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A rich bat community from the Araucaria Forest in Southern Brazil

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ABSTRACT
The Atlantic Forest in Brazil is a biodiversity hotspot, with the Araucaria Forest as one of its unique ecosystems. This study updates the species of bats from Balsa Nova, Paraná, by combining literature records, museum specimens, and recent fieldwork. We document 22 species, including three new records for the area. Additionally, we provide reproductive data for *Anoura geoffroyi* and *Myotis riparius*. Balsa Nova has the highest recorded bat species richness in the Araucaria Forest. Continued sampling efforts will likely reveal further species, enhancing our understanding of the region's chiropteran diversity.
Keywords: Araucaria Mixed Forest, Bugre, Chiroptera, inventory, São Luiz do Purunã

RESUMO - Comunidade rica em morcegos na Floresta com Araucária no Sul do Brasil
A Mata Atlântica no Brasil é um hotspot de biodiversidade, em que a Floresta com Araucárias como um de seus ecossistemas únicos. Este trabalho teve como objetivo atualizar a lista de espécies de morcegos de Balsa Nova, Paraná, combinando registros da literatura, espécimes em museu e trabalhos de campo recentes, documentando 22 espécies, incluindo três novos registros para a área. Ademais, fornecemos dados reprodutivos para *Anoura geoffroyi* e *Myotis riparius*. Balsa Nova é a área com a maior riqueza de espécies de morcegos registrada na Floresta com Araucárias. Esforços contínuos de amostragem, utilizando redes de neblina, armadilhas de harp e bioacústica, provavelmente revelarão mais espécies, aprimorando nossa compreensão da riqueza quiropterológica da região.
Palavras chave: Bugre, Chiroptera, Floresta Ombrófila Mista, inventário, São Luiz do Purunã

The Neotropical region, with its unparalleled diversity of animal species, stands as a critical area for conservation efforts (Olson & Dinerstein 1998; Costa et al. 2005; Fleming & Kress 2013). Bats, a significant part of this diversity, can account for up to 50% of mammal richness in certain areas of tropical forests in the Neotropical region (Patterson & Pascual 1972; Timm 1994; Aguirre 2002).

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In Brazil, the order Chiroptera is represented by nine families, comprising 68 genera and more than 180 species (Garbino et al. 2024), with at least 117 recorded in the Atlantic Forest biome (Varzinczak et al. 2015). This biome, a biodiversity hotspot due to its high degree of species endemism (Myers et al. 2000), is of utmost importance for conservation efforts. Despite being the most studied Brazilian biome regarding its chiropterofauna, the current knowledge of bats in the Atlantic Forest biome remains unsatisfactory (Lourenço et al. 2010; Bernard et al. 2011; Varzinczak et al. 2015; Muylaert et al. 2017).

The Araucaria, or Mixed Forest, is an essential part of the Atlantic Forest, and it has suffered a significant reduction, with only 4.34% of its historical range left (Zorek et al. 2024). More alarming, less than 1% of the remaining Araucaria Forest is old-growth vegetation, and only 3% of the area they cover is protected (Carlucci et al. 2021). This ecosystem is found mainly in Paraná and Santa Catarina states in southern Brazil, and the loss of habitat affected not only the plant diversity but also the local fauna that inhabit and use it (Carlucci et al. 2021).

In the state of Paraná, seven families, 38 genera, and 72 species of bats have been recorded to date (Miretzki 2003; Bianconi et al. 2009; Scultori et al. 2009; Passos et al. 2010; Moratelli et al. 2011; Carvalho et al. 2014, 2019; Portella et al. 2017; Cláudio et al. 2023; Olímpio et al. 2024), for many of these species it represents their southernmost record (Passos et al. 2010). Across Paraná three main vegetation types occur: Rain Forest, Araucaria Forest, and Semi-Deciduous Forest (Maack, 1981), yet most studies on bats are concentrated in the Rain Forest (Bernard et al. 2011). The Araucaria Forest, however, remains underexplored, with only a few locations providing data on bat fauna. One such site is the municipality of Balsa Nova, where 19 bat species have been recorded (Miretzki 2003; Miranda & Bernardi 2006; Miranda et al. 2006, 2009).

This study aims to provide an updated list of bat species of Balsa Nova, Paraná, Brazil, a fragment of the Araucaria Forest, by combining records from the literature, museum specimens, and recent fieldwork in the area.

Balsa Nova is a municipality in the metropolitan region of Curitiba, the capital of the state of Paraná, Brazil (Fig. 1). It is formed by a mosaic of environments, such as the Araucaria Forest in various stages of succession, grasslands, and altered environments. It is inserted in the Environmental Protection Area of the Devonian Escarpment (Miranda 2004). The municipality of Balsa Nova is divided into two districts: São Luiz do Puruña and Bugre.

Fieldwork was conducted only in the Bugre district, which has a remnant of the Araucaria Forest of approximately 700 hectares of continuous forest. The study site was on private property (latitude -25.4977; longitude -49.6567) with around 90 hectares. Also, we searched for previous literature published about bat richness reported to Balsa Nova in Google Scholar using the keywords: “Balsa Nova, “Paraná”, “Bugre”, “São Luiz do Puruña”, “morcegos”, “bats”, “Chiroptera”, and “quiróptera” in different combinations. Furthermore, we enriched our species inventory by studying specimens housed at the Mammal Collection of the Federal University of Paraná (DZUP/CCMZ) from Balsa Nova, which houses specimens collected in both districts.

Monthly sampling lasted two to five nights between July 2020 and February 2021.

Furthermore, additional fieldwork was conducted in December 2021, January and December 2022, and February 2023. Each night, between nine and 12 mist nets (6 x 3 m) were used, positioned 0.5 m from the ground on an existing trail and perpendicularly over one stream that crosses the property. Additionally, a longer net (15 x 6 m) was used in October, December 2020, and January 2021, positioned 2 m from the ground. The mist nets were reviewed at 30-minute intervals. The nets were operated for six hours from sunset. The sampling effort was calculated according to Straube & Bianconi (2002). Female's reproductive status was classified following Kunz (1973).

Captured specimens were individually packed in numbered cotton bags. Bats were identified according to Miranda et al. (2011), Moratelli et al. (2011), Loureiro et al. (2018), and Díaz et al. (2021). Voucher specimens were prepared and deposited at the Mammal Collection of the Federal University of Paraná (DZUP/CCMZ) (n= 29). All activities that involved handling the bats were authorized by the Brazilian Federal Government agency responsible, the ICMBio, via the SISBIO system – Sistema de Autorização e Informação em Biodiversidade (License No. 75943-1).

In our analysis, we recorded 22 bat species in the municipality of Balsa Nova based on fieldwork, voucher specimens in the DZUP/CCMZ collection, and literature sources (Table 1). The family Phyllostomidae is represented by 12 species from the subfamilies Micronycterinae (1 species), Desmodontinae (1), Phyllostominae (2), Glossophaginae (3), Carollinae (1), and Stenodermatinae (4). The family Vespertilionidae is represented by nine species from the subfamilies Vespertilioninae (6) and Myotinae (3), while only one species of the family Molossidae was recorded.

Fieldwork resulted in 30 days of sampling, with an effort of 31,284 h.m^2, and 176 bats from 17 species captured (including eight recaptures) (Table 1). Notably, the following species were recorded for the first time in Balsa Nova during the fieldwork: *Anoura geoffroyi* Gray, 1838, *Sturnira tildae* de la Torre, 1959, and *Neoeptesicus diminutus* (Osgood, 1915) (Table 1). The collected specimens and their voucher numbers are available in Supplementary Material 1. During fieldwork, reproductive data was obtained for *Anoura geoffroyi* Gray, 1838, *Carollia perspicillata* (Linnaeus, 1758), *Pygoderma bilabiatum* (Wagner, 1843), *Sturnira lilium* (É. Geoffroyi, 1810), *Myotis riparius* Handley, 1960, and *Myotis ruber* (É. Geoffroyi, 1806) (Table 2).

In addition, 117 bat specimens from 17 species were identified from the DZUP/CCMZ collection, collected between 2003 and 2023 (Supplementary material 1). Last, from the literature sources we identified 18 bat species recorded in both São Luiz do Purunã and Bugre districts (Table 1). All species recorded in the literature had at least one voucher specimen in the DZUP/CCMZ collection or were sampled during fieldwork. The accumulation curve shows that the first report of a bat species from Balsa Nova was in 2003, and a pick of diversity occurred from 2006 to 2008, a stabilization during 2010 and 2018, and additional species were found from 2020 onwards (Fig. 2).

The richness of bat species reported here is highly relevant because, among studies in the Araucaria Forest, Balsa Nova is the area with the greatest species richness, versus Ponta Grossa with two species reported (Almeida et al. 2005), Fernandes Pinheiro and Campos Gerais with eight species (Reis et al. 2000; Zanon & Reis 2007), Guarapoava with 10 species (Miranda & Zago 2015), Fazenda Rio Grande with 11 species

(Graciolli & Biancoini 2007), Campinhos with 14 species (Arnone & Passos 2007), São Francisco de Paula with 16 species (Marques & Fabian 2011; Marques et al. 2011), and Telêmaco Borba with 21 species of bats recorded (Reis et al. 1999, 2000; Peracchi et al. 2006). Although Balsa Nova and Telêmaco Borba have almost the same number of species records, it is essential to highlight that the latter is encountered in an ecotone of ecosystems of the Atlantic Forest (Reis et al. 2006), which may contribute to this higher richness of species reported to the area. The area of Balsa Nova also relevant because it is the type locality of *Neoeptesicus taddeii* (Miranda, Bernardi and Passos, 2006), a Data Deficient species (Miranda et al. 2006; Solari 2017).

Miretzki (2003) reported the occurrence of only one species from Balsa Nova, *Lasiurus blossevillii* (Lesson, 1826), in the São Luiz do Purunã district and highlighted the need for basic information about the bat fauna in the municipality. Subsequently, between 2006 and 2010 other studies improved the bat fauna knowledge of the municipality (Miranda & Bernardi 2006; Miranda et al. 2006, 2009), comprising 18 species. The 22 bat species now reported for Balsa Nova represent about 11.8% of the known bat richness for Brazil (Garbino et al. 2024), 26% of the Atlantic Forest biome, and 30.5% of the known richness for the state of Paraná (Bianconi et al. 2009; Scultori et al. 2009; Passos et al. 2010; Moratelli et al. 2011; Carvalho et al. 2014, 2019; Portella et al. 2017; Cláudio et al. 2023; Olímpio et al. 2024).

Among this diversity, it is worth mentioning *Myotis izecksohni* Moratelli et al., 2011, a common species for the locality, for which there is little information on its distribution, ecology, and biology (Moratelli et al. 2011; Dias et al. 2015). To date, only three locations in Paraná have a record of *M. izecksohni*, Campinhos (Arnone & Passos 2007), Guarapuava (Miranda & Zago 2015; Miranda et al. 2019), and Balsa Nova (Moratelli et al. 2011; present study). Additionally, we obtained reproductive information for *A. geoffroyi*, which previously had information only for Trinidad and Tobago and central regions in Brazil (Heideman et al. 1992; Baumgarten & Vieira 1994; Heideman & Bronson 1994; Zortéa 2003; Farias et al. 2018; Reis et al. 2022). Yet, our study provided unprecedented reproductive information for *M. riparius*, whose reproductive pattern was unknown.

Our field efforts extended over two years, during which we documented only a portion of the Municipality's bat diversity. Bergallo et al. (2003) suggest that a minimum of 1000 captures are necessary to satisfactorily know the chiropterofauna of a locality in the Atlantic Forest. However, in higher latitudes with seasonal climes and more severe winters, it is more difficult to capture that number of specimens (considering that most studies last around one year). Also, Meyer et al. (2010) recommend long-term sampling for 15 to 20 years to characterize the bat fauna of a locality. Considering these estimates, only some places in the Atlantic Forest have satisfactory knowledge about the bat fauna. The high diversity of bats listed here is due to years of study in the area and stresses the importance of reviewing several data sources, such as fieldwork, literature, and museum specimens, to have a clear picture of the whole diversity in the area.

Sampling efforts in the region continue, and we are now using mist nets, harp traps, active searches for roots, and bioacoustics monitoring. Using those approaches, we expect to increase the species list, especially for insectivore bats.

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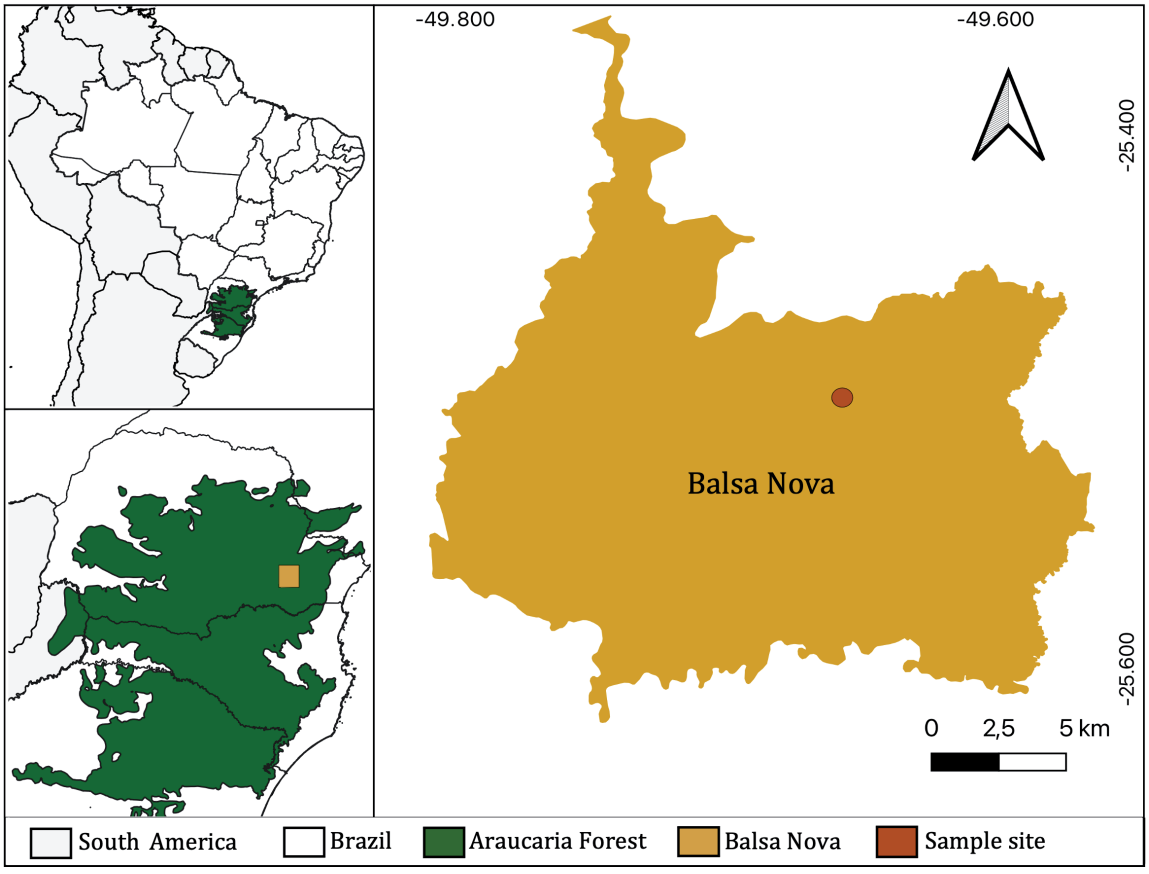

Figure 1. Map of Balsa Nova, Paraná, Brazil. The red dot indicates the sample site (Bugre district).

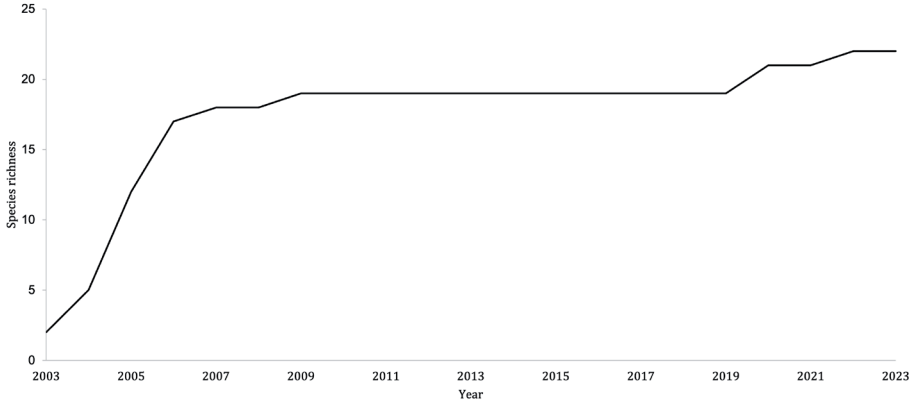

Figure 2. Species accumulation curve of known bat diversity in Balsa Nova, Parana, Brazil.

Table 1. Species, subfamilies, and families of bats from Balsa Nova, Paraná, Brazil. The "Field" column denotes specimens captured by us during sampling, "Museum" refers to the number of voucher specimens previously stored in the DZUP collection, and "Literature" refers to records in the literature.

Taxon	Field	Museum	Literature
Phyllostomidae			
Micronycterinae Van Den Bussche, 1992 (1)			
Micronycteris megalotis (Gray,1842)	1		Miranda et al. (2009)
Desmodontinae Wagner, 1840 (1)			
Desmodus rotundus (É. Geoffroy, 1810)	4	4	Miranda et al. (2009)
Phyllostominae Gray, 1825 (2)			
Chrotopterus auritus (Peters, 1856)		3	Miranda et al. (2009)
Mimon bennettii (Gray, 1838)		9	Miranda & Bernardi (2006); Miranda et al. (2009)
Glossophaginae Bonaparte, 1845 (3)			
Glossophaga soricina (Pallas, 1766)			Miranda et al. (2009)
Anoura caudifer (É. Geoffroy, 1818)	1	1	Miranda et al. (2009)
Anoura geoffroyi Gray, 1838	3		
Carolliinae Miller, 1924 (1)			
Carollia perspicillata (Wagner,1843)	19	3	Miranda et al. (2009)
Stenodermatinae Gervais, 1856 (4)			
Artibeus lituratus (Olfers, 1818)	5	2	Miranda et al. (2009)
Pygoderma bilabiatum (Wagner, 1843)	10	2	Miranda et al. (2009)
Sturnira lilium (É. Geoffroy, 1810)	99	10	Miranda et al. (2009)
Sturnira tildae de la Torre, 1959	1		
Molossidae			
Molossus molossus (Pallas, 1766)		4	Miranda et al. (2009)
Vespertilionidae Gray, 1821			
Vespertilioninae Gray, 1821 (6)			
Neoeptesicus brasiliensis (Desmarest, 1819)	1	8	Miranda et al. (2009)
Neoeptesicus furinalis (d'Orbigny e Gervais, 1847)	3	8	Miranda et al. (2009)
Neoeptesicus diminutus (Osgood, 1915)	2		
Neoeptesicus taddeii (Miranda, Bernardi & Passos, 2006)	1	26	Miranda et al. (2006)
Histiotus velatus (I. Geoffroy, 1824)	1	5	Miranda et al. (2009)
Lasiurus blossevilli ([Lesson, 1826])	6	1	Miretzki (2003); Miranda et al. (2009)
Myotinae Tate, 1942 (3)			
Myotis izecksohni Moratelli Peracchi Dias e Oliveira, 2011	14	10	
Myotis riparius Handley, 1960	2		Miranda et al. (2009)
Myotis ruber (É. Geoffroy,1806)	2	18	Miranda et al. (2009)

Table 2. Female reproductive status and young specimens captured in the District of Bugre, Balsa Nova, Paraná. The table only shows the months that fieldwork was conducted. P = pregnant, L = lactating, PL = post lactating, I = inactive, P*= pregnant and lactating simultaneously, Y = young.

	2020						**2021**			**2022**		**2023**
	Jul	Agu	Sep	Oct	Nov	Dec	Jan	Feb	Dec	Jan	Dec	Feb
Anoura geoffroyi				1 P/ 1 I		1 L						
Carollia perspicillata						1 P/ 1 I	3I	1P				
Pygoderma bilabiatum			1 I	1 I					1L	1J/ 1PL		
Sturnira lilium	1 PL/ 1 I		4 I	1 P/ 4 I	8 P/ 2 L/ 4 I	1 L / 2 I	23Y/4L	1Y		1P *	1 I	
Myotis riparius						1 PL	1 I					
Myotis ruber						2 L						
Myotis izecksohni						1 I						
Neoeptesicus brasiliensis										1 L		

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