navarro et al., 2017). Continuous polyestry is less commonly (Tamsitt & Valdivieso, 1963; Taddei, 1976), as well monoestry patterns, as found by Duarte & Talamoni (2010) in southeast Brazil in a Semideciduous Seasonal Forest fragment. For *S. lilium* bats was registered a bimodal polyestry in the study area, with two pregnancy peaks (August to November and February), followed by two lactating peaks (with more abundance in December and March) and two peaks of young bats (more abundant in February and June). Polyestry is common throughout geographic distribution area of *S. lilium*, with bimodal polyestry pattern in some regions such as Central America and south Brazil (Fleming et al., 1972; Mello et al., 2009; Kaku-Oliveira et al., 2010).

Recapture of *S. lilium* bats assisted in estimating the gestation, lactation, and weaning times. According to Costa et al. (2007), fetus is only detectable by probing after a third of pregnancy time (i.e., after about a month), and identification method for reproductive stage by probing is limited due to difficulty in identifying pregnant females before the first month of gestation. A female of *S. lilium* was captured in September and classified as non-pregnant, and then recaptured three months after lactating stage, indicating a gestation time of approximately three and a half months for this species (Taddei, 1976). Little is known about weaning range age in *S. lilium*, however estimates from copulation to weaning, indicate a reproduction time about 11 months in this species (Godoy et al., 2011). In our study, some females were pregnant and lactating at capture, and then recaptured without signs of post-

lactation, indicating a weaning up between three or four months. Considering the gestation time of three and half months and the range weaning of three or four months, reproductive time found here for *S. lilium* had about seven and half months.

Males of both species with evident scrota are found practically all over the year in the study area, being more frequent during dry season. Highest abundance of *A. lituratus* males in reproductive stages occurs in August, associated with the beginning of first peaks of pregnant females. Evidences suggests that spermatogenesis is continuous, seasonally independent and fertile all over the year in males of *A. lituratus* and *S. lilium* (Beguelini et al., 2009; Duarte & Talamoni, 2010; Morais et al., 2013; Notini et al., 2015). However, peaks of sperm production can occur synchronized with female reproductive cycle (Beguelini et al., 2013). The use of testis position alone is not good indicator to assess the stage of reproduction in males, once during the field triage procedure, due to stress and excitation this character can be altered, in this case, we suggest that further work be performed using histological and hormonal techniques (Crichton & Krutzsch, 2000).

Influence of climatic variables on bat abundance

Our results indicate a potentially influence of precipitation and temperature in bats species abundance during the sampling period (September 2016 to August 2017). The establishment of organisms in the most different terrestrial environments depends fundamentally on abiotic factors, such temperature, humidity and precipitation (Begon et al. 1986). Thus, the environmental conditions of a place directly influence the structure of a community and its lifestyle (Ricklefs & Miller, 2000). For *A. lituratus* and S.lilium resource availability drive the seasonal abundance. Therefore, abiotic factors act indirectly in its seasonal variation, favoring the growth of fruits required by its diet (Carvalho, 2014, Laurindo & Gregorin, 2019) We suggest a long-term sampling with these species (e.g., at least three years) in order to check potential and with more accurately the effects of climatic variables on bats species abundance. Moreover, sometimes sampling during one year can be misleading, with the year presenting an atypical pattern regarding to previous years, such as: a warmest or coldest year compared to previous ones, or even a year with highest rates of precipitation and humidity than previous ones. In addition, changes in climate caused by global warming, deforestation, and climatic events such as El Niño and La Niña are becoming more frequent, changing the pattern of dry and rainy seasons along different regions. For the state of Paraná, hot days and nights is rising at a rate of 0.1 to 0.4% per year and there has been observed an acceleration of hydrological cycle, increasing frequency of more intense rainfalls and the occurrence of longer droughts (Silva & Guetter, 2003; Silva et al., 2015). Our results find a possible influence of temperature and precipitation variation on species abundance, but considering the climate inconsistencies in a short period of time, food and resource availability can have been more influential to reproduction pattern of bats during the sampling time.

Climate change directly affect bats reproduction, which can lead to severe ecological impacts, considering the importance of bats to dissemination and polinization of chiropterochoric plants (Muscarella & Fleming, 2007; Fleming et al., 2009; Aguiar et al., 2016). Alterations in temperature and rainfall can change the phenological patterns and plants fruit production, affecting ecological interactions between fruits and bat species (Cleland et al., 2007; Jones & Rebelo, 2013; Laurindo et al., 2017). In addition, we highlight that a year of sampling is likely a short time to evaluate the effects of climatic variables in reproductive cycle of bat species, specially under climate changes scenarios where important conditions for reproduction can vary year from year (Godoy et al., 2014). However, data here presented contribute to understand the

reproductive biology and abundance changes over one year of *A. lituratus* and *S. lilium* in a Semideciduous Seasonal Forest fragment in southern Brazil, reducing the knowledge gap about reproduction pattern of these species.

Acknowledgements

We thank two anonymous reviewers who provided helpful suggestions and comments on a previous version of this manuscript. We are grateful to everyone who helped during field sampling. The authors also thanks to Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for scholarship granted to the second author and to Instituto Ambiental do Paraná (IAP) for the license work to collect in São Camilo State Park.

Conflicts of interest

The authors declare no conflict of interest to declare.

Referências

Aguiar, L.M., Bernard, E., Ribeiro, V., Machado, R.B. & Jones, G. (2016). Should I stay or should I go? Climate change effects on the future of Neotropical savannah bats. Global Ecology and Conservation, 5, 22-33. https://doi.org/10.1016/j.gecco.2015.11.011

Alvares, C.A., Stape, J.L., Sentelhas, P.C., Gonçalvez, J.L. de M. & Sparovek, G. (2013). Köppen's climate classification map for Brazil. Meteorologische Zeitschrift, 22: 711–728. https://doi.org/10.1127/0941-2948/2013/0507

Andrade, T. Y., Thies, W., Rogeri, P. K., Kalko, E. K., & Mello, M. A. (2013). Hierarchical fruit selection by Neotropical leaf-nosed bats (Chiroptera: Phyllostomidae). Journal of Mammalogy, 94(5), 1094-1101. https://doi.org/10.1644/12-MAMM-A-244.1s

Begon, M., Harper, J. L., & Townsend, C. R. (1986). Ecology. Individuals, populations and communities. Blackwell scientific publications.

Bernard, E. (2002). Diet, activity and reproduction of bat species (Mammalia, Chiroptera) in Central Amazonia, Brazil. Revista Brasileira de Zoologia, 19(1): 173-188. https://doi.org/10.1590/S0101-81752002000100016

Beguelini, M.R.; Moreira, P.R.; Faria K.C.; Marchesin, S.R. & Morielle-Versute, E. (2009). Morphological characterization of the testicular cells and seminiferous epithelium cycle in six species of Neotropical bats. Journal of Morphology, 270(8): 943-953. https://doi.org/10.1002/jmor.10731

Beguelini, M.R.; Puga, C.C.; Taboga, S.R. & Morielle-Versute E. (2013). Annual reproductive cycle of males of the flat-faced fruit-eating bat, *Artibeus planirostris* (Chiroptera: Phyllostomidae). General and comparative endocrinology, 185: 80-89. https://doi.org/10.1016/j.ygcen.2012.12.009

Bolker B. (2020). bbmle: Tools for General Maximum Likelihood Estimation. R package version 1.0.23.1. https://cran.r-project.org/web/packages/bbmle/index.html

Brändel, S.D., Hiller, T., Halczok, T.K., Kerth, G., Page, R.A., & Tschapka, M. (2020). Consequences of fragmentation for Neotropical bats: The importance of the matrix. Biological Conservation, 252, 108792. https://doi.org/10.1016/j.biocon.2020.108792

Burnham K.P. & Anderson D.R. (2002). Model selection and multimodel inference: a practical information-theoretic approach, 2nd edn. Springer, New York.

Camargo, G.; Fischer, E.; Gonçalves, F.; Fernandes, G. & Ferreira, S. (2009). Morcegos do Parque Nacional da Serra da Bodoquena, Mato Grosso do Sul, Brasil. Chiroptera Neotropical, 15(1): 417-424. Retrieved from: https://www.academia.edu/22694035/Morcegos_do_Parque_Nacional_da_Serra_da_Bodoquena_Mato_Grosso_do_Sul_Brasil

Cantidio L.S. & Souza, A.F. (2019). Aridity, soil and biome stability influence plant ecoregions

in the Atlantic Forest, a biodiversity hotspot in South America. Ecography, 42: 1–12. https://doi.org/10.1111/ecog.04564

Carvalho, F., Fabián, M. E., & Menegheti, J. O. (2014). Variação sazonal no número de capturas de *Artibeus lituratus* (Olfers, 1818) e *Sturnira lilium* (É. Geoffroy St.-Hilaire, 1810)(Chiroptera: Phyllostomidae) no estrato superior de um remanescente de Mata Atlântica no sul do Brasil. Biotemas, 27(3), 131-138.

Castillo-Navarro, Y.; Serrano-Cardozo, V.H. & Ramírez-Pinilla, M.P. (2017). Biología reproductiva de *Artibeus lituratus* y *Artibeus jamaicensis* (Phyllostomidae: Stenodermatinae) en un área urbana en Colombia. Mastozoología neotropical, 24(1): 69-84. Retrieved from: https://www.redalyc.org/articulo.oa?id=45753369007

Chambers, J.M. (1992). Linear models. Chapter 4 of Statistical Models in S eds J. M. Chambers and T. J. Hastie, Wadsworth & Brooks/Cole.

Charles-Dominique, P. (1986). Inter-relations between frugivorous vertebrates and pioneer plants: *Cecropia*, birds and bats in French Guyana. In Frugivores and seed dispersal (pp. 119-135). Springer, Dordrecht.

Cleland, E.E., Chuine, I., Menzel, A., Mooney, H. A. & Schwartz, M.D. (2007). Shifting plant phenology in response to global change. Trends in ecology & evolution, 22(7), 357-365. https://doi.org/10.1016/j.tree.2007.04.003

Crawley, M.J. (2015). Statistics, An introduction using R. Second edition, John Wiley & Sons, Chichester.

Crichton, E. G., & Krutzsch, P. H. (Eds.). (2000). Reproductive biology of bats. Academic Press.

Costa, L.M.; Almeida, J.C. & Esbérard, C.E. (2007). Dados de reprodução de *Platyrrhinus lineatus* em estudo de longo prazo no Estado do Rio de Janeiro (Mammalia, Chiroptera, Phyllostomidae). Iheringia: Série Zoologia, 97(2): 152-156. http://doi.org/10.1590/S0073-47212007000200004

Dinerstein, E. (1986). Reproductive ecology of fruit bats and the seasonality of fruit production in a Costa Rican cloud forest. Biotropica, 307-318. https://doi.org/10.2307/2388574

Dettke, G.A.; Crespão, L.M.P.; Siquerolo, L.V.; Siqueira, E.L. & Caxambú, M.G. (2018). Floristic composition of the seasonal semideciduous forest in southern Brazil: Reserva Biológica das Perobas, state of Paraná. Acta Scientiarum - Biological Sciences 40: 1–14. https://doi.org/10.4025/actascibiolsci.v40i1.35753

Duarte, A.P.G. & Talamoni, S.A. (2010). Reproduction of the large fruit-eating bat *Artibeus lituratus* (Chiroptera: Phyllostomidae) in a Brazilian Atlantic forest area. Mammalian Biology-Zeitschrift für Säugetierkunde, 75(4): 320-325. https://doi.org/10.1016/j.mambio.2009.04.004

Durant, K.A.; Hall, R.W.; Cisneros, L.M.; Hyland, R.M. & Willig, M.R. (2013). Reproductive phenologies of phyllostomid bats in Costa Rica. Journal of Mammalogy, 94(6): 1438-1448. https://doi.org/10.1644/13-MAMM-A-103.1

Esbérard, C.E.L.; Motta, A.G.; Almeida, J.C.; Ferreira, L.C.S. & Costa, L.M. (2006). Reproduction of *Chrotopterus auritus* (Peters) in captivity (Chiroptera, Phyllostomidae). Brazilian Journal of Biology, 66(3): 955-956. https://doi.org/10.1590/S1519-69842006000500022

Estrada, A. & Coates-Estrada, R. (2001). Species composition and reproductive phenology of bats in a tropical landscape at Los Tuxtlas, Mexico. Journal of Tropical Ecology, 17(5): 627-646. *https://doi.org/10.1017/S026646740100147X*

Fleming, T.H.; Hooper, E.T. & Wilson, D.E. (1972). Three Central American bat communitis: structure, reproductive cycles, and movement patterns. Ecology, 53(4): 555-569. *https://doi.org/10.2307/1934771*

Fleming, T.H., Geiselman, C. & Kress, W.J. (2009). The evolution of bat pollination: a phylogenetic perspective. Annals of botany, 104(6), 1017-1043. *https://doi.org/10.1093/aob/mcp197*

Gardner, A. L. ed. (2008). Mammals of South America, volume 1: Marsupials, Xenarthrans, Shrews, and Bats. Chicago, University of Chicago Press. 690p.

Gittleman, J.L. & Thompson, S.D. (1988). Energy allocation in mammalian reproduction. American zoologist, 28(3): 863-875. *https://doi.org/10.1093/icb/28.3.863*

Godoy, M.S.M.; Carvalho, W.D.; Freitas, G.P.; Freitas, L.N.; Costa, L.M.; Luz, J.L.; Lopes, C.E. & Esbérard, C.E.L. (2011). Dados reprodutivos de *Sturnira lilium* (E.Geoffroy. 1810) em estudo de longo prazo no estado do Rio de Janeiro, Brasil. Chiroptera Neotropical suppl, 17, 40-43.

Godoy, M.S.M.; Carvalho, W.D. & Esbérard, C.E.L. (2014). Reproductive biology of the bat *Sturnira* lilium (Chiroptera, Phyllostomidae) in the Atlantic Forest of Rio de Janeiro, southeastern Brazil. Brazilian Journal of Biology, 74(4): 913-922. *http://doi.org/10.1590/1519-6984.22612*

Haddad, N.M.; Brudvig, L.A.; Clobert, J. et al. (2015). Habitat fragmentation and its lasting impact on Earth's ecosystems. Science Advances, 1: 1–9. https://doi.org/10.1126/sciadv.1500052

Happold, D.C. & Happold, M. (1990). Reproductive strategies of bats in Africa. Journal of Zoology, 222(4): 557-583. https://doi.org/10.1111/j.1469-7998.1990.tb06014.x

IAP (Instituto Ambiental do Paraná) (2006). Plano de Manejo do Parque Estadual de São Camilo, Curitiba: Instituto Ambiental do Paraná. Available at: < http://www.iap.pr.gov.br/modules/conteudo/conteudo.php?conteudo=1216> Access in: 12 July 2020.

Joly, C.A.; Metzger J. P. & Tabarelli, M. (2014). Experiences from the Brazilian Atlantic Forest: ecological findings and conservation initiatives. New Phytologist, 204: 459–473. https://doi.org/10.1111/nph.12989

Jones, G., & Rebelo, H. (2013). Responses of bats to climate change: learning from the past and predicting the future. In Bat evolution, ecology, and conservation (pp. 457-478). Springer, New York, NY.

Kaku-Oliveira, N.Y.; Munster, L.C.; Rubio, M.P. & Passos, F.C. (2010). Reprodução em cinco espécies de morcegos filostomídeos na Reserva Natural do Salto Morato, Guaraqueçaba, Paraná. Chiroptera Neotropical, 16(1A): 21-23.

Klose S.M.; Smith, C.L.; Denzel, A.J. & Kalko, E.K. (2006). Reproduction elevates the corticosterone stress response in common fruit bats. Journal of Comparative Physiology, 192(4): 341-350. https://doi.org/10.1007/s00359-005-0067-4

Korine, C.; Speakman, J. & Arad, Z. (2004). Reproductive energetics of captive and free-ranging egyptian fruit bats (Rousettus aegyptiacus). Ecology, 85(1): 220-230. https://doi.org/10.1890/02-0632

Laurindo, R.S., Gregorin, R., & Tavares, D. C. (2017). Effects of biotic and abiotic factors on the temporal dynamic of bat-fruit interactions. Acta Oecologica, 83, 38-47. https://doi.org/10.1016/j.actao.2017.06.009

Laurindo, R. S., & Gregorin, R. (2019). Temperature and resource availability drive the seasonal abundance of *Artibeus lituratus* (Chiroptera: Phyllostomidae) in Atlantic Forest remnants of southeastern Brazil. Mammalia, 83(4), 383-389.

Laurindo, R.S. & Vizentin-Bugoni J. (2020). Diversity of fruits in *Artibeus lituratus* diet in urban and natural habitats in Brazil: a review. Journal of Tropical Ecology 36, 65–71. https://doi.org/10.1017/S0266467419000373

Liebsch, D. & Mikich, S.B. (2009). Fenologia reprodutiva de espécies vegetais da Floresta Ombrófila Mista do Paraná, Brasil. Brazilian Journal of Botany, 32(2): 375-391. https://doi.org/10.1590/S0100-84042009000200016

Lima, I.P.D. & Reis, N.R. (2004). The availability of Piperaceae and the search for this resource by *Carollia perspicillata* (Linnaeus) (Chiroptera, Phyllostomidae, Carolliinae) in Parque Municipal Arthur Thomas, Londrina, Paraná, Brazil. Revista Brasileira de Zoologia, 21(2): 371-377. https://doi.org/10.1590/S0101-81752004000200035

Lima, C.S. & Fabián, M.E. (2016). Reproductive biology of *Artibeus fimbriatus* Gray 1838 (Chiroptera) at the southern limit of its geographic range. Biota Neotropica, 16(4): 1-4. https://doi.org/10.1590/1676-0611-bn-2016-0231

Mangiafico, S.S. (2021). rcompanion: Functions to Support Extension Education Program Evaluation. R package version 2.4.1. https://CRAN.Rproject.org/package=rcompanion

Marinho-Filho, J. (2003). Notes on the reproduction of six phyllostomid bat species in southeastern Brazil. Chiroptera Neotropical, 9(1-2): 173-175.

Marques, M.C. & Oliveira, P.E.A.M. (2004). Fenologia de espécies do dossel e do sub-bosque de duas Florestas de Restinga na Ilha do Mel, sul do Brasil. Revista Brasileira de Botânica, 27(4): 713-723. https://doi.org/10.1590/S0100-84042004000400011

Mello, M.A.R. & Fernandez, F.A.S. (2000). Reproductive ecology of the bat *Carollia perspicillata* (Chiroptera: Phyllostomidae) in a fragment of the Brazilian Atlantic coastal forest. Zeitschrift für Säugetierkunde, 65(5): 340-349. Retrieved from: https://www.biodiversitylibrary.org/page/45522943#page/370/mode/1up

Mello, M.A.R.; Kalko, E.K.V. & Silva, W.R. (2009). Ambient temperature is more important than food availability in explaining reproductive timing of the bat *Sturnira lilium* (Mammalia: Chiroptera) in a montane Atlantic Forest. Canadian Journal of Zoology, 87(3): 239-245. http://doi.org/10.1139/Z09-010

Mikich, S.B. & Silva, S.M. (2001). Composição florística e fenologia das espécies zoocóricas de remanescentes de Floresta Estacional Semidecidual no centro-oeste do Paraná, Brasil. Acta botanica brasílica, 15(1): 89-113. https://doi.org/10.1590/S0102-33062001000100010

Miranda, J. M. D.; Bernardi, I. P. & Passos, F. C. (2011). Chave ilustrada para determinação dos morcegos da Região Sul do Brasil. Curitiba, João MD Miranda.

Morais, D.B.; Paula, T.A.; Barros, M.S.; Balarini, M.K.; Freitas, M.B. & Matta, S.L. (2013). Stages and duration of the seminiferous epithelium cycle in the bat *Sturnira lilium*. Journal of anatomy, 222(3): 372-379. https://doi.org/10.1111/joa.12016

Morellato, P.C. & Leitao-Filho, H.F. (1996). Reproductive phenology of climbers in a southeastern Brazilian forest. Biotropica, 28(2): 180-191. https://doi.org/10.2307/2389073

Morellato, P.L.C.; Talora, D.C.; Takahasi, A.; Bencke, C.C.; Romera, E.C. & Zipparro. V.B. (2000). Phenology of Atlantic rain forest trees: a comparative study. Biotropica, 32(4): 811-823. https://doi.org/10.1111/j.1744-7429.2000.tb00620.x

Morrison, D.W. (1980). Foraging and day-roosting dynamics of canopy fruit bats in Panama. Journal of Mammalogy, 61(1): 20-29. https://doi.org/10.2307/1379953

Muscarella, R. & Fleming, T.H. (2007). The role of frugivorous bats in tropical forest succession. Biological reviews, 82(4), 573-590. https://doi.org/10.1111/j.1469-185X.2007.00026.x

Notini A.A.; Farias, T.O.; Talamoni, S.A. & Godinho, H.P. (2015). Annual male reproductive activity and stages of the seminiferous epithelium cycle of the large fruit-eating *Artibeus lituratus* (Chiroptera: Phyllostomidae). Zoologia (Curitiba), 32 (3): 195-200. https://doi.org/10.1590/S1984-46702015000300003

Novaes, R.L.M. & Nobre, C.C. (2009). Dieta de *Artibeus lituratus* (Olfers, 1818) em área urbana na cidade do Rio de Janeiro: frugivoria e novo registro de folivoria. Chiroptera Neotropical, 15(2): 487-493. Retrieved from: https://www.academia.edu/1082392/Dieta_de_Artibeus_lituratus_Olfers_1818_em_%C3%A1rea_urbana_na_cidade_do_Rio_de_Janeiro_frugivoria_e_novo_registro_de_folivoria

Ortêncio-Filho, H.; Reis, N.R.; Pinto, D. & Vieira, D.C. (2007). Aspectos reprodutivos de *Artibeus lituratus* (Phyllostomidae) em fragmentos florestais na região de Porto Rico, Paraná, Brasil. Chiroptera Neotropical, 13(2): 313-318.

Pacheco, S.M.; Sodré, M.; Gama, A.R.; Bredt, A.; Cavallini, E.M.; Marques, R. V.; Guimarães, M. M. & Bianconi, G. V. (2010). Morcegos urbanos: status do conhecimento e plano de ação para a conservação no Brasil. Chiroptera Neotropical, 16(1): 629-647. Retrieved from: https://www.academia.edu/10102018/Morcegos_Urbanos_Status_do_Conhecimento_e_

Plano de A%C3%A7%C3%A3o para a Conserva%C3%A7%C3%A3o no Brasil

Parolin, L.C., Bianconi, G.V., & Mikich, S.B. (2016). Consistency in fruit preferences across the geographical range of the frugivorous bats *Artibeus*, *Carollia* and *Sturnira* (Chiroptera). Iheringia. Série Zoologia, 106, 1–6. https://doi.org/10.1590/1678-4766e2016010

Parolin, L. C., Lacher Jr, T. E., Bianconi, G. V., & Mikich, S. B. (2021). Frugivorous bats as facilitators of natural regeneration in degraded habitats: A potential global tool. Acta Oecologica, 111, 103748. https://doi.org/10.1016/j.actao.2021.103748

Passos, F.C.; Carvalho, F. & Mottin, V. (2013). Dados reprodutivos de *Sturnira lilium* (Phyllostomidae: Stenodermatinae) em estudo de longo prazo na região sul de Santa Catarina. VII Encontro Brasileiro para o Estudos dos Quirópteros: Biologia e Ecologia: 156-158.

Pellón, J. J., Rivero, J., Williams, M., & Flores, M. (2021). Trophic relationships within the genus *Carollia* (Chiroptera, Phyllostomidae) in a premontane forest of central Peru. Journal of Mammalogy, 102(1), 195-203.

Pereira, T.S.; Costa, M.L.M.; Moraes, L.F.D. & Luchiari, C. (2008). Fenologia de espécies arbóreas em floresta Atlântica da Reserva Biológica de Poço das Antas, Rio de Janeiro, Brasil. Iheringia: Série Botânica, 63(2): 329-339. Retrieved from: http://www.fzb.rs.gov.br/upload/20140328114129ih63_2_p329_339.pdf

R Core Team. (2021). R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna. http://www.R-project.org/

Reis, N.R.D.; Barbieri, M.L.D.S.; Lima, I.P.D. & Peracchi, A.L. (2003). O que é melhor para manter a riqueza de espécies de morcegos (Mammalia, Chiroptera): um fragmento florestal grande ou vários fragmentos de pequeno tamanho? Revista Brasileira de Zoologia, 20(2): 225-230. https://doi.org/10.1590/S0101-81752003000200009

Ribas, M. R., Batista, S. C., & Aranha, J. M. (2020). Ocorrência e taxas de infestação de Streblidae (Diptera, Hippoboscoidea) em morcegos (Mammalia, Chiroptera) em um fragmento de floresta estacional semidecidual no oeste do Paraná, Brasil. Iheringia. Série Zoologia, 110. https://doi.org/10.1590/1678-4766e2020026

Ribeiro, M.C.; Metzger, J.P.; Martensen, A.C.; Ponzoni, F.J. & Hirota, M.M. (2009). The Brazilian Atlantic Forest: How much is left, and how is the remaining forest distributed? Implications for conservation. Biological Conservation, 142: 1144–1156. http://dx.doi.org/10.1016/j.biocon.2009.02.021

Ricklefs, R.E. & Miller, G.L. (2000). Ecology. 4th ed. Freeman, New York.

Sartore, E.R. & Reis, N.R. (2015). Trophic similarity and coexistence of *Carollia perspicillata* and *Sturnira lilium* (Phyllostomidae), two sympatric fruit bats from the Brazilian Atlantic Forest. Mammalia, 80(4): 377-384. https://doi.org/10.1515/mammalia-2014-0058

Sekiama, M.L.; Reis, N.R.; Peracchi, A.L. & Rocha, V.J. (2001). Morcegos do Parque Nacional do Iguaçu, Paraná (Chiroptera, Mammalia). Revista brasileira de Zoologia, 18(3): 749-754. https://doi.org/10.1590/S0101-81752001000300011

Silva, M.E.S. & Guetter, A.K. (2003). Mudanças climáticas regionais observadas no estado do Paraná. Terra livre, 1(20), 111-126. Retrieved from: https://www.agb.org.br/publicacoes/index.php/terralivre/article/view/178/162

Silva, A. G., Gaona, O., & Medellín, R. A. (2008). Diet and trophic structure in a community of fruit-eating bats in Lacandon Forest, Mexico. Journal of Mammalogy, 89(1), 43-49. https://doi.org/10.1644/06-MAMM-A-300.1

Silva, W.L., Dereczynski, C., Chang, M., Freitas, M., Machado, B. J., Tristão, L. & Ruggeri, J. (2015). Tendências observadas em indicadores de extremos climáticos de temperatura e precipitação no estado do Paraná. Revista Brasileira de Meteorologia, 30(2), 181-194. https://doi.org/10.1590/0102-778620130622

Silva, T.M.C.; Carvalho W.A.C.; Terra M. de C.N.S.; Santos R.M. dos; Santos A.B.M. & Souza C.R. (2019). Anthropic disturbances as the main driver

of a semideciduous seasonal forest fragment in Minas Gerais. Rodriguésia, 70: e03352017. http://dx.doi.org/10.1590/2175-7860201970065

SIMEPAR. (2018). Sistema Metereológico do Paraná. Curitiba, Simepar. Available at <http://www.simepar.br>.

Straube, F.C. & Bianconi, G.V. (2002). Sobre a grandeza e a unidade utilizada para estimar esforço de captura com utilização de redes-de-neblina. Chiroptera Neotropical, 8(1-2): 150-152.

Taddei, V.A. (1976). The reproduction of some Phyllostomidae (Chiroptera) from the northwestern region of the state of São Paulo. Boletim de Zoologia 1(1): 313-330. https://doi.org/10.11606/issn.2526-3358.bolzoo.1976.121587

Tamsitt, J.R. & Valdivieso, D. (1963). Reproductive cycle of the big fruit-eating bat, *Artibeus lituratus* Olfers. Nature, 198(4875): 104-104. https://doi.org/10.1038/198104a0

Trajano, E. (1984). Ecologia de populações de morcegos cavernícolas em uma região cárstica do sudeste do Brasil. Revista brasileira de Zoologia 2(5): 255-320. https://doi.org/10.1590/S0101-81751984000100001

Wickham, H. (2016). ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag New York.

Willig, M.R. (1985). Reproductive activity of female bats from northeast Brazil. Bat Research News, 26(2): 17-20. Retrieved from: http://hydrodictyon.eeb.uconn.edu/people/willig/Willig_pdf/SJ_11_Willig_1985.pdf

Zortéa, M. (2003). Reproductive patterns and feeding habits of three nectarivorous bats (Phyllostomidae: Glossophaginae) from the Brazilian Cerrado. Brazilian Journal of Biology, 63(1): 159-168. https://doi.org/10.1590/S1519-69842003000100020

Zortéa, M. (2007). Subfamília Stenodermatinae, p. 107-128. In: Reis, N. R.; Peracchi, A. L.; Pedro, W. A. & Lima, I. P. 2007. Morcegos do Brasil. Londrina: Editora da Universidade Estadual de Londrina.