AVIAN BIOLOGY RESEARCH **9** (4), 2016 273–281

Spatial variation in bird assemblages are linked to environmental heterogeneity in agricultural landscapes in the province of Entre Ríos, Argentina

Antonio E. Frutos[a,c], Cesar F. Reales[a], Rodrigo E. Lorenzón[b] and Ana L. Ronchi-Virgolini[c*]

[a]*Centro de Investigaciones Científicas y Transferencia de Tecnología a la Producción – Universidad Autónoma de Entre Ríos – Provincia de Entre Ríos - Concejo Nacional de Investigaciones Científicas y Técnicas. Facultad de Ciencia y Tecnología, Matteri y España – Entre Ríos, Diamante (Argentina)*
[b]*Instituto Nacional de Limnología – Concejo Nacional de Investigaciones Científicas y Técnicas – Universidad Nacional del Litoral. Paraje "El Pozo". CP 3000 Santa Fe, Argentina*
[c]*Universidad Autónoma de Entre Ríos, Argentina*
**E-mail: lronchi@gmail.com*

ABSTRACT

Natural environments have been altered by many human actions and during the last decades this process has been hastened in an alarming way. In the Pampean and Espinal ecoregions of Argentina, agriculture was the major contributor, producing a homogeneous landscape of cultivated lands interrupted by few small, isolated pieces of natural environment or noncultivated lands. We studied bird assemblages in two types of agricultural landscapes, one with crops located within a heterogeneous landscape matrix, such that crops were bordered by different types of noncultivated environments, and the other with crops located within a homogeneous landscape matrix away from noncultivated areas. The main objective was to compare the bird assemblage structure and composition between these two landscapes to test the hypothesis that heterogeneous agricultural landscapes support greater bird diversity than do homogeneous landscapes. We recorded 33% of the total abundance in the crops within a homogeneous matrix (CHOM) and 67% of the total abundance in the crops within a heterogeneous matrix (CHEM). The CHEM points had greater species richness, and composition of species differed between CHOM and CHEM. Thus, the results support the hypothesis that environmental heterogeneity increases bird diversity in agricultural areas, with important consequences for ecosystem services that biodiversity provides to agricultural ecosystems and for the conservation value of these systems. The fact that the protected areas by themselves are not sufficient to guarantee biodiversity conservation emphasises the important role that areas under cultivation can play. Our data provides evidence that the presence of uncultivated environments can increase the importance of agricultural lands for biodiversity conservation and, at the same time, can benefit agroecosystems by supporting bird species that can function as biological control agents of agricultural pests.

Keywords: crops, homogeneous landscapes, noncultivated environments, forest

1. INTRODUCTION

Natural environments have been altered by many human actions (*e.g.* agriculture, stockbreeding, and urbanisation), and during the last decade this process has been hastened in an alarming way (Benton *et al.*, 2003; Foley *et al.*, 2005; Ramankutty *et al.*, 2008). In the Pampean and Espinal ecoregions of Argentina, agriculture contributes most to this transformation, producing a mostly homogeneous landscape of cultivated lands interrupted by a few small, isolated pieces of natural environment or noncultivated lands (Laan and Verboom, 1990; Gavier-Pizarro *et al.*, 2011).

Environmental heterogeneity (*i.e.* spatial variation in physical conditions, such as soil and topography, and in the biotic environment) typically increases the biodiversity of a region (Boutin *et al.*, 2001; Jobin *et al.*, 2001; Jones and Sieving, 2006; Stein *et al.*, 2014). This positive relationship between environmental heterogeneity and biodiversity reflects the fact that heterogeneous environments provide more niches than do homogenous environments and, thereby, support more diverse communities of organisms (Rosenzweig, 1995).

The positive impact of environmental heterogeneity on biodiversity is especially important in agricultural ecosystems. The benefit to ecosystem services that biodiversity provides to agricultural systems, such as biological control and pollination, has become increasingly recognised in the last decade or so (Jobin *et al.*, 2001; Marshall and Moonen, 2002; Whelan *et*

Paper 1600684 doi: 10.3184/175815516X14725499175863

al., 2008; Solari and Zaccagnini, 2009; see review in Tscharntke *et al.*, 2005). This, together with the large areas devoted to agriculture, emphasises the important contribution that agricultural areas can make to the maintenance of biodiversity in the future. Tscharntke *et al.* (2005) point out the need for studies that document the factors that help to increase and maintain biodiversity in agricultural ecosystems. For example, several studies have documented the importance of birds to ecosystem services such as biological pest control (*e.g.*, Strong *et al.*, 2000; Perfecto *et al.*, 2004).

Birds are considered good indicators for evaluating the potential of a region to support a diverse array of organisms because they are easy to observe and monitor (Aparicio and Lyons, 1998). At both local and landscape scale, the main factor affecting spatial variation in bird species richness is the level of environmental heterogeneity, determined mainly by variation in vegetation structure (Willson, 1974; Rotenberry, 1985; Ronchi-Virgolini *et al.*, 2010).

Here, we studied bird assemblages in two types of agricultural landscapes. In one, crops were located within a heterogeneous landscape matrix, such that crops were bordered by different types of noncultivated environments. In the second, crops were located within a homogeneous landscape matrix away from noncultivated areas. The main objective was to compare the bird assemblage structure and composition between these two landscapes to test the hypothesis that heterogeneous agricultural landscapes support greater bird diversity than homogeneous landscapes. To complement this, we also assessed the richness and composition of birds in noncultivated environments, including forested and second-growth areas located along roadsides, identifying the contribution of these environments to the richness and composition of bird communities found in agricultural landscapes.

2. METHODS

2.1 Study area

Birds were sampled in agricultural areas located in Victoria, Entre Ríos province, Argentina (32°26′13.4″S – 60°13′56″W) (Figure 1). The landscape of the area is dominated by an agricultural and livestock matrix with isolated patches of noncultivated environments, including forests, roadsides with arboreal vegetation, meadows linked to the perimeter fences that divide the fields, and small superficial water ponds. The climate is mild to warm and humid, with an annual average temperature of 19 °C and an average annual rainfall of 900 mm; most rain occurring from October to April (73%) (Rojas and Saluso, 1987).

2.2 Sampling design

Birds were sampled using point counts (see below) in three different habitat sites. In the first, crops with homogeneous matrix (CHOM), sample points were located in sites sown with *Triticum* sp., *Glycine max* and *Zea mays*. All point counts were located at least 600 m from any noncultivated lands. In the second habitat, crops with heterogeneous matrix (CHEM), sample points were located with the same

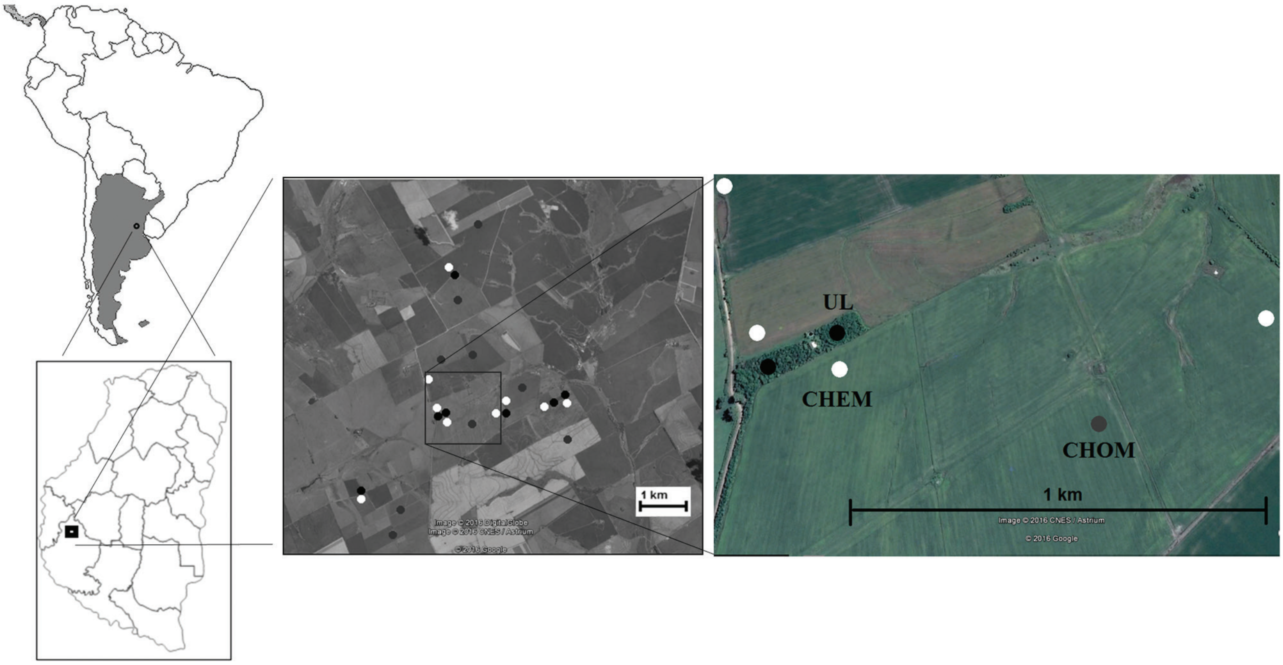

Figure 1 Study area. The black circles represent point counts in uncultivated lands (UL); gray circles represent point counts in crops with homogeneous matrix (CHOM); white circles represent point counts in crops with heterogeneous matrix (CHEM) (adapted from Google Earth, accessed 9 June 2016).

type of crops as in CHOM, but point counts were located at least 75 m but no more than 100 m from noncultivated lands. Finally, in uncultivated lands (UL), surveys were conducted along roadsides and edges of crops that supported shrubs, small patches of forests and forest strips located at the edges of roads. The arboreal strata of these woods were primarily composed of exotic species such as *Melia azedarach*, *Ligustrum lucidum*, *Morus nigra*, and *Eucalyptus* spp., as well as fruit species such as *Ficus carica*, *Malus domestica* and *Citrus* spp. Although less common, some native species, such as *Acacia caven*, *Celtis ehrenbergiana*, *Phytolacca dioica*, and *Schinus molle* were also present, together with some species from the north of Argentina, such as *Jacaranda mimosifolia* and *Tabebuia alba*. The herbaceous stratum reached a height of ~30 cm during the winter (from June to September) and was made up of different species of grass; during the spring (from September to December), it was dominated by *Cirsium* sp., with a height of ~120 cm.

2.3 Bird counts

Birds were sampled with 75 m radius 10 min point counts (Ralph *et al.*, 1996; Huff *et al.*, 2000) in crop habitats (CHOM and CHEM) from June to December 2012. Nine points were located within crops in a homogeneous landscape matrix (CHOM) and nine were located within crops in a heterogeneous landscape matrix (CHEM). Points in CHOM and CHEM were separated from each other by at least 300 m to independence among points. In addition, seven points with 25 m radius were located within woods and by the roadside next to the woods (UL), with points separated from each other by only 75 m since these points were not included in statistical analysis (*i.e.*, when comparing CHOM *vs* CHEM). Instead, results from these additional points were used to obtain more information about the species that use uncultivated spaces and to determine if there was a qualitative relationship between those species and the ones that use cultivated environments. All points were sampled for two consecutive days to avoid variations caused by the change in climatic conditions; points were not sampled on days with rain or high winds. Each point was sampled 12 times (six visits in the winter season and six visits during spring) at intervals of 15 days. Surveys were completed during the four hours after sunrise, a period with greater stability for detection of birds (Ralph *et al.*, 1996; Huff *et al.*, 2000). All counts were conducted by two observers through direct observation using 10×50 binoculars. Species were identified following Narosky and Yzurieta (2010); taxonomy follows Remsen *et al.* (2016).

2.4 Data analysis

Species were classified according to residency status following Fandiño and Giraudo (2010): resident (R); southern migrants from the north (SMN); and southern migrants from the south (SMS). The categories of longitudinal migrants from the east (LME) and longitudinal migrants from the west (LMW) were not included as none of the species detected corresponded to these categories.

To implement the statistics analysis, the 12 visits to each count point were combined analysing these nine point counts for each type of landscape (nine points of CHEM and nine of CHOM). Uncultivated sites (UL) were not included in the statistical analysis because it was not part of the objectives of this work. The point counts at these sites (UL) did not maintain the minimum distance (250 m) recommended to ensure the independence of the data because of the small size of forest patches.

We combined results of the 12 visits per point (nine points in CHEM and nine in CHOM) to compare species richness (*i.e.* the total number of species registered in the 12 visits to each point) and abundance (*i.e.* mean number of birds recorded among the 12 visits to each point) per point between landscape types. We used nonparametric Mann–Whitney tests because the data did not meet assumptions of parametric tests.

We used nonmetric multi-dimensional scaling (NMDS) to graphically compare species composition between CHEM and CHOM; NMDS was performed using PC-ORD Version 4.0 (McCune and Mefford, 1999). NMDS graphically represents similarities (and differences) in the composition of species between landscapes and samples (Clarke and Warwick, 2001). This analysis was based on the average of the relative abundance of each species among the 12 visits to every count point. Similarly, we used a multivariate analysis of variance based on permutations (PERMANOVA) to compare the composition of species between both types of landscapes CHEM and CHOM. PERMANOVA was implemented in R (R Core Team, 2015) by using vegan package (Oksannen, 2011) with significance based on 999 permutations.

We distinguished two groups of species to examine the relationship of species with the different landscapes: exclusive species (*i.e.* species detected only in one type of landscape during the sampling period) and additional species (*i.e.* species detected in different landscapes during the sampling period) (Robinson and Terborgh, 1990). In addition, an indicator species analysis (ISA) (Dufrêne and Legendre, 1997) was performed to determine which species were more frequent and/or abundant in each of the landscapes matrices. In all tests, differences were considered significant at $P<0.05$; values are reported as mean ± SE.

3. RESULTS

In all the sampling area, including cultivated and uncultivated lands, we detected a total of 3783 records belonging to 85 species, 16 of which were migrants (13 SMN and 3 SMS) (Table 1). A total of 2198 birds of 56 species were detected in CHOM and CHEM, combined;

Table 1 General species list, residency status, exclusive species, indicator species, total abundance and relative abundance. CHEM: crops with heterogeneous matrix; CHOM: crops with homogeneous matrix; R: resident; SMN: southern migrants from the north; SMS: southern migrants from the south; C: crops (it includes CHOM and CHEM); UL: uncultivated lands; relative abundance (%): is the percent of individuals detected divided the total records in the area of crops

Species	Residency status	Exclusive species	Indicator species	Relative abundance (%)	
				CHEM	CHOM
Nothura maculosa	R	C	–	1.59	2.18
Rhynchotus rufescens	R	C	–	0.27	0.09
Syrigma sibilatrix	R	–	–	0.09	0.09
Rupornis magnirostris	R	UL	–	0.00	0.00
Caracara plancus	R	–	–	0.00	0.09
Falco sparverius	R	C	–	0.05	0.05
Milvago chimango	R	–	–	0.18	0.09
Vanellus chilensis	R	C	–	0.82	0.96
Columbina picui	R	–	CHEM	2.27	0.36
Leptotila verreauxi	R	–	–	0.14	0.00
Patagioenas maculosa	R	–	–	0.05	0.00
Patagioenas picazuro	R	–	–	0.23	0.00
Zenaida auriculata	R	–	–	5.60	5.32
Myiopsitta monachus	R	UL	–	0.00	0.00
Coccyzus melacoryphus	SMN	UL	–	0.00	0.00
Guira guira	R	UL	–	0.00	0.00
Tyto alba	R	UL	–	0.00	0.00
Asio flammeus	R	UL	–	0.00	0.00
Bubo virginianus	R	UL	–	0.00	0.00
Systellura longirostris	R	UL	–	0.00	0.00
Chlorostilbon lucidus	R	–	–	0.05	0.00
Colaptes campestris	R	–	–	0.18	0.09
Colaptes melanochloros	R	UL	–	0.00	0.00
Melanerpes candidus	R	UL	–	0.00	0.00
Veniliornis mixtus	R	UL	–	0.00	0.00
Picumnus cirratus	R	UL	–	0.00	0.00
Taraba major	R	UL	–	0.00	0.00
Anumbius annumbi	R	UL	–	0.00	0.00
Asthenes pyrrholeuca	SMS	UL	–	0.00	0.00
Drymornis bridgesii	R	UL	–	0.00	0.00
Furnarius rufus	R	–	CHEM	2.64	0.23
Lepidocolaptes angustirostris	R	UL	–	0.00	0.00
Phacellodomus striaticollis	R	–	–	0.14	0.00
Synallaxis albescens	R	–	–	0.05	0.00
Synallaxis frontalis	R	UL	–	0.00	0.00
Camptostoma obsoletum	R	UL	–	0.00	0.00
Elaenia spectabilis	SMN	UL	–	0.00	0.00
Elaenia parvirostris	SMN	CHEM	–	0.05	0.00
Machetornis rixosa	R	CHEM	–	0.09	0.00
Myiarchus swainsoni	SMN	UL	–	0.00	0.00
Pitangus sulphuratus	R	–	CHEM	1.64	0.14
Pseudocolopteryx sclateri	R	CHEM	–	0.14	0.00
Pyrocephalus rubinus	R	CHEM	–	0.05	0.00
Serpophaga subcristata	R	UL	–	0.00	0.00
Tyrannus melancholicus	SMN	UL	–	0.00	0.00
Tyrannus savana	SMN	–	–	0.05	0.00
Xolmis irupero	R	C	–	0.09	0.05

Table 1 Contd.

Species	Residency status	Exclusive species	Indicator species	Relative abundance (%)	
				CHEM	CHOM
Phytotoma rutila	R	UL	–	0.00	0.00
Cyclarhis gujanensis	R	UL	–	0.00	0.00
Vireo olivaceus	SMN	UL	–	0.00	0.00
Petrochelidon pyrrhonota	SMN	–	–	*4.14*	*0.77*
Progne tapera	SMN	–	–	0.32	0.05
Tachycineta leucorrhoa	R	–	–	4.37	1.96
Troglodytes aedon	R	–	–	1.55	0.59
Polioptila dumicola	R	–	–	0.05	0.00
Turdus amaurochalinus	R	–	–	0.00	0.05
Turdus rufiventris	R	–	–	0.09	0.32
Mimus patagonicus	SMS	–	–	0.09	0.00
Mimus saturninus	R	–	CHEM	0.36	0.00
Mimus triurus	SMS	–	–	0.18	0.00
Geothlypis aequinoctialis	R	–	–	0.50	0.05
Coryphospingus cucullatus	R	–	–	0.09	0.00
Embernagra platensis	R	CHEM	–	0.23	0.00
Paroaria coronata	R	–	CHEM	0.59	0.14
Poospiza melanoleuca	R	–	–	0.05	0.09
Poospiza nigrorufa	R	CHEM	–	0.05	0.00
Sicalis flaveola	R	–	–	0.18	0.05
Sicalis luteola	R	–	–	18.38	8.01
Sporophila caerulescens	SMN	–	CHEM	2.00	0.77
Sporophila hypoxantha	SMN	CHEM	–	0.09	0.00
Sporophila ruficollis	SMN	CHOM	–	0.00	0.05
Pipraeidea bonariensis	R	UL	–	0.00	0.00
Thraupis sayaca	R	UL	–	0.00	0.00
Volatinia jacarina	SMN	–	–	0.68	0.41
Ammodramus humeralis	R	C	–	1.91	0.96
Zonotrichia capensis	R	–	–	7.19	4.23
Agelaioides badius	R	–	CHEM	2.46	0.18
Icterus pyrrhopterus	R	UL	–	0.00	0.00
Molothrus bonariensis	R	–	CHEM	1.68	0.32
Molothrus rufoaxillaris	R	–	–	0.14	0.05
Pseudoleistes virescens	R	CHEM	–	0.18	0.00
Sturnella superciliaris	R	C	CHOM	2.55	4.19
Saltator aurantiirostris	R	–	–	0.05	0.00
Sporagra magellanica	R	–	–	0.23	0.23
Passer domesticus	R	–	–	0.05	0.00

1585 birds from 69 species were detected in the noncultivated habitats.

Of the species identified in the cultivated area, 10 are migrants (8 SMN and 2 SMS) (Table 1). We recorded 729 individuals (33% of the total) belonging to 34 species in the homogeneous landscape (CHOM) and 1469 individuals (67% of the total) belonging to 53 species in the heterogeneous landscape (CHEM). The most abundant species in CHOM were: *Sicalis luteola* (24.1% of the total number of records in the CHOM); *Zenaida auriculata* (16%); *Zonotrichia capensis* (12.8%); *Sturnella superciliaris* (12.6%); *Nothura maculosa* (6.6%); and *Tachycineta leucorrhoa* (5.9%). The families best represented in CHOM were: Thraupidae with seven species and 28.7% of the total abundance; Icteridae with four species and 14.3% of the total abundance; Hirundinidae with three species and 8.4% of the total abundance; and Falconidae with three species and 0.7% of the total abundance. The most abundant species in CHEM were: *Sicalis luteola* (27.5% of the total number of records in the CHEM); *Zonotrichia capensis* (10.8%); *Zenaida auriculata* (8.4%); *Tachycineta leucorrhoa*

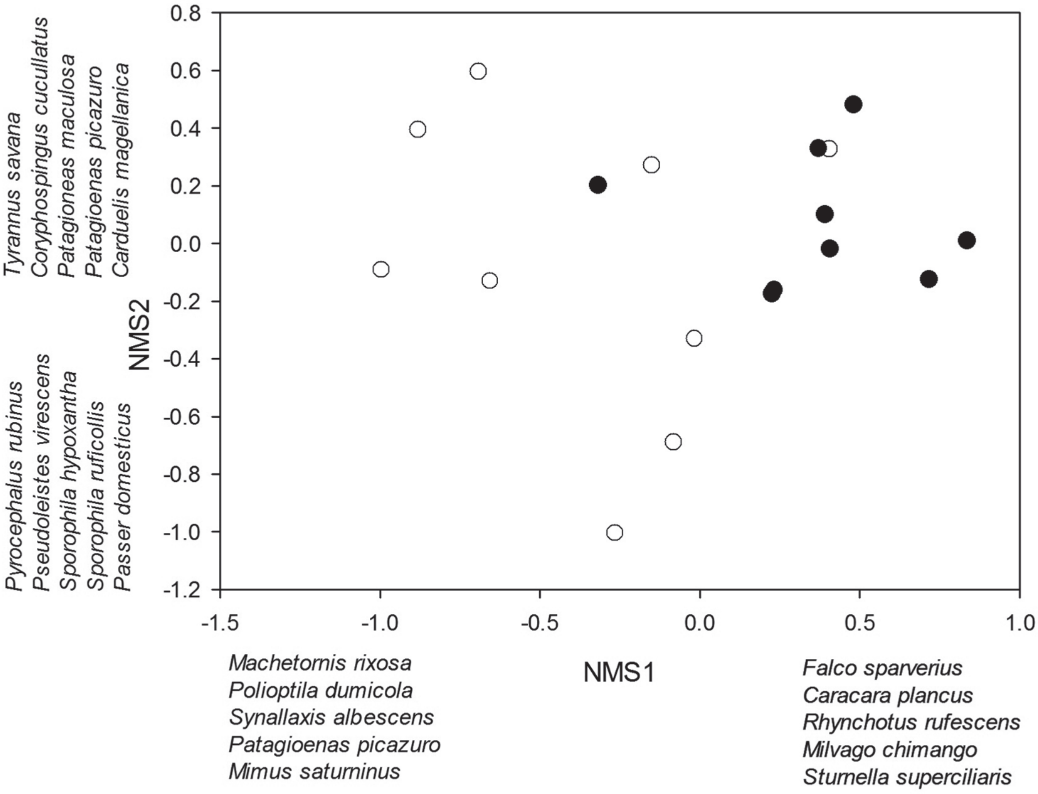

Figure 2 Nonmetric multi-dimensional scaling (NMDS) ordination based on relative abundances per sample (*i.e.* the average of the relative abundances from each species among the 12 visits to every count point) for homogeneous (solid symbols) and heterogeneous (open symbols) landscape matrices. Axes reflect differences in composition between homogeneous and heterogeneous landscape matrices. The five species most highly correlated with each axis are indicated.

(6.5%); *Petrochelidon pyrrhonota* (6.2%); and *Furnarius rufus* (3.9%). The families best represented in CHEM were: Thraupidae with 10 species and 33.4% of the total abundance; Tyrannidae with seven species and 3.1% of the total abundance; Columbidae with five species and 12.4% of the total abundance; and Icteridae with five species and 10.5% of the total abundance. The CHEM points had greater species richness (CHEM: 21.3 ± 1.2 per point; CHOM: 12.6 ± 1.7; Mann–Whitney: $P = 0.005$) and abundance (CHEM: 14 ± 3.1 per point; CHOM: 7 ± 1.5; Mann–Whitney: $P = 0.005$).

Composition of species differed between CHOM and CHEM (PERMANOVA: $F_{1,16} = 3.5$, $P = 0.002$; $R^2 = 0.18$). Points from CHOM landscape were closer together in the NMDS ordination (Figure 2), indicating relatively high similarity in species composition. In contrast, CHEM points were farther apart in the ordination, indicating a greater level of difference in species composition among points in CHEM than in CHOM (Figure 2).

Only three species were recorded in the CHOM landscape whereas 22 species were restricted to CHEM. Finally, one and eight species were selected as indicators (indicator species analysis) of CHOM and CHEM, respectively (Table 2).

Of the 69 species detected in points located in uncultivated areas, 29 (42%) were not recorded in either of the crop landscape, including 5 SMN, 1 SMS and 23 R (Table 1). Twenty six species (38%) were also observed in CHOM and 38 (55%) in CHEM.

Table 2 Indicator species analysis (ISA). CHEM: crops with heterogeneous matrix; CHOM: crops with homogeneous matrix

Species	Site	*P* value
Columbina picui	CHEM	0.0004
Furnarius rufus	CHEM	0.0002
Pitangus sulphuratus	CHEM	0.0002
Mimus saturninus	CHEM	0.0282
Sporophila caerulescens	CHEM	0.0170
Paroaria coronata	CHEM	0.0178
Molothrus bonariensis	CHEM	0.0012
Sturnella superciliaris	CHOM	0.0028
Agelaioides badius	CHEM	0.0006

4. DISCUSSION

Currently, it is widely accepted that natural protected areas alone are insufficient to guarantee conservation of biodiversity (Lindenmayer *et al.*, 2006) and that areas under productive usage (*e.g.* agricultural lands) need to contribute to conservation (Miller, 1996). This need, together with the ecosystem services that biodiversity provides to productive systems (Tscharntke *et al.*, 2005), highlights the need to evaluate which factors favour higher levels of biodiversity in agricultural ecosystems.

Results of this study demonstrate differences in richness, abundance and composition of bird species in two types of landscape matrices: homogeneous, dominated by cultivated areas, and heterogeneous, with the presence of additional land-cover types, such as woods, bushes and meadows. These results indicate that environmental heterogeneity, defined as the presence of nonagricultural land cover helps maintain more diverse bird assemblages. Thus, the results support the hypothesis that environmental heterogeneity increases bird diversity in agricultural areas, with important consequences for ecosystem services that biodiversity provides to agricultural ecosystems and for the conservation value of these systems.

In this study, bird species richness was greater in those crops located in a heterogeneous landscape. Similarly, Zaccagnini *et al.* (2011) reported greater bird species richness in wooded habitats in comparison to areas on which cattle were raised. Consequently, they found a positive relationship between bird species richness and structurally more complex vegetation, and a negative relationship with the crops. Greater bird diversity in heterogeneous agricultural landscapes may reflect the fact that many species may use the uncultivated borders of crops for shelter and foraging (Collazo and Bonilla–Martinez, 1988; Naranjo and Chacon–Ulloa, 1997; Bilenca, 2000; Goijman, 2005). In contrast to our results, Solari and Zaccagnini (2009) did not find any difference in bird species richness and density when comparing cultivated areas with and without terraces and arboreal borders. However, those authors pointed out that a large percentage of the species were only detected in terraces and arboreal borders, and not inside the crops, again demonstrating the importance of structural complexity.

Many of the species detected in this study were found only in the noncultivated habitats and not in the croplands. This result agrees with Marigliano *et al.* (2010), who observed that only 15% of the species in agricultural landscapes were reported within the cultivated plots, whereas the remainder were found only in the border habitats. Thus, it is likely that many bird species found in agroecosystems require the presence of uncultivated patches with natural environments, such as woods, and otherwise would not be found in such agricultural landscapes.

Spatial variations in composition of species among point counts, graphically demonstrated through NMDS, was considerably less among points located in the crops in the homogeneous landscape compared to points located in the heterogeneous landscape (*i.e.* points closer to patches of uncultivated lands). The differences in composition between the different landscapes were due to the increased presence of species related to the open environment in the CHOM (*Falco sparverius, Caracara plancus, Rhynchotus rufescens, Milvago chimango* and *Sturnella superciliaris*) and the increased presence of species related to the uncultivated environment (grasslands, shrublands and forests) in the CHEM (*Machetornis rixosa, Polioptila dumicola, Synallaxis albescens, Patagioenas picazuro* and *Mimus saturninus*). Greater spatial variation among points in the heterogeneous landscape may reflect the fact that not all points were close to the same type of uncultivated environment and, consequently, the species contributions of those environments differed. These differences were reflected in the dimension two of NMDS. *Pyrocephalus rubinus*, *Pseudoleistes virescens*, *Sporophila hypoxantha*, *Sporophila ruficollis* and *Passer domesticus* were better represented at points of crop within a heterogeneous matrix near uncultivated environments with tall grass, while *Tyrannus savana*, *Coryphospingus cucullatus*, *Patagioenas maculosa*, *Patagioenas picazuro* and *Sporagra magellanicas* were better represented at points of crop within a heterogeneous matrix near uncultivated environments with forest.

Points located in the heterogeneous landscape supported a higher percentage of those species present in the uncultivated patches that consisted of natural or semi-natural woods. The eight species that were more frequent and/or abundant (*i.e.* indicator species) within crops located in the heterogeneous landscape (*Agelaioides badius*, *Columbina picui*, *Furnarius rufus*, *Mimus saturninus*, *Molothrus bonariensis*, *Paroaria coronata*, *Pitangus sulphuratus* and *Sporophila caerulescens*), were also detected in the woods and, in general, are species that depend on those structurally more complex environments. An exception was *Sporophila caerulescens*, which, although not dependent on the existence of woods, does use noncultivated border habitats, dominated by weeds such as *Sorghum halepense*, for foraging and nesting. The only species that was selected as an indicator of crops within a homogeneous landscape was *Sturnella superciliaris*, a species typically associated with open habitats such as grasslands (Narosky and Yzurieta, 2010).

Many of the species registered in the CHEM points and/or in the woods include arthropods in their diets (Beltzer, 1995; Latino and Beltzer, 1999; Alessio *et al.*, 2005; Del Barco and Beltzer, 2005; Beltzer and Quiroga, 2008) and, thus, may be able to act as biological control agents of some agricultural pests. Thus, results suggest that the presence of uncultivated patches of natural or semi-natural environments can favour the ecosystem services provided by birds in agricultural ecosystems.

The environmental heterogeneity produced by the presence of small patches of uncultivated habitats may help to increase the total bird species richness of the area by supporting species that require such environments. In addition, presence of such habitats can also increase the abundance of those species that are more dependent on crop habitats by acting as buffers when crops are being planted or harvested, times during which the environment is deeply modified and less suitable for many birds. This is particularly important as it greatly benefits species conservation within agroecosystems (that take up the highest proportion of territory in the region).

The fact that the protected areas by themselves are not sufficient to guarantee biodiversity conservation emphasises the important role that areas under cultivation can play (Miller, 1996; Lindenmayer *et al.*, 2006). Our data provides evidence that the presence of uncultivated environments can increase the importance of agricultural lands for biodiversity conservation and, at the same time, can benefit agroecosystems by supporting bird species that can function as biological control agents of agricultural pests. In this sense, we consider it important to investigate the minimum percentages of an area to be preserved as uncultivated environment within agroecosystems to ensure high levels of biodiversity, and to manage measures to regulate this activity.

5. ACKNOWLEDGMENTS

We thank Maria Del Carmen Vicari and Santiago Belluzo for allowing us to work on thier property. We are also grateful to Carlos Ignacio Piña and John Blake for their revisions and suggestions to help improve this work. We also thank everyone who helped and accompanied our field activities.

6. REFERENCES

Alessio, V.G., Beltzer, A.H., Lajmanovich, R.C. and Quiroga, M.A. (2005) Ecología alimentaria de algunas especies de Passeriformes (Furnariidae, Tyrannidae, Icteridae y Emberizidae): consideraciones sobre algunos aspectos del nicho ecológico. *INSUGEO Miscelánea*, **14**, 441–482.

Aparicio, K. and Lyons, T. (1998) Las aves definen las áreas protegidas. *Especies*, **1**, 26.

Beltzer, A.H. (1995) Biología alimentaria del Pirincho Guira guira (Aves: Cuculidae) en el valle aluvial del río Paraná medio, Argentina. *Revista de Ecología Latinoamericana*, **2**, 13–18.

Beltzer, A.H. and Quiroga, M. (2008) Alimentación del Cuclillo Canela (*Coccyzus melacoryphus*) en la Isla Carabajal, Santa Fe, Argentina. *Natura Neotropicalis*, **39**, 7–17.

Benton, T.G., Vickery, A.J. and Wilson, J.D. (2003) Farmland biodiversity: is habitat heterogeneity the key? *Trends Ecol. Evol.*, **18**, 182–188.

Bilenca, D. (2000) Los agroecosistemas y la conservación de la biodiversidad: el caso del pastizal pampeano. *Gerencia Ambiental*, **67**, 566.

Boutin, C., Jobin, B., Bélanger, L., Baril, A. and Freemark, K.E. (2001) Hedgerows in the farming landscapes of Canada. In: Barr, C. and Petit, S. (eds), *Hedgerows of the world: their ecological functions in different landscapes*. Proceedings of the Annual IALE (UK), pp. 33–42. Conference held at the University of Birmingham, International Association for Landscape Ecology, UK Region, Lymm.

Clarke, K.R. and Warwick, R.M. (2001) *Change in marine communities: an approach to statistical analysis and interpretation*. Second edition. PRIMER-E Ltd., Plymouth, UK.

Collazo, J.A. and Bonilla-Martinez, G.I. (1988) Comparación de la riqueza de aves entre plantaciones de pino hondureño (*Pinus caribea*) y áreas de bosque nativo en el Bosque Estatal de Carite, Cayey, Puerto Rico. *Caribbean Journal of Science*, **24**, 1–10.

Del Barco, O. and Beltzer, A.H. (2005) Ecología alimentaria del Tordo Músico, *Agelaioides badius* (Aves: Icteridae) en el valle de inundación del río Paraná. *FABICIB*, **9**, 41–46.

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

Fandiño, B. and Giraudo, A.R. (2010) Revisión del inventario de aves de la provincia de Santa Fe, Argentina. *Revista FABICIB*, **14**, 116–137.

Foley, J.A., DeFries, R., Asner, G.P., Barford, C., Bonan, G., Carpenter, S.R., Chapin, F.S., Coe, M.T., Daily, G.C., Gibbs, H.K., Helkowski, J.H., Holloway, T., Howard, E.A., Kucharik, C.J., Monfreda, C., Patz, J.A., Prentice, I.C., Ramankutty, N. and Snyder, P.K. (2005) Global consequences of land use. *Science*, **309**, 570–574.

Gavier-Pizarro, G.I., Calamari, N.C., Thompson, J.J., Canavelli, S.B., Bernardos, J.N. and Zaccagnini, M.E. (2011) Expansion and intensification of row crop agricultural in the Pampas and Espinal of Argentina can reduce ecosystem service provision by changing avian density. *Agr. Ecosyst. Environ.*, **154**, 44–55.

Goijman, A.P. (2005) *Rol de las terrazas como conectores para las aves de bosques entre parches de vegetación natural*. Tesis de Licenciatura, Universidad de Buenos Aires.

Huff, M.H., Bettinger, K.A., Ferguson, H.L., Brown, M.J. and Altman, B. (2000) *A habitat based point-count protocol for terrestrial birds, emphasizing Washington and Oregon*. General technical report PNW-GTR– 501. Forest Service, U.S. Dept. of Agriculture, Pacific Northwest Research Station, Portland.

Jobin, B., Choiniere, L. and Bélanger, L. (2001) Bird use of three types of field margins in relation to intensive agriculture in Québec, Canada. *Agr. Ecosyst. Environ.*, **84**, 131–143.

Jones, G.A. and Sieving, K.E. (2006) Intercropping sunflower in organic vegetables to augment bird predators of arthropods. *Agr. Ecosyst. Environ.*, **117**, 171–177.

Laan, R. and Verboom, B. (1990) Effects of pool size and isolation on amphibian communities. *Biol. Conserv.*, **54**, 251–62.

Latino, S. and Beltzer, A.H. (1999) Ecología trófica del Benteveo *Pitangus sulphuratus* (Aves: Icteridae) en el valle de inundación del río Paraná, Argentina. *Orsis*, **14**, 69–70.

Lindenmayer, D.B., Franklin, J.F. and Fischer, J. (2006) General management principles and a checklist of strategies to guide forest biodiversity conservation. *Biol. Conserv.*, **131**, 433–445.

Marigliano, N.L., Navarro, C.I. and Brandán, Z.J. (2010) Aves asociadas a los bordes de una parcela cultivada con trigo (Burruyacú, Tucumán, Argentina). *Acta Zoológica Lilloana*, **54**, 121–128.

Marshall, E.J.P. and Moonen, A.C. (2002) Fields margins in northern Europe: their functions and interactions with agriculture. *Agr. Ecosyst. Environ.*, **89**, 5–21.

McCune, B. and Mefford, M.J. (1999) *PC-ORD. Multivariate análisis of ecological data*. Versión 4.28. MjM Software Design, Gleneden Beach, OR.

Miller, K.R. (1996) Conserving biodiversity in managed landscapes. In: Szaro, R.C. and Johnson, D. (eds), *Biodiversity in managed landscapes: Theory and practice*, pp. 425-441. Oxford University Press, New York.

Naranjo, L.G. and Chacon-Ulloa, P. (1997) Diversidad de insectos y aves insectívoras de sotobosque en hábitats perturbados de la selva lluviosa tropical. *Caldasia*, **19**, 507–520.

Narosky, T. and Yzurieta, D. (2010) *Guía para la identificación de la Aves de Argentina y Uruguay*. Decimosexta edición. Edición Total. Vázquez Mazzini Editores, B. Aires.

Oksanen, J. (2011) Multivariate analysis of ecological communities in R: vegan tutorial. http://cran.r-project.org [accessed 13 July 2016].

Perfecto, I., Vandermeer, J.H., Bautista, G.L., Nuñez, G.I., Greenberg, R., Bichier, P. and Landgridge, S. (2004) Greater predation in shaded cofee farms: the role of resident neotropical birds. *Ecology*, **85**, 2677–2681.

R Core Team (2015) R: A language and environment for statistical computing. Version 3.2.1. R Foundation for Statistical Computing. Vienna, Austria. http://www.R-project.org/ [accessed 13 July 2016].

Ralph, C., Geupel, G., Pyle, P., Martin, T., De Sante, D. and Mila, B. (1996) *Manual de métodos de campo para el monitoreo de aves terrestres*. General technical report PSW-GTR 159, Pacific Southwest Research Station, US, Forest Services, Departament of Agriculture.

Ramankutty, N., Evan, A.T., Monfreda, C. and Foley, J.A. (2008) Farming the planet. Geographic distribution of global agricultural lands in the year 2000. *Global Biogeochemical Cycles*, **22**, GB1003.

Remsen, J.V., Jr., Areta J.I., Cadena, C.D., Jaramillo, A., Nores, M., Pacheco, J.F., Pérez-Emán, J., Robbins, M.B., Stiles, F.G., Stotz, D.F. and Zimmer, K.J. (2016) A classification of the bird species of South America. American Ornithologists' Union. http://www.museum.lsu.edu/~Remsen/SACCBaseline.html [accessed 13 July 2016].

Robinson, S.K. and Terborgh, J. (1990) Birds communities of the Cocha Cashu Biological Station in Amazonian Perú. In: Gentry, A.H. (ed), *Four Neotropical rainforests*, pp. 199–216. Yale University Press, New Haven.

Rojas, A. and Saluso, J.H. (1987) *Informe climático de la Provincia de Entre Ríos*. Publ. Téc., 14, INTA EEA, Entre Ríos, Paraná, Argentina.

Ronchi-Virgolini, A.L., Lorenzón, R.E., Beltzer, A. and Alonso, J. (2010) Ensambles de aves en el Parque Nacional Pre-Delta (Diamante, Argentina): un análisis de la importancia ornitológica de distintas unidades ambientales. *El Hornero*, **25**, 27–40.

Rosenzweig, M.L. (1995) *Species diversity in space and time*. Cambridge University Press, Cambridge.

Rotenberry, J.T. (1985) The role of habitat in avian community composition: physiognomy or floristic? *Oecologia*, **67**, 213–217.

Solari, M.L. and Zaccagnini, M.E. (2009) Efecto de bordes arboreos y terrezas sobre la riqueza y densidad de aves en lotes de soja de Entre Ríos, Argentina. *BioScriba*, **2**, 90–100.

Stein, A., Gerstner, K. and Kreft, H. (2014) Environmental heterogeneity as a universal driver of species richness across taxa, biomes and spatial scales. *Ecol. Lett.*, **17**, 866–880.

Strong, A.M., Sherry, T.W. and Holmes, R.T. (2000) Bird predation on herbivorous insects: indirect effects on sugar maple saplings. *Oecologia*, **125**, 370–379.

Tscharntke, T., Klein, A.M., Kruess, A., Steffan-Dewenter, I. and Thies, C. (2005) Landscape perspectives on agricultural intensification and biodiversity – ecosystem service management. *Ecol. Lett.*, **8**, 857–874.

Whelan, C.J., Wenny, D.G. and Marquis, R.J. (2008) Ecosystem services provided by birds. *Ann. NY. Acad. Sci.*, **1134**, 25–60.

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

Zaccagnini, M.E., Thompson, J., Bernardos, J., Calamari, N., Goijman, A. and Canavelli, S. (2011) Riqueza, ocupación y roles funcionales potenciales de las aves en relación a los usos de la tierra y productividad de agroecosistemas: un ejemplo en la ecoregión pampeana. In: Laterra, P., Jobbagy, E.G., Paruelo, J.M. (eds), *Valoración de servicios ecosistémicos: Conceptos, herramientas y aportes*. Capítulo 8. pp. 185–207. http://www.agro.uba.ar/users/paruelo/libros/Laterraetal_ValoracionServEcosistemicos.pdf [Accessed 19 september 2016.]