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COMPARISON OF DIURNAL BIRDS OF PREY COMMUNITY BETWEEN NATURAL AND ANTHROPIZED ENVIRONMENTS IN HIGHLAND GRASSLANDS OF RIO GRANDE DO SUL, BRAZIL

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Abstract: The highland grasslands, characteristic of the mountain region of the state of Rio Grande do Sul, have been used historically for several commercial purposes, including extensive livestock, forestry, and agriculture. The biodiversity has a high endemism, but there is a lack of studies on various animal and plant groups. Birds of prey are a great group to assess environmental quality, as they are top predators. This study aimed to test if the diurnal birds of prey community is changing due to the replacement of native grasslands by other human economic activities. We surveyed birds of prey at 12 sampling points from August 2018 to June 2019, including protected grasslands and livestock grasslands, agricultural, and forestry areas. We obtained 1,582 records of birds of prey of 17 species, and the highest richness and number of records, were obtained in the protected grasslands (17 spp.; 393 records) and livestock grasslands (15 spp.; 434 records), followed by agriculture (13 spp.; 418 records) and forestry areas (9 spp.; 337 records). There was a significant difference in the richness of birds of prey in the protected grasslands, livestock grasslands and agriculture areas over the forestry areas. In the number of records, there was a significant difference between livestock grasslands and agriculture areas over forestry areas. This study showed that the conversion of native grassland areas, mainly by forestry, affects the composition of the diurnal birds of prey community, especially the rarest and most endangered species.

Keywords: Conservation; Forestry; Land use change; Open landscapes; Raptor assemblage.

INTRODUCTION

The highland grasslands of southern Brazil integrate the Atlantic Forest biome. It is present in large extensions, interspersed with mosaics of Araucaria forests, marshes, and peat bogs (Boldrini 2009a, 2009b). They are currently under great impact and undergoing drastic changes due to the rapid and continuous replacement, de-characterization, and fragmentation of their environments (Boldrini 2009a). These environments were used since the early 18th century for extensive livestock and are currently being replaced by other economic activities such

as forestry and agriculture (Boldrini 2009a, 2009b, Overbeck *et al.* 2009). Forestry is considered the most important threat to the birdlife of that region (Fontana *et al.* 2009). It is a recent economic activity in the highland grasslands, beginning around 1975 (Bristot 2001) and which received a great economic incentive to supply the wood and cellulose industry (Bristot 2001, Boldrini 2009b). At the same time, the use of agricultural monocultures began to advance over the highland grasslands, such as apple, potato, corn, and soy crops (Fontana *et al.* 2009, Overbeck *et al.* 2009). Bilenca and Miñarro (2004), consider agricultural mechanization a relevant factor in the loss of environments for open field birds.

Many taxonomic groups are still poorly sampled in this region (Pillar *et al.* 2009). Among the studied groups, it is known that the highland grasslands have a high number of endemic species of plants (Boldrini 2009a) and a high number of bird species (Fontana *et al.* 2009), many of them considered threatened of extinction (Fontana *et al.* 2008, 2009).

Birds of prey are cosmopolitan animals that occupy various environments (Sick 1997). They are generally top predators, sensitive to environmental changes and, consequently, excellent indicators of environmental quality (Newton 1979, Sergio *et al.* 2005). In the state of Rio Grande do Sul, 64 species have already been recorded: 35 are represented by eagles or hawks, 11 by falcons, 14 by owls, and four by vultures (Franz *et al.* 2018). Among the diurnal species that inhabits open fields, 23 have already been recorded in the highland grasslands of Rio Grande do Sul (Voss *et al.* 1998, Petersen *et al.* 2011, Zilio *et al.* 2013, Chiarani & Fontana 2019, WikiAves 2019). It is important to say that some of them depend exclusively on these environments, not tolerating drastic changes due to anthropogenic changes (Bencke *et al.* 2003).

In this context, we aimed to analyze whether the diurnal birds of prey community is being affected by the anthropic changes that occur in the highland grasslands landscape of southern Brazil. We hypothesize the decrease in the richness and detections of birds of prey from open fields to areas with anthropic changes. Considering the change in the landscape caused by the replacement of open field environment with forestry, we evaluated whether forest birds of prey species occupy this environment.

MATERIAL AND METHODS

Study area

We conducted the study in the municipality of São Francisco de Paula (29º23'S; 50º23'W), northeast of Rio Grande do Sul, Brazil (Figure 1). The predominant environment of the region is the mosaic of highland grasslands with Araucaria forests (Boldrini 2009b). The climate is of the Cfb type (temperate climate, with mild summer), according to the Köpen classification. Precipitation is well distributed, with an annual average ranging from 1900 to 2200 mm (Alvares *et al.* 2013).

To carry out the study, we considered the main categories of land use in formerly open landscapes in São Francisco de Paula: "non-forest natural formation", "planted forest," and "agriculture" (MapBiomas 2020). The sum of the areas occupied by these categories in 2018 corresponded to 70,6 % of the municipality's total area (MapBiomas 2020), 326,571 ha (IBGE 2019). We renamed the three classes above as described below, reclassifying the category "natural non-forest formation" to two types of native grasslands: (1) protected grasslands – native open fields inserted in protected areas, with uses defined by law (Rio Grande do Sul 2016); (2) livestock grasslands – native open fields on private properties, used for extensive livestock; (3) Agricultural areas - areas originally covered by fields, replaced by agricultural monocultures, such as potatoes, soybeans, and corn; (4) Forestry areas - areas originally covered by fields, now covered by exotic forests, especially American pine (*Pinus* spp.).

Design, method and sampling effort

The definition of the sampling units occurred by research through MapBiomas database (2020) and satellite images (Google Earth 2018) to identify areas for each category (Table 1). We evaluated all sampling units in a pilot field and identified elevated positions for observation, with a vision of at least 500 m in all directions (Granzinolli & Motta-Junior 2010). For each environment category, we selected three sample units, totaling 12 observation points. Subsequently, we performed

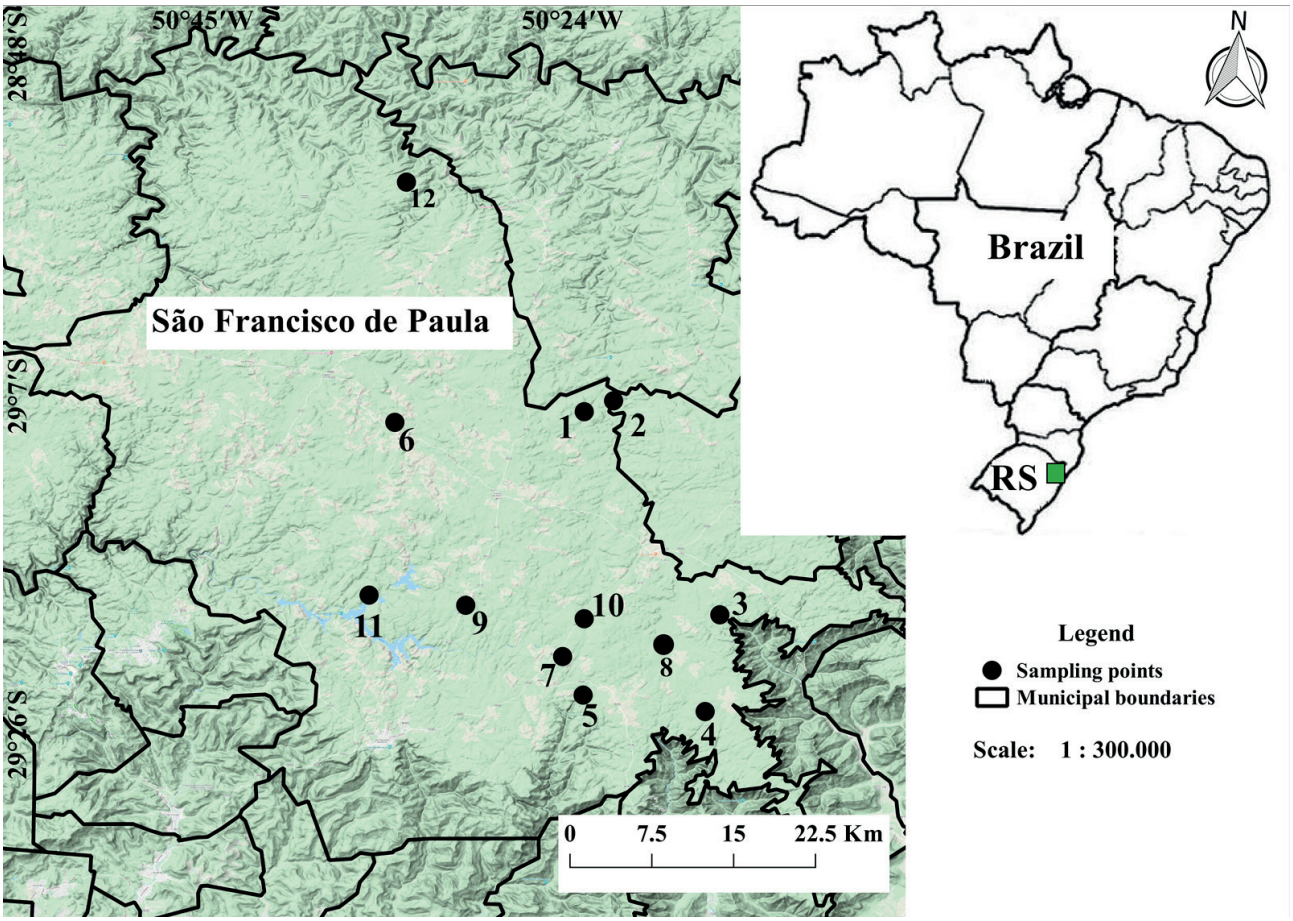

Figure 1. The 12 sampling points (black dots) in the municipality of São Francisco de Paula, Rio Grande do Sul, Brazil.

four field campaigns, one per climatic season: winter (August 19 to September 9, 2018), spring (November 17 to December 5, 2018), summer (February 27 to March 15, 2019), and autumn (04 to 19 June 2019), totaling 48 samples.

We recorded birds of prey using the fixed point observation technique (Blondel *et al.* 1970), with a daily sampling totaling six hours of observation (9:00 h to 15:00 h), favoring the detection of birds of prey with less abundance (Granzinolli & Motta-

Table 1. Sampling units (*datum* SIRGAS2000) in the municipality of São Francisco de Paula. PG – grasslands in protected areas; LG – grasslands with extensive livestock; AG – agriculture; FO – forestry.

Point	Locality	Latitude/Longitude	Environment
1	Parque Estadual do Tainhas 1	29°8'6.22"S, 50°23'21.16"W	PG
2	Parque Estadual do Tainhas 2	29°7'28.97"S, 50°21'41.29"W	PG
3	Estação Ecológica Aratinga	29°19'36.72"S, 50°15'39.18"W	PG
4	10 Km northwest of CPCN Pró-Mata	29°25'5.70"S, 50°16'29.30"W	LG
5	Morro do Cavalo	29°24'9.81"S, 50°23'24.94"W	LG
6	Lajeado Grande	29°8'42.07"S, 50°34'3.92"W	LG
7	RS 484/020	29°21'58.60"S, 50°24'34.90"W	AG
8	Casa Branca	29°22'32.64"S, 50°17'54.98"W	AG
9	RS 110	29°19'4.31"S, 50°30'4.90"W	AG
10	RS020	29°20'12.48"S, 50°23'5.48"W	FO
11	Blang	29°18'59.48"S, 50°34'51.97"W	FO
12	Cazuza Ferreira	28°56'23.32"S, 50°32'32.21"W	FO

Junior 2010). Records were performed directly, audibly, and visually. We sampled on sunny days so that all points had the same lighting conditions respected. We followed the species nomenclature according to Piacentini *et al*. (2015).

Statistical analysis

We presented richness, frequency of occurrence, and the number of records per environment using descriptive statistics. To evaluate sampling effectiveness, we used Chao 1 richness estimator with the analyses performed using the software EstimateS 9.1.0 (Colwell 2013). We compared environments trough richness and the number of raptor records by ANOVA/MANOVA tests and posthoc tests by Tukey in the SPSS software (IBM Corporation Released 2017). Additionally, we compare seasonality using one-way ANOVA in R environment (R 3.5.1, R Development Core Team 2018), with vegan 2.5-6 package (Oksanen *et al*. 2015). We describe and analyze the richness of the raptor community between environments, relating the presence/absence of species. To verify the pattern of distribution of birds of prey in the different sampled environments, we used principal coordinates analysis (PCoA) in the software Past 3.26 (Hammer *et al*. 2001). For all tests, we considered the level of significance of $p < 0.05$.

RESULTS

We performed 288 hours of sampling, resulting in 1,582 records of 17 species (26.6 % of the birds of prey richness from the Rio Grande do Sul state), distributed in three families (Table 2). The species accumulation curve did not show complete stabilization, with approximately 94 % of the species estimated by Chao 1 (18.09 ± 0.25) (Figure 2).

Table 2. Birds of prey detected by environment in São Francisco de Paula municipality (Rio Grande do Sul). R – records; FR – frequency of occurrence; PG – grasslands in protected areas; LG – grasslands with extensive livestock; AG – agriculture; FO – forestry; NI – unidentified. [CR] (Critically endangered) - BirdLife International 2016, Rio Grande do Sul 2014; [NT] (Near threatened) – Rio Grande do Sul 2014.

Family/ species	PG		LG		AG		FO		Total	
	R	FR	R	FR	R	FR	R	FR	R	FR
Cathartidae										
Cathartes aura	65	5.42	70	5.83	49	4.08	59	4.92	243	5.06
Coragyps atratus	127	10.58	145	12.08	148	12.33	124	10.33	544	11.33
Sarcoramphus papa[NT]	1	0.08	-	-	-	-	-	-	1	0.02
Accipitridae										
Elanus leucurus	2	0.17	1	0.08	4	0.33	-	-	7	0.15
Circus buffoni	1	0.08	8	0.67	7	0.58	2	0.17	18	0.38
Heterospizias meridionalis	21	1.75	14	1.17	26	2.17	-	-	61	1.27
Urubitinga urubitinga	1	0.08	-	-	-	-	1	0.08	2	0.04
Urubitinga coronata[CR]	3	0.25	3	0.25	-	-	-	-	6	0.13
Rupornis magnirostris	10	0.83	15	1.25	18	1.50	20	1.67	63	1.31
Geranoaetus albicaudatus	6	0.50	17	1.42	1	0.08	-	-	24	0.50
Geranoaetus melanoleucus[NT]	13	1.08	5	0.42	9	0.75	-	-	27	0.56
Buteo brachyurus	3	0.25	3	0.25	-	-	-	-	6	0.13
Falconidae										
Caracara plancus	50	4.17	73	6.08	71	5.92	55	4.58	249	5.19
Milvago chimachima	13	1.08	19	1.58	5	0.42	19	1.58	56	1.17
Milvago chimango	27	2.25	22	1.83	52	4.33	47	3.92	148	3.08
Falco sparverius	39	3.25	23	1.92	15	1.25	2	0.17	79	1.65
Falco femoralis	2	0.17	4	0.33	2	0.17	-	-	8	0.17
NI	9	0.75	12	1.00	11	0.92	8	0.67	40	0.83

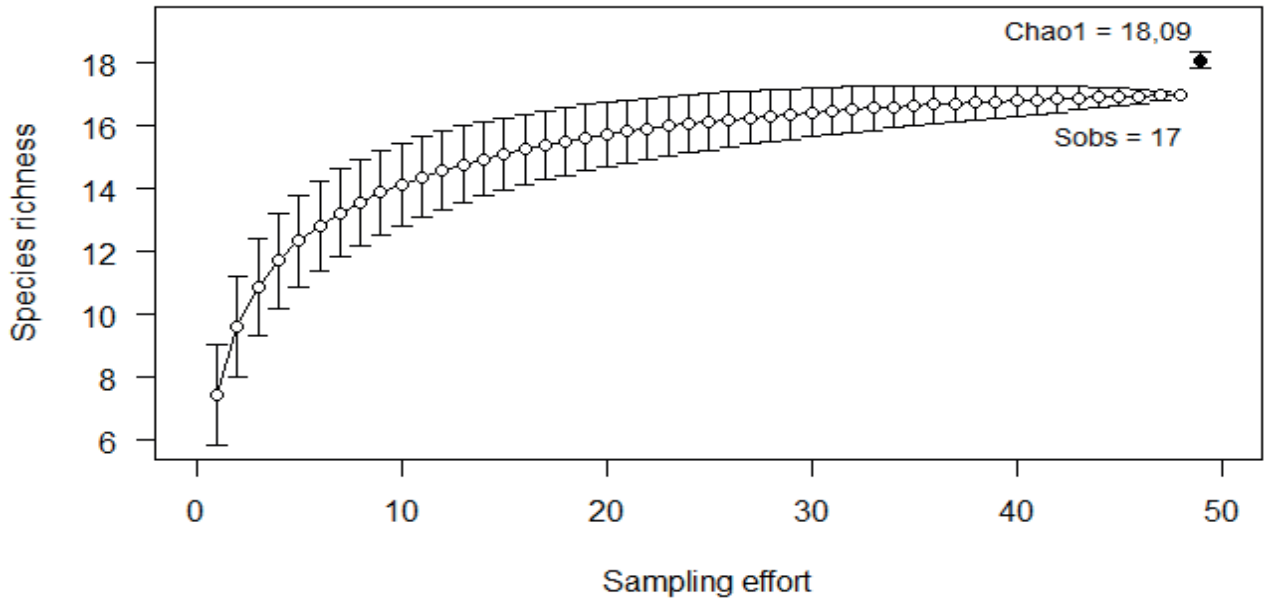

Figure 2. Accumulation curve (± SD) and Chao 1 richness estimator for the diurnal birds of prey community in the 48 samples, São Francisco de Paula, Brazil: Sobs = species observed.

The most recorded bird of prey was *Coragyps atratus* (Cathartiformes, Cathartidae), with 544 records, and the least common species was *Sarcoramphus papa* (Cathartiformes, Cathartidae) with one record (Table 2). Protected grasslands had the highest richness (N = 17; 100 % of the species recorded), and livestock grasslands had the highest number of birds of prey records, totaling 434 records (Figure 3, Table 3).

MANOVA demonstrated an effect of changes in environment on the richness and number of records of diurnal birds of prey [Pillai = 0.564; Z (6.88) = 5.764; $p < 0.001$]. Subsequent one-way ANOVA showed the effect in relation to richness [Z (3.44) = 12.106; $p < 0.001$] and the number of records [Z (3.44) = 4.757; $p = 0.006$]. Considering the species richness, one-way ANOVA showed a significant difference between the protected grasslands and forestry ($p < 0.0001$); livestock grasslands and forestry ($p < 0.0001$); agriculture areas and forestry ($p = 0.0061$). Regarding the number of records, one-way ANOVA showed a significant difference between livestock grasslands and forestry ($p = 0.0052$); agriculture areas and forestry ($p = 0.0272$). There was no significant difference in the other comparisons (Figure 3).

Three species were observed exclusively in grasslands areas: *S. papa* (only in protected grasslands), *Urubitinga coronata* (Accipitriformes, Accipitridae), and *Buteo brachyurus* (Accipitriformes, Accipitridae). The species *Urubitinga urubitinga* (Accipitriformes, Accipitridae) was recorded on two occasions: once in a protected grassland (August 29, 2018) and once in a forestry area (June 9, 2019). We did not observe these four species in agriculture areas. In the forestry areas, we did not detect the species *S. papa*, *Elanus leucurus* (Accipitriformes, Accipitridae), *Heterospizias meridionalis* (Accipitriformes, Accipitridae), *U. coronata*, *Geranoaetus albicaudatus* (Accipitriformes, Accipitridae), *Geranoaetus melanoleucus* (Accipitriformes,

Table 3. Richness and number of birds of prey records by environment in the municipality of São Francisco de Paula. PG - grasslands in protected areas; LG - grasslands with extensive livestock; AG - agriculture; FO - forestry.

Environment	Richness (total / mean by sampling)	Number of records (total / mean by sampling)
PG	17 / 8.4	393 / 32.8
LG	15 / 8.3	434 / 36.2
AG	13 / 7.5	418 / 34.8
FO	9 / 5.7	337 / 28.1

Accipitridae), *B. brachyurus*, and *Falco femoralis* (Falconiformes, Falconidae). In the principal coordinates analysis (PCoA), we observed the total separation of protected grasslands about forestry areas and partial overlap of agriculture areas and livestock grasslands about protected grasslands, more evident in this last comparison. Axis 1 explained 23.9 % of the variation, and axis 2 explained 15.6 % of the distribution of birds of prey recorded in this study (Figure 4).

Regarding seasonality, one-way ANOVA showed that there was no significant difference between the seasons ($p > 0.99$). Still, we observed the highest richness of birds of prey in autumn and winter (16 species), followed by spring (13 species) and summer (11 species). The high number of birds of prey records occurred in spring (28.1 %), followed by winter (26.8 %), summer (22.7 %), and autumn (22.4 % of the total records).

We recorded three threatened or nearly threatened species for the state of Rio Grande do Sul, *U. coronata* ("critically endangered"), *G. melanoleucus*, and *S. papa* (both in the "near threatened" category) (Rio Grande do Sul 2014).

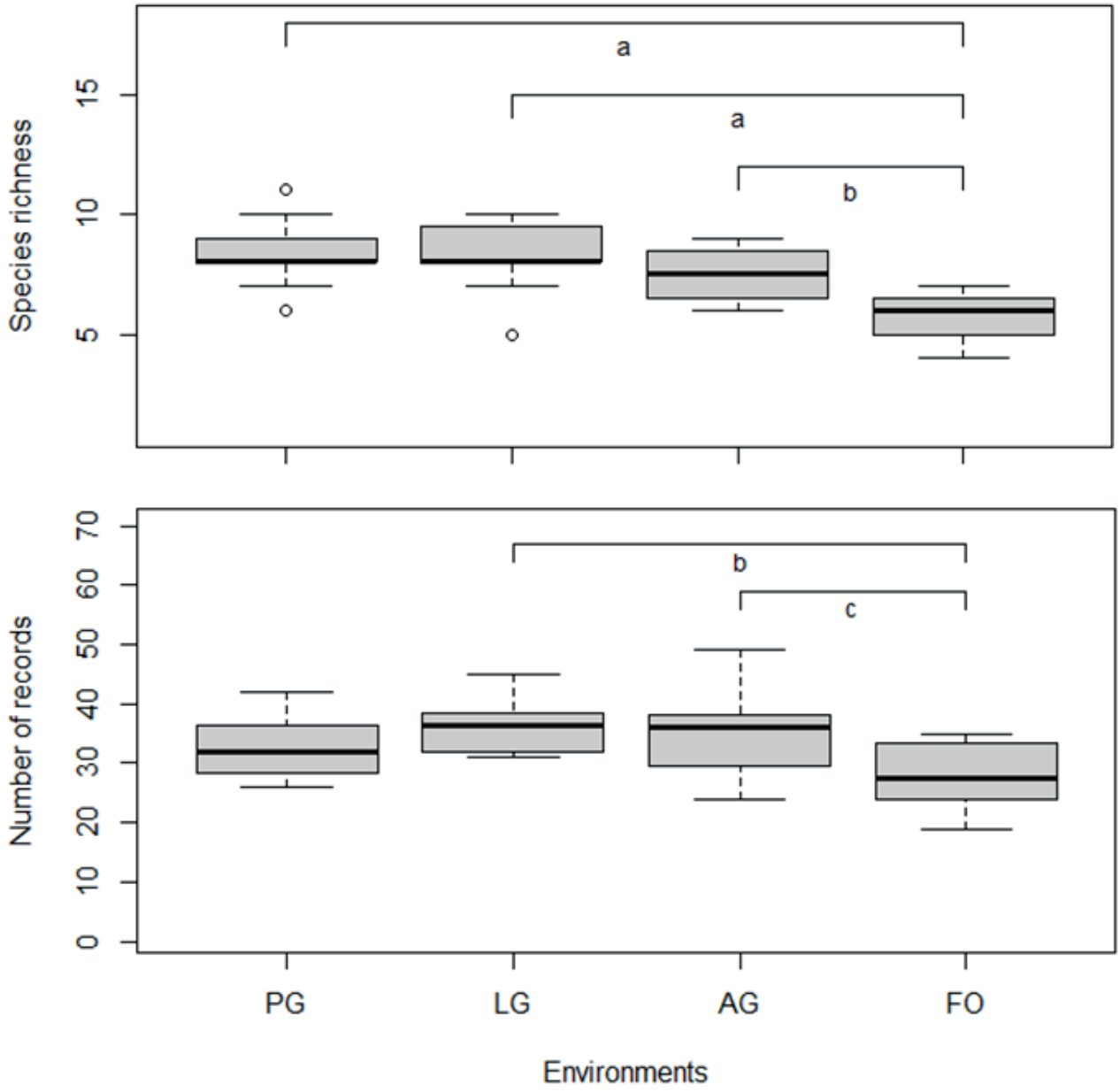

Figure 3. Comparison of richness and number of birds of prey records by environment in the municipality of São Francisco de Paula (a – $p < 0.0001$; b – $p < 0.01$; c – $p < 0.05$). PG - grasslands in protected areas; LG - grasslands with extensive livestock; AG - agriculture; FO - forestry.

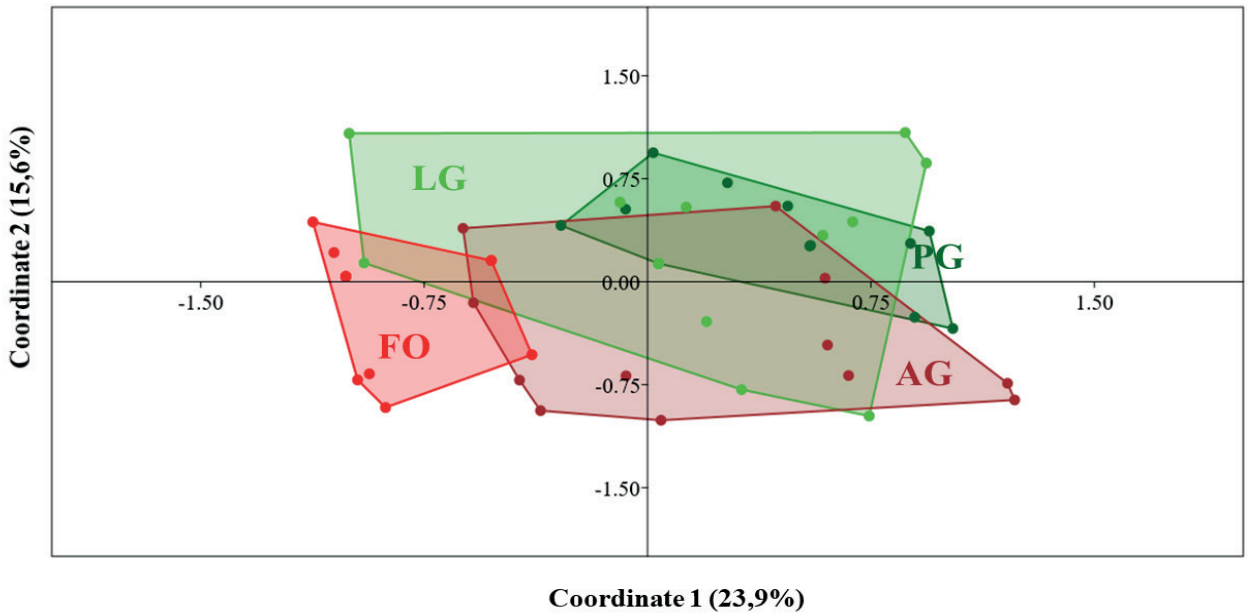

Figure 4. Principal Coordinates Analysis of diurnal birds of prey registered in São Francisco de Paula municipality, Rio Grande do Sul, Brazil. PG - grasslands in protected areas; LG - grasslands with extensive livestock; AG - agriculture; FO - forestry.

DISCUSSION

The native grasslands, both protected and livestock grasslands, have a greater richness of diurnal birds of prey than monocultures, especially forestry areas. Some studies have proven the modification or loss of part of the bird's diversity in commercial plantations or areas invaded by *Pinus* (Allan *et al.* 1997, Zurita *et al.* 2006). Our study showed a decrease of 47.05 % in the richness of the forestry areas in comparison to protected grasslands. Only *Rupornis magnirostris* (Accipitriformes, Accipitridae), considered a habitat generalist (Belton 1994), had a higher number of records in the areas of forestry than in the other environments (Table 2). Of the other eight species present in forestry areas, six of them were among the most frequent birds of prey in this study: *C. atratus*, *Cathartes aura* (Cathartiformes, Cathartidae), *Caracara plancus* (Falconiformes, Falconidae), *Milvago chimango* (Falconiformes, Falconidae), *Milvago chimachima* (Falconiformes, Falconidae) and *Falco sparverius* (Falconiformes, Falconidae). Contrary to our expectation, we did not see the addition of new species of forest birds of prey in the tree plantations.

We did not find a significant difference in the richness and number of birds of prey records between protected grasslands and livestock grasslands, in part, because the protected areas of the study region are partly inserted in private properties, where livestock farming also occurs. Due this, these areas' similarity indicates that possibly these birds are not under pressure in those kinds of rural areas outside protected areas, especially in large fields extensions like those that we sampled in this study. The use of native fields for livestock is considered the economic activity with the least impact for birds in southeastern South America, since performed moderately, with, for example, a reduced number of animals per hectare (Develey *et al.* 2008, Fontana *et al.* 2009, Azpiroz *et al.* 2012, Dotta *et al.* 2015, Fontana *et al.* 2016).

The number of birds of prey records was higher in agriculture areas than in protected grasslands, which can be explained by the increase in the number of records of two raptors considered opportunists, *C. plancus*, and *M. chimango* (Pedrana *et al.* 2008). Birds of prey respond in different ways to changes in their environments, and in some situations, they can be positively associated with agricultural areas (Shrag *et al.* 2009). In our case, the number of recordings of *M. chimango* in agriculture and forestry areas was higher than in the grassland areas. This species is considered tolerant of environmental changes, increasing its density, especially in plowed

agricultural fields (Belton 1994, Sick 1997, Leveau & Leveau 2002). In a single moment, we observed 28 individuals foraging in the soil in a recently harvested potato crop (March 11, 2019).

Regarding the rare or endangered species recorded in the study, *U. coronata* and *S. papa* were observed only in native grasslands (being that *S. papa* was seen only in protected grasslands – Estação Ecológica Aratinga). A globally endangered species (BirdLife International 2016), *U. coronata* lives in open environments such as grasslands, savannahs, and mountainous areas (Collar *et al.* 1992, Sick 1997). The highland grasslands are the last area of occurrence of *U. coronata* in the state of Rio Grande do Sul (Bencke *et al.* 2003), demonstrating the importance of the study region for the conservation of the species. *G. melanoleucus* has been recorded in three types of environment, except for forestry areas, which corroborates other studies that mention that this species has some plasticity and can be found in agricultural areas (Bierregaard Jr. 1998, López *et al.* 2017).

Grasslands are among the most altered and threatened ecosystems in the world, due to the big difference between habitat loss and low degree of protection (Henwood 2010, Azpiroz *et al.* 2012). About 1 % of grassland areas in southeastern South America have some protection (Henwood 2010). Considering only the last 19 years (2000 to 2018), the municipality of São Francisco de Paula had a reduction of 24.2 % in the areas of grasslands (from 197,800 ha to 149,814 ha). Accordingly, there was an increase of 539 % of agricultural areas (4,352 ha to 23,467 ha) and 379 % of forestry areas (12,629 ha to 47,883 ha) (MapBiomas 2020). This substitution has been occurring due to the slow abandonment of livestock activity in the region, which is not economically profitable, compared to the agricultural and forestry sectors, which are more lucrative and with high investment (Bristot 2001, Fontana *et al.* 2009, Overbeck *et al.* 2009).

In this study, we demonstrate that the diurnal birds of prey community are negatively affected through the replacement of native grasslands by commercial pine plantations. In forestry areas, the richness was almost half than the one found in native fields in protected areas, mainly composed of generalist species. We did not observe a significant loss of richness in the agricultural areas, but we draw attention to the absence of threatened species, such as *U. coronata*. The similar richness seen in protected grasslands and livestock grasslands demonstrates that extensive livestock farming does not affect the diurnal birds of prey raptor community. However, the slow abandonment of this economic activity in private properties and the current pace of replacement of native fields by monocultures can result in excessive fragmentation of grassland areas in the near future. This also reinforces the importance of the maintenance and expansion of existing protected areas and encourage the creation of new ones in the highland grasslands.

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