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USE AND IMPORTANCE OF CROP AND FIELD-MARGIN HABITATS FOR BIRDS IN A NEOTROPICAL AGRICULTURAL ECOSYSTEM

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Abstract. The Neotropical Region has experienced large habitat transformations as a result of intensified agriculture. These changes have affected the populations of many species of birds in the Espinal ecoregion of Argentina. However, relationships between birds and agriculture in the neotropics are poorly known. We assessed the effects of crops and field margins in an area of agriculture typical for the Espinal ecoregion on the structure of the bird community, and we assessed the value of this habitat for species of conservation concern. Birds and vegetation were sampled in and along the margins of fields of soybean (the most widespread crop) and alfalfa. Twenty-five of the 41 species recorded—including all the species of conservation concern—were found almost exclusively in field margins; only five species occurred almost exclusively in within the fields. All other species were found in both margins and fields. Density, richness, and diversity were much greater on the margins than in the fields. Bird density in soy fields was lower than in alfalfa. Bird richness and diversity in the two crops, however, did not differ. Density in field margins increased with the cover and height of trees and shrubs. Most of the field-margin species were woodland-border species, but the species of conservation concern were all associated with grassy field margins. Because further declines in the populations of these threatened species are expected, their conservation in agricultural areas would benefit from a broad policy of habitat-conservation plans for field margins such as those practiced in North America and Europe.

Key words: alfalfa, bird abundance, bird richness, farmland birds, grasslands, South American agriculture, soybean.

Uso e Importancia de los Cultivos y Hábitats de Borde en un Agroecosistema Neotropical

Resumen. En la región neotropical están ocurriendo grandes transformaciones de hábitat debido a la producción de cultivos y ganado. Sin embargo se conoce muy poco sobre las relaciones entre la avifauna neotropical y la agricultura. Estudiamos el efecto de los cultivos y sus bordes, de un agroecosistema típico de la ecorregión del Espinal en Argentina, sobre la estructura de la comunidad de aves a escala local y sobre el valor para las especies amenazadas de la región. Las aves y la vegetación fueron muestreadas en cultivos de soja (el cultivo más ampliamente distribuido) y alfalfa, y sus bordes asociados. La densidad, riqueza y diversidad de aves fueron comparadas utilizando ANOVA de dos factores y se realizó un PCA para resumir la información sobre la estructura de la vegetación de los bordes de cultivos. Veinticinco especies, sobre un total de 41, fueron registradas casi exclusivamente en los bordes, y cinco en cultivos. La densidad, riqueza y diversidad fueron mucho mayores en bordes que dentro de cultivos. Los campos con soja tuvieron menor densidad de aves que los de alfalfa, sin embargo no se encontraron evidencias que el tipo de cultivo influya sobre la densidad de aves de los bordes del mismo. La riqueza y la diversidad no presentaron diferencias entre cultivos. La densidad de aves en los bordes aumentó con la cobertura y la altura de los árboles y arbustos. La mayor densidad, riqueza y diversidad de aves encontrada en los bordes en comparación con los cultivos se debió principalmente a diferencias en la estructura de la vegetación. Las especies amenazadas estaban asociadas a los bordes de cultivos con pastos. La conservación de aves amenazadas de pastizales se beneficiaría con el establecimiento de planes de conservación de hábitat de borde de cultivo tal como ocurre en otros continentes.

INTRODUCTION

Intensification of agricultural practices can affect populations of wild animals and plants in farmlands negatively (McLaughlin and Mineau 1995, Robinson and Sutherland 2002). In the USA, for example, 75% of species of grassland bird have experienced large population declines over the past 30 years as a consequence of significant changes in land use (Askins 1993, 2007, Herkert 1995). In Europe, 70% of grassland and steppe species have also experienced substantial declines associated with rapid changes in agricultural practices (Donald et al. 2001, 2006). Agriculture has also had negative effects on the grassland avifauna of other continents (see Gourip 1988).

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In Argentina, grasslands and savannas are the ecosystems most affected because they have been profoundly transformed by crop and cattle production (Soriano et al. 1992, Krapovickas and Di Giacomo 1998). Soy has become the main crop in Argentina, increasing from 3% in the early 1970s to nearly 40% in 2005, covering 15 million ha of the Pampas and Espinal ecoregions (Paruelo et al. 2005). At present, less than 25% of these original grassland ecosystems remains uncultivated (Viglizzo et al. 2001), and the network of protected grasslands in Argentina covers less than 1% (Krapovickas and Di Giacomo 1998). Moreover, traditional livestock grazing has diminished with the transformation to more intensive agriculture (Oesterheld 2008).

Modern, more intensive agriculture is associated with regional population declines of the Argentine avifauna. Over the past 100 years, the distributions of a number of endemic grassland species, including the Strange-tailed Tyrant (*Alectrurus risora*; Di Giacomo and Di Giacomo 2004), Saffron-cowled Blackbird (*Xanthopsar flavus*; Fraga et al. 1998), Black-and-white Monjita (*Heteroxolmis dominicana*; Fraga 2003), and Pampas Meadowlark (*Sturnella defillippi*; Tubaro and Gabelli 1999) have contracted substantially, and the the Eskimo Curlew (*Numenius borealis*) has gone extinct (Roberts et al. 2009). Other species, including the Buff-breasted Sandpiper (*Tringytes subruficollis*; Lanctot et al. 2002), Ruddy-headed Goose (*Chloephaga rubidiceps*; Blanco et al. 2003), and several *Sporophila* seedeaters (Silva 1999) are now rare and local. Also, inappropriate use of organophosphate pesticides has caused widespread mortality of raptors in Espinal savannas and Pampas grasslands (Woodbridge et al. 1995, Goldstein et al. 1996). The Yellow Cardinal (*Gubernatrix cristata*) formerly occurred throughout the Espinal and Chaco savannas, but it is now endangered (Birdlife International 2004), and its populations are fragmented.

In agricultural areas, some types of habitat patches, such as field margins, streams, and railway lines, are important for the survival of many birds that require herbaceous plants, bushes, and trees for nesting and shelter (Dodds et al. 1995, Warner 1994). In the USA, Best et al. (1990) found that the composition of the avifauna present in croplands is influenced by the characteristics of field margins, and Camp and Best (1994) found the density of nesting birds to be higher on the margins of fields of crops. In England, similar studies of the effects of hedgerows found that the richness and density of associated birds increased with the presence of trees (Green et al. 1994, Parish et al. 1994, 1995, MacDonald and Johnson 1995, Hinsley and Bellamy 2000). However, woody edges can also have adverse effects on some woodland birds, for example, when they operate as ecological traps for birds that nest in trees by supporting, on the edge, predation or parasitism rates greater than in continuous woodlands (Gates and Gysel 1978). Grassland birds experience other negative effects near woody edges in fragmented grasslands. For example, in the midwestern USA, besides the subsequent reductions in the size of patches of grasslands, negatively affecting grassland birds' abundance, nesting success, and population viability (Winter and Faaborg 1999, Fletcher and Koford 2003, Herkert et al. 2003), proximity to woody edges can increase nest predation and brood parasitism of grassland birds (Bergin et al. 2000, Bollinger and Gavin 2004, Fletcher 2005, Patten et al 2006, Pietz et al. 2009).

In an extensively agricultural landscape, such as the grasslands and savannas of Argentina, the composition of the mosaic, based on the proportions of elements present (crops, pastures, wetlands and vegetation along the field margins), should influence the composition of the avian community strongly (see Bennett et al. 2006). Smith et al. (2008) indicated three key ecological functions of field margins in agricultural landscapes: to increase species density (biodiversity value), to provide habitats for rare or endangered species (conservation value), and to enhance ecosystem services, such as pest control and decomposition (functional value). The objective of our study is to assess the effect of field margins in a typical agro-ecosystem in Argentina on the structure of the bird community on a local scale, i.e., biodiversity value, and the importance of this habitat for bird conservation, i.e., conservation value. Specifically, we asked the following questions: (1) are the species using field margins different from those using the associated crops? (2) Are the densities, species richness, and diversity of birds higher in field margins than in the associated crops? (3) Which type of field margin maximizes density, richness, and diversity of birds? (4) Do field margins function as refuges for species of conservation importance?

METHODS

STUDY AREA

The study was carried out near San Francisco (31° 30′ S, 62° 05′ W), northeastern Córdoba province, Argentina. The current landscape consists of plains occupied by crops and pastures, >80% of the region being covered with soybean (*Glycine max*) and alfalfa (*Medicago sativa*). Along secondary roads the margins of fields of crops and pastures support other types of vegetation, including trees, shrubs, and grasses, of both native and exotic species. This landscape was originally covered by grasslands, alternating with patches of xerophytic woods, known as Espinal savanna (Lewis and Collantes 1974).

BIRD SAMPLING

We selected 12 fields of soybean (sown on stubble of wheat) and 12 fields of alfalfa, each 15 ha or larger, with roads on two sides of the fields. Bird were counted out along linear transects of fixed width (Bibby et al. 1992) within each field and along the associated field margins in January 2000. To ensure the independence of each count, we selected fields separated by a minimum distance of 500 m (Ralph et al. 1993).

Within the crop, each transect was 200 m long and 100 m wide and at a minimum distance of 100 m from the edge of the crop. All birds within the transect were recorded, but distances from the observer were not taken into consideration because estimates assuming maximum detectability in a fixed-distance band of 50 m on either side from observer in open habitats did not differ from estimates generated by distance sampling (Rotella et al 1999). Birds observed in flight were not counted.

Fields of crops were separated from other fields by secondary roads or fences. Each 200-m transect along a field margin was parallel to the edge of the crop along a secondary road and was marked with paint on fence posts. In each case, the width of the band under observation was equivalent to the width of the field margin (≤10 m). Distances from the observer were not taken into consideration, as we assumed that all birds within the field-margin transect were recorded on account of the short distances from the observer.

The bird counts took place in the morning, under similar weather conditions, toward the end of the breeding season (according to de la Peña 1987). Counts were repeated four to six times, and the average of the counts from each field was used for the analysis. On the basis of previous field work in the area (breeding seasons 1996–97, 1997–98) we assumed bird counts were representative of the community of birds breeding in the area.

CROP CHARACTERISTICS

To characterize crop structure, we selected for sampling five points along each transect within each soybean field. We randomly selected five plants and measured their height and diameter. We calculated the weed cover of each field by the "central quadrat" method (Matteucci and Colma 1982), and we also measured the distance between plants. We calculated the average of all data so so as to find one mean value per field for each variable.

In alfalfa fields, we randomly placed five 1-m^2 plots within each field and used a wooden rod marked at 10-cm intervals to measure height and cover of alfalfa, *Carduus acanthoides*, and other common plants of the families Asteraceae and Poaceae, and also bare ground cover. In all cases we calculated the averages for each field.

Landowners provided data on hectares cultivated, age of each crop, and the number of applications of pesticides and herbicides during the growing season. For alfalfa, we were informed before the study about the number of days after drilling and the number of cuttings,.

FIELD MARGINS

We place five small transects in each field margin perpendicular to the bird-sampling transects. Each of these transects was as long as the field margin, and along each we measured 17 variables: width of the vegetation in the field margin, height and cover of the herbaceous layer (grasses and other herbaceous plants), height and cover of the middle or shrub layer and of the high stratum or tree layer (trees with a diameter of more than 10 cm at breast height), the height and cover of the main species in each transect, presence/absence of plants with flowers or fruits, and the species richness of plants with seeds and fruits. We measured plants' maximum height with a rod marked at 10-cm intervals. Measurements of cover were calculated as the width of the border or field margin that was covered by vegetation. In all cases we calculated averages for each perpendicular transect. Additionally, we counted the number of native and exotic trees and shrubs along 200 m of each field margin. We considered a tree layer to be present in a field margin when there were 10 trees or more along a bird-sampling transect.

DATA ANALYSIS

We considered each crop-field transect and each field-margin transect as a unit of sampling. We calculated the mean density per hectare of each species of bird in every sampling unit. The area sampled in the crop transects was 2 ha (200 × 100 m). We calculated the area sampled in the field margins as the mean width of the field margin multiplied by the length of the transect (200 m). We identified and recorded all individuals so we could compare densities in both types of habitat (crop and field margin).

We estimated diversity with the Shannon–Wiener index (Rosenzweig 1995) because rare species exert a greater influence on the estimation of diversity, making it is more useful for considering species of conservation concern. We compared the total density, richness, and diversity (H', Shannon–Wiener index) of birds in the various types of habitat by a two-factor analysis of variance (Zar 1996). The factors considered were habitat type (with two levels, crop and field margin) and type of crop (with two levels, soybean and alfalfa). Because the original data showed proportionality among the means and the standard deviations, we transformed them logarithmically in order to normalize the distribution and obtain homogeneity of variance (Zar 1996). In cases where we found no significant interaction, we considered the principal effects of the treatments. When the interaction was significant, we analyzed it by a test of simple effects (Snedecor and Cochran 1967).

As many of the measurements of habitat characteristics were correlated (Wiens 1989), we used principal-component analysis to obtain a group of new, unrelated variables (principal components) that summarize the basic information on vegetation structure and composition at field margins. The matrix of original data (17 × 24) consisted of the values of 17 variables of structure and composition for the 24 field margins we studied. We used a correlation matrix and applied a normalized varimax rotation to maximize the correlation between each component and the raw variables. We then correlated the values of the scores of the principal components for each sampling unit with the density of each species, total bird density, and species richness in the corresponding unit.

RESULTS

CHARACTERIZATION OF THE CROP TYPES

The soybean fields were similar in date planted (age) and management (insecticide and herbicide application) (Table 1). The alfalfa fields were less homogenous because alfalfa is a perennial that is cut periodically, and the dates on which various fields in the same area are planted differ (Table 1).

SPECIES COMPOSITION OF BIRDS IN CROPS AND FIELD MARGINS

We recorded a total of 41 species during the bird counts in the crop fields and field margins. We categorized each species as a crop specialist, field-margin specialist, generalist, or ubiquitous according to its pattern of use of the habitat types (Table 2).

Although we recorded a total of 26 species in soybean and alfalfa fields, only five occurred principally in crop fields (i.e., they were absent or recorded only once in field margins). The Southern Lapwing and White-browed Blackbird occurred more densely and frequently in alfalfa (see Table 2 for scientific names).

We recorded a total of 37 species in the field margins, 25 of which occurred almost exclusively in the margins. The Picui Ground-Dove and Picazuro Pigeon were recorded only in field margins, whereas the Eared Dove was also recorded in crops. The Campo Flicker and Green-barred Woodpecker, together with two species of Cuculidae, the Dark-billed and Striped Cuckoos, and the Glittering-bellied Emerald were recorded exclusively in field margins. Most species of Passeriformes that were only recorded in field margins belonged to the families Furnariidae and Tyrannidae. Four species of the family Emberizidae, the Grassland Sparrow, Rufous-collared Sparrow, Saffron Finch, and Double-collared Seedeater, were frequent in all habitats, although they were all much more abundant in field margins than in crops. We recorded the seven remaining species in different habitats but in low densities and frequencies, so we were unable to establish their habitat preferences (Table 2).

Most of the species recorded (75%, Table 2) in the field margins are largely insectivorous, whereas most of the crop species are omnivorous (60%, Table 2). The nest substrates of birds using field margins and crops differed; 92% of the field-margin species nest in trees, whereas all crop species nest on the ground (Table 2). The ubiquitous species are mostly granivores and ground nesters (Table 2).

We recorded four species of conservation concern according to the criteria of Fraga (1997) and BirdLife International (2004): the Dark-throated Seedeater, Bearded Tachuri, Dinelli's Doradito and Upland Sandpiper. We recorded the first two of these seldom and in low densities, so it was difficult to assign them to a preferred habitat, but they are obligate grassland birds (Vickery et al. 1999). Dinelli's Doradito was more abundant in field margins and, not surprisingly, the Upland

TABLE 1. Characteristics of fields of soybean (n = 12) and alfalfa (n = 12) in which birds were recorded near San Francisco, Córdoba, Argentina.

	Mean ± SE	Min	Max
Soybean			
Area (ha)	28.1 ± 1.3	15	30
Age of crop (days)	52.7 ± 0.9	48	55
Herbicide applications (number)	1.3 ± 0.1	1	2
Pesticide applications (number)	0.3 ± 0.1	0	1
Height of soybean plants (cm)	45.3 ± 5.0	25.6	69.8
Diameter covered by soybean plants (cm)	35.7 ± 3.1	22.6	53.6
Distance between rows (cm)	55.0 ± 1.5	50.0	60.0
Weed density (ha^{-1})	350.3 ± 87.7	0	801.9
Alfalfa			
Area (ha)	16.0 ± 1.1	10	25
Age of pasture (months)	15.8 ± 1.9	9	22
Cover of alfalfa (%)	48.3 ± 7.0	5	80
Height of alfalfa (cm)	32.5 ± 4.9	5	54
Cover of *Carduus acanthoides* (%)	10.7 ± 1.2	9	13
Height of *Carduus acanthoides* (cm)	70.0 ± 10.0	50	90
Cover of Asteraceae (%)	33.4 ± 9.3	7	55
Height of Asteraceae (cm)	50.0 ± 10.0	30	100
Cover of Poaceae (%)	18.8 ± 4.8	12	31
Height of Poaceae (cm)	30.0 ± 10.0	10	90
Bare ground (%)	30.5 ± 4.1	8	57
Alfalfa cuts (number)	1.5 ± 0.5	0	6
Herbicide applications (number)	0.2 ± 0.1	0	1
Pesticide applications (number)	0.5 ± 0.4	0	4

TABLE 2. Birds recorded in fields and margins of alfalfa and soybean near San Francisco, Córdoba, Argentina, with food habits, nest site, mean (± SE) density (ha^{-1}) in each habitat, and frequency (percentage of the total censuses, in parentheses). Information on feeding and nesting from del Hoyo et al. (1992) and de la Peña (1987).

		Alfalfa		Soybean	
Category and species	Food, nest[a]	Field margin	Crop	Field margin	Crop
Crop species					
Spotted Nothura *Nothura maculosa*	O, Gd		0.17 ± 0.07 (42)		0.06 ± 0.03 (25)
Southern Lapwing *Vanellus chilensis*	I, Gd		0.88 ± 0.33 (42)		0.05 ± 0.03 (17)
Upland Sandpiper *Bartramia longicauda*	I, Nb		0.13 ± 0.06 (33)	0.21 ± 0.21(8)	0.06 ± 0.03 (25)
White-faced Whistling-Duck *Dendrocygna viduata*	O, Gd				0.90 ± 0.83 (17)
White-browed Blackbird *Leistes superciliaris*	O, Gd	0.53 ± 0.53 (8)	1.46 ± 0.66 (67)		0.15 ± 0.11 (17)
Field-margin species					
Picazuro Pigeon *Columba picazuro*	G, Tr			0.21 ± 0.21 (8)	
Picui Dove *Columbina picui*	G, Tr	3.73 ± 2.66 (25)		1.44 ± 0.76 (25)	
Eared Dove *Zenaida auriculata*	G, Tr	3.81 ± 1.30 (50)	0.13 ± 0.13 (8)	10.83 ± 3.82 (50)	0.03 ± 0.03 (8)
Dark-billed Cuckoo *Coccyzus melacoryphus*	I, Tr	0.45 ± 0.45 (8)			
Guira Cuckoo *Guira guira*	I, Tr	0.91 ± 0.91 (8)	0.02 ± 0.02 (8)	1.78 ± 1.05 (25)	
Striped Cuckoo *Tapera naevia*	I, Tr	0.45 ± 045 (8)			
Glittering-bellied Emerald *Chlorostilbon aureoventris*	I, Tr	0.45 ± 0.45 (8)			
Campo Flicker *Colaptes campestris*	I, Tr	1.61 ± 1.08 (17)			
Green-barred Woodpecker *Colaptes melanochloros*	I, Tr	0.40 ± 0.40 (8)			
Rufous Hornero *Furnarius rufus*	I, Tr	2.49 ± 1.10 (42)	0.04 ± 0.04 (8)	4.53 ± 1.59 (58)	
Firewood-gatherer *Anumbius annumbi*	I, Tr	2.62 ± 1.15 (42)		4.28 ± 2.70 (50)	0.06 ± 0.04 (17)
Chotoy Spinetail *Schoeniophylax phryganophilus*	I, Tr	3.20 ± 1.18 (42)		6.04 ± 2.31 (58)	0.06 ± 0.06 (8)
Pale-breasted Spinetail *Synallaxis albescens*	I, Tr	3.62 ± 1.34 (50)	0.04 ± 0.04 (8)	2.18 ± 1.02 (33)	
Freckle-breasted Thornbird *Phacellodomus striaticollis*	I, Tr	0.27 ± 0.27 (8)	0.02 ± 0.02 (8)	2.09 ± 1.01 (33)	0.01 ± 0.01 (8)
Cattle Tyrant *Machetornis rixosa*	I, Tr	0.69 ± 0.69 (8)		2.08 ± 1.03 (33)	
Great Kiskadee *Pitangus sulphuratus*	I, Tr	2.19 ± 1.52 (25)	0.06 ± 0.06 (8)	1.87 ± 1.41 (17)	
Fork-tailed Flycatcher *Tyrannus savana*	I, Tr	4.06 ± 1.87 (33)		4.31 ± 1.83 (42)	
Dinelli's Doradito *Pseudocolopteryx dinelliana*	I, Sh	0.23 ± 0.23 (8)	0.02 ± 0.02 (8)	0.51 ± 0.35 (17)	
House Wren *Troglodytes aedon*	I, Tr	9.95 ± 2.60 (75)	0.04 ± 0.04 (8)	7.46 ± 1.19 (92)	0.04 ± 0.04 (8)
Chalk-browed Mockingbird *Mimus saturninus*	I, Tr	0.28 ± 0.28 (8)		0.21 ± 0.21 (8)	
House Sparrow *Passer domesticus*	O, Tr	0.92 ± 0.92 (8)		5.31 ± 3.76 (25)	
Masked Yellowthroat *Geothlypis aequinoctialis*	I, Sh	0.45 ± 0.45 (8)			
Saffron Finch *Sicalis flaveola*	G, Tr	0.43 ± 0.43 (8)			
Bay-winged Cowbird *Molothrus badius*	O, Tr	0.91 ± 0.91 (8)			
Shiny Cowbird *Molothrus bonariensis*	O, Gd	6.72 ± 3.43 (33)	0.15 ± 0.15 (8)	3.05 ± 1.61 (25)	
Ubiquitous species					
Grassland Sparrow *Ammodramus humeralis*	G, Gd	9.21 ± 2.31 (75)	0.56 ± 0.16 (67)	7.27 ± 2.97 (50)	0.08 ± 0.05 (25)
Rufous-collared Sparrow *Zonotrichia capensis*	O, Gd	5.93 ± 1.37 (83)	0.17 ± 0.07 (42)	8.55 ± 2.15 (75)	0.10 ± 0.07 (17)
Grassland Yellow-Finch *Sicalis luteola*	G, Gd	0.22 ± 0.22 (8)	0.06 ± 0.04 (17)	1.86 ± 1.18 (25)	0.09 ± 0.05 (25)
Double-collared Seedeater *Sporophila caerulescens*	G, Sh	22.63 ± 4.01 (100)	0.21 ± 0.10 (33)	11.96 ± 3.41 (67)	0.17 ± 0.12 (25)
Other species					
Snail Kite *Rostrhamus sociabilis*	I, Re			0.21 ± 0.21 (8)	
Chimango Caracara *Milvago chimango*	S, Tr	0.28 ± 0.28 (8)	0.02 ± 0.02 (8)		0.02 ± 0.02 (8)
Burrowing Owl *Athene cunicularia*	I-C, Gd	0.35 ± 0.35 (8)	0.04 ± 0.04 (8)	0.40 ± 0.40 (8)	
Bearded Tachuri *Polystictus pectoralis*	I, Sh	0.81 ± 0.81 (8)	0.06 ± 0.04 (17)	0.15 ± 0.15 (8)	
Spectacled Tyrant *Hymenops perspicillata*	I, Sh		0.02 ± 0.02 (8)		
Pipit *Anthus* sp.	I, Gd	1.22 ± 1.22 (8)	0.04 ± 0.04 (8)		0.08 ± 0.08 (8)
Dark-throated Seedeater *Sporophila ruficollis*	G, Sh	0.81 ± 0.81 (8)	0.06 ± 0.06 (8)	0.21 ± 0.21 (8)	

[a] O, omnivore; I, insectivore; G, granivore; S, scavenger; C, carnivore; Gd, ground; Nb, nonbreeding; Tr, trees; Sh, shrubs.

Sandpiper was more abundant in fields. The first three species had nests in some of the field margins. These three passerines are austral migrants, present in Córdoba only during the breeding season, whereas the Upland Sandpiper is a nonbreeding migrant from North America (Nores et al. 1983).

BIRD DENSITY, RICHNESS, AND DIVERSITY IN CROPS AND FIELD MARGINS

There was an interaction between habitat and crop ($F_{1,44}$ = 6.44, P = 0.015). The simple effects showed that (1) density in field margins was much greater than in crops (alfalfa: $F_{1,44}$ = 198.38, P < 0.001; soybean: $F_{1,44}$ = 312.38, P < 0.001), (2) density in soybean fields was lower than in alfalfa fields ($F_{1,44}$ = 13.77, P < 0.001), and (3) density in margins of fields of the two crops did not differ ($F_{1,44}$ = 0.01, P = 0.901) (Fig. 1A). Species richness was greater in field margins than in crops ($F_{1,44}$ = 32.36, P < 0.001; Fig. 1B). We found no differences between the types of crop, and there was no interaction between both factors. Bird diversity was also greater in field margins than in crops ($F_{1,44}$ = 36.58, P < 0.001; Fig. 1C). We found no differences between the types of crop, and the interaction between both factors did not show any differences.

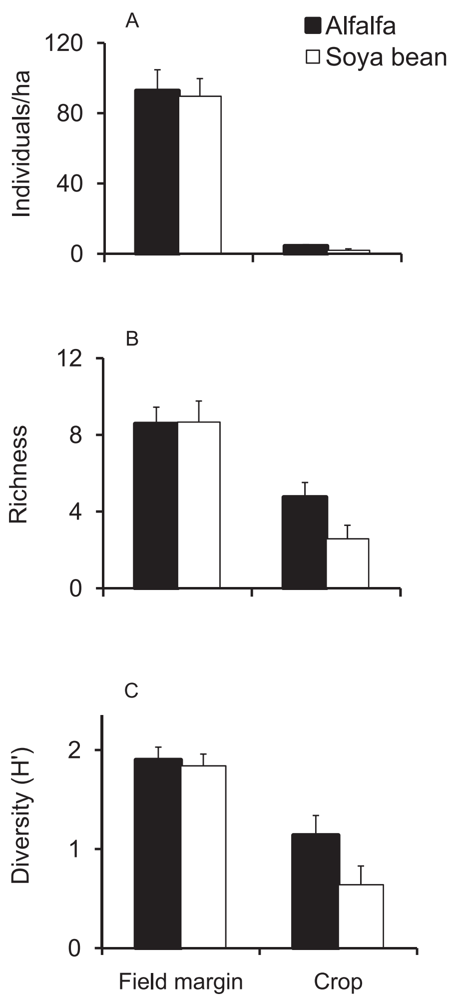

FIGURE 1. Mean (± SE) of (a) density, (b) species richness, and (c) species diversity of birds in fields and margins of alfalfa and soybean near San Francisco, Córdoba, Argentina.

EFFECT OF THE STRUCTURE AND COMPOSITION OF VEGETATION AT FIELD MARGINS

Two principal components explained 50% of the variance in the matrix of original data (Table 3). The first principal component (PC1) was positively correlated with the presence of the tree and shrub strata, as these variables provided the greatest loading. The second principal component (PC2) was positively related with cover and height of Johnson grass (*Sorghum halepense*), a dominant grass in the low stratum.

Total bird density in field margins increased with an increase in the presence, cover, and height of the tree layer, represented by PC1 (Fig. 2). In the two principal components, the scores of each field margin were correlated with the density of the species present in four or more counts. We explored associations of these species with habitat where correlations

TABLE 3. Variables of vegetation structure and composition measured on field margins near San Francisco, Córdoba, Argentina, and loadings with the first two principal components (PC) extracted by a principal-components analysis, with the percentage of variance explained.

Variable	PC1	PC2
Mean width of the field-margin vegetation from fence to road	0.199	0.063
Mean height of the herbaceous layer	0.022	0.616
Mean height of the middle stratum or shrub layer	0.292	0.161
Mean height of the high stratum or tree layer	0.786	−0.366
Mean cover of the herbaceous layer	0.205	0.069
Mean cover of the middle stratum or shrub layer	0.031	0.062
Mean cover of the high stratum or tree layer	0.863	−0.261
Number of trees with a diameter <10 cm at breast height	0.914	−0.016
Number of *Melia azedarach* shrubs with trunk <10 cm	0.956	−0.047
Mean height of *Artemisia annua* plants	−0.435	0.242
Mean height of *Sorghum halepense* plants	0.011	0.897
Mean height of *Melia azedarach* plants	0.712	0.017
Cover of *Artemisia annua*	−0.317	−0.175
Cover of *Sorghum halepense*	−0.129	0.896
Cover of *Melia azedarach*	0.844	0.171
Species richness of flowering plants	0.473	−0.137
Species richness of plants with seeds and fruits	0.157	−0.513
Percentage variance explained	31.5	18.5
Percentage variance accumulated	31.5	50.0

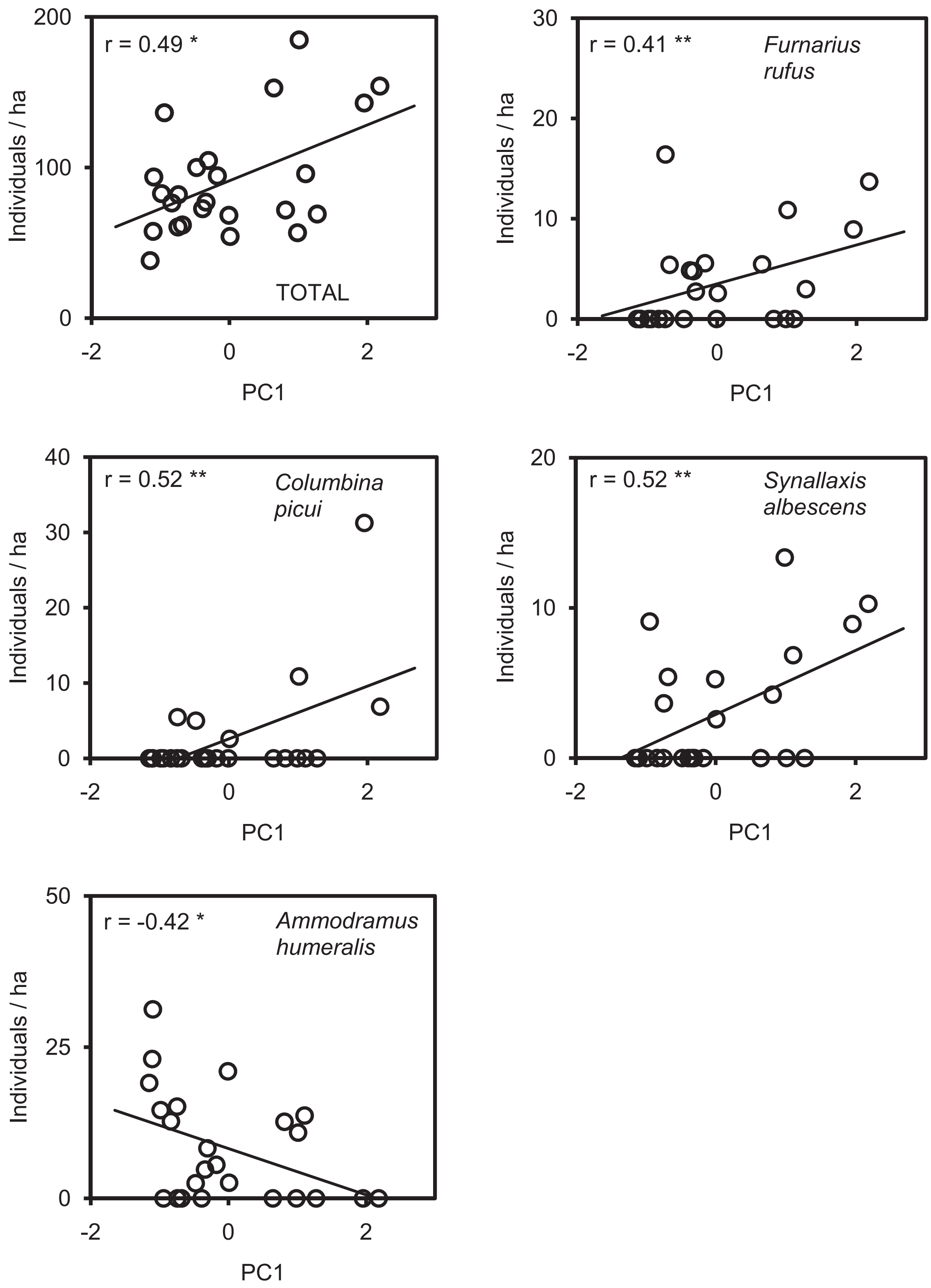

FIGURE 2. Correlation between bird density (ha^{-1}) in each field margin studied near San Francisco, Córdoba, Argentina, and its score in the first principal component (PC1) representing the height, cover, and abundance of trees and shrubs. In each case the value for the correlation coefficient and its significance are shown (*$P < 0.05$; **$P < 0.01$). Total: total bird density.

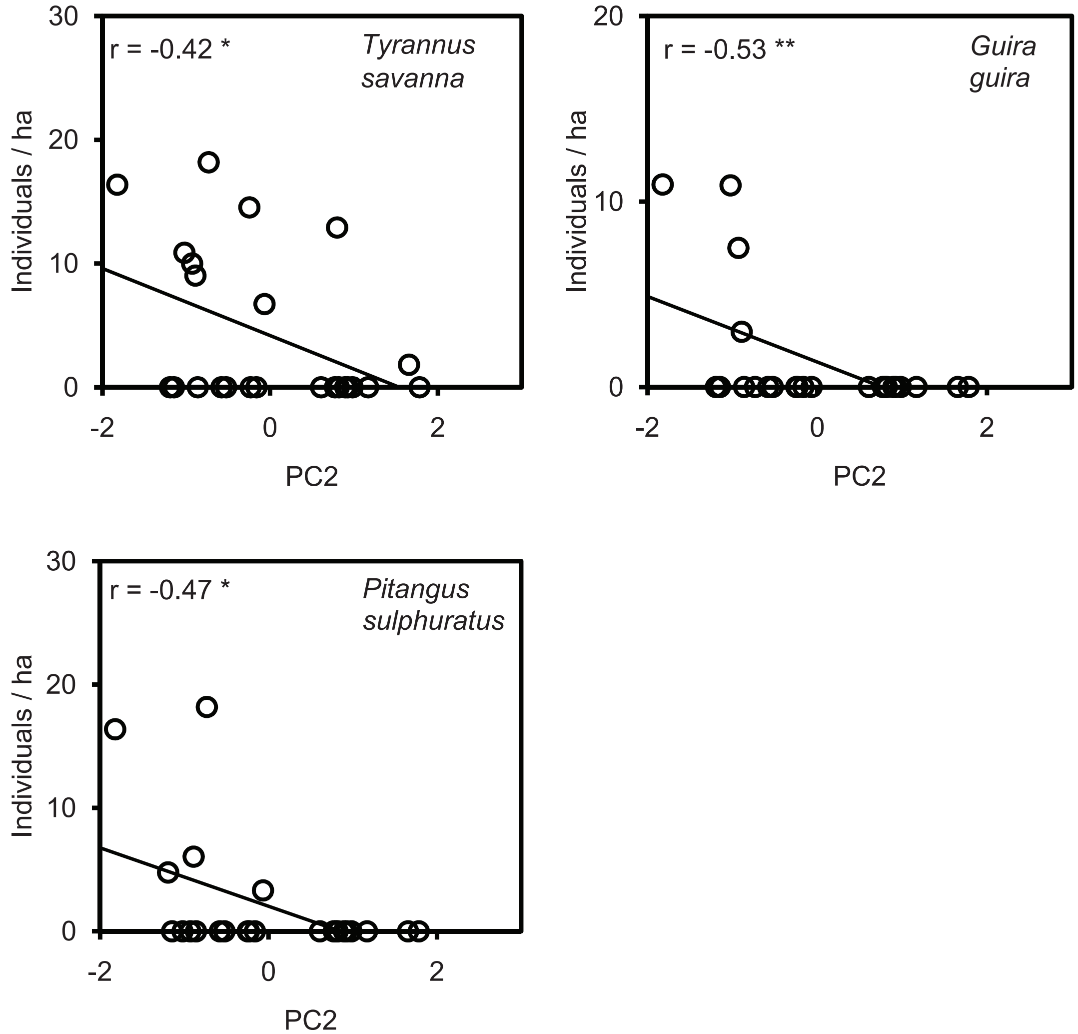

FIGURE 3. Correlation between bird density (ha^{-1}) in each field margin studied near San Francisco, Córdoba, Argentina, and its score in the second principal component (PC2) representing the height and cover of *Sorghum halepense*. In each case the value for the correlation coefficient and its significance are shown (*$P < 0.05$; **$P < 0.01$).

were significant. The Rufous Hornero, Pale-breasted Spinetail, and Picui Dove were positively associated with cover and presence of the high stratum (PC1), whereas the Grassland Finch was associated with a reduced high stratum (Fig. 2). The Guira Cuckoo, Fork-tailed Flycatcher, and Great Kiskadee decreased in density as cover and height of the Johnson grass increased (PC2; Fig. 3).

DISCUSSION

BIRD SPECIES COMPOSITION IN CROPS AND FIELD MARGINS

In the area we studied, the bird assemblages in field margins differed from those in crop fields, and we think this difference is related to the birds' requirements for feeding and nesting. In the USA, Best et al. (1990) found that the majority of birds that use maize crops are omnivorous ground feeders during the reproductive season, whereas species restricted to field margins are mainly insectivorous and all of them forage and nest in trees and bushes. In England, insectivorous birds and those nesting in trees and shrubs are more abundant in hedgerows (MacDonald and Johnson 1995, Sparks et al. 1996).

In our area, the habitat generalists (Grassland Sparrow, Rufous-collared Sparrow, Saffron Finch, and Double-collared Seedeater) feed primarily on seeds and nest near the ground, using both crop and field margin habitats, although we found their densities to be higher in field margins. According to Stotz et al. (1996) and Sick (1985), these four species are associated with human-disturbed habitats.

The species we recorded in field margins are common in woodlands of central Argentina (Narosky and Yzurieta 1985). In Argentina, there are no previous studies of birds in agro-ecosystems or woodland margins. Bucher et al. (2001) and Dardanelli et al. (2006), however, studied fragments of woodland in an agricultural landscape near our study site. According to Dardanelli et al. (2006), 6 species we found in field margins would be classified as typical woodland species, 8 as woodland-margin species, and 10 as generalists. Bucher et al. (2001) reported an association between habitat preference and the size of woodland fragment. By their criteria, 16 species we encountered would be classified as capable of living in fragments of 1.5 ha, 7 species as capable of living in fragments from 14 to 80 ha, We recorded no species requiring fragments larger than 80 ha. Such data indicate that most of the field-margin species in our study area were widespread or border species in the original woodlands. Our findings are consistent with studies in England and the USA in that birds that live in field margins in Argentina typically occur along woodland borders (Knopf 1994, Forman, 1995).

BIRD DENSITY, RICHNESS, AND DIVERSITY IN CROPS AND FIELD MARGINS

Birds occurred more densely in alfalfa than in soybean fields. Alfalfa, which is periodically grazed or cut for hay or silage, has a more heterogeneous vegetation structure than does soybean. We observed breeding behavior of the Southern Lapwing, White-browed Blackbird, and Double-collared Seedeater in alfalfa fields. In a study of alfalfa fields, Frawley and Best (1991) found that cutting alfalfa reduces the density and richness of species that attempt to nest in those fields. We did not consider the effects of differences in structure between different fields of alfalfa, but these differences should be addressed in the future.

We observed very few birds perching on soybean plants but often saw birds perching on the occasional weed that emerged from the crop, or on patches of ground where the crop was uneven. We did not observe active nests or reproductive behavior in soy fields. Vickery et al (2003) found that grassland birds avoid agricultural fields of soybean and alfalfa in Córdoba province, and there are no other studies on breeding birds' use of soybeans that could serve as a comparison for our data. Azpiroz and Blake (2009) suggested that several species of grassland birds are absent from barley fields because they provide limited opportunities for ground-nesting birds negatively affected by cultivation.

The greater density, species richness, and diversity of birds found in field margins as compared to crops is due mainly to the great differences in vegetation structure, as reported in similar studies (Best 1983, Jobin et al. 2000). Interestingly, we found that the density of birds in field margins was not significantly influenced by the adjacent crop, even though bird density was greater in alfalfa fields than in soybean fields. Studies elsewhere have found that field margins surrounded by pastures had more bird species and greater bird abundance than similar margins of grain crops (Parish et al. 1995, Sparks et al. 1996, Fuller et al. 1997).

The high density and height of vegetation in the tree and shrub layer in field margins were associated with a greater total density of birds. This result is similar to observations in English hedgerows (Green et al. 1994, MacDonald and Johnson 1995) and Canadian field margins (Jobin et al. 2000), where the total density of birds present in hedgerows and field margins is positively correlated with the height of the vegetation, the number of trees, and general heterogeneity in the plants' structure. Although we did not discern an association of the components with richness, Parish et al. (1994, 1995) found that richness of birds is positively correlated with the quantity and height of trees.

IMPORTANCE OF FIELD MARGINS IN AGRICULTURAL AREAS OF ARGENTINA

Our study suggests that in areas of soybean and alfalfa production in Argentina, field margins are very important for maintaining the density of birds. Also, three species of conservation importance were associated with margins of alfalfa fields, although we could not determine the degree of association because of the low number of birds observed. However, these three species were found nesting during this study, and adults were seen taking food to their nestlings and engaging in territorial behavior.

The expansion of agriculture in this region will further reduce the number and area of patches with natural vegetation. Likewise, intensification of agriculture will reduce the area of field-margin habitats. As a result of this study, we conclude that this increased agricultural activity will decrease the abundance and diversity of birds, having an especially negative effect on species of conservation concern. This study and evidence from other regions of Argentina demonstrate that bird conservation would benefit from instigation of a habitat-conservation plan for field margins in areas where soybean production is increasing. Conservation could be achieved through economic incentives for the protection of spontaneous vegetation on field margins, as is done in Europe, by promoting management that favors the protection of plants of greater interest, or by minimizing mechanical and chemical control of vegetation along borders, which would favor the maintenance of environmental services in these landscapes (see Smallshire et al. 2004, Vickery et al. 2004). In addition, maintaining and improving the connectivity of field-margin habitat would provide corridors that could function to facilitate the reintroduction or maintenance of biodiversity in agro-ecosystems on the landscape scale (Altieri 1999, Donald and Evans 2006).

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