

Article

The seasonal role of field characteristics on seed-eating bird abundances in agricultural landscapes

Emmanuel ZUFIAURRE^{a,*}, Mariano CODESIDO^a, Agustín M. ABBA^b, and David BILENCA^a

^aGrupo de Estudios sobre Biodiversidad en Agroecosistemas (GEBA), Departamento de Biodiversidad y Biología Experimental, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires and IEGEBA (UBA-CONICET). Ciudad Universitaria, Pabellón II, 4° Piso, (C1428EHA). Ciudad Autónoma de Buenos Aires, Argentina and ^bCentro de Estudios Parasitológicos y de Vectores (CEPAVE) CCT-CONICET-LA PLATA-UNLP. Calle 120 entre 61 y 62 S/N, La Plata, (B1902CHX), Buenos Aires, Argentina

*Address correspondence to E. Zufiaurre. E-mail: ezufiaurre@ege.fcen.uba.ar.

Received on 2 December 2015; accepted on 15 April 2016

Abstract

In temperate agroecosystems, avian responses in abundance and distribution to landscape attributes may be exacerbated by the coupling of natural seasons and farming practices. We assessed the seasonal roles of field type, field use in the surroundings, and distance from a field to the nearest woodlot on the abundance of seed-eating birds in a 225,000 km² study area in the Pampas of central Argentina. During spring-summer and autumn of 2011–2013, we randomly selected 392 fields and used transect samples to collect data on abundance and presence of seed-eating bird species. We recorded a total of 11,579 individuals belonging to 15 seed-eating bird species. We used generalized lineal mixed models to relate bird abundance to field type, field use in the surroundings, and distance to the nearest woodlot. In spring-summer (breeding season) most bird responses were associated with their nesting requirements. Species that build their nests in trees, such as eared doves *Zenaida auriculata*, picazuro pigeons *Patagioenas picazuro*, and monk parakeets *Myiopsitta monachus*, were more abundant in fields closer to woodlots, whereas grassland yellow-finches *Sicalis luteola*, which nest at areas with tall grasses, were more abundant in fields with livestock use patches in the field surroundings. In autumn (non-breeding season), most bird responses were associated with foraging and refuge needs. The high abundance of eared doves in crop stubbles and the association of pigeons at field surroundings dominated by croplands or at crop stubbles surrounded by livestock use fields revealed the intimate association of these species to sites with high availability of food resources. In addition, both picazuro pigeons and spot-winged pigeons *Patagioenas maculosa* were associated with woodlots, which provide suitable roosting sites. Our results show that in temperate agroecosystems, the relationships between field characteristics and seed-eating bird abundances vary with season.

Key words: field surroundings, field type, granivorous birds, stubbles, temperate agroecosystems, woodlots.

Land-use patterns and landscape structure affect species abundances by modifying habitat and resources availability, so that greater abundance of birds is often related to the appropriate combination of resources (Wilson et al. 1996; Robinson and Sutherland 1999,

2002). Bird assemblages are sensitive to such changes, even though each species may respond differently depending on its ecological features and life-history traits (Donald et al. 2001; Verhulst et al. 2004; Codesido et al. 2012). In particular, seed-eating birds depend on

suitable sites for foraging, and agroecosystems can provide those food resources (Buckingham et al. 1999; Robinson and Sutherland 1999; Robinson et al. 2004). The particular use of a certain field, such as crop fields and livestock paddocks, can explain the abundances of bird species in a certain field (Wilson et al. 1996; Moorcroft et al. 2002). However, sometimes the abundance of birds in arable habitat is not attributable merely to resources in these areas, but rather reflects relative availability of resource-rich habitats across the neighborhood landscape (Robinson et al. 2001, 2004; Prevedello and Vieira 2010).

In temperate agroecosystems, the effects of seasonality on biotic communities may be exacerbated by the coupling of natural seasons and farming practices (Benton et al. 2003). Landscape elements (croplands, rangelands, woodlot patches) undergo seasonal changes in their structure, phenology, and disturbance regimes. This seasonality affects not only local bird abundances but also the distribution of different species among habitats (Law and Dickman 1998; Atkinson et al. 2002). In addition, avian requirements (foraging, roosting, breeding) also change seasonally, so that some species may differentially use some landscape elements in different seasons (Wiens 1989).

Changes in farming practices can also greatly affect avian biodiversity (VanBeek et al. 2014). One major change is when farmers switch from a till system, where crop stubble is plowed down following harvest, to a no-till system, where crop stubble is allowed to remain standing and the soil is not plowed. Two major changes occur as farming switches from a till to a no-till system: the amount of post-harvest grain in fields and the vegetation structure (Moorcroft et al. 2002; Whittingham et al. 2006; Abba et al. 2015). As a result of no-till farming, a large amount of waste grain to remaining in standing stubble; this leads to a larger total food resource for birds that is available for a much longer time period (Bucher and Ranvaud 2006).

As elsewhere in South America (Morton et al. 2006), the establishment of agroecosystems and the adoption of new farming practices in the Pampas of central Argentina has substantially modified both landscape structure and biodiversity. The Pampas is one of the richest agricultural areas of the world, covering about 52 million hectares of productive organic soils which were originally covered by grasslands (Soriano 1991). This huge flat plain was primarily a livestock-raising area but during the last decades, cattle raising in the Pampas has been progressively restricted to marginal areas, and natural rangelands and pastures have been replaced by cropland (Baldi and Paruelo 2008). The most dramatic technological innovations which increased agricultural intensification occurred in 1996 with the dual introduction of genetically modified soybeans (*Glycine* sp.) tolerant to glyphosate and no-till agricultural practices (Aizen et al. 2009). Due to this intensification, which in some places allowed farmers to harvest 2 crops per year, pastures and annual forage have been progressively displaced and animal stocking rate has increased in those lands with less agricultural aptitude (Viglizzo et al. 2010).

Another major change which added complexity to the landscape structure in the Pampas has been the introduction of woodlots. Trees were originally absent from the Pampas (Soriano 1991) but woodlands of both native and exotic trees have self-established along riparian zones and roadsides. Woodlots have also been intentionally planted near rural buildings and in areas of cattle grazing (Ghersa et al. 2002; Zalba and Villamil 2002). The introduction of trees to the Pampas was followed by the expansion of opportunistic birds, such as doves, pigeons, and parakeets since woodlots provide suitable sites for nesting and roosting (Daguerra 1936; Bucher and Aramburú 2014).

Several studies point out the role of crop stubbles as a key factor in promoting variations in populations of seed-eating birds (Moorcroft et al. 2002; Potts 2003; Suárez et al. 2004). However, most of these studies have been carried out in Europe, where farming has been practiced for long historic periods (Sutherland 2004; Evans and Green 2007), and there no studies regarding the role of stubbles in the Neotropics, where the farming history is comparatively much shorter. In some cases, the availability of stubbles could increase bird abundances so that some species may become harmful to agriculture (Bucher and Ranvaud 2006; Canavelli et al. 2012). In the Pampas of central Argentina, recent studies have shown that the abundances of some seed-eating birds (e.g., eared doves *Zenaida auriculata*; rufous-collared sparrows *Zonotrichia capensis*; and grassland sparrows *Ammodramus humeralis*) were related to the percentage of cropland in the rural landscape (Filloy and Bellocq 2007). In croplands, most of these studies have been carried out on standing crops (Canavelli et al. 2014; Weyland et al. 2014; Codesido et al. 2015), and little is known about the role of stubbles under no-till systems and its effect on seed-eating bird populations (Leveau and Leveau 2004).

The aim of this study is to assess the seasonal roles of certain field characteristics (i.e., field type, field use in the surroundings, and distance to the nearest woodlot) on the abundance of common seed-eating birds in the Pampas of central Argentina. This analysis was carried out in 2 contrasting periods of the year (spring-summer and autumn), coincidentally with the breeding and non-breeding seasons of birds and when croplands were on stubbles stage right after harvest.

Materials and methods

Study area

Our study area extends 225,000 km² (500 km north to south, 450 km east to west; 33–39°S, 57–63°W) in the Pampas region of central Argentina (Figure 1). The climate is warm-temperate, with mean temperatures varying between 15°C in the south and 18°C in the north. Annual rainfall decreases from 1,000 mm in the NE to 800 mm in the SW. The natural vegetation of the study area was originally a tall grass-steppe dominated by grasses such as *Nasella*, *Piptochaetium*, *Aristida*, *Bromus*, and *Poa*, intermingled with prairies, marshes, and edaphic communities (Soriano 1991). At present, most natural systems of the Pampas have been replaced by agroecosystems used for intensive crop production under no-till system or cattle grazing (Bilenca et al. 2012).

In the Pampas, agricultural landscapes may vary from areas dominated by cropland or pure pastoral farming to landscapes characterized by mixed farming (Codesido et al. 2013). The fields under livestock use are natural or semi-natural grasslands and annual or perennial pastures. In summer, dominant crops are soybean, corn *Zea mays*, and sunflower *Helianthus annuus*, whereas in winter crops such as wheat *Triticum aestivum* and barley *Hordeum vulgare* prevail (Bolsa de Cereales 2015). Farming practices in the region are predominantly the no-till system, which represents almost 80–90% of Pampas agriculture (Bolsa de Cereales 2015). Under no-tillage, farming activity is generally restricted to the application of a non-selective glyphosate herbicide before planting. Fields receive no tillage and seeds are directly drilled into the soil surface. This agricultural practice is used to protect the soil and maintain moisture, so mainly no-till practice is repeated in the same field (Viglizzo et al. 2010).

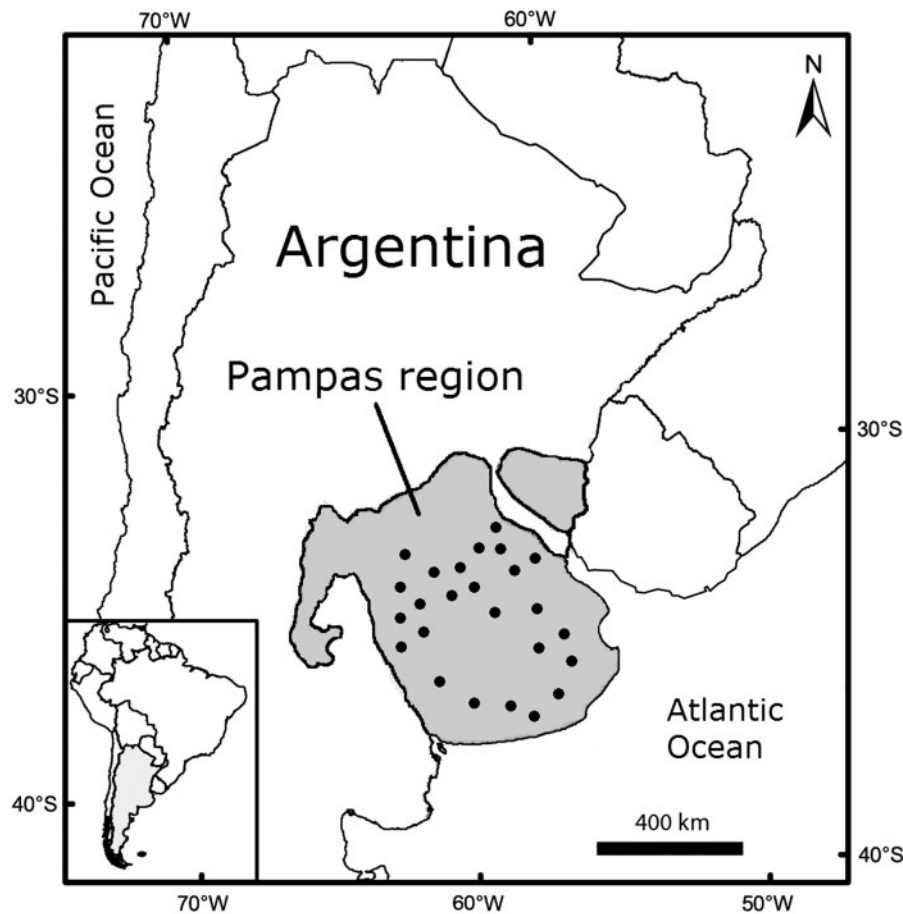


Figure 1. The locations of the 25 study sites (black circles) in Pampas region, central Argentina.

Data collection

We randomly selected 25 sites distributed evenly throughout our study area (Figure 1), which had varying proportions of land under crop production and livestock use (Codesido et al. 2012, 2013). In each of these sites we selected 4 independent fields; 2 crop stubbles, and 2 livestock paddocks (which were at least 1,500 m apart). Field stubbles (~43 ha on average; range: 15–180 ha) were surveyed right after harvest and included wheat, barley, and rye *Secale cereale* in spring-summer and soybean, corn, sunflower, and sorghum *Sorghum* sp. in autumn. Livestock paddocks (~47 ha on average; range: 15–316 ha) included pastures of alfalfa *Medicago sativa*, clover *Trifolium* sp., ryegrass *Lolium* sp., along with paddocks with natural or semi-natural grasslands dominated by *Paspalum* sp., *Nasella* sp., and *Festuca* sp. We carried out 4 surveys in each site: 2 during spring-summer (December–January 2011–2012 and 2012–2013) and 2 during autumn (April–June 2012 and 2013). Thus, each site was surveyed twice each season throughout 2 years, but each sampling was carried out in different fields, so that we avoided temporal dependence among data. In total, we surveyed 392 fields (196 of each field type), since during December 2011 we could not survey 2 sampling sites due to logistical problems.

Bird surveys were carried out 4 h after dawn by the same observer (EZ). Within each field and avoiding boundaries (50 m), we established a transect that was 700 m long and 100 m wide (Bibby et al. 2000). For ~15 min and at a constant pace, all birds within the transect were recorded and counted in order to complete bird sampling at each transect, resulting in a sampling effort of ~5,880 min

(98 h). We recorded all birds seen and/or heard within the transect, including birds entering and leaving the transect within 15 m (Azpiroz and Blake 2009). We roughly estimated at each field the proportion of crop fields surrounding that field, in order to classify the surrounding fields into 5 categories (pure cropland, predominantly cropland, mixed, predominantly livestock land, and pure livestock land). In addition, we recorded the distance in meters from the center of the transect to the nearest woodlot (including either patches of natural treed vegetation or of planted trees > 0.2 ha; Codesido et al. 2013, 2015). Distance was estimated in the field and then corroborated and measured using Google Earth. We described the habitat structural features of each field by recording the following variables at 4 0.25 m² rings that were thrown down in 4 different points at each field: vegetation cover (%), estimated visually and then corroborated by photographs), vegetation height, and litter height (cm, measured with a tape measure, and then averaged).

Data analyses

Separate analyses were conducted for each season (spring-summer and autumn). First, we recorded the percentage of occurrence (% of transects on which a species was recorded) of each bird species on each field type, and then compared the field occurrence between field types by means of tests of difference of proportions (Zar 2010). We also analyzed the differences in structural features of fields under different field types by means of one-way Anova for litter height and vegetation cover (with the corresponding transformation), and

Wilcoxon test for vegetation height (since this variable did not fit analyses assumptions for parametric test; Zar 2010).

We used generalized lineal mixed models (Pinheiro and Bates 2000) to analyze the association between field characteristics and the abundances of seed-eating birds. The number of birds per transect was the response variable (henceforth: birds/transect), whereas the explanatory variables were as follows: field type (FTYP, with 2 levels: stubbles or livestock rangeland), field surroundings (FSUR, with 5 levels arranged according the % of use of the surrounding fields) and the interaction of both variables (FSUR * FTYP) (all as categorical variables), and distance to the nearest woodlot (DIST) (a continuous variable). All these variables were specified as fixed effects, whereas site was treated as a random effect. Since the variance was much greater than the mean, the abundances of species data fitted negative binomial distribution and a logit link function was used in all models (Pinheiro and Bates 2000). In all cases we checked for normality and homogeneity of variance of residuals by means of graphical validation tools for the negative binomial GLMM (Zuur et al. 2009).

Models performances were evaluated with information-theoretic procedures (Burnham and Anderson 2002). The AICc weight of a model (w_i) is the relative likelihood that the specific model is the best of the suite of all models. Coefficient estimates were calculated using model-averaged coefficient estimates based on w_i of all candidate models (10 models in total; Online Appendix 1). We calculated 95% confidence intervals for coefficients of explanatory variables, so that when a confidence interval did not include zero indicated that the considered factor had a statistically significant effect on bird abundance (Burnham and Anderson 2002). Conclusions were based on the best model, considering the best model to that which has both a) the highest value of w_i and b) the IC of estimated coefficients of variables included in the model exclude zero (Burnham and Anderson 2002). Statistical analyses were carried out using the package glmmADMB (Fournier et al. 2012) implemented in R software, Version 3.2.1 (R Development Core Team 2015). Values of abundance are reported as mean \pm standard error.

We restricted our analyses of the relationship between abundance of seed-eating birds and field characteristics to those species which had >30% field occurrence in each season in the study area (Azpiroz and Blake 2009). In some cases, we adjusted the sites included in the analyses for a particular species according to the geographical distribution of that species in the study area. Thus, we adjusted our analyses for monk parakeet *Myiopsitta monachus* and spot-winged pigeon *Patagioenas maculosa* by considering only 20 sites that lay within the distribution of each species (Narosky and Di Giacomo 1993; Bucher and Aramburú 2014). This adjustment allowed us to avoid non-detection of these species simply because the species are absent from those sites (Codesido et al. 2011).

Table 1. Mean number (\pm standard error) and range (in brackets) of structural features of fields and analyses between use (crop stubbles and livestock use) in the Pampas of central Argentina, during spring-summer and autumn

Season	Spring-summer N = 192		Autumn N = 200	
	Stubbles N = 96	Livestock use N = 96	Stubbles N = 100	Livestock use N = 100
Vegetation cover (%)	66 \pm 2.4(5–100) ***	76.3 \pm 2(20–100)	63.8 \pm 2.6(5–100) ***	81.3 \pm 1.9(5–100)
Vegetation height (cm)	29.1 \pm 1.4(5–80) *	39.8 \pm 2.8(2–150)	24.5 \pm 2(0–82) **	29.3 \pm 2(3–110)
Litter height (cm)	2.8 \pm 0.3(0–25) n.s.	2.2 \pm 0.6(0–43)	4.4 \pm 0.5(0–55) ***	1.8 \pm 0.4(0–36)

Notes: Wilcoxon test for vegetation height, and one-way Anova for litter height and vegetation cover. n.s., not significant differences.

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

Results

Structural features of each field type

Crop stubbles and livestock paddocks were structurally different. In spring-summer, vegetation cover and vegetation height in livestock paddocks were 16% and 37% higher than in stubbles, respectively, even though they did not show any statistical differences in litter height (Table 1). As in spring-summer, fields under different use also showed structural differences in autumn; both vegetation cover and vegetation height in livestock paddocks were 27% and 20% higher than in stubbles. Moreover, in autumn litter height was 144% higher in stubbles than in livestock paddocks (Table 1).

Assemblage of seed-eating birds

We recorded a total of 11,579 individuals belonging to 15 seed-eating bird species. All species were recorded in spring-summer ($N = 4,018$ individuals; Figure 2A) and 13 species in autumn ($N = 7,561$ individuals; Figure 2B).

In spring-summer, eared doves were the most frequent species at the 192 studied fields (55.7% of the fields), followed by grassland yellow-finches *Sicalis luteola* (48.4%), rufous-collared sparrows (38.5%), monk parakeets (34.9%), and picazuro pigeons *Patagioenas picazuro* (32.3%). Eared doves were also the most abundant species (7.5 ± 1.3 birds/transect; 35.7% of the total seed-eating bird assemblage), followed by grassland yellow-finches (5.1 ± 0.7 birds/transect; 24.3%), monk parakeets (3.9 ± 0.6 birds/transect; 18.6%), picazuro pigeons (1.5 ± 0.3 birds/transect; 7%), and rufous-collared sparrows (1.3 ± 0.2 birds/transect; 6.2%; Figure 2A).

In autumn, grassland yellow-finches and picazuro pigeons were the species with the highest field occurrence (47.5% of 200 fields each), followed by monk parakeets (43.5%), eared doves (36.5%), and spot-winged pigeons (31.5%). Half of individuals of the seed-eating birds assemblage were eared doves (19.2 ± 4.9 birds/transect; 50.7%), followed by monk parakeets (7.5 ± 1.4 birds/transect; 20%), grassland yellow-finches (6 ± 1.1 birds/transect; 15.9%), picazuro pigeons (1.9 ± 0.2 birds/transect; 5.1%), and spot-winged pigeons (0.8 ± 0.1 birds/transect; 2%; Figure 2B).

In general, seed-eating bird species did not show any significant differences in their field occurrence between field types ($P > 0.05$; Figure 2), with the exception of great pampa-finches *Embernagra platensis*, which was only found at livestock paddocks in autumn (6% vs. 0%; $P = 0.01$; Figure 2B).

Seed-eating birds and field characteristics

In spring-summer, coinciding with the breeding season, 4 out of the 5 bird species considered in our analyses (eared doves, grassland yellow-finches, rufous-collared sparrows, monk parakeets, and picazuro pigeons) showed a significant response in their abundances in a

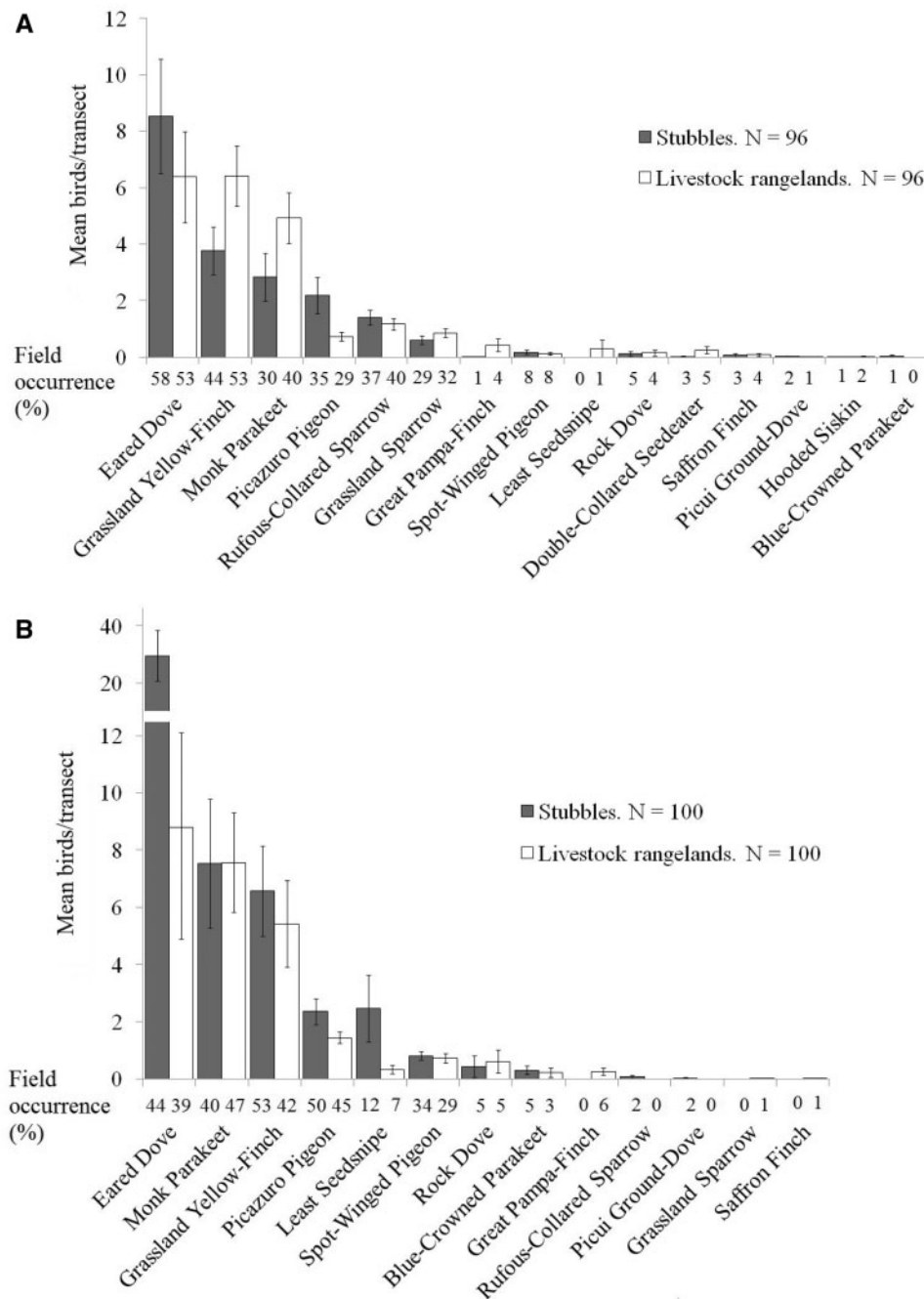


Figure 2. Mean abundance (\pm standard error) by transect (birds/transect) of seed-eating birds and percentage of occurrence (% of transects on which a species was recorded) of each bird species on each field type (crop stubbles and livestock rangelands) in the Pampas of central Argentina, during spring-summer (A) and autumn (B).

certain field to at least one of the originally variables considered (Online Appendix 2). Three species (eared dove, picazuro pigeon, and monk parakeet) showed an inverse relationship to the distance to the nearest woodlot (Table 2A), that is, they had a greater abundance in fields that were closer to woodlots (Coefficients estimated = -0.001 ± 0.0005 , -0.003 ± 0.0008 , and -0.002 ± 0.0008 for eared dove, picazuro pigeon, and monk parakeet, respectively; Online Appendix 3). Moreover, grassland yellow-finches responded to field surroundings, showing lower abundances at fields surrounded by pure cropland (Figure 3A; Online Appendix 3). In addition, monk parakeets were also associated with the field type (Table

2A; Online Appendix 3), and were 73% more abundant in livestock paddocks (5.9 ± 1 birds/transect) than in crop stubbles (3.4 ± 1 birds/transect). We did not detect any relationship in the abundance of rufous-collared sparrows with the variables considered (Table 2A).

In autumn, coinciding with the non-breeding season, 3 out of the 5 bird species considered in our analyses (grassland yellow-finches, picazuro pigeons, monk parakeets, eared doves, and spot-winged pigeons) showed a significant response in their abundance in a certain field to at least one of the originally variables considered (Online Appendix 2). Eared doves were associated with the field type (Table

2B; Online Appendix 3), with abundances in crop stubbles (29.6 ± 8.8 birds/transect) being 236% higher than in livestock paddocks (8.8 ± 3.9 birds/transect). Picazuro pigeons were significantly more abundant at transects with both crop stubbles and field surroundings dominated by livestock use (Table 2B; Figure 4; Online Appendix 3). In addition, spot-winged pigeons were significantly less abundant when field surroundings were dominated by livestock use (Figure 3B; Online Appendix 3). Moreover, both pigeon species were more abundant at fields closer to woodlots (Coefficients estimated = -0.002 ± 0.0005 and -0.002 ± 0.0007 , for picazuro pigeon and spot-winged pigeon, respectively; Online Appendix 3). We did not detect any relationship in the abundance of monk parakeets and grassland yellow-finches with the variables considered (Table 2B; Online Appendix 3).

Table 2. Best supported model of general linear mixed models (GLMM) for each seed-eating bird species, testing for the effect of field characteristics (FTYP = field type, DIST = distance to the nearest woodlot, and FSUR = field surroundings) on species abundance, in the Pampas of central Argentina; (A) spring-summer; (B) autumn

(A) Spring-summer				
Species	Best model	k	AICc	Wi
Eared dove	DIST ⁽⁻⁾	4	937.9	0.601
Grassland Yellow-finch	FSUR	7	895.6	0.374
Monk parakeet	DIST ⁽⁻⁾ + FTYP	5	647.5	0.842
Picazuro pigeon	DIST ⁽⁻⁾	4	489.4	0.509
Rufous-collared sparrow	Null model	3	569.4	0.325
(B) Autumn				
Species	Best model	k	AICc	Wi
Eared dove	FTYP	4	905.3	0.521
Monk parakeet	Null model	3	852.1	0.432
Grassland Yellow-finch	Null model	3	898.7	0.366
Picazuro pigeon	DIST ⁽⁻⁾ + FSUR*FTYP	13	663.7	0.573
Spot-winged pigeon	DIST ⁽⁻⁾ + FSUR	8	386.4	0.397

Notes: K = number of parameters. All bird species considered in the analyses had >30% field occurrence, and species are ordered according to their respective abundances in each season.

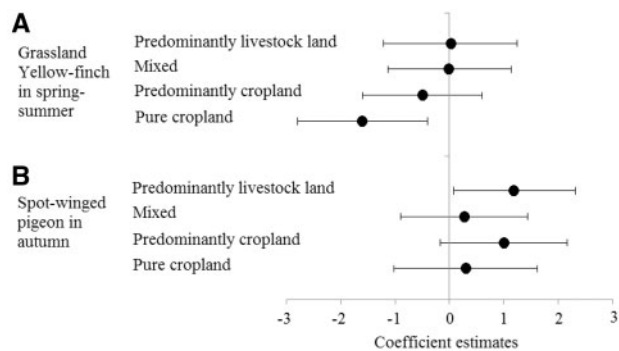


Figure 3. Model-averaged coefficient estimates and 95% confidence intervals for coefficients of explanatory variable field surroundings, compared with pure livestock land for (A) grassland yellow-finches in spring-summer and (B) spot-winged pigeons in autumn. Confidence intervals excluding zero indicates that the considered factor explains bird abundance.

Discussion

To the best of our knowledge, this is the first attempt to analyze the relationship between seed-eating birds and field characteristics (field type, field use in the surroundings, and distance to the nearest woodlot) in the Pampas of central Argentina, at the period when croplands are in crop stubbles stage. Previous studies have shown that responses of birds to field characteristics are usually season dependent (Moorcroft et al. 2002). Our results show that in temperate agroecosystems, the relationships between field characteristics and seed-eating bird abundance also vary seasonally. We found that there was a general response pattern in spring-summer (breeding season) when most bird responses were associated with their nesting requirements, while in autumn (non-breeding season), most bird responses were associated with foraging and refuge needs.

During spring-summer, coincidentally with the breeding season of birds, eared doves, picazuro pigeons, and monk parakeets were more abundant in fields near to woodlots, which is agreement with the fact that all these species build their nests in trees (Daguerre 1936; Narosky and Di Giacomo 1993; Oniki and Willis 2000). In addition, during spring-summer grassland yellow-finches were more abundant in those fields under livestock use in the field surroundings, which is in agreement with the nesting habits of this species in patches with tall grasses (Cozzani and Zalba 2009), many of which can still be found at such paddocks. Thus, these results suggest that during the breeding season, seed-eating birds were associated with the presence of suitable elements to nesting in the landscape. This pattern is similar to previous works in the same region for picazuro pigeons (Leveau and Leveau 2011; Codesido et al. 2015) and for monk parakeets (Bucher and Aramburú 2014; Codesido et al. 2015) in which both species showed a positive response to the presence of woodlots.

On the other hand, in autumn (i.e., non-breeding season) most bird responses were associated with foraging and refuge resources. Autumn is a critical season for the bird assemblage in the Pampas (Codesido et al. 2008) because the food supply of insects tends to decrease and many migratory insectivore species leave the region at the end of the summer (Codesido et al. 2008). Our results show that some seed-eating species increase their population numbers in autumn, which might be due to recruitment from the previous breeding season and local migrations. The high abundance of eared doves in

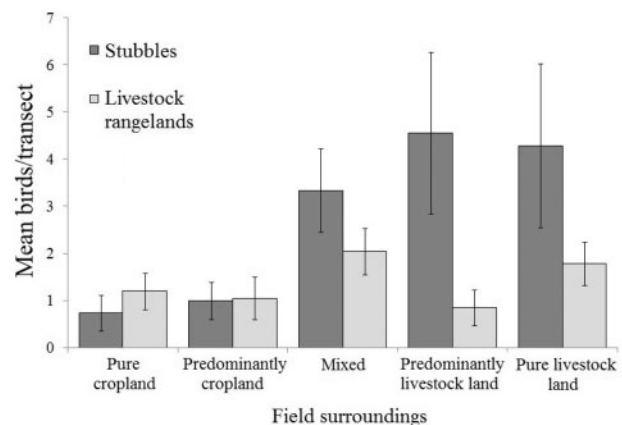


Figure 4. Mean abundance and standard error per transect (birds/transect) of picazuro pigeons in autumn according to field type (crop stubbles and livestock ranglands) and dominant use of field surroundings in the Pampas of central Argentina.

autumn at crop stubbles, as well as the association of pigeons at field surroundings dominated by croplands or at stubbles with field surroundings dominated by livestock use reveal the intimate association of these species to sites with high availability of food resources (seeds) in the non-breeding season. The response of eared doves to stubbles during autumn is in agreement with studies showing that cultivated grain is a significant fraction in the diet of this species throughout the year, particularly in autumn (Murton et al. 1974; Bucher and Nores 1976). Similar results have been found in farmlands of other regions of the world, pointing out the key role of stubbles in populations of many seed-eating birds (Wilson et al. 1996; Moorcroft et al. 2002; Evans and Green 2007). Other studies in European farmlands also suggest that some seed-eating birds may use stubbles as an anti-predation strategy (Whittingham et al. 2006).

In addition to crop stubbles, in autumn both picazuro pigeon and spot-winged pigeon were also associated with proximity to woodlots, which are important roosting sites for both species (Narosky and Di Giacomo 1993). This result reinforces previous observations pointing out that the introduction of trees in the Pampas allowed the expansion of pigeons through providing suitable sites as refuge (Daguerra 1936; Narosky and Di Giacomo 1993).

Besides the general patterns of species requirements detected for seed-eating birds during both breeding and non-breeding seasons, some species also showed species-specific responses. During spring-summer, livestock paddocks supported higher abundance of monk parakeets than stubbles. The diet of monk parakeets is wide, and includes wild seeds, fruits, crops, insects, and flowers (Aramburú 1997). This result could be due to the fact that during this season wild grasses and pastures are flowering and seeding at livestock paddocks and may provide higher variety of food resources than stubbles for monk parakeets.

In summary, we have shown that seed-eating birds do respond to field type as well as to field use in the surroundings fields, and to proximity to woodlots in agroecosystems of central Argentina. These responses varied seasonally, probably in relation to breeding and non-breeding seasons, plant phenology, crop identity, etc. (Moorcroft et al. 2002; Benton et al. 2003) and with specific requirements or life-history traits of particular species, as also reported for other taxa like small mammals in the same temperate agroecosystems (González-Fischer et al. 2012). Our results also suggest that crop stubbles may contribute to sustain high population numbers of several of these seed-eating species in periods where crops are not susceptible to damage, but that may end up contributing to further damage when crops are again in stages of crop emergence or maturity (Bucher and Ranvaud 2006; Canavelli et al. 2012). Thus, future studies should consider an assessment of some kind of stubble management techniques (reduction of spilled grains, crop turnovers, etc.) as effective tools in pest bird control strategies (Canavelli et al. 2012). In addition, future studies are needed in order to identify whether bird abundance is related to the specific identity of stubbles and rangelands (natural grasslands, pastures, etc.) and to the identity and ecological features of the tree species conforming woodlots (Codesido et al. 2015).

Acknowledgments

Special thanks to the workers and owners of all the agricultural establishments that allowed access to work on their property (particularly to Alan Goodall, INTA Pergamino, Education Center for the Total Production—CEPT—No5, the town of Miranda, firefighters of Udaquiola, family Laplace, and the agricultural establishments of Tatay, El Haras, Hinojales, Pelerí, La Torcacita, Don Remigio, Santa Elena de Inchauspe, Monte Unión, La

Providencia, Manantiales). We appreciate the improvements in English usage made by Elizabeth Hobson through the Association of Field Ornithologists' program of editorial assistance.

Funding

Financial support was provided by Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET PIP 2010-2012 GI 11220090100231), Agencia Nacional de Promoción Científica y Tecnológica (BID PICT2010-1412), Universidad Nacional de La Plata (PPID/N004) and Universidad de Buenos Aires (UBACyT GC 20020090100070; GC 20020120100018).

Supplementary material

Supplementary material can be found at <http://www.cz.oxfordjournals.org/>.

References

- Abba AM, Zufiaurre E, Codesido M, Bilenca DN, 2015. Burrowing activity by armadillos in agroecosystems of central Argentina: biogeography, land use, and rainfall effects. *Agr Ecosyst Environ* 200:54–61.
- Aizen MA, Garibaldi LA, Dondo M, 2009. Expansión de la soja y diversidad de la agricultura Argentina. *Ecol Aust* 19:45–54 (in Spanish).
- Aramburú RM, 1997. Ecología alimentaria de la cotorra *Myiopsitta monachus* en la provincia de Buenos Aires, Argentina (Aves: *Psittacidae*). *Physis Secc C* 53:29–32 (in Spanish).
- Atkinson PW, Fuller RJ, Vickery JA, 2002. Large-scale patterns of summer and winter bird distribution in relation to farmland type in England and Wales. *Ecography* 25:466–480.
- Azpiroz AB, Blake JG, 2009. Avian assemblages in altered and natural grasslands in the northern campos of Uruguay. *Condor* 111:21–35.
- Baldi G, Paruelo JM, 2008. Land-use and land cover dynamics in South American temperate grasslands. *Ecol Soc* 13:6. [cited 2015 November 30] Available from: <http://www.ecologyandsociety.org/Vol06303/iss2/art6/>.
- Benton TG, Vickery JA, Wilson JD, 2003. Farmland biodiversity: is habitat heterogeneity the key? *Trends Ecol Evol* 18:182–188.
- Bibby CJ, Burgess ND, Hill DA, Mustoe SH, 2000. *Bird Census Techniques*. San Diego (CA): Academic Press.
- Bilenca DN, Codesido M, González Fischer CM, Pérez Carus LC, Zufiaurre E et al., 2012. Impactos de la transformación agropecuaria sobre la biodiversidad en la provincia de Buenos Aires. *Rev Mus Argent Cienc Nat* 14:189–198 (in Spanish).
- Bolsa de Cereales. 2015. Relevamiento de tecnología agrícola aplicada de la bolsa de cereales, Argentina [cited 2015 November 30]. Available from: <http://www.bolsadecereales.com/tetaa> (in Spanish).
- Bucher EH, Aramburú RM, 2014. Land-use changes and monk parakeet expansion in the Pampas grasslands of Argentina. *J Biogeogr* 41:1160–1170.
- Bucher EH, Nores M, 1976. Ecología de la alimentación de la paloma *Zenaida auriculata*. *Physis Secc C* 35:17–32.
- Bucher EH, Ranvaud RD, 2006. Eared dove outbreaks in South America: patterns and characteristics. *Acta Zool Sin* 52:564–567.
- Buckingham DL, Evans AD, Morris AJ, Orsman CJ, Yaxley R, 1999. Use of set-aside land in winter by declining farmland bird species in the UK. *Bird Study* 46:157–169.
- Burnham KP, Anderson DR, 2002. *Model Selection and Multimodel Inference: A Practical Information—Theoretic Approach*. 2nd edn. New York: Springer.
- Canavelli SB, Aramburú R, Zaccagnini ME, 2012. Aspectos a considerar para disminuir los conflictos originados por los daños de la cotorra *Myiopsitta monachus* en cultivos agrícolas. *El Hornero* 27:89–101.
- Canavelli SB, Branch LC, Cavallero P, González C, Zaccagnini ME, 2014. Multi-level analysis of bird abundance and damage to crop fields. *Agr Ecosyst Environ* 197:128–136.

- Codesido M, González-Fischer C, Bilenca D, 2008. Asociaciones entre diferentes patrones de uso de la tierra y ensambles de aves en agroecosistemas de la región Pampeana, Argentina. *Ornitol Neotrop* 19:575–585.
- Codesido M, González-Fischer C, Bilenca D, 2011. Distributional changes of landbird species in agroecosystems of central Argentina. *Condor* 113:266–273.
- Codesido M, González-Fischer C, Bilenca D, 2012. Agricultural land-use, avian nesting and rarity in the Pampas of central Argentina. *Emu* 112:46–54.
- Codesido M, González-Fischer CM, Bilenca DN, 2013. Landbird assemblages in different agricultural landscapes: a case study in the Pampas of central Argentina. *Condor* 115:8–16.
- Codesido M, Zufiaurre E, Bilenca D, 2015. Relationship between pest birds and landscape elements in the Pampas of central Argentina. *Emu* 115:80–84.
- Cozzani N, Zalba SM, 2009. Estructura de la vegetación y selección de hábitats reproductivos en aves del pastizal pampeano. *Ecol Aust* 19:35–44.
- Daguerre JB, 1936. Sobre nidificación de las aves de la provincia de Buenos Aires. *El Hornero* 6:280–288.
- Donald PF, Green RE, Heath MF, 2001. Agricultural intensification and the collapse of Europe's farmland bird populations. *Proc R Soc Lond B* 268:25–29.
- Evans AD, Green RE, 2007. An example of a two-tiered agri-environment scheme designed to deliver effectively the ecological requirements of both localised and widespread bird species in England. *J Ornithol* 148:279–286.
- Filloj J, Bellocq MI, 2007. Patterns of bird abundance along the agricultural gradient of the Pampean Region. *Agr Ecosyst Environ* 120:291–298.
- Fournier DA, Skaug HJ, Ancheta J, Ianelli J, Magnusson A et al., 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. *Optim Method Softw* 27:233–249.
- Ghersa CM, de la Fuente E, Suarez S, León RJ, 2002. Woody species invasion in the Rolling Pampa, Argentina. *Agr Ecosyst Environ* 88:271–278.
- González-Fischer CM, Baldi G, Codesido M, Bilenca D, 2012. Seasonal variations in small mammal-landscape associations in temperate agroecosystems: a study case in Buenos Aires province, central Argentina. *Mammalia* 76:399–406.
- Law BS, Dickman CR, 1998. The use of habitat mosaics by terrestrial vertebrate fauna: implications for conservation and management. *Biodivers Conserv* 7:323–333.
- Leveau LM, Leveau CM, 2004. Bird richness and abundance in pampean agroecosystems during the post-breeding period. *Ornitol Neotrop* 15:371–380.
- Leveau LM, Leveau CM, 2011. Uso de bordes de cultivo por aves durante invierno y primavera en la pampa austral. *El Hornero* 26:149–157.
- Moorcroft D, Whittingham MJ, Bradbury RB, Wilson JD, 2002. The selection of stubble fields by wintering granivorous birds reflects vegetation cover and food abundance. *J Appl Ecol* 39:535–547.
- Morton DC, Defries RS, Shimabukuro YE, Anderson LO, Arai E et al., 2006. Cropland expansion changes deforestation dynamics in the southern Brazilian Amazon. *Proc Natl Acad Sci USA* 103:14637–14641.
- Murton RK, Bucher EH, Nores M, Gomez E, Reartes J, 1974. The ecology of the eared dove *Zenaida auriculata* in Argentina. *Condor* 76:80–88.
- Narosky T, Di Giacomo A, 1993. *Las Aves de la Provincia de Buenos Aires: Distribución y Estatus*. Buenos Aires: Vázquez Mazzini Editores y LOLA.
- Oniki Y, Willis EO. 2000. Nesting behavior of the picazuro pigeon *Columba picazuro* (Columbidae, Aves). *Rev Brasil Biol* 60:663–666.
- Pinheiro JC, Bates DM, 2000. *Mixed-Effects Models in S and S-Plus*. New York: Springer.
- Potts D, 2003. The myth of the overwintered stubble. *Bird Study* 50:91–93.
- Prevedello JA, Vieira MV, 2010. Does the type of matrix matter? A quantitative review of the evidence. *Biodivers Conserv* 19:1205–1223.
- R Development Core Team. 2015. *R: A Language and Environment for Statistical Computing*. Vienna: R Foundation for Statistical Computing [cited 2015 November 30]. Available from: <http://www.R-project.org>.
- Robinson RA, Hart JD, Holland JM, Parrott D, 2004. Habitat use by seed-eating birds: a scale-dependent approach. *Ibis* 146:87–98.
- Robinson RA, Sutherland WJ, 1999. The winter distribution of seed-eating birds: habitat structure, seed density and seasonal depletion. *Ecography* 22:447–454.
- Robinson RA, Sutherland WJ, 2002. Post-war changes in arable farming and biodiversity in Great Britain. *J Appl Ecol* 39:157–176.
- Robinson RA, Wilson JD, Crick HQP, 2001. The importance of arable habitat for farmland birds in grassland landscapes. *J Appl Ecol* 38:1059–1069.
- Soriano A, 1991. Río de la Plata Grasslands. In: Coupland R, editor. *Natural Grasslands: Introduction and Western Hemisphere*. Amsterdam: Elsevier, 367–407.
- Suárez F, Garza V, Oñate JJ, García de la Morena EL, Ramírez A et al., 2004. Adequacy of winter stubble maintenance for steppe passerine conservation in central Spain. *Agr Ecosyst Environ* 104:667–671.
- Sutherland WJ, 2004. A blueprint for the countryside. *Ibis* 146:230–238.
- VanBeek KR, Brawn JD, Ward MP, 2014. Does no-till soybean farming provide any benefits for birds? *Agr Ecosyst Environ* 185:59–64.
- Verhulst J, Báldi A, Kleijn D, 2004. Relationship between land-use intensity and species richness and abundance of birds in Hungary. *Agr Ecosyst Environ* 104:465–473.
- Viglizzo EF, Frank FC, Carreño LV, Jobbágy EG, Pereyra H et al., 2010. Ecological and environmental footprint of 50 years of agricultural expansion in Argentina. *Glob Change Biol* 17:959–973.
- Weyland F, Baudry J, Ghersa CM, 2014. Rolling Pampas agroecosystem: which landscape attributes are relevant for determining bird distributions? *Rev Chil Hist Nat* 1:1–12.
- Wiens JA, 1989. *The Ecology of Bird Communities*. Vol 1. *Foundations and Patterns*. Cambridge: Cambridge University Press.
- Wilson JD, Taylor R, Muirhead LB, 1996. Field use by farmland birds in winter: an analysis of field type preferences using resampling methods. *Bird Study* 43:320–332.
- Whittingham MJ, Devereux CL, Evans AD, Bradbury RB, 2006. Altering perceived predation risk and food availability: management prescriptions to benefit farmland birds on stubble fields. *J Appl Ecol* 43:640–650.
- Zalba SM, Villamil CB, 2002. Woody plant invasion in relictual grasslands. *Biol Invasions* 4:55–72.
- Zar JH, 2010. *Biostatistical Analysis*. 5th edn. New Jersey: Pearson Prentice Hall.
- Zuur AF, Ieno EN, Walker NJ, Saveliev AA, Smith GM, 2009. *Mixed Effects Models and Extensions in Ecology with R*. New York: Springer.