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PROGRAMA DE PÓS-GRADUAÇÃO EM ECOLOGIA E EVOLUÇÃO DA BIODIVERSIDADE
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COMUNIDADE DE AVES EM ÁREAS CAMPESTRES DEGRADADAS POR CULTIVOS, EM PROCESSO DE RESTAURAÇÃO NO BIOMA PAMPA, SUL DO BRASIL

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“Ultimately, the future of a natural ecosystem depends not on protection from humans but on its relationship with the people who inhabit it or share the landscape with it.”

Willian R. Jordan III, a founder of the field of restoration ecology

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RESUMO

A conversão dos ambientes naturais devido a outros usos da terra tem dado enfoque à restauração ecológica, que se destina a recuperar ecossistemas degradados. A degradação de terras nativas não é diferente para os campos do bioma Pampa, no Rio Grande do Sul, que compreendem 63% da sua área e grande parte do seu uso é destinado à agropecuária. Os objetivos deste estudo foram avaliar a estrutura e composição das comunidades de aves em áreas de restauração passiva e ativa em campos do sul do Brasil, relacionando-as a variáveis da vegetação e verificando a influência dos remanescentes campestres do entorno das paisagens em restauração. Este é o primeiro estudo de restauração avaliando a comunidade de aves realizado nestes campos e nos do sudeste da América do Sul. Quatro áreas de restauração passiva e uma de ativa, que anteriormente tinham cultivos, foram comparadas a áreas de referência, ou seja, campos nativos. As comunidades de aves foram amostradas de 2015 a 2017, através de pontos de contagem com raio de 100 m e duração de 5 min. As variáveis da vegetação – altura, grau de obstrução lateral e cobertura do solo – foram amostradas através de cinco parcelas em cada ponto de contagem das aves. Utilizou-se pacotes de análises de comunidade do programa R para as análises estatísticas e o programa QuantumGIS para as análises de paisagem. Não foram encontradas diferenças significativas na riqueza de espécies, abundância ou composição das comunidades de aves entre restauração passiva e áreas de referência, e o número de espécies de aves associadas ao campo também foi similar. Sete espécies responderam significativamente ao tipo de campo, ano de amostragem, altura da vegetação, gramíneas baixas e/ou presença de herbáceas. Além disso, oito espécies registradas estão global ou regionalmente ameaçadas de extinção, sendo três delas exclusivas das áreas de restauração. Já na área de restauração ativa, depois de três anos consecutivos de monitoramento, a riqueza de espécies de aves e a abundância foram maiores do que a área de referência, e a composição de espécies também diferiu em ambas as áreas. Seis atributos da vegetação foram diferentes entre restauração ativa e a área de referência, mas no terceiro ano de monitoramento as gramíneas e as herbáceas se tornaram mais similares ao campo nativo. Quanto à análise de paisagem, encontramos que a riqueza de espécies, a abundância e a ocorrência de oito espécies analisadas individualmente não apresentaram uma relação significativa com a quantidade de remanescentes de campo nativo do entorno das áreas em restauração. Com cautela para a extrapolação dos resultados devido ao número máximo de réplicas que foram possíveis, foi permitido concluir que tanto a restauração passiva quanto a restauração ativa podem ser utilizadas para a conservação das aves campestres, pois parecem fornecer estrutura do habitat adequado para as aves especialistas de campo. Também é importante levar em consideração a matriz da paisagem do entorno, a qual pode influenciar no processo de restauração. É recomendado mais estudos envolvendo a restauração de ambientes degradados e esforços de longo prazo, avaliando não apenas plantas como tradicionalmente realizado, mas também animais, fornecendo informações mais consistentes e aplicáveis, além de complementares.

Palavras-chave: aves campestres, campos, conservação, recuperação

ABSTRACT

Bird community in degraded grassland areas by crops, in restoration process in the Pampas biome, south of Brazil.

Conversion of natural habitats due to other land uses has focused on ecological restoration, which is aimed to recover degraded ecosystems. Degradation of native habitats also occur in Pampas biome grasslands in Rio Grande do Sul, which comprise 63% of its area and much of its use is destined to agriculture. The objectives of this study were evaluate the structure and composition of the bird communities in passive and active restoration sites of southern Brazil. We also relate them to vegetation variables, and verify the influence of the remnats grasslands of the landscape surrounding the restoration sites. This is the first study of restoration evaluating the bird community realized in these grasslands and in the southeastern South America. Four passive restoration sites and one active which previously had crops were compared to reference areas, i.e. native grasslands. Bird communities were sampled from 2015 to 2017 in point counts of 5 min and 100-m radius. The vegetation variables – height, degree of visual obstruction and soil cover – were surveyed through five plots at each point count of birds. We used community analysis packages from R software for the estatistical analyzes, and QuantumGIS for the landscape analyzes. We did not found significant differences in species richness, abundance and composition of bird communities between passive restoration and reference areas, and the number of bird species associated to grasslands were also similar. Seven species responded significantly to the grassland type, survey year, vegetation height, low grasses and/or herbs presence. In addition, eight species recorded are globally or regionally threatened, three of them exclusive to the restoration sites. In the active restoration site, after three consecutive years of monitoring, bird species richness and abundance were higher than the reference area, and species composition also differed in both sites. Six vegetation attributes were different between active restoration and reference area, but in the third year of monitoring grasses and herbaceous became more similar to the native grassland. As for landscape analysis, we found species richness, abundance and occurrence of eight species analyzed individually did not show significant relationship with the amount of the native grasslands remnants surrounding the restoration sites. With caution to extrapolate the results due to the maximum number of replicates that were possible, it was possible to conclude that both passive and active restoration can be used for the bird conservation, since they seem to provide suitable habitat structure for the grassland birds. It is also important consider the surrounding landscape matrix, which can influence the restoration process. Futher studies involving the restoration of degraded habitats and long-term efforts are recommended, evaluating not only plants as tradicionally accomplished, but also animals, providing more consistent and applicable, as well as complementary information.

Keywords: grassland birds, grasslands, conservation, recovery

APRESENTAÇÃO

Os ambientes campestres são naturalmente encontrados em quase todos os continentes (exceto na Antártica) e se caracterizam por apresentar animais especializados às suas particularidades, como clima, solo e vegetação típica, a qual é praticamente desprovida de árvores e composta por muitas espécies de gramíneas e compostas. Infelizmente, globalmente os campos sofrem muitas ameaças devido a práticas agropecuárias, fragmentação, introdução de espécies exóticas e substituição por florestas (Gibson 2009, Bond e Parr 2010). No Brasil, os campos do bioma Pampa ocupam uma área que corresponde a 63% do estado do Rio Grande do Sul, sendo que ainda são muito negligenciados, pois não recebem a mesma importância que os ecossistemas florestais, principalmente quanto ao cumprimento das leis e ao código florestal (Overbeck et al. 2007, 2015). Devido a essa descaracterização e a consequente perda da biodiversidade dos campos sul-brasileiros documentada cada vez mais em literatura científica e acessível (p.e., Overbeck et al. 2007, Vélez-Martin et al. 2015), é importante a integração da comunidade científica com os manejadores destes campos, como os pecuaristas, e também o envolvimento de outras organizações (p.e., SAVE Brasil-Alianza del Pastizal), para ser possível a conservação deste relevante bioma.

Nesse contexto, a realização de estudos visando a conservação dos remanescentes campestres, tentando conciliar interesses produtivos com a manutenção da diversidade biológica, é necessária, assim como pesquisas que também tenham foco em sistemas degradados (Andrade et al. 2015). A restauração dos ambientes campestres tem sido uma das alternativas utilizadas para recuperar áreas originais de campo que foram substituídas por algum outro uso, e que foram degradadas (Zaloumis e Bond 2011), sendo considerada como o futuro da biologia da conservação (Young 2000). A restauração pode ser ativa ou passiva, ou seja, quando há ou não intervenção humana, e é muito mais conhecida e aplicada em ambientes florestais, sendo as plantas o táxon mais avaliado. Em países como a África do Sul, Austrália e Estados Unidos, e parte da Europa, a restauração ecológica tem sido difundida e utilizada, sendo que as práticas empregadas e informações obtidas com a restauração de ambientes campestres podem servir como base para sua aplicação nos campos do sul da América do Sul, incluindo do Brasil. Além disso, estudos desse tipo são relevantes para futuras tomadas de decisões para conservação das áreas campestres, seja por meio da necessidade do uso de técnicas de restauração, ou apenas através do manejo correto, o qual pode ser suficiente para a restauração espontânea.

A partir do exposto acima, desenvolvemos o primeiro estudo relacionado à comunidade de aves em ambientes campestres degradados por cultivos, em processo de restauração no Bioma Pampa, o qual é também o primeiro a ser desenvolvido nos campos do sudeste da América do Sul. Nossos resultados possibilitaram a obtenção de informações a respeito dos processos de restauração, ativa e passiva, sendo possível avaliar se realmente são efetivos e fornecem habitat e recursos necessários para a manutenção e conservação das aves em campos degradados no sul do Brasil. A tese está dividida em três capítulos, os quais estão estruturados na forma de artigos científicos. No primeiro capítulo avaliamos ambientes em restauração passiva, verificando a estrutura e composição da comunidade de aves e sua relação com variáveis da estrutura e cobertura da vegetação. As análises deste capítulo foram desenvolvidas na Australian National University, em colaboração com o Dr. David Lindenmayer, durante meu doutorado-sanduíche em Canberra na Austrália, de maio a agosto de 2017. Esse artigo foi submetido para publicação na revista *Plos One*, Qualis Capes A1, em 04 de dezembro de 2018. Além disso, os resultados parciais deste artigo foram apresentados no XXIII e XXV Congresso Brasileiro de Ornitologia, em 2016 e 2018, respectivamente. O segundo capítulo se trata de um estudo de caso, onde o objetivo principal foi observar a mudança da comunidade de aves em uma área em restauração ativa, por três anos consecutivos de monitoramento após o início das técnicas de restauração. Este artigo foi submetido para publicação no periódico *Restoration Ecology*, Qualis Capes B1, em 11 de dezembro de 2018. O terceiro e último capítulo aborda a influência dos remanescentes de campo nativo do entorno das áreas em restauração sobre a riqueza e abundância das comunidades de aves, levando-se em consideração a quantidade deste tipo de habitat. Nós pretendemos submetê-lo para publicação na revista *Landscape Ecology*, Qualis Capes A1.

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CAPÍTULO 1

Passive restoration is a useful tool to conserve grassland birds in the Brazilian Pampas

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Passive restoration conserve grassland birds

Passive restoration is a useful tool to conserve grassland birds in the Brazilian Pampas

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Abstract

Restoration has been pointed out as a useful tool to conserve native grasslands worldwide. In Brazil, the Pampas grasslands biome is one of the most converted ecosystems, with approximately 64% of the natural grasslands lost due to agriculture and other anthropic impacts. However, there is a lack of knowledge on restoration in Brazil, despite it having been considered one of the most important issues concerning the conservation of native grasslands in southeastern South America. We studied for the first time grassland passive restoration in agricultural abandonment from 10 throught 35 years, in attempt to recover altered ecosystems and promote biodiversity conservation as a management type to be considered in the future. We compared the structure and composition of bird communities in sites in process of passive restoration with reference areas. We also quantified relationships between bird occurrence and the structure and cover of the vegetation. We found no significant differences in species richness, abundance or composition in bird communities between passive restoration and reference areas, and the number of grassland-specialist bird species was similar. Sixteen species were absent from sites in process of passive restoration but occurred in reference areas. Seven species responded significantly to grassland type, survey year, vegetation height, low grasses and/or presence of herbs. We recorded eight species that are under global and/or regional threat, some of which were exclusive to each type of grassland. Our results permit to conclude that passive restoration is an appropriate management tool to conserve grassland birds, and recovery lands become a structurally suitable habitat for grassland specialists birds and species of conservation concern such Grass Wren (*Cistothorus platensis*) and Pearly-bellied Seedeater (*Sporophila pileata*).

Introduction

Vegetation restoration has been used to recover altered ecosystems that have been degraded, damaged or destroyed [1–3]. Where the aim is to undertake restoration for faunal recovery, restoration programs must provide suitable habitat and associated key resources such as for nesting, foraging and shelter [3–6]. Ecological restoration has advanced worldwide as an academic discipline in the last two decades [7,8], with initiatives undertaken in many ecosystems and countries [2,9]. There are two broad types of restoration, active and passive restoration [10]. Active restoration involves human interventions such as the deliberate planting of trees, grasses, forbs (e.g., [11,12]), with a range of management techniques applied to influence the successional trajectory of recovery [13–15]. In grasslands these techniques can include hay transposition from conserved grasslands, movement of soil, removal of soil that contains an abundance of seeds of invasive species, and management of livestock [16]. Intrinsic ecosystem resilience, level of human degradation, grazing, and characteristics of the landscape are factors affecting the degree and type of active restoration necessary to recover degraded areas [14]. Passive restoration is natural colonization or unassisted recovery (i.e. secondary succession), without additional remedial actions [13–15]. Passive restoration typically occurs after the abandonment of land uses such as agriculture, and it may enable recolonization of disturbed areas by native species of plants, and/or by exotic species [13]. The effectiveness of passive restoration depends on such factors as the length of time that land has been used for other purposes, whether seeds of native plants remain in the soil, intensity and duration of past land management, landscape context, and soil conditions [2,3,17,18].

Grasslands require extensive restoration because they have been widely degraded [19], mainly for conversion to agriculture and exotic pastures for livestock and targeted for afforestation [20]. In the Brazilian Pampas, 36% natural grasslands remain [21], and only 1.38% of this area is protected [22]. Few laws or regulations are applied to minimize the loss of non-forest ecosystems in Brazil [20], including the Brazilian Pampas. Five challenges exist for grassland-conservation initiatives in Brazil: (1) restoration efforts are more often directed to forests; (2) there is no practice of restoration in Brazilian grasslands; (3) no native seeds are commercially available to assist restoration; (4) vegetation management for conservation is not yet a widely accepted conservation strategy; and (5) there is no broad acceptance of the need for restoration in grassland habitats [23].

Birds are used as indicators of habitat's change provided that perform important ecological functions, thus they may serve to evaluate the recovery of biodiversity during ecosystems restoration through fast responses to habitat development [24–26]. Vegetation structure has direct influence on bird communities as their requirements for nesting, foraging, perching. Further, grassland birds are strongly associated with tall-grass and short-grass habitats [27–30]. Therefore, changes in vegetation structure will influence on structure and composition of birds [29]. In Brazilian Pampas, there are approximately 90 grassland bird species that depend on this habitat during all or part of their life cycle, and 21% of these species are threatened [30].

Grassland restoration may range from the improvement of a degraded site to major interventions to recover grassland on sites that have been entirely cleared [31]. Globally, abandonment of farmland has increased, influenced by rural-urban migration [32–34], and is therefore the major form of passive restoration in grasslands. Several studies of grassland restoration have evaluated the response only of plants, and almost nothing is known about the response of other groups such as birds [8,35]. In southern Brazil, the effectiveness of restoration in Pampas grasslands is unknown [16]. Here, we compared the bird communities in grassland in process of passive restoration and natural grasslands (hereafter termed "reference areas"). We posed three questions:

Question 1. Are there differences in the bird assemblages between areas subject to passive restoration and reference areas? We hypothesized that the bird community in areas subject to passive restoration would be different from those in reference areas. Some specialist bird species and species of conservation concern would be missing from passive restoration sites because areas in process of restoration would be more structurally simple and therefore support fewer niches and other resources for bird species [36].

Question 2. Which vegetation structure and cover attributes influence the occurrence of individual bird species? We predicted that vegetation height, density and the occurrence of grasses would be the main features influencing the occurrence of bird species in both in restoring and reference areas. Such vegetation features influence habitat use and are essential requirements for birds [29,37].

Question 3. Do vegetation structure and composition differ between passive restoration and reference areas? We predicted that the structure and composition of the vegetation would be more complex in the reference sites than passive restoration sites. We made this prediction because some key attributes of grasslands that are important for bird species are lost with human disturbance of the grassland. These attributes can include the occurrence of native plants species, the loss or degradation of surrounding natural areas [38] and heterogeneity of vegetation height [37].

Material and methods

Study area

We carried out field work in the southern part of the state of Rio Grande do Sul, Brazil, in the Pampas biome (Fig 1). In the region where we sampled sites, ~ 32% of grasslands have been degraded by agriculture and intensive cattle grazing [18], and it is difficult to find natural grassland sites with low levels of cattle stocking.

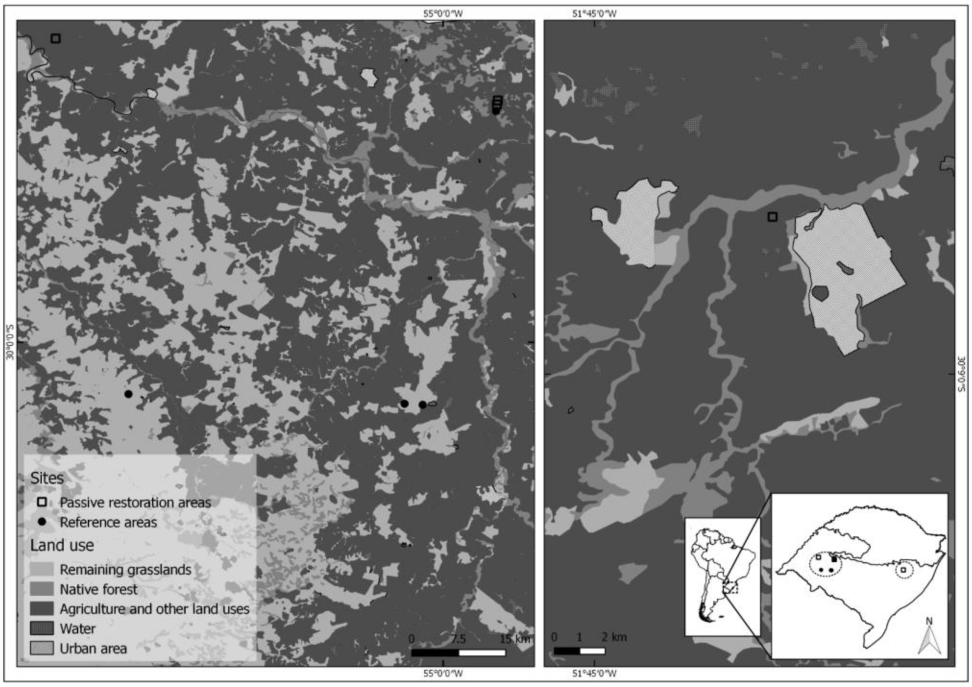

Fig 1. Eight sampled sites in the Pampas biome, grasslands of southern Brazil.

Four passive-restoration sites and four reference areas. Land use *sensu* [39].

We focused on 4 sites of passive restoration (RP) and 4 reference areas (RE; Fig 1). Passive restoration was abandoned agricultural land that was formerly soybean (*Glycine max*) or rice (*Oryza sativa*) crops, with the time since abandonment ranging from 10 to about 35 yr ago. These areas have not been subject to any type of subsequent human intervention and were the only restoring areas found in an intensive search during 6 months of study design. We assume these areas in passive restoration are comparable based on our own experience and literature. The potential recovery of vegetation depends on productivity level, soil conditions, and proximity to natural grasslands remnants [40,41]. A study in Pampas grassland and in other southern hemisphere grasslands showed that areas in about 10 years after abandonment of cultivation did not differ in the plant species richness [41] and floristic composition to grassland remnants [42], indicating a grassland recovery perspective. Moreover, a previous study evaluating grassland vegetation also in Pampas biome showed high restoration capacity after a long-term severe grazing intensity in short periods of grazing exclusion [43]. Passive-restoration sites ranged from 65 to 600 ha, and were located in the municipalities of Eldorado do Sul (RP1: 30.0854°S, 51.6769°W; ~ 22 meters above sea level), Manoel Viana (RP2: 29.4950°S, 55.6441°W; ~ 73 m a.s.l.), and São Francisco de Assis (RP3: 29.5978°S, 54.9090°W; ~ 112 m a.s.l.; RP4: 29.6046°S, 54.9105°W; ~ 117 m a.s.l.). All sites had similar relief (elevation from 30 to 400 m a.s.l.), soil type (hydromorphic and deep, with high or low fertility) and climate [44].

Reference areas were dominated by natural grassland, and were used as benchmark grasslands against which to compare vegetation structure and bird species occurrence with passive restoration sites. These sites ranged from 260 to 1,200 ha, and were located in the municipalities of Rosário do Sul (RE1: 30.1021°S, 55.0640°W; ~ 128 m a.s.l.; RE2: 30.1039°S, 55.0339°W; ~ 126 m a.s.l.), São Francisco de Assis (RE3: 29.6157°S, 54.9119°W; ~ 121 m a.s.l.) and Alegrete (RE4: 30.0860°S, 55.5231°W; ~ 144 m a.s.l.).

The RP and RE sites were lightly grazed, i.e. with a low cattle stocking rate (≤ 1 animal units per ha). Extensive grazing has been part of the culture and management of these grasslands for at least two centuries, so it is very difficult to find a grassland without this land use. This management is intrinsic to the landscape of the Brazilian Pampas and important to its maintenance and diversity [18,45]. For each site, the sampled area was approximately 180 ha, except for RP4 that had 65 ha which were totally sampled.

Bird sampling

We surveyed sites during the bird breeding season (between November and February), once in 2015–2016 and once in 2016–2017. Prior to commencing surveys, point counts were marked in each site (Google Earth Pro), giving a total of 80 point counts in RP (n = 40) and RE (n =

40). Each point count was completed in a plot of 100-m radius, separated from other plots by at least 300 m, and located at least 150 m from a field edge (i.e. fences separating surrounding areas and other land uses). We surveyed birds for 5 min in each point count, beginning immediately after sunrise [46–48]. All surveys were completed by T.W.S., and on days of favorable weather conditions (i.e. no rain or strong wind). We recorded the number of individuals of each bird species seen and/or heard, and birds in flight were not considered. We used information in [49] to identify bird species representative of grasslands in southeastern South America, followed [50] for taxonomy, and the IUCN Red List [51] and Rio Grande do Sul [52] to determine the conservation status of each species.

Vegetation sampling

We completed surveys of vegetation structure and cover at all plots where we conducted point counts for birds, and in the same period (2015-2017). We surveyed 5 quadrats in each point count (n = 400), one in the central point and the others in each cardinal direction (north, south, east, west), 50 m distant from the central point (S1 Fig). We surveyed 3 vegetation variables in each quadrat: mean vegetation height, mean percentage degree of visual obstruction (both vegetation structure), and mean percentage soil cover. In each quadrat, we used a plastic frame measuring 1×1 m and divided internally into 16 quadrants (each 0.25×0.25 cm) (adapted from [53]). We placed graduated plastic rods vertically in the center and at the 4 corners of the frame to measure the vegetation height (cm). To establish the degree of visual obstruction (density), we placed the frame vertically on one side of the quadrat, and the observer was positioned 4 m away from the frame, and at a height of 1 m from the soil (crouched) [54], and we recorded the number of quadrants filled by vegetation. To measure soil cover, we positioned the quadrat horizontally and measured the number of quadrants filled with different functional groups of plants: low grasses, tall grasses, herbs, shrubs, *Eryngium* spp., *Baccharis* spp., exposed soil, water and cattle dung [55–57]. To obtain a mean value for vegetation variables at the count-point level, we calculated the mean for each of the 5 quadrats per point count. All vegetation sampling was conducted by one observer (T.W.S.).

Statistical analysis

To address Questions 1 and 2 about differences in the structure and composition of the bird communities, we used ANOVA to evaluate bird species richness and abundance observed in RP and RE at the site level, using car package in R [58,59]. We estimated species richness for RP and RE in the Chao 1 estimator [60] with 100 randomizations, using EstimateS 9 [61].

To compare richness and abundance at the count-point level, and presence/absence of birds between RP and RE and relate them to vegetation variables, we fitted general linear mixed models (GLMM) using glmer function in lme4 package in R [62]. We used all bird species recorded at the study sites when the response variable was species richness and abundance, creating models from the Poisson family. We selected 11 bird species (with >10 occurrences; response variable), and constructed binomial (presence/absence) and Poisson (abundance) models. Initially, we checked the correlation among explanatory variables using corvif function in R [63]. Degree of visual obstruction and tall grasses were positively correlated with vegetation height (r = 0.81 for both), therefore these 2 variables were dropped from this analysis. Hereafter, we used the pairs function in FactoMiner package to quantify the level of correlation among vegetation-cover variables [64]. Then, we used only vegetation height, low grasses and herbs as the independent variables, in addition to the type of grassland (RP and RE), and survey year (1 [2015–2016] and 2 [2016–2017]). We standardized the 3 vegetation variables using the scales package in R [65], because low grasses and herbs were measured as a percentage whereas vegetation height was measured in centimeters. To avoid pseudoreplication, we used ‘site’ as the random effect in all models. Our full model for each of three response variables (richness, presence/absence and abundance) was: 'x = glmer (response variable ~ Type_grassland * Survey_year + H_veg.r + Low_gras.r + Herb.r + (1|Site), family = poisson [or binomial])'. We ran all possible models and compared them using the AICc command with the dredge function of the MuMIn package in R [66]. All analyses were performed using R 3.4.3 [59], at a significance level of $\alpha = 0.05$.

To verify the bird species composition in RP and RE, we performed a Nonmetric Multidimensional Scaling (NMDS) with the Jaccard dissimilarity index, using the metaMDS function in the vegan package in R [67]. And, we tested NMDS significance with manyglm function of the mvabund package in R, using the binomial family [68]. To examine differences in structure and composition of vegetation between RP and RE (Question 3), we used one-way analysis of variance (ANOVA) and a Kruskal-Wallis test depending upon the homoscedasticity of Levene's test. These tests were performed using car package in R [58], at a significance level of $\alpha = 0.05$.

Results

General findings

We recorded 61 bird species and 762 individuals (Table 1): 429 individuals of 46 species in the reference areas, and 333 individuals of 45 species in the passive-restoration areas. Among these species, 16 were found only in RE, while 15 species were restricted in RP. *Ammodramus humeralis* was recorded in the majority of the point counts (n =101) and was the most abundant species in both RE (n = 82 individuals) and RP (n = 68 individuals).

TABLE 1. Number of individuals of bird species sampled in 2015–2017 in passive restoration (RP) and reference areas (RE), grasslands of the Pampas biome, and frequency of occurrence in the eight sites.

Family and species	**Habitat**		**Frequency of occurrence (%)**
	RE	**RP**	
Rheidae			
Greater Rhea (*Rhea americana*)*[c]	3	0	12.5
Tinamidae			
Red-winged Tinamou (*Rhynchotus rufescens*)*	1	7	25
Spotted Nothura (*Nothura maculosa*)*	9	5	50
Anatidae			
Brazilian Teal (*Amazonetta brasiliensis*)	2	3	25
Columbidae			
Eared Dove (*Zenaida auriculata*)	2	0	25
Ruddy Ground Dove (*Columbina talpacoti*)	0	1	12.5
Cuculidae			
Guira Cuckoo (*Guira guira*)	6	8	25
Smooth-billed Ani (*Crotophaga ani*)	0	1	12.5
Charadriidae			
Southern Lapwing (*Vanellus chilensis*)*	4	1	25
Scolopacidae			
South American Snipe (*Gallinago paraguaiae*)	5	2	50
Jacanidae			
Wattled Jacana (*Jacana jacana*)	2	4	25
Threskiornithidae			
Plumbeous Ibis (*Theristicus caerulecens*)	2	0	12.5
Strigidae			
Burrowing Owl (*Athene cunicularia*)*	0	6	12.5

Family and species	**Habitat**		**Frequency of**
	RE	**RP**	**occurrence (%)**
Picidae			
Campo Flicker (*Colaptes campestris*)*	2	4	37.5
Falconidae			
Southern Caracara (*Caracara plancus*)*	3	0	25
Chimango Caracara (*Milvago chimango*)*	0	1	12.5
Furnariidae			
Rufous Hornero (*Furnarius rufus*)*	6	1	50
Firewood-gatherer (*Anumbius annumbi*)*	10	6	62.5
Stripe-crowned Spinetail (*Cranioleuca pyrrhophia*)	1	0	12.5
Chotoy Spinetail (*Schoeniophylax phryganophilus*)	3	2	37.5
Tyrannidae			
White-crested Tyrannulet (*Serpophaga subcristata*)	1	0	12.5
Bran-colored Flycatcher (*Myiophobus fasciatus*)	1	0	12.5
Spectacled Tyrant (*Hymenops perspicillatus*)*	0	1	12.5
Yellow-browed Tyrant (*Satrapa icterophrys*)	0	1	12.5
Gray Monjita (*Xolmis cinereus*)*	3	0	12.5
Streamer-tailed Tyrant (*Gubernetes yetapa*)*[e]	0	3	12.5
Cattle Tyrant (*Machetornis rixosa*)*	0	2	12.5
Great Kiskadee (*Pitangus sulphuratus*)	2	3	37.5
Tropical Kingbird (*Tyrannus melancholicus*)	9	1	37.5
Fork-tailed Flycatcher (*Tyrannus savana*)*	8	14	75
Hirundinidae			
Brown-chested Martin (*Progne tapera*)*	3	3	37.5

Family and species	**Habitat**		**Frequency of occurrence (%)**
	RE	**RP**	
Troglodytidae			
House Wren (*Troglodytes aedon*)	2	0	12.5
Sedge Wren (*Cistothorus platensis*)*[e]	5	6	50
Turdidae			
Creamy-bellied Thrush (*Turdus amaurochalinus*)	0	1	12.5
Mimidae			
Chalk-browed Mockingbird (*Mimus saturninus*)*	6	4	50
Motacillidae			
Ochre-breasted Pipit (*Anthus nattereri*)*[bd]	1	0	12.5
Hellmayr`s Pipit (*Anthus hellmayri*)*	58	1	62.5
Thraupidae			
Grassland Yellow-Finch (*Sicalis luteola*)*	100	32	87.5
Blue-black Grassquit (*Volatinia jacarina*)*	0	17	37.5
Red-crested Finch (*Coryphospingus cucullatus*)	2	0	12.5
Pearly-bellied Seedeater (*Sporophila pileata*)*[d]	1	9	50
Marsh Seedeater (*Sporophila palustris*)*[ad]	2	0	12.5
Chestnut Seedeater (*Sporophila cinnamomea*)*[be]	0	8	12.5
Double-collared Seedeater (*Sporophila caerulescens*)	2	2	25
Rusty-collared Seedeater (*Sporophila collaris*)*[e]	0	7	12.5
Green-winged Saltator (*Saltator similis*)	1	0	12.5
Golden-billed Saltator (*Saltator aurantiirostris*)	1	0	12.5
Great Pampa-Finch (*Embernagra platensis*)*	4	7	62.5
Wedge-tailed Grass-Finch (*Emberizoides herbicola*)*	4	21	87.5

Family and species	**Habitat**		**Frequency of**
	RE	**RP**	**occurrence (%)**
Long-tailed Reed Finch (*Donacospiza albifrons*)*	3	0	12.5
Red-crested Cardinal (*Paroaria coronata*)	7	1	25
Sayaca Tanager (*Thraupis sayaca*)	0	1	12.5
Emberizidae			
Grassland Sparrow (*Ammodramus humeralis*)*	82	68	100
Rufous-collared Sparrow (*Zonotrichia capensis*)	25	30	100
Parulidae			
Masked Yellowthroat (*Geothlypis aequinoctialis*)	8	7	62.5
Icteridae			
Chestnut-capped Blackbird (*Chrysomus ruficapillus*)	0	12	12.5
Yellow-rumped Marshbird (*Pseudoleistes guirahuro*)*	4	12	37.5
Grayish Baywing (*Agelaioides badius*)	7	0	12.5
Screaming Cowbird (*Molothrus rufoaxillaris*)*	0	1	12.5
Shiny Cowbird (*Molothrus bonariensis*)*	2	1	25
White-browed Meadowlark (*Sturnella superciliaris*)*	14	5	62.5

* Species representative of southeastern South America grasslands [49]

[a] Endangered globally

[b] Vulnerable globally

[c] Near-threatened globally

[d] Vulnerable in Rio Grande do Sul

[e] Near-threatened in Rio Grande do Sul

Question 1. Are there differences in the bird assemblages between areas subject to passive-restoration and reference areas?

There were no significant differences in species richness and abundance (total number of birds) between RP and RE at the site level (ANOVA, $F_{1,6} = 0.06$, $P = 0.82$; $F_{1,6} = 2.2$, $P = 0.19$, respectively). However, there was a significant positive effect of the type of grassland on species richness (GLMM Poisson, $P = 0.049$) and abundance (GLMM Poisson, $P = 0.032$) at the count-point level (Table 2), i.e. both variables were higher in reference areas compared to passive restoration. Chao 1 curves reached a plateau only for RE (Chao 1 estimate = 49 species, 95% CI = 47-60), and for RP more species would be found with more effort (Chao 1 estimate = 69 species, 95% CI = 52-137; Fig 2). Bird species composition did not differ significantly between RP and RE (manyglm binomial, $P = 0.28$) (Fig 3).

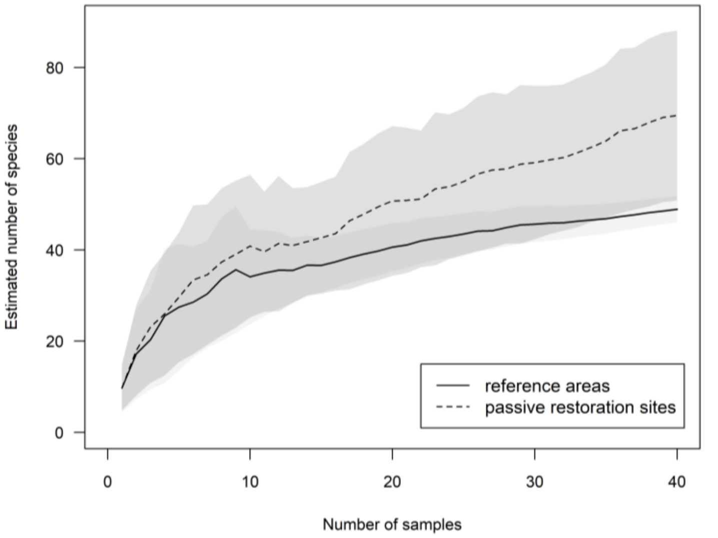

Fig 2. Estimated species richness for passive-restoration sites (RP) and reference areas (RE).

We based in Chao 1 estimator (mean ± 95% CI).

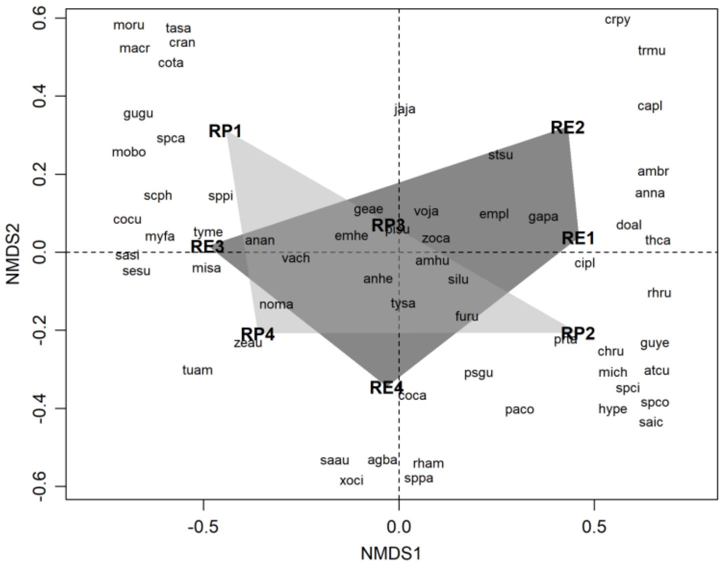

Fig 3. NMDS of bird species in passive-restoration sites (RP) and reference areas (RE) in Pampas biome.

We based on the presence/absence of bird species, and used the Jaccard dissimilarity index, stress = 0.09. Species acronyms are formed by the first two letters of the genus and species as in Table 1.

Of the 61 bird species we recorded, 25 species detected in RE and 28 species in RP are associated with grasslands in southeastern South America (Table 1). Twenty-five species were considered grassland specialists, i.e. bird species restricted solely to grassland habitats or species which make extensive use of grassland habitats [49]. We found 6 of these grassland specialist bird species only in RP (*Athene cunicularia*, *Milvago chimango*, *Hymenops perspicillatus, Gubernetes yetapa*, *Volatinia jacarina*, *Sporophila cinnamomea*), and 6 only in RE (*Rhea americana*, *Caracara plancus*, *Xolmis cinereus*, *Anthus nattereri*, *Sporophila palustris*, *Donacospiza albifrons*), with 13 species occurring both in RP and RE.

We detected 8 bird species of conservation concern: *G. yetapa*, *S. cinnamomea*, *Sporophila collaris*, *R. americana*, *A. nattereri*, *S. palustris*, *Cistothorus platensis*, and

Sporophila pileata. The three first species were recorded only in RP, the other 3 only in reference areas, while Sedge Wren and Pearly-bellied Seedeater occurred in both RP and RE (Table 1).

Question 2. Which vegetation structure and cover attributes influence the occurrence of individual bird species?

Of the 11 bird species analyzed with GLMM, 7 exhibited a significant response to the 5 explanatory variables (Table 2). There were significant effects of:

1. Type of grassland on the *Anthus hellmayri* and *Zonotrichia capensis* – positive effect;
2. Survey year on the *Anumbius annumbi* (negative effect) and *Tyrannus savana* (positive effect);
3. Vegetation height on the *A. hellmayri* (negative effect) and *Emberizoides herbicola* (positive effect);
4. Coverage of low grasses on species *Sicalis luteola* (positive effect);
5. Coverage of herbs on species *Nothura maculosa* (positive effect).

TABLE 2. GLMM results for the structure of bird communities between grasslands of passive-restoration sites and reference areas of the Pampas biome.

Models	**Estimate (SE)**[a]	**Z value**	***P***[b]
Species richness			
Intercept	1.02 (0.07)	13.58	< 0.001
Treatment-reference area	0.20 (0.10)	1.97	**0.049**

Models	**Estimate (SE)**[a]	**Z value**	***P***[b]
Species abundance			
Intercept	1.42 (0.09)	16.58	< 0.001
Treatment-reference area	0.25 (0.12)	2.15	**0.032**
Nothura maculosa (13 presences)			
Presence/Absence			
Intercept	-3.34 (0.58)	-5.78	< 0.001
Treatment-reference area	1.05 (0.66)	1.59	0.11
Herbs	0.90 (0.26)	3.48	**< 0.001**
Abundance			
Intercept	-3.25 (0.52)	-6.27	< 0.001
Treatment-reference area	0.96 (0.57)	1.68	0.09
Herbs	0.69 (0.20)	3.38	**< 0.001**
Anumbius annumbi (13 presences)			
Presence/Absence			
Intercept	-0.86 (1.01)	-0.85	0.40
Survey year-1	-1.38 (0.70)	-1.97	**0.049**
Abundance			
Intercept	-2.28 (0.51)	-4.51	< 0.001
Survey year-2	-0.79 (0.54)	-1.46	0.144
Tyrannus savana (16 presences)			
Presence/Absence			
Intercept	-5.40 (1.38)	-3.92	< 0.001
Treatment-reference area	-0.90 (1.01)	-0.90	0.37
Survey year-2	1.76 (0.70)	2.53	**0.011**

Models	**Estimate (SE)**^{a}	**Z value**	***P***^{b}
Abundance			
Intercept	-2.55 (0.73)	-3.47	< 0.001
Treatment-reference area	-17.13 (209.02)	-0.08	0.93
Survey year-B	0.92 (0.59)	1.55	0.12
Treatment-reference area : survey year-B	16.64 (209.02)	0.08	0.94
Anthus hellmayri (34 presences)			
Presence/Absence			
Intercept	-6.85 (2.13)	-3.21	0.001
Treatment-reference area	3.97 (2.11)	1.89	0.06
Height vegetation	-3.17 (1.11)	-2.87	**0.004**
Abundance			
Intercept	-5.24 (1.37)	-3.83	< 0.001
Treatment-reference area	3.14 (1.44)	2.18	**0.03**
Height vegetation	-1.76 (0.52)	-3.39	**< 0.001**
Sicalis luteola (65 presences)			
Presence/Absence			
Intercept	-0.57 (0.53)	-1.07	0.29
Low grasses	0.54 (0.29)	1.84	0.07
Abundance			
Intercept	-0.61 (0.32)	-1.93	0.05
Low grasses	0.35 (0.16)	2.15	**0.03**
Embernagra platensis (11 presences)			
Presence/Absence			
Intercept	-2.96 (0.43)	-6.92	< 0.001

Models	**Estimate (SE)**[a]	**Z value**	***P***[b]
Low grasses	-0.55 (0.30)	-1.82	0.07
Herbs	-0.96 (0.52)	-1.85	0.06
Abundance			
Intercept	-3.02 (0.41)	-7.3	< 0.001
Low grasses	-0.49 (0.28)	-1.75	0.08
Herbs	-0.88 (0.49)	-1.81	0.07
Emberizoides herbicola (20 presences)			
Presence/Absence			
Intercept	-2.23 (0.34)	-6.58	< 0.001
Height vegetation	0.81 (0.25)	3.24	**0.001**
Abundance			
Intercept	-2.26 (0.26)	-8.47	< 0.001
Height vegetation	0.82 (0.17)	4.85	**< 0.001**
Ammodramus humeralis (101 presences)			
Presence/Absence			
Intercept	0.68 (0.47)	1.44	0.15
Abundance			
Intercept	-0.16 (0.25)	-0.66	0.51
Zonotrichia capensis (47 presences)			
Presence/Absence			
Intercept	-2.04 (0.96)	-2.12	0.03
Treatment-reference area	3.14 (1.37)	2.30	**0.021**
Survey year	0.80 (0.52)	1.53	0.13
Treatment-reference area : survey year	-2.38 (0.81)	-2.95	**0.003**

Models	**Estimate (SE)**[a]	**Z value**	***P***[b]
Abundance			
Intercept	-1.18 (0.23)	-5.12	< 0.001
Low grasses	-0.30 (0.16)	-1.82	0.07
Geothlypis aequinoctialis (13 presences)			
Presence/Absence			
Intercept	-2.67 (0.49)	-5.48	< 0.001
Abundance			
Intercept	-2.70 (0.50)	-5.46	< 0.001
Leistes superciliaris (15 presences)			
Presence/Absence			
Intercept	-4.76 (1.37)	-3.48	< 0.001
Survey year	1.03 (0.66)	1.56	0.12
Low grasses	-0.68 (0.49)	-1.39	0.16
Abundance			
Intercept	-3.42 (0.78)	-4.37	< 0.001
Survey year-B	0.79 (0.55)	1.44	0.15
Low grasses	-0.47 (0.28)	-1.70	0.09

Results of generalized linear mixed models (GLMM) created to test for differences in richness, abundance and presence/absence of bird species with more than 10 occurrences between grasslands of passive-restoration sites and reference areas of the Pampas biome.

[a] SE: Standard Error

[b] Significant *P*-values are highlighted in bold

Question 3. Does vegetation structure and composition differ between passive-restoration and reference areas?

There were significant differences in 2 of the 11 vegetation variables between RP and RE (Fig 4, Table 3). The RP sites were characterized by greater vegetation height (Kruskal-Wallis, *H* = 4.08, df = 1, *P* = 0.043). In contrast, RE areas supported more low grasses (ANOVA, $F_{1,6}$ = 7.19, *P* = 0.037).

TABLE 3. Mean ± SD of the vegetation variables in passive-restoration sites (RP1 – RP4) and reference areas (RE1 – RE4) of the Pampas biome.

Vegetation variables	**RP1**	**RP2**	**RP3**	**RP4**	**RE1**	**RE2**	**RE3**	**RE4**
Mean vegetation height (cm)	56.86 ± 15.96	52.73 ± 19.97	33.64 ± 14.25	30.55 ± 13.95	22.09 ± 6.46	23.17 ± 5.09	32.12 ± 13.69	22.6 ± 14.26
Degree of visual obstruction (%)	74.17 ± 18.09	58.02 ± 19.3	43.44 ± 18.25	28.39 ± 11.59	18.75 ±12.96	27.88 ± 10	31.97 ± 13.99	30.63 ± 25.12
Low grasses (%)	20.42 ± 24.05	27.97 ± 16.38	51.32 ± 14.37	51.46 ± 16.14	76.06 ± 20.64	64.75 ± 9.88	52.88 ± 17.02	58.5 ± 16.94
Tall grasses (%)	64.84 ± 22.25	53.02 ± 19.84	24.69 ± 13.25	25.31 ± 13.7	16.5 ± 20.7	28.13 ± 10.57	23.69 ± 16.43	18.13 ± 20.12
Herbs (%)	8.91 ± 3.32	9.22 ± 5.44	18.38 ± 10.93	17.92 ± 9.82	2.41 ± 1.63	4.5 ± 3.57	15 ± 8.29	13.44 ± 7.33
Shrubs (%)	0.05 ± 0.26	1.88 ± 4.1	0.28 ± 0.87	0.73 ± 1.55	0	0.94 ± 3.06	1.5 ± 2.32	0.31 ± 1.14

Vegetation variables	**RP1**	**RP2**	**RP3**	**RP4**	**RE1**	**RE2**	**RE3**	**RE4**
Eryngium spp. (%)	3.75 ± 5.61	0.99 ± 2.66	0.25 ± 1.12	0.1 ± 0.36	1.81 ± 2.05	0	0	1.56 ± 2.81
Baccharis spp. (%)	1.3 ± 1.75	2.08 ± 4.52	0.94 ± 2.86	1.46 ± 1.91	1.16 ± 2.01	0	3.88 ± 3.97	0.25 ± 0.65
Exposed soil (%)	0.31 ± 0.76	2.24 ± 4.57	1.38 ± 2.92	1.04 ± 2.19	0.88 ± 1.82	0.56 ± 1.31	0.56 ± 1.43	6.38 ± 12.15
Water (%)	0.42 ±1.15	0.42 ± 1.36	1.88 ± 3.64	0.63 ± 1.46	0	0.13 ± 0.56	1.06 ± 2.7	0
Cattle dung (%)	0	0.36 ± 1.13	0.75 ± 1.1	1.35 ± 0.99	0.97 ± 1.04	1.06 ± 1.59	1.5 ± 1.38	1.31 ± 1.7

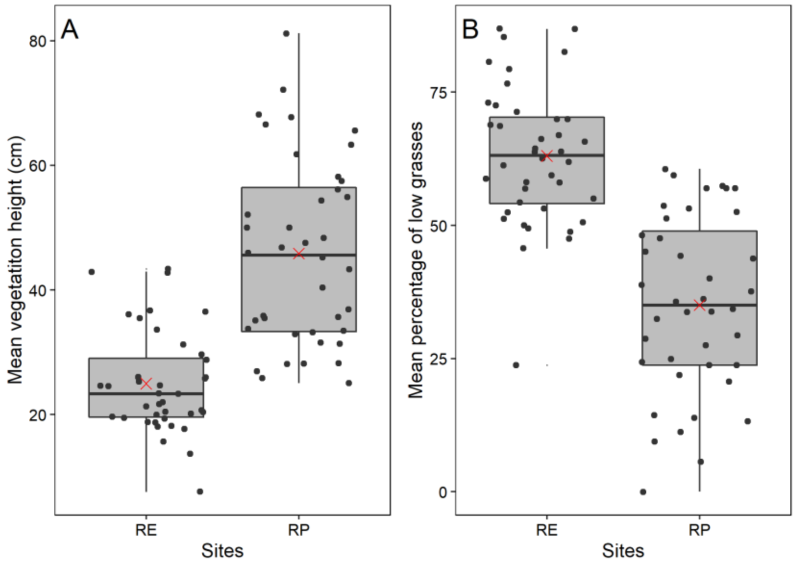

Fig 4. Significant vegetation variables (*P* < 0.05) in passive-restoration sites (RP) and reference areas (RE).

(A) Mean vegetation height and (B) mean percentage of low grasses. Boxplot values are represented by medians and means (red crosses).

Discussion

Restoration programs are critically important for biodiversity conservation [3], particularly as there are more than 2 billion hectares of degraded land worldwide [69] – including grasslands which are extensively degraded globally [70]. Much of this grassland degradation is due to the global expansion of agriculture [34]. Little is known about biotic responses to passive grassland restoration [71], especially for some key groups of biota such as birds [8,72]. We found similarity in bird species richness, abundance and community composition between RP and RE areas. Additionally, grasslands specialists and threatened birds' species were found in both RP and RE areas. Likewise, few vegetation variables had marked differences between RP and RE, moreover the region where the sites are inserted is considered to have natural regeneration potential of medium to high [73]. Grasslands become more structurally complex and more plant species rich as more time elapses since disturbance and previous clearing, which may be explaining few differences in vegetation structure and cover between RP and RE. Although it was not possible to survey a larger number of passive-restoration sites (because they simply do not exist or we did not find landowners committed to the study), our results are a first attempt to understand how grassland bird communities might respond to passive grassland restoration in southern Brazil.

Bird community in passive restoration sites vs. reference areas

We did not find significant differences in the bird species richness, occurrence of individual species and composition in RP compared with RE areas. However, we observed that species richness and abundance of birds at the count-point level was higher in RE. Previous studies have shown that native grassland regeneration on abandoned agricultural land may be important for biodiversity conservation [4,74,75]. A study in abandoned grassland in southern Sweden also found no significant difference in species richness and abundance of butterflies and vascular plants relative to grazed grasslands [76]. Then, although restored grasslands do not support identical structural conditions to those of native grasslands, they may nevertheless provide suitable habitat for grassland birds [4,77].

Vegetation attributes and occurrence of individual bird species

We found few vegetation attributes that influenced the occurrence of individual bird species. Contrary to our initial hypothesis (Question 2), vegetation height influenced the occurrence of only 2 species (*A. hellmayri* and *E. herbicola*). In a study of Uruguayan grasslands, vegetation structure explained only little of the variation in the presence and numbers of grassland birds [29]. Other studies considered vegetation height to be an important predictor of the occurrence of the grassland birds, in addition to the amount of bare-ground and litter depth [28,37]. *Anthus hellmayri* occupies areas where the grass height is intermediate to high [28,78]. However, we observed this species in low grasslands (i.e. RE sites), and only one individual in RP. *Emberizoides herbicola* was more abundant in tall grasslands (i.e. RP sites), consistent with findings of previous studies [49,79].

Vegetation structure and plant composition can have a strong influence on bird species richness and abundance [27,36]. Bird populations respond to habitat modification, and understanding such responses in restored habitats is essential for managing and conserving grassland bird species [5]. We believe other unmeasured vegetation variables, floristics as well as landscape factors may be influencing the occurrence of bird species in our study system [29], as the substantial amount of native grassland surrounding of the sites (pers. observ.).

Structure and cover vegetation

We found few differences in vegetation structure and cover between sites in process of passive restoration and reference areas. Relative to reference areas, passive restoring sites were characterized by greater values for vegetation height, whilst there was greater cover of low grass in reference areas. Such differences were expected because time for recovery of restoration areas to resemble reference grasslands is uncertain. Passive regeneration depends on the degree of degradation, duration and intensity of agricultural practices [80], development of vegetation restructure similar to natural grasslands depends on adjacent seed sources, and vicinity of adequate matrix of remnant grasslands [42,81]. Some studies found that recovery may be relatively rapid, ranging from 10 to 40 yr [15]. In other studies, up to 50 yr in Europe and 60 yr in North America can be required to restore grasslands to a condition similar to reference areas [42]. Our results are important as they are an initial analysis of structural differences between reference sites and areas subject to passive-restoration. Furthermore, at the sites surveyed, the periods of abandonment were until 35 yr; shorter than the time to recovery to a benchmark condition for grasslands in other parts of the world. Perhaps this is due to the landscape features that allow colonization by target species and reduction of propagation of invasive species [23], which favors the presence of grassland birds, or climate conditions that may accelerate the grasslands rate of succession [82].

Grassland-specialist birds and threatened bird species

We observed that grassland-specialist birds were present in both passive-restoration and reference sites, and in a similar numbers of bird species. Some differences in species between RP and RE were associated with differences in vegetation structure, such as differences in grass height. *Volatinia jacarina* and *S. cinnamomea* occurred only in RP, and the *E. herbicola* had more individuals in these kinds of sites, which had greater cover of tall grass – grass height in which these 3 bird species commonly occur [49,79]. Whilst, *A. hellmayri* and *Sicalis luteola* had more individuals in RE, sites with greater cover of low grass, but it has been reported in other studies that these species occupy grasses of intermediate and tall heights [28,49]. We recorded endangered bird species similar in RP and RE, probably because the feed and breeding resources for species are similar in both grassland types. However, sometimes restored habitats do not support specialist and sensitive species birds to disturbance [83], thus more studies are need to understand the dynamic relationship between birds and changes in habitats and landscapes [84].

Implications for management and conservation

We provide information that passive restoration in degraded grasslands, such as after abandonment of cultivation, may contribute to grassland bird conservation. The absence of marked differences in the structure (species richness and abundance) and composition of bird communities between passive restoring and reference areas suggests that grasslands in process of passive restoration can provide suitable habitat for many species of grassland birds. This includes several grassland-specialist species of conservation concern, probably because passive restoring areas provide appropriate food and breeding resources. However, some species did not occur in sites in process of passive restoration. Therefore, there is a need to ensure that existing undisturbed grasslands are not subject to further clearing and land conversion.

We suggest the use of passive restoration as a tool in grassland conservation, highlighting the occurrence of important grassland bird species that were exclusive or more abundant in the passive restoration sites, as *Emberizoides herbicola*, *Volatinia jacarina* and *Sporophila* spp. that are associated with tall grasses. For example, new conservation units can be settled in recovery areas, not only in preserved areas that are currently rare. Additionally, passive restoration is an easy and lower cost way of restoration, considering the non-necessity of use of high technology and specimen’s seedlings.

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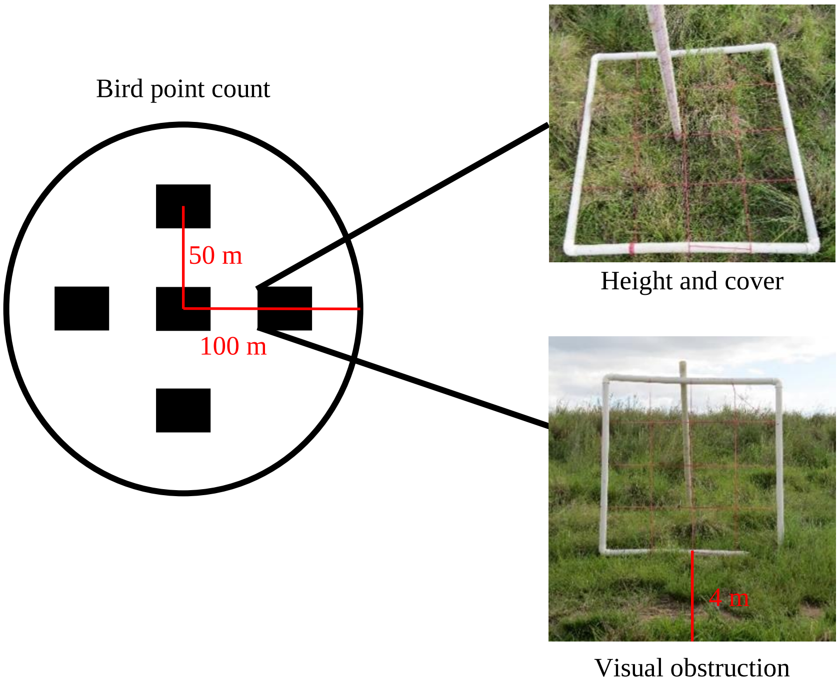
Supporting information

S1 Fig. Diagram of vegetation sampling in eight sites of passive-restoration and reference areas from 2015 to 2017, southern Brazil. Five quadrats in each bird point count. Details of measures of height (cm; in the centre and at the four corners of the frame), visual obstruction (%; the observer crouched positioned four meters away from the frame) and soil cover (%; different functional groups of plants).



CAPÍTULO 2

Success of active restoration in grasslands: A case study based on birds in southern Brazil

Artigo submetido para publicação no periódico *Restoration Ecology*

Success of active restoration in grasslands: A case study based on birds in southern Brazil

Running head: Active-restoration success based on birds

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Abstract

Grasslands in southeastern South America have been extensively converted to several land uses such as agriculture, threatening regional biodiversity. Active restoration has been viewed as a management alternative for recovery of degraded areas worldwide, although most studies are conducted in forests and none has evaluated the effect of active restoration of grasslands in southeastern South America. From 2015 through 2017 we monitored a federally owned tract of grassland from the beginning of the active-restoration process. We compared the bird community in this active-restoration area (RA) with a reference area (RE) in Pampas grasslands in southern Brazil. We sampled birds by point counts and surveyed vegetation structure in plots.

After three years of active restoration, bird species richness and abundance were higher in RA (30 species, 171 individuals) than RE (22 species, 154 individuals). The species composition also differed between the two habitats. Grassland-dependent species were present in both RA and RE. The vegetation structure differed between RA and RE in six attributes: height, visual obstruction, short and tall grasses, herbs, and shrubs, but grasses and herbs approached those in RE in year 3 of restoration. Since it has been known that active restoration is useful in promoting species diversity, we encourage studies of the use of long-term restoration efforts, and suggest that more restoration studies are necessary in grasslands, based not only on plants but also on animals such as birds.

Key words: agriculture, conservation, grassland birds, land use, Pampas grasslands, recovery

Implications for Practice

- Active-restoration areas can adequately support grassland-dependent bird species.
- Bird communities of grasslands degraded by agriculture can rapidly recover (3 years) after active restoration.
- Active restoration can be used to manage the recovery of vegetation structure and bird communities in degraded grasslands in southern Brazil.

Introduction

Land use is the major driver of biodiversity change and grasslands may experience large losses in biodiversity because of their sensitivity to conversion (Sala et al. 2000). Active restoration implies interventions in a degraded habitat to accelerate and influence the successional trajectory of recovery (Holl & Aide 2011). Active restoration is used when natural regeneration is slow and involves high costs due to human assistance (Holl & Aide 2011; Crouzeilles et al. 2017). Human interventions for recovery of degraded tropical forests include planting nurserygrown seedlings, addition of desired plant species, direct seeding, manipulation of disturbance regimes (e.g., thinning and controlled burning), and soil amendment (Barral et al. 2015; Crouzeilles et al. 2017). For grassland restoration, some techniques used are hay transfer from conserved grassland, soil and native species transplantation, direct seeding, removal of topsoil containing seeds of invasive species, and seed transport through suitable management of cattle (Le Stradic et al. 2014; Vieira & Overbeck 2015). Few cases have been reported in tropical and temperate grasslands (Bond & Parr 2010), but these techniques and their results have been described in the United States, Australia, and Europe.

Each type of area will pose unique challenges and require different approaches for restoration (Gibson 2009). Grassland processes are poorly understood, experience with restoring their taxonomic and functional diversity is limited, and the general public is unaware of the importance of grassland ecosystems (Zaloumis & Bond 2011). Thus, conservation issues aimed at the preservation and restoration of biodiversity in agricultural environments are considered of great weight in the present century (Bennett et al. 2006). Birds are considered good indicators of environmental changes and serve to evaluate the recovery of biodiversity in habitat restoration (Latja et al. 2016), mainly because the composition of bird assemblages may change according to vegetation successional stage (Munro et al. 2011; Batisteli et al. 2018). Restoration studies usually involve plants and birds as the focal taxa occurs in less than 10% studies (Brudvig 2011; Kollmann et al. 2016).

Southern Brazilian Pampas grasslands are part of southeastern South America grasslands and are widely used for agriculture, afforestation, and livestock grazing (Soriano et al. 1991; Overbeck et al. 2007; Azpiroz et al. 2012). At present, 64% of the Pampas area has been converted to such uses, imperiling grassland biodiversity (MMA 2011). Currently no active restoration of degraded habitats is being conducted in the Pampas biome, which reinforces the importance of evaluating the efficiency of recovery techniques for grassland vegetation and birds. This case study is the first evaluation of the effects of active restoration on a bird community in southern Brazilian grasslands. Additionally, the techniques used for vegetation restoration were tested for the first time.

We compared the structure and composition of the bird community of an active-restoration site with a native grassland area in the Brazilian Pampas during 3 successive years of monitoring. We also related the bird species composition to vegetation structure variables and evaluated differences between the active-restoration and native-grassland sites. We hypothesized that in the third year of monitoring, the bird community in the active-restoration site would resemble the native grassland more than in the first and second years of restoration. Since that active restoration aims to accelerate the recovery of biodiversity, and the birds have responded to the fast development of vegetation structure (Catterall et al. 2012).

Methods

Study Area

We worked in two grassland sites (native and active restoration) located in a 50,000-ha Brazilian army reserve in the Pampas biome. The sites are in Rosário do Sul municipality, in the Central Depression geomorphologic province in the state of Rio Grande do Sul, Brazil, where 17% of grasslands are degraded and 47% converted to farming and cattle grazing (Andrade et al. 2015). The climate is subtropical humid (‘Cfa’ in Köppen’s climate classification) with hot summers and cold winters (Alvares et al. 2013). The mean annual rainfall is 1,750 mm (Nimer 1989).

The Active Restoration Site (RA; 30°04’32.65”S, 55°04’36.01”W) was approximately 400 ha in area and 126 m a.s.l., was planted to soybeans for more than 10 years, and was abandoned in 2013, i.e., the last crop was harvested and no further management was conducted. The restoration experiment (the first in the Brazilian Pampas) is part of the Degraded Area

Recovery Project (PRAD), a partnership among the Brazilian Army, Brazilian Institute of Environment and Renewable Natural Resources (IBAMA), Federal University of Rio Grande do Sul (UFRGS), Federal University of Pampa (UNIPAMPA), and Brazilian Agricultural Research Corporation (Embrapa Pecuária Sul). Prior to restoration, the area contained lovegrass (*Eragrostis plana*), the main invasive exotic plant species in the Pampas biome, and shrubs (*Baccharis* spp. and *Senecio* sp.), which shaded out the grassland vegetation of interest. The restoration techniques, beginning in 2015, were fallowing, mechanical mowing, controlled cattle grazing (≤ 1 head/ha), periods of exclusion of stock (i.e., no cattle), and cattle as agents of transport and dispersal of seeds of native plant species. For this, before the cattle were herded to the restoring site, they were allowed to graze in a native grassland area (described below). In the restoration process, it was not necessary to sow native plant species.

The Native Grassland Site (RE; 30°06’08”S, 55°03’50”W; ~ 128 m a.s.l.) was considered the reference area, or benchmark grassland. The site covers 700 ha approximately 4 km from the RA site, and was used to produce native seeds for the cattle to introduce them into the active restoration site. The Reference area was stocked with 1 head/ha of cattle.

Bird Sampling

We sampled birds in the breeding season (spring and summer) from 2015 through 2017. We sampled the RA four times, twice in 2015 before (zero stage of restoration) and after mechanical mowing, once in 2016, and once in 2017. We sampled the RE three times, once each year in the same period as the RA samples. At each site we recorded birds in 10 point counts of 5 min and 100-m radius, 300 m apart and previously marked in Google Earth Pro (Bibby et al. 2000; Fontana et al. 2018). Point counts were initiated shortly after sunrise. All surveys were completed by T.W.S. in favorable and similar weather conditions. We recorded the number of individuals of each bird species seen and/or heard; individuals in flight were not recorded. We used Azpiroz et al. (2012) for bird species representative of grasslands in southeastern South America, and we followed global (IUCN 2017) and regional (DOE 2014) lists of threatened species and Remsen et al. (2018) for taxonomy.

Vegetation Sampling

We surveyed five quadrat plots of vegetation (*n* = 100) in each bird point count in the same sampling period (2015–2017). We surveyed three vegetation variables: vegetation height, percentage degree of visual obstruction, and percentage soil cover. Soil cover was classified in nine categories: short and tall grasses, herbs, shrubs, *Eryngium* spp., *Baccharis* spp., exposed soil, water, and cattle dung (Fuhlendorf et al. 2006; Bencke & Dias 2010, unpublished data). Each 1 × 1–m quadrat was located at the center of the point count and in each cardinal direction (North, South, East, West), 50 m distant from the central point. For all variables we used a 1 m^2 plastic frame divided into 16 quadrants (each 0.25 × 0.25 cm; Daubenmire 1959). Vegetation height (cm) was measured in the center and at the four corners of the quadrat. To evaluate visual obstruction, we placed the frame vertically in the plot, and the observer crouched at a height of 1 m above the ground and a distance of 4 m from the frame (Robel et al. 1970), and recorded the number of quadrants filled by vegetation. For soil cover we positioned the frame horizontally on each quadrat and counted the number of quadrants filled with the different categories of plants. To obtain a mean value for vegetation variables at the point-count level, we calculated the mean for each of the 5 quadrats per point count. All vegetation sampling was conducted by T.W.S.

Statistical Analysis

To determine the species composition in RA and RE in each year, we plotted a Nonmetric Multidimensional Scaling (NMDS) with the Jaccard dissimilarity index, using the metaMDS function. We excluded singleton and doubleton bird species (n = 22), leaving 18 species. Previously, we verified using ANOVA that the structure of bird community in RE did not change over the years (richness: $F_{2,27} = 0.84$, $P = 0.45$; abundance: $F_{2,27} = 1.16$, $P = 0.33$). To test for differences in species composition, we fitted a Permutational Multivariate Analysis of Variance (PERMANOVA) with Pairwise multilevel comparison using adonis post hoc. We also fitted vegetation variables for ordination, using the envfit function based on 9999 permutations. All analyses were performed in the vegan package in R (Oksanen et al. 2017; R Core Team 2018), except PERMANOVA post hoc in the pairwiseAdonis package (Arbizu 2017), at a significance level of $\alpha = 0.05$. We used the Levene test to verify the homoscedasticity of variables, and then the Kruskal-Wallis Test with Dunn's Test post hoc to compare the vegetation variables between RA and RE. We used ANOVA for only one vegetation variable (*Baccharis* spp.).

Results

From 2015 to 2017, we recorded 336 individuals of 40 bird species, including 182 individuals of 30 species in RA (171 individuals, disregarding the zero stage), and 154 individuals of 22 species in RE (Figure 1; Table 1). Twelve species were present in both types of grassland, and 22 bird species are restricted to or make extensive use of grassland habitats (RA = 16, RE = 15). At both sites, *Ammodramus humeralis* (Grassland Sparrow) and *Sicalis luteola* (Grassland Yellow-Finch) were the most abundant shared species. *Embernagra platensis* (Great Pampa-Finch), *Zonotrichia capensis* (Rufous-collared Sparrow) and *Volatinia jacarina* (Blue-black Grassquit) were the most abundant species in RA, and *V. jacarina* was exclusive to this site. *Anthus hellmayri* (Hellmayr's Pipit), exclusive to RE, and *Sturnella superciliaris* (White-browed Meadowlark) were the most abundant species in RE (Figure 2). We recorded three species that are threatened globally and/or regionally: *Sporophila pileata*

(Pearly-bellied Seedeater) in RA and *Cistothorus platensis* (Sedge Wren) and *Anthus nattereri* (Ochre-breasted Pipit) in RE. The species composition differed significantly between RA and RE (PERMANOVA, $F_{3,56} = 8.04$, $p < 0.001$; Figure 3). In 3 years of monitoring the RA site since the zero stage, the bird species richness and abundance increased approximately 82 and 85%, respectively, and in the third year of monitoring the bird community in RA resembled RE more than in the first and second years of restoration (Figure 4; Table 1).

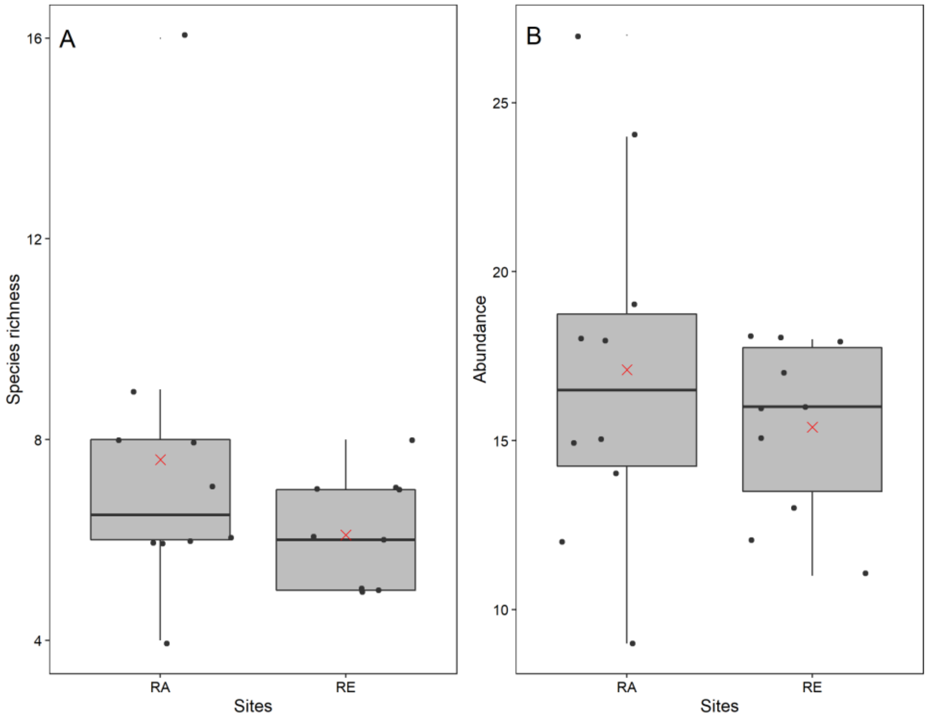

Figure 1. Bird species richness (A) and abundance (B) recorded in active-restoration site (RA) and reference area (RE) from 2015 through 2017 in southern Brazil. Boxplot values are represented by medians (black horizontal lines) and means (red crosses).

Table 1. Bird species and number of individuals recorded in active restoration (RA) and reference areas (RE) in Brazilian grasslands from 2015 through 2017.

Family and Species	**RA**			**RE**
	Year 1	**Year 2**	**Year 3**	
Tinamidae				
Rhynchotus rufescens (Red-winged Tinamou)*	0	1	1	1
Nothura maculosa (Spotted Nothura)*	0	0	1	0
Anatidae				
Amazonetta brasiliensis (Brazilian Teal)	0	0	0	4
Columbidae				
Zenaida auriculata (Eared Dove)	0	0	2	0
Cuculidae				
Guira guira (Guira Cuckoo)	0	0	1	0
Coccyzus melacoryphus (Dark-billed Cuckoo)	0	0	1	0
Charadriidae				
Vanellus chilensis (Southern Lapwing)*	0	0	0	2
Scolopacidae				
Gallinago paraguaiae (South American Snipe)	0	0	0	1
Jacanidae				
Jacana jacana (Wattled Jacana)	0	0	0	5
Ardeidae				
Butorides striata (Striated Heron)	0	0	2	0
Threskiornithidae				
Theristicus caerulecens (Plumbeous Ibis)	0	0	0	2
Falconidae				

Family and Species	**RA**			**RE**
	Year 1	**Year 2**	**Year 3**	
Caracara plancus (Southern Caracara)*	0	0	0	1
Psittacidae				
Myiopsitta monachus (Monk Parakeet)	2	0	0	0
Furnariidae				
Furnarius rufus (Rufous Hornero)*	0	0	2	5
Synallaxis frontalis (Sooty-fronted Spinetail)	0	0	1	0
Tyrannidae				
Elaenia spectabilis (Large Elaenia)	0	1	0	0
Myiophobus fasciatus (Bran-colored Flycatcher)	0	0	1	0
Pitangus sulphuratus (Great Kiskadee)	0	1	2	2
Tyrannus savana (Fork-tailed Flycatcher)*	0	1	1	2
Hirundinidae				
Progne tapera (Brown-chested Martin)*	0	0	0	1
Troglodytidae				
Troglodytes aedon (House Wren)	1	0	0	0
Cistothorus platensis (Sedge Wren)*[c]	0	0	0	4
Mimidae				
Mimus saturninus (Chalk-browed Mockingbird)*	0	1	0	0
Motacillidae				
Anthus nattereri (Ochre-breasted Pipit)*[a, b]	0	0	0	1
Anthus hellmayri (Hellmayr`s Pipit)*	0	0	0	34
Thraupidae				
Sicalis luteola (Grassland Yellow-Finch)*	12	7	6	35

Family and Species	**RA**			**RE**
	Year 1	**Year 2**	**Year 3**	
Volatinia jacarina (Blue-black Grassquit)*	4	8	15	0
Sporophila pileata (Pearly-bellied Seedeater)*[b]	0	1	1	0
Sporophila caerulescens (Double-collared Seedeater)	0	0	4	0
Embernagra platensis (Great Pampa-Finch)*	11	1	1	1
Emberizoides herbicola (Wedge-tailed Grass-Finch)*	0	1	2	0
Donacospiza albifrons (Long-tailed Reed Finch)*	3	0	0	3
Paroaria coronata (Red-crested Cardinal)	0	0	3	0
Emberizidae				
Ammodramus humeralis (Grassland Sparrow)*	11	14	10	27
Zonotrichia capensis (Rufous-collared Sparrow)	0	12	11	2
Parulidae				
Geothlypis aequinoctialis (Masked Yellowthroat)	0	1	2	2
Pseudoleistes guirahuro (Yellow-rumped Marshbird)*	0	3	0	0
Pseudoleistes virescens (Brown-and-yellow Marshbird)*	0	1	0	0
Molothrus bonariensis (Shiny Cowbird)*	0	2	0	1
Sturnella superciliaris (White-browed Meadowlark)*	0	0	1	18

* Species representative of southeastern South America grasslands (Azpiroz et al. 2012)

[a] Vulnerable globally

[b] Vulnerable regionally

[c] Near-threatened regionally

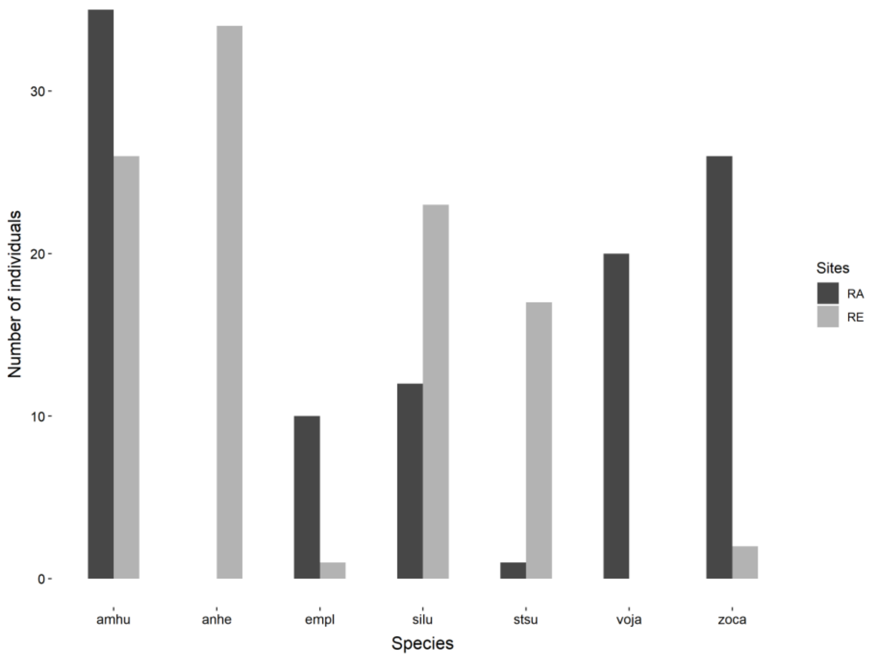

Figure 2. Bird species more abundant in active-restoration site (RA) and reference site (RE) sampled from 2015 through 2017 in grasslands of southern Brazil. Species acronyms are formed by the first two letters of the genus and species, as in Table 1.

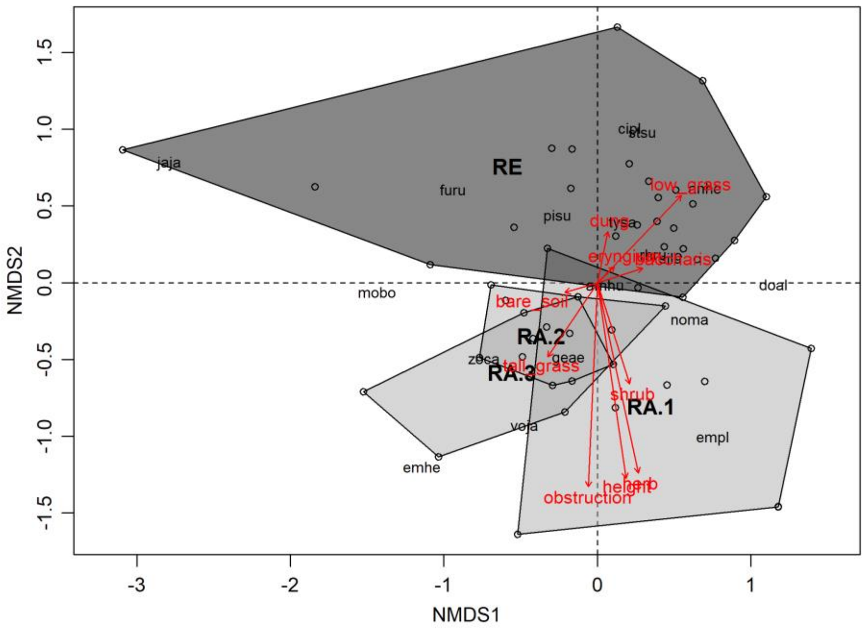

Figure 3. Nonmetric Multidimensional Scaling (NMDS) of the bird species in the active-restoration site from years 1 to 3 (RA) and reference area (RE) in grasslands of southern Brazil and their relationship with vegetation structure variables. Stress = 0.16. Species acronyms are formed by the first two letters of the genus and species, as in Table 1.

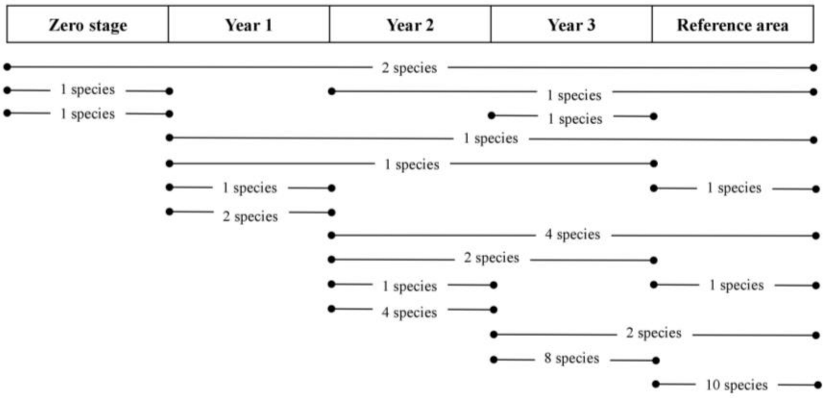

Figure 4. Number of bird species recorded in each year of monitoring of a site in process of active-restoration (2015–2017) in southern Brazilian grasslands, compared with the number of bird species of a reference area.

Of the 11 vegetation variables analyzed, six differed between RA and RE, and are the same variables that influenced the bird species composition, except tall grasses (Figure 3). Vegetation height, visual obstruction, tall grasses, herbs and shrubs were all higher in RA, while the variable ‘short grasses’ was higher in RE (Kruskal-Wallis, $p < 0.001$). Nevertheless, in year 3, grasses and herbs in RA were more similar to RE. After 3 years of monitoring, the soil at the RA site did not show erosive processes and had a high number of native grassland plant species (e.g., *Paspalum* spp. grasses), but the lovegrass has not yet been fully controlled (IBAMA 2018).

Discussion

Losses of native grasslands have been documented worldwide (Buisson et al. 2018), with more than 45% of temperate grasslands now converted or lost (Hoekstra et al. 2005). Theoretical knowledge allied to management practices have been developed to more effectively conserve and restore degraded grasslands (White et al. 2000; Buisson et al. 2018). Our case study is the first to examine how active restoration can affect bird species richness and abundance in South America. The results must be considered with caution, because replication was not possible and our sample was local. We obtained similar results to previous studies in the United States that found similar bird species richness and abundance or density between active restoring and native grassland areas, such as in Iowa (Fletcher & Koford 2002; Van Dyke et al. 2004), wetlands of North and South Dakota (Ratti et al. 2001) and wetlands of New York, which also found differences in species composition, similarly to our study case (Brown & Smith 1998).

Ammodramus humeralis and *Sicalis luteola*, the most abundant species shared between RA and RE, occupy a range of vegetation heights and are tolerant of habitat changes (Isacch et al. 2005; Azpiroz et al. 2012). *Volatinia jacarina*, one of the most abundant species in RA and exclusive to this habitat, is a tall-grass species, mainly for nesting (Azpiroz et al. 2012; Dias et al. 2017; Rising 2018). *Anthus hellmayri* was exclusive and abundant in RE, since it is restricted to grasslands, and hence sensitive to conversion of grasslands to other land uses such as croplands (Azpiroz & Blake 2009; Azpiroz et al. 2012). We recorded *Sporophila pileata*, the only threatened species recorded in RA, beginning with the second year of monitoring. This is a tall-grass bird, with a decreasing population due to overgrazing (Codesido & Fraga 2009; IUCN 2017), and the abundant tall grasses in RA provide a suitable habitat.

Vegetation structure attributes predict the direction of plant succession and the improvement of environmental conditions and colonization by animals (Ruiz-Jaen & Aide

2005; Chaves et al. 2015). We observed differences between RA and RE in six variables of vegetation structure, which may have resulted in the difference in species composition between the two habitats. Despite this, we recorded grassland-dependent bird species at both the RA and RE sites, perhaps because of the greater height and degree of visual obstruction in RA resulting from the conspicuous presence of shrubs and *Baccharis* spp., and because this woody vegetation in grasslands provides resources for birds, increasing diversity (Dias et al. 2014). A previous study in temperate grasslands of Hungary also detected recovery of grass diversity within 3 years after active restoration started (Török et al. 2012). It is known that the recovery of birds is strongly correlated with vegetation structure (George & Zack 2001; Ruiz-Jaen & Aide 2005).

We found that this bird community is recovering rapidly following active restoration of a grassland area. Our results were positive to the site in process of active restoration for having higher species richness, support bird species associated with grasslands and show quick recovery when compared with the reference area, since the number of species in RA almost doubled in each year of monitoring. For future research, the ideal would be long-term studies to monitor areas under active restoration, and integrate assessments of other groups of animals to understand the biodiversity recovery in degraded areas and measure restoration success. Studies such as our in field-scale and small site-specific experiments should be used to inform and support long-term and large-scale restoration efforts (Gerla et al. 2012). Active restoration is used to accelare the successional trajectory of degraded habitats and may be useful to recover and conserve the biodiversity, despite of high costs, besides most of the time the changes are not immediate (Holl & Aide 2011). Thus, each case should be analyzed individually and depends on the goal to be achieved, since that studies evaluating passive restoration in grassland habitats also have shown positive results for plants and fauna recovery (e.g. Torchelsen et al. 2018, Kitazawa et al. 2019, Reiley et al. 2019).

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CAPÍTULO 3

Bird community responses in restoration grassland habitats to the remaining native vegetation surrounding

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Bird community responses in restoration grassland habitats to the remaining native vegetation surrounding

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Abstract

Context Understanding that surrounding landscape influences the species diversity and abundance in fragments, a considerable amount of native vegetation cover may positively affect the species at the local scale, regardless of the sizes of individual habitat patches in the landscape.

Objectives We intended to verify if species richness, abundance, and occurrence of individual species of grassland birds in restoration sites are influenced by the amount of native grassland surrounding within of the landscape.

Methods We censured birds by 5 min point counts in four passive and one active restoration sites in Brazilian Pampas. We established a 1 km-radius buffer in each area, and we calculated the percentage of native grassland vegetation in the surrounding landscape.

Results Bird species richness and abundance did not have significant relationship with the amount of native grassland surrounding of the landscape. We found the same results to occurrence of eight grassland bird species analyzed individually.

Conclusions The surrounded native grassland matrix did not influence species richness and abundance, and responses to habitat modification are species-specific. Even so, previously the landscape features were important to vegetation structure recovery. We strongly suggest that landscape context should be used as an additional approach to contribute to conservation strategies in habitats recovery.

Keywords Active restoration; Grassland birds; Landscape; Pampas biome, Passive restoration

Introduction

Global biodiversity has been constantly impacted leading most species live in fragmented patches, that are resulted of the land use changes and habitat destruction (Haddad et al. 2015; Fletcher et al. 2018). Thus, surrounding landscape influences the species abundance and diversity in fragments since can connect landscapes, influence dispersal habitat fragments, and depending of the land use can alter conditions of habitat patches negatively or positively (Öckinger et al. 2012). Landscapes that retain substantial amounts of native vegetation cover should yield large positive ecological response at the local scale (Kroll et al. 2014).

Community structure is influenced by landscape configuration, and diversity within a patch depends on the structure of the surrounding landscape (Dauber et al. 2003), e.g. the dependence of the surroundings on a community in a restored habitat. Species richness can be shaped by physical environment that include several characteristics of habitat patch area, as quality, habitat amount, configuration and connectivity (Aggemyr et al. 2018). In case of the birds, which the individuals can occur across a variety of habitat patches, seeking resources among of them (Whitaker and Warkentin 2010; Lee and Carroll 2014), the ratio of native grassland remaining patches to the landscape can affect the presence of bird species in the grasslands (Cerezo et al. 2011). And, the greater the amount of native grassland in patches, the greater the richness and abundance of birds (da Silva et al. 2015). Therefore, bird species distribution and occurrence can be strongly influenced by landscape characteristics (Lee and Carroll 2014).

Grasslands have been replaced and fragmented due to land use change, mainly by agricultural expansion (Pretelli et al. 2018), and restoration of degraded habitats, i.e. recovery of an ecosystem, is still not widely applied for tropical and subtropical grasslands (Buisson et al. 2018). Conservation strategies for preservation and restoration of habitats should consider the quality of the whole landscape (Fahrig 2001). In grassland restoration the spontaneously vegetative recovery depends of the seed banks persistence, and of the seed input from external sources as native grasslands surround of the restoration sites that can promote seeds rain (Favreto and Medeiros 2006; Andrade et al. 2015; Vieira et al. 2015). Hence, well-conserved landscape patches are important, since recovery is affected by surrounding land use matrix that serves as a vital source of propagules (Holl and Aide 2011).

The total number of species in a given habitat type within a landscape increases with the total amount of that habitat in the landscape, regardless of the sizes of individual habitat patches in the landscape (Fahrig 2013). From this and considering the large proportion of degraded grasslands in Brazilian Pampas biome, firstly we compared the bird communities structure of restoration sites with native grasslands, and we found similarity between of them (see Chapters 1 and 2 of this thesis). Here, our objective is to verify if species richness, abundance, and occurrence of individual species of grassland birds in the same restoration sites are influenced by the amount of native grassland available within of the landscape. We expected that restoration sites surrounded by more amounts of native grassland vegetation would have larger diversity and occurrence of individual bird species. The landscape matrix can facilitate the dispersal and movement of organisms between habitat patches, that can provide additional habitat for them (Haynes et al. 2007; Lindenmayer et al. 2010).

Methods

Study area

We carried out the study in five restoration sites located at the Pampas biome, state of Rio Grande do Sul, south Brazil. Four sites were passively restored, i.e. after agricultural abandonment of more than 10 years of soy and/or rice crops, ranging from 65 to 600 ha. The other site is being actively restored since 2015, previously it had at least 10 years of soybean crop. The size of this area is 400 ha and some techniques were used to recovery it. The grasslands at this region have been usually converted for agriculture and afforestation, and besides native grassland, remaining native forest can be found occasionally. This work is part of the first study evaluating bird communities in restoration habitats developed in grasslands of South America. Detailed description of the study areas is in the Chapters 1 and 2 of this thesis.

Bird sampling

We sampled birds in two breeding seasons (between November and February) in 2015-2016 and 2016-2017. We surveyed birds in point counts of 5 min and 100-m radius, totalizing 50 point counts for all sites. For more details of bird sampling view above Chapters 1 and 2 this thesis. Distance from the observer to birds were measured with a rangefinder. We recorded 30 grassland associated bird species (*sensu* Azpiroz et al. 2012), but for analysis we used the 17 species with five or more occurrences. We used the relative species richness and abundance because we sample different numbers of point counts in each site according size of them (Table 1).

Table 1 Grassland bird relative number of individuals per point count, buffer total area, and area of native grassland in passive (RP) and active (RA) restoration sites in Brazilian Pampas biome. Conservation status global (G; IUCN 2017) and regional (R; DOE 2014): VU – vulnerable, NT – near threatened

	Sites (number of point counts)				
Species	**RP1 (12)**	**RP2 (12)**	**RP3 (6)**	**RP4 (10)**	**RA (10)**
Ammodramus humeralis	0.08	1.92	4.33	1.8	2.5
Anumbius annumbi	0.17	0	0.33	0.2	0
Athene cunicularia	0	0.5	0	0	0
Cistothorus platensis $^{\text{NT (R)}}$	0	0.5	0	0	0
Emberizoides herbicola	0.5	0.83	0.17	0.4	0.1
Embernagra platensis	0.33	0.25	0	0	1.2
Mimus saturninus	0.17	0	0	0.2	0.1
Nothura maculosa	0	0	0.67	0.1	0
Pseudoleistes guirahuro	0	0.92	0.17	0	0.3
Rhynchotus rufescens	0	0.58	0	0	0.1
Sicalis luteola	0	0.67	2.5	0.9	1.9
Sporophila cinnamomea $^{\text{VU (G), NT (R)}}$	0	0.67	0	0	0
Sporophila collaris $^{\text{NT (R)}}$	0	0.58	0	0	0
Sporophila pileata $^{\text{VU (R)}}$	0.25	0	0.5	0.3	0.1
Sturnella superciliaris	0.25	0.08	0.17	0	0
Tyrannus savana	0.5	0.08	0.17	0.6	0.1
Volatinia jacarina	0.17	0.17	2.17	0	1.2
Relative number of species	0.75	1.08	1.67	0.8	1
Relative number of individuals	2.42	7.75	11.17	4.5	7.6
Total buffer area (ha)	1275	1120	920	769	1007
Native grassland surrounding area (ha)	510 (40 %)	818 (73 %)	534 (58 %)	515 (67 %)	856 (85 %)

Landscape data

We obtained satellite images of Bing Maps Aerial, using Quantum GIS 2.18 (QGIS Development Team 2016). For each site, firstly we insert a 250-m buffer from point counts of birds (100-m radius and 150-m of the edges). After, we insert a buffer of 1-km radius surrounding the smaller buffer (Fig. 1), because encompass home ranges of most neotropical songbirds (Lee and Carroll 2014), and it is sufficiently size large to birds perceive as a landscape (Rodewald and Yahner 2001). We drew polygons of all land uses, except native grassland, inside the buffer for each site using a 1:20,000 scale screen. Land use types were monocultures, native forest, water bodies, and anthropization. We calculated their percentages for each buffer and subtracted of total area of the buffer to obtain the percentages of native grassland area (Table 1). It was not possible to perform analysis of the size and distance of native grassland patches in relation to point counts in the buffer that we establish, because most grasslands were continuous, not isolated.

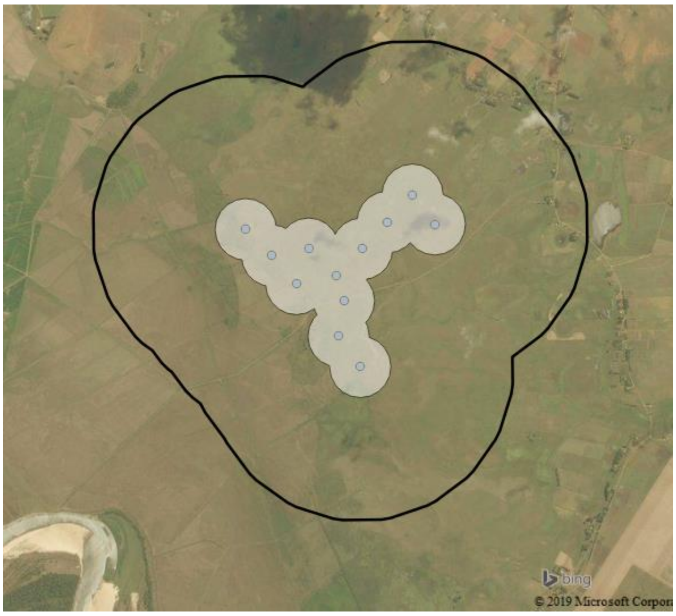

Fig. 1 Example of buffer of the point counts of birds (white) and of 1-km radius buffer (black line) inserted in the restoration sites

Statistical analysis

We performed linear regression to verify if there was relationship of the relative species richness, abundance, and occurrence of individual species of grassland birds with the amount of native grassland habitat available within the landscape. We used ‘lm’ function of ‘stats’ package in R software (R Core Team 2018). We adjusted individual relative species abundance using detection probability values obtained from Distance 7.1 Release 1 (Thomas et al. 2010). We were allowed calculate the detectability for eight species. Three of them could be evaluated individually because they were more abundant (*Ammodramus humeralis*, *Sicalis luteola* and *Volatinia jacarina*), and the others were combined in two groups: (1) *Emberizoides herbicola* and *Embernagra platensis*; (2) *Sporophila cinnamomea*, *S. collaris* and *S. pileata*. We grouped species according the same use of habitat to breed and feed in southern Brazil (e.g., similar vegetation structure type, grass height and foraging strategy; Azpiroz et al. 2012; pers. observ.). After, to obtain the estimated relative abundances we divided the number of individuals recorded by the detection probability (McCallum 2005).

Results

We found a positive correlation between relative species richness (r = 0.08; R^2 = 0.006) and abundance (r = 0.43; R^2 = 0.19) of grassland birds and the amount of native grassland of the landscape, but for both its was not significant (P > 0.05; Fig. 2). All eight bird species evaluated individually also showed non-significant difference in relation to amount of native grassland (P > 0.05) and low percentage of variance explained (R^2 < 0.3; Fig. 3).

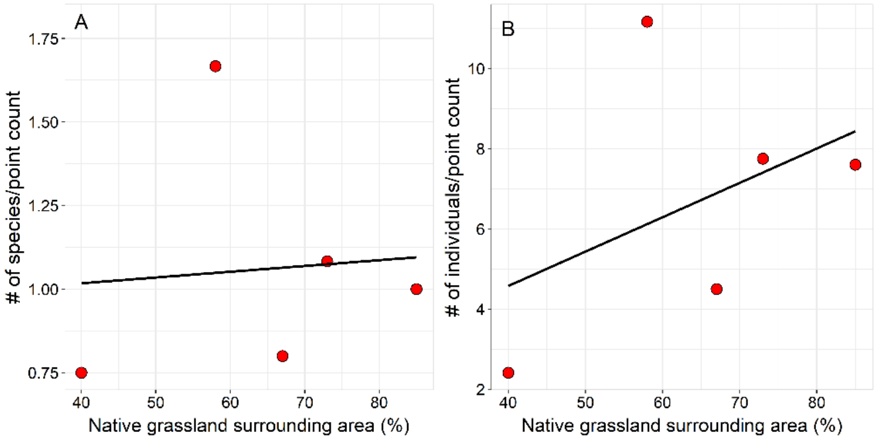

Fig. 2 Grassland bird relative species richness (A; R^2 = 0.006) and abundance (B; R^2 = 0.19) to amount of native grassland of the landscapes, both not significant (P > 0.05)

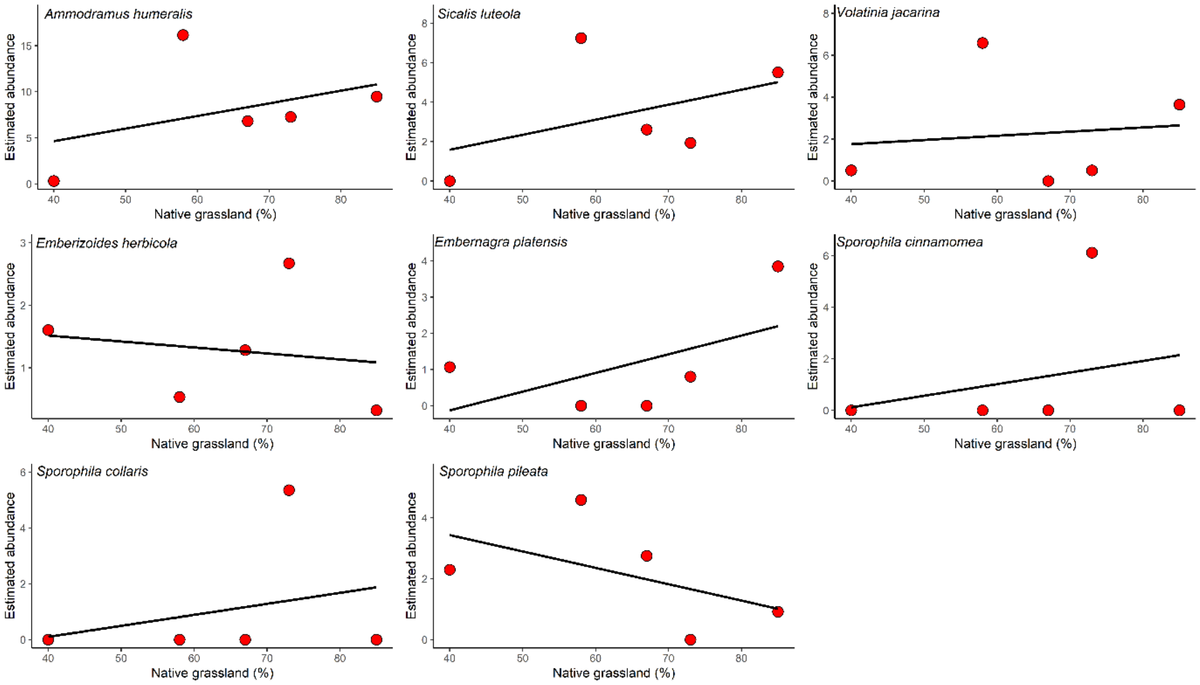

Fig. 3 Grassland bird relative number of individuals per point count within each site to amount of native grassland vegetation of the landscapes. All bird species did not show significant relation ($P > 0.05$) and had low percentage of variance explained ($R^2 < 0.3$)

Discussion

The surrounding landscape matrix influences the response of species on habitat fragments (Pretelli et al. 2018), and responses of organisms to landscape attributes provide information about management improvements in habitats (Kroll et al. 2014). The amount of native vegetation in this context may provide additional habitat for species, and can be considered a key driver of species richness (Lindenmayer et al. 2010). Previous studies showed significant positive relationship between bird species diversity and amount of native vegetation in surrounding (e.g., Haire et al. 2000; Lindenmayer et al. 2010; Wentworth et al. 2010). Landscapes with large areas of continuous grasslands strongly affect richness and abundance of grassland specialist’s birds (Codesido et al. 2013; Pretelli et al. 2018). Thus, the surrounding context have been considered more important issue than assess patch size and isolation (Collinge et al. 2003; Lindenmayer et al. 2010). We did not find strong evidence of this association of the landscape with species richness, abundance and individual species of grassland birds, however we believe that more replicates could provide more robust information on the surroundings of Brazilian grasslands in restoration. The problem remains in found the restoration areas and permissions in enough number to sampling, which were our main difficult in this work. Moreover, in our two previous studies evaluating the bird species richness, abundance and composition in these same five restoration sites, we found recovery potential on bird community comparing with native grasslands (Chapters 1 and 2 this thesis). The continuous native grassland surrounding of restoration sites may have influenced such similarity. Therefore, the neutral response we found does not preclude benefits of remain grasslands, and could have reduction of habitat quality despite quantity of native vegetation cover over half of surrounding landscape.

A high proportion of native grasslands in the landscape can further the recovery within of grasslands in process of restoration (Waldén et al. 2017). Thus, the restoration sites that we evaluated can be well established with regard to habitat structure, as vegetation, providing necessary resources for birds and habitat suitability. Furthermore, the areas sampled had large size of continuous restoration grasslands and thus grassland amount surrounding has few impact on grassland birds (Lockhart and Koper 2018). In addition, when the remaining habitat in the landscape is below 30% the effects of fragmentation begin to more expressive (With and Crist 1995; Fahrig 2003). However, our sites had at least 40% of native grassland that may be other reason of the low influence of relation of the grassland birds' community to amount of native grassland surrounding, same results found in a study conducted in the same region (Camilotti 2009). Considering the eight individual species that did not show significant relation in occurrence to amount of native grassland surrounding, may be associated to factors described previously, and each species respond differently to habitat and landscape transformation what is known for other environments (Manning et al. 2004; Fischer and Lindenmayer 2007).

Our results present the first approach in landscape matrix analysis in restoration habitats of grasslands of South America. Due our reduced number of study sites, we should have caution to extrapolate our results. However, even though we did not find relation of the surrounding landscape with the richness and abundance of grassland birds, previously the landscape features were important for the vegetation structure recovery (Overbeck et al. 2013). In addition, it is know that the amount of native habitat surrounding can significantly influence the diversity of bird species. We reinforce the necessity of considering landscape context as complementarity approach to guide future decisions making on habitat management in restoration, and for the establishment of conservation strategies.

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CONCLUSÕES GERAIS

A pesquisa que realizei e que foi aqui apresentada é de grande relevância desde que levanta como temática a conservação dos campos baseada em uma visão de recuperação deste ambiente a partir de áreas que outrora foram degradadas. No Brasil, a avaliação da comunidade de aves em ambientes restaurados tem sido estudada somente em florestas. Contudo, constatei que tal manejo pode ter resultados positivos também para os campos e, portanto, deve ser considerada em projetos de conservação. A capacidade de recuperação dos campos do bioma Pampa mostrou que a diversidade de aves é recuperada, tanto se a restauração for passiva quanto ativa. A estrutura da comunidade de aves nas áreas restauradas mostrou similaridade com o campo nativo no que diz respeito ao número de espécies, indivíduos, espécies associadas ao campo e de interesse de conservação. Com isso, acredito que a restauração dos campos, antes degradados, é capaz de fornecer recursos necessários para a manutenção e conservação das aves campestres no sul do Brasil. Além disso, julgo necessário considerar a matriz da paisagem do entorno das áreas restauradas, podendo ser uma ferramenta adicional para avaliação das comunidades de habitats em restauração, pois se bem conservada essa vegetação remanescente serve como uma fonte de propágulos de espécies de plantas nativas e de recursos para as aves, como alimentação e reprodução.

Apesar dos meus resultados terem sido positivos em relação a recuperação das aves campestres, sei que as áreas degradadas devem ser analisadas individualmente quanto à capacidade de restauração e, se necessário, quais técnicas ser empregadas. Acredito que resultados mais conclusivos de conservação da biodiversidade nestes ambientes serão alcançados levando em consideração a avaliação de mais de um táxon e o monitoramento de longo prazo, o que necessita recursos e efetivo para sua execução. Para esses esforços, primeiramente, é necessário um grande empenho na busca e permissão de mais áreas para o desenvolvimento destes estudos, o que foi nossa maior dificuldade no estudo atual – a de conseguir um maior número de réplicas. Um aspecto necessário para alcançar isso é a divulgação dos resultados para a comunidade que utiliza os campos, através da sensibilização sobre a possibilidade de conciliar o uso do campo com sua conservação. A restauração tem sido considerada o futuro da conservação da biodiversidade, e por isso é importante a continuidade de pesquisas nessa área, diante das constantes transformações que os ambientes naturais e, consequentemente, os organismos têm sofrido. Em razão disso, almejo dar continuidade a tais pesquisas envolvendo a avaliação e monitoramento das aves frente à recuperação de campos degradados.

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