ARTICLE

COMPOSITION AND FUNCTIONAL STRUCTURE OF BIRD ASSEMBLAGES IN THREE NATIVE HABITAT REMNANTS IN CENTRAL RIO GRANDE DO SUL STATE, BRAZIL

GUILHERME SEMENTILI-CARDOSO

FÁBIO MAFFEI

REGINALDO JOSÉ DONATELLI

São Paulo State University (Unesp), Av. Eng. Luiz Edmundo C. Coube, 14-01, Núcleo Habitacional Presidente Geisel, 17.033-360, Bauru, São Paulo, Brazil, guilherme.sementili@unesp.br

Abstract: The "Uruguayan Savannas" and the "Alto Paraná Atlantic forests" are two dominant ecoregions in the central portion of Rio Grande do Sul state, southern Brazil. However, large areas of these habitats are threatened by anthropogenic activities and require urgent conservation efforts. In order to access the status of bird assemblages in this region, we conducted surveys on three farms located in the central region of Rio Grande do Sul state, Brazil. We aimed to analyze the variation in functional structure (trophic guilds and foraging strata) and species composition within these farms. After 432 hours of transect surveys, we recorded 219 species across the three locations. This finding indicates that these farms host ~31% of the regional bird species pool. Bird community diversity differed among the three farms. Two of the recorded species are threatened with extinction (*Hydropsalis anomala* (Gould, 1838) and *Dromococcyx pavoninus* (Pelzeln, 1870), 24 endemics to the Atlantic Forest, and 40 subject to illegal trading. Our data provide evidence that agricultural land holdings can serve as important refuges for birds in this region. Additionally, even areas dominated by forestry activity can maintain relevant biodiversity when associated with conservation practices.

Keywords: avian survey, ecotone, hotspot.

ASSEMBLEIAS DE AVES EM TRÊS REMANESCENTES DE HABITAT NATIVO NA REGIÃO CENTRAL DO ESTADO DO RIO GRANDE DO SUL, BRASIL

Resumo: Os "Campos Sulinos" e as "Florestas Atlânticas do Alto Paraná" são duas ecorregiões dominantes na porção central do estado do Rio Grande do Sul, sul do Brasil. No entanto, grandes áreas desses habitats estão ameaçadas por atividades antropogênicas e exigem esforços urgentes de conservação. Para avaliar o estado das assembleias de aves nesta região, realizamos levantamentos em três fazendas localizadas na região central do estado do Rio Grande do Sul, Brasil. Nosso objetivo foi analisar a variação na estrutura funcional (guildas tróficas e estratos de forrageio) e na composição de espécies nessas fazendas. Após 432 horas de levantamentos de transectos, registramos 219 espécies nos três locais. Esse resultado indica que essas fazendas abrigam cerca de 31% do pool de espécies de aves da região. A diversidade da comunidade de aves diferiu entre as três fazendas. Duas das espécies registradas estão ameaçadas de extinção (*Hydropsalis anomala* Gould, 1838 e *Dromococcyx pavoninus* Pelzeln, 1870), sendo 24 endêmicas da Mata Atlântica e 40 sujeitas ao comércio ilegal. Nossos dados fornecem evidências de que as áreas agrícolas podem servir como refúgios importantes para aves nesta região. Além disso, mesmo áreas dominadas pela atividade florestal podem manter uma biodiversidade relevante quando associadas a práticas de conservação.

Palavras-chave: levantamento de aves, ecótonos, hotspot.

Introduction

The "Uruguayan Savannas" and the "Alto Paraná Atlantic forests" are two dominant habitats in central Rio Grande do Sul state, southern Brazil (Borsato et al., 2015). These ecoregions have high biological relevance as they contain a significant proportion of areas threatened by anthropogenic activities and in urgent need of conservation (Cordeiro & Hasenack, 2009). The open habitats of "Uruguayan Savannas" occupy about 63% of their original extent in the state, but the remaining areas are degraded, with only 36% under some form of conservation designation (Ribeiro et al., 2021). Despite intense anthropogenic activity, these natural grasslands and savannas are the best-conserved habitats in Rio Grande do Sul, since the Alto Paraná Atlantic forests occupy less than 17% of their original extent in the state (Borsato et al., 2015).

In the boundaries between Uruguayan Savannas and Alto Paraná Atlantic forests, there are several habitat types, such as Dense and Mixed Ombrophilous forests, Deciduous and Semideciduous Seasonal Forests, Savanna and Steppe fields (Leite & Klein, 1990). Habitat diversity is greater in ecotone areas, which is directly reflected in faunal diversity. This contact between habitats supports greater species richness and abundance, thus, these locations may sustain assemblages that would otherwise be restricted to separate ecosystems (Baker et al., 2002; Kark et al., 2007). In addition, transition habitats can act as centers of evolutionary innovation (Moritz et al., 2000), particularly for birds (Kark et al., 2007), and may contain a greater number of endemic species than areas of uniform habitat (Kark & Van Resenburg, 2006).

Spatial and temporal distribution of birds is a crucial tool for the management and conservation of species in ecotones, especially in severely degraded areas. Birds are sensitive to fragmentation and diversity often decline in response to the disturbance of natural habitats (Watson et al., 2005). Since sensitivity varies among taxa, and birds respond promptly to environmental changes, bird assemblage dynamics can act as a bioindicator of habitat quality (Padoa-Schioppa et al., 2006). Faunal inventories provide critical knowledge about the composition of biological communities, providing the basis for management actions (Santos, 2003). Establishing a network of interconnected natural habitat patches is essential for the conservation of avian diversity, as protected areas provide important resources (i.e. nesting areas, food, refugia) to the maintenance of endemic and threatened taxa in otherwise modified landscapes (Bruner et al., 2001).

Here we characterized the composition and functional structure of bird assemblages in three locations in ecotone areas between the "Uruguayan Savannas" and the "Alto Paraná Atlantic forests" in the central region of Rio Grande do Sul state, Southern Brazil. We described the functional structure in terms of feeding guilds and habitat stratification, and assessed the presence of threatened, endemic and species subjected to illegal trade. These findings may indicate the biological relevance of these areas for bird conservation.

Material and methods

Study area

The study was conducted in three forestry farms (Fig. 1) located in the central region of Rio Grande do Sul, which has a humid subtropical climate (Cfa, according to Köppen) in regions with altitudes below 600 m (Kuinchtner & Buriol, 2001). The average temperature varies between -3° C and 18° C for cold months and above 22 ° C in the hottest months. The annual rainfall is distributed around 1400 mm (Maluf, 2000). The farms are situated in eucalyptus silviculture areas, where native vegetation remnants are preserved as required by governmental policies.

The "Sede" farm (29°48'44.08 "S, 51°50'34.74" W), located in the municipality of Taquari, contains substantial industrial infrastructure (total area of 203 ha, with 33 ha of conservation). In this farm, the conservation areas have dense riparian forests bordering the Taquari River. These riparian forests have dense understory, composed by vines, bushes and native bamboo thickets. This farm is located inside the urban perimeter of the municipality, and is crossed by trails used by illegal fishermen, hunters and loggers.

The "Mundo Novo 1" farm (29° 38'59.09 "S, 51°53'34.31" W), located in the municipality of Bom Retiro de Sul, has 464 ha, with 114 ha destined for conservation areas, including around 20 ha of flooded fields formed by damming local streams. This location is different from the others, as it has a sharp topographic gradient, which varies around 100 m in elevation. In the lowlands, the flooded fields create an extensive swampy physiognomy. In the highlands, predominates the eucalyptus sylviculture along with semideciduous and riparian forests which follow the course of the riverbeds.

Finally, the "Menezes" farm, located in the municipality of Butiá (30 ° 13'39.85 "S 51 ° 57'40.50" W), covers 1581 ha, of which 342 ha are reserved for conservation. In this farm, we found dense riparian and semideciduous forests that follows the rivers and streams in the region. The forests have a dense understory, composed mainly by vines and bamboo thickets. In the southern portion, we observed patches of mixed ombrophylous forests, also called Araucaria forests.

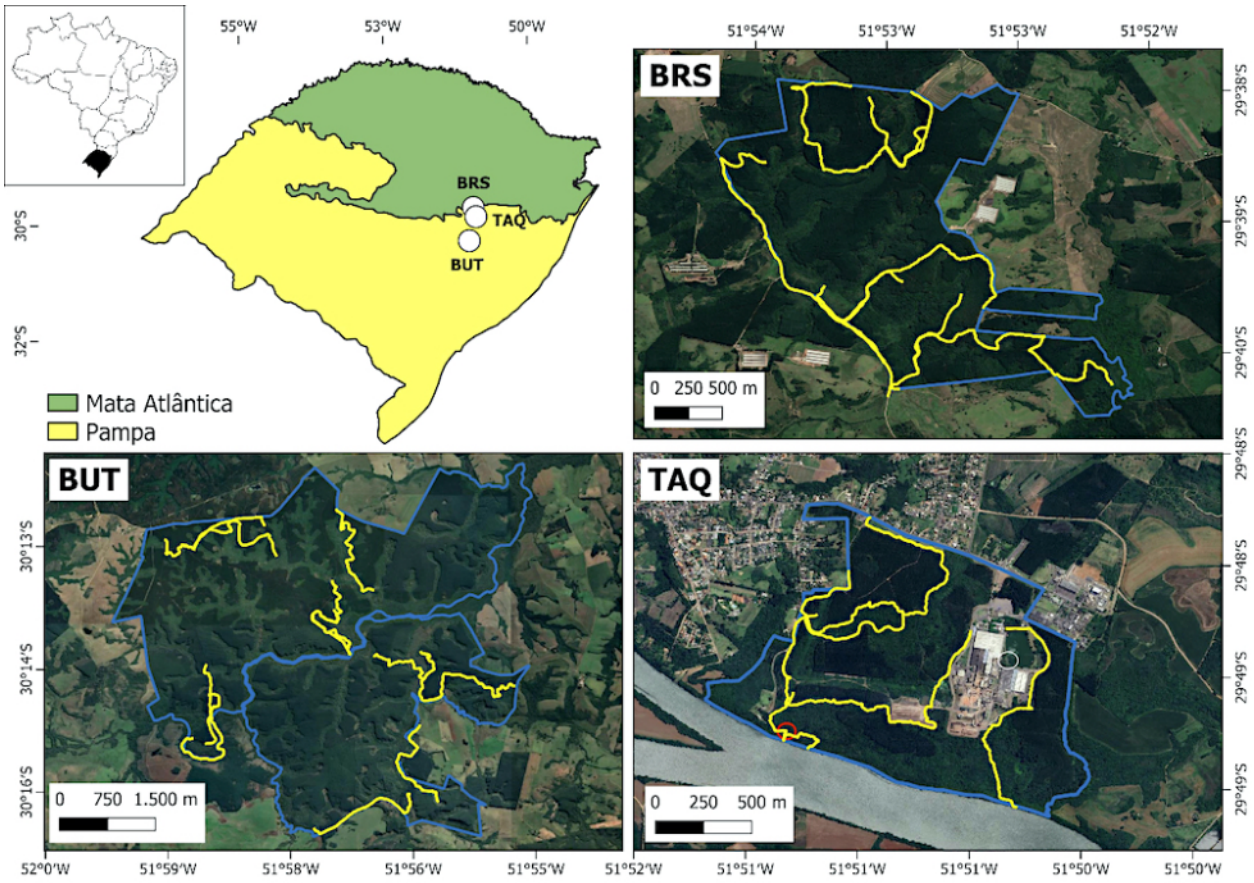

Fig. 1. Location of the three sampled areas in the central region of the Rio Grande do Sul state (BRS – Bom Retiro do Sul; TAQ – Taquari; BUT – Butiá). We highlighted the limits of each area (blue lines) and the line transects (yellow lines).

In the three farms, the areas of native forest are restricted to secondary forests at an intermediate succession stage. Despite the distance between the three municipalities, they are in the transition zone between the "Uruguayan Savannas" and the "Alto Paraná Atlantic forests" (Borsato et al., 2015).

Avian Surveys

We surveyed the bird assemblages using line transects (Bibby et al., 2000) in four discrete sampling campaigns: July/2017 (C1), October/2017 (C2), February/2018 (C3) and June/2018 (C4). During each campaign at each farm, we conducted a total of six transects. Each transect was surveyed twice in a single day, for three hours each during dawn (5:00-9:00h AM) and dusk (4:00-8:00h PM). Thus, we carried out 144h of surveys per farm (3 hours x 2 periods x 6 transects x 4 campaigns), totaling 432h of total sampling effort. The transects routes were marked with GPS, and each transect was 1.54 ± 0.23km (mean ± sd) in length. During each survey, one observer with 10x30 binoculars walked a pre-established route, recording all bird seen and/or heard. When possible, we also collected photographic and sound records (using a camera with telephoto lens and a digital recorder with a directional microphone). In each sampling campaign, we followed different transects, to avoid repeat sampling the same locations. To obtain a more comprehensive survey, we also recorded additional species detected outside the standardized sampling. These additional records were not included in the quantitative analyzes of abundance and richness parameters.

Taxonomic ordering and nomenclature of birds follows Pacheco et al. (2021). To characterize the habitat usage and the feeding guild of each species, we used information in Wilman et al. (2014). For feeding guilds, we pooled species according to the percentage of use of a given food item, classifying them as: Insectivores (INV), Vertivores (VER), generalist predators (vertebrates and invertebrates - PRE), Piscivores (PIS), Frugivores (fruits, pseudofruits and infrutescences - FRU), Granivores (seeds, grains and spores - GRA), Nectarivores (nectar, pollen, gums and other exudates - NEC), Scavengers (scavenge, garbage, carrion, and trawlers - SCA), Herbivores (other plant parts in addition

to those mentioned above - HER) and Omnivores (food items of animal and plant origin in the same proportion - OMN). Habitat use is based on the percentage of use of a given environment for each species, categorizing strata in the following categories: aquatic (AQU), ground (GRO), understory (UND), midstory (MID), canopy (CAN), mixed strata (MIX), aerial (AER) and pelagic (PEL).

The endemic status of species was based on Bencke et al. (2006) for Atlantic Forest species. Species' conservation status was based on the International Union for Conservation of Nature's Endangered Red List (IUCN, 2021), the Brazilian Endangered Species List (ICMBio, 2018) and the Red Book List of endangered fauna in Rio Grande do Sul (Rio Grande do Sul, 2014). We also identified species susceptible to exploitation, based on the Guide to Trafficked Birds in Brazil (Costa & Monteiro, 2016). For this characterization, we included additional detections from outside the formal surveys, as they provide a broader view of the bird assemblage. The dataset is available in a public repository (Sementili-Cardoso et al., 2023).

Diversity Assessment

To analyze diversity patterns, we used individual-based rarefaction curves (Colwell et al., 2012), using the Hill number q = 0, which corresponds to species richness (Chao et al., 2014). We corrected for the effects of different abundances among the three locations by extrapolating the curves of the farms with the lowest number of detections (Colwell et al., 2012; Chao & Jost, 2012). We calculated 95% confidence intervals using a 200-replication bootstrap (Chao et al., 2013), which allowed us to assess whether there is a significant difference among the three diversity profiles. The rarefaction and extrapolation were used using the online software iNext (Chao et al., 2016).

We also assessed diversity and similarity using a traditional approach with Shannon and Gini-Simpson index. The first measures the uncertainty about the identity of species in each sample, while the latter measures the probability that two individuals, drawn randomly from the sample, will be of different species (Roswell et al., 2021). We also assessed similarity between the sampled sites using Sørensen index, as it allows to determine the amount of species that overlaps between the multiple communities (Socolar et al., 2016). The diversity and similarity indices were calculated in the online software online SpadeR (Chao et al., 2015).

Results

The greatest species richness was found at Bom Retiro do Sul, where habitats were more varied compared to the other two farms (Tab. 1). Bom Retiro do Sul had the greatest number of detections followed by Taquari and Butiá. The most abundant species and the richest families

Tab. 1. Avian richness and abundance on each farm. Numbers in parentheses represent the richness / abundance for a given taxon.

Variables	TAQ	BRS	BUT	Total
Species				
Total Richness	122	187	124	213
Families with highest richness	Tyrannidae (12)	Tyrannidae (14)	Tyrannidae (26)	Tyrannidae (26)
	Thraupidae (11)	Thraupidae (20)	Thraupidae (12)	Thraupidae (21)
Detections				
Total Abundance	2100	2660	1736	6493
Species with highest abundance	*Turdus rufiventris* (Vieillot, 1818) (122)	*Zonotrichia capensis* (Statius Muller, 1776) (112)	*Z. capensis* (111)	*T. rufiventris* (335)
	Basileuterus culicivorus (Deppe, 1830) (120)	*T. rufiventris* (111)	*T. rufiventris* (102)	*Z. capensis* (328)
Diversity indices				
Shannon Diversity (H')	4.169	4.593	4.176	4.412
Simpson Dominance (1-D)	0.976	0.987	0.975	0.981

were the same accross the three farms, suggesting a similar composition. Taquari and Butiá shared the largest number of species in common, while Butiá and Bom Retiro do Sul had the lowest number of shared species. The same pattern was observed in the diversity indices, as Bom Retiro do Sul had the greatest values in Shannon and Gini-Simpson indices. In total, we recorded 213 species and 6496 detections (see Sementili-Cardoso et al., 2023), with an additional six species (2.7% of the total) detected exclusively outside the sampling period. Similarity pairwise comparison shows that Taquari and Bom Retiro do Sul farms tend to be more similar to each other than the Butiá área (Sørensen similarity: Butiá – Taquari: 0.794; Butiá – Bom Retiro do Sul: 0.795; Bom Retiro do Sul – Taquari: 0.858).

Bird assemblages on all the three farms had a similar feeding guild structure (Fig. 2). Insectivores were most numerous, followed by omnivores and frugivores species. However, in Taquari there were as many granivores as frugivores. Habitat stratification was also similar across the three farms (Fig. 2), with ground-dwelling species dominating, followed by species from the midstory and understory strata. Despite low total richness, aquatic species were more numerous in Taquari and Bom Retiro do Sul, compared to in Butiá.

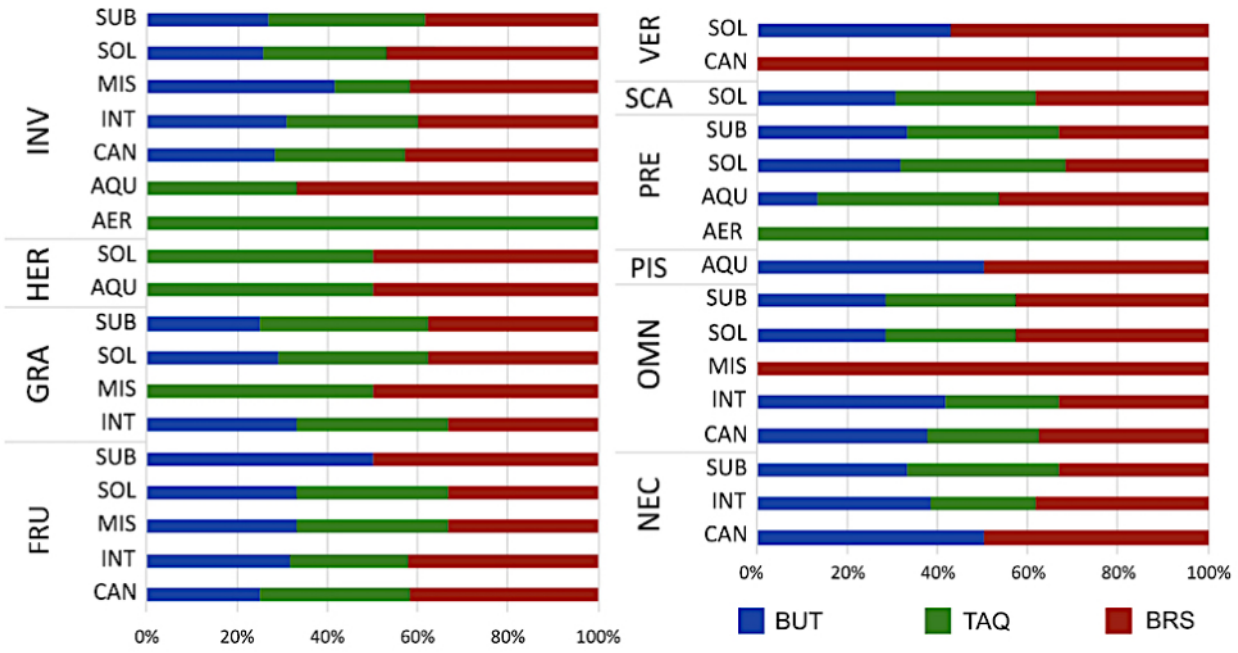

Fig. 2. Proportion of species subdivided according to diet and foraging strata recorded on each farm. Guilds: INV - insectivores; OMN - omnivores; FRU - frugivores; GRA - granivores; PRE - generalist predators; NEC - nectarivores; VER - vertivores; DET - detritivores; PIS - piscivores; HER - herbivores. Strata: GRO - ground; MID - midstory; UND - understory; CAN - canopy; MIX - mixed terrestrial; AQU - aquatic; AER - aerial.

Bom Retiro do Sul had higher diversity than both Butiá and Taquari farms, which were very similar to one another (Fig. 3). All curves appeared to be reaching the asymptote, suggesting sampling was adequate and that further surveys would only have added very rare species. Conservation relevance of the species is outlined in Tab. 2. Butiá had the highest number of endangered and quarry species, and had more endemic species than the other farms.

Discussion

The three bird assemblages represent a considerable portion of avian regional diversity, with the farms supporting 31.1% of the avian species richness present in Rio Grande do Sul state (Franz et al., 2018). The feeding guilds and foraging strata are quite similar among locations, even with defined seasonality, which affects the availability of resources in subtropical environments (Karr, 1976).

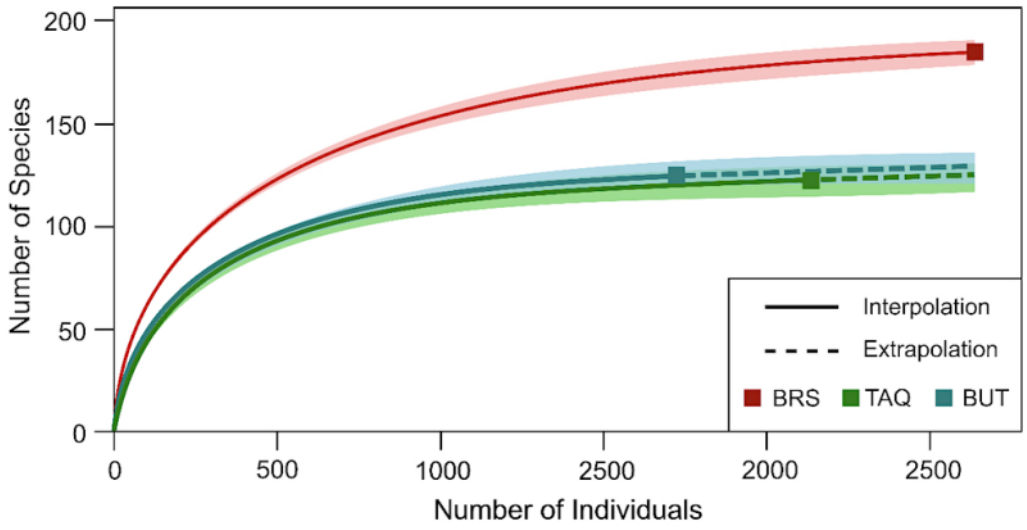

Fig. 3. Rarefaction curve with 95% confidence intervals for the three farms (BRS – Bom Retiro do Sul; TAQ – Taquari; BUT – Butiá). The dotted line represents the extrapolation of curves to 2660 detections.

Tab. 2. Endangered, endemic and quarry species found in each of the farms. Endangered species are classified according to IUCN (2020), ICMBio (2018) and Rio Grande do Sul (2014), respectively, with the categories "Least Concern" (LC), "Near Threatened" (NT), "Vulnerable" (VU) and "Endangered" (EN).

Endangered Species	TAQ	BRS	BUT
Dromococcyx pavoninus (Pelzeln, 1870) (LC/LC/VU)	X		X
Hydropsalis anomala (Gould, 1838) (NT/NT/EN)			X
Species with Conservation Relevance			
Endemic Species	14	19	20
Quarry Species	25	35	21

The farm in Bom Retiro do Sul showed greater richness, abundance and diversity than those observed in the other two farms. Such patterns are probably influenced by the vegetation structure and degree of anthropogenic disturbance in each farm (Marsden et al., 2001; Lindsey et al., 2019). Bom Retiro do Sul contains a greater variety of habitats, ranging from humid fields to well protected seasonal forests. This provides a greater range of microhabitats for birds, resulting in a partition of habitat use and lower niche overlap, and so supporting greater diversity and abundance (Urban & Smith, 1989; Manhães et al., 2015; Lara et al. 2015).

Another feature of Bom Retiro do Sul is the extensive flooded fields formed by damming small streams, which offer additional habitats not available on the other two farms (Ma et al., 2010). Because the flooded fields are subject to seasonal variation, the specific composition of the community in humid areas tends to fluctuate between seasons according to the availability of a given resource, such as food or shelter (Losito & Baldassarre, 1995; Bolduc & Afton, 2004).

The richness and diversity of Butiá and Taquari were very similar, although the two locations differ in their landscape structure. The Taquari farm has a limited area of native vegetation, and experiences considerable human disturbance due to a nearby urban area. Despite these conditions, the avian assemblage is very similar to that of Butiá farm, which has the largest conservation area of the three farms. This similarity can be attributed to the habitat struc-

ture of the two farms, since the conservation areas in both are dominated by riparian forests. Although Taquari is the most disturbed of the three locations, the forest associated with the Taquari River has a complex structure, with a closed canopy and dense understory. Thus, despite the small area of native vegetation, the fragments in Taquari are important for the maintenance of a specialist avifauna that depends on a dense forest structure (Lindsey et al., 2019). The degree of disturbance also supports generalist species, which consequently increases the richness and abundance of the local avifauna. In a similar way, the riparian forest in Butiá is associated with a large number of rivers and streams of variable size, creating an extensive network of native vegetation. (Teixeira et al., 2018).

Such features increase the conservationist relevance of these two farms, since riparian forests are extremely important for the movement of birds, serving as ecological corridors for the movement of species among fragments (Naiman et al., 1993; Machtans et al., 1996). In human-dominated matrices (e.g. pasture, monoculture and silviculture), remaining forest fragments help maintain avian diversity at both local and regional levels (Saab, 1999; Fletcher & Hutto, 2008).

The occurrence of some feeding guilds could be influenced by the degree of disturbance. Understory insectivores are particularly sensitive to habitat disturbance (Sekercioglu, 2002), and their richness and abundance decline as a response to fragmentation. Disturbed environments can also influence the richness of omnivorous species, since the processes of fragmentation and deforestation accelerate the replacement of more specialized taxa by omnivorous generalists (Motta-Júnior, 1990), which favors the prevalence of this guilds in small fragments (Willis, 1979). The proportion of understory invertivores are similar among the three farms, which implies that forest remnants in the three areas have enough resources to maintain specialist taxa. In a similar way, generalist birds represented by omnivores have an equivalent proportion among the areas, suggesting that the areas are conserved enough to avoid skewness in the distribution of omnivores.

Frugivores, granivores and generalist predators showed similar richness across the three farms. The presence of frugivorous birds is important for the maintenance of plant diversity, since they act as important zoochoric dispersers (Gentry, 1982). Thus, they contribute to forest regeneration (Jordano et al., 2006), especially in the early stages of community succession (Duncan & Chapman, 1999). Abundance of granivores and generalist predators was greater in Bom Retiro do Sul, which may be related to the presence of extensive open areas. Generalist vertivores tend to be more numerous in open and disturbed environments (Vianna et al., 2017), as they depend on visual acuity to detect their prey (Jones et al., 2007), allowing a more effective foraging than in dense forest areas. The abundance of granivores in Bom Retiro do Sul is also related to the availability of grasses typical of open areas, which provide abundant food resources for these birds (Chettri et al., 2005).

Ground-dwelling birds were the dominant component of all three assemblages, followed by birds from the midstory and understory. Ground-dwelling birds include a considerable number of taxa, both in open and closed habitat. The presence of midstory and understory birds is indicative of the capacity of each farm to provide resources for the maintenance of more specialized fauna. Most of these birds are frugivorous and forest insectivores, corroborating other studies in Atlantic Forest areas (Donatelli et al. 2004; 2007; Vianna et al., 2017). Understory birds are more sensitive to forest changes because they depend on the density of vegetation below the canopy to move in the environment (Bierregaard Jr & Stouffer, 1997).

The region suffers severe threats to bird conservation. Fragmentation and loss of habitat are the main causes of declines in bird biodiversity (Marini & Garcia, 2005), resulting from irregular occupation of land and real estate speculation that occurs in Rio Grande do Sul state (MMA, 2000). The main effects of habitat loss and fragmentation are the selective extinction of specialist species, leaving vacant niches for generalists to colonize (Gimenes & dos Anjos, 2003). Such effects may be occurring at the three farms, since the most abundant species were all generalists. However, assessing temporal trends in species' abundances would require repeated surveys over several years. In Brazil, the replacement of native environments by commercial forestry is a very common practice, and can result in a decrease in resources for bird species (Jacoboski et al., 2016). However, when forestry activity is associated with sustainable management and conservation practices of native remnants, such impacts can be mitigated (Marsden et al., 2001), helping to maintain biodiversity at the regional level. Therefore, the assessment of bird assemblages in in a historical level needs additional surveys over the years.

In addition to land cover change including deforestation and fragmentation, we witnessed the impacts of pastoral activity in native areas (i.e. erosion by cattle encroachment) and episo-

des of illegal capture for wildlife trafficking. The properties adjacent to the Bom Retiro do Sul and Butiá farms carry out cattle breeding, and we observed cattle incursions into conservation areas. Cattle movement opens trails and clearings in closed habitats, mainly impacting understory birds (Martin & McIntyre, 2007). There is an inverse relationship between the pressure of pastoral activity and stratified foraging in birds, causing the abundance and diversity of birds to decline in locations where cattle forage (Martin & Possingham, 2005). Since overall diversity does not differ among areas, we argue that these disturbances have a minor impact on bird richness and abundance. In a similar way, the proportions of generalist feeding guilds and foraging strata are not skewed toward a specific farm, suggesting that the impacts of these disturbances do not change these functional features of the assemblage.

Capture of wild birds was witnessed during sampling. Contact with local communities revealed that several species suffer substantial trapping pressure for illegal wildlife trade. Such activities impact the dynamics of local bird assemblages (Marini & Garcia, 2005), and areas where birds are trafficked and marketed act as a "sinkhole" (Regueira & Bernard, 2012), causing a significant decline in bird diversity. Management and environmental education actions must be implemented to reduce the impact of wildlife trapping, encouraging local communities to take an active role in bird conservation. These actions could be particularly relevant in the "Sede" farm, as it is located inside the urban area of Taquari municipality. The contact of the locals with the conservation areas are more frequent, making it easier to them to capture native birds. In this regard, this farm could be a priority conservation area, as the impacts of anthropic activities in the urban could influence bird assemblages in the near future. Our data help to diagnose the species that suffers illegal trapping, which can help in decision-making about the management of resources and efforts to conserve the species most threatened by these activities.

Conclusions

The bird assemblages on the three studied farms contribute for the preservation of regional bird diversity, and thetrophic structure was similar across the farms. These patterns highlighted the importance of conserving forest remnants in association with silviculture, such as the eucalyptus plantations.

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References

Dos Anjos, L. & R. Boçon. 1999. Bird communities in natural forest patches in southern Brazil. Wilson Bull. 111(3): 397-414.

Dos Anjos, L. 2001. Bird communities in five Atlantic forest fragments in southern Brazil. Ornitol. Neotrop. 12(1): 11-27.

Baker, J., K. French & R. J. Whelan. 2002. The edge effect and ecotonal species: bird communities across a natural edge in southeastern Australia. Ecology. 83(11): 3048-3059. DOI: https://doi.org/10.1890/0012-9658(2002)083[3048:TEEAES]2.0.CO;2

Bencke, G. A., G. N. Maurício, P. F. Develey & J. M. Goerck. 2006. Áreas Importantes para a Conservação das Aves no Brasil: Estados do Domínio da Mata Atlântica. São Paulo, SAVE Brasil.

Bibby, C. J., N. D. Burgess & D. A. Hill. 2000. Bird Census Techniques. San Diego, Academic Press.

Bierregaard Jr, R. O. & P. C. Stouffer. 1997. Understory birds and dynamic habitat mosaics in Amazonian rainforests. In: Laurance, W. F. & R. O. Bierregaard Jr. Tropical Forest Remnants: Ecology, Management, and Conservation of Fragmented Communities. Chicago, University of Chicago Press.

Bolduc, F. & A. D. Afton. 2004. Relationships between wintering waterbirds and invertebrates, sediments and hydrology of coastal marsh ponds. Waterbirds. 27(3): 333-341. DOI: https://doi.org/10.1675/1524-4695(2004)027[0333:RBWWAI]2.0.CO;2

Borsato, R., R. Loyola & P. Lemes. 2015. Ecorregiões do Brasil: Prioridades terrestres e marinhas. Curitiba, Instituto LIFE.

Bruner, A. G., R. E. Gullison, R. E. Rice & G. A. da Fonseca. 2001. Effectiveness of parks in protecting tropical biodiversity. Science. 291(5501): 125-128. DOI: https://doi.org/10.1126/science.291.5501.125

Chao, A. & L. Jost. 2012. Coverage-based rarefaction and extrapolation: standardizing samples by completeness rather than size. Ecology. 93(12): 2533-2547. DOI: https://doi.org/10.1890/11-1952.1

Chao, A., Y. T. Wang & L. Jost. 2013. Entropy and the species accumulation curve: a novel entropy estimator via discovery rates of new species. Methods Ecol. Evol. 4(11): 1091-1100. DOI: https://doi.org/10.1111/2041-210X.12108

Chao, A., N. J. Gotelli, T. C. Hsieh, E. L. Sander, K. H. Ma, R. K. Colwell & A. M. Ellison. 2014. Rarefaction and extrapolation with Hill numbers: a framework for sampling and estimation in species diversity studies. Ecol. Monogr. 84(1): 45-67. DOI: https://doi.org/10.1890/13-0133.1

Chao, A., K. H. Ma, T. C. Hsieh & C. H. Chiu. 2015. Online Program SpadeR (Species-richness Prediction And Diversity Estimation in R). Available in: <http://chao.stat.nthu.edu.tw/wordpress/software_download/>. Access on: 28 jan. 2023

Chao, A., K. H. Ma, & T. C. Hsieh. 2016. iNEXT (iNterpolation and EXTrapolation) Online: Software for Interpolation and Extrapolation of Species Diversity. Available in: <http://chao.stat.nthu.edu.tw/wordpress/software_download/>. Acess on: 28 jan. 2023.

Chettri, N., D. C. Deb, E. Sharma & R. Jackson. 2005. The relationship between bird communities and habitat. Mount. Research Develop. 25(3): 235-243. DOI: https://doi.org/10.1659/0276-4741(2005)025[0235:TRBBCA]2.0.CO;2

Colwell, R. K., A. Chao, N. J. Gotelli, S. Y. Lin, C. X. Mao, R. L. Chazdon & J. T. Longino. 2012. Models and estimators linking individual-based and sample-based rarefaction, extrapolation and comparison of assemblages. J. Plant. Ecol. 5(1): 3-21. DOI: https://doi.org/10.1093/jpe/rtr044

Cordeiro, J. L. & H. Hasenack. 2009. Cobertura vegetal atual do Rio Grande do Sul. In: Pillar, V. P., S. C. Müller, Z. M de S. Castilhos, & A. V. A. Jacques. Campos sulinos: conservação e uso sustentável da biodiversidade. Brasília, Ministério do Meio Ambiente.

Corrêa, L. L. C., D. E. Silva & L. H. Cappellari. 2012. Avifauna do município de São Sepé, sul do Brasil. Scient. Plena. 8(9): 1-10.

Costa, F. J. V. & K. R. G. Monteiro. 2016. Guia de identificação das aves traficadas no Brasil. Florianópolis, BECONN.

Donatelli, R. J., T. V. V. D. Costa & C. D. Ferreira. 2004. Dinâmica da avifauna em fragmento de mata na fazenda Rio Claro, Lençóis Paulista, São Paulo, Brasil. Rev. Bras. Zool. 21(1): 97-114. DOI: https://doi.org/10.1590/S0101-81752004000100017

Donatelli, R. J., C. D. Ferreira, A. C. Dalbeto & S. R. Posso. 2007. Análise comparativa da assembléia de aves em dois remanescentes florestais no interior do Estado de São Paulo, Brasil. Rev. Bras. Zool. 24(2): 362-375. DOI: https://doi.org/10.1590/S0101-81752007000200015

Duncan, R. S. & C. A. Chapman. 1999. Seed dispersal and potential forest succession in abandoned agriculture in tropical Africa. Ecol. Appl. 9(3): 998-1008. DOI: https://doi.org/10.1890/1051-0761(1999)009[0998:SDAPFS]2.0.CO;2

Favretto, M. A., T. Zago & A. Guzzi. 2008. Avifauna do Parque Natural Municipal Rio do Peixe, Santa Catarina, Brasil. Atual. Ornitol. 141(1): 87-93.

Fletcher, R. J. & R. L. Hutto. 2008. Partitioning the multi-scale effects of human activity on the occurrence of riparian forest birds. Landsc. Ecol. 23(6): 727-739. DOI: https://doi.org/10.1007/s10980-008-9233-8

Franz, I., C. E. Agne, G. A. Bencke, L. Bugoni & R. A. Dias. 2018. Four decades after Belton: a review of records and evidences on the avifauna of Rio Grande do Sul, Brazil. Iheringia Ser. Zool. 108(1): e2018005. DOI: https://doi.org/10.1590/1678-4766e2018005

Gentry, A. H. 1982. Patterns of Neotropical plant species diversity. pp. 1-84. In: Hecht, M. K., B. Wallace & G. T. Prance. (Eds.). Ecology and Evolution. Boston, Springer.

Gimenes, M. R. & L. dos Anjos. 2003. Efeitos da fragmentação florestal sobre as comunidades de aves. Acta Sci. Biol. Sci. 25(2): 391-402.

ICMBIO. Instituto Chico Mendes de Conservação da Biodiversidade. 2018. Sumário Executivo do Livro Vermelho da Fauna Brasileira Ameaçada de Extinção. Brasília, Instituto Chico Mendes de Conservação da Biodiversidade.

IUCN. International Union for Conservation of Nature. 2021. The IUCN Red List of Threatened Species. Available in: <http://www.iucnredlist.org>. Access on 10 dez. 2021.

Jacoboski, L. I., A. D. Mendonça-Lima & S. M. Hartz. 2016. Structure of bird communities in eucalyptus plantations: nestedness as a pattern of species distribution. Braz. J. Biol. 76(3): 583-591. DOI: https://doi.org/10.1590/1519-6984.18614

Jones, M. P., K. E. Pierce Jr & D. Ward. 2007. Avian vision: a review of form and function with special consideration to birds of prey. J. Exot. Pet Med. 16(2): 69-87. DOI: https://doi.org/10.1053/j.jepm.2007.03.012

Jordano, P., M. Galetti, M. A. Pizo & W. R. Silva. 2006. Ligando frugivoria e dispersão de sementes à biologia da conservação. In: Rocha, C. F. D., H. G. Bergallo, M. van Sluys & M. A. S. Alves (Eds.). Biologia da conservação: essências. São Paulo, Rima Editora.

Kark, S. T. F. Allnutt, N. Levin, L. L. Manne & P. H. Williams. 2007. The role of transitional areas as avian biodiversity centres. Glob. Ecol. Biogeogr. 16(2): 187-196. DOI: https://doi.org/10.1111/j.1466-8238.2006.00274.x

Kark, S. & B. J. Van Rensburg. 2006. Ecotones: marginal or central areas of transition? Isr. J. Ecol. Evol. 52(1): 29-53. DOI: https://doi.org/10.1560/IJEE.52.1.29

Krügel, M. M. & L. dos Anjos. 2000. Bird communities in forest remnants in the city of Maringá, Paraná State, Southern Brazil. Ornitol. Neotrop. 11(4): 315-330.

Kuinchtner, A. & G. A. Buriol. 2001. Clima do Estado do Rio Grande do Sul segundo a classificação climática de Köppen e Thornthwaite. Discip. Sci., Sér. Ciênc. Nat. Tecnol. 2(1): 171-182.

Lara, C., B. Pérez, C. Castillo-Guevara & M. A. Serrano-Meneses. 2015. Niche partitioning among three tree-climbing bird species in subtropical mountain forest sites with different human disturbance. Zool. Stud. 54(1): 1-7. DOI: https://doi.org/10.1186/s40555-015-0106-y

Leite, P. F. & R. M. Klein. 1990. Vegetação. In: Instituto Brasileiro de Geografia e Estatística (Ed.). Geografia do Brasil: Região Sul. Rio de Janeiro, IBGE.

Lindsey, B. R. A., G. M. Bochio & L. Dos Anjos. 2019. Bird species that occupy river edge in continuous forest tend to be less sensitive to forest fragmentation. Rev. Bras. Ornitol. 27(3): 172-186.

Losito, M. P. & G. A. Baldassarre. 1995. Wetland use by breeding and postbreeding female mallards in the St. Lawrence River Valley. Wilson Bull. 107(1): 55-63.

Ma, Z., Y. Cai, B. Li & J. Chen. 2010. Managing wetland habitats for waterbirds: an international perspective. Wetlands. 30(1): 15-27. DOI: https://doi.org/10.1007/s13157-009-0001-6

Machtans, C. S., M. A. Villard & S. J. Hannon. 1996. Use of riparian buffer strips as movement corridors by forest birds. Conserv. Biol. 10(5): 1366-1379.

Maluf, J. R. T. 2000. Nova classificação climática do Estado do Rio Grande do Sul. Rev. Bras. Agrometeorol. 8(1): 141-150.

Manhaes, M. A., M. M. Dias & A. L. C. Lima. 2015. Feeding resource partitioning between two understorey insectivorous birds in a fragment of Neotropical cloud forest. Braz. J. Biol. 75(4): 176-183. DOI: https://doi.org/10.1590/1519-6984.09114

Marini, M. A. & F. I. Garcia. 2005. Conservação de aves no Brasil. Megadiversidade. 1(1): 95-102.

Marsden, S. J., M. Whiffin & M. Galetti. 2001. Bird diversity and abundance in forest fragments and *Eucalyptus plantations* around an Atlantic Forest reserve, Brazil. Biodivers. Conserv. 10(5): 737-751. DOI: https://doi.org/10.1590/1519-6984.09114/0.1023/A:1016669118956

Martin, T. G. & S. McIntyre. 2007. Impacts of livestock grazing and tree clearing on birds of woodland and riparian habitats. Conserv. Biol. 21(2): 504-514. DOI: https://doi.org/10.1111/j.1523-1739.2006.00624.x

Martin, T. G. & H. P. Possingham. 2005. Predicting the impact of livestock grazing on birds using foraging height data. J. Appl. Ecol. 42(2): 400-408. DOI: https://doi.org/10.1111/j.1365-2664.2005.01012.x

MMA. Ministério do Meio Ambiente. 2000. Avaliação e ações prioritárias para a conservação da biodiversidade da Mata Atlântica e Campos Sulinos. Brasília, Ministério do Meio Ambiente.

Moritz, C., J. L. Patton, C. J. Schneider & T. B. Smith. 2000. Diversification of rainforest faunas: an integrated molecular approach. Ann. Rev. Ecol. Evol. 31(1): 533-563. DOI: https://doi.org/10.1146/annurev.ecolsys.31.1.533

Motta-Júnior, J. C. 1990. Estrutura trófica e composição das avifaunas em três habitats terrestres na região central do estado de São Paulo. Ararajuba. 1(1): 65-71.

Naiman, R. J., H. Decamps & M. Pollock. 1993. The role of riparian corridors in maintaining regional biodiversity. Ecol. Appl. 3(2): 209-212. DOI: https://doi.org/10.2307/1941822

Pacheco, J. F., L. F. Silveira, A. Aleixo, C. E. Agne, G. A. Bencke, G. A. Bravo, G. R. R. Brito, M. Cohn-Haft, G. N. Maurício, L. N. Naka, F. Olmos, S. R. Posso, A. C. Lees, L. F. A. Figueiredo, E. Carrano, R. C. Guedes, E. Cesari, I. Franz, F. Schunck & V. Q. Piacentini. 2021. Annotated checklist of the birds of Brazil by the Brazilian Ornithological Records Committee—second edition. Ornt. Res. 29(2): 94-105. DOI: https://doi.org/10.1007/s43388-021-00058-x

Padoa-Schioppa, E., M. Baietto, R. Massa & L. Bottoni. 2006. Bird communities as bioindicators: The focal species concept in agricultural landscapes. Ecol. Ind. 6(1): 83-93. DOI: https://doi.org/10.1016/j.ecolind.2005.08.006

Regueira, R. F. S. & E. Bernard. 2012. Wildlife sinks: Quantifying the impact of illegal bird trade in street markets in Brazil. Biol. Conserv. 149(1): 16-22. DOI: https://doi.org/10.1016/j.biocon.2012.02.009

Ribeiro, S., L. F. Moreira, G. E. Overbeck, & L. Maltchik. 2021. Protected Areas of the Pampa biome presented land use incompatible with conservation purposes. J. Land Use Sci. 16(3): 260-272. DOI: https://doi.org/10.1080/1747423X.2021.1934134

Rio Grande do Sul. 2014. Decreto n.º 51.797, de 8 de setembro de 2014. Porto Alegre, Assembleia Legislativa do Estado do Rio Grande do Sul. Available in: <http://www.al.rs.gov.br/filerepository/replegis/arquivos/dec%2051.797.pdf>. Access on 08 jan. 2021.

Roswell, M., J. Dushoff & R. Winfree. 2021. A conceptual guide to measuring species diversity. Oikos. 130: 321–338. DOI: https://doi.org/ 10.1111/oik.07202

Saab, V. 1999. Importance of spatial scale to habitat use by breeding birds in riparian forests: a hierarchical analysis. Ecol. Appl. 9(1): 135-151. DOI: https://doi.org/10.2307/2641174

Santos, A. J. 2003. Estimativas de riqueza em espécies. In: Cullen Jr, L., R. Rudran & C. Valladares-Padua (Eds.). Métodos de estudos em biologia da conservação e manejo da vida silvestre. Curitiba, Editora da Universidade Federal do Paraná.

Scherer, J. D. F. M., A. L. Scherer & M. V. Petry. 2010. Estrutura trófica e ocupação de hábitat da avifauna de um parque urbano em Porto Alegre, Rio Grande do Sul, Brasil. Biotemas. 23(1): 169-180. DOI: https://doi.org/10.5007/2175-7925.2010v23n1p169

Sementili-Cardoso, G., R. J. Donatelli & F. Maffei. 2023. Supplementary File of the article "COMPOSITION AND FUNCTIONAL STRUCTURE OF BIRD ASSEMBLAGES IN THREE NATIVE HABITAT REMNANTS IN CENTRAL RIO GRANDE DO SUL STATE, BRAZIL". figshare. Dataset. DOI: https://doi.org/10.6084/m9.figshare.23523990.v1

Sekercioglu, C. H. 2002. Forest fragmentation hits insectivorous birds hard. Dir. Sci. 1(1): 62-64. DOI: https://doi.org/ 10.1100/tsw.2002.190

Socolar, J. B., J. J. Gilroy, W. E. Kunin & D. P. Edwards. 2016. How should beta-diversity inform biodiversity conservation?. Trends Ecol. Evol. 31(1): 67-80. DOI: https://doi.org/10.1016/j.tree.2015.11.005

Teixeira, M., G. L. E. Junior, G. Nicolini, N. Dametto, F. Lucheta, E. Périco & E. M. de Freitas. 2018. Structure of the arboreal community of a riparian forest in southernmost Brazil. Bras. J. Bot. 41(1): 77-89. DOI: https://doi.org/10.1007/s40415-017-0426-8

Urban, D. L. & T. M. Smith. 1989. Microhabitat pattern and the structure of forest bird communities. Am. Nat. 133(6): 811-829.

Vianna, R. M., R. J. Donatelli, R. Whitacker, R. M. Martins & G. Sementili-Cardoso. 2017. Dynamics of the bird communities in two fragments of Atlantic Forest in São Paulo, Brazil. Biologia. 72(8): 913-926. DOI: http://dx.doi.org/10.1515/biolog-2017-0101

Watson, J. E., R. J. Whittaker & D. Freudenberger. 2005. Bird community responses to habitat fragmentation: how consistent are they across landscapes?. J. Biogeogr. 32(8): 1353-1370. DOI: https://doi.org/10.1111/j.1365-2699.2005.01256.x

Wilman, H., J. Belmaker, J. Simpson, C. de la Rosa, M. M. Rivadeneira & W. Jetz. 2014. EltonTraits 1.0: Species-level foraging attributes of the world's birds and mammals. Ecology. 95(7): 2027-2027. DOI: https://doi.org/10.1890/13-1917.1

Willlis, E. O. 1979. The composition of avian communities in remanscent woodlots in southern Brazil. Pap. Avulsos Zool. 33(1): 1-25.

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