



# Comparison of the bird community in livestock farms with continuous and rotational grazing in eastern Uruguay

Federico Pérez<sup>1</sup> · Joaquín Aldabe<sup>1,2</sup>

Received: 2 February 2022 / Revised: 8 November 2022 / Accepted: 12 November 2022 / Published online: 13 December 2022  
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## Abstract

Grassland birds are the most endangered bird group in Uruguay, mainly due to habitat loss. Livestock farming is the most widespread agricultural activity in Uruguay. Grazing practices modify grassland plant structure. The most pervasive grazing systems in the country are continuous and rotational grazing, although with high diversity in their application. We studied the plant structure and the grassland bird community in 40 cattle ranches in eastern Uruguay, which include continuous grazing systems (CGSs) and rotational grazing systems (RGSs). RGS had a higher average grass height and greater habitat heterogeneity than CGSs, with a difference of 3.7 cm in grass height, 3.1 cm more heterogeneity within paddocks, and 2.1 cm more heterogeneity between paddocks. Also, RGS had a greater richness and an effective number of species per farm than CGS, with averages of 2.8 more species and 7.7 more effective number of species in RGS in relation to CGS. The presence of four species was significantly greater in RGS and one in CGS. However, there were no exclusive species to any grazing system. Our study shows a discreet positive effect of RGS on the ranch's grassland bird community, probably related to the structural diversity generated by these systems. Contrary to other works, this is the first work that reports a difference in species richness between rotational and continuous grazing systems. We, therefore, conclude that the grazing system is a relevant factor when managing grasslands to enhance bird biodiversity.

**Keywords** Grassland management · Plant structure · Rotational grazing systems · Structural diversity

## Introduction

Grassland birds respond to vegetation structure (e.g., height and leaf density) (MacArthur and MacArthur 1961; Norment et al. 1999; Isacch et al. 2004; Gojman and Zaccagnini 2008; Fisher and Davis 2010; Isacch and Cardoni 2011; Dias et al. 2014). They occupy diverse ecological niches, there being tall grasslands specialists, short grasslands specialists, and others that use a wide range of heights (Azpiroz et al. 2012). Therefore, many studies have concluded the need for conservation practices that create a mosaic of vegetation

structure (Fuhlendorf et al. 2006; Davis et al. 2020; Sliwinski et al. 2020).

South American southern cone grasslands are one of the few and largest temperate prairies and savannahs in the world (Soriano 1992). Since the sixteenth century, cattle introduction has considerably transformed these grasslands (Modernel et al. 2016). Cattle grazing has generated a shortening and homogenization of the vegetation structure, concentrating it between the first 10 cm of height (Soriano 1992; Altesor et al. 1998, 2006; Rodríguez et al. 2003). These modifications to vegetation's structure have resulted in habitat loss for grassland birds, mainly tall grasslands specialists, and their subsequent population decline (Comparatore et al. 1996; Isacch and Martínez 2001; Isacch et al. 2003; Azpiroz and Blake 2009; Dias et al. 2017).

Traditional continuous grazing systems (CGSs) and rotational grazing systems (RGSs) are the prevalent grazing methods in the region. Traditional CGS consists of permanent grazing throughout the year in every paddock. In RGS, cattle are concentrated in a few groups and moved periodically, alternating periods of occupation and rest

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Communicated by: Carla Fontana, Ph D. (Associated Editor)

✉ Federico Pérez  
federicopirez94@gmail.com

<sup>1</sup> Departamento de Sistemas Agrarios y Paisajes Culturales, Centro Universitario Regional del Este, Universidad de La República, Ruta 15, Km 28.500, Rocha, Uruguay

<sup>2</sup> Alianza del Pastizal, Aves Uruguay-BirdLife International, Montevideo, Uruguay

in every paddock (Briske et al. 2008). In CGS, cattle can graze selectively for preferred species as they can access to the entire grazing area. In RGS, cattle have less area since they are more concentrated than in CGS and therefore graze more intensively and homogeneously while other paddocks are resting (Bailey and Brown 2011). There is no scientific consensus on whether any of these systems are productively superior to the other (Briske et al. 2008; Barnes et al. 2008; Briske et al. 2008). However, many traditional CGSs are associated with grassland degradation and overgrazing due to selective grazing and minimal management decision (Kothmann 2009). The response of birds to different grazing systems as habitat generators for a diverse bird assemblage has been poorly evaluated and with different results (Isacch and Cardoni 2011; Murray et al. 2016; Pipher et al. 2016; M. Sliwinski et al. 2019; Milligan et al. 2020; Codesido and Bilenca 2021). Cozzani and Zalba (2009) propose to conserve patches of tall tussock as bird refuges, but this management was not incorporated into the overall management of the farms. Therefore, its viability in commercial terms has not been evaluated. Knowing the viability of a biodiversity management action in commercial farms is necessary for farmers to apply them (Neilly et al. 2018; Aldabe et al. 2019).

According to MacArthur and MacArthur (1961), there is a greater diversity of birds in an ecosystem when there is greater structural diversity. Compared to traditional CGS, RGSs are expected to have greater richness and diversity of birds given their greater structural diversity associated with more diversity of ecological niches, as a result of the greater temporal-spatial variation in grazing intensity between paddocks. In this paper, we evaluate the vegetation structure and grassland bird communities in RGS and traditional CGS in eastern Uruguay.

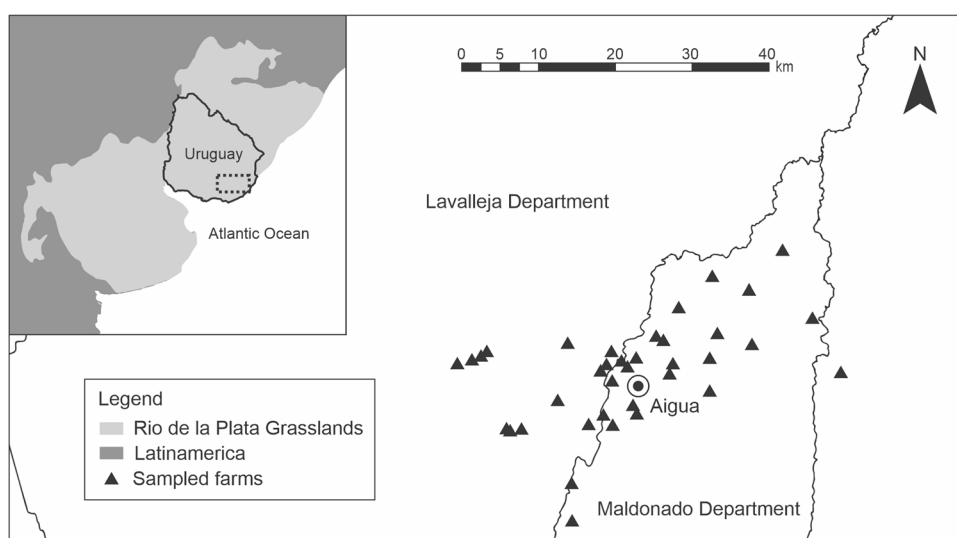
## Methods

### Study area

The present study was conducted on 40 cattle ranches in the states of Maldonado and Lavalleja in eastern Uruguay ( $34^{\circ}12'10''$  S;  $54^{\circ}45'48''$  W) (Fig. 1). The ranches were located in the geomorphological unit of Sierras del Este in a range of heights from 0 to 500 m a.s.l. (Brazeiro et al. 2012), where plains and hills (*sierras*) are prevalent (Baeza et al. 2019). Ranches were equally distributed between hills and plains. The grasslands of the hills are located on shallow rocky soils, with moderate slopes and the presence of trees, given their proximity to rocky woodlands (*bosque serrano*). The grasslands of the plains are located on deep and fertile soils where the grasses develop with greater density and less presence of trees (Lezama et al. 2011).

The average ranch area was 250 hectares, with a maximum of 1290 hectares and a minimum of 40 hectares. Of the 40 ranches sampled the first year, 24 were CGS, and 16 were RGS. In the second year, there were 8 CGS and 32 RGS since several ranches changed their grazing system that year. Grazing systems were classified in conjunction with managers. The RGS varied between ranches, with an average of 10 paddocks, and at least a third were resting at any moment. The RGS had more than one herd of cattle. Paddock occupation time varied between 5 and 25 days, while resting time ranged from 20 days to 6 months. On the other hand, CGS had an average of 9 paddocks, and only a few had a single paddock without grazing, although it occupied a small proportion of the ranch area compared to RGS. Seventy-five percent of the sampled paddocks corresponded to natural grasslands, and the remaining

**Fig. 1** Ranch's location where we conducted the study during spring of 2015 and the spring of 2016 to the summer of 2017



were artificial pastures. RGS had 74% of their paddocks with natural grasslands, while CGSs had 78% with natural grasslands.

### Bird sampling

Two samples from each ranch were recorded in two different seasons: the first from October to December 2015 and the second from December 2016 to January 2017, taking this time for the higher activity of birds and the presence of summer visitors and migrants. Due to the typical inter-annual climate variability present in the country, the first sampling was during a drought season, while the second was rainy. Bird surveys consisted of two observers simultaneously counting all visible birds along six transects per ranch (300 m long), trying to locate each transect in a different paddock. Transects were located far from fences and neighboring woodlands to avoid measuring their effects on the presence or absence of some species (birds use fences as perches, and forests may attract other species unrelated to grasslands). On CGS, six transects were located in grazed paddocks. On RGS, three transects were located in grazed paddocks and three in resting paddocks. The latter were identified with the help of managers or by evaluating grasses' state and absence of fresh dung. We counted all birds observed or heard along the transect that used the paddock. We conducted the surveys between 07:00 and 10:00 and 16:00 and 19:00 when the birds are known to be most active.

### Environmental variables sampling

At each transect, we sampled grass height and percentage of tree cover. Grass height was measured every 50 m with Robel's method, recording six measurements, and then averaged. The method measures the visual obstruction caused by vegetation on a 1.5 m high pole divided into 10 cm segments (Robel et al. 1970). The observer records the lowest visible segment on the pole from a 4 m distance and 1 m height. The percentage of tree cover for the whole paddock was estimated visually during sampling. The percentage of artificial pasture cover was measured by satellite image.

### Data modeling

Samples between years were assumed to be independent, given the marked climatic differences between years, which led to significant differences in grass height (see "Results"). Therefore, a sample of 80 observations was distributed in 40 ranches. Statistical analyses included (1.) modeling of plant structure and (2.) modeling of grassland birds' community. All analyses were conducted with R 4.0.0 (R Core Team, 2020).

**Relation of the grazing system to the vegetation structure** We evaluated the differences in vegetation structure between ranches using multiple linear regression with the grazing system, season (rainy or dry), and topographic area (plains or hills) as explanatory variables. We used three variables as descriptors of vegetation structure: average grass height, structural heterogeneity between paddocks (HBP), and structural heterogeneity within paddocks (HWP). HBP corresponded to the variability in grass height between paddocks and was estimated as the standard deviation of the average grass height of the ranch paddocks. HWP corresponded to the variability in grass height within paddocks and was estimated as the average of the standard deviation of the grass height of each ranch paddock.

**Relation of the grazing system to the bird community** We evaluated the grassland birds' community using bird richness per ranch and the effective number of species per ranch (ENS) as response variables (Jost 2010). Bird richness corresponded to the number of grassland bird species observed on each ranch. We used ENS as an alternative to conventional biodiversity indices, which Jost (2010) defined as the exponential of Shannon's diversity index (Shannon 1948). Conventional biodiversity indices are non-intuitive, non-linear parameters that are difficult to compare with each other (Jost 2010). We classified grassland birds based on Azpiroz et al. (2012) and personal observations.

We run statistical models with these two variables to assess the relationship between grassland birds with the following explanatory variables: grazing system, percentage of tree cover (average of transects data), percentage of natural cover, topographic zone (hills or plains), ranch area, and season (dry or rainy). A generalized linear model (GLM) with binomial error distribution evaluated the effect of the grazing systems on the probability of occurrence of each species. A GLM with Poisson error distribution evaluated the effect of the grazing systems and other environmental variables on species richness per ranch. Finally, a linear model (LM) with normal distribution evaluated the effect of the grazing systems and other environmental variables on the ENS.

In all analyses, we considered a significance value of  $(\alpha) \leq 0.05$ . We used a stepwise variable selection method to obtain the minimally adequate model, with Akaike information criteria (AIC) as selection criteria (Akaike 1974). For the LM, we verified the normality assumption with the Jarque and Bera (1987) test and logarithmic transformations were performed, if needed. We performed Breusch and Pagan (1979) tests to evaluate the homoscedasticity assumption. We evaluated outliers with Cook's distance (Cook 1977). We used the *visreg* package for the graphical representation of the models (Breheny and Burchett 2017?), which plots how the expected values of the response

variable change depending on the explanatory variable chosen, maintaining the other explanatory variables fixed.  $R^2$  and quasi  $R^2$  were calculated to assess the percentage of variability explained by the explanatory variables included in the models.

Before modeling, we standardized continuous explanatory variables (ranch area, percentage of tree cover, and percentage of natural cover) to allow comparison between model coefficients (Schielzeth 2010). In addition, we calculated the effect size and their confidence intervals, as proposed by Nakagawa and Cuthill (2007). The use of effect size is because hypothesis tests estimate the significance of explanatory variables but do not estimate the magnitude of the effect of interest or the precision of that estimate. We interpret effect size as small effect (between 0.2 and 0.5), medium effect (between 0.5 and 0.8), or large effect (more than 0.8) (Cohen 2013).

## Results

### Vegetation structure

Grass height ranged from 1.8 to 43.5 cm between ranches, averaging  $11.4 \pm 8.0$  cm. The LM determined a significant effect of the grazing system and season over grass height (Table 1), with an adjusted  $R^2$  of 55% (Table 2). Based on the model coefficients, grass height was 3.68 cm higher in RGS than in CGS (difference between both treatments' estimates). Also, grass height was 4.24 cm higher in the rainy season than in the dry season. Figure 2 graphs the model results between grazing treatments.

**Table 1** ANOVA (one-way analyses of variance) table of linear models for vegetation structure variables. *Df*, degrees of freedom. *P*-value: (\*\*\*) less than 0.001, (\*) less than 0.05, (NS) not significant

	Df	Sum square	Mean square	Z value	P
Lineal model for grass height					
Grazing system	1	14	13.97	65.90	***
Season	1	7	7	33	***
Residuals	77	16.30	0.21		
Lineal model for structural heterogeneity between paddocks					
Grazing system	1	13.51	13.51	37	***
Season	1	5.42	5.42	14.80	***
Residuals	77	28.12	0.37		
Lineal model for structural heterogeneity within paddocks					
Grazing system	1	7.40	7.40	29.09	***
Season	1	1.70	1.70	6.68	*
Topographic zone	1	0.87	0.87	3.4	NS
Residuals	76	19.33	0.25		

**Table 2** Linear model coefficients for grass height. The first and second estimates correspond to grass height during the dry season at CGS and RGS, respectively. The third estimate corresponds to the increase in grass height during the rainy season. *SE*, standard error; *CI*, confidence interval; *LL*, lower limit; *UL*, upper limit

	Estimate	SE	95% CI	
			LL	UL
CGS in the dry season	4.65	1.09	3.92	5.52
RGS in the dry season	8.34	1.12	5.90	11.35
In the rainy season	4.24	1.12	2.46	6.49

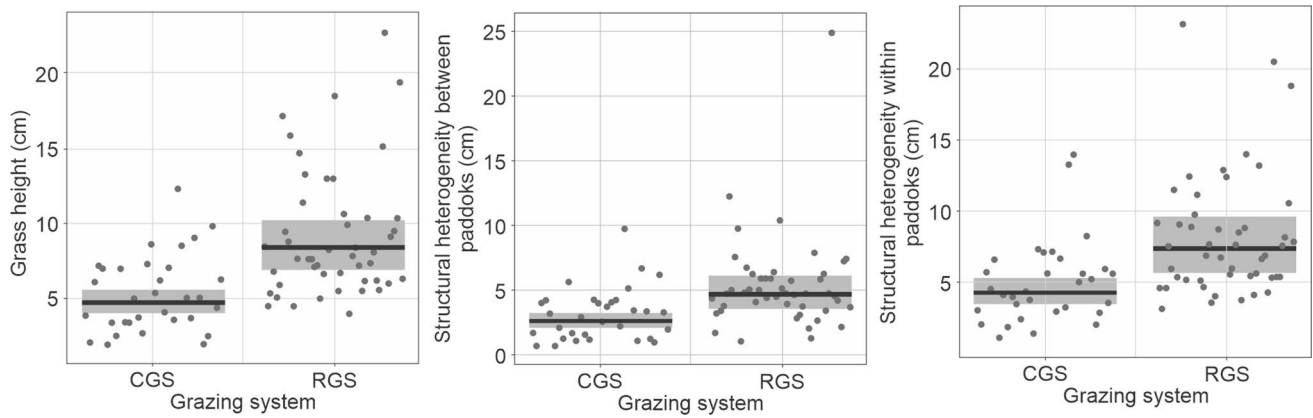
$R^2 = 0.55$ ;  $P < 0.001$

The HBP ranged from 1.0 to 44.7 cm between ranches, with an average of  $6.4 \pm 5.7$  cm. The LM determined a significant effect of the grazing system and season over HBP (Table 1), with an adjusted  $R^2$  of 39% (Table 3). Based on the model coefficients, HBP was 2.08 cm higher in RGS than in CGS (difference between both treatments' estimates). Also, HBP was 1.95 cm higher in the rainy season than in the dry season.

The structural HWP ranged from 1.0 to 27.9 cm between ranches with an average of  $7.6 \pm 4.8$  cm. The LM determined a significant effect of the grazing system and season over HWP (Table 1), with an adjusted  $R^2$  of 31% (Table 4). Based on the model coefficients, HWP was 3.06 cm higher in RGS than in CGS (difference between both treatments' estimates). Also, HBP was 1.56 cm higher in the rainy season than in the dry season. The topographic zone effect was included in the model but was not significant.

### Bird community

**Relation of the type of grazing and presence of different species of birds** We recorded 53 grassland bird species, of which 12 were grassland obligate species, and three were globally threatened species (Table 5). The five most common species were *Furnarius rufus*, *Molothrus bonariensis*, *Nothura maculosa*, *Tyrannus savana*, and *Vanellus chilensis*. The GLM to assess the effect of grazing systems on the probability of occurrence of each species found significant effects for five species. According to the models, the occurrence of four species was significantly higher in RGS: *Embernagra platensis*, *Phacellodomus striaticollis*, *Progne tapera*, and *Sicalis flaveola*. On the other hand, the occurrence of one species was significantly higher in CGS: *Nengetus cinereus*. Only one grassland obligate species (*E. platensis*) responded to the grazing system. Both species responded positively to the RGS. However, no significant effect of the grazing system on the threatened species was detected (Table 5).



**Fig. 2** Linear models for vegetation structure variables. They show the positive effect of rotational systems (RGSs) over grass height (left), structural heterogeneity between paddocks (center), and struc-

tural heterogeneity within paddocks (right). Solid lines represent the fitted equation, and gray-shaded areas represent the 95% confidence intervals

**Table 3** Linear model coefficients for structural heterogeneity between paddocks. The first and second estimates correspond to structural heterogeneity between paddocks during the dry season at CGS and RGS, respectively. The third estimate corresponds to increased structural heterogeneity between paddocks during the rainy season. *SE*, standard error; *CI*, confidence interval; *LL*, lower limit; *UL*, upper limit

	Estimate	SE	95% CI	
			LL	UL
CGS in the dry season	2.53	1.12	2.02	3.16
RGS in the dry season	4.61	1.16	2.90	6.87
In the rainy season	1.95	1.16	0.80	3.47

$R^2 = 0.39; P < 0.001$

**Table 4** Linear model coefficients for structural heterogeneity within paddocks. The first and second estimates correspond to structural heterogeneity within paddocks during the dry season at CGS and RGS, respectively. The third and fourth estimates correspond to the change in structural heterogeneity within paddocks during the rainy season and in the plains zone, respectively. *SE*, standard error; *CI*, confidence interval; *LL*, lower limit; *UL*, upper limit

	Estimate	SE	95% CI	
			LL	UL
CGS in the dry season	4.41	1.11	3.57	5.45
RGS in the dry season	7.47	1.14	4.95	10.68
In the rainy season	1.56	1.13	0.26	3.23
In the plains zones	-0.84	1.12	-1.57	0.07

$R^2 = 0.31; P < 0.001$

**Relation of grazing system with species richness and ENS per ranch** The species richness per ranch ranged from 10 to 29 species, with an average of  $20.4 \pm 4.08$  species. The GLM determined a significant effect of the grazing system

on species richness (Table 6), with an adjusted quasi  $R^2$  of 11% (Table 7). The model detected a significant difference in species richness between the different grazing systems, with an estimated mean of 21.5 species and 18.7 species in the RGS and CGS, respectively (Fig. 3). The other explanatory variables showed no significant effect (percentage of tree cover, percentage of natural cover, topographic area, ranch area, and season). Cohen’s *d* estimated a medium effect size of grazing system over species richness ( $d = 0.48$ , lower limit = 0.46, upper limit = 1.41).

The ENS per ranch ranged from 86 to six species, averaging  $45.7 \pm 16.5$  effective number of species. The LM determined a significant effect of the grazing system over ENS (Table 8), with an adjusted  $R^2$  of 4% (Table 9). The model detected a significant difference in ENS between the different grazing systems, with an estimated mean of 48.8 species and 41.1 species in the RGS and CGS, respectively. The other explanatory variables showed no significant effect (percentage of tree cover, percentage of natural cover, topographic area, ranch area, and season). Cohen’s *d* estimated a medium effect size of grazing system over ENS ( $d = 0.55$ , lower limit IC = 0.46, upper limit IC = 1.56).

## Discussion

Grassland birds are Uruguay’s most endangered bird group (Aldabe et al. 2013). Knowing the effect of different management practices is necessary for their conservation. We hypothesized that rotational grazing systems have more diverse bird communities than continuous grazing systems because the former have more structurally heterogeneous grasslands. Our results support this hypothesis. Our models found significantly higher heterogeneity between and within

**Table 5** List of grassland birds registered. The table shows the common and scientific names of each species and their observed percentage of occurrence in continuous (CGS) and rotational (RGS) systems separately. *P*-value corresponds to the statistical significance of the

effect of the grazing system on the probability of occurrence of each species (binomial GLM for each species). *P*-value: (NS) not significant, (\*) significant. <sup>1</sup>Grassland obligate species following Vickery et al. (1999); <sup>2</sup>Globally endangered species following IUCN (2022)

Family/species	Common name	Percentage of occurrence in CGS	Percentage of occurrence in RGS	<i>P</i> -value
Rheidae				
<i>Rhea americana</i>	Greater rhea	9%	23%	NS
Tinamidae				
<i>Rhynchotus rufescens</i> <sup>1</sup>	Red-winged tinamou	19%	19%	NS
<i>Nothura maculosa</i> <sup>1</sup>	Spotted tinamou	82%	94%	NS
Ardeidae				
<i>Syrigma sibilatrix</i>	Whistling heron	6%	6%	NS
Threskiornithidae				
<i>Theristicus caerulescens</i>	Plumbeous ibis	16%	10%	NS
Accipitridae				
<i>Circus cinereus</i>	Cinereous harrier	3%	0%	NS
Falconidae				
<i>Milvago chimango</i>	Chimango caracara	25%	33%	NS
<i>Falco femoralis</i> <sup>1</sup>	Aplomado falcon	0%	4%	NS
<i>Falco sparverius</i>	American kestrel	28%	40%	NS
Charadriidae				
<i>Vanellus chilensis</i> <sup>1</sup>	Southern lapwing	93%	91%	NS
Scolopacidae				
<i>Gallinago paraguaiiae</i> <sup>1</sup>	South American snipe	19%	19%	NS
Columbidae				
<i>Zenaida auriculata</i>	Eared dove	65%	69%	NS
Psittacidae				
<i>Myiopsitta monachus</i>	Monk parakeet	50%	56%	NS
Cuculidae				
<i>Guira guira</i>	Guira cuckoo	31%	31%	NS
Strigidae				
<i>Athene cunicularia</i> <sup>1</sup>	Burrowing owl	28%	27%	NS
Picidae				
<i>Colaptes campestris</i>	Campo flicker	56%	58%	NS
Furnariidae				
<i>Furnarius rufus</i>	Rufous hornero	84%	94%	NS
<i>Anumbius annumbi</i>	Firewood-gatherer	75%	79%	NS
<i>Limnocites rectirostris</i> <sup>2</sup>	Straight-billed reedhaunter	0%	4%	NS
<i>Phacellodomus striaticollis</i>	Freckle-breasted thornbird	16%	35%	*
Tyrannidae				
<i>Heteroxolmis dominicana</i> <sup>2</sup>	Black-and-white monjita	3%	19%	NS
<i>Nengetus cinereus</i>	Gray monjita	84%	56%	*
<i>Xolmis irupero</i>	White monjita	78%	90%	NS
<i>Hymenops perspicillatus</i>	Spectacled tyrant	22%	42%	NS
<i>Machetornis rixosa</i>	Cattle tyrant	37%	48%	NS
<i>Pitangus sulphuratus</i>	Great kiskadee	72%	96%	NS
<i>Tyrannus melancholicus</i>	Tropical kingbird	66%	73%	NS
<i>Tyrannus savana</i> <sup>1</sup>	Fork-tailed flycatcher	91%	92%	NS
<i>Pyrocephalus rubinus</i>	Vermilion flycatcher	84%	90%	NS
Hirundinidae				
<i>Progne chalybea</i>	Gray-breasted martin	0%	6%	NS

**Table 5** (continued)

Family/species	Common name	Percentage of occurrence in CGS	Percentage of occurrence in RGS	P-value
<i>Progne tapera</i>	Brown-chested martin	72%	96%	*
<i>Tachycineta leucorrhoa</i>	White-rumped swallow	72%	65%	NS
<i>Notiochelidon cyanoleuca</i>	Blue-and-white swallow	44%	42%	NS
<i>Alopochelidon fucata</i>	Tawny-headed swallow	0%	2%	NS
<i>Stelgidopteryx ruficollis</i>	Southern rough-winged swallow	9%	0%	NS
<b>Motacillidae</b>				
<i>Anthus furcatus</i> <sup>1</sup>	Short-billed pipit	6%	8%	NS
<i>Anthus correndera</i> <sup>1</sup>	Correndera pipit	16%	10%	NS
<i>Anthus hellmayri</i> <sup>1</sup>	Hellmayr’s pipit	12%	8%	NS
<b>Thraupidae</b>				
<i>Sporophila caerulescens</i>	Double-collared seedeater	6%	12%	NS
<i>Sicalis luteola</i> <sup>1</sup>	Grassland yellow finch	78%	90%	NS
<i>Sicalis flaveola</i>	Saffron finch	37%	62%	*
<i>Donacospiza albifrons</i>	Long-tailed reed finch	0%	8%	NS
<i>Embernagra platensis</i> <sup>1</sup>	Great Pampa finch	34%	75%	*
<b>Cardinalidae</b>				
<i>Cyanoloxia glaucoacaerulea</i>	Glaucous-blue grosbeak	0%	6%	NS
<b>Emberizidae</b>				
<i>Zonotrichia capensis</i>	Rufous-collared sparrow	0%	2%	NS
<i>Ammodramus humeralis</i> <sup>1</sup>	Grassland sparrow	66%	69%	NS
<b>Icteridae</b>				
<i>Molothrus rufoaxillaris</i>	Screaming cowbird	6%	4%	NS
<i>Molothrus bonariensis</i>	Shiny cowbird	94%	90%	NS
<i>Agelaioides badius</i>	Grayish baywing	12%	12%	NS
<i>Xanthopsar flavus</i> <sup>1,2</sup>	Saffron-cowled blackbird	16%	23%	NS
<i>Pseudoleistes virescens</i>	Brown-and-yellow marshbird	47%	65%	NS
<i>Leistes superciliosus</i> <sup>1</sup>	White-browed meadowlark	9%	15%	NS
<i>Gnorimopsar chopi</i>	Chopi blackbird	9%	2%	NS

**Table 6** ANOVA (one-way analyses of variance) table of generalized linear model for species richness. It shows the significant effect of the grazing system on the response variable. Df, degrees of freedom. P-value: (\*\*) less than 0.01

	Df	Deviance resid	Df resid	Dev	Pr(> Chi)
NULL			79	66.5	
Grazing system	1	7.46	78	59	**

**Table 7** Generalized linear model coefficients for species richness. The estimates correspond to the number of species for CGS and RGS. SE, standard error; CI, confidence interval; LL, lower limit; UL, upper limit

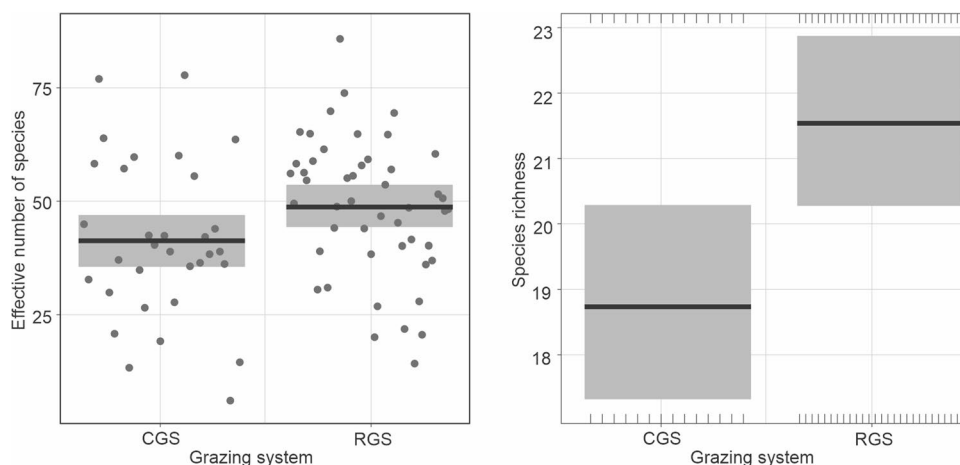
	Estimate	SE	95% CI	
			LL	UL
CGS	18.72	0.04	17.26	20.27
RGS	21.52	0.05	20.31	23.05

R<sup>2</sup> = 0.11; P = 0.006

paddocks in RGS than CGS. In addition, contrary to other works in the Rio de la Plata Grasslands (Isacch and Martínez 2001; Codesido and Bilenca 2021), we found significantly more diverse grassland bird communities in RGS compared to CGS. Our success in detecting such an effect might be explained by the much larger number of ranches assessed here. The positive effect of structural heterogeneity on the grassland bird community is consistent with other studies (Fuhlendorf et al. 2006; Davis et al. 2020; Sliwinski et al. 2020). However, the magnitude of the treatment’s effect on the bird community was moderate, considering the low explained variability of our models (R<sup>2</sup>). This may be due to the homogenization of treatments as a result of drought during the first year of sampling.

As for structural heterogeneity, RGS had higher HBP than CGS. This was because RGS had two types of paddocks: rested and grazed. Grass height in the rested paddocks was 67% greater than in the grazed ones. Contrary to what we expected, RGS also had higher structural HWP. This was not

**Fig. 3** Generalized linear model (left) and linear model (right) for bird community variables. They show the positive effect of rotational systems (RGSs) on species richness (left) and the effective number of species (right). Solid lines represent the fitted equation, and gray-shaded areas represent the 95% confidence intervals



**Table 8** ANOVA (one-way analyses of variance) table of linear model for effective number of species per ranch (ENS). It shows the significant effect of the grazing system on the response variable. *Df*, degrees of freedom. *P*-value: (\*) less than 0.05

	<i>Df</i>	Sum sq	Mean sq	<i>Z</i> value	<i>Pr(&gt;F)</i>
Grazing system	1	1133	1133	4.33	*
Residuals	78	20,408	262		

**Table 9** Linear model coefficients for effective number of species per ranch (ENS). The estimates correspond to the effective number of species for CGS and RGS. *SE*, standard error; *CI*, confidence interval; *LL*, lower limit; *UL*, upper limit

	Estimate	SE	95% CI	
			LL	UL
CGS	41.09	2.86	35.40	46.80
RGS	48.77	3.69	41.42	56.09

$R^2 = 0.04$ ;  $P = 0.04$

expected given the more intensive and homogeneous grazing of paddocks that theoretically occurs in RGS (Bailey and Brown 2011). This may be because the RGS included in this study had medium-sized paddocks, which avoids intensive grazing and, thus, the homogenization of the grass structure within the paddock.

As for the bird community, on average, 13% more species per ranch were observed on RGS, a relatively small difference of 2.8 species. Potentially, a more considerable difference could be expected given the wide range of tall grass species that could be found on the ranches, but no such species were registered (Azpiroz et al. 2012). Based on our statistical models, the grazing system explained 4% and 11% of the variability in the richness and the effective number of species present on the ranches, respectively. This indicates that there are other important variables responsible

for the bird community's variability that we did not consider. Additionally, the drought period may have also affected both treatments. This climatic event might explain the lower structural heterogeneity shown by our models and resulted in all paddocks being heavily grazed because of food shortages. This may partially explain the moderate effect of treatments on the bird community. Furthermore, other studies showed that grazing systems alone do not have an effect on the grassland bird community and that longer rest periods are needed (Sliwinski et al. 2019) or even land sparing (Dotta et al. 2016). Another possible explanation is that in most CGS, there was at least one patch of tall tussock (mainly of *Paspalum quadrifolium* and *Erianthus angustifolius*) or paddock under deferment, which could replace the role of resting paddocks in RGS, and therefore homogenizing the effect of the treatments.

No species were recorded exclusively for any of the treatments. The moderate effect of the grazing system on the bird community could be due to the species identified in our probability of occurrence models. *Embernagra platenis*, *Phacellodomus striaticollis*, *Progne tapera*, and *Sicalis flaveola* were mostly benefited by RGS. These ranches had a higher grass height than CGS and corresponded with the habitat requirements of these species, which prefer medium and tall grassland sites (Azpiroz and Blake 2009; Dias et al. 2014). Likewise, the presence of *P. tapera*, considering that it is insectivorous, may be due to the higher abundance of insects in taller grasslands, given the higher biomass (Krueess and Tscharrntke 2002).

As for the weaknesses of our study, it was complex to classify the ranches according to the grazing system. This was because several of the sampled CGS were in the process of transitioning to rotational systems. Moreover, we surveyed equal amounts of grazed and resting paddocks in the RGS, which did not necessarily reflect reality. In addition, we did not consider landscape features that might explain local species richness differences among ranches.



Our results suggest that RGS can have more grassland bird species than CGS if CGSs have a high grazing intensity that prevents the paddocks from developing HWP. If the grazing intensity is low, which generates HWP, we cannot discard that CGSs have the same or more grassland bird species than RGS. In this sense, it is necessary to include grazing intensity data and stocking levels (number of livestock and kg) to compare the grassland bird community between grazing systems.

## Conclusions

The rotational grazing systems studied had higher and more heterogeneous grasslands than continuous grazing systems, possibly due to the variation in the temporal and special grazing pressure of the RGS.

The effect of the grazing system on the grassland birds' community was low, possibly due to the water deficit that occurred during the samplings that limited grass growth and to the influence of tall tussocks as substitutes for tall grasses. In this study, we showed that the way ranchers manage their livestock grazing influences species richness. Considering the high percentage of grassland area on private hands in the Rio de la Plata grasslands, this result suggests the importance of grazing systems on grassland bird conservation. However, to confirm if rotational grazing systems promote higher bird species richness, future efforts should be focused on assessing differences between continuous and rotational grazing systems with more contrasting vegetation structures, considering grazing intensity and landscape effects.

**Acknowledgements** This work was supported by the International Program, U.S. Forest Service, Alianza del Pastizal-BirdLife International, Aves Uruguay, and Centro Universitario Regional del Este, Universidad de la República, Uruguay.

**Funding** International Programs, US Forest Service; Alianza del Pastizal-BirdLife International; Aves Uruguay.

**Data availability** Not applicable.

**Code availability** Not applicable.

## Declarations

**Ethics approval** Not applicable.

**Consent to participate** Not applicable.

**Consent for publication** Not applicable.

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