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Bird-habitat relationship in semi-arid natural grasslands and exotic pastures in the west pampas of Argentina

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Abstract

In the semi-arid grasslands of the west pampas, in Argentina, extended natural grasslands still persist only with cattle grazing. However, in the last years there has been an important increase in the cultivation of African pasture species. We evaluated the incidence of the replacement of natural grasslands by exotic pastures on bird diversity in spring–summer and in winter. In five different grassland habitats (two native and three sown pastures), we sampled bird populations using the strip transect method and vegetation variables simultaneously at the same sites. We used multiple regressions to examine the relative importance of habitat variables on richness, abundance and presence of bird species. The replacement of native grasslands (Sorgastral) by sown pastures results in habitat modifications such as changes in green vegetation, percentage of bare ground and distance to trees. When native grasslands are moderately grazed (mixed grassland) plant species richness increases notably relative to other native and exotic pastures. Some vegetation variables were correlated with bird species richness or with some bird populations. However, the habitat variable that best described bird

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species richness and bird abundance was plant species richness, which varied both with the grazing history of the native grassland and with the type of pasture used as replacement. Consequently, grassland replacement by sown pastures in the west pampas results in changes in bird alpha diversity; decreasing diversity with respect to mixed grasslands, but favoring it in relation to the climax grassland (Sorgastral). The composition of grassland bird communities in natural grasslands would be little affected by exotic pastures replacement. However, since some vegetation variables best represented in some habitats had particular effects on the abundance and presence of specific grassland birds, managers and policy makers should take into account the complexity of the processes associated with changes in land use of the west pampas. This would not only decrease the probability of negative effects on the total bird diversity but also would decrease the risk of local extinction of declining species.

Keywords: West pampas; Semi-arid grasslands; Bird diversity; Pastures; Grazing; Argentina

1. Introduction

Plant species composition and vegetation structure gives terrestrial environments their physical configuration characteristic, which has been demonstrated to be important in determining the abundance and distribution of birds. Vegetative structure and floristic composition are assumed to be the primary proximate factors that determine where and how birds use resources, affecting habitat selection (see Hildén, 1965; Rotenberry, 1985; Block and Brennan, 1993). Vegetation presumably also acts as an ultimate factor by its association with critical variables such as food, nesting sites and cover from predators. Individuals most likely select habitats that provide them with an optimal combination of resources that allows them to perform multiple activities (e.g., foraging, breeding, roosting; Hildén, 1965; Fretwell and Lucas, 1970; Block and Brennan, 1993; Steele, 1993). Consequently, modifications in the vegetation cover caused by management practices are predicted to influence bird species composition and their relative abundance (Gabrey et al., 1999). Bird diversity is positively correlated with habitat structural complexity (Mac Arthur and Mac Arthur, 1961; Wiens, 1973; Roth, 1976). Explanations for this relationship emphasize the role of habitat complexity in promoting niche diversification, and thus diversity (Willson, 1974; Roth, 1976).

Ecosystem disturbances such as fragmentation, changes in vegetation structure, replacement of tall grasses by short grasses, introduction of exotic species, replacement of grasslands by croplands or pastures, introduction of domestic predators and decrease or extinction of native predators (Bock and Bock, 1988; Herkert, 1994; Vickery et al., 1994; Comparatore et al., 1996; Jobin et al., 1996; Helzer and Jelinsky, 1999, but see different publications in Goriup, 1988) have been observed to produce changes on populations and communities of grassland birds. The semi-arid grasslands of the west pampas, the western limit of the pampas region in Argentina (León and Anderson, 1983) are of particular interest for the study of grassland bird communities. Agricultural development has severely reduced and fragmented native habitats throughout the Rio de la Plata grasslands in South America (Soriano et al., 1991). Agroecosystems have replaced native grasslands in a broad fraction of the region. However, in central Argentina (San Luis Province; 'west pampas' *sensu* Soriano et al., 1991) extended natural grasslands still persist, because semi-arid conditions and soil fragility have constrained agriculture expansion (León et al., 1984). Not more than 10 years ago, grazing was the main factor modeling grass cover structure and composition in the west pampas relict grasslands. Only one exotic grass species, the African lovegrass (*Eragrostis curvula*), was frequently used as sown pasture in the region, although always occupying a minor proportion (5–10%) of the grazing lands. Yet, in the last decade, new African grass species (*Panicum coloratum* and *Digitaria eryantha*) have become available for farmers, and in some ranches high proportions of the original grasslands have been replaced by these sown pastures. Rains, higher now than in the past (see forward), have also stimulated these changes in land use.

We evaluated the incidence of the replacement of natural grasslands by exotic pastures on bird species richness and abundance in the west pampas. We analysed the relationships between bird species richness and abundance with habitat characteristics in two types of pastures (native and sown), as well as the relative importance of the presence of particular bird species in these habitats. We evaluated these relationships seasonally and analysed the results under the perspective of the sustainable management of natural grasslands.

2. Materials and methods

2.1. Study area

We conducted the study in central San Luis Province, Argentina, in several ranches located on a strip of approximately 50 km east–west and 35 km north–south (Fig. 1). According to Peña Zubiate et al. (1998), the strip occupies (from east to west) the vegetation-soil units corresponding to sandy flat with anthropogenic dunes, sandy flat with permanent lagoons, and central sandy flat. These areas constitute important constrains to agriculture (increasing from east to west), determined by drought and sandy soils, poor in organic matter and with low water retention capacity (Peña Zubiate et al., 1998).

The original vegetation of the region was described as grassland with islets or patches of "chañar" (*Geoffroea decorticans*), isolated "calden" (*Prosopis caldenia*) and "alpataco" (*Prosopis alpataco*) (Anderson et al., 1970, 1978). *Sorghastrum pellitum* ("cow grass"), the dominant species in the climax vegetation ("Sorgastral"; usually 3–4 cattle/ha), has been used to identify later successional stages (Anderson et al., 1978). Other grasses associated with *S. pellitum* are *Elyonurus muticus*, *Bothriochloa springfieldii*, *Chloris retusa*, *Schizachyrium plumigerum*, *Eragrostis lugens*, *Sporobolus subinclusus*, *Aristida spegazzini*, *Poa ligularis* and *Poa lanuginosa*. Nowadays, these grasslands are not uniform, as their composition varies according to their management history (Anderson et al., 1978; Aguilera et al., 1998). The main

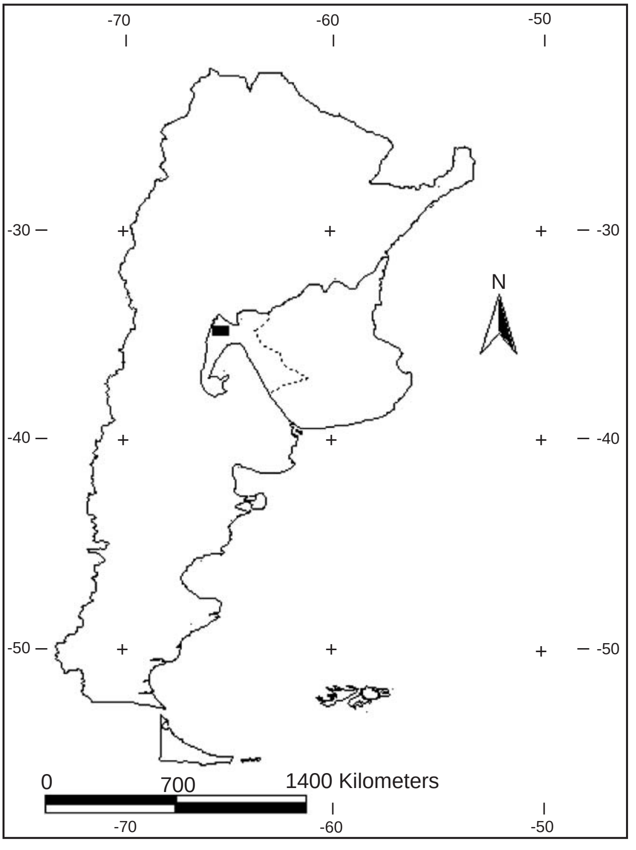


Fig. 1. Pampa Region in Argentina and location of the study area (box). Subdivision indicates the limit of Western Pampa sub-region (after Soriano et al., 1991).

activity in this region is cattle breeding on natural grasslands, although in the eastern part of the region an important proportion of grassland has already been replaced with sown pastures and crops (Peña Zubiate et al., 1998). We will refer to these grassland communities modified by grazing history as "mixed grasslands" (usually 5–6 cattle/ha). Mixed grasslands are normally dominated by *Elyonurus muticus* and other perennial grasses, although most of the original plant species persist and the forage quality of the pasture is moderate to good. While sorgastral grasslands are located mainly towards the west of the study area (in the central sandy flat unit), mixed grasslands occur in all the area but are dominant in the center and east, where human impact is higher. Mixed grasslands have higher plant diversity than sorgastral, especially because species evenness increases as *S. pellitum* dominance decreases due to cattle selective grazing (Anderson et al., 1978). Additionally, cattle grazing and agriculture have promoted the propagation of *chañar* and *calden* trees into the grasslands. As a consequence, natural grasslands under grazing present a higher structural heterogeneity than pristine (ungrazed or slightly grazed) grasslands.

Exotic pastures are represented by *E. curvula, D. eriantha*, and in a lesser proportion, *P. coloratum*. All of them are African species introduced in the region to increase the stocking rate of cattle ranches. *E. curvula* was introduced 40 years ago, and its sustainability and cow profitability has been largely tested in the region (Marchi et al., 1974). When this species is established in the pasture it forms dense clumps of vegetation, with only scarce spots where other spontaneous species can grow. *D. eriantha* and *P. coloratum* are new pastures in the area, and their livestock carrying capacity and sustainability had not been sufficiently studied (Frasinelli et al., 1992). Exotic pastures are more abundant towards the east of the area, but their presence in the west has increased in the last 10 years, replacing not only overgrazed -degraded- native grasslands, but also mixed and climax grasslands of good forage quality and high conservation value (Demaría et al., 2003).

San Luis Province presents a clear differentiation between a rainy period in the spring–summer and a dry one in the fall–winter. The study area is included between 400 and 500 mm average annual historical isohyets, but mean annual precipitation has increased in the last 50 years (near 20% in comparison with the previous 50 years at Villa Mercedes city, 60 km NE from the study area; Veneciano et al., 2000). The water balance (modified Penman Index; 1994–99 period) indicates the existence of a permanent water deficit during the year (Veneciano et al., 2000). The mean temperature varies approximately between 8 °C (July) and 23 °C (January), with a frost-free period of 142 days (1983–99) (Veneciano et al., 2000).

For this study, we have considered each kind of sown pasture (*Eragrostis, Digitaria* and *Panicum*) and native grassland (sorgastral and mixed grassland) as different habitats and have denominated them "pasture types".

2.2. Bird sampling

We sampled bird populations using the strip transect method (Emlen, 1971) during spring–summer (November 1999 and early March 2000) and winter (July and August 2000), on several paddocks of each pasture type. We census two or four transects by paddock, depending on their size. Because paddocks were often larger than 500 ha, and similar paddocks were located far away one from each other representing a logistic constrain, we selected more than one transect by paddock to census. However, to avoid pseudoreplication (Hurlbert, 1984), we interspersed transects within each paddock as much as possible (at least 200 m apart) to diminish spatial dependence. We conducted 58 counts (distributed in 29 paddocks) during winter (sorgastral: 8, mixed grassland: 18, *Eragrostis*: 16, *Panicum*: 4, *Digitaria*: 12), and 66 (distributed in 30 paddocks) during spring–summer (sorgastral: 12, mixed grassland: 18, *Eragostris*: 18, *Panicum*: 6, *Digitaria*: 12). Strip transects were 500×60 m and its longitude and rate of traverse were concordant with Conner and Dickson (1980). All censuses were conducted during the 4 h after sunrise or during the last 3 h of daylight. We did not census birds under extreme weather conditions (windy and/or rainy days) because of their adverse effect on bird activity (Conner and Dickson, 1980). At each transect we recorded species, number of individuals, and the site where the birds were perched: grassland, tree and/or both. We did not count birds in transit, but we counted those that were searching food in flight. The summer data of pipits (*Anthus* spp.) were not included in the specific population analysis because pipits do not sing during that season and so species identification is impossible.

2.3. Vegetation sampling

We sampled vegetation simultaneously and in the same paddocks where birds were sampled. We used a metallic frame of 0.5×1.0 m to delimit 10 plots along each paddock. Variables recorded inside each paddock were:

- *Soil cover*: proportion of soil surface covered with green vegetation, dead vegetation (including litter) and bare ground (%, visual estimation).
- *Species richness*: number of plant species.
- *Vegetation layers* : We determined the number of dominant vegetation strata, distinguishing among short grasses, tall grasses, herbs, and also discriminating between vegetative and reproductive structures.
- *Modal height*: we estimated the vertical standing plant biomass, using the Robel pole technique (Robel et al., 1970). With this method we were able to determine height and vertical obstruction of vegetation cover. We used a 1.5 m, 5 cm graduated ruler that was kept vertically in the center of the frame, while the observer looked at the ruler from 3 m away, keeping his visual line at near 1 m from the ground. We recorded the lowest mark in the graduated scale that the observer was able to see (that is, the lowest mark free from vegetation obstruction). Higher values of modal height represent taller and denser standing vegetation.
- *Distance to trees* : visual estimated distance (m) to the nearest tree, as an indicator of the relative importance of trees in the site; in locations where there were no trees, an arbitrary distance of 1000 m was recorded.

2.4. Statistical analysis

We evaluated differences in vegetation and other habitat variables in spring–summer and winter among pasture types using a one-way ANOVA (Zar, 1996). Because distance to trees is not expected to change seasonally, we evaluated mean distance to trees among pastures considering both seasons together. Differences in bird species richness among pasture types (habitats) were also assessed using a one-way ANOVA. The data were transformed using a $\log_{10}(x+1)$ transformation when the assumption of homocedasticity was violated (Zar, 1996). In some cases the vegetation data were heterocedastic even after being transformed, yet we used a parametric test since, in spite of violating that assumption, using a parametric test has more statistical power than using the respective non-parametric test (Underwood, 1997). When significant differences were detected, we used an a posteriori least significant difference (LSD) test to discriminate means (Zar, 1996).

Mean bird species richness for each habitat (pasture type) was considered an estimator of alpha diversity. Also we considered the contribution of sown pastures to grassland bird species richness of the area.

We used stepwise forward regression (Neter et al., 1990) to examine the relative importance of vegetation variables (mean by paddock) on bird species richness and density (mean by paddock) in spring–summer and winter. For some species we could not use abundance as our response variable because in most surveys we did not find birds (data not normally distributed); in those cases we employed logistic regression analysis (Trexler and Travis, 1993). With this technique we related presence/absence data of birds with vegetation variables. For the analyses at the species level we considered only the specific grassland species (excepting birds of prey and Greater Rhea (*Rhea americana*), because they have a very high range of habitat use, not appropriately contemplated in our sampling technique).

3. Results

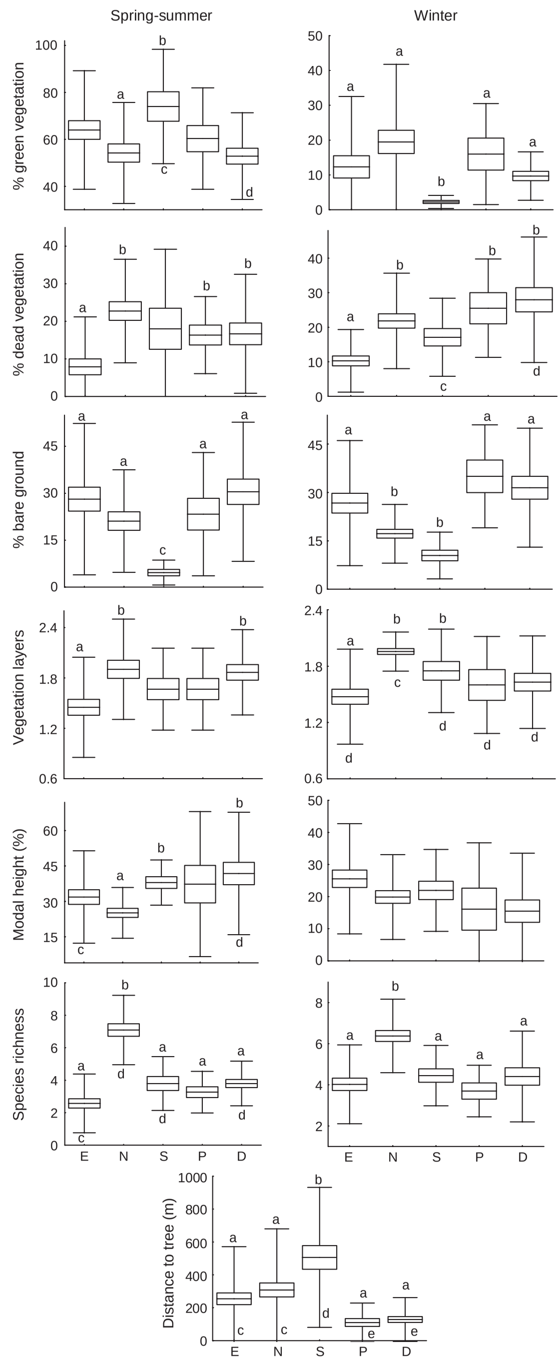
3.1. Vegetation and habitat characteristics

We found that the five habitats differed in relation to all of the vegetation variables measured during both periods, spring–summer and winter (Table 1; Fig. 2).

Table 1
One-way ANOVA results of vegetation and habitat variables for each season among pasture types in the west pampas of Argentina

	MS	*F*	*P*
Summer			
% green vegetation	1541	3.06	0.02
% dead vegetation	1024	4.67	0.002
% bare ground	1952	4.84	0.001
Vegetation layers	1.16	3.78	0.006
Modal height	1212	2.92	0.02
Species richness	96.4	31.91	<0.00001
Winter			
% green vegetation	1151	3.85	0.005
% dead vegetation	1512	8.50	<0.00001
% bare ground	2148	9.67	<0.00001
Vegetation layers	1.30	7.38	0.00002
Modal height	487	1.9	0.1
Species richness	38.46	11.33	<0.00001
Summer–winter			
Distance to tree	1.53	4.44	0.002

The variable "distance to tree" is assessed considering both seasons. Df = 4 for all comparisons.


Spring-summer
Winter
% green vegetation
% dead vegetation
% bare ground
Vegetation layers
Modal height (%)
Species richness
Distance to tree (m)
E
N
S
P
D

The Sorgastral showed the highest percentage of green vegetation and the lowest percentage of bare ground during spring–summer. However, during winter it had the lowest percentage of green vegetation and of bare ground. In general Sorgastral showed the highest distance to nearest tree. Mixed grassland had high values of vegetation layers and notably high values of plant species richness during both seasons, and low vegetation density shown by its low modal height values during spring–summer. *Eragrostis* had low percentages of dead vegetation during both seasons, and low modal height values and the lowest plant species richness during spring–summer. *Digitaria* presented high values of vegetation layers in spring–summer; however it showed the lowest distance to nearest tree together with *Panicum*.

3.2. Bird–habitat relationships

A total of 28 bird species were recorded during the study period (total species richness for the whole area). Among them, 13 were highly grassland dependent species (five were permanent resident, four were summer resident and four were occasional species; Table 2).

Natural grasslands and sown pastures had 22 species each, sharing 16 of these species. Mean bird species richness (alpha diversity) differed significantly among habitats in both periods (Table 2; $F_{4,61(\text{spring–summer})} = 6.47$, $P = 0.0002$; $F_{4,53(\text{winter})} = 4.87$, $P < 0.002$). In both seasons mixed grasslands had the higher values of bird species richness (LSD test, $P < 0.05$; Table 2), and no differences were detected among the other pastures.

During spring–summer, bird species richness was positively correlated with plant species richness (Fig. 3), considering all habitats together, and it was negatively correlated with dead vegetation and distance to the nearest tree (Table 3). Bird abundance was also positively correlated with plant species richness during spring–summer (Table 3). However, during the winter period, no vegetation variable was correlated either with bird species richness or bird abundance.

Sorgastral and mixed grassland had a grassland-bird community that was not different in composition to that of exotic pastures (Table 2). However, abundance and presence of some grassland bird species correlated with some vegetation variables, which sometimes were best represented in particular habitat types. *Anthus chacoensis* density was positively correlated with modal height (Table 4; Fig. 4), however we did not find a clear relationship between this result and differences among pastures for modal height. *Ammodramus humeralis* presence was positively correlated with plant species richness during the spring–summer period and with

Fig. 2. Box and whisker plots (mean, ±SE and ±SD) of vegetation variables in natural and sown pastures in the west pampas of San Luis Province, Argentina. There are two levels of comparisons using LSD test, and they area represented above and bellow the box and whisker plots, and at each level different letters represent specific significant differences ($P < 0.05$). Pastures: *Eragrostis curvula* (*E*), mixed grassland (*N*), sorgastral (*S*), *Panicum coloratum* (*P*) and *Digitaria eriantha* (*D*).

Table 2
Mean bird species abundance (individuals/transect) recorded in natural grasslands and sown pastures of the west pampas of Argentina

Number of strip transects	Sorgastral		*Mixed grassland*		*Eragrostis*		*Panicum*		*Digitaria*		MS[a]	TG[b]
	S–S 12	W 8	S–S 18	W 18	S–S 18	W 16	S–S 6	W 4	S–S 12	W 12		
A: grassland dependent species												
Rhea americana	0	0	0.06	0	0	0	0	0	0	0	Pr	H
Nothura darwini	0	0	0.22	0.06	0.17	0.13	0.50	0.25	0.08	0.25	Pr	O
Nothura maculosa	0	0	0[c]	0[c]	0	0	0	0	0	0	O	O
Rynchotus rufescens	0	0	0.11	0	0.17	0	0.33	0	0.25	0	Sr	O
Circus cinereus	0	0	0[c]	0	0	0	0	0	0	0	O	C
Circus buffoni	0	0	0	0	0	0	0.17	0	0	0	O	C
Asio flammeus	0	0	0	0.06	0	0	0	0	0	0	O	C
Anthus correndera	0	0	0.29	0	0.22	0	1.67	0	0	0	Sr	I
Anthus chacoensis	3.63	0	3.57	0	0.56	0	0	0	0.08	0	Sr	I
Ammodramus humeralis	0.08	0	2.17	0.56	0.22	0.13	2.17	0	0.67	0.08	Pr	G
Sicalis luteola	0	0	1.72	0	0.28	1.44	0	1.75	1.67	0	Pr	G
Sturnella loyca	1.83	0	2.56	0.11	0.67	0	1.67	0.25	3.08	2.00	Pr	O
Leistes supercilliaris	0	0	1.11	0	0	0	1.50	0	0	0	Sr	O
B: woody-dependent or habitat-independent species												
Polyborus plancus	0	0	0.17	0	0	0	0	0	0	0	Pr	C
Milvago chimango	0.42	0	0.11	0	0.06	0	0.17	0	0	0	Pr	C–I
Falco femoralis	0	0	0.06	0	0	0	0	0	0.08	0	Pr	C
Falco sparverius	0	0	0	0	0	0	0.17	0.25	0	0.08	Pr	C–I
Vanellus chilensis	0	0	0	0	0.06	0.13	0	0.50	0	0	Pr	O
Athene cunicularia	0	0	0	0	0	0.06	0.33	0	0	0	O	C–I
Annumbius annumbi	0	0.13	0.33	0	0.33	0.06	0	0	0.08	0	Pr	I
Agriornis murina	0	0	0	0	0	0.06	0	0	0	0	O	I
Xolmis irupero	0	0	0.06	0	0	0.06	0	0	0	0	O	I
Troglodytes aedon	0	0	0	0	0	0.06	0	0	0	0	O	I
Zonotrichia capensis	0	0	0.17	0.11	0.17	0	0	0	0.33	0	Pr	G
Diuca diuca	0	0	0.06	0	0	0	0	0	0.08	0	O	G
Sicalis flaveola	0	0	0.33	0	0	0	0	0	0.50	0	Sr	G
Molothrus bonaeriensis	0	0	0.17	0	0.06	0	0	0	0	0	Pr	O
Molothrus badius	0	0	0.11	0	0	0	0	0	0	0	O	O
Mean habitat richness	2.10	0.36	4.40	2.00	1.06	1.06	3.17	1.50	1.92	0.67		
LSD test-spring–summer	a	—	b	—	a	—	a	—	a	—		
LSD test-winter	—	a	—	b	—	a	—	a	—	a		
Grassland birds species	3	0	9	4	7	3	7	3	6	3		

The species are grouped regarding grassland dependence. Data are separated with regards to season and habitat. Migratory status (MS) and trophic guild (TG) are indicated for each species. Seasons included spring–summer (S–S) and winter (W). A posteriori LSD test results of bird richness by season are included in two files at the bottom of the table; different letters mean significant differences ($P<0.05$).

[a]Migratory status: Pr, permanent resident; Sr, summer resident; O, occasional (less than 4 records in the 124 censuses).

[b]Guild: H, herbivore, G, granivore; I, insectivore; O, omnivore; C, carnivore (according to Capurro and Bucher, 1986; Canevari et al., 1991; Marone, 1992).

[c]Species recorded only out of transect in a habitat and season.

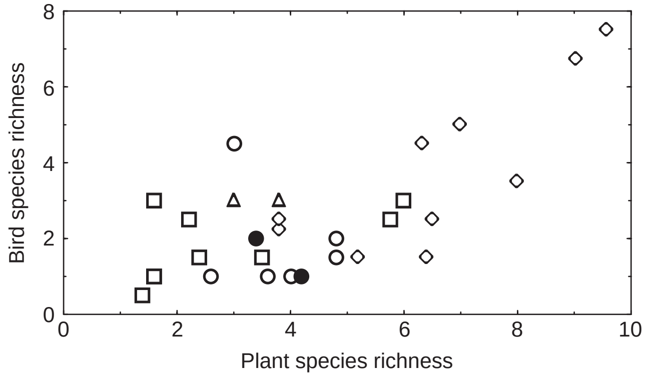


Fig. 3. Number of bird species plotted as a function of number of plant species during spring–summer period for natural grasslands and sown pastures from the west pampa region, San Luis Province, Argentina. References: Black dot—sorgastral, open rhomboid—mixed grassland, open square—*Eragrostis*, open circle—*Digitaria* and open triangle—*Panicum*.

Table 3
Results of a stepwise forward regression examining the relationship of vegetation variables with bird species richness and bird abundance in the west pampas of Argentina, during the spring–summer period ($N = 30$)

	Beta coefficient	SE	*P*-level
Bird richness			
Plant species richness	0.85	0.14	<0.00001
% dead vegetation	−0.32	0.14	<0.03
Distance to tree	−0.26	0.13	<0.05
Bird abundance			
Plant species richness	0.51	0.19	0.01

Only those variables that were significantly correlated ($P<0.05$) with bird variables are shown.

vegetation layers during winter (Table 4), and both variables had high values in mixed grasslands in the respective seasons. *Sicalis luteola* presence was negatively correlated with green vegetation (lower in mixed grasslands and *Digitaria*) and positively correlated with plant species richness (higher in mixed grasslands) in spring–summer (Table 4). On the other hand, this species was positively correlated with vegetation layers and bare ground, and negatively correlated with plant species richness during winter (Table 4); characteristics associated with those of exotic pastures (Fig. 2). *Leistes superciliaris* was only recorded during the spring–summer period and its presence was negatively associated with distance to the nearest tree (Table 4); which had lower values of sown pastures than natural grasslands (Fig. 2). *Rynchotus rufescens* presence was positively correlated with vegetation layers (Table 4). *Nothura darwinii*, *Anthus correndera* and *Sturnella loyca* were not significantly correlated with any of the analysed variables.

Table 4
Results examining the relationship between the abundance (only *Anthus chacoensis*) or presence of some bird species and vegetation variables, in the west pampas of Argentina

	Beta coefficient	SE	*P*-level
Spring–summer			
Anthus chacoensis ($N = 14$)			
Modal height	0.66	0.23	<0.02
Rynchotus rufescens ($N = 30$)			
Vegetation layers	0.42	0.17	0.02
Ammodramus humeralis ($N = 30$)			
Species richness	0.66	0.18	0.001
Sicalis luteola ($N = 30$)			
% green vegetation	−0.58	0.22	<0.02
Species richness	0.58	0.27	0.04
Leistes superciliaris ($N = 30$)			
Distance to tree	−0.35	0.16	<0.04
Winter ($N = 29$)			
Ammodramus humeralis			
Vegetation layers	0.66	0.16	<0.001
Sicalis luteola			
Vegetation layers	0.60	0.18	<0.01
% bare ground	0.55	0.17	<0.01
Species richness	−0.44	0.17	0.01

Only those variables that were significantly correlated ($P < 0.05$) with the presence of any bird species are shown.

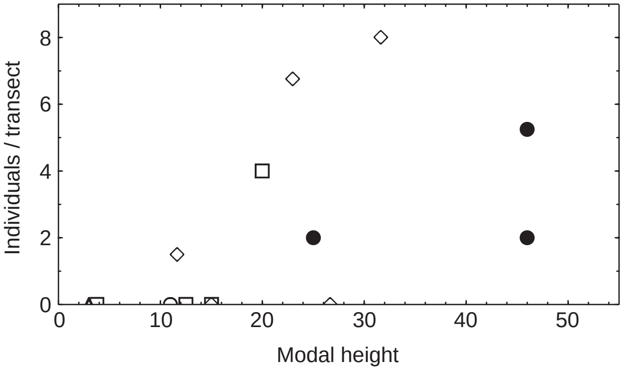


Fig. 4. Chaco Pipit number of individuals plotted as a function of modal height during spring period for natural grasslands and sown pastures from the west pampa region, San Luis Province, Argentina. References: Black dot—sorgastral, open rhomboid—mixed grassland, open square—*Eragrostis*, open circle—*Digitaria* and open triangle—*Panicum*.

4. Discussion

The replacement of native grasslands (Sorgastral) by sown pastures results in habitat modifications like changes in green vegetation, bare ground and distance to trees. When native grasslands are moderately grazed (mixed grassland) plant species richness increases notably compared with other native and exotic pastures. Some of these variables were related to bird species richness or to some bird populations (e.g., vegetation layers to *Rynchotus rufescens*, bare ground to *Sicalis luteola*). However, the habitat variable that best described bird species richness and bird abundance was plant species richness, which varied both with the grazing history of the native grassland (see Introduction) and with the type of pasture used as replacement. Consequently, grassland replacement by sown pastures in the west pampas results in changes in bird alpha diversity; decreasing diversity with respect to mixed grasslands, but in some cases favoring it in relation to the climax grassland highly dominated by *Sorghastrum*. The composition of grassland bird communities in natural grasslands would be little affected by exotic pastures replacement. However, we should take into consideration that the variability in some vegetation variables best represented in some habitats, had particular effects on the abundance and presence of specific grassland birds.

Bird species richness was not explained by plant species richness during winter. This can be due to the fact that differences in plant richness among habitats were higher in spring–summer than in winter, when dry weather and low temperatures have negative effects on green vegetation and modal height. Wiens (1989) states that since resource levels, shelter, and many other habitats features undergo large seasonal changes in most environments, seasonal variation in bird habitat occupancy is not unexpected. Marone (1991) in the Monte Desert (habitat bordering the western pampas) also found that bird diversity was explained by habitat complexity during the breeding season, but not in winter. The author justified this by the dominance of granivores during winter, which spread over the habitat without tracking the environmental gradient. In our study we observed that, within the grassland species, insectivorous were absent in the winter, and the dominant species was a granivore (*Ammodramus humeralis*). The positive relationship of these bird species with vegetation layers suggests that this bird could be selecting some plant characteristic that covariates with this variable, such as reproductive structures (presence of seeds).

Trees attract numerous birds because they provide perching, nesting and/or foraging sites. This may explain the positive relationship between nearby trees and bird species richness.

All the grassland species considered in the analysis, except for *S. loyca*, *A. correndera* and *Nothura darwinii,* were correlated with some of the habitat variables. However, this information per se does not mean causality. *A. correndera* and *N. darwinii* were not present in Sorgastral. This suggests that both bird species benefit from cattle grazing of the original grassland or from its replacement by sown pastures. Isacch and Martínez (2001) studying birds of *Paspalum quadrifarium* grasslands in the wet pampas region, also observed that the modification of the grassland structure by fire and cattle grazing generated a major use of the grassland by *A. correndera* and *N. maculosa*, a species related to *N. darwinii.* Other bird species as *R. rufescens* and *S. luteola* are also favored from sorgastral alteration or replacement.

On the other hand, at least one species—*A. chacoensis*—was abundant in both types of natural grasslands. The relatively high density of *A. chacoensis* in spring–summer in natural grasslands correlated with a particular structure of the habitat like the modal height. This variable presented high values in spring–summer in Sorgastral and *Digitaria*. The use of tall grasslands for this species had already been mentioned, contrary to the habits of the other species of this genus, which prefer open areas, as short grass habitat (Straneck, 1987; Canevari et al., 1991). However more studies would be necessary to know the specific requirements of this enigmatic species.

4.1. Management implications

The results of the present study show that differences in vegetation structure and plant species richness, associated with grassland management history and grassland replacement by sown pastures, have direct effects on bird populations of the west pampas. Therefore, this must be taken into account by conservation planers or policy makers, in order to conserve bird communities and specific bird populations. The main focus must be put in species with restrictive habitat requirements, like *A. chacoensis*, that seems to be selecting a habitat with a particular structure (high modal height). Likewise, the opposite relationships with the same variable shown by other species of birds should be kept in mind in management practices, keeping enough habitat variability to include the requirements of the different species and to assure the requirements of the most threatened ones.

Management must be also directed to minimize breeding season disturbances, since that period concentrates the major number of species and abundance of birds. Fire should be avoided during the breeding season (spring–summer period), but perhaps it could be used in prescribed burns at the end of the winter with a minimum impact on birds, taking into account their low richness in this period.

Moderate cattle grazing of natural grasslands may be an adequate management policy to maintain bird diversity and threatened grassland bird populations, because of its positive effect on plant diversity. However, if stoking rate is excessive and resting periods are not implemented, grassland can be degraded, with negative effects on plant production and diversity (Aguilera et al., 1998).

Simultaneously, grazing and plough events favor the ingression of trees into the mixed grasslands and pastures, conferring them structural heterogeneity. This fact was reflected in the positive association between bird species richness and proximity to trees, mainly due to the contribution of birds associated with them. However, we detected that trees facilitated the ingression of predator birds (e.g. *Falco femoralis, Polyborus plancus*) and nest parasites (*Molothrus bonaeriensis*), which could have negative effects on the populations of typical grassland birds (Herkert, 1994).

Eragrostis curvula is the most widespread pasture in semi-arid grasslands. Like *Sorgastrum pellitum*, this species is highly dominant and so its pastures present low plant and bird diversity. Its contribution to grassland bird diversity is poor, but it is not a pasture type currently in expansion in the area. *Panicum* and *Digitaria* presented slightly better conditions for grassland birds, determined by higher structural complexity and plant richness than *Eragrostis*. These new pastures are expanding quickly (Aguilera et al., 1999; Collado, 1999), becoming highly predominant in some areas of the region (Demaría et al., 2003). Increased rains also favor agriculture expansion in the west pampa (Veneciano et al., 2000). Moreover, sorgastral—the original ecosystem of the region—is quickly disappearing from the west pampa landscape, due to the combination of grassland replacement and grassland use by cows (Demaría et al., 2003). Mixed grasslands, although they still remain as the most common ecosystem in the west, are also disappearing in the east of the area. Managers and policy makers should keep all these processes in mind, because they can negatively affect total (gamma) bird diversity of the west pampa and could generate local extinction of declining species.

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References

Aguilera, M., Steinacker, D., Demaría, M., Avila, A., 1998. Estados y transiciones de los pastizales de *Sorghastrum pellitum* del área medanosa central de San Luis, Argentina. Ecotrópicos 11, 107–120.

Aguilera, M., Demaría, M., Avila, A., Steinaker, D., 1999. Impacto de la intensificación del uso de la tierra en la diversidad vegetal. In: Matteucci, S.D., Solbrig, O.T., Morello, J., Halffter, G. (Eds.), Biodiversidad y Uso de la Tierra. Conceptos y Ejemplos de Latinoamérica. EUDEBA, Buenos Aires, pp. 515–528.

Anderson, D.L., Del Aguila, J.L., Bernardón, A.E., 1970. Las formaciones vegetales de la provincia de San Luis. Revista de Investigación Agropecuaria 2 (VII) no. 3.

Anderson, D.L., Orionte, E.L., Vera, J.C., 1978. Una reliquia del pastizal de San Luis. Ecología 3, 139–151.

Block, W.M., Brennan, L.A., 1993. The habitat concept in ornithology: theory and applications. Current Ornithology 11, 35–89.

Bock, C.E., Bock, J.H., 1988. Grassland birds in southeastern Arizona: impacts of fire, grazing and alien vegetation. International Council of Bird Preservation. Technical Publications 7, 43–58.

Canevari, M., Canevari, P., Carrizo, G.R., Harris, G., Rodriguez Mata, J., Straneck, R., 1991. Nueva Guía de las Aves Argentinas, vol. II. Fundación Acindar, Buenos Aires.

Capurro, H.A., Bucher, E.H., 1982. Poblaciones de aves granívoras y disponibilidad de semillas en el bosque chaqueño de Chamical. Ecosur 9, 117–131.

Collado, A.D., 1999. Cambios de uso, cobertura de la tierra y retroceso del pastizal natural en San Luis. Valoración mediante teledetección. Revista Argentina de Producción Animal 19, 111–118.

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

Conner, R.N., Dickson, J.G., 1980. Strip transect sampling and analysis for avian habitat studies. Wildlife Society Bulletin 8, 4–10.

Demaría, M.R., McShea, W.J., Koy, K., Maceira, N.O., 2003. Pampas deer conservation with respect to habitat loss and protected area considerations in San Luis, Argentina. Biological Conservation 115, 121–130.

Emlen, J.T., 1971. Population densities of birds derived from transect counts. Auk 88, 323–342.

Frasinelli, C.A., Stritzler, N.P., Veneciano, J.H., Casagrande, J.R., Marchi, A., Funes, M.O., 1992. *Digitaria eriantha*. Una forrajera estival promisoria. Revista de Divulgación Ciencia y Tecnología en el Desarrollo de la Provincia de San Luis No. 2, 17pp.

Fretwell, S.D., Lucas, H., 1970. On territorial behavior and other factors influencing habitat distribution in birds. Acta Biotheoretica 19, 16–52.

Gabrey, S.W., Afton, A.D., Wilson, B.C., 1999. Effects of winter burning and structural marsh management on vegetation and winter bird abundance in the Gulf Coast Chenier Plain, USA. Wetlands 19, 594–606.

Goriup, P.D., 1988. Ecology and Conservation of Grassland Birds. International Council of Bird Preservation, Technical Publication No. 7, 250pp.

Helzer, C.J., Jelinsky, D.E., 1999. The relative importance of patch area and perimeter-area ratio to grassland breeding birds. Ecological Applications 9, 1448–1458.

Herkert, J.R., 1994. The effects of habitat fragmentation on midwestern grassland bird communities. Ecological Applications 4, 461–471.

Hildén, O., 1965. Habitat selection in birds. A review. Annales Zoologici Fennici 2, 53–75.

Hurlbert, S., 1984. Pseudoreplication and the design of ecological field experiments. Ecological Monographs 54, 187–211.

Isacch, J.P., Martínez, M.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 la provincia de Buenos Aires, Argentina. Ornitología Neotropical 12, 345–354.

Jobin, B., DesGranges, J.L., Boutin, C., 1996. Population trends in selected species of farmland birds in relation to recent developments in agriculture in the St. Lawrence Valley. Agriculture, Ecosystems and Environment 57, 103–116.

León, R.J.C., Anderson, D.L., 1983. El límite occidental del pastizal pampeano. Tuexenia 3, 67–82.

León, R.J.C., Rusch, G.M., Oesterheld, M., 1984. Pastizales pampeanos—Impacto agropecuario. Phytocoenologia 12, 201–218.

Mac Arthur, R.H., Mac Arthur, J.W., 1961. On bird species diversity. Ecology 42, 594–598.

Marone, L., 1991. Habitat features affecting bird spatial distribution in the Monte desert, Argentina. Ecología Austral 1, 77–86.

Marone, L., 1992. Seasonal and year to year fluctuations of bird populations and guild in the Monte Desert, Argentina. Journal of Field Ornithology 63, 297–308.

Marchi, A., Giraudo, C.G., Haidar, V.H., 1974. El pasto llorón cv. Tanganyka en la cría bovina. Satisfacción de los requerimientos de materia seca digestible. Revista Argentina de Producción Animal 5, 246–258.

Neter, J., Wasserman, W., Kutner, M.H., 1990. Applied Linear Statistical Models, third ed. Irwin Inc., Boston, USA.

Peña Zubiate, C.A., Anderson, D.L., Antonio, M.G., Saenz, J.L., d'Hiriart, A., Giulietti, J.D., Echeverría J.C., 1998. Carta de suelos y vegetación de la Provincia de San Luis. Instituto Nacional de Tecnología Agropecuaria/Gobierno de la Provincia de San Luis, San Luis, Argentina.

Robel, R.J., Briggs, J.N., Dayton, A.D., Hulbert, L.C., 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23, 295–297.

Rotenberry, J.T., 1985. The role of habitat in Avian community composition: physiognomy or floristics? Oecologia 67, 213–217.

Roth, R.R., 1976. Spatial heterogeneity and bird species diversity. Ecology 57, 773–782.

Steele, B.B., 1993. Selection of foraging and nesting sites by Black-throated blue Warblers—their relative influence on habitat choice. Condor 95, 568–579.

Straneck, R.J., 1987. Aportes sobre el conocimiento y distribución de la Cachirla Amarillenta, *Anthus lutescens* Pucheran y la Cachirla Chaqueña, *Anthus chacoensis* Zimmer (Aves, Motacillidae). Revista del Museo Argentino de Ciencias Naturales "Bernardino Rivadavia" 14, 95–102.

Soriano, A., León, R.J.C., Sala, O.E., Lavado, R.S., Deregibus, V.A., Cauhépé, M.A., Scaglia, O.A., Velázquez, C.A., Lemcoff, J.H., 1991. Río de La Plata grasslands. In: Coupland, R.T. (Ed.), Natural Grasslands, Introduction and Western Hemisphere: Ecosystems of the World, vol. 8A. Elsevier, Amsterdam, London, New York, Tokio, pp. 367–407.

Trexler, J.C., Travis, J., 1993. Nontraditional regression analyses. Ecology 74, 1629–1637.

Underwood, A., 1997. Experiments in Ecology. Their Logical Design and Interpretation Using Analysis of Variance. Cambridge University Press, Cambridge, UK.

Veneciano, J.H., Terenti, O.A., Federigi, M.E., 2000. Villa Mercedes (San Luis): reseña climática del siglo XX. Instituto Nacional de Tecnología Agropecuaria, Información Técnica No. 156. Provincia de San Luis, Argentina.

Vickery, P.D., Hunter, M.L., Melvin, S.M., 1994. Effects of habitat area on the distribution of grassland birds in Maine. Conservation Biology 8, 1087–1097.

Wiens, J.A., 1973. Pattern and process in grassland bird communities. Ecological Monographs 43, 237–270.

Wiens, J.A., 1989. The Ecology of Bird Communities, vol. 1, Foundations and Patterns. Cambridge University Press, Cambridge 539pp.

Willson, M.F., 1974. Avian community organization and habitat structure. Ecology 55, 1017–1029.

Zar, J.H., 1996. Biostatistical Analysis. Prentice-Hall, Inc., Englewood Cliff, NJ.