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Responses of birds to planting of *Lotus tenuis* pasture in the Flooding Pampas, Argentina

Manuel Agra[A,B], *David Bilenca*[A] *and Mariano Codesido*[A]

[A]Grupo de Estudios sobre Biodiversidad en Agroecosistemas (GEBA), Departamento de Biodiversidad y Biología Experimental, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Argentina and IEGEBA (UBA/CONICET), Intendente Güiraldes 2160 – Ciudad Universitaria – Pabellón II – Cuarto piso, Ciudad Autónoma de Buenos Aires, C1428EGA, Argentina.
[B]Corresponding author. Email: manuelagra@ege.fcen.uba.ar

Abstract. The Flooding Pampas is the most important livestock region of Argentina, but is a region where replacement of originally natural, perennial tussock grasses by pasture species is changing the heterogeneity of the grassland system. We evaluated the response of grassland bird assemblages of the Flooding Pampas to planting of *Lotus tenuis* (Lotus) pasture, which mainly modifies vegetation structure by reducing vertical heterogeneity. Species richness and abundance of birds were compared between fields of Lotus pasture and semi-natural grasslands. Avian species richness and abundance were both greater in semi-natural grassland than in Lotus pasture. When grouped by nesting habits (grassland specialists, generalists), species richness and abundance of grassland specialists was greater in semi-natural grassland, whereas richness and abundance of generalist species was greater in Lotus pasture. An indicator-species analysis showed that five grassland birds were closely linked to semi-natural grassland vegetation, with two of those species – Hudson's Canastero (*Asthenes hudsoni*) and Bay-capped Wren-Spinetail (*Spartonoica maluroides*) – of conservation concern.[1] In contrast, generalist species, such as Southern Lapwings (*Vanellus chilensis*) and Burrowing Owls (*Athene cunicularia*), were associated with Lotus pasture. Planting of Lotus pasture has negative effects on species that naturally occur in tussock grassland. Grassland management methods, such as intercropping and rotational grazing, could help reconcile the effects of livestock production and the conservation grassland bird conservation in the Flooding Pampas.

Additional keywords: agroecosystem, grassland birds, habitat management, South America.

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Introduction

Worldwide, planting of pasture species in agricultural systems causes loss and degradation of natural grassland systems, leading to changes in communities of grassland birds (Vickery *et al*. 1999; Robinson and Sutherland 2002; Askins *et al*. 2007; Azpiroz *et al*. 2012), and has become a major conservation concern (BirdLife International 2012*a*, 2012*b*, 2012*c*; International Union for Conservation of Nature 2014). In south-eastern South America, species richness and abundance of grassland birds is lower in modified pastures than in native grasslands (Isacch *et al*. 2005; Azpiroz and Blake 2009). However, such decreases in abundance are not uniform for all species, with species potentially responding differently depending on life history and their degree of habitat specialisation (Robinson and Sutherland 2002; Murphy 2003).

Flooding Pampas is a natural grassland ecosystem and the most important livestock region of Argentina (Soriano 1991). Pastoral landscapes in the Flooding Pampas are also the most extensive wildlife habitat in the intensive agricultural Pampas region and, therefore, represent key habitats for biodiversity (Bilenca and Miñarro 2004; Codesido *et al*. 2008, 2013). However, the natural grasslands have been undergoing systematic change as a result of fire and continuous grazing, causing a decrease in the area occupied by tall grasslands (0.5–1.5 m tall) and favouring the emergence of short grasslands (less than 0.5 m tall) with a high percentage of annual and exotic forbs (Sala *et al*. 1986; Soriano 1991). These habitat changes have altered the availability of resources for grassland birds, such as food, shelter and nesting sites, and in turn influenced the species richness of the avian communities and abundance of several species of bird (Comparatore *et al*. 1996; Isacch and Martínez 2001). For example, birds of tall grasslands are more frequently recorded in agricultural areas where semi-natural grassland dominates (Isacch and Cardoni 2011; Cardoni *et al*. 2012) whereas habitat generalists, such as Southern Lapwings

[1]Although three species of conservation concern are mentioned in the Discussion, we do not include the third species (the Bearded Tachuri, *Polystictus pectoralis*) here because it is too rare to be detected by the indicator-species analysis.

(*Vanellus chilensis*) and Burrowing Owls (*Athene cunicularia*), are frequently recorded in heavily grazed fields (Isacch and Cardoni 2011; Cavalli *et al*. 2014).

In recent years, there has been an increasing interest in planting of the legume *Lotus tenuis* (Lotus hereafter) in the Flooding Pampas, as it provides high forage value for cattle (Rodríguez and Jacobo 2010). Lotus pastures have been planted over semi-natural grasslands, which are usually composed of perennial tussock grasses. Before planting of Lotus pasture, land managers often use glyphosate herbicide to control weeds and other existing vegetation, which further alters grassland community structure by reducing the heterogeneity of vegetation (Rodríguez and Jacobo 2010). Despite these changes to grassland habitats as a result of planting of Lotus pastures, there have been no studies of the responses of the avian grassland community to planting of Lotus pasture. Such studies are warranted to assess the role of Lotus pasture in shaping avian assemblages in the Flooding Pampas.

The aim of this paper is to analyse avian responses to changes in habitat heterogeneity resulting from the replacement of perennial tussock grasses with short Lotus pasture (Benton *et al*. 2003). More specifically, we test the hypothesis that avian species richness and abundance are lower in Lotus pastures than in semi-natural grasslands. We also test the hypothesis that the species richness and abundance of grassland specialist birds is greater in semi-natural grasslands than in Lotus pastures, and the species richness and abundance of generalist birds is greater in Lotus pasture.

Materials and methods

Study area

Our study was conducted within the Flooding Pampas, a 90 000-km^2 region of grassland in central-eastern Argentina (35°–38°S, 57°–63°W). Mean annual daily temperature is ~15°C, with warm summers and cool winters (mean daily temperature 21.5–23.5°C in January, and 7.5–9.5°C in July); mean annual rainfall ranges from 800 to 1000 mm (Soriano 1991). Grasslands of the Flooding Pampas have evolved under light grazing conditions, but were heavily disturbed after the arrival of Europeans in the 16th century with the introduction of domestic herbivores and, probably, frequent fire (Sala *et al*. 1986). The original community was characterised by a 60–80 cm tall grassland dominated by tussock grasses – probably various species of the genera *Nasella*, *Piptochaetium, Bromus* and *Paspalum* (patches of *Paspalum quadrifarium*-dominated grasslands can reach a height of 1–1.8 m). Other herbaceous communities include prairies, marshes and edaphic communities (Soriano 1991; Perelman *et al.* 2003). Unlike other parts of the Pampas where agriculture has replaced >75% of the native vegetation, >80% of the Flooding Pampas remain as semi-natural grasslands (i.e., originally natural grasslands that were subjected to the above anthropogenic disturbances). However, in the last 10–20 years, increasing areas of the tall grassland communities have been removed and replaced by pastures (Herrera *et al*. 2009).

We conducted surveys on two experimental ranches: the IIB-INTECH ranch (800 ha; 35°37′20.86″S, 57°59′40.20″W), and the Experimental Manantiales ranch (680 ha; 35°44′40.78″S, 58°03′23.02″W). Both ranches are located in Chascomús County, Buenos Aires province, where cattle-breeding and farming are the main activities and livestock is typically stocked at densities of 0.7–1 head of cattle ha^{-1}.

Experimental design and surveys of birds

At each ranch, avian assemblages and habitat heterogeneity were evaluated in two habitats: (1) fields planted with Lotus pasture and on which glyphosate was applied (see Rodríguez and Jacobo 2010); and (2) fields of semi-natural grassland. Surveys were conducted monthly from November 2011 to March 2012, covering the duration of the breeding season.

On each ranch we located 10 survey points in each of the two habitats (i.e. a total of 20 points per habitat). Survey points were at least 150 m apart. Surveys were conducted during the 3 hours after dawn (0615 hours–0915 hours) and the 3 hours before sunset (1700 hours–2000 hours). We recorded all birds seen or heard within a 50-m radius of the survey point within a 5-min period (following Bibby *et al*. 2000), with the exception of individuals in flight and not using the survey area (Codesido *et al*. 2011). We conducted one survey at each site in each month (i.e. 40 surveys per month, and a total of 200 surveys over the study period). Surveys were conducted in the morning and in the evening, with each habitat having half its points sampled during each time zone. In addition, surveys were conducted alternately to avoid the effect of time zone. For example, if a point was surveyed in the morning at one sampling, it was surveyed in the evening at the next sampling.

We then determined avian species richness and abundance for each survey point. We also classified each species of bird based on its nesting habitat into two groups (Codesido *et al*. 2012, 2013): grassland specialists and generalists. Grassland specialists were those species that breed exclusively in grasslands. Generalist species were those that breed in more than one type of habitat, which may include grasslands but also includes cropfields, pastures, rural facilities or treed vegetation. We excluded from wetland species from our analyses, because their breeding depends on the presence of water (Codesido *et al*. 2012).

Vegetation structure

Each month, we also estimated vegetation structural parameters (height and cover) within each 50-m radius survey point (Matteucci and Colma 1982) after completing the count of birds at each point. We classified vegetation height using a graduated ruler in the following seven height strata: 0 (i.e., bare ground), <10 cm tall, 10–24 cm, 25–49 cm, 50–74 cm, 75–99 cm and ≥100 cm tall. Then, we estimated vegetation cover for each of the height strata, considering the whole 50-m radius.

Data analysis

We calculated the Simpson diversity index to characterise the heterogeneity of vertical coverage in both habitats and for every month's survey on a total of 20 survey points for each habitat. We used the Simpson index formula:

$$\mathrm{D} = \left(\Sigma_{i=1}^{S} n_i(n_i - 1)\right) / N(N-1)$$

where S is the total number of strata per point (S = 7), n_i is the percentage of each coverage stratum and $N = \Sigma^{S}_{i=1}\ n_i$.

Avian species richness was expressed simply as the number of species per point per month, whereas bird abundance was estimated as the number of individuals per point.

We compared habitat heterogeneity, bird species richness and abundance between habitats using a two-factor analysis of variance (ANOVA) with repeated measures for one factor (month) (Zar 1999) so as to consider the dependence among data resulting from sampling birds at the same points each month. When variables did not meet assumptions for parametric tests they were transformed by applying a log10 transformation. We performed a simple effects test when significant interactions between habitats and month were detected (Zar 1999). The software used for these analyses was Infostat (Di Rienzo *et al.* 2013).

To identify the characteristic species of each habitat, we performed an indicator species analysis (ISA), which provides values that range from 0 (non-indicative habitat species) to 100 (perfect habitat indicative species; Dufrêne and Legendre 1997). Values for ISA were obtained for Lotus and grassland habitats. A perfect habitat indication for a species meant that it had been exclusively seen in one habitat and not in the other. Values of ISA were analysed by a Monte Carlo test randomisation that compared the calculated observation value with the same information but randomly obtained for each habitat ($n = 1000$ permutations). The ISA was performed with PC-Ord (McCune and Mefford 1999). We used a probability of < 0.05 as criterion for every analysis. We described the associations between indicator species and vegetation height by means of a graphical representation in which we grouped vegetation heights into three categories: low (0–24 cm tall), medium (25–74 cm) and high ($\geq$75 cm).

Results

Vertical heterogeneity of vegetation was higher in semi-natural grassland than in Lotus pasture (two-factor ANOVA: Habitat effect, $F_{1,38} = 76.4$, $P < 0.0001$). Grasslands had greater cover in the range 50 – $\geq$100 cm tall and was characterised by the dominance of *Paspalum quadrifarium*, *Agropyrum elongatum* and *Festuca arundinacea*. These three tussock grasses were often encountered with other less abundant grasses, such as *Botriochloa lagurioides* and dicotyledons, such as *Cynara carduncculus* and *Solanum malacoxylum*. Lotus pasture had greater cover of vegetation 10–50 cm tall and was characterised by dominance of *Lotus tenuis* and with *Lolium* spp. and forbs like *Trifolium repens* present.

We recorded a total of 1460 individual birds of 39 species: 915 in grassland and 545 in Lotus pasture. Of the 39 species, 10 were grassland specialists and 29 generalists (see Supplementary material, available online only).

Both mean species richness and mean abundance of birds were higher in semi-natural grassland than in Lotus pasture at the beginning of the sampling period (November) and at the end (March) (species richness (Fig. 1*a*): habitat × time interaction two-factor ANOVA: $F_{4,152} = 4.7$, $P < 0.05$; simple effect test: November, $F_{1,180} = 35.4$, $P < 0.05$, March, $F_{1,180} = 8.2$, $P < 0.05$; bird abundance (Fig. 1*b*): habitat × time interaction two-factor ANOVA: $F_{4,152} = 3.4$, $P < 0.05$; simple effect test: November, $F_{1,158} = 14.6$, $P < 0.05$, March, $F_{1,158} = 10.5$, $P < 0.05$).

When grouping species based on nesting habits, species richness of grassland specialists was higher in grassland than in Lotus pasture (two-factor ANOVA: $F_{1,38} = 2.7$, $P < 0.05$; Fig. 2*a*). The abundance of grassland specialists was also always higher in grassland than in Lotus pasture, even though the magnitude of the difference among habitats varied according to the sampling period (habitat × time interaction two-factor ANOVA: $F_{4,152} = 2.8$, $P < 0.05$; simple effect test: November, $F_{1,147} = 52.4$, $P < 0.0001$; December, $F_{1,147} = 18.7$, $P < 0.0001$; January, $F_{1,147} = 16.8$, $P < 0.0001$; February, $F_{1,147} = 24.4$, $P < 0.0001$; March, $F_{1,147} = 44.4$, $P < 0.0001$; Fig. 2*b*).

Species richness of generalist species was higher in Lotus pasture than in grassland (two-factor ANOVA: $F_{4,152} = 2.9$, $P < 0.05$), particularly during the middle of the sampling period (simple effect test: January, $F_{1,189} = 4.5$, $P < 0.05$; February, $F_{1,189} = 6.9$, $P < 0.05$; Fig. 2*c*). The abundance of generalist species was also higher in Lotus pasture than in grassland (two-factor ANOVA: $F_{1,38} = 4$, $P < 0.05$; Fig. 2*d*).

The ISA identified eight species associated with grasslands and two species associated with Lotus pasture, with percentages of indicator values ranging from 81 to 100 ($P < 0.05$; Fig. 3). The two species associated with Lotus pasture were generalist species, Southern Lapwing and Burrowing Owl, and were associated with low and medium-height vegetation strata (Fig. 3*a*–*b*). Five of the species associated with grasslands were grassland specialists – Hudson's Canastero (*Asthenes hudsoni*), Bay-capped Wren-Spinetail (*Spartonoica maluroides*), Brown-and-yellow Marshbird (*Pseudoleistes virescens*), Great Pampa-Finch

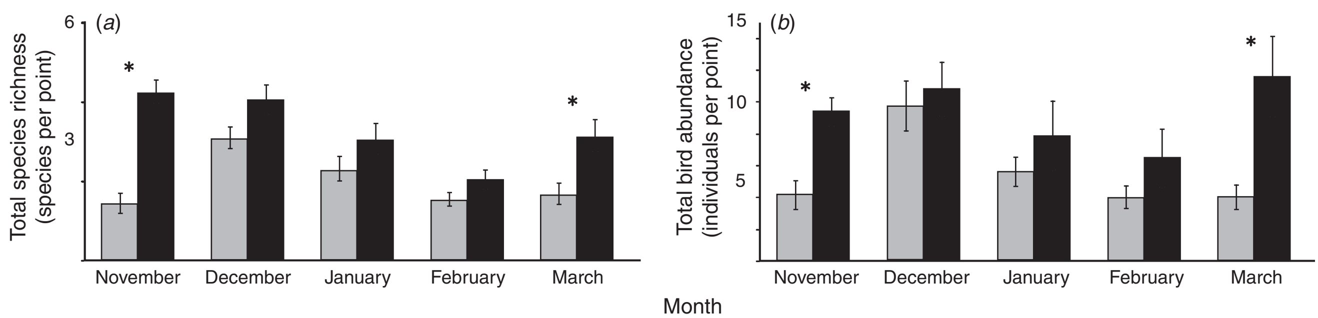

Fig. 1. Monthly mean (± s.e.) (*a*) species richness and (*b*) abundance of birds in Lotus pasture (grey bars) and semi-natural grassland (black bars) in the Flooding Pampas, Argentina. Asterisks indicate significant interactions of habitat × month ($P < 0.05$; two-way ANOVA with repeated-measures for month).

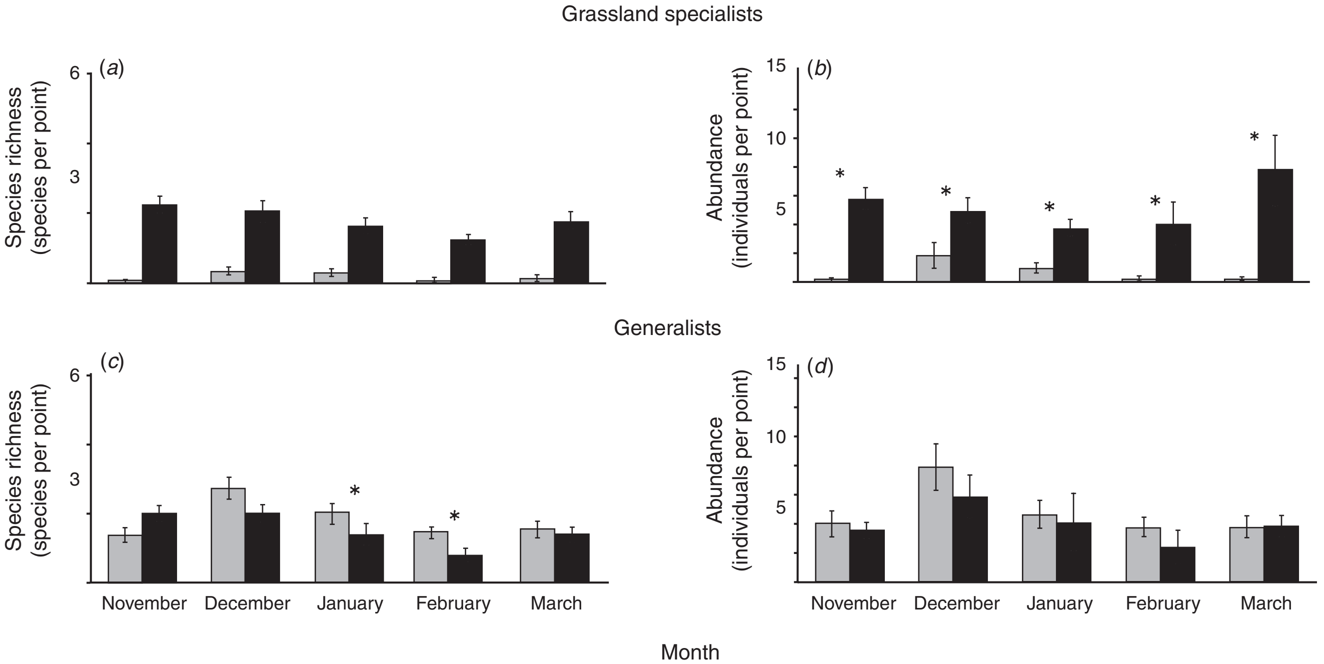

Fig. 2. Monthly mean (± s.e.) species richness and abundance of: (*a–b*) grassland specialist birds; and (*c–d*) generalist species of birds in Lotus pasture (grey bars) and semi-natural grassland (black bars) in the Flooding Pampas, Argentina. Asterisks indicate significant interactions of habitat × month ($P < 0.05$; two-way ANOVA with repeated measures for month).

(*Embernagra platensis*) and Grassland Yellow-Finch (*Sicalis luteola*) – and three were generalist species – Rufous-collared Sparrow (*Zonotrichia capensis*), Great Kiskadee (*Pitangus sulphuratus*) and White-browed Blackbird (*Sturnella superciliaris*). Most of the grassland species were associated with medium-tall and high vegetation strata (Fig. 3*c–j*).

Discussion

We found significant differences in the species richness and abundance of birds between Lotus pasture and semi-natural grasslands in the Flooding Pampas. Planting of Lotus pasture modifies the vegetation structure by reducing overall vertical heterogeneity compared to semi-natural grasslands. Moreover, planting of Lotus pasture also alters the vertical distribution of vegetation cover by increasing the cover of low 10–49 cm herbaceous vegetation, and simultaneously reducing vegetation cover ≥50 cm tall compared to grasslands.

Overall species richness and abundance of birds were higher in semi-natural grassland than in Lotus pasture. This result is consistent with changes resulting from habitat loss in grassland avian assemblages described for both South and North America (Brennan and Kuvlesky 2005; Azpiroz *et al*. 2012) and with studies showing that most species of birds respond negatively to replacement of natural vegetation with pasture, in North America (Murphy 2003; Askins *et al*. 2007) and in the West Inland Pampas (a region defined and mapped by Soriano 1991; Isacch *et al*. 2005). The differences in the abundance and species richness of birds between semi-natural grassland and Lotus pasture were greater at the beginning (November) and at the end (March) of the sampling period, reflecting differences in nesting activity at these times, with nesting in early stages in November and with increases in numbers with recruitment of young to the local population at the end of the breeding season (March).

Grassland specialists had greater species richness and abundance in semi-natural grassland whereas generalists had greater species richness and abundance in Lotus pasture. Three species associated with grasslands appeared exclusively in grassland habitat: Hudson's Canastero, Bay-capped Wren-Spinetail and Brown-and-yellow Marshbird. In addition, we observed reproductive behaviour of these species in grassland (M. Agra and M. Codesido, pers. obs.). It would appear that the reduction in height and heterogeneity of vegetation and habitat have direct implications on the species that strongly depend on tall tussock grassland in which to nest, as reported elsewhere (Isacch and Martínez 2001; Cardoni *et al*. 2012). In addition, three species associated with grassland were generalist species that used grasslands to feed but not necessarily to nest (Rufous-collared Sparrow, Great Kiskadee and White-browed Blackbird).

Lotus pasture is characterised by low vegetation, providing suitable habitat for Southern Lapwings and Burrowing Owls, which commonly use disturbed habitats with short vegetation (Isacch and Cardoni 2011; Cavalli *et al*. 2014). These generalist species nest on the ground and in holes, respectively, and take advantage of the simplification in habitat heterogeneity that Lotus pasture presents. Conversely, we did not observe active nests or reproductive behaviour of grassland specialists in Lotus pasture. Many grassland species not recorded from Lotus pasture, such as the Bay-capped Wren-Spinetail and Great Pampa-Finch, place their nests in tall grasses (Azpiroz *et al*. 2012; Cardoni *et al*. 2012), which also suggests that nest-site availability

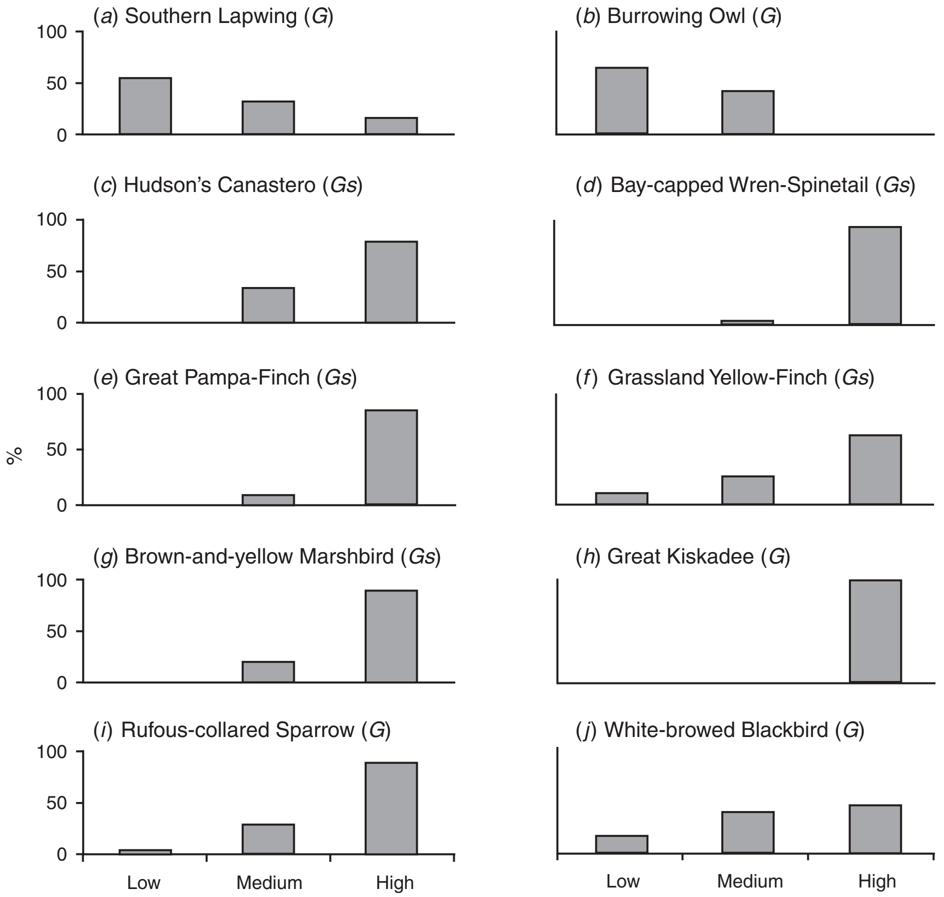

Fig. 3. Relationship between cover of vegetation heights and the percentage of occurrence of: (*a*–*b*) species associated with Lotus pasture; and (*c*–*j*) species asociated with semi-natural grassland. Vegetation cover classified into three height classes: Low (0–24 cm tall), Medium (25–74 cm) and High ($\geq$75 cm). Species are indicated as *G*, generalists, or *Gs*, grassland specialists.

plays an important role in determining bird communities in this habitat type. This factor is thought to be key in shaping avian assemblages in agricultural areas (Murphy 2003; Askins *et al*. 2007; Azpiroz and Blake 2009; Isacch and Cardoni 2011).

In summary, species richness and bird abundance is lower in Lotus pasture than in semi-natural grassland. Further, species richness and abundance of grassland specialists was greater in semi-natural grassland, whereas that of generalist species was greater in Lotus pasture. These differences, at least in part, are the result of the major change to habitat from grassland to Lotus pasture, which significantly alters the structure and heterogeneity of the habitat (Isacch *et al*. 2005; Azpiroz and Blake 2009; Isacch and Cardoni 2011). Other factors, such as the availability of food, roosting sites and nesting material might also vary between the semi-natural (grassland) and modified (Lotus pasture) habitats.

Conservation implications

We recorded three grassland specialists categorised as Near Threatened globally (International Union for Conservation of Nature 2014) and as Vulnerable in Argentina (AOP/SADS 2008): Hudson's Canastero (BirdLife International 2012*a*), Bay-capped Wren-Spinetail (BirdLife International 2012*b*) and Bearded Tachuri (*Polystictus pectoralis*; Birdlife International 2012*c*). The Flooding Pampas is an important agroecosystem and the continued advance of agricultural systems in this and other parts of the Pampas region is of conservation concern for the birds of the region (Bilenca and Miñarro 2004; Codesido *et al*. 2013). In addition to the loss of grassland habitat and its replacement with pasture species, such as Lotus, the application of herbicides for promotion of pasture growth also affects grassland seed-banks and, consequent additional long-term changes in vegetation structure (Rodríguez and Jacobo 2010). If intensified, this practice will lead to increased loss and fragmentation of grassland habitats and reducing the populations and distributional ranges of birds of the Pampas (Azpiroz *et al*. 2012).

To conserve Pampas birds in these agroecosystems, it is necessary to combine conservation of grassland elements and livestock management, particularly during the breeding season (Temple *et al*. 1999). The introduction of Lotus pastures is an effective way to increase livestock productivity and could be continued sustainably by activities such as intercropping of Lotus pasture and native grasses (Entio and Mujica 2011) and sustainable grassland management (Jacobo *et al.* 2006; Rodríguez and Jacobo 2010, 2012; Isacch and Cardoni 2011; Bilenca *et al*. 2012). Such sympathetic livestock production, along with grassland conservation, is needed to sustain the biodiversity of the Flooding Pampas.

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References

AOP–SADS (2008). 'Categorización de las Aves de Argentina Según su Estado de Conservación.' (Aves Argentinas/Secretaría de Ambiente y Desarrollo Sostenible: Buenos Aires, Argentina.)

Askins, R., Chávez-Ramírez, F., Dale, B., Haas, C., Herkert, J., Knopf, F., and Vickery, P. (2007). Conservation of grassland birds in North America: understanding ecological processes in different regions. *Ornithological Monographs* **64**, 1–46.

Azpiroz, A. B., and Blake, J. G. (2009). Avian assemblages in altered and natural grasslands in the northern Campos of Uruguay. *Condor* **111**, 21–35. doi:10.1525/cond.2009.080111

Azpiroz, A. B., Isacch, J. P., Dias, R. A., Di Giacomo, A. S., Suertegaray Fontana, C., and Morales Palarea, C. (2012). Ecology and conservation of grassland birds in southeastern South America: a review. *Journal of Field Ornithology* **83**, 217–246. doi:10.1111/j.1557-9263.2012.00372.x

Benton, T., Vickery, J., and Wilson, J. (2003). Farmland biodiversity: is habitat heterogeneity the key? *Trends in Ecology & Evolution* **18**, 182–188. doi:10.1016/S0169-5347(03)00011-9

Bibby, C. J., Burgess, N., Hill, D., and Mustoe, S. (2000). 'Bird Census Techniques.' (Academic Press: San Diego, CA.)

Bilenca, D. N., and Miñarro, F. O. (2004). 'Identificación de Áreas Valiosas de Pastizal en las Pampas y Campos de Argentina, Uruguay y Sur de Brasil.' (Fundación Vida Silvestre Argentina: Buenos Aires.)

Bilenca, D. N., Codesido, M., González Fischer, C. M., Pérez Carusi, L. C., Zufiaurre, E., and Abba, A. (2012). Impactos de la transformación agropecuaria sobre la biodiversidad en la provincia de Buenos Aires. *Revista del Museo Argentino de Ciencias Naturales* **14**, 189–198.

BirdLife International (2012*a*). *Asthenes hudsoni*. In 'IUCN Red List of Threatened Species. Version 2014.3'. (International Union for Conservation of Nature and Natural Resources: Gland, Switzerland.) Available at www.iucnredlist.org [Accessed 29 April 2015].

BirdLife International (2012*b*). *Spartonoica maluroides*. In 'IUCN Red List of Threatened Species. Version 2014.3'. (International Union for Conservation of Nature and Natural Resources: Gland, Switzerland.) Available at www.iucnredlist.org [Accessed 29 April 2015].

BirdLife International (2012*c*). *Polystictus pectoralis*. In 'IUCN Red List of Threatened Species. Version 2014.3'. (International Union for Conservation of Nature and Natural Resources: Gland, Switzerland.) Available at www.iucnredlist.org [Accessed 29 April 2015].

Brennan, L., and Kuvlesky, W. (2005). North American grassland birds: an unfolding crisis? *Journal of Wildlife Management* **69**, 1–13. doi:10.2193/0022-541X(2005)069<0001:NAGBAU>2.0.CO;2

Cardoni, D. A., Isacch, J. P., and Iribarne, O. (2012). Effects of cattle grazing and fire on the abundance, habitat selection, and nesting success of the Bay-capped Wren-Spinetail in coastal saltmarshes of the Pampas region. *Condor* **114**, 803–811. doi:10.1525/cond.2012.110186

Cavalli, M., Baladrón, A., Isacch, J. P., Martínez, G., and Bó, S. (2014). Prey selection and food habits of breeding Burrowing Owls (*Athene cunicularia*) in natural and modified habitats of Argentine pampas. *Emu* **114**, 184–188. doi:10.1071/MU13040

Codesido, M., González-Fischer, C. M., and Bilenca, D. N. (2008). Asociaciones entre diferentes patrones de uso de la tierra y ensambles de aves en agroecosistemas de la región pampeana, Argentina. *Ornitologia Neotropical* **19**, 575–585.

Codesido, M., González-Fischer, C., and Bilenca, D. (2011). Distributional changes of landbird species in agroecosystems of central Argentina. *Condor* **113**, 266–273. doi:10.1525/cond.2011.090190

Codesido, M., González-Fischer, C., and Bilenca, D. (2012). Agricultural land uses, avian nesting and rarity in the Pampas of central Argentina. *Emu* **112**, 46–54. doi:10.1071/MU11049

Codesido, M., González-Fischer, C., and Bilenca, D. (2013). Landbird assemblages in different agricultural landscapes: a case-study in the Pampas of central Argentina. *Condor* **115**, 8–16. doi:10.1525/cond.2012.120011

Comparatore, V., Martínez, M., Vasallo, A., Barg, M., and Isacch, J. P. (1996). Abundancia y relaciones con el hábitat de aves y mamíferos en pastizales de *Paspalum quadrifarium* manejados con fuego (Buenos Aires, Argentina). *Interciencia* **21**, 228–237.

Di Rienzo, J. A., Casanoves, F., Balzarini, M. G., Gonzalez, L., Tablada, M., and Robledo, C. W. (2013). InfoStat versión 2013. (Grupo InfoStat, FCA, Universidad Nacional de Córdoba: Argentina.) Available at http://www.infostat.com.ar [Verified 25 May 2015].

Dufrêne, M., and Legendre, P. (1997). Species assemblages and indicator species: the need for a flexible asymmetrical approach. *Ecological Monographs* **67**, 345–366.

Entio, L., and Mujica, M. (2011). Resiembra natural en *Lotus tenuis* implantado con diferentes sistemas de siembra. *Agrociencia* **45**, 431–441.

Herrera, L. P., Laterra, P., Maceira, N., Zelaya, K., and Martínez, G. (2009). Fragmentation status of tall-tussock grassland relicts in the flooding Pampas, Argentina. *Rangeland Ecology and Management* **62**, 73–82. doi:10.2111/08-015

Isacch, J. P., and Cardoni, D. A. (2011). Different grazing strategies are necessary to conserve endangered grassland birds in short and tall salty grasslands of the Flooding Pampas. *Condor* **113**, 724–734. doi:10.1525/cond.2011.100123

Isacch, J. P., and Martínez, M. (2001). Estacionalidad y relaciones con la estructura del hábitat de la comunidad de aves de pastizales de paja colorada (*Paspalum quadrifarium*) manejados con fuego en Buenos Aires, Argentina. *Ornitologia Neotropical* **12**, 345–354.

Isacch, J. P., Maceira, N., Bo, S., Demaría, M., and Peluc, S. (2005). Bird-habitat relationship in semiarid natural grasslands and exotic pastures in the west pampas of Argentina. *Journal of Arid Environments* **62**, 267–283. doi:10.1016/j.jaridenv.2004.11.008

International Union for Conservation of Nature (2014). 'IUCN Red List of Threatened Species. Version 2014.3'. (International Union for Conservation of Nature and Natural Resources: Gland, Switzerland.) Available at http://www.iucnredlist.org [Verified 9 April 2015].

Jacobo, E. J., Rodríguez, A., Bartoloni, N., and Deregibus, V. A. (2006). Rotational grazing effects on rangeland vegetation at a farm scale. *Rangeland Ecology and Management* **59**, 249–257. doi:10.2111/05-129R1.1

Matteucci, S., and Colma, A. (1982). 'Metodología para el Estudio de la Vegetación.' (Organización de Estados Americanos: Washington, DC.)

McCune, B., and Mefford, M. (1999). 'PC-ORD for Windows. Multivariate Analysis of Ecological Data. Version 4.01.' (MjM Software Design: Gleneden Beach, USA.)

Murphy, M. T. (2003). Avian population trends within the evolving agricultural landscape of eastern and central United States. *Auk* **120**, 20–34. doi:10.1642/0004-8038(2003)120[0020:APTWTE]2.0.CO;2

Perelman, S. B., Burkart, S. E., and León, R. J. C. (2003). The role of a native tussock grass (*Paspalum quadrifarium* Lam.) in structuring plant communities in the Flooding Pampa grasslands, Argentina. *Biodiversity and Conservation* **12**, 225–238. doi:10.1023/A:1021948723714

Robinson, R. A., and Sutherland, W. J. (2002). Post-war changes in arable farming and biodiversity in Great Britain. *Journal of Applied Ecology* **39**, 157–176. doi:10.1046/j.1365-2664.2002.00695.x

Rodríguez, A., and Jacobo, E. (2010). Glyphosate effects on floristic composition and species diversity in the Flooding Pampa grassland (Argentina). *Agriculture, Ecosystems & Environment* **138**, 222–231. doi:10.1016/j.agee.2010.05.003

Rodríguez, A., and Jacobo, E. (2012). 'Manejo de Pastizales Naturales para una Ganadería Sustentable en la Pampa Deprimida.' (Fundación Vida Silvestre Argentina/Aves Argentinas: Buenos Aires, Argentina.)

Sala, O. E., Oesterheld, M., León, R. J., and Soriano, A. (1986). Grazing effects upon plant community structure in subhumid grasslands of Argentina. *Vegetatio* **67**, 27–32.

Soriano, A. (1991). Río de la Plata grasslands. In 'Ecosystmes of the World. Vol. 8A. Natural Grasslands: Introduction and Western Hemisphere'. (Ed. R. T. Coupland.) pp. 367–407. (Elsevier: Amsterdam, Netherlands.)

Temple, S., Brick, M., Paine, L., Undersander, D., and Sample, D. (1999). Nesting birds and grazing cattle: accommodating both on Midwestern pastures. *Studies in Avian Biology* **19**, 196–202.

Vickery, P., Tubaro, P., Cardoso Da Silva, J., Peterjohn, B., Herkert, J., and Cavalcanti, R. (1999). Conservation of grassland birds in the western hemisphere. *Studies in Avian Biology* **19**, 2–26.

Zar, J. H. (1999). 'Biostatistical Analysis.' (Prentice-Hall: Englewood Cliff, NJ.)