FACULDADE DE BIOCIÊNCIAS

PROGRAMA DE PÓS-GRADUAÇÃO EM ZOOLOGIA

ESTRUTURA DA ASSEMBLEIA E USO DO HABITAT POR AVES NA ECOREGIÃO DA SAVANA URUGUAIA: CAMPOS SEMI-NATURAIS *VS.* CAMPOS DE SOJA

Thaiane Weinert da Silva

DISSERTAÇÃO DE MESTRADO

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Orientadora: Dra. Carla Suertegaray Fontana

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SUMÁRIO

RELAÇÃO DE FIGURAS

CAPÍTULO 1

CAPÍTULO 2

APÊNDICE FOTOGRÁFICO

RELAÇÃO DE TABELAS

CAPÍTULO 1

CAPÍTULO 2

“Em Rivera e Livramento
Pajadores lado a lado
Teu país e meu estado
Se unem no sentimento
Por saber que és atento
às coisas da natureza
Me responda com clareza
Do fundo do coração
O que viste em meu rincão
Que te mostrou mais beleza?

Su Querencia és tan hermosa
Un derroche de beleza
Aquí la naturaleza
Fue pródiga y generosa
las misiones és gloriosa
história curcificada
Su memória ensagrentada
le muestra el tiempo inmutable
como señal imborrable
A su tierra colorada…”

(Paulo de Freitas Mendonça e Jose Curbelo, Querências Amigas)

Dedico à minha família e a quem realmente acreditou e me apoiou nesta empreitada.

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RESUMO

A ecoregião da Savana Uruguaia vem sendo constantemente alterada, principalmente quanto ao uso do solo para implantação de pastagens e agricultura intensiva. Consequentemente, a qualidade dos habitats e as populações de aves também são afetadas. Estudos que gerem informações sobre como a densidade das espécies varia em ambientes alterados, e que possam proporcionar ações de conservação das áreas naturais são necessários. Entre 2010 e 2012 amostramos as espécies de aves, através de pontos de contagem, em áreas de campos semi-naturais e de cultivos de soja com manchas de campos, no Rio Grande do Sul e no Uruguai. Avaliamos, em dois capítulos, (1) as diferenças na riqueza, densidade e composição das assembleias de aves nestes dois tipos de uso do solo e (2) os padrões de uso do habitat pelas aves campestres através da avaliação da riqueza e abundância das mesmas nestes diferentes ambientes. Com referência ao primeiro capítulo, os cultivos de soja apresentaram menor riqueza de espécies do que os campos semi-naturais. O mesmo ocorreu com a densidade das espécies, sendo que espécies consideradas mais especialistas apresentaram os maiores valores de densidade em áreas de campo semi-natural e espécies mais comuns e generalistas foram abundantes na soja. Quanto à composição de espécies, os tipos de uso do solo foram claramente separados. Cinco das espécies registradas são consideradas ameaçadas ou quase ameaçadas global e/ou regionalmente - *Rhea americana*, *Athene cunicularia* e *Xolmis dominicanus* foram registradas tanto nas áreas de soja quanto nas de campos semi-naturais, já *Cistothorus platensis* e *Xanthopsar flavus* foram registradas apenas nos campos semi-naturais). Quanto ao segundo capítulo, estabelecemos um *buffer* de 100 metros para cada um dos 160 pontos amostrados, e calculamos a porcentagem de cada tipo de uso do solo nos tampões, em cada ponto. Dentre as espécies de aves campestres analisadas, a maioria delas ocorreu preferencialmente em campos naturais e/ou campos naturais úmidos, e nenhuma usou primeiramente as áreas de soja. Além disso, mais de 60% dos registros de ocorrência e do número total de indivíduos destas aves foram registrados nos *buffers* compostos por mais de 90% de campo natural. A partir destes resultados, concluímos o quão importantes são as áreas de campo natural para a manutenção da assembleia de aves. Para a conservação dessas espécies, porém, são necessárias algumas medidas importantes dentre as quais podemos destacar: 1) práticas de manejo (por exemplo, a manutenção de manchas de campo entre os cultivos de soja) e 2) políticas que aliem a produção da agricultura e a conservação da biodiversidade. Além disso, é importante entender a resposta das diferentes espécies de aves frente às alterações do habitat que estão acontecendo na região.

Structure of assemblage and habitat use by birds in the Uruguayan savanna ecoregion: semi-natural grasslands *vs.* soybean fields

ABSTRACT

The Uruguayan savanna ecoregion has been affected by land use changes, particularly livestock production and monocultures, such as soybean. As consequence, the habitat quality and the avian assemblages in the region are also being affected, and if we are to protect this habitat and its bird species, studies that generate information that can be used for conservation interventions in the region are essential. We sampled bird species in semi-natural grassland and soybean sites with grassland patches, in Rio Grande do Sul and Uruguay, between 2010 and 2012. In two chapters we evaluated (1) the differences in species richness, density and composition of the avian assemblage in semi-natural grasslands and soybean fields, and (2) the patterns of habitat use by grassland birds, through assessment of species richness and abundance. In the first chapter, we found that soybean fields have the lower species richness. Moreover, species considered as grassland specialists had the greatest value of density in semi-natural grassland sites, and species that are common and habitat generalists were more abundant in the soybean fields. Turning to species composition, our results demonstrated that the types of land use were clearly separated. Among the species recorded, five are classified as threatened or near-threatened according to global and/or regional red lists: *Rhea americana*, *Athene cunicularia* and *Xolmis dominicanus* were recorded in both soya and semi-natural grassland sites, whereas *Cistothorus platensis* and *Xanthopsar flavus* were recorded only in semi-natural grassland sites. In the second chapter we analyzed the habitat use of grassland birds by establishing a buffer of 100 meters in each of the 160 points sampled. We calculated the percentage of each land use type in each buffer and found that most of the grassland's bird species analyzed occurred preferentially in sites with large percentage of natural grasslands and/or wet grasslands, and none of them used the soybean fields preferentially. Moreover, more than 60% of the records occurred in the buffers composed by over 90% of natural grassland, and the same pattern was found for the total number of individuals of all bird species. Based on our results, we can conclude that the natural grassland sites are important for the maintenance of the avian assemblage in the region. For the conservation of the grasslands in the region, some important measures are needed, such as 1) control on agricultural management practices (e.g. maintain patches of grasslands in the soybean fields), and 2) development of policies combining agriculture production and conservation of biodiversity.

APRESENTAÇÃO

Proposta geral

Os campos do sudeste da América do Sul ocupam uma área com cerca de 700.000 km², abrangendo quatro países: sul do Paraguai, nordeste e centro da Argentina, extremo sul do Brasil e todo o Uruguai (Bilenca e Minãrro 2004, Di Giacomo e Krapovickas 2005, Azpiroz et al. 2012). O bioma Pampa brasileiro compreende os campos da região das Missões e parte do Planalto Médio, além de toda a metade sul do Estado do Rio Grande do Sul (Pillar et al. 2006), ocupando uma área de 63% do Estado (Roesch et al. 2009). No Uruguai, atualmente os campos naturais ainda cobrem, aproximadamente, 70% do país (Gautreau 2010). A área compreendida pelos campos da metade sul do Rio Grande do Sul, todo o Uruguai (ambas as áreas deste estudo) e pequena parte das províncias de Entre Ríos e Corrientes na Argentina, é definida como ecoregião da Savana Uruguaia (WWF 2012). Esta ecoregião apresenta grande riqueza de aves, com aproximadamente 400 espécies. No entanto, 12.5% delas encontram-se sob alguma forma de ameaça de extinção no bioma Pampa brasileiro e 6% nos campos uruguaios devido às fortes pressões geradas por atividades agropecuárias, que estão alterando suas comunidades naturais (Develey e Jaworski 2009, WWF 2012, IUCN 2013).

Segundo dados do Ministério do Meio Ambiente, restam apenas 23% da cobertura original de campos nativos do Pampa gaúcho e a maior perda se deve à conversão em plantações de árvores exóticas (i.e. *Eucalyptus* sp., *Acacia* sp. e *Pinus* sp.) e soja (*Glycine max*) (Develey e Jaworski 2009). A pequena representatividade de Unidades de Conservação (UC) no bioma Pampa, com 2.23% da área total considerando-se tanto as UCs de proteção integral quanto as de uso sustentável, agrava a situação dos campos da região, onde pelo menos 88 áreas estão listadas como prioritárias para a conservação da biodiversidade (Bilenca e Minãrro 2004, MMA 2007). O mesmo ocorre no Uruguai, onde apenas 1.7% do território estão protegidos por Unidades de Conservação, contando com as áreas que estão em processo de inclusão no Sistema Nacional de Áreas Protegidas de Uruguay (SNAP) (Ministerio de Vivienda, Ordenamiento Territorial y Medio Ambiente 2010). Quanto às áreas importantes para conservação dos campos gaúchos e uruguaios, destaca-se a presença de 31 Áreas Importantes para a Conservação das Aves, também conhecidas por IBAs (*Important Bird Areas*) (Devenish et al. 2009), além de 15 AVPs (Área Valiosa de Pastizal), em que ambas correspondem a áreas total ou parcialmente cobertas por campos naturais e que ainda se mantêm em bom estado de conservação (Bilenca e Miñaro 2004). Desta forma, a falta de representatividade dos campos em unidades de conservação, juntamente às ameaças existentes, leva à necessidade de se executarem ações imediatas para conservar o que ainda resta de campo nativo, tornando-se indispensáveis mais estudos para estimar o papel da alteração da paisagem na composição de assembleias de aves nos campos sul-americanos (Azpiroz e Blake 2009).

A composição das espécies de plantas e a estrutura da vegetação dão aos ambientes terrestres sua característica de configuração física, sendo um importante fator na determinação da abundância e distribuição das aves (Isacch et al. 2005). Os campos naturais, tanto no Brasil quanto no Uruguai, têm sido alterados pelo homem para pastagens e o uso da terra para a agricultura intensiva (Altesor et al. 1998). A intensificação da agricultura leva à diminuição da biodiversidade e perda da qualidade dos habitats originais, não só devido à utilização crescente e generalizada de insumos e maquinaria, mas também devido à fragmentação do habitat (Batáry et al. 2007). Consequentemente, a transformação da paisagem devido a essa fragmentação inclui modificações nas áreas e configuração das manchas (Baldi et al. 2006, Medan et al. 2011).

Para orientar os esforços de conservação e de gestão pública, bem como para estabelecer áreas prioritárias e desenvolver planos de ação para conservação, é preciso conhecimento das áreas que apresentem espécies ameaçadas, e também compreender os efeitos da fragmentação do habitat sobre a avifauna (Gressler 2008, Di Giacomo et al. 2010). A quantificação da diversidade (i.e. riqueza e densidade de espécies) da avifauna fornece importantes subsídios para caracterizar e monitorar a qualidade ambiental de uma determinada área (Vielliard et al. 2010).

Diante disso, este estudo tem como objetivo geral avaliar a influência da plantação de soja na estrutura (riqueza, diversidade e densidade) e uso do habitat da assembleia de aves nos campos gaúchos e uruguaios. Esta pesquisa foi realizada em colaboração com o trabalho de doutorado da pesquisadora Graziela Dotta, intitulado "Agricultural Production and Biodiversity Conservation in the Grasslands of Brazil and Uruguay", realizado na University of Cambridge (UK) sob supervisão do Professor Dr. Andrew Balmford. A mestranda participou ativamente em todos os levantamentos de avifauna nas áreas escolhidas para o desenvolvimento desta dissertação de mestrado, sendo que os mesmos foram realizados durante o período de primavera-verão em 2010-2011 e 2011-2012.

Estrutura da Dissertação

Esta dissertação de mestrado apresenta-se na forma de dois artigos científicos focados na influência da plantação de soja na estrutura e uso do habitat da assembleia de aves na ecoregião da Savana Uruguaia. Os artigos ainda não foram submetidos para publicação e estão redigidos em inglês americano.

O primeiro artigo (Capítulo 1) tem como objetivo geral verificar as possíveis diferenças existentes na composição, diversidade e densidade de aves entre áreas sob dois tipos de uso do solo. Os resultados parciais desde artigo foram apresentados na forma de pôster no XX Congresso Brasileiro de Ornitologia, que foi realizado em novembro de 2013, em Passo Fundo-RS. O artigo está no formato apropriado para ser submetido no periódico *The Condor: Ornithological Applications*.

Já o segundo artigo (Capítulo 2) tem como objetivo principal identificar os padrões de uso do habitat pelas espécies de aves campestres, através da avaliação da riqueza e abundância das mesmas em paisagens compostas por campos naturais e de soja. Os resultados desde artigo serão apresentados na forma de pôster no XXX Congresso Brasileiro de Zoologia, que será realizado em fevereiro de 2014, em Porto Alegre-RS. O artigo está no formato apropriado para ser publicado no periódico *Journal of Field Ornithology*.

As conclusões gerais desta dissertação estão inseridas após o Capítulo 2, na página 81. Ao final, é apresentado o mapa de localização da ecoregião da Savana Uruguaia, além de algumas imagens das áreas de estudo e espécies de aves registradas nas mesmas.

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CAPÍTULO 1

Estrutura da assembleia de aves em dois tipos de uso do solo na ecoregião da Savana Uruguaia

Artigo a ser submetido para publicação no periódico *The Condor: Ornithological Applications*

Avian assemblages in the Uruguayan savanna ecoregion

RESEARCH ARTICLE

Structure of avian assemblages in two land use types in the Uruguayan savanna ecoregion

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ABSTRACT

Conversion of the grasslands into crops is one of the major factors leading to the decline of grassland's birds. Areas under agriculture generally hold only more generalist species. We studied possible differences in the composition, diversity and density of birds in areas under two different land use types: livestock ranching under semi-natural grasslands and soybean with patches of grassland. We evaluate possible changes in the structure of the avian community and our results demonstrated that areas with soybean have lower bird's species richness than semi-

natural grasslands. Regarding species' densities, most of the birds showed higher density in areas of semi-natural grassland and species more common and habitat-generalists were more abundant in soybean fields. For species composition, the two types of land use were clearly separated: in semi-natural grassland the species typical of grasslands and soybean sites species that are benefited by crops. Among species classified as near threatened or threatened, either regionally or globally, all had higher density on semi-natural grassland sites, showing the importance of maintaining these areas. Better agricultural management practices coupled with policies that make agricultural production less harmful to the biodiversity should be developed, since the maintenance of grasslands' birds in soybean fields is related to the presence of semi-natural grassland patches amid soybean crops.
Keywords: agriculture, bird density, conservation, composition, grasslands, soybean

Estrutura da assembleia de aves em dois tipos de uso do solo na ecoregião da Savana Uruguaia

RESUMO

A conversão dos campos naturais em cultivos agrícolas é um dos fatores que impactam a densidade de aves campestres. Áreas de agricultura, em geral, comportam mais espécies generalistas. Nesse estudo, avaliamos possíveis diferenças na composição, diversidade e densidade de aves entre áreas sob dois diferentes usos do solo (campo semi-natural e plantação de soja com manchas de campo). Utilizamos o método de pontos de contagem para amostrar as aves. As áreas de soja apresentaram uma menor riqueza de espécies e a maioria das espécies de aves foram mais abundantes em áreas de campo nativo. Espécies

comuns e generalistas foram mais abundantes nos campos com soja. Quanto à composição de espécies, os dois tipos de uso do solo foram claramente separados, com espécies características de campos nas áreas de campo semi-natural e espécies beneficiadas pelos cultivos nas áreas de soja. Registramos cinco espécies regional ou globalmente ameaçadas ou quase ameaçadas (*Rhea americana, Athene cunicularia, Cistothorus platensis, Xanthopsar flavus, Xolmis dominicanus*), todas com maior densidade em áreas de campo natural. O desenvolvimento de práticas e políticas de manejo que façam a produção agrícola e pecuária menos prejudiciais à biodiversidade são essenciais, uma vez que a manutenção das aves campestres em campos com soja está relacionada à existência de manchas de campos naturais entre os cultivos.
Palavras-chave: agricultura, densidade de aves, conservação, composição, campos, soja

INTRODUCTION

Agricultural areas are well known to be less diverse than native grasslands, both within and outside protected areas and the species found on agricultural fields are in general more generalist species (Herzon and O'Hara 2007, Codesido et al. 2013). Agricultural intensification is considered as one of the major causes of population decline of grassland's birds worldwide (Chamberlain 2000, Askins et al. 2007, Azpiroz et al. 2012b). Species respond differently to habitat changes, according to characteristics such as life history and plasticity (Filloy and Bellocq 2007, Lemoine et al. 2007).

Agriculture brings a number of changes that affect virtually all aspects and processes of ecosystems, reducing the area of original habitats and transforming landscapes, which can result in few isolated fragments of natural habitats (Gilpin et al. 1992, Baldi and Paruelo 2008, Bilenca et al. 2008, Medan et al. 2011). The conversion of grasslands into crops is one of the most important factors leading to the decline of the grassland's birds and has a strong influence on species' population (With et al. 2008, Derner et al. 2009, Azpiroz et al. 2012b). Crop's production generates adverse effects on the biodiversity, mainly because of the mechanization and use of herbicides and fertilizers, but livestock production also has negative effects (Filloy and Bellocq 2007). Management practices that increase the vegetation heterogeneity tend to be positive for grassland's birds because of the higher variability on the structure and/or composition of vegetation (Derner et al. 2009).

The land use in the Uruguayan savanna ecoregion has been recently changing, and the grasslands' are being replaced by crops, particularly soya and corn during the Austral spring and summer, and exotic pastures (oats and ryegrass) during the Austral fall and winter (Gressler 2008). The significant number of threatened birds and the small representation of those grasslands in protected areas make necessary the development of strategies that try to integrate the agricultural sector and conservation organizations, both governmental and non-governmental, for the conservation of this ecoregion (MMA 2007, Develey et al. 2008). Habitat modification and fragmentation are among the main threats to the grasslands in the Uruguayan savanna ecoregion, and planted pastures increased by 32% between 1980-1990 in Uruguay (Martino 2004). Moreover, almost 16% of the original vegetation of Rio Grande do Sul was replaced from 1976 to 2002, mostly because of the introduction of exotic species for forage (i.e. ryegrass, lovegrass and other species); agricultural activity, mainly soybean and rice, and the increase in use of fertilizers and herbicides; and forestry (i.e. *Eucalyptus* sp. and *Pinus* sp.) (Martino

2004, MMA 2007, Develey et al. 2008, Cordeiro and Hasenack 2009). Moreover, patches of natural grassland without any sort of production, or under low densities of livestock are almost nonexistent in the region.

Our main goal was to investigate the possible differences in bird's species composition, species richness and density in areas under two types of land use: 1) semi-natural grassland used for extensive livestock production and 2) soybean fields with grassland patches. Furthermore, we compared the bird's community structure, looking for possible changes according to the land use. We also analyzed the responses of birds classified as near-threatened and threatened, regionally and globally, to verify the effects of changes in land use on them (Marques et al. 2002, Azpiroz et al. 2012a, IUCN 2013). Finally, we discussed some alternatives aiming the conservation of grassland's birds in the region.

METHODS

Study Area

Our study was conducted in 8 farms in the Uruguayan savanna ecoregion. Four have their areas under soybean fields (S) during the Austral summer, and either wheat (in Uruguay) or ryegrass (in Brazil) during the Austral winter. In all of them there are grassland patches within the crop: in Brazil – Dom Pedrito (31°04'25"S; 54°20'33"W) (90.3% soya and 9.7% grassland) and Santana do Livramento counties (30°56'39"S; 55°24'45"W) (91.5% soya and 8.5% grassland) – state of Rio Grande do Sul, RS; and in Uruguay – Vichadero (31°40'23"S; 54°33'09"W) (82.7% soya and 17.3% grassland) and Melo (32°13'29"S; 54°34'01"W) (89.2% soya and 10.8% grassland) – Department of Rivera-DR and Melo, Department of Cerro Largo-DCL (Figure 1). The other 4 farms are covered with semi-natural grassland (N), and the main activity is extensive livestock (cattle stocking rate/ha: N1 0.96; N2 0.57; N3 0.89; N4 0.75): in Brazil – Dom Pedrito county (30°58’58”S; 54°20’12”W) – RS; and in Uruguay – Rivera (30°58’19”S; 55°26’40”W) and Vichadero (31°40’04”S; 54°31’30”W), DR, and Melo (32°21’03”S; 53°58’54”W), DCL.

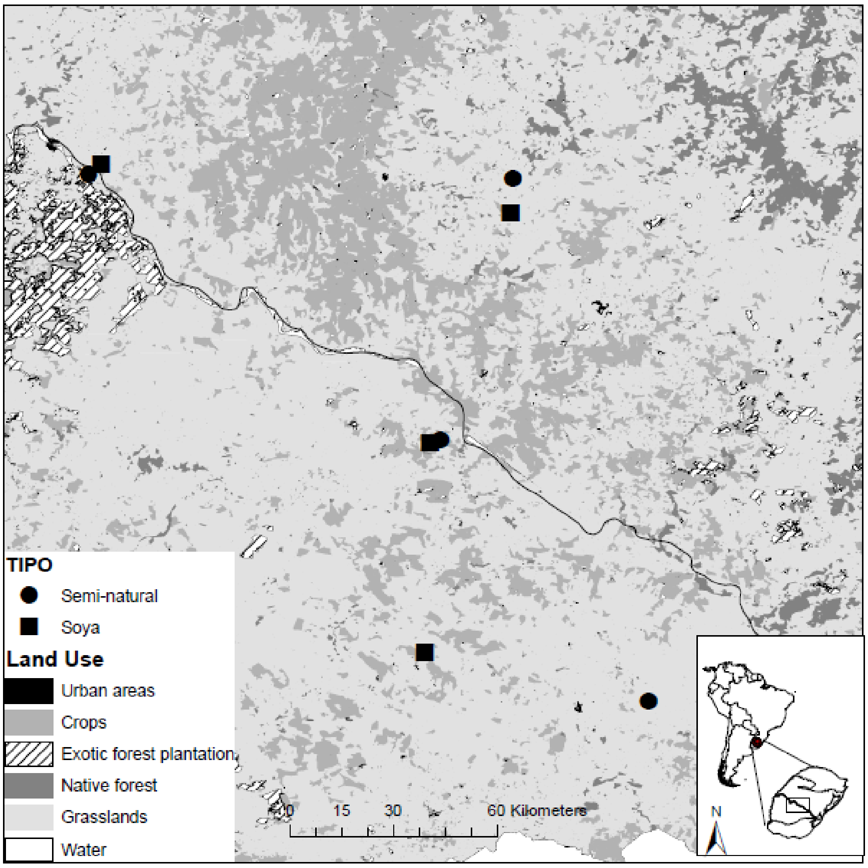

Figure 1. Study sites, according to land use type, in the grasslands of the Uruguayan savanna ecoregion. ‘Semi-natural’ are the semi-natural grassland sites under cattle ranching, and ‘Soya’ the soybean fields.

We choose these sites based on climate characteristics, type of soil (deep soils), and topography ranging from smooth to wavy (from 30 to 400 m a.s.l.) (Hasenack et al. 2010). Soybean fields have he same type of management with tillage of genetically modified seeds and use of glyphosate. The sowing period occur between October and November, with a few later-maturing varieties being planted in December, and harvest begins on late March to April (personal observation TWS and GD).

Bird Sampling

We surveyed each of the 8 sites during the Austral spring-summer, once in 2010-2011 and the second time in 2011-2012. In each site we distributed 20 points systematically, at least 100 meters from the edge, with circular plots and unlimited radius, separated from each other by 300 m. We surveyed birds through 5-minute point counts, through visual and auditory records (Ralph et al. 1995, Bibby et al. 2000). Birds flying were not counted. Surveys started with the species activity in the morning (from 6:00 hr) and last for around four hours. We only carried out surveys in days without wind and/or rain. Distances from the observer were measured with a telemeter. TWS and GD carried out all the surveys.

Statistical Analysis

Species richness. We computed the richness in each site as the total number of species found in all the sampled points. We used Chao 1 estimator of richness, which is based on species abundance, to verify if sampling effort was sufficient (Colwell and Coddington 1994). Chao 1 was calculated with 100 randomizations, using EstimateS 8.2.0 (Colwell 2009). We used ANOVA to test for differences between richness on the different types of land use, with a significance level of $\alpha=0.05$, previously testing for homoscedasticity with a Levene's test. All analyses were performed using R 2.15.2 (R Core Team 2012, package 'car', Fox and Weisberg 2011).

Population densities. We estimated individual species density in each land use using the MCDS (Multiple Covariates Distance Sampling) engine in Distance 6.0 (Thomas et al. 2009). Aquatic, raptors, swallows and swifts species were excluded from the density analyzes because the point-count methods we used is not the most appropriate method for estimate their density. Species with more than 30 observations were analyzed individually (Fritcher et al. 2004). In this case we post-stratified analysis by sample in order to obtain species density in each site. Other species were assigned to 5 groups using characteristics of habitat and conspicuity, in order to achieve the minimum number of observation required to produce a reliable detection function on Distance and, therefore, better estimates of density (Azpiroz and Blake 2009, Phalan et al. 2011 supporting online material). For species analyzed as a group we used the group detection probability function and post-stratified the model by species to obtain each species density in each site. We truncated 10% of the data with the largest distances within each species individually and within each group to avoid double counting of the same individual, as recommended by Buckland et al. (2001). We compared the following models for each species and group: half-normal and hazard-rate with a cosine adjustment, simple polynomial and hermite polynomial adjustment. We chose the model based on the Kolmogorov-Smirnov probability test for goodness of fit and on Cramer-von-Mises uniform and cosine probability test for plausibility, and then compared the AIC (Akaike's Information Criterion) to select the model with the lowest value. Density estimates are shown with 95% confidence intervals. We used ANOVA to check whether there were significant differences in density between land use types, with a significance level of $\alpha=0.05$, previously testing for homoscedasticity with a Levene's test. All analyses were performed using R 2.15.2 (R Core Team 2012, package ‘car’, Fox and Weisberg 2011).

Community composition. We used the number of individuals of each species in each type of land use to graphically represent similarities and differences among them by using a Nonmetric Multidimensional Scaling (NMDS), with the Bray-Curtis index. NMDS is often used to verify which communities are more similar in studies involving several sites (Tejeda-Cruz and Sutherland 2004). For this we used the package ‘vegan’ in R 2.15.2 (R Core Team 2012, Oksanen et al*.* 2012). Aquatic, raptors, swallows and swifts species were also excluded from these analyzes.

RESULTS

Species Richness

We recorded 2,998 individuals from 32 families and 87 species in the two types of land use (Supplemental Material Table S1), 1,453 individuals from 75 species in the semi-natural grassland, and 1,564 individuals from 57 species in soybean. Chao 1 curves indicated that sampling effort was not sufficient for semi-natural grassland sites and probably more species would be found with more effort or complementing surveys with a different method. However, for soybean fields accumulation curve ends to stabilization (Figure 2). Estimated species richness (Chao 1 95% CI) were 67 (60-95) in areas of livestock ranching under semi-natural grasslands and 50 (43-84) in soybean with grassland patches (ANOVA, $F_{1,6}$ = 14.3, P = 0.003).

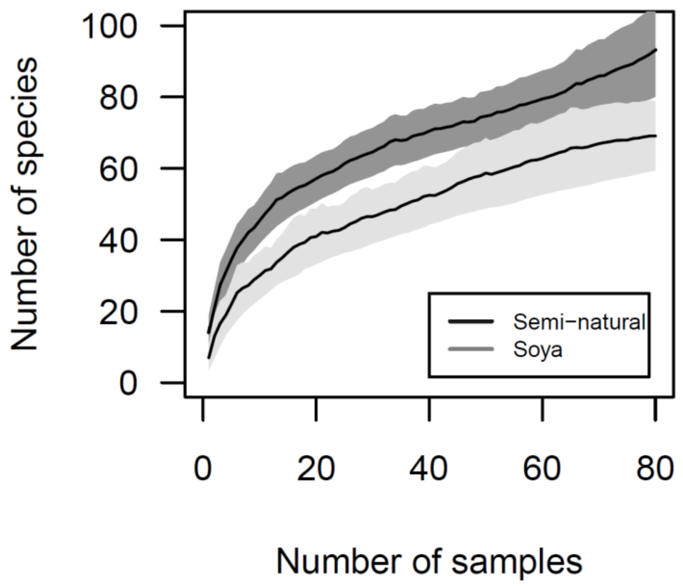

Figure 2. Sample-based bird species accumulation curves with Chao 1 estimator (mean ± 95% CI) for semi-natural grasslands and soybean with grassland patches.

Population Densities

Among the 22 species with enough observations for individual density estimations, 17 had higher densities in semi-natural grassland and 4 in soybean, only 1 species (Grassland Sparrow - *Ammodramus humeralis*) had equal density in both types of land use (Table 1). Moreover, Grassland Yellow-Finch (*Sicalis luteola*) in semi-natural grassland and Eared Dove (*Zenaida auriculata*) had greater density in soybean. Four species had densities significantly higher in semi-natural grassland sites: Plumbeous Ibis (*Theristicus caerulescens*) (ANOVA, $F_{1,6}$ = 6, P = 0.05), Campo Flicker (*Colaptes campestris*) (ANOVA, $F_{1,6}$ = 7.6, P = 0.03), Rufous Hornero (*Furnarius rufus*) (ANOVA, $F_{1,6}$ = 18.3, P = 0.005) and Great Kiskadee (*Pitangus sulphuratus*) (ANOVA, $F_{1,6}$ = 14.8, P = 0.009).

Table 1. Density of birds analyzed individually and 95% Confidence Interval in the two types of land use: soybean with grassland patches (S) and livestock ranching under semi-natural grasslands (N).

	Habitat	
Species	S	N
Greater Rhea *Rhea americana*	0.05	0.01
95% CI	0.011-0.185	0.009-0.043
Red-winged Tinamou *Rhynchotus rufescens*	0.42	0.33
95% CI	0.227-0.77	0.176-0.638
Southern Lapwing *Vanellus chilensis*	0.07	0.16
95% CI	0.032-0.164	0.076-0.335
Picazuro Pigeon *Patagioenas picazuro*	0.01	0.03
95% CI	0.001-0.162	0.003-0.422
Eared Dove *Zenaida auriculata*	1.57	0.06
95% CI	0.673-3.665	0.025-0.121
Guira Cuckoo *Guira guira*	0.01	0.06
95% CI	0.0007-0.130	0.005-0.830
Campo Flicker *Colaptes campestris*	0.01	0.05
95% CI	0.001-0.025	0.023-0.095
Monk Parakeet *Myiopsitta monachus*	0.05	0.07
95% CI	0.010-0.241	0.023-0.187
Rufous Hornero *Furnarius rufus*	0.05	0.31
95% CI	0.022-0.112	0.187-0.523
Firewood-gatherer *Anumbius annumbi*	0.01	0.08
95% CI	0.004-0.041	0.043-0.146

Great Kiskadee *Pitangus sulphuratus*	0.02	0.08
95% CI	0.007-0.038	0.043-0.14
Fork-tailed Flycatcher *Tyrannus savana*	0.19	0.39
95% CI	0.049-0.767	0.103-1.471
Chalk-browed Mockingbird *Mimus saturninus*	0.04	0.06
95% CI	0.010-0.140	0.027-0.143
Hellmayr's Pipit *Anthus hellmayri*	0.07	0.11
95% CI	0.025-0.180	0.048-0.266
Red-crested Cardinal *Paroaria coronata*	0.03	0.07
95% CI	0.015-0.071	0.040-0.13
Grassland Yellow-Finch *Sicalis luteola*	0.27	1.00
95% CI	0.162-0.457	0.736-1.361
Great Pampa-Finch *Embernagra platensis*	0.08	0.18
95% CI	0.035-0.202	0.088-0.351
Rufous-collared Sparrow *Zonotrichia capensis*	0.16	0.49
95% CI	0.079-0.308	0.320-0.759
Grassland Sparrow *Ammodramus humeralis*	0.37	0.37
95% CI	0.226-0.597	0.230-0.607
Brown-and-yellow Marshbird *Pseudoleistes virescens*	0.06	0.20
95% CI	0.012-0.315	0.092-0.432
Shiny Cowbird *Molothrus bonariensis*	0.03	0.15
95% CI	0.009-0.077	0.071-0.327
White-browed Blackbird *Sturnella superciliaris*	0.08	0.07
95% CI	0.042-0.149	0.038-0.14

Species Composition

Two types of land use were clearly separate by the axis NMDS 2 (Figure 3). The Eared Dove was strongly associated with soybean. The semi-natural grasslands are marked by species characteristic of this type of land use – such as the Campo Flicker, the Firewood-gatherer (*Anumbius annumbi*) and the Black-and-white Monjita (*Xolmis dominicanus*). Moreover, there were more species associated to semi-natural grasslands than to soybean fields.

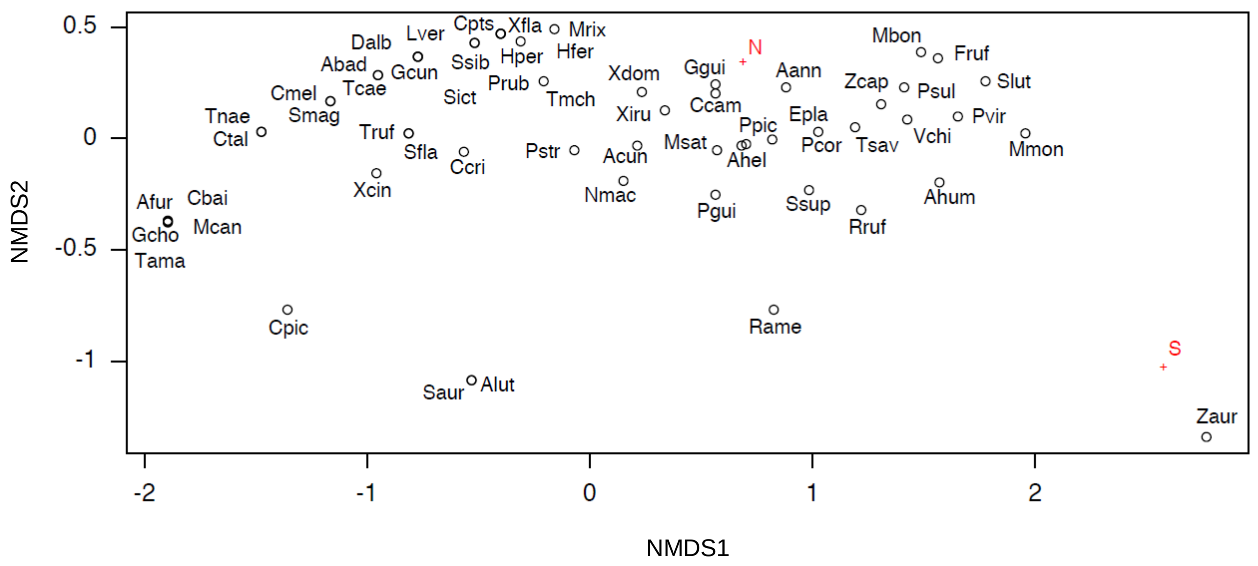

Figure 3. Nonmetric Multidimensional Scaling (NMDS) based on the abundance of species in the two types of land use, using Bray-curtis similarity index. N: semi-natural grasslands, S: soybean fields with grassland patches.

Among species classified in any of the categories of threat or as near-threatened, either regionally or globally, we recorded: Greater Rhea (*Rhea americana*), Burrowing Owl (*Athene cunicularia*), Sedge Wren (*Cistothorus platensis*), Saffron-cowled Blackbird (*Xanthopsar flavus*) and Black-and-white Monjita. The Burrowing Owl, classified as 'near-threatened' in Uruguay, was recorded both in soybean and semi-natural grasslands. The Sedge Wren and the Saffron-cowled Blackbird were recorded only in semi-natural grasslands, and the Black-and-white Monjita was found in both semi-natural grassland and soybean sites.

DISCUSSION

Species Richness

The number of species we found in the soybean fields can be considering high for a crop habitat; however, Azpiroz and Blake (2009) stated that a relatively high number of bird species can be recorded on crop fields provided the management processes, from planting to harvest, generate some differences in the vegetation structure. Nevertheless, many of the bird species are likely to disappear as disappear as time passes – when crops replace the natural habitats and the land use switches from a rich and complex ecosystem to a simpler one, such as soybean monoculture (Blum et al. 2008). The grassland patches in the soybean fields might increase the heterogeneity of vegetation in the site, which varies according to the size of the patches as well as their proximity with continuous natural grassland areas (Gressler 2008).

The presence of some species, such as the Black-and-white Monjita, on the soybean fields can be explained by the occurrence of the grassland patches within the matrices of crop, which may supply areas for foraging. It has been reported that this species, together with Saffron-cowled Blackbird, can be seen on crop fields (Azpiroz and Blake 2009, BirdLife International 2013).

Population Densities

Fifteen out of the 22 species that were analyzed individually are considered representative to the southeastern South America grasslands (Azpiroz et al. 2012b) and make extensive use of grassland's habitats. For instance the Red-winged Tinamou (*Rhunchotus rufescens*) is a grassland specialist usually found on tall grasses and shrubs, but able to survive on pastures and agricultural lands (Stotz et al. 1996, Sick 1997). We found it in three semi-natural grassland sites and in soybean fields that were in the middle stage of development with tall plants that could provide shelter. The Grassland Yellow-Finch was the most abundant species in semi-natural grassland, being found in both wet and dry grasslands, as well as tall grasses (Belton 1984, Sick 1997, Isaach et al. 2005). Among species that had higher density in soya, the Eared Dove is common and considered as a grassland generalist, which benefits from soybean crops being considered as a crop pest (Gavier-Pizarro et al. 2012). We observed this species in large quantities feeding on soybean seeds.

The density of both Rufous Hornero and Great Kiskadee were higher in the semi-natural sites. In spite of the fact that both species are considered usually common and abundant, occurring in several habitats, the semi-natural grasslands have a greater abundance of resources than the soybean fields, such as food and shelter. The other two species that had higher densities on semi-natural grasslands, Campo Flicker and Plumbeous Ibis, are more dependent to open habitats, with the first occurring seasonally in wetland, grassland and pastures (Stotz et al. 1996) and the latter in moist or flooded pastureland, as well as marshes and swamps (Belton 1994, BirdLife International 2013).

Threatened species were exclusive to or had greater densities in semi-natural grassland sites, except by the Greater Rhea. It is an omnivorous species and during our survey on soybean fields, we observed a significant amount of soybean seeds, which might be being used for foraging, since soybean producers reported Greater Rhea feeding on soybean shoots in the study region.

Species Composition

Monocultures are reported as affecting key factors in determining the community of birds in an area, such as reducing areas for nest building, food supply, and shelter (Azpiroz and Blake 2009). Di Giacomo and Casanave (2010) found evidence of difference on birds' species composition between crop fields (soybean and alfafa) and natural grasslands, in Argentina. The differences were mainly because of a reduction in food supply and nesting availability on the crops. In the Pampas region of Argentina many bird species were found to be tolerant to changes on land use, from natural grassland to crops, while others were sensitive to the intensity of land use and its changes over the time (Filloy and Bellocq 2007). Our study agree with Di Giacomo and Casanave (2010) and Filloy and Bellocq (2007), and the results pointed out that replacing the natural habitat with crops could be more harmful for the bird community than using the grassland for livestock production; in the condition that ranching is under natural vegetation and cattle management respects the animal stock limits for the region. Moreover, bird's communities are likely to be more homogeneous in crops fields than in more complex habitats such as natural grasslands (Hsu et al. 2010).

Turning to species of conservation interest, the Greater Rhea, globally considered as 'near threatened', experienced a strong population decline in southern

Brazil caused by hunting and the advance of soybean, corn and wheat monocultures (BirdLife International 2013, IUCN 2013). The Burrowing Owl is considered as ‘near threatened’ in Uruguay and, even that it is still common in the region, their populations are decreasing due to alteration of land use and fragmentation of the natural grasslands, mainly because of the increase of eucalypt plantations (Azpiroz et al. 2012a).

The Sedge Wren is considered ‘endangered’ in Rio Grande do Sul and ‘vulnerable’ in Uruguay, and is associated with habitats on wet or saturated soils that are easily drained or grounded. It is considered sensitive to crops and pastures that replace the natural grassland (Bencke et al. 2003, Azpiroz et al. 2012a). It was recorded only in one area of semi-natural grassland, reinforcing the importance of maintaining the grasslands to guarantee its survival on the region. Both the Saffron-cowled Blackbird and the Black-and-white Monjita are considered ‘vulnerable’, regionally and globally, and their populations have been declining mainly due to natural habitat destruction and alteration of land use (Bencke et al. 2003, Azpiroz et al. 2012a, IUCN 2013). The fact that the Black-and-white Monjita was recorded in soybean fields might be related with several factors: 1) the soybean in the site the species was observed is relatively recent, and our bird’s surveys were carried out on the second year of cultivation; 2) soybean can provide availability of food for insectivorous species, such as the Black-and-white Monjita; and 3) the grassland patches might facilitate the persistence of the species in the crop during the feeding periods. It is important to notice that a couple and a young individual of the species were observed for more than once in a semi-natural grassland area neighboring the soybean field. On the other hand, Azpiroz and Blake (2009) recorded the Black-and-white Monjita only in crop areas in a study carried out in Paysandú and Salto, and

Gressler (2008) observed the same species in areas adjacent to corn crops. These facts open perspectives for new studies about the biology of the species, to understand how they use these agricultural landscapes and to provide subsidies for proposals to the management and conservation of the species.

Habitat conservation extends protection to all other species typical of the grasslands that were not found in our study but are certainly present in the ecoregion of the Uruguayan savanna, such as the Bearded Tachuri (*Polystictus pectoralis*), the Sharp-tailed Tyrant (*Culicivora caudacuta*) and the Seedeaters (*Sporophila* sp.) (Azpiroz et al. 2012b).

Implications for Conservation

As expected, livestock ranching under semi-natural grasslands had the higher species richness, and also supported more species considered representative to the southeastern South America grasslands defined according to Azpiroz et al. (2012b). Some species that had higher densities on soybean fields were generalist species, common to several habitat types and not restricted to grasslands. The expansion of cultivated fields on the grasslands is likely to result in changes in the distribution and patterns of abundance of bird species, as well as adversely affect species restricted to natural grassland (Azpiroz and Blake 2009, Codesido et al. 2011). The replacement of natural grassland by crops leads to a homogenization of the landscape and, as consequence, to a change in the bird's community in the region; however, the levels of change will depend of both species' sensitivity and plasticity to the new landscape (Filloy and Bellocq 2007).

Both food production and the provision of ecosystem services and conservation of biodiversity rely on almost the same area in the grasslands of the

Uruguayan savanna ecoregion. Therefore, further studies should focus on the elaboration of manuals of best management practices that are able to combine production targets and the environmental conservation in the region (Bilenca et al. 2008). Conservation practices and production management in this region should be considered together, and discussed among farmers, conservationists, and government agencies, and should include: 1) implementation of protected areas; 2) sustainable use of the grasslands; 3) performing research on breeding biology, distribution, and population viability of grassland's birds that are under pressure by the increase of crops in their natural habitats; and 4) preservation of natural grassland patches within the soybean fields and other crops.

We concluded that there is one major aspect to take into consideration regarding grassland's birds and crop fields: it is important to maintain the grassland patches within crop fields, since they can still hold some bird species and might be important to guarantee a more heterogeneous landscape, i.e. maintaining a landscape with different types of land use and resources for the species (landscape complementation) (Dunning et al. 1992). We may interpret our results as a first step in a range of research that is still needed to understand the factors that allow the permanence of grassland's birds in crops with grassland patches.

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SUPPLEMENTAL MATERIAL

Table S1. Number of individuals and species sampled in the two types of land use of the Uruguayan savanna ecoregion, including aquatic, raptors, swallows, and swifts species. S: soybean with grassland patches, and N: livestock ranching under semi-natural grasslands.

	Habitat	
Family/species	S	N
Rheidae		
Greater Rhea *Rhea americana*	40	6
Tinamidae		
Red-winged Tinamou *Rhynchotus rufescens*	47	33
Spotted Nothura *Nothura maculosa*	10	9
Anhimidae		
Southern Screamer *Chauna torquata*	6	5
Anatidae		
White-faced Whistling-Duck *Dendrocygna viduata*	4	0
Brazilian Teal *Amazonetta brasiliensis*	12	0
Silver Teal *Anas versicolor*	7	0
Masked Duck *Nomonyx dominicus*	20	0
Ciconiidae		
Wood Stork *Mycteria americana*	0	1
Ardeidae		
Cocoi Heron *Ardea cocoi*	1	0
Great Egret *Ardea alba*	1	1

Whistling Heron *Syrigma sibilatrix*	0	5
Snowy Egret *Egretta thula*	1	0
Threskiornithidae		
White-faced Ibis *Plegadis chihi*	0	3
Bare-faced Ibis *Phimosus infuscatus*	3	0
Plumbeous Ibis *Theristicus caerulescens*	0	4
Cathartidae		
Turkey Vulture *Cathartes aura*	5	7
Lesser Yellow-headed Vulture *Cathartes burrovianus*	0	2
Black Vulture *Coragyps atratus*	0	1
Accipitridae		
White-tailed Kite *Elanus leucurus*	1	0
Savanna Hawk *Buteogallus meridionalis*	1	1
Rallidae		
Common Gallinule *Gallinula galeata*	1	0
White-winged Coot *Fulica leucoptera*	22	0
Charadriidae		
Southern Lapwing *Vanellus chilensis*	79	53
Recurvirostridae		
Black-necked Stilt *Himantopus mexicanus*	18	0
Scolopacidae		
Baird's Sandpiper *Calidris bairdii*	0	1
Columbidae		
Ruddy Ground Dove *Columbina talpacoti*	0	2
Picui Ground Dove *Columbina picui*	1	1

Picazuro Pigeon *Patagioenas picazuro*	13	24
Eared Dove *Zenaida auriculata*	868	26
White-tipped Dove *Leptotila verreauxi*	0	5
Cuculidae		
Guira Cuckoo *Guira guira*	4	27
Striped Cuckoo *Tapera naevia*	0	2
Strigidae		
Burrowing Owl *Athene cunicularia*	7	13
Alcedinidae		
Green Kingfisher *Chloroceryle americana*	0	1
Picidae		
White Woodpecker *Melanerpes candidus*	0	1
Green-barred Woodpecker *Colaptes melanochloros*	0	3
Campo Flicker *Colaptes campestris*	5	26
Cariamidae		
Red-legged Seriema *Cariama cristata*	2	5
Falconidae		
Southern Caracara *Caracara plancus*	2	1
Yellow-headed Caracara *Milvago chimachima*	2	4
Chimango Caracara *Milvago chimango*	2	4
American Kestrel *Falco sparverius*	6	20
Psittacidae		
Monk Parakeet *Myiopsitta monachus*	86	113
Furnariidae		
Common Miner *Geositta cunicularia*	0	4

Rufous Hornero *Furnarius rufus*	18	103
Freckle-breasted Thornbird *Phacellodomus striaticollis*	5	9
Firewood-gatherer *Anumbius annumbi*	9	38
Tyrannidae		
Cliff Flycatcher *Hirundinea ferruginea*	0	9
Vermilion Flycatcher *Pyrocephalus rubinus*	0	8
Spectacled Tyrant *Hymenops perspicillatus*	0	8
Yellow-browed Tyrant *Satrapa icterophrys*	0	7
Gray Monjita *Xolmis cinereus*	1	3
White Monjita *Xolmis irupero*	4	19
Black-and-white Monjita *Xolmis dominicanus*	3	17
Cattle Tyrant *Machetornis rixosa*	0	11
Great Kiskadee *Pitangus sulphuratus*	20	78
Tropical Kingbird *Tyrannus melancholicus*	1	10
Fork-tailed Flycatcher *Tyrannus savana*	22	51
Hirundinidae		
Blue-and-white Swallow *Pygochelidon cyanoleuca*	0	7
Brown-chested Martin *Progne tapera*	13	7
Gray-breasted Martin *Progne chalybea*	2	5
White-rumped Swallow *Tachycineta leucorrhoa*	0	2
Cliff Swallow *Petrochelidon pyrrhonota*	0	1
Troglodytidae		
Sedge Wren *Cistothorus platensis*	0	7
Turdidae		
Rufous-bellied Thrush *Turdus rufiventris*	1	4

Creamy-bellied Thrush *Turdus amaurochalinus*	0	1
Mimidae		
Chalk-browed Mockingbird *Mimus saturninus*	12	20
Motacillidae		
Yellowish Pipit *Anthus lutescens*	4	1
Short-billed Pipit *Anthus furcatus*	0	1
Hellmayr's Pipit *Anthus hellmayri*	13	23
Thraupidae		
Red-crested Cardinal *Paroaria coronata*	18	39
Long-tailed Reed Finch *Donacospiza albifrons*	0	5
Saffron Finch *Sicalis flaveola*	1	4
Grassland Yellow-Finch *Sicalis luteola*	35	126
Great Pampa-Finch *Embernagra platensis*	15	29
Incertae sedis		
Golden-billed Saltator *Saltator aurantiirostris**	4	1
Emberizidae		
Rufous-collared Sparrow *Zonotrichia capensis*	20	63
Grassland Sparrow *Ammodramus humeralis*	63	58
Icteridae		
Chopi Blackbird *Gnorimopsar chopi*	0	1
Saffron-cowled Blackbird *Xanthopsar flavus*	0	8
Yellow-rumped Marshbird *Pseudoleistes guirahuro*	18	14
Brown-and-yellow Marshbird *Pseudoleistes virescens*	39	95
Bay-winged Cowbird *Agelaioides badius*	0	4
Shiny Cowbird *Molothrus bonariensis*	15	96

White-browed Blackbird *Sturnella superciliaris*	30	26
Fringillidae		
Hooded Siskin *Sporagra magellanica*	0	3

*Formerly placed in the Thraupidae family.

CAPÍTULO 2

Uso do habitat por aves campestres em campos naturais e cultivos de soja no sul do Brasil e Uruguai

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Habitat use by grassland birds in natural and soybean fields in southern Brazil and Uruguay

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Abstract

The habitat use of grassland's birds has been affected by livestock production and the replacement of natural grassland by crops. Although some generalist species may be benefited by such changes, habitat alteration is detrimental to populations of the most sensitive species. In this study, we investigated the patterns of habitat use by grassland's birds through assessment of their richness and abundance in a landscape composed by semi-natural habitat and agricultural fields. We sampled grassland birds in 160 100-m radius point counts: 80 in semi-natural grassland dominated landscape, and 80 in soybean fields with grassland patches. Adding a 100-m radius buffer, we classified vegetation coverage according to three classes of land use: grasslands, wet grasslands and soybean fields. We used a GLMM to analyze both occurrence and abundance of grassland birds found in the study area. Among the 31 species recorded, 12 had enough number of observations and could be analyzed. Seven of them showed a significant response to the Grasslands and/or Wet Grasslands cover. Over 60% of the records and the total number of individuals of all species were observed in those points in which the buffers were composed by at least 90% of semi-natural grasslands. Five species recorded are of conservation concern. Most of the grassland bird species preferred sites with increase natural grassland cover and no species used soybean fields primarily. Research at the landscape scale and a better understanding of the responses of grassland's birds to habitat modification are still needed to help establishing conservation practices aiming the maintenance of natural grasslands and its avifauna in southern Brazil and Uruguay.

Keywords: abundance, conservation, grassland changes, richness, wet grasslands

Habitat use, as well as habitat occupancy, is the way an individual or population uses biological and physical resources in the habitat (Krausman 1999, Fuller 2012). Suitable nest sites within local patches of natural habitat and foraging habitats in the surrounding landscape are some factors that determine the habitat use of grassland's birds (Söderström and Pärt 2000). Habitats with greater vegetation diversity support more specialized species, and increase the individual species' abundances (Pickett and Siriwardena 2011). In addition, the use of agricultural fields by grassland's birds depend on the matrix surrounding the crops (Best et al. 2001). Moreover, livestock can influence the availability of resources for a range of organisms by inducing changes in the vegetation structure (Derner et al. 2009).

The South American grasslands and habitat requirements of many bird species are still poorly studied when it comes to the consequences of habitat modification and bird's communities in the landscape level, particularly when compared to North American and European grasslands (Vickery et al. 1999, Cerezo et al. 2011). Beyond fragmentation, synergistic effects, such as limited food supply by pesticide use, should also be considered in the evaluation of grassland's bird's populations decline along with investigations of habitat use requirements (Söderström and Pärt 2000). Moreover, the ratio of remaining patches of natural habitats to the landscape scale may be the main factor influencing the persistence of some birds' populations in the grasslands (Cerezo et al. 2011).

Changes in the land use of natural grasslands influence on bird's populations, and fragmentation caused by those land use changes may limit some habitat specialist species, strongly affecting bird's communities that occur in the grasslands (Filloy and Bellocq 2007, Cerezo et al. 2011). Total species richness in agricultural mosaics is influenced by the presence of native vegetation in its surroundings (Haslem and Bennett 2008). Therefore, the size of the patches of natural grassland as well as the conservation state of the habitat surrounding the fragment amid crops can influence the density and occurrence of many bird species (Johnson 2001, Haslem and Bennett 2008).

Our goal was to investigate the patterns of habitat use by grassland's birds through assessment of species presence/absence and abundance in a landscape composed by natural and agricultural fields. A better understanding of habitat use by grassland's birds is required to provide information about the impact of agriculture on the grassland's avifauna of southern Brazil and Uruguay.

Methods

Study area

We conducted our study in eight private farms in southern Brazil and northern Uruguay. Four farms had their areas under soybean fields with patches of natural grasslands, and were located in the municipalities of Dom Pedrito (31°04'25"S; 54°20'33"W) and Santana do Livramento (30°56'39"S; 55°24'45"W), both in the state of Rio Grande do Sul, Brazil, and Vichadero (31°40'23"S; 54°33'09"W) and Melo (32°13'29"S; 54°34'01"W). The last two farms were located respectively in the Departments of Rivera (DR) and Cerro Largo (DCL), in Uruguay. The other four farms were covered with semi-natural grasslands, and the main economic activity was extensive cattle ranching: in Brazil, Dom Pedrito (30°58'58"S; 54°20'12"W) and in Uruguay, DR (30°58'19"S; 55°26'40"W and 31°40'04"S; 54°31'30"W), and DCL (32°21'03"S; 53°58'54"W) (map available in Chapter 1, section 'Methods').

Bird sampling

We conducted sampling of birds during the Austral spring-summer (from October to March), in 2010-2011 and in 2011-2012. We systematically distributed 20 points, separated from each other by 300 m in each of the eight areas. We conducted census in all 20 points in each of the eight areas (160 points), and surveyed bird species through 5-min point counts (Ralph et al. 1995). We recorded birds associated with grasslands in Southeastern South America, following Azpiroz et al. (2012b), within a radius of 100 m. Two of us, TWS and GD carried out all the surveys. We did not count birds on flight. Aquatic, raptors, swallows and swifts species were not used in the analysis.

Description of land uses

To evaluate habitat use we calculated the proportion of vegetation cover types in every point by adding a buffer of 100-m radius. The size of the buffer was based on the mean territory size of grassland's bird species in the region during the breeding season (usually less than 2 ha) (Söderström and Pärt 2000). First, we obtained satellite images from 2010 and 2011 using Quantum GIS 1.8.0, with the complement Bing Aerial Layer, except for the semi-natural grassland site in Melo for which we used Google Satellite Layer. Then, we drew the buffers and polygons of type of land use in each point, using a 1:20 000 scale screen in Quantum GIS 1.8.0. Finally, we classified land use into three classes and calculated the percentages of each class for each buffer. Land use types defined were: 1) Grasslands: Grassland sites with little or none woody vegetation; 2) Wet Grasslands: Wetland habitats, tall grass, vegetation more dense; 3) Soybean: Crops are planted in the period between October and beginning of December (depending on the variety used) and harvest begins in late March, management is done with tillage of genetically modified seeds and use of glyphosate (Table 1). In some points there were also forest patches and human-made ponds, which were not included in the analysis because their percentage was not representative in the buffers, representing only between 4-8% of the total points (160). We excluded one point because it contained vines as part of the vegetation cover.

Table 1. Percentage of the five land use types in four soybean fields and four semi-natural grassland sites sampled in Southern Brazil and Northern Uruguay.

Land use	Semi-natural grasslands	Soybean fields
NGR	69.64%	3.11%
WGR	28.70%	8.94%
SOY	0%	86.67%
FOR	1.48%	1.03%
WAT	0.18%	0.25%

Statistical analysis

To test the relationships between the presence/absence and abundance of grassland's birds to the vegetation cover in the buffers we fitted general linear mixed models (GLMM) using the function 'lmer' in 'lme4' R package (Bates et al. 2012, R Core Team 2012). We included only 12 out of the 31 bird's species recorded on the study sites in the GLMM analysis, as they did not have sufficient records to enable modeling (less than 17 occurrences). We created models of the binomial family when the response variable was presence (1) or absence (0) of the species in the buffers, and models of the Poisson family when the response variable was abundance, i.e. the number of individuals counted during the 5-min surveys on each point. We use the functions 'panel' and 'corvif' in the package 'AED' of R (Zuur et al. 2009, R Core Team 2012) to check, respectively, the correlation between the variables and to detect collinearity. Grasslands and Soybean classes were highly negatively correlated (r = -0.83), therefore we chose to use only Grasslands. Thus, we only used two fixed effect variables in the models (Grasslands and Wet Grasslands). To control for non-independence of the data, as we had 20 points in each site, we used the variable "Area identification" as the random effect in all models. We selected models by dropping the less significant variable in the full model, and then comparing models using 'anova' command (Zuur et al. 2009). All analysis were performed using R 2.15.2 (R Core Team 2012), at significance level of α=0.05.

Results

We recorded 31 grassland bird species in the 159 point counts sampled, 30 species in semi-natural grassland sites and 24 in soybean fields (Table 2). Seven species were recorded only in the semi-natural grassland sites – Common Miner (*Geositta cunicularia*), Spectacled Tyrant (*Hymenops perspicillatus*), Cattle Tyrant (*Machetornis rixosa*), Sedge Wren (*Cistothorus platensis*), Short-billed Pipit (*Anthus furcatus*), Long-tailed Reed Finch (*Donacospiza albifrons*) and Saffron-cowled Blackbird (*Xanthopsar flavus*) - and only one species were exclusive of soybean sites – Red-legged Seriema (*Cariama cristata*). Five of the recorded species are classified as threatened or near-threatened, according to the Red List of IUCN (IUCN 2013), and the Red Lists of Rio Grande do Sul (Marques et al. 2002) and Uruguay (Azpiroz et al. 2012a): Greater Rhea (*Rhea americana*; 'Near Threatened' globally), Burrowing Owl (*Athene cunicularia*; 'Near Threatened' in Uruguay), Sedge Wren ('Endangered' in Rio Grande do Sul and 'Vulnerable' in Uruguay), Black-and-white Monjita (*Xolmis dominicanus*) and Saffron-cowled Blackbird (both 'Vulnerable' regionally and globally).

Table 2. Grassland bird species sampled in the eight study sites in Southern Brazil and Northern Uruguay, during the spring and summer, from 2010 to 2012. SOY: sites of soybean with grassland patches. GRA: farms of semi-natural grassland.

Family/species	Habitat
Rheidae	
Greater Rhea *Rhea americana**	SOY/GRA
Tinamidae	
Red-winged Tinamou *Rhynchotus rufescens*	SOY/GRA
Spotted Nothura *Nothura maculosa*	SOY/GRA
Charadriidae	
Southern Lapwing *Vanellus chilensis*	SOY/GRA
Strigidae	
Burrowing Owl *Athene cunicularia**	SOY/GRA
Picidae	
Campo Flicker *Colaptes campestris*	SOY/GRA
Cariamidae	
Red-legged Seriema *Cariama cristata*	SOY
Furnariidae	
Common Miner *Geositta cunicularia*	GRA

Rufous Hornero *Furnarius rufus*	SOY/GRA
Freckle-breasted Thornbird *Phacellodomus striaticollis*	SOY/GRA
Firewood-gatherer *Anumbius annumbi*	SOY/GRA
Tyrannidae	
Spectacled Tyrant *Hymenops perspicillatus*	GRA
Gray Monjita *Xolmis cinereus*	SOY/GRA
White Monjita *Xolmis irupero*	SOY/GRA
Black-and-white Monjita *Xolmis dominicanus**	SOY/GRA
Cattle Tyrant *Machetornis rixosa*	GRA
Fork-tailed Flycatcher *Tyrannus savana*	SOY/GRA
Troglodytidae	
Sedge Wren *Cistothorus platensis**	GRA
Mimidae	
Chalk-browed Mockingbird *Mimus saturninus*	SOY/GRA
Motacillidae	
Yellowish Pipit *Anthus lutescens*	SOY/GRA
Short-billed Pipit *Anthus furcatus*	GRA
Hellmayr's Pipit *Anthus hellmayri*	SOY/GRA
Thraupidae	
Long-tailed Reed Finch *Donacospiza albifrons*	GRA
Grassland Yellow-Finch *Sicalis luteola*	SOY/GRA
Great Pampa-Finch *Embernagra platensis*	SOY/GRA
Emberizidae	
Grassland Sparrow *Ammodramus humeralis*	SOY/GRA
Icteridae	

Saffron-cowled Blackbird *Xanthopsar flavus**	GRA
Yellow-rumped Marshbird *Pseudoleistes guirahuro*	SOY/GRA
Brown-and-yellow Marshbird *Pseudoleistes virescens*	SOY/GRA
Shiny Cowbird *Molothrus bonariensis*	SOY/GRA
White-browed Blackbird *Sturnella superciliaris*	SOY/GRA

* Asterisks indicate those species classified as threatened or near-threatened according to global and local red lists.

The Grassland Yellow-Finch (*Sicalis luteola*) was the most abundant species in all points (158 individuals) and in the semi-natural grassland sites (125 individuals). The Grassland Sparrow (*Ammodramus humeralis*) was the species recorded in more points (81) and it was the most abundant species in soybean sites (59 individuals). Of the 12 species analyzed with GLMM, seven showed significant response to the variables tested (Grasslands and/or Wet Grasslands): Southern Lapwing (*Vanellus chilensis*), Rufous Hornero (*Furnarius rufus*), Firewood-gatherer (*Anumbius annumbi*), Fork-tailed Flycatcher (*Tyrannus savana*), Grassland Yellow-Finch, Great Pampa-Finch (*Embernagra platensis*) and Shiny Cowbird (*Molothrus bonariensis*) (Table 3). Additionally, the Grassland Sparrow showed a trend towards habitats with higher incidence of Wet Grasslands. The remaining four species showed no preference for habitat use: Red-winged Tinamou (*Rhynchotus rufescens*), Spotted Nothura (*Nothura maculosa*), Hellmayr’s Pipit (*Anthus hellmayri*) and White-browed Blackbird (*Sturnella superciliaris*).

Table 3. Results of the generalized linear mixed models created to test the relationships between the occurrence (Presence/Absence) and abundance of grassland's bird species to the composition of the habitats in eight study sites in Southern Brazil and Northern Uruguay, during the spring and summer, from 2010 to 2012.

Species models	Estimate (SE)[a]	Z value	p[b]
Red-winged Tinamou (60 observations)			
Presence/Absence			
Intercept	-0.489 (0.886)	-0.552	0.581
Wet Grasslands	0.088 (1.218)	0.073	0.942
Semi-natural Grasslands	-1.251 (1.158)	-1.080	0.280
Abundance			
Intercept	-1.137 (0.595)	-1.912	0.056
Wet Grasslands	-0.015 (0.777)	-0.019	0.985
Semi-natural Grasslands	-0.326 (0.748)	-0.436	0.663
Spotted Nothura (17 observations)			
Presence/Absence			
Intercept	-2.330 (0.438)	-5.319	> 0.001
Wet Grasslands	0.548 (1.008)	0.544	0.587
Semi-natural Grasslands	0.261 (0.655)	0.398	0.690
Abundance			
Intercept	-2.344 (0.400)	-5.859	> 0.001
Wet Grasslands	0.616 (0.892)	0.691	0.489
Semi-natural Grasslands	0.104 (0.612)	0.171	0.864
Southern Lapwing (29 observations)			

Presence/Absence			
Intercept	-1.859 (0.433)	-4.299	> 0.001
Wet Grasslands	0.210 (0.934)	0.224	0.822
Semi-natural Grasslands	0.679 (0.621)	1.094	0.274
Abundance			
Intercept	-2.178 (0.460)	-4.732	> 0.001
Semi-natural Grasslands	1.901 (0.546)	3.482	**> 0.001**
Rufous Hornero (38 observations)			
Presence/Absence			
Intercept	-3.098 (0.543)	-5.704	> 0.001
Wet Grasslands	3.668 (0.861)	4.259	**> 0.001**
Semi-natural Grasslands	2.383 (0.635)	3.750	**> 0.001**
Abundance			
Intercept	-2.063 (0.452)	-4.560	> 0.001
Wet Grasslands	2.203 (0.626)	3.521	**> 0.001**
Semi-natural Grasslands	1.384 (0.576)	2.405	**0.016**
Firewood-gatherer (20 observations)			
Presence/Absence			
Intercept	-3.877 (0.875)	-4.431	> 0.001
Wet Grasslands	2.893 (1.235)	2.343	**0.019**
Semi-natural Grasslands	2.273 (1.032)	2.203	**0.028**
Abundance			
Intercept	-3.935 (0.908)	-4.335	> 0.001
Wet Grasslands	2.407 (1.167)	2.063	**0.039**
Semi-natural Grasslands	2.624 (1.048)	2.503	**0.012**

Fork-tailed Flycatcher (33 observations)			
Presence/Absence			
Intercept	-2.073 (0.330)	-6.283	> 0.001
Semi-natural Grasslands	1.671 (0.506)	3.304	**0.001**
Abundance			
Intercept	-1.852 (0.292)	-6.338	> 0.001
Semi-natural Grasslands	1.354 (0.425)	3.186	**0.001**
Hellmayr's Pipit (25 observations)			
Presence/Absence			
Intercept	-2.576 (0.814)	-3.165	0.002
Wet Grasslands	1.530 (1.257)	1.217	0.224
Semi-natural Grasslands	0.289 (1.108)	0.261	0.794
Abundance			
Intercept	-2.134 (0.759)	-2.810	0.005
Wet Grasslands	0.474 (1.078)	0.440	0.660
Semi-natural Grasslands	-0.251 (1.002)	-0.250	0.802
Grassland Yellow-Finch (63 observations)			
Presence/Absence			
Intercept	-1.240 (0.574)	-2.161	0.031
Wet Grasslands	3.079 (1.028)	2.995	**0.003**
Abundance			
Intercept	-0.810 (0.446)	-1.819	0.069
Wet Grasslands	1.083 (0.325)	3.336	**0.001**
Great Pampa-Finch (29 observations)			
Presence/Absence			

Intercept	-3.920 (0.900)	-4.354	> 0.001
Wet Grasslands	5.981 (1.359)	4.403	**> 0.001**
Abundance			
Intercept	-3.286 (0.661)	-4.968	> 0.001
Wet Grasslands	3.961 (0.751)	5.272	**> 0.001**
Grassland Sparrow (81 observations)			
Presence/Absence			
Intercept	-0.276 (0.468)	-0.589	0.556
Wet Grasslands	1.565 (0.896)	1.746	0.081
Abundance			
Intercept	-0.607 (0.326)	-1.862	0.063
Wet Grasslands	0.645 (0.514)	1.257	0.209
Semi-natural Grasslands	0.106 (0.462)	0.230	0.818
Shiny Cowbird (21 observations)			
Presence/Absence			
Intercept	-3.246 (0.686)	-4.729	> 0.001
Wet Grasslands	2.895 (1.105)	2.620	**0.009**
Abundance			
Intercept	-2.870 (0.682)	-4.210	> 0.001
Wet Grasslands	2.694 (0.545)	4.945	**> 0.001**
White-browed Blackbird (23 observations)			
Presence/Absence			
Intercept	-3.136 (1.350)	-2.323	0.020
Wet Grasslands	-1.343 (1.941)	-0.692	0.489
Semi-natural Grasslands	0.110 (1.716)	0.064	0.949

Abundance			
Intercept	-3.850 (1.210)	-3.182	0.001
Wet Grasslands	1.025 (1.098)	0.934	0.350
Semi-natural Grasslands	0.978 (1.060)	0.923	0.356

[a] The significant P-values are highlighted in bold.

[b] SE: Standard Error.

Grouping all the grassland's bird species recorded in the 159 point counts, over 60% of the records of occurrence and the total number of individuals of all species was in those points presenting at least 90% of semi-natural grasslands, i.e. Grasslands and Wet Grasslands (Fig. 1). Moreover, the presence/absence and abundance of bird species increased according to the increase in percentage of semi-natural grassland. We observed the same pattern for the six grassland's bird species more abundant in the region (Fig. 2).

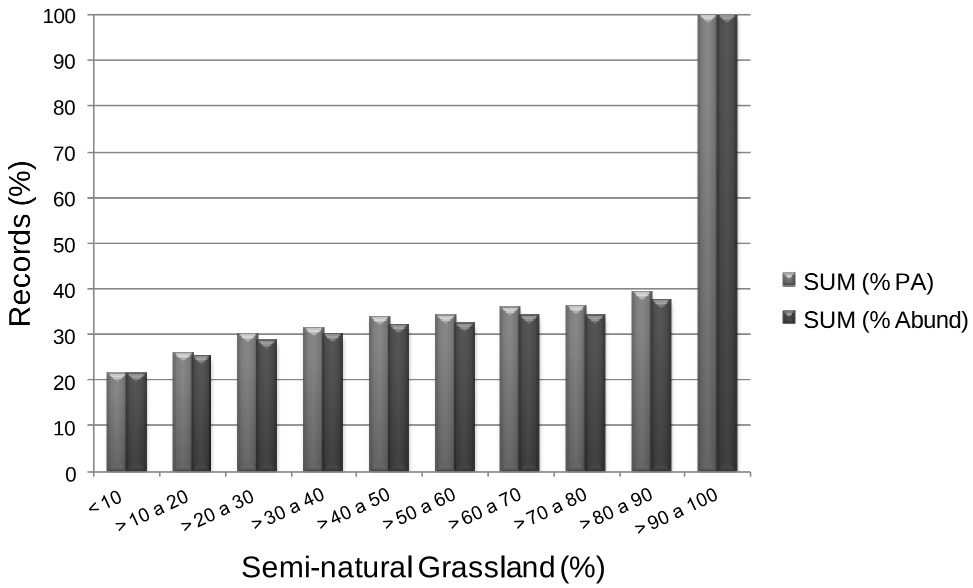

Figure 1. Cumulative percentage of the total records (SUM %PA) and cumulative percentage of the total number of individuals (SUM %Abund) of grassland bird species sampled in the eight study sites by the percentage of semi-natural grassland in the 159 point counts from 2010 to 2012, Southern Brazil and Northern Uruguay.

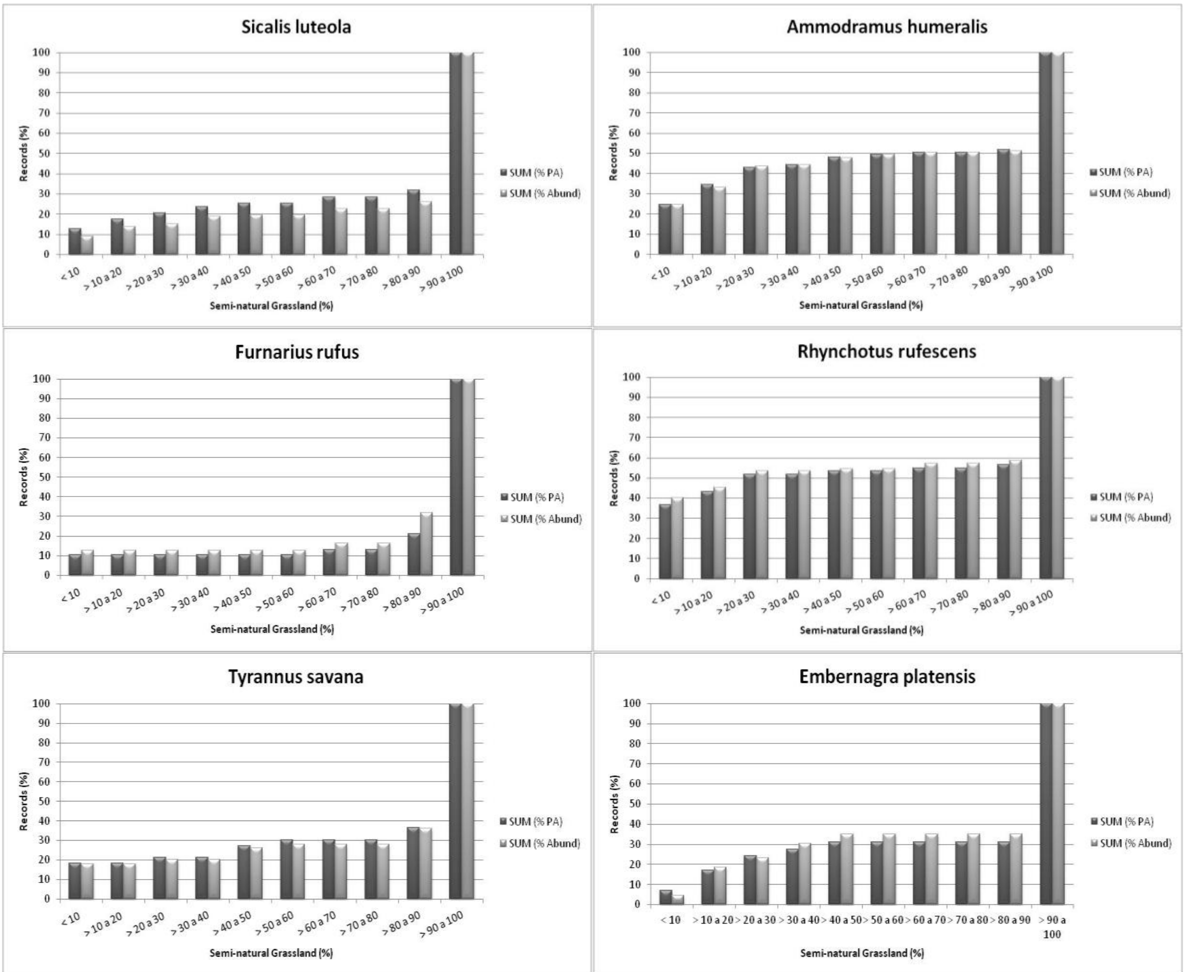

Figura 2. Cumulative percentage of the total records (SUM %PA) and cumulative percentage of the total number of individuals (SUM %Abund) of six bird species more abundant in the semi-natural grassland areas in the Southern Brazil and Northern Uruguay.

Discussion

In general, our results showed that grassland's bird species make use of Grasslands (with sparse vegetation) and/or Wet Grasslands, and may show differences in their relative tolerance to human-made changes in the habitats (Filloy and Bellocq 2007). In this way, some bird species were able to use soybean fields, e.g. for foraging, due to the influence of the remaining patches of semi-natural grasslands among the crops, what might be considered as landscape complementation (Dunning et al. 1992). However, long-term consequences to grassland bird's populations are still unknown.

It is well known that the greater the complexity of vegetation structure, especially in grassland patches with thick and tall grass, the higher the diversity and abundance of grassland's birds (Olechnoivski et al. 2009). Vegetation structure also influences the distribution patterns of grassland's birds between fragments and their habitat use (Herkert 1994). Thus, the higher occurrence and abundance we found for some species (e.g. Grassland Yellow-Finch, Great Pampa-Finch, and Grassland Sparrow) in habitats with higher incidence of Wet Grasslands is likely linked to higher availability of resources in these habitats, such as nest sites and food (Filloy and Bellocq 2007). Wet grasslands and wetlands are not usually converted to soybean because of all the moisture and the soil type, which are not suitable for agriculture (Isacch et al. 2004).

Most of the 19 species that we did not have enough observations to include in the analysis have been often recorded at distances greater than the defined radius. However, those species are present in the semi-natural grasslands and make extensive use of grasslands' habitats, most of them making broader use of the vegetation structure of the grasslands (Azpiroz et al. 2012b). This patterns extends to the five species of conservation concern recorded, which also use semi-natural grasslands, but might be more restricted in the changed habitats because of their sensitivity to the replacement of grassland by cropland (Azpiroz et al. 2012b).

Grassland Yellow-Finch, Great Pampa-Finch and Shiny Cowbird occurred preferentially in sites with higher proportion of Wet Grasslands. Corroborating the results we found, Grassland Yellow-Finch was also more abundant in such habitats other studies in Southeastern South America (e.g. Zalba and Cozzani 2004, Dias and Burger 2005, Develey et al. 2008, Bencke and Dias 2010). The presence of the Grassland Yellow-Finch was positively correlated with the species richness of plants (Isacch et al. 2005), and wet habitats were used by the species for roosting, despite foraging in short grass' vegetation habitats (Dias and Burger 2005). The Great Pampa-Finch shows preference for tall grass and marshy habitats (Belton 1985), and the abundance of Grassland Yellow-Finch and Great Pampa-Finch is greater in habitats with greater percentage of tall grass coverage (Isacch and Martínez 2001), that usually occurs in wet grasslands. We have also found the Great Pampa-Finch in semi-natural grassland patches amid soybean fields. In our study the Shiny Cowbird was recorded in open grasslands and trees, however, the buffers in which we recorded the species had significant cover of Wet Grasslands. Another study recorded the species in open grasslands (Bencke and Dias 2010); however the species is also found in crops (Azpiroz and Blake 2009, Gavier-Pizarro et al. 2012). The Grassland Sparrow also showed a trend to Wet Grassland habitats. In the western pampas of Argentina its presence was positively correlated with plant's species richness and vegetation layers (Isacch et al. 2005), although it has also benefited from the increase of croplands (Filloy and Bellocq 2007, Codesido et al. 2013).

In our study, the Southern Lapwing preferred Grasslands habitats. Although the species use pastures and other areas with low grass cover and intensive grazing (Belton 1984, Zalba and Cozzani 2004), and is able to forage in eventually flooded grassland (Dias and Burger 2005), the species decrease its abundance with the increase of percentage of tall grass (Isacch and Martínez 2001). Nevertheless, the species is dependent of dry substrates and short grass for nesting (Dias and Burger 2005).

Two species occurred in sites with significant natural vegetation cover (Grasslands and Wet Grasslands), the Rufous Hornero and the Firewood-gatherer, both use different portions of the habitat for distinct purposes. The Rufous Hornero usually forages in grasslands, but roosting and breeding occur in dense vegetation, such as evergreen trees or shrubs (Fraga 1980). The Firewood-gatherer uses short grasslands and can be seasonally found in wet grasslands, needing trees or bushes to nest (Remsen 2003). Both species can also use the fences for breeding.

Unlike the species previously mentioned, there were four birds that did not show preference for habitat type: Red-winged Tinamou, Spotted Nothura, Hellmayr’s Pipit and White-browed Blackbird. Isaach et al. (2005) found the presence of Red-winged Tinamou positively correlated with vegetation layers; occurring in grassland with vegetation of intermediate size and containing woody elements (Bencke 2009). The Spotted Nothura is mostly found in short and not too dense grassland, also occurring in crop fields (Belton 1984, Sick 1997). The species, however, also occupies grassland of intermediate height (Isacch and Martínez 2001). The Hellmayr’s Pipit was the only sampled species restricted to grassland habitats of Southeastern South America (Azpiroz et al. 2012b), where it can be found in dry and rocky grasslands (Belton 1985). The White-browed Blackbird is found in the vicinity of and foraging in field crops and dry grasslands; however, it occurs in grassland with intermediate vegetation sizes and woody elements (Belton 1985, Dias and Burger 2005).

According to our results, over 60% of the species records and over 60% of the total number of observed individuals were made in sites with more than 90% of semi-natural grasslands as coverage of the buffers. Additionally, under the threshold of 90% of semi-natural grasslands coverage, species and individuals slightly increase in number. This result highlight the fact that soybean fields are not suitable habitats for grassland's birds and that the conservation of natural habitats is crucial for maintaining the population of grassland's birds: grassland's bird species require a minimum percentage of grasslands to maintain their populations.

Conclusions

We found that most of the grassland's bird species analyzed preferred to use semi-natural grasslands, although some species did not seem to exhibit any preference for habitat type. Nevertheless, none species used soybean fields primarily, confirming the importance of maintaining semi-natural grasslands for increasing the diversity and abundance of grassland's birds. Although we did not have sufficient number of observations to model some species, including threatened or near-threatened ones, we are aware that these species usually make extensive use of grassland habitats.

Fragmentation of landscape can benefit some species of flora and fauna that are more habitat generalists due to the favorable conditions created by the new land use (Farina 1997). However, it is unknown to what extent data of presence/absence and species abundance are appropriate to evaluate their persistence at long-term periods, particularly in either crops or fragments of natural habitat within crops (Azpiroz et al. 2012b). The presence of birds in fields with crops depends on the characteristics of the crops themselves, but also on the landscape matrix in which they are located (Best et al. 2001). The soybean fields we conducted our surveys are recent with less than 3 years of crop’s rotation. This means the semi-natural grassland have been replaced in those areas not long ago and still remain in great extensions surrounding the crops, what might influence the occurrence of birds in the soybean sites. Likewise, species that had greater ability to use human-made habitats are less vulnerable to the effects of fragmentation (Cerezo et al. 2011).

A multiscale understanding of habitat use would improve the efforts for the conservation of birds in farmlands (Best et al. 2001). Future research should focus the landscape scale, analyzing the influence of different habitat types at the macro-scale surrounding area. Management and conservation interventions to maximize species richness at local scale might be insufficient to guarantee the survival of species at regional scale. By looking not only at species richness, but also at species-specific abundance, particularly of grassland’s birds of major concern, it is essential if we are to protect the grasslands and its species.

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CONCLUSÕES GERAIS

Nossos resultados permitem entender uma parcela dos efeitos das alterações do habitat sobre as espécies de aves campestres e enfatizam a relevância da conservação dos campos gaúchos e uruguaios. Além disso, mostramos que as manchas de campo natural entre os cultivos de soja conseguem suportar determinado número de espécies de aves a curto prazo. A heterogeneidade da paisagem tem grande influência na presença das aves em cada tipo de habitat, ressaltando a necessidade de novos estudos nessa linha de pesquisa, ou até mesmo de monitoramentos a longo-prazo, que poderão nos permitir uma maior compreensão sobre a sensibilidade ou plasticidade das espécies em ambientes campestres alterados.

Este estudo foi de grande valia para meu aprendizado não só para o conhecimento das espécies de aves campestres em si, mas também de como a estrutura do ambiente tem grande influência sobre a presença das mesmas. Também contribuiu para meu amadurecimento e crescimento como bióloga, e do quanto é importante um bom planejamento dos nossos projetos e desde o início termos claramente quais são nossos objetivos e quais metas queremos alcançar.

APÊNDICE FOTOGRÁFICO

Ecoregião da Savana Uruguaia (destacado em amarelo). Fonte: WWF (2012).

Estâncias com plantação de soja com manchas de campo natural em Santana do Livramento-RS (S1), Departamento de Cerro Largo-Uruguai (S2), Dom Pedrito-RS (S3) e Departamento de Rivera-Uruguai (S4).

Estâncias com campos naturais em Dom Pedrito-RS (N1), Departamento de Rivera-Uruguai (N2), Departamento de Rivera-Uruguai (N3) e Departamento de Vichadero-Uruguai (N4). Fonte: Graziela Dotta.

Espécies registradas durante o presente estudo. A – *Rhea americana*, B – *Xolmis dominicanus*, C – *Tyrannus savana*, D – *Xanthosar flavus*. Fonte: Graziela Dotta.

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Fonts for statistical metrics. Report the following metrics in italics: n for sample size, P for probability values, G as the test statistic from a G-test, t_a for the test statistic from paired or two sample t-test with a degrees of freedom, U from a Mann-Whitney U-test, $F_{a,b}$ as the test statistic from an F-ratio with a,b = numerator and denominator degrees of freedom (degrees of freedom are not italicized), r and r_s for Pearson and Spearman correlation coefficients, r^2 for the coefficient of determination, and K and w_i for the number of parameters and Akaike weights. Report the following statistical information in normal font, not italics: SD for standard deviation, SE for standard error, CI for confidence interval, CV for coefficient of variation, df for degrees of freedom, ns for nonsignificant, Dev for model deviance, BIC for Bayesian Information Criterion, χ^2_a for chi- square statistics with a degrees of freedom, and ANOVA for analysis of variance. Use AIC_c and $QAIC_c$ for (quasi) Akaike's Information Criterion. All variables are italicized unless they are denoted by a Greek letter, in which case they are *not* italicized.

Subscripts and superscripts. Use true subscripts and superscripts and do not raise or lower the text.

Supplementary material. Please name and cite all supplemenary files with the name Supplementary Appendix or Supplementary "X". Combine supplementary material into one file when possible.

Symbols. < used in a sentence does not take a space around it. There were <10 birds feeding.

Tables. Cite tables within the text in numerical order. Use Arabic numbers, e.g., Table 1. Table title is in sentence case (only the first word of the title starts with a capital letter). Table headings also are sentence case. Tables should be in Word or Excel format. Table citations in parentheses should be separated from literature citations with a semicolon, but can appear together with figure citations: text text text (Table 1 and Figure 1; Jones and Johnson 1978).

Keep tables as simple as possible. Orient tables vertically. They should be intelligible without reference to the manuscript text. Do not restate results given in the text. Do not use solid vertical or horizontal lines in tables. Do not include extensive raw tabular material either as
tables or appendices: Either upload as Supplementary Material or cite your website. If birds are listed in several tables within the manuscript, scientific names should be given only in one table, the one with the comprehensive species list. The only exception to the phylogenetic order of species is if another logical order of species is used, for example one based on Results.
How to format a table:

- Table data are all in individual cells.
- Table title and footnotes are NOT in cells.

- There are no extra rows or columns or solid horizontal or vertical lines within the table.
  The only lines should be the natural gridlines between cells.
- Data are not aligned using tabs or spaces. Place all text and data flush left in each cell.
- Column heads spanning multiple columns should be set up using Word's Merge Cell function.
- Table is an editable Word table, created using MS Word's table function.
- **Omit the column of AIC values and report only the lowest value of AIC (or AIC_{C}, $QAIC_{C}$) in a footnote to the table.**

Indents: Please note that inserting an em space (by selecting from Word's Special Character list) is the recommended way to maintain levels of indent in a structured stub column. Keyboard spaces, indents, and tab characters will not be recognized by the typsetting software.
Sample table:

Table 1. Wintering locations in South America of Red-eyed Vireos (*n* = 10) migrating from northwestern Pennsylvania. Values are means (with SD in parentheses), and *n* is the number of days used to estimate location. Letters correspond to maps in Figure 2.

Bird	Latitude	Longitude	*n*
A	N 1.39° (2.90)	W 64.15° (0.98)	150
B	N 0.56° (2.05)	W 64.15° (0.98)	147
C	S 3.54° 92.99)	W 69.00° (1.11)	157
D	S 3.80° (2.56)	W 65.2° (0.70)	151
E[a]	N 1.52° (2.61)	W 59.15° (0.66)	38
	N 1.08° (2.30)	W 62.42° (0.63)	119
F	S 0.55° (3.13)	W 69.93° (0.94)	166
G	N 3.27° (2.12)	W 62.87° (0.91)	148
H	N 7.24° (2.24)	W 64.38° (0.71)	160
I[a]	S 0.64° (2.45)	W 60.62° (0.83)	35
	S 3.01° (1.80)	W 63.33° (0.73	110
J[b]	N 1.81° (1.73)	W 63.70° (0.52)	157

[a] Individual changed locations during seasons; listed in chronological order.
[b] Not depicted in Figure 2.

Taxonomy. Give the scientific name in parentheses at the first mention of a species both in the Abstract and in the article. Scientific and American English names of birds, and their order of presentation in the manuscript, including figures and tables, should follow:
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The only exception to the phylogenetic order of species is if another logical order of species is used, for example one based on Results. Alphabetical order of presentation is never acceptable. Do not give subspecific information unless it is pertinent and has been determined to be critical.

Throughout the manuscript capitalize English names of bird species (e.g., Red-winged Blackbird) but not bird groups (e.g., blackbirds) except in a list (Red-winged and Tricolored Blackbirds). Common names of plants, mammals, etc., should not be capitalized. This rule applies to all references, figures, and tables. Do not refer to birds by four-letter banding codes.

For plant taxonomy, use the USDA Plants database, http://plants.usda.gov/

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Title of article. Maximum word count is 25. Center and bold the title. Scientific names of species are not necessary in article titles but may be included. Do not include a list of species names in the title. Titles may not include numerical series or designations. Do not include the authority for taxonomic names in the Title or Abstract. Avoid vague declarations (…effects of…), and strive for specific information content (…fungi kill tardigrades…). See also **Running Head**.

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U.S. or **USA** or **United States** or **United States of America**. No US. UK is okay.

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Red-eyed Vireo migration

RESEARCH ARTICLE

Prolonged spring migration in the Red-eyed Vireo (*Vireo olivaceus*) Paul A.

Callo,[1]* Eugene S. Morton,[2,3] and Bridget J. M. Stutchbury[3,a]

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* Corresponding authors: Paul Callo, pcallo@mbc.edu; Eugene Morton, mortone@si.edu]

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ABSTRACT
We used archival geolocators to track the migration of Red-eyed Vireos (*Vireo olivaceus*), abundant forest songbirds with significantly increasing breeding-population trends, to identify important stopover and wintering regions. All individuals from a single breeding site (n = 10) wintered in northwestern South America, an extensively forested region, and in spring used a consistent route, crossing the Gulf of Mexico from the Yucatan to Louisiana. . . .
Keywords: frugivory, geolocators, geologgers, migration, Red-eyed Vireo, stopovers, *Vireo olivaceus*

Migración Prolongada de Primavera en Vireo olivaceus

RESUMEN

Usamos geolocalizadores para rastrear la migración de Vireo olivaceu, un ave canora de bosque abundante con tendencias a incrementar su población reproductiva, para identificar regioanes importantes de parada e invernada. Todos los individuos de un único sitio de reproducción (*n* = 10) pasaron el invierno en el noroccidente de Sur América, una région con bosques extensos. En la primavera, las aves usaron una ruta común, cruzando el golfo de México desde Yucatán hasta Luisiana. . . .

INTRODUCTION

Widespread and long-term effects on populations of songbirds that migrate to the tropics for the northern winter are driven by both breeding-ground productivity and mortality during migration and the nonbreeding season (Terbrough 1980, Sherry and Holmes 1995, Faaborg et al. 2010). Data on the timing of migration, routes taken, stopover locations and durations, and overwintering locations are needed to permit an informed assessment of conservation needs and for projecting future population trends. For most Western Hemisphere songbirds, banding recovery records that link breeding and tropical wintering sites are too infrequent to answer these and other questions. However, tracking of small birds for a full year is now possible using light- level geolocators (Stutchbury et al. 2009), which make it feasible to map migration routes and destinations of breeding populations.

METHODS

We used data from light-level geolocators (Mk20S, 0.6 g; British Antarctic Survey [BAS]) deployed on male Red-eyed Vireos (*n* = 26) between 3 and 17 June 2011 and retrieved between 26 May and 9 June 2012 (*n* = 10) at the 150-ha Hemlock Hill Field Station in northwestern Pennsylvania (41.8°N, 79.9°W). The site is covered by mature mixed-deciduous forest with scattered Eastern Hemlocks (Tsuga canadensis). Individuals were captured by use of a targeted playback of Red-eyed Vireo song and a 6-m mist net. A taxidermic mount of a male Red-eyed vireo was used in most instances. Geolocators were attached to birds using a leg-loop harness made of a 2.5-mm Teflon ribbon (Stutchbury et al. 2011).

RESULTS

Wintering Locations and Migration Routes [second level heading]

All Red-eyed Vireos from the Hemlock Hill breeding population wintered in a similar region in northwestern South America that represented an area of ~15% of the total winter range (Table 1 and Figure 1). Average distance between individuals (all pairwise comparisons, *n* = 45) was 712 ± 300 km (mean ± SD), and average nearest-neighbor distance was 286 ± 142 km (*n* = 10). Most individuals (8 of 10) occupied a single wintering region, but two individuals (Figure 2E, 2I) first occupied a winter site from late October to the beginning of December before moving ~40 km westward to their final wintering region, where they stayed for 4 months.

The spring migration route was very similar among all 10 individuals (Figure 2) as birds migrated through Central America to the Yucatan Peninsula.

Stopovers and rate of migration [third level heading]. Spring migration, from start to finish, averaged 46 days (range 39–52 days), and with stopovers, migration rate averaged 146 km day^{-1} (Table 2). However, most of the spring migration consisted of stopover days, and individuals covered the journey of

~6,600 km in only 13 days of flight. Migration rate and stopover duration varied greatly among different stages of the journey (Table 2 and Figure 2). Red-eyed vireos had prolonged stopvers in Colombia (18.6 ± 4.9 days [all durations reported as means ± SD]; range: 12–27 days) immediately after beginning spring migration. Spring migration rate through South America was very slow, averaging 72 km^{-1} day, and increased significantly as birds traveled through Central America (mean = 178 km day^{-1}) and completed their journey across the Gulf of Mexico and through the United States to the breeding site (mean= 310 km^{-1} day; one way ANOVA, $F = 33.5$, df = 2 and 27, $P < 0.0001$; Table 2). Most birds also had a shorter stopver (6.3 ± 3.3 days) in Central Nicaragua.

Fourth-level heading. All birds remained at the breeding site throughout August, but the onset of fall migration in September was unknown because birds could have moved south with no change in longitude compared with the breeding site. Average arrival date at the wintering site was October 22 (range: October 14 to November 4).

DISCUSSION

Red-eyed Vireos from this population all overwintered in northwestern South America (Figure 1) in either the Amazon or Orinoco River basins. This is perhaps the most pristine region in South America, with >90% forest cover (Fraser et al. 2012). Two of the 10 Red-eyed Vireos (Figure 2E, 2I) changed locations during the winter season, both to the southwest of their initial site, but over relatively short distances (400 km). Intratropical migration has also been documented using geologgers for Veeries (Catharus fuscescens; Heckscher et al. 2011; 5 of 5) and Purple Martins (Progne subis; Fraser et al. 2012; 63 of 95), but both of these species move over long distances (average movement >500 km) from site to site within South America. Little is known about Red- eyed Vireos' behavior on their wintering grounds (Cimprich et al. 2000), but they appear to have high social tolerance, typical of highly frugivorous species while not breeding. They often occur in groups of conspecifics as well as mixed-species flocks in the tropical forest canopy and edge, and they are largely silent (Ridgely and Tudor 1989, Ridgely and Greenfield 2001).

Spring migration featured a prolonged stopover (18.6 ± 4.9 days) in Colombia soon after departure from winter sites (Figure 2 and Table 2). Very long spring stops do not occur in Purple Martins or Wood Thrushes (Fraser et al. 2012, Stanley et al. 2012) but have been documented with geolocators in Swainson's Thrush (Catharus ustulatus; Delmore et al. 2012). Swainson's Thrushes breeding in inland British Columbia, and wintering in South America, had long spring stops.

ACKNOWLEDGMENTS

We thank L. Welch and J. Silverton for assistance with field work and E. Jones for statistical assistance. We also thank O. Love. This research was funded by the Natural Sciences and Engineering Research Council of Canada and by grants from Mary Baldwin College.

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Faaborg, J., R. T. Holmes, A. D. Anders, K. L. Bildstein, K. M. Dugger, S. A. Gauthreaux, Jr., P. Heglund, K. A. Hobson, A. E. Jahn, D. H. Johnson, et al. 2010. Conserving migratory land birds in the New World: Do we know enough? Ecological Applications 20:398–418.

APPENDIX

[The Appendix may contain text and/or tables. Avoid long appendices, or upload them as supplemental information, calling it Supplemental Appendix. Short appendices may reside in the manuscript and be published as part of the manuscript file. If there is more than one Appendix, then label them Appendix A, Appendix B, etc. Tables within appendices continue the table numbering from the earlier sections of the paper, e.g., “Table 5 in Appendix A.” Same for figures.

Figure 1. Wintering locations in South America of Red-eyed Vireos (*n* = 10) tracked with geolocators from one breeding population in northwestern Pennsylvania (**inset**). Typical standard deviation in latitude and longitude for mean location is shown with lines for one bird (also see Table 1).

Figure 2. Estimated migration routes, timing, and destination for individual male Red-eyed Vireos (*n* = 9) (**A–I**) tracked with geolocators from the Hemlock Hill, Pennsylvania, breeding population, 2011 to 2012. Dashed lines indicate periods where locations are uncertain because of equinox periods or low-confidence sunrise-sunset transitions. The individual maps are arranged according to time of departure from South America from earliest (**A**) to latest (**I**). One bird was omitted because of space constraints (departed March 31, arrived May 8).

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Table 1. Wintering locations in South America of Red-eyed Vireos (*n* = 10) migrating from northwestern Pennsylvania. Values are means (with SD in parentheses), and *n* is the number of days used to estimate location. Letters correspond to maps in Figure 2.

Bird	Latitude	Longitude	*n*
A	N 1.39° (2.90)	W 64.15° (0.98)	150
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D	S 3.80° (2.56)	W 65.2° (0.70)	151
E[a]	N 1.52° (2.61)	W 59.15° (0.66)	38
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J[b]	N 1.81° (1.73)	W 63.70° (0.52)	157

[a] Individual changed locations during seasons; listed in chronological order.
[b] Not depicted in Figure 2.

Table 2. Spring migration distance, duration, and rate, and cumulative duration of stopovers in South America, Central America, and the United States (including the Gulf of Mexico crossing for Red-eyed Vireos (n = 10) migrating from northern South America to northwestern

Migration variable	South America	Central America	Gulf crossing and United States	Start-to-finish
Distance (km)	1,636 ± 252	2,150 ± 234	2,848 ± 195	6,631 ± 397
Duration (days)	23.3 ± 4.7	13.1 ± 3.3	9.7 ± 2.2	45.9 ±4.6
Rate (km day^{-1})	72.4 ± 17.5	178.4 ± 66.9	310.0 ± 89.3	145.9 ±18.4
Stopovers (days)	18.6 ± 4.9	9.2 ± 3.3	3.5 ± 2.0	33.4 ± 4.8

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Book
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ROGERS, C. A., R. J. ROBERTSON, AND B. J. STUTCHBURY. 1991. Patterns and effects of parasitism by *Protocalliphora sialia* on Tree Swallow nestlings. In: Bird-parasite interactions: ecology, evolution and behaviour (J. E. Loye and M. Zuk, eds.), pp. 123–139. Oxford University Press, Oxford, UK.
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