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INVENTORIES OF BIRDS AND MEDIUM TO LARGE-BODIED MAMMALS IN FIVE ATLANTIC FOREST REMNANTS IN SOUTHERN BRAZIL

Juliano A. Bogoni[1], *Luan G. Araujo Goebel*[1]*, *Talita C. Bogoni*[2] & *Manoel Santos-Filho*[1]

1 Universidade do Estado de Mato Grosso, Centro de Pesquisa de Limnologia, Biodiversidade e Etnobiologia do Pantanal; Programa de Pós-Graduação em Ciências Ambientais, Laboratório de Mastozoologia, Cidade Universitária, Av. Santos Dumont s/n, CEP: 78200-000, Cáceres, Mato Grosso, Brazil.

2 Instituto Federal Catarinense, *Campus* Concórdia, Rod. SC-283, Km 8, Vila Fragosos, CEP: 89700-000, Concórdia, Santa Catarina, Brazil.

E-mails: bogoni.ja@gmail.com; lg.araujogoebel@gmail.com (*corresponding author); tbogoni@gmail.com; manoel.filho@unemat.br

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Abstract: Birds and mammals are two species-rich taxonomic groups that play several roles in terms of ecosystem functioning. Yet, these homoeothermic vertebrates face several threats to survive worldwide. Our major aims were (1) to provide a checklist of both birds and medium- to large-bodied mammals and (2) to explore the patterns of diversity and composition of birds and mammals in five forest fragments of Semideciduous Forest, located in the Ipumirim municipality, Santa Catarina, Brazil. The mammal inventory was performed using camera-trapping, active search and visual signals and vocalizations. The bird inventory was obtained by occasional records from camera-trapping and active search, complemented by the point count method. We analysed the data with classical diversity descriptors, a rarefaction approach, and a dissimilarity index. We obtained 210 independent records for both taxonomic groups, which included 57 species. Among them, 37 bird species and 20 medium- to large-bodied mammal species were included. Both for birds and mammals, the richness among sites was not significantly different when compared via rarefaction curves and was also equally dissimilar among the sites in terms of species composition. We conclude that the homoeothermic vertebrates in the study area represent only an incomplete parcel of a once-diverse transitory region regarding phytophysiognomy and associated fauna. Even so, faunistic inventories can provide valuable information on species distribution, occurrence, and persistence, which is essential for advancing macroecological studies on persistent Wallacean gaps in medium- to large-sized birds and mammals in certain Neotropical regions, heavily modified by ongoing human activities.

Key-words: tropical forest; camera-trapping; human-modified landscapes; neotropical; biodiversity.

INTRODUCTION

Birds and mammals are two species-rich taxonomic groups that play several roles in terms of ecosystem functioning (*e.g.*, seed dispersal and communities assembling; Sekercioglu 2006; Lacher *et al.* 2019). Yet, these homoeothermic vertebrates face several threats worldwide, such as fragmentation, habitat loss, and defaunation (Galetti *et al.* 2013; Peres *et al.* 2016). Throughout Brazil, 1,971 bird species have been described (Pacheco *et al.* 2021), with approximately 10% (193 taxa) under some level of endangerment (Marini & Garcia 2005). Mammals described in Brazil include 778 species, distributed differently across the vast Brazilian territory and in terms of threats (Abreu Jr. *et al.* 2023). The Atlantic Forest is the ecoregion with the most endemic bird species in Brazil and the second in terms of bird species richness (Marini & Garcia 2005). In the Atlantic Forest, there are approximately 453 mammal species, of which approximately 92 are endemic (Graipel *et al.* 2016; Oliveira *et al.*, 2024).

Due to the synergy of habitat loss and degradation and high-levels of biodiversity, the Atlantic Forest is classified as a biodiversity hotspot (Myers *et al.* 2000). However, this biome is subjected to several chronic human-induced modifications (*e.g.* habitat fragmentation and loss, defaunation) that compromise ecosystem functioning (Canale *et al.* 2012; Bogoni *et al.* 2016). For example, the fragmentation of forests has a strong impact on biodiversity with more than 2/3 of mammal species disappearing when habitats are fragmented (Bogoni *et al.* 2024). The effects of fragmentation on mammals in the Atlantic Forest show that fragments smaller than 200 ha are disproportionally small and perturbed to safeguard mammal assemblages, decreasing species richness and population sizes (Chiarello 1999).

Across the subtropical portion of the Atlantic Forest, the Semideciduous Forest and Mixed Ombrophilous Forest — located majorly in southern states — are among the most modified and reduced vegetal formations. As a result of chronic historical deforestation, numerous small-sized fragments have been created (<50 ha) and are currently inserted into a highly modified matrix of agroecosystems and human settlements (Eduardo 1974; Paim 2006; Ribeiro *et al.* 2009). Moreover, in this region, there are important gaps in information about species distributions (*i.e.*, Wallacean shortfalls; Bogoni *et al.* 2013; Hortal *et al.* 2015). Consequently, this gap induces or is joined to other shortfalls in knowledge (*e.g.*, Raunkiaeran [*i.e.*, species trait diversity], Hutchinsonian [*i.e.*, abiotic tolerances], Eltonian [*i.e.*, ecological interactions] and Prestonian [*i.e.*, population patterns] shortfalls), compromising future studies in ecology and conservation (Hortal *et al.* 2015).

Given this context, determining species list and distribution patterns is the first step to elaborate and provide subsidies for conservation strategies (Bogoni *et al.* 2017; Rosa & Souza 2017). Santa Catarina state harbours more than 426 bird and 139 mammal species (Rosáro 1996; Rupp *et al.* 2008; Cherem *et al.* 2004). However, the studies are concentrated in a few areas (*e.g.*, coastal zones and Dense Ombrophilous Forests). The increasing efforts in ornithological studies in Santa Catarina are still concentrated in the Atlantic Forest *sensu stricto* (*i.e.*, the region of Dense Ombrophilous Forest between the Atlantic Ocean and the Serra Geral) (Piacentini *et al.* 2006). Studies on mammals started in the 1990s and were also concentrated on coastal regions and islands (*e.g.*, Graipel *et al.* 2001). However, in the last two decades, studies have focused on other regions (*e.g.* Cherem 2005; Cáceres *et al.* 2007; Cherem *et al.* 2007; Bogoni *et al.* 2013; Hendges *et al.* 2015).

Despite some studies in the interior plateaus of Santa Catarina state (*e.g.*, Bogoni *et al.* 2013), to our knowledge, there are no inventories of bird species in this micro-region, whereas mammals have been inventoried in only three forest remnants (Bogoni *et al.* 2013). Furthermore, while vertebrate inventories have been conducted extensively in several regions of the Atlantic Forest — particularly within protected areas (Lima *et al.* 2017) — there remains a notable lack of assessment and documentation of vertebrate fauna on private forest fragments absorbed by highly human-modified landscape matrices. Therefore, our main objectives were (1) to provide a checklist of both birds and medium- to large-bodied mammals and (2) to explore the patterns of diversity and composition of birds and mammals in five forest fragments of Semideciduous Forest, located in the Ipumirim municipality, Santa Catarina, Brazil.

MATERIAL AND METHODS

Study area

We developed this study from 2010 to 2014 and complemented it in 2021 across five forest remnants of Semideciduous Forest (FESD) located in the Ipumirim municipality, Santa Catarina, southern Brazil (Figure 1). The region is characterized by being in an ecotone between Semideciduous Forest (FESD) and Mixed Ombrophilous Forest (FOM), which contains many small rural properties and has been effectively colonized since the 1940s, and its main activity has been logging (Locatelli 1985; Veloso *et al.* 1991). The climate is a humid subtropical climate with hot summers, according to the Köppen-Geiger

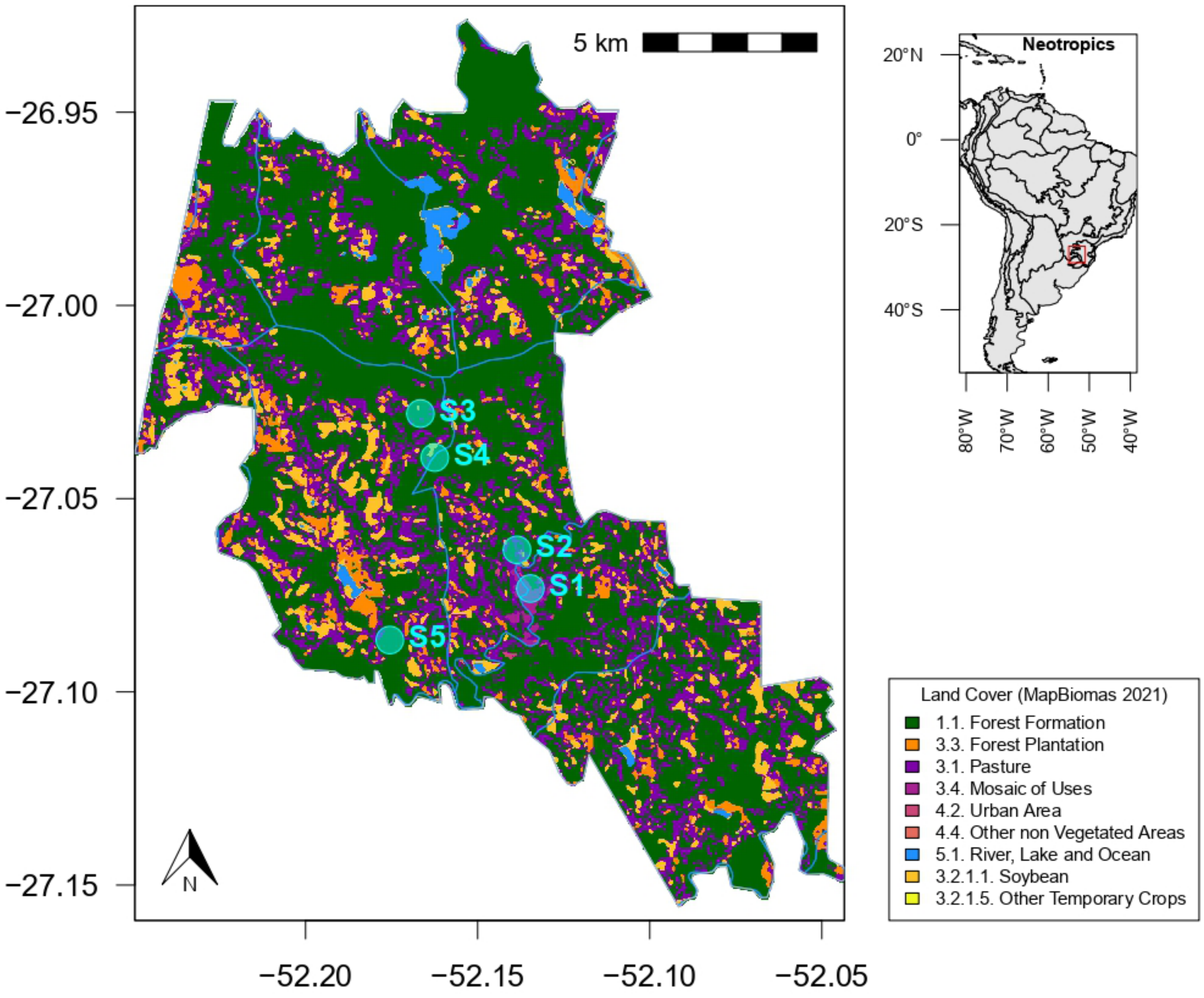

Figure 1. Locations of the five forest remnants (sites) where both birds and medium- to large-bodied mammals were inventoried in Ipumirim municipality, Santa Catarina state, Brazil.

classification, with an average annual temperature of 19°C and an average precipitation of 1,400 mm/year (Monteiro 2001; Peel *et al.* 2007).

The site S1 (27°04’40” S; 52°08’07” W; 564 meters above sea level [m.a.s.l.]) is located within the urban area of the municipality and characterized by a small tract (28.0 ha) of riparian forest bordering the Engano River (Figure 1), where selective logging was intense during the 1940s, with only small-sized trees (<10 m) and some individuals of *Luehea candicans*, *Anadenanthera colubrina*, and *Erythrina falcata* remaining. The other sites: S2 (27°02’56” S; 52°08’04” W; 677 m.a.s.l.; 127.5 ha); S3 (27°01’39” S; 52°09’58” W; 893 m.a.s.l.; 55.0 ha); S4 (27°02’20” S; 52°09’43” W; 899 m.a.s.l.; 47.0) and S5 (27°05’10” S; 52°10’30” W; 664 m.a.s.l.; 51.0 ha) are located within the rural limits of the municipality and are composed of fragments embodied in a similar matrix (*i.e.*, silviculture and agriculture), presenting a similar history of exploitation, such as selective logging until the 2000s (Figure 1). Nevertheless, some of these fragments (*e.g.* S2, S3, and S5) had important hydric resources and high-rugged terrain containing some large individuals (*ca.* 15 m) of *Araucaria angustifolia*, whereas S4 was characterized by the presence of some large individuals (*ca.* 12 m) of *Cedrela fissilis*.

Bird and mammal inventories

The mammal inventory was performed using different methods: (1) camera-trapping; (2) active search; and (3) visual signals and vocalizations. Camera trapping was performed only on fragments S3, S4, and S5 in a previous study published by

Bogoni *et al.* (2013) and complemented at site S2 in 2021. The mammal sampling via camera-traps in S1 — performed in the same period as S3, S4, and S5 — was not performed because of the risk of camera-trap theft or vandalism (see Meek *et al.* 2018). Therefore, mammals were recorded via camera-traps between October 2010 and July 2011 with the camera-trap model *Tigrinus* ® 6.0D (see Bogoni *et al.* 2013; S3, S4 and S5) and from June to August 2021 using a Neewer ® 940 nm camera-trap (S2).

The camera-traps were installed at each site (S3, S4, and S5) for 2,160 hours (*i.e.*, 90 camera-trap-days [CTD]), checked weekly and equally switched from one site to another every 360 hours (*i.e.*, 15 days). Different points within the sites were sampled during each temporal replica, totalling six points per site. Due to logistic issues, in S2, the camera-trap was not switched but worked for an equal period of 90 CTD across four different points within the site. To maximize the possibility of recording the species, attractive baits (*i.e.*, fruit, flesh, sardines, and salt) were used simultaneously. The active search, visual signals (*e.g.*, footprints and faeces) and vocalizations were obtained through 12 expeditions (monthly) with random walks of three hours each at sites S3, S4 and S5 (a total of 36 hours per site) (Lyra-Jorge *et al.* 2008; Bogoni *et al.* 2013) and — due to logistic issues — in four expeditions (trimonthly) at sites S1 and S2 (a total of 12 hours per site). To identify mammal tracks, we used an identification guide (Becker & Dalponte 2013).

The bird inventories were obtained from occasional records from the aforementioned mammalian sampling methods, but mainly via the point count method (Blondel 1970). The point count method was performed for the diurnal birds during the first three hours of the morning (*i.e.*, from 06:00 AM to 09:00 AM) on four occasions at each site (*i.e.*, trimonthly), totalling 12 hours of sampling effort at each site. We determined a five-point count in each fragment to observe and/or perform auditory detections during the 30 min per point (considering 30 min for moving between points) and covering a fixed radius of ~50-75 m (including neighbouring areas of the fragments). In this sampling, we recorded any bird species present at the site-scale using visualizations and vocalizations, assisted by binocular support, illustrated, and acoustic guides (Ralph *et al.* 1995; Vielliard 1995; Ghizoni-Jr *et al.* 2013; Bini 2009). Birds and mammals that have gregarious habits are considered a single record. For both groups, whenever possible, during the inventories, the animals were photographed (Supplementary Material S1 and S2).

Additionally, we obtained the threat status of each species according to the International Union for Conservation of Nature (IUCN 2024) and according to the Brazilian and Santa Catarina official list of threatened species (Santa Catarina 2011; Brazil 2022). However, to compose the dataset, we considered records of the same species as independent if the intervals between photos exceeded one hour (60 minutes). (Gómez *et al.* 2005; Oliveira-Santos *et al.* 2009). Mammal and bird alpha taxonomy followed Abreu-Jr *et al.* (2023) and Bini (2009), respectively, while some recent taxonomic changes were updated according to specific literature.

Data analysis

We analysed the data with classical diversity descriptors (*i.e.*, species richness and the number of independent records as a proxy of abundance values; Magurran 2004). To evaluate the alpha-diversity across the five sites, we employed a rarefaction approach using the Chao index (Chao *et al.* 2014) for each taxonomic group. This method involves estimating species richness at a uniform sample coverage across all sites. The sample coverage serves as a metric for inventory completeness, utilizing richness values for a specified sample size or coverage. This enables us to make statistical comparisons — according to confidence intervals of 95% — typically at twice the minimum abundance of any given assemblage, based on these estimates (Chao *et al.* 2014; Hsieh *et al.* 2019). In addition to rarefaction, we also generated extrapolation curves to predict species richness at larger sample sizes using the *iNEXT* R-package (Hsieh *et al.* 2019).

We also used a dissimilarity index based on Bray-Curtis distance coefficient to evaluate the differences in species composition per taxonomic group among the sites prior to transformation via Hellinger (Legendre & Gallagher 2001). Although Bray-Curtis tends to give weight to the most abundant species, the range of species records was not discrepant (see Table 1 and 2). Hence, we calculated the alignment between these paired clusters to assess the congruence between parallel dendrograms for each taxon, where a lower value indicates the best alignment quality (Galili 2015). These analyses generate hierarchical dendrograms representing dissimilarity, which was subsequently evaluated through cophenetic correlation, serving as a measure to assess the robustness of cluster patterns within the dissimilarity dendrogram, providing insight into the fidelity with which the dendrogram maintains the original pairwise distances among the unmodelled data points (see Legendre & Legendre 1998). Posteriorly, we tested the significance of dendrogram clustering (*i.e.*, site grouping) using a similarity profile analysis (SIMPROF), considering statistically significant groupings at $p \leq 0.05$. SIMPROF is an analysis for assessing the number of significant clusters produced in a dendrogram (Clarke *et al.* 2008). These analyses were implemented via *clustsig* (Whitaker and Christman 2010), vegan (Oksanen *et al.* 2013), *pvclust* (Suzuki *et al.* 2006), and *dendextend* (Galili 2015) R-packages. All data analyses were performed in R (R Core Team 2017).

RESULTS

We obtained 210 independent records for both taxonomic groups, resulting in 57 species (Supplementary Material S1 and S2). We obtained 133 independent records of 37 bird species and 77 independent records of 20 medium- to large-bodied mammal species (Table 1 and 2; the small-bodied *Philander quica* was also included in the analysis). Considering that the sampling coverage ranged from 0.52 (S1) to 0.88 (S3), the observed and estimated species richness for birds ranged from 8 to 27 and 12.8 to 36.9, respectively (Table 1). For mammals (sampling coverage from 0.62 [S3] to 0.96 [S4]), the species richness ranged from 4 to 12 (estimates 4.4 to 15.5; Table 2). The richest site in terms of bird species was S2 ($S_{obs} = 27$; $S_{est} = 36.9$; Table 1), and for mammals, it was S3 ($S_{obs} = 12$; $S_{est} = 15.5$; Table 2); however, for both birds and mammals, the richness among sites was not significantly different when compared via rarefaction and extrapolation curves (Figure 2).

The bird assemblages were dissimilar — on average — at 61.7% (range: 17.2% to 84.8%) among sites, forming a significant cluster of S3, S4, and S5 (Fig. 3). For mammals, sites were 67.3% (20% to 100%) dissimilar, forming a significant group in S4 and S5 (Figure 3). Among the sites, the species composition of both taxa was highly aligned (alignment quality = 0.09), with a cophenetic correlation revealing that the clusters were well represented (r = 0.94; Fig. 3). The bird species with most independent records were *Troglodytes aedon* Vieillot, 1809 (13 records), *Columbina talpacoti* (Temmick, 1809) (10 records), *Leptotila rufaxilla* (Richard and Bernard, 1792) (9 records) and *Vanellus chilensis* (Molina, 1782; 8 records; Table 1). The more frequent mammal species were *Cerdocyon thous* (Linnaeus, 1766; 15 records), *Didelphis aurita* (Wied-Neuwied, 1826; 8 records), *Nasua nasua* (Linnaeus, 1766) and *Eira barbara* (Linnaeus, 1758) (the last two with 7 records each; Table 2). Several species from both groups had one single record (Table 1 and 2; Figures 3 and 4), such as *Herpailurus yagouaroundi* (É. Geoffroy Saint-Hilaire, 1803), whereas *Coendou* sp. was recorded in two opportunities in S2 via both vocalization and visualization.

Among the species recorded, no birds are considered under threat (Table 1). Among mammals, only *Leopardus pardalis* (Linnaeus, 1758) and *Puma concolor* (Linnaeus, 1771) are under threat (Endangered [EN] and Vulnerable [VU], respectively) according to the Santa Catarina list (SANTA CATARINA 2011), whereas *Leopardus guttulus* Hensel, 1872, *P. concolor* and *H. yagouaroundi* are listed in the Red Book of Threatened Species of Brazil (both classified as VU) (MMA 2016). *Lontra longicaudis* (Olfers, 1818) and *Sapajus nigritus* Goldfuss, 1809 are classified as near-threatened (NT) and *Dasyprocta azarae* (Lichtenstein, 1823) is classified as data-deficient (DD) in the IUCN red list (IUCN 2024; Table 2).

DISCUSSION

Understanding the patterns and processes of species distribution is a critical point for ecology and conservation efforts (Phillips *et al.* 2004). For this purpose, databases on species occurrence provide fundamental information to address our major knowledge gaps (Cabral *et al.* 2017; Hortal *et al.* 2015). Accordingly, we provide a list of birds and medium- to large-bodied mammals resulting in the occurrence of 57 species (37 birds and 20 mammals), complementing the findings of a previous study performed in this region, where 13 mammal species were recorded (Bogoni *et al.* 2013).

Table 1. List of bird species recorded in five subtropical Atlantic Forest fragments located in Ipumirim municipality, southern Brazil. Acronyms are: VI: visualization; CT: camera-trap; VO: vocalization.

Class	**Order**	**Species**	**Independent Records**							**Status**		
			Method	**S1**	**S2**	**S3**	**S4**	**S5**	**Total**	**SC**	**MMA**	**IUCN**
Aves	Accipitriformes	*Buteo magnirostris* (Gmelin, 1788)	VI, VO	0	0	1	1	2	4	-	-	LC
	Coraciiformes	*Chloroceryle amazona* (Latham, 1790)	VI	3	0	0	0	0	3	-	-	LC
	Cathartiformes	*Coragyps atratus* (Bechstein, 1783)	VI	0	1	0	1	1	3	-	-	LC
	Charadriiformes	*Vanellus chilensis* (Molina, 1782)	VI, VO	0	1	3	2	2	8	-	-	LC
	Columbiformes	*Columbina talpacoti* (Temmick, 1809)	VI	3	0	3	2	2	10	-	-	LC
		Leptotila rufaxilla (Richard & Bernard, 1792)	VI, VO	0	1	3	3	2	9	-	-	LC
		Leptotila verreauxi Bonaparte, 1855	VI, CT	0	0	1	0	0	1	-	-	LC
		Patagioenas picazuro Temminck, 1813	VI	0	1	1	0	0	2	-	-	LC
	Coraciiformes	*Baryphthengus ruficapillus* (Vieillot, 1818)	VI	0	1	0	0	0	1	-	-	LC
	Cuculiformes	*Crotophaga ani* Linnaeus, 1758	VI, VO	0	2	2	2	1	7	-	-	LC
		Guira guira (Gmelin, 1788)	VI, VO	0	0	3	1	2	6	-	-	LC
		Piaya cayana (Linnaeus, 1766)	VI	1	3	0	1	0	5	-	-	LC
	Falconiformes	*Phalcoboenus chimango* (Vieillot, 1816)	VI, VO	0	0	1	0	0	1	-	-	LC
	Galliformes	*Penelope obscura* Temminck, 1815	VI, CT, VO	0	0	2	0	1	3	-	-	LC
	Gruiformes	*Aramides saracura* (Spix, 1825)	VI, CT, VO	1	2	3	0	1	7	-	-	LC
	Passeriformes	*Saltator similis* d'Orbigny & Lafresnaye, 1837	VI	0	1	0	0	0	1	-	-	LC

Table 1. Continues on next page...

Table 1. ...continued

Class	Order	Species	Independent Records							Status		
			Method	S1	S2	S3	S4	S5	Total	SC	MMA	IUCN
		Cyanocorax chrysops (Vieillot, 1818)	VI, VO	1	3	0	0	0	4	-	-	LC
		Sporophila caerulescens (Vieillot, 1823)	VI	1	1	0	0	0	2	-	-	LC
		Sicalis flaveola (Linnaeus, 1766)	VI	0	1	0	0	0	1	-	-	LC
		Zonotrichia capensis (Muller, 1776)	VI	0	1	0	0	0	1	-	-	LC
		Furnarius rufus (Gmelin, 1788)	VI, VO	1	1	0	0	0	2	-	-	LC
		Pygochelidon cyanoleuca (Vieillot, 1817)	VI	0	2	0	0	0	2	-	-	LC
		Molothrus bonariensis (Gmelin, 1789)	VI	0	1	0	0	0	1	-	-	LC
		Mimus saturninus (Lichtenstein, 1823)	VI, VO	0	0	0	2	1	3	-	-	LC
		Pyrocephalus rubinus (Boddaert, 1783)	VI	0	2	0	0	0	2	-	-	LC
		Paroaria coronata (Miller, 1776)	VI	0	2	0	0	0	2	-	-	LC
		Thraupis sp.	VI	0	1	0	0	0	1	-	-	LC
		Troglodytes aedon Vieillot, 1809	VI, VO	0	2	5	3	3	13	-	-	LC
		Turdus albicollis Vieillot, 1818	VI	0	1	0	0	0	1	-	-	LC
		Turdus rufiventris Vieillot, 1818	VI, VO	0	0	4	0	3	7	-	-	LC
		Pitangus sulphuratus (Linnaeus, 1766)	VI, VO	1	1	0	0	0	2	-	-	LC
	Pelecaniformes	*Theristicus caudatus* (Boddaert, 1783)	VI	0	2	2	0	1	5	-	-	LC

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Class	Order	Species	Independent Records							Status		
			Method	S1	S2	S3	S4	S5	Total	SC	MMA	IUCN
	Piciformes	*Colaptes campestris* (Vieillot, 1818)	VI, VO	0	1	0	0	0	1	-	-	LC
		Ramphastos dicolorus Linnaeus, 1766	VI, VO	0	2	1	0	1	4	-	-	LC
	Psittaciformes	*Pionus maximiliani* (Kuhl, 1820)	VI, VO	0	0	2	0	1	3	-	-	LC
	Struthioniformes	*Crypturellus obsoletus* (Temmick, 1815)	VO	0	3	0	1	0	4	-	-	LC
	Trogoniformes	*Trogon surrucura* (Spix, 1824)	VI	0	1	0	0	0	1	-	-	LC
			Observed richness	**8**	**27**	**16**	**11**	**15**	**37**			
			Estimated richness	**12.8**	**36.9**	**18.4**	**13.4**	**19.4**	**-**			

Table 2. List of mammal species recorded in five subtropical Atlantic Forest fragments located in Ipumirim municipality, southern Brazil. Acronyms are: VI: visualization; CT: camera-trap; VO: vocalization; FO: footprint.

Class	Order	Species	Independent Records							Status		
			Method	S1	S2	S3	S4	S5	Total	SC	MMA	IUCN
Mammalia	Carnivora	*Cerdocyon thous* (Linnaeus, 1766)	VI, CT	0	4	2	6	3	15	-	-	LC
		Leopardus guttulus Hensel, 1872	CT	0	0	2	3	0	5	-	VU	LC
		Leopardus pardalis (Linnaeus, 1758)	VI	0	1	0	0	0	1	EN	-	LC
		Puma concolor (Linnaeus, 1771)	FO	0	0	1	0	0	1	VU	VU	LC
		Herpailurus yagouaroundi (É. Geoffroy Saint-Hilaire, 1803)	VI	0	1	0	0	0	1	-	VU	LC
		Eira barbara (Linnaeus, 1758)	CT	0	0	2	2	3	7	-	-	LC

Table 2. Continues on next page...

Table 2. ...continued

Class	Order	Species	Independent Records							Status		
			Method	**S1**	**S2**	**S3**	**S4**	**S5**	**Total**	**SC**	**MMA**	**IUCN**
		Galictis cuja (Molina, 1782)	VI, CT	0	0	0	2	2	4	-	-	LC
		Nasua nasua (Linnaeus, 1766)	VI, CT	0	3	1	2	1	7	-	-	LC
		Procyon cancrivorus (G.[Baron] Cuvier, 1798)	FO	1	0	2	0	0	3	-	-	LC
		Lontra longicaudis (Olfers, 1818)	VI	4	0	0	0	0	4	-	-	NT
	Cetartiodactyla	*Mazama* sp.	VI	0	1	0	0	0	1			LC
	Cingulata	*Dasypus novemcinctus* Linnaeus, 1758	VI, CT	0	1	1	1	2	5	-	-	LC
		Cabassous tatouay (Desmarest, 1804)	CT	0	0	1	0	0	1	-	-	LC
	Didelphimorphia	*Didelphis albiventris* Lund, 1840	VI, CT	0	2	2	0	0	4	-	-	LC
		Didelphis aurita (Wied-Neuwied, 1826)	VI, CT	2	5	1	0	0	8	-	-	LC
		Philander quica Olfers, 1818	CT	0	0	1	0	0	1	-	-	LC
	Primates	*Sapajus nigritus* Goldfuss, 1809	CT	0	0	0	2	1	3	-	-	NT
	Rodentia	*Hydrochoerus hydrochaeris* (Linnaeus, 1766)	VI	3	0	0	0	0	3	-	-	LC
		Dasyprocta azarae (Lichtenstein, 1823)	CT	0	0	1	0	0	1	-	-	DD
		Coendou sp.	VO, VI	0	2	0	0	0	2	-	-	LC
			Observed richness	**4**	**9**	**12**	**7**	**6**	**20**			
			Estimated richness	**4.4**	**11.4**	**15.5**	**7.2**	**6.8**	**-**			

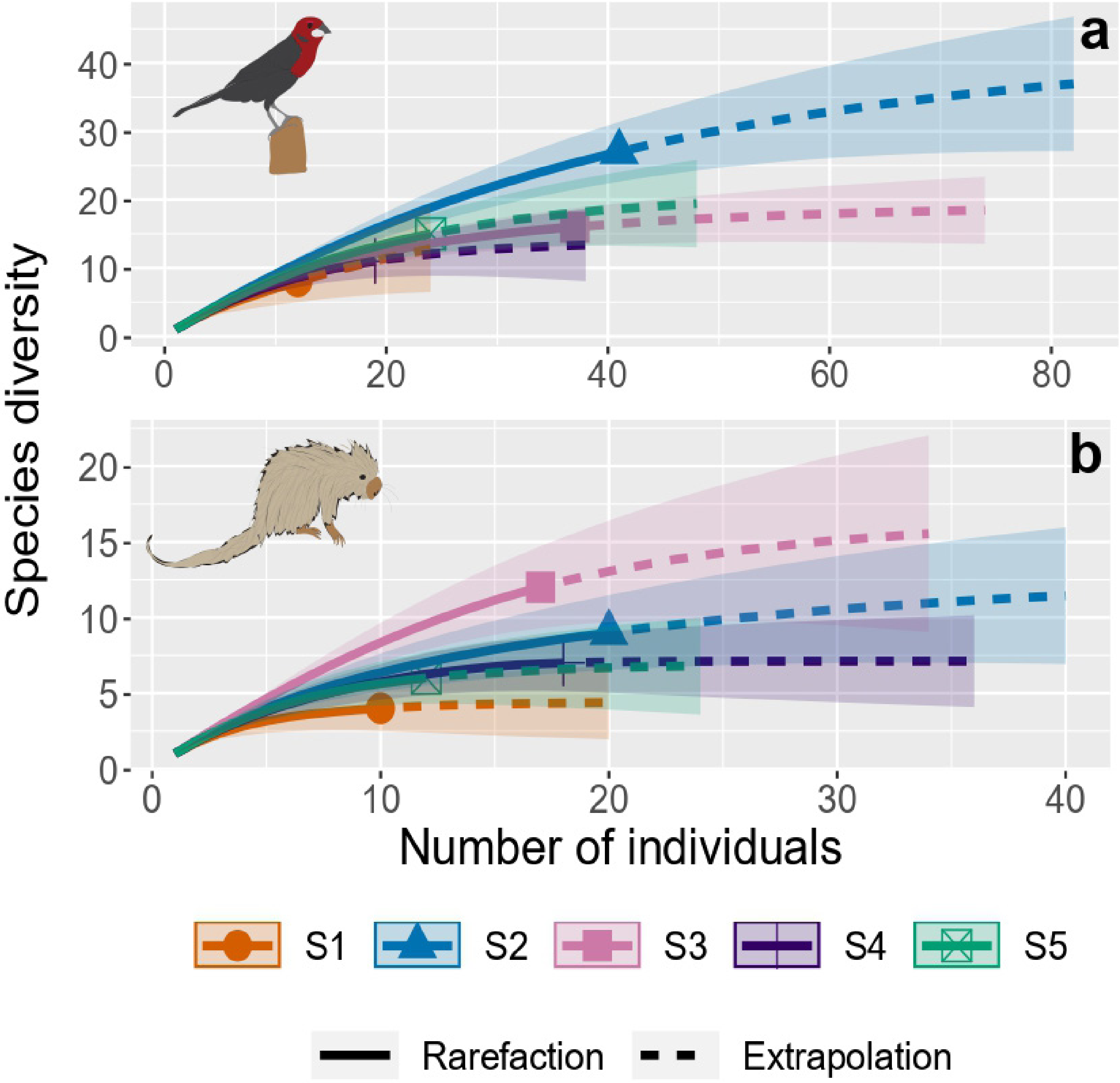

Figure 2. Rarefaction curves derived from the interpolation-extrapolation approach to compare bird (a) and medium- to large-bodied mammal (b) diversity at five sites located in the subtropical Atlantic Forest, Brazil.

Due to the low sampling effort, the bird species richness was underestimated in comparison with other studies in mainland areas of Santa Catarina state (*e.g.* Fontana *et al.* 2008; Guzzi & Favretto 2014; Oliveira *et al.* 2014) or in other Atlantic Forest areas (*e.g.* Bornschein & Reinert 2000; Develey & Martensen 2006), but it still provides important information in terms of species distribution across a poorly studied region.

The richness of medium- to large-bodied mammals (both observed [7.60 ±3.05] and estimated [9.06 ± 4.40]) was ca. 2-fold lower than the mean richness of the entire Atlantic Forest (*i.e.*, 14.49 species) (Bogoni *et al.* 2017). In the subtropical portion of the Atlantic Forest — such as other major regions in Brazil — the vertebrate fauna has experienced severe impacts from human-induced changes, such as habitat loss and defaunation (*e.g.* Canale *et al.* 2012; Galetti *et al.* 2013; Bogoni *et al.* 2016; Peres *et al.* 2016). These threats invariably not only result in the loss of large-bodied vertebrate species, but also consistently decrease the ecological functions and ecosystem processes performed by these elements of regional biotas, such as seed dispersal, seed predation, and several other ecological functions performed only by specialist species (Galetti *et al.* 2013). For instance, drivers of habitat change in the Northeast and Southeast Atlantic Forest have led

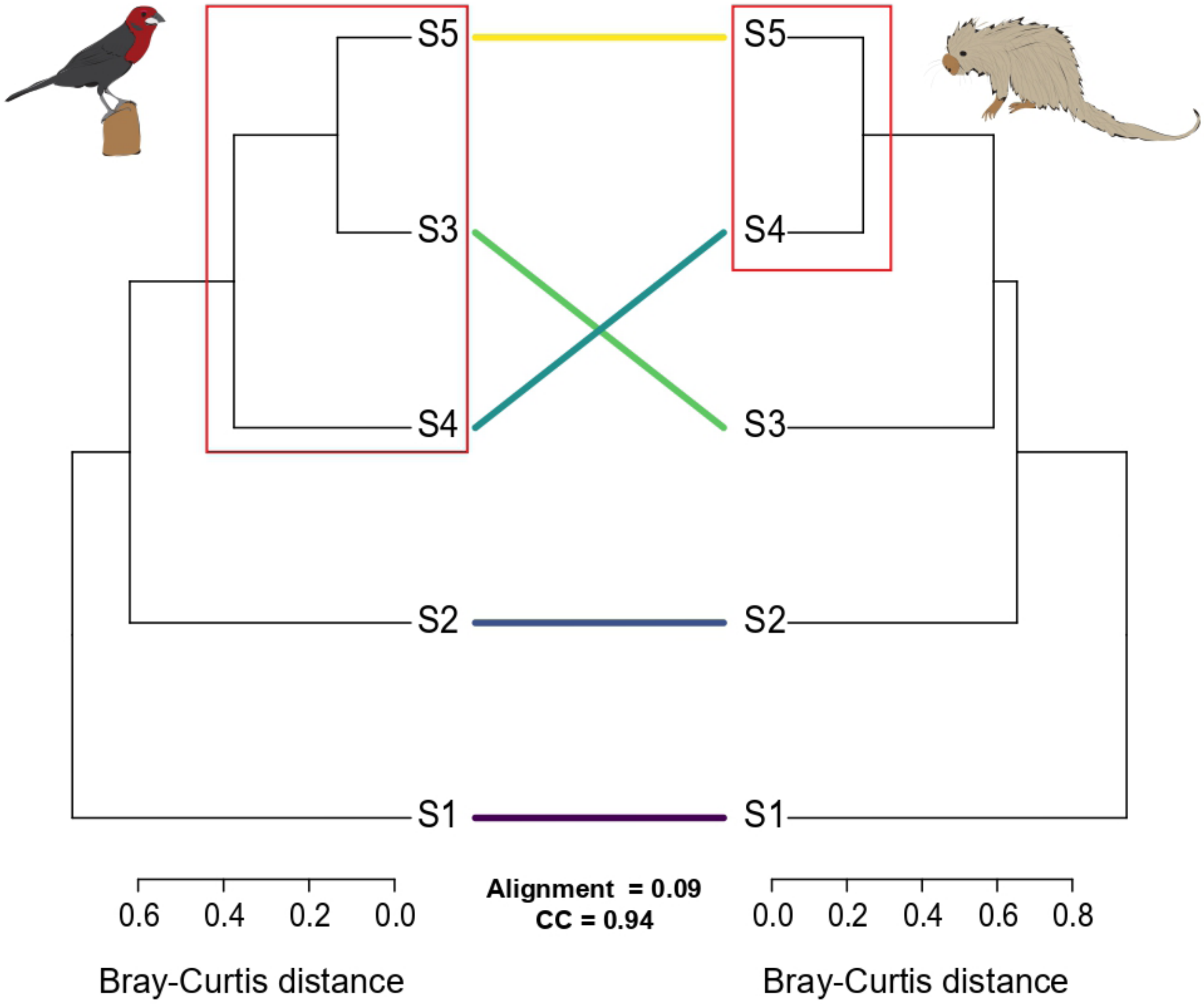

Figure 3. Dissimilarity of bird and medium to large-bodied mammal species composition and dendrogram alignments across five sites located in the subtropical Atlantic Forest, Brazil. Red rectangles represent sites where the species composition was significantly similar. The alignments of each fragment are illustrated in different colors.

to a decline in species diversity and a reduction in the average body size of the surviving species. This frequently culminates in the exclusive persistence of adaptable or matrix-tolerant mammal species, which are typically generalist (Chiarello 1999; Galetti *et al.* 2009; Canale *et al.* 2012; Jorge *et al.* 2013).

Our results reinforce this pattern, given that the vast majority of mammal species recorded can be classified as habitat and feed generalists (*e.g.*, Magioli *et al.* 2021). However, specialist animals such as wild cats and jacús (*Penelope obscura*) persist in the region. Although the effects of habitat loss and degradation remain in the region, the rugged terrain poses a significant challenge to the agricultural mechanization of large areas — a factor that could potentially benefit the relictual biodiversity (Bogoni *et al.* 2016). Despite facing hunting pressures and selective logging, the region could benefit from more effective landscape management to preserve a substantial portion of its original biodiversity (*e.g.*, Arroyo-Rodriguez *et al.* 2020). This can be achieved by creating a mosaic where interconnected native areas coexist associated with the terrain's ruggedness, facilitating corridors and a permeable matrix exhibiting low structural contrast.

Another highlighting result is the difference in species composition among the areas (> 60% for both taxa). This result is in accordance with other studies that showed that landscape features lead to a non-random modification in species composition (Radford & Bennett 2007; Smith *et al.* 2011; Bogoni *et al.* 2016; Regolin *et al.* 2017). For birds, the sites more distant from the urban area (S3, S4, and S5) formed a significant grouping in terms of species composition, despite site S2 — nearest to the urban area — being the richest site. According to other studies, the presence of urban landscapes presumably alters the composition of vertebrate assemblages and tends to lead to decreases in species richness and abundance (Radford & Bennett 2007; Smith *et al.* 2011). Our mammal results were very similar (significantly grouping sites S4 and S5). Conditions of land-use and altitude are factors that influenced mammal fauna in a previous study in the region (Bogoni *et al.* 2013) such as in other regions of Santa Catarina state (Bogoni *et al.* 2016; Regolin *et al.* 2017).

We fully recognize the difference in sampling efforts and temporal sample asynchrony to achieve these inventories. Despite these biases, our rarefaction approach showed that the trends of the number of individuals vs. richness tended to stabilize (see Figure 2), revealing that the extrapolated richness for both groups (see Table 1 and 2) probably indicates the species recorded and the cryptic ones (*i.e.* pseudo-absences). Differences in sampling methods and efforts can affect the estimation of the local richness and detectability of some species, which are typically rare or threatened (Lyra-Jorge *et al.* 2008; Bogoni *et al.* 2021). Moreover, the bird species checklist can be considered a preliminary assessment of bird diversity in this region — limiting a complete interpretation of our results — reinforcing the importance of new inventories to contribute to curbing some biodiversity knowledge shortfalls in terms of local biota completeness and species distribution (Hortal *et al.* 2015). For instance, we recorded only a half-part (46.9%) of bird species compared with an inventory conducted in an indigenous land in this FESD-FOM ecotone (see Santos *et al.* 2014), whereas mammals reached ca. 2-fold more than other inventories performed in this region (see Cherem & Althoff 2019). Moreover, the asynchrony between inventories (S1, S3, S4, and S5 in 2010-2011 and S2 in 2021) can also include biases in terms of species composition given that the sites inventoried in 2010-2011 may no longer have the same species composition. Despite this assumption, our grouping analysis showed that both birds and mammals at site S2 were intermediaries in terms of species dissimilarity in relation to other sites (see Figure 3).

Among the bird species recorded, none is under some threat category according to regional, national or international red lists. This finding reinforces that chronic and several environmental modifications oversimplified the fauna, given that the species under threat (absent in this inventory) generally require larger and preserved tracts of native areas across landscapes (Smith *et al.* 2011; Jorge *et al.* 2013). For mammals, seven species are threatened according to at least one of the aforementioned red lists, such as the felids *L. guttulus*, *L. pardalis*, *P. concolor*, and *P. yagouaroundi*. The mustelid *L. longicaudis* and the primate *S. nigritus* are near threatened with extinction, and the rodent *D. azarae* is classified as insufficient data. The main conditions used to define threat factors in Atlantic Forest mammals are body size, diet, patterns of reproduction, and fecundity (Graipel *et al.* 2016), and these species present at least one of these factors in their life history traits (Bogoni *et al.* 2022). Moreover, the conflict with domestic dogs (here recorded to *H. yagouaroundi*) is another factor that negatively influences native fauna, and the presence of feral cats is an important threat to bird species (Winter & Wallace 2006; Doherty *et al.* 2017).

Based on our results, we can conclude that the homoeothermic vertebrates in the study area represent only an incomplete parcel of a once-diverse transitory region regarding phytophysiognomy and associated fauna; thus, more intensive studies are needed to avoid pseudo-absences, which can reach 11% for mammals (see Bogoni *et al.* 2022). Even so, our faunistic inventories — despite being limited — can provide valuable information on species distribution, occurrence, and persistence, being fundamental to developing macroscale studies against persistent Wallacean gaps of birds and medium- to large-bodied mammals in some Neotropical regions highly modified by chronic human activities. The strong evidence of the oversimplification of regional fauna across the subtropical Atlantic Forest landscape is highly linked to habitat loss and hunting; therefore, the management of private areas in these regions can avoid additional declines in vertebrate biotas.

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CONFLICT OF INTEREST

The authors have no conflicts of interest.

AUTHORS CONTRIBUTION

JAB: conceptualization, data obtaining, figures, and writing the manuscript draft; LGAG: manuscript major editing; TCB: data obtaining and manuscript editing; MSF: manuscript major editing. We thank three anonymous reviewers for their valuable contributions to this manuscript.

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SUPPLEMENTARY MATERIAL

Figure S1. Some bird species recorded in five subtropical Atlantic Forest fragments located in Ipumirim municipality, southern Brazil. (A) *Theristicus caudatus* (Boddaert, 1783); (B) *Buteo magnirostris* (Gmelin, 1788); (C) *Paroaria coronata* (Miller, 1776); (D) *Trogon surrucura* (Spix, 1824); (E) *Leptotila verreauxi* Bonaparte, 1855; (F) *Penelope obscura* Temminck, 1815.

Figure S2. Some mammal species recorded in five subtropical Atlantic Forest fragments located in Ipumirim municipality, southern Brazil. (A) *Leopardus guttulus* Hensel, 1872; (B) *Herpailurus yagouaroundi* (É. Geoffroy Saint-Hilaire, 1803); (C) *Hydrochoerus hydrochaeris* (Linnaeus, 1766); (D) *Cerdocyon thous* (Linnaeus, 1766); (E) *Nasua nasua* (Linnaeus, 1766); (F) *Philander frenatus* Olfers, 1818; (G) *Dasypus novemcinctus* Linnaeus, 1758; (H) *Cabassous tatouay* Desmarest, 1804; (I) *Eira barbara* (Linnaeus, 1758); (J) *Didelphis aurita* (Wied-Neuwied, 1826); (K) *Sapajus nigritus* Goldfuss, 1809; (L) *Galictis cuja* (Molina, 1782).

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