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http://dx.doi.org/10.1071/MU13028

Avian responses to varying intensity of cattle production in *Spartina densiflora* saltmarshes of south-eastern South America

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Abstract. Saltmarshes of *Spartina densiflora* in south-eastern South America have been modified by anthropogenic activities, mainly production of livestock. We examined the effect of the intensity of cattle production on the structure of saltmarsh vegetation and the effect of these changes to vegetation on the richness, composition and size of the avian populations and the abundance of nests. The levels of cattle production were based on the combined intensity of prescribed burning and cattle grazing, classed as: (1) High grazing – High burning (HH), (2) Low grazing – Low burning (LL) and (3) No grazing – No burning (NN). Cattle production altered the vegetation structure of saltmarshes and indirectly modified the richness, composition and size of their avian populations and the abundance of nests. Saltmarshes with either LL or NN production levels were inhabited by tall grassland specialists and generalists and by species specialised to live in a mosaic of short and tall grassland patches. Conversely, saltmarshes with HH production levels were inhabited by short-grassland specialists. That avian species diversity does not differ between *S. densiflora* saltmarsh subject to low or no human impacts has several potential interpretations, which are discussed. These findings have implications for management of grasslands to maintain avian diversity.

Additional keywords: Argentina, cattle grazing, conservation, fire, grassland birds, Pampas.

Received 16 April 2013, accepted 5 September 2014, published online 2 February 2015

Introduction

Saltmarshes are globally unique ecosystems dominated by particular halophytic vegetation, and restricted to the narrow interface between marine and terrestrial ecosystems (Esselink *et al*. 2000; Adam 2002). Most saltmarshes around the world are dominated by grasses, mainly different species of the cordgrass *Spartina*, are also covered by shrub species (Adam 1990). In south-eastern South America, the dominant saltmarsh plant is *Spartina densiflora*, with the larger areas associated with brackish water bordering the mouths and estuaries of rivers and coastal lagoons from southern Brazil to northern Patagonia in Argentina (Bortolus 2006; Isacch *et al*. 2006). Many of these coastal saltmarshes are used for livestock production, which is typically accompanied by prescribed burning (Isacch *et al*. 2004; Isacch and Cardoni 2011; Cardoni *et al*. 2012) owing to the low digestibility of the mature plants for herbivores (Canepuccia *et al*. 2008). Saltmarshes have commonly been used for production of livestock (e.g. cattle, sheep, horses) on other continents for many years (e.g. North America (Adam 1990), Europe (Bouchard *et al*. 2003), and Australia (Laegdsgaard *et al*. 2009)).

Worldwide, grazing by livestock and associated fire practices are major drivers of change to grasslands, including grassy saltmarsh habitats (Fleischner 1994; Bardgett *et al*. 1995). Such disturbance causes indirect and direct effects on the wildlife that use these habitats by changing plant diversity (Bakker *et al*. 2008) and habitat structure (Vickery *et al*. 2001) and decreasing the biomass of foliar arthropods (Dennis *et al*. 2008) and, in turn, altering the abundance and richness of bird species (Gonnet 2001; Isacch and Martínez 2001; García *et al*. 2008; Isacch and Cardoni 2011), the suitability of the habitat for nesting and feeding by birds (Gonnet 2001; Vickery *et al*. 2001; Chase 2002) and changing the rates of avian nest predation (Zalba and Cozzani 2004) and breeding success (Sutter and Ritchison 2005). The degradation of saltmarsh and grassland habitats due to livestock production has been considered an important cause of population declines in grassland birds around the world (Knopf 1994; Sauer *et al*. 2005; Azpiroz *et al*. 2012).

Spartina densiflora saltmarshes are largely restricted to the large shoreline of protected lagoons in Rio Grande do Sul, Brazil, and along estuaries, such as the Rio de la Plata of Argentina and Uruguay (Isacch *et al*. 2006). Particularly in Argentina, the largest areas of *Spartina densiflora* saltmarsh occur along the coast of the Pampas region (Cabrera 1976), the largest area of grassland in South America. These grasslands have been greatly altered or lost through agricultural development over the last 150 years, including replacement of natural grasslands with crops and development of pasturelands for grazing of livestock (Viglizzo *et al*. 2001; Medan *et al*. 2011; Bilenca *et al*. 2012). The largest intact grasslands of the region are now confined to areas subject to flood or on brackish soils, such as *S. densiflora* saltmarsh, which thus provide habitat for much of the remaining native wildlife of the Pampas (Isacch *et al*. 2004; Canepuccia *et al*. 2008; Baladrón *et al*. 2012). The saltmarshes of south-eastern South America in particular are inhabited by several highly specialised bird species, such as the Bay-capped Wren-Spinetail (*Spartonoica maluroides*) and Dot-winged Crake (*Porzana spiloptera*) (Martínez *et al*. 1997; Isacch *et al*. 2004; Aldabe *et al*. 2006; Cardoni *et al*. 2007, 2013; Isacch and Cardoni 2011), which are considered near-threatened and vulnerable respectively (BirdLife International 2014*a*, 2014*b*), and by many other species dependent on tall grasslands, such as the Sedge Wren (*Cistothorus platensis*), Hudson's Canastero (*Asthenes hudsoni*) (BirdLife International 2014*c*), Great Pampa-Finch (*Embernagra platensis*) and Short-eared Owl (*Asio flammeus*) (Isacch *et al*. 2004; Cardoni *et al*. 2007; Cardoni 2011; Isacch and Cardoni 2011; Azpiroz *et al*. 2012; Codesido *et al*. 2012).

Our hypothesis is that the intensification of cattle production directly modifies the vegetation structure of *Spartina densiflora* saltmarsh, decreasing the cover and height of vegetation, with consequent effects on the species composition and richness of the avian community, and the abundance and nesting of birds associated with tall grass cover. We predict that intensification of cattle production will lead to: (1) a decrease in the abundance of specialist bird species of saltmarsh (e.g. Bay-capped Wren-Spinetail); and (2) an increase in the abundance of species associated with short grasslands (e.g. Correndera Pipit (*Anthus correndera*)). The aim of our study was to assess the effects of different intensities of cattle production on the physiognomy of the vegetation and the avian assemblages in a *S. densiflora* saltmarsh in south-eastern South America.

Methods

Study area

The study was undertaken at the Mar Chiquita coastal lagoon, Argentina (37°40′9″S, 57°23′9″W), a UNESCO Man and the Biosphere Reserve (see http://www.unesco.org/mabdb/br/brdir/directory/biores.asp?mode=all&code=ARG+07 [verified 6 November 2014]) and which is included within the South-eastern South America saltmarshes reserve system (Isacch *et al*. 2006). The main habitats surrounding the lagoon are intertidal mudflats and extensive plains primarily covered with halophytic vegetation dominated by *Spartina densiflora* (Isacch *et al*. 2006). Ranches in the region are dedicated mainly to production of livestock (León *et al*. 1984). The entire biosphere reserve is subject to human use, either under the control of national, provincial or municipal governments (~40% of the total area of the reserve) and with land-uses including cattle production, cropping and tourism, or in private ownership (~60% of the area), with ranches dedicated to livestock production, primarily cattle production, without governmental management constraints (Isacch 2008).

Surveys of birds and vegetation

Surveys were undertaken during 2008, within areas of *S. densiflora* saltmarsh on ranches. These ranches were fenced into individual paddocks. We selected sites, identifying three classes of cattle production based on the intensity of land-use : (1) High grazing – High burning (HH), which comprised paddocks burned systematically throughout the year and with high density of cattle (~1.3 head of cattle ha^{-1}); (2) Low grazing – Low burning (LL), which comprised paddocks burned only in winter and with lower livestock density (~0.5 head ha^{-1}); and (3) No grazing – No burning (NN), which were paddocks that had not been subject to grazing or fire for at least 6 years. To determine the density of cattle, we counted the numbers per paddock and determined the area of each paddock using Google Earth (Google Inc., Mountain View, CA).

Birds were surveyed on fixed-width transects 100 m long and 60 m wide (Bibby *et al*. 1997). Eight transects were placed randomly within the study sites for each of the three intensity of land-use categories (total 24 transects), with transects separated by at least 200 m. We were careful to distribute transects through areas of similar environmental conditions to avoid co-variation between physical variables (such as salinity and flooding) and land uses. Transects were positioned in at least two different areas per category of land-use intensity. We assumed that detectability of birds was the same for the 60-m width of transect (after Isacch and Martínez 2001; Isacch *et al*. 2004; Cardoni *et al*. 2007, 2012; Isacch and Cardoni 2011). Each transect was surveyed within 4 h of sunrise (between 0800 and 1100 hours) by the same person (D. A. Cardoni) four times in each season: summer (January–February), autumn (April–May), winter (July–August) and spring (October–November). We did not conduct surveys during extreme weather (i.e. wind-speeds >20 km h^{-1} or rainy days) (Conner and Dickson 1980). We recorded the numbers of all birds seen or heard. The mean number of individuals of each species from all four surveys in each season was used to indicate abundance for a species.

Vegetation was sampled in two 1-m^2 plots (using a sampling frame) placed at 25 m and 75 m along the length of each of the 24 bird transects. In each plot we (1) estimated the percentage vegetation cover as a visual estimate of the projected proportion of the plot covered by tall grass, and (2) measured the height (cm) of the tallest grass in the centre of the sample frame. The results for the two plots were averaged for each transect.

Analysis of bird and vegetation variables

To determine the variation in vegetation structure (cover and height) and birds (total abundance – i.e., abundance per transect compared among categories of land use and species richness) between the different land-use intensities (NN, LL, HH) and between seasons, we analysed data using a repeated-measure analysis of variance (ANOVA; Zar 1999), with land-use intensity (NN, LL, HH) as the grouping factor and season (summer, autumn, winter, spring) as the repeated measure. We used $P < 0.01$ as the level of significance for vegetation variables (percentage coverage and height) and $P < 0.05$ for bird variables (abundance and species richness). We used a Tuckey test for comparing means of bird and vegetation variables compared among categories of land use, and the simple effect test (referring to the effects of one factor – land use or season – on a response variable (e.g. bird richness) when the interaction between season and land-use intensity was significant. Percentage vegetation cover was arcsine square-root transformed before analysis.

To evaluate association of specific bird assemblages with saltmarsh subject to differing land-use intensity, we applied non-metric multi-dimensional scaling (Clarke and Gorley 2001) to a pairwise similarity matrix by using a Bray Curtis Similarity Index to order land-use intensities in a two-dimensional plane. The relevant contribution of each species of bird in the two-dimensional plot was determined by an analysis of dissimilarity using the SIMPER routine (Clarke and Gorley 2001). Bird species with greater percentage contributions to the discrimination of saltmarsh subject to different land-use intensities can then be considered representative or diagnostic for each avian assemblage. Finally, we performed a one-way analysis of similarity (ANOSIM; Clarke and Gorley 2001) to test the hypothesis that avian assemblages differ between land-use intensities. We predicted that specific assemblages of birds (e.g. saltmarsh specialists, species of short grasslands such as Correndera Pipit, Bar-winged Cinclodes, Austral Negrito) would be associated with different vegetation structure resulting from the differing land-use intensities. Values of R close to 1 indicate a very different species composition between groups, whereas values close to 0 indicate a strong similarity.

All statistical analyses were performed using the PRIMER software package (PRIMER software package; Clarke and Gorley 2001).

Abundance of nests

We systematically searched for nests during the austral breeding season of October 2007 to February 2008, by haphazard walking (after Winter *et al*. 2003) through the study sites; this method of survey performed best in our system. We conducted three 5-h searches over the breeding season, in October, December and February, with similar sampling effort in the three land-use intensity classes (NN, LL, HH). To test whether abundance of nests varied between land-use intensity we used a chi-square goodness-of-fit tests with Yates' correction (Zar 1999), performed using PRIMER.

Results

Vegetation structure

Repeated-measure ANOVA showed that vegetation cover within each land-use intensity did not vary significantly between seasons ($F_{6,63} = 2.08$, $P = 0.07$). This vegetation variable also did not show differences among seasons ($F_{3,53} = 3.74$, $P = 0.016$). Further, saltmarsh ungrazed and unburnt for at least 6 years (NN) had significantly higher values of vegetation cover than marshes used for cattle grazing (HH, LL), and saltmarsh with low levels of burning and grazing (LL) had significantly higher values of vegetation cover than saltmarsh subject to higher intensity of grazing and burning (HH) ($F_{2,21} = 1650$, $P < 0.0001$; Fig. 1*a*).

The height of vegetation within each land-use intensity did not vary significantly between seasons ($F_{6,63} = 2.39$, $P = 0.04$; Fig. 1*b*). The vegetation height did not vary significantly among seasons ($F_{3,63} = 3.65$, $P = 0.018$). However, NN saltmarsh had significantly taller vegetation than saltmarsh used for cattle grazing (HH, LL), LL saltmarsh had significantly taller vegetation than HH saltmarsh ($F_{2,21} = 1843$, $P = 0.0001$; Fig. 1*b*).

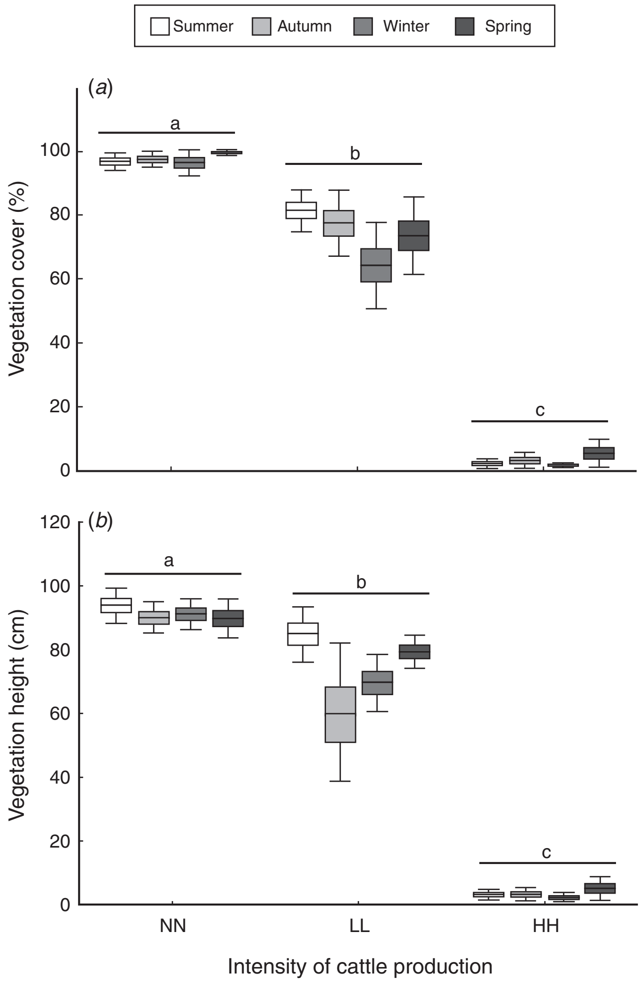

Fig. 1. (*a*) Vegetation cover and (*b*) vegetation height of *Spartina densiflora* saltmarsh subject to three intensities of cattle production in four seasons through the year. NN, no grazing, no burning; LL, low grazing, low burning; HH, high grazing, high burning. Boxes show standard error, whiskers standard deviation, and the horizontal line within the boxes is the mean. Different letters show significant differences between intensity of land-use (*a posteriori* Tukey test, $P < 0.01$).

Abundance and species richness of birds

We recorded 18 species of bird using *S. densiflora* saltmarsh (Table 1). Eight species were recorded in NN saltmarsh, 10 in LL saltmarsh and five in HH saltmarsh. Bird species richness (number of species per transect) within each land-use intensity did not vary between seasons ($F_{6,63} = 0.74$, $P = 0.62$; Fig. 2*a*). No variation in the number of bird species was found among season ($F_{3,63} = 1.37$, $P = 0.26$). Species richness was higher in NN and HH saltmarsh than LL saltmarsh ($F_{2,21} = 7.53$, $P = 0.004$; Fig. 2*a*). Total abundance of birds (species combined) within each land-use intensity did not vary between seasons ($F_{6,63} = 0.93$, $P = 0.48$; Fig. 2*b*). Again, no variation in the number of bird species was found among seasons ($F_{3,\ 63} = 1.05$, $P = 0.38$). Total abundance was greater in NN and HH saltmarsh than LL saltmarsh ($F_{2,21} = 5.30$, $P = 0.016$; Fig. 2*b*).

Table 1. Mean abundance of bird species in *Spartina densiflora* saltmarsh subject to three intensities of grazing management

NN, saltmarsh ungrazed and unburned for at least 6 years; LL, saltmarsh burned only in winter and with lower density of cattle; HH, saltmarsh burned systematically throughout the year and with high density of cattle. Figures are means for all transects and all seasons combined ($N = 128$ transects for each land-use intensity class)

Species		NN	LL	HH	Overall
Bay-capped Wren-Spinetail	*Spartonoica maluroides*	0.86 ± 1.04 (0-3)	1.14 ± 1.65 (0-5)	0	0.70 ± 1.24 (0-5)
SedgeWren	*Cistothorus platensis*	0.50 ± 0.79 (0-3)	0.11 ± 0.42 (0-2)	0	0.21 ± 0.57 (0-3)
Freckle-breasted Thornbird	*Phacellodomus striaticollis*	0.18 ± 0.39 (0-1)	0	0	0.06 ± 0.24 (0-1)
GrasslandYellow-Finch	*Sicalis luteola*	0.29 ± 0.60 (0-2)	0.43 ± 0.79 (0-3)	0	0.25 ± 0.61 (0-3)
Great Pampa-Finch	*Embernagra platensis*	0.11 ± 0.31 (0-1)	0.14 ± 0.45 (0-2)	0	0.09 ± 0.33 (0-2)
Yellow-winged Blackbird	*Agelasticus thilius*	0	0.25 ± 0.70 (0-3)	0	0.09 ± 0.43 (0-3)
Spectacled Tyrant	*Hymenops perspicillatus*	0	0.11 ± 0.42 (0-2)	0	0.04 ± 0.25 (0-2)
Short-eared Owl	*Asio flammeus*	0.07 ± 0.38 (0-2)	0	0	0.03 ± 0.22 (0-2)
Rufous-collared Sparrow	*Zonotrichia capensis*	0	0.07 ± 0.26 (0-1)	0	0.03 ± 0.16 (0-1)
Hudson's Canastero	*Asthenes hudsoni*	0	0.07 ± 0.26 (0-1)	0	0.03 ± 0.16 (0-1)
Correndera Pipit	*Anthus correndera*	0	0	1.58 ± 1.41 (0-5)	0.48 ± 1.06 (0-5)
Bar-winged Cinclodes	*Cinclodes fuscus*	0	0	0.29 ± 0.70 (0-2)	0.10 ± 0.41 (0-2)
Austral Negrito	*Lessonia rufa*	0	0	0.36 ± 0.85 (0-4)	0.08 ± 0.47 (0-4)
Southern Lapwing	*Vanellus chilensis*	0	0	1.04 ± 1.27 (0-4)	0.35 ± 0.87 (0-4)
Long-winged Harrier	*Circus buffoni*	0.07 ± 0.26 (0-1)	0	0	0.03 ± 0.16 (0-1)
Chimango Caracara	*Milvago chimango*	1.57 ± 1.75 (0-6)	0.25 ± 0.91 (0-4)	0	0.64 ± 1.33 (0-6)
Plumbeous Rail	*Pardirallus sanguinolentus*	0	0.04 ± 0.19 (0-1)	0	0.01 ± 0.11 (0-1)
Maguari Stork	*Ciconia maguari*	0	0	0.14 ± 0.82 (0-4)	0.05 ± 0.45 (0-4)
Total Species		8	10	5	18

Avian assemblage composition

We identified two avian assemblages associated with the saltmarsh. One assemblage was associated with NN and LL saltmarsh (ANOSIM: NN *v.* LL $R = 0.135$, $P = 25.7\%$), characterised by two species with high percentage contributions to assemblage discrimination: Chimango Caracara (*Milvago chimango*) and the Bay-capped Wren-Spinetail (Table 2). A second assemblage was associated with saltmarsh subject to high-intensity grazing and burning (HH) (NN *v.* HH $R = 1$, $P = 2.9\%$; LL *v.* HH $R = 1$, $P = 2.9\%$), and characterised by two bird species with high percentage contributions to assemblage discrimination: Correndera Pipit and Southern Lapwing (*Vanellus chilensis*) (Table 2).

Nest abundance

We found a total of 56 nests, of eight species: 33, of six species, in NN saltmarsh, and 23, of four species, in LL saltmarsh; no nesting was recorded in HH saltmarsh. There was no significant difference in abundance of nests between NN and LL saltmarsh ($\chi^2_1 = 1.78$, $P = 0.18$). For individual species, there were no significant differences in number of nests between NN and LL saltmarsh for Bay-capped Wren-Spinetail ($\chi^2_1 = 0.25$, $P = 0.65$), Grassland Yellow-Finch (*Sicalis luteola* ; $\chi^2_1 = 0.14$, $P = 0.71$) and Great Pampa-Finch ($\chi^2_1 = 1.23$, $P = 0.27$). Significantly more Chimango Caracara nests were found in NN saltmarsh than LL saltmarsh ($\chi^2_1 = 4.38$, $P = 0.036$). Other species recorded nesting in *S. densiflora* saltmarsh but at frequencies too low for statistical comparison were Sedge Wren, Chiloe Wigeon (*Anas sibilatrix*) and Long-winged Harrier (*Circus buffoni*) in NN saltmarshes, and Yellow-billed Pintail (*Anas georgica*) in LL saltmarshes.

Discussion

Our results show that moderately intense levels of cattle production in *Spartina densiflora* saltmarsh (LL land-use intensity) can be compatible with the persistence of bird species of *Spartina densiflora* saltmarsh, both tall-grassland generalist species (Isacch *et al*. 2001, 2004, 2013) and saltmarsh specialists (Cardoni *et al*. 2012; Isacch *et al*. 2013). Other studies of the avifauna of tall grasslands have shown that the combination of moderate intensities of grazing and burning provide habitat for a broader diversity of grassland bird species than undisturbed grassland by increasing habitat heterogeneity in both time and space (Fuhlendorf *et al*. 2006; Coppedge *et al*. 2008; Isacch and Cardoni 2011), and because moderate disturbance regimes can enhance ecosystem heterogeneity and promote an increase in biological diversity (Wiens 1997). We are aware that livestock production unavoidably creates disturbances, such as grazing and trampling of vegetation and use of fire as a tool to manage vegetation.

Avian assemblages

Cattle production directly modifies the structure of *S. densiflora* saltmarsh vegetation (percentage coverage and height), which, in turn, affects avian species richness (number of species) and community composition, as well as the abundance of birds using the saltmarsh. Ungrazed and unburnt saltmarsh (NN) and saltmarsh subject to moderate levels of grazing and burning (LL) were used by both specialist and generalist tall-grassland bird species (Isacch *et al*. 2001, 2004; Isacch and Cardoni 2011; Cardoni *et al*. 2012). One species, the near-threatened Hudson's Canastero (López-Lanús *et al*. 2008; BirdLife International 2014*c*), prefers a mosaic of tall and short grassland (Comparatore *et al*. 1996; Isacch and Cardoni 2011), and was observed only in LL saltmarsh indicating that moderately intensive grazing and burning can be beneficial for this species. It could, thus, function as an indicator of agricultural landscapes subject to moderate intensities of livestock production. Studies in North America have also found that low intensities of grazing had a positive effect on

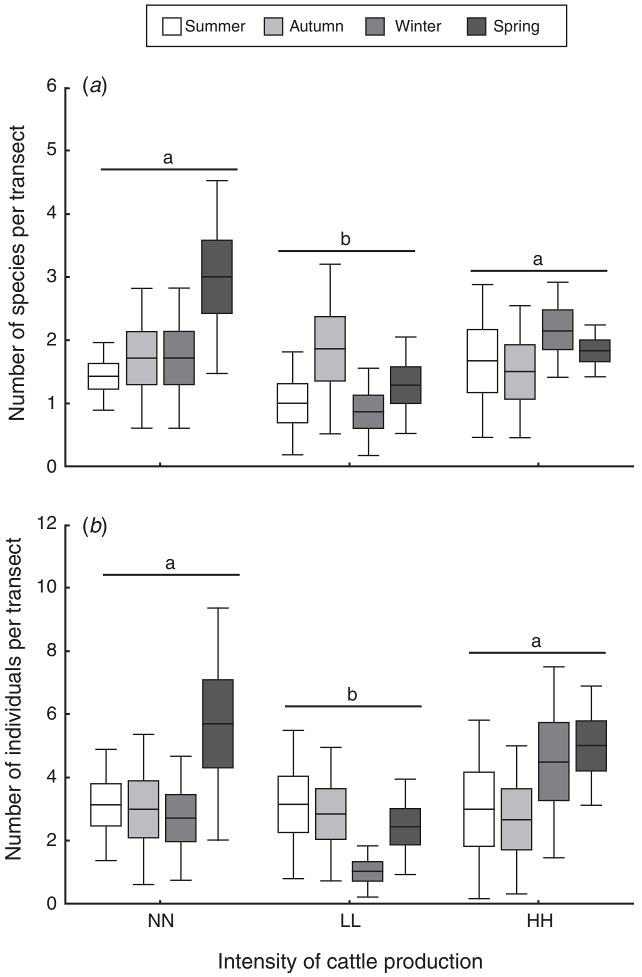

Fig. 2. (*a*) Species richness (number of species per transect) and (*b*) total abundance of birds (number of individuals per transect, species combined) in *Spartina densiflora* saltmarsh subject to three intensities of cattle production in four seasons through the year. NN, no grazing, no burning; LL, low grazing, low burning; HH, high grazing, high burning. Boxes show standard error, whiskers standard deviation, and the horizontal line within the box is the mean. Different letters show significant differences between intensity of land-use (*a posteriori* Tukey test, $P < 0.05$).

the abundance of species that require patchy habitat composed of short and tall grass, such as the Grasshopper Sparrow (*Ammodramus savannarum*) (Vickery 1996; Powell 2008).

In contrast to ungrazed and moderately grazed and burnt saltmarsh, only birds typical of short grassland were recorded in heavily grazed and burnt saltmarsh (HH); this management regime caused the total replacement of the tall grassland (>70 cm tall) by short grassland (<15 cm). Several studies have shown that birds of tall grassland respond rapidly to changes in cover of tall grass, both in our region (Isacch and Martínez 2001; Isacch *et al*. 2004; Cardoni *et al*. 2007; Isacch and Cardoni 2011; Codesido *et al*. 2012) and elsewhere in the world (Verhulst *et al*. 2004; With *et al*. 2008), where the composition of bird communities is strongly related to the structural complexity of vegetation (Roth 1976; Wiens 1997).

Table 2. Contribution of species to the average Bray–Curtis similarity between groups of samples (SIMPER analysis) in saltmarsh subject to three intensities of cattle production

NN, saltmarsh ungrazed and unburned for at least 6 years; LL, saltmarsh burned only in winter and with lower density of cattle; HH, saltmarsh burned systematically throughout the year and with high density of cattle. Figures in parentheses are the average similarity for each land-use intensity

	% contribution	Cumulative % contribution
NN (71.3)		
Chimango Caracara	36.56	36.56
Bay-capped Wren-Spinetail	30.51	67.08
Sedge Wren	12.71	79.79
Grassland Yellow-Finch	11.99	91.78
LL (53.6)		
Bay-capped Wren-Spinetail	45.42	45.42
Grassland Yellow-Finch	21.36	66.78
Great Pampa-Finch	15.32	82.09
Chimango Caracara	7.08	89.18
Spectacled Tyrant	5.81	94.99
HH (77.7)		
Correndera Pipit	47.41	47.41
Southern Lapwing	42.77	90.18

Both ungrazed and unburned saltmarsh (NN) and saltmarsh subject to low levels of grazing and burning (LL) had similar species composition: bird species typical of *S. densiflora* saltmarsh, such as the Bay-capped Wren Spinetail and Sedge Wren, and species of tall grassland, such as the Grassland Yellow-Finch, Great Pampa-Finch and Chimango Caracara. The most abundant species in NN and LL saltmarsh were the Bay-capped Wren-Spinetail and Caracara Chimango. Conversely, the avian assemblage of saltmarsh subject to high-intensity cattle production (HH) was characterised by only two bird species: the Correndera Pipit and Southern Lapwing.

Breeding

We recorded few species of birds breeding in *S. densiflora* saltmarsh, with the Bay-capped Wren-Spinetail and Chimango Caracara comprising 81% of all nests recorded. Grassland ecosystems typically support low densities of nesting birds (Vickery *et al*. 1992; Warner 1992; Fondell and Ball 2004) and *S. densiflora* saltmarsh is a rather short grassland (~80 cm tall) subject to frequent flooding by tides and rainfall (Canepuccia *et al*. 2008, 2009). The risk of flooding combined with the risk of predation by terrestrial or aerial predators reduces the availability of suitable nesting sites, and nest survival in saltmarsh is very low, especially for those species that use *S. densiflora* saltmarsh as an alternative habitat to other typical tall grasslands from de Pampas for breeding, such as the Great Pampa-Finch, Grassland Yellow-Finch and Chimango Caracara (Cardoni 2011). However, the most specialised saltmarsh species, the Bay-capped Wren-Spinetail (Cardoni *et al*. 2013) has relatively high breeding success compared with other bird species breeding in pampas grassland (Llambías *et al*. 2009; Cardoni *et al*. 2012), such as Great Pampa-Finch, Grassland Yellow-Finch (Cardoni 2011), Spectacled Tyrants (*Hymenops perspicillatus* (Pretelli and Isacch 2013), and success is similar in undisturbed low-intensity land-use saltmarsh (Cardoni *et al*. 2012). Conversely, no breeding was recorded in saltmarsh subject to high-intensity cattle production (HH), even by short grassland species. This may be a result of the risk of flood (tidal, rainfall) for ground-nesting species. The high abundance of Correndera Pipit, the most abundant species in HH saltmarsh, may be a response to the temporary abundance of flying insects available during the breeding period (Canepuccia *et al*. 2009).

Conservation implications

The extensive distribution of *S. densiflora* marshes at the coast of the Pampas region of south-eastern South America (32 000 ha; Isacch *et al*. 2006) provides habitat for birds of tall grassland that were once more widely distributed but are now mainly confined to marginally productive tall grasslands, species such as Short-eared Owls, Sedge Wrens, Hudson's Canastero, Yellow Grassland-Finches and Great Pampa-Finches (Isacch and Martínez 2001; Isacch *et al*. 2004; Cardoni *et al*. 2007; Cardoni 2011; Isacch and Cardoni 2011; this study). Owing to the degradation of other tall grasslands of the Pampas (Isacch *et al*. 2003; Cerezo *et al*. 2011; Codesido *et al*. 2011), *S. densilfora* saltmarsh with good levels of vegetation cover and height should be conserved and managed. This does not necessarily entail the exclusion of grazing by livestock, but the intensity of livestock production must be managed to maintain a semi-natural tall-grassland structure to provide habitat for avian species adapted to tall grassland, as has been suggested for other tall temperate grasslands of south-eastern South America (Azpiroz *et al*. 2012).

Acknowledgements

We appreciate the improvements in English usage made by Bruce Peterson through the Association of Field Ornithologists' program of editorial assistance. Financial support was provided by Consejo Nacional de Investigaciones Científicas y Técnica (CONICET), Agencia Nacional de Promoción Científica y Tecnológica (Argentina), Universidad Nacional de Mar del Plata (to O. Iribarne) and Neotropical Grassland Conservancy (to D. A. Cardoni).

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