

Landscape associations of globally threatened grassland birds in the Aguapey river Important Bird Area, Corrientes, Argentina

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Summary

The Aguapey river basin in the Pampas grasslands of Argentina is the last refuge for a complete assemblage of globally threatened and Near Threatened birds. We evaluated the influence of landscape characteristics on the occurrence and abundance of six globally threatened and Near Threatened passerines. We used point counts to census birds and vegetation and quantified landscape characteristics 1,000 m from the count centres using remote sensing tools. Strange-tailed Tyrants *Alectrurus risora* were associated with higher percentages of tall-grass *Andropogon lateralis* in lowland areas. Saffron-cowled Blackbirds *Xanthopsar flavus* and Black-and-white Monjitas *Heteroxolmis dominicana* were associated with rolling landscape with wet lowland grasslands and marshes linked with dry upland grasslands. Marsh Seedeater *Sporophila palustris* and Chestnut Seedeater *S. cinnamomea* were associated with tall grasslands and marshes. Rufous-throated Seedeater *S. ruficollis* was not clearly associated with any type of habitat. The Aguapey grasslands are used mainly for livestock grazing and afforestation. Since 1995, approximately 50% of the original grassland habitat has been planted with exotic trees. If this trend continues, Saffron-cowled Blackbirds are likely to become extinct in the Aguapey river basin which currently supports the largest population of this species in Argentina. We recommend guidelines for establishing future reserves and wildlife management actions based on the landscape responses detected in this study. Future action should consider: maintaining connectivity between the Aguapey grasslands and the Ibera Nature Reserve, creating a protected area, designing a land use plan for the basin, avoiding afforestation in large blocks, removal of government incentives for large afforestation projects, and studying the viability of threatened bird populations in extensive cattle ranching areas.

Introduction

The grasslands of the world are considered to be one of the terrestrial biomes in which biodiversity and ecosystem services are at greatest risk because there is a great disparity between the extent of habitat loss and protection (Hoekstra *et al.* 2005). The 'Río de la Plata Grasslands' or 'Pampas Grasslands' (Soriano *et al.* 1991) in southern South America, recognized as one of the highest priority areas for conservation in the Neotropics (Collar *et al.* 1992, Dinerstein *et al.* 1995, Wege and Long 1995) have been severely affected by livestock production and agriculture (Leon *et al.* 1984). The conservation of grassland birds in the Neotropics is a critical issue because nearly 10% of the globally threatened bird species of South America inhabit grasslands, compared to 6.3% for the world as a whole (Collar *et al.* 1994).

Since the beginning of the 20th Century, mechanisation and intensification of farming in Argentina have affected entire populations of grassland birds in a short period of time. No fewer than 25 endemic Pampas grassland-specialists have been listed as threatened or Near Threatened at the global level (BirdLife International 2008). Populations of most of these grassland specialists have declined markedly or are now very fragmented (Krapovickas and Di Giacomo 1998); for example, since 1900 the range of the Strange-tailed Tyrant *Alectrurus risora* has decreased by 90% (Di Giacomo and Di Giacomo 2004); the Pampas Meadowlark *Sturnella defillippi* has decreased by >80% (Tubaro and Gabelli 1999) and both the Saffron-cowled Blackbird *Xanthopsar flavus* and the Black-and-white Monjita *Heteroxolmis dominicana* have decreased by at least 50% (Fraga *et al.* 1998, Fraga 2003). Other species, including sandpipers (Lancot *et al.* 2002) and several *Sporophila* seedeaters (Silva 1999), are now rare and very local. Most of the areas that currently contain the last viable populations of these birds have recently been identified as Important Bird Areas (IBAs) using the global criteria established by BirdLife International (Di Giacomo 2005b).

The Aguapey river basin in Corrientes province, Argentina, was identified as an Important Bird Area (IBA) where eight globally threatened and four Near Threatened grassland birds occur (Di Giacomo 2005b). The Aguapey river population of Saffron-cowled Blackbirds is the larger of two remaining populations in Argentina (Fraga *et al.* 1998), and remaining populations of Strange-tailed Tyrants and Black-and-white Monjitas are among the most important in Argentina (Fraga 2003, Di Giacomo and Di Giacomo 2004). The Aguapey river basin was identified recently as a critical area for urgent protection in the 'Global Gap Analysis' (Rodriguez *et al.* 2004) because it supports a high number of threatened species not yet covered by the global network of protected areas.

At present, information on the breeding ecology of these grassland birds is scarce. There are no accurate population estimates of threatened birds in most IBAs and the basic ecological requirements for maintaining viable populations are completely unknown (Vickery *et al.* 1999). Studies of the habitat associations involving threatened species are necessary to develop priority areas for conservation, ecologically-based reserve design and action plans. The aim of this study was to investigate the habitat associations of a set of species of global conservation concern in the grasslands of the Aguapey river in Corrientes province, Argentina. We studied the abundance and occurrence of grassland birds in several types of grassland using bird and vegetation censuses and remote sensing tools. We asked: what type of grassland do grassland birds use during the breeding season? Is the presence of any of these species associated with any particular landscape configuration? We used two levels of analysis to determine whether birds occupied sites at a local or a landscape scale. At the local scale, vegetation structure is important for nest site selection, territory maintenance and foraging. Site occupancy at landscape level involves the dynamics of habitat connectivity and fragmentation.

Methods

Study area

The Aguapey river basin (250,000 ha, central coordinates: 28°36'S, 56°56'W, Figure 1) is located in the northeast of Corrientes province, Argentina, in the "Northern Campos" sub-division of the Rio de la Plata grasslands (Soriano *et al.* 1991). The landscape is a matrix of natural humid grasslands where tall-grass 'paja colorada' *Andropogon lateralis* dominates flat lowlands (Carnevali 1994). Depressions and drainage areas that slope towards the river are flooded for several months a year and are dominated by *Paspalum* spp. Permanently flooded marshes are connected to the river and are interspersed with tall grasses of *Rhynchospora corymbosa* and *Panicum* spp. Near the river there are sandy hills covered in 'espartillo' *Elionurus muticus* and 'flechilla' *Aristida jubata* dry grassland. Patches of humid forest occur in low areas among the sand hills, and there is 'Atlantic Forest' type riparian forest on the banks and islands. The main

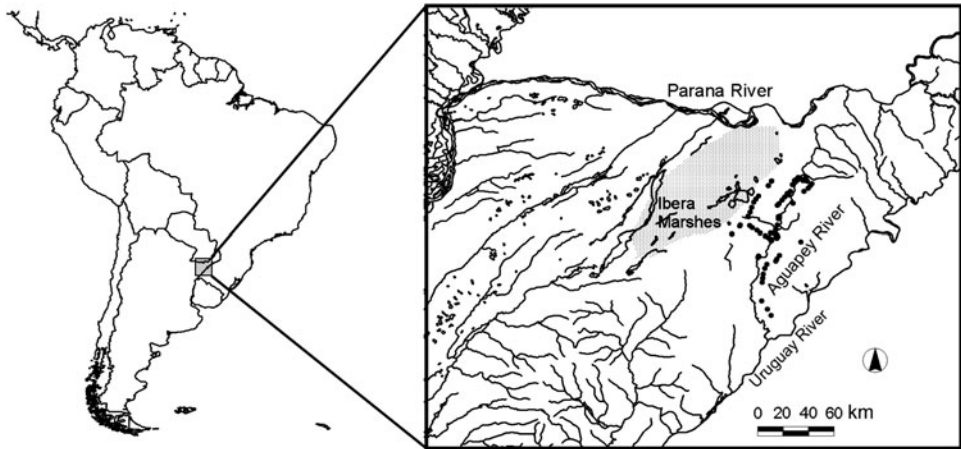


Figure 1. Map of the Aguapey River study area in the province of Corrientes, NE Argentina, showing the position of the 67 bird point counts mentioned in the text.

activity in the region is cattle production and, in recent years, extensive planting of pine trees (Parera and Moreno 2000, Di Giacomo and Krapovickas 2001, Di Giacomo 2005b).

Satellite image analysis

Aguapey river area is a poorly known region, with a small human population and a minimal road network. Before starting the fieldwork, we prepared a preliminary map of the vegetation and land use of the study area to determine the distribution of point counts in a stratified form across all available open habitats. We used two Landsat ETM+ satellite images with a resolution of 28.5 m per pixel. Scenes 255/079 2-Nov-2000 and 255/080 18-Nov-2000 were provided by the National Commission of Space Activities of Argentina (CONAE) with complete geometrical correction, calibration and registration. We used a maximum-likelihood algorithm for classification. We classified the landscape mosaic in the study area by recognizing eight classes representing the main habitats for birds using a detailed map of the vegetation and landforms of Corrientes province (Carnevali 1994). The selected classes were: 1) LOW: lowland grassland dominated by *Andropogon lateralis*; 2) UPG: upland dry grassland dominated by *Aristida jubata* and *Elionurus muticus*; 3) BOG: seasonally flooded grassland dominated by *Paspalum* spp.; 4) MAR: marshes; 5) MOD: modified grasslands (overgrazed, pastures and crops); 6) FOR: natural forests; 7) AFF: plantations of *Pinus* spp. and *Eucalyptus* spp.; 8) WAT: open water, including small artificial dams, natural ponds, streams and rivers.

During the fieldwork (in 2002) we detected some changes in land use compared to the original satellite images obtained in 2000. To conduct a more accurate landscape analysis, we prepared a new supervised classification to create a more detailed map of habitats in the study areas, incorporating land-cover data obtained during previous fieldwork. This final map was based on two more recent LANDSAT 7 ETM satellite images (scenes 255/079 25-Feb-2002 and 255/080 8-Nov-2002). We used a maximum-likelihood algorithm for classification and we assessed image classification accuracy through an error matrix and Kappa Statistic.

Bird counts and records

We carried out fieldwork in the five open habitat classes: Low grassland (LOW), Upland dry grassland (UPG), Seasonally flooded grassland (BOG), Marsh (MAR), and Modified grassland

(MOD) to obtain data on grassland birds. We recorded abundance of birds in 67 point counts from October to November 2002, using standard methods proposed by Ralph *et al.* (1995). We used 10-min 100-m radius point counts at the centre of each patch of open habitat, following the same method used during a previous study in Argentine grassland (Vickery *et al.* 2003). Each point was separated by 500–1,000 m to maintain independence (Figure 1).

We also recorded globally threatened birds as we travelled between point counts.

Landscape metrics

We digitized the geographic position of the centre of each point count and the locations of all bird species into a geographic information system (GIS) which also contained vegetation and land use maps.

We used ArcView 3.2 (ESRI) to create 1,000-m radius buffers (314 ha) around the centre of each point count or record and extracted a set of landscape derived variables from the vegetation and land use maps. We characterized the landscape in each buffer area by measuring the covered area of each vegetation cover class (as percentage of cover of LOW, UPG, BOG, MAR, MOD, FOR, AFF and WAT), the distance (km) to the Aguapey river (RIV), and the number of all cover types present in the buffer as an index of heterogeneity or habitat richness (RIC) (Forman 1995). We considered that a buffer of 1,000 m radius would be sufficient to cover the 'home range' requirements of species that carry out wide-ranging daily movements, such as Saffron-cowled Blackbird (Fraga *et al.* 1998), and for Strange-tailed Tyrant and Black-and-white Monjita that perform aerial displays that cover >200 m, (Di Giacomo and Di Giacomo 2004, Di Giacomo and Di Giacomo unpublished data). We recognize that the buffer of 1,000 m radius extends beyond individual territories of the seedeaters but we think it is important to evaluate habitat condition at a landscape scale that incorporates habitat continuity and connectivity for these species as well.

Statistical analyses

We used the Kruskal-Wallis test to determine whether there were any differences in the relative abundance of birds between different classes of grasslands, and when the value was significant, we made multiple comparisons between groups. The critical value of Z used in the comparisons between groups was adjusted for an α level of significance of 0.05 (two tailed) with a adjustment for multiple comparisons (Siegel and Castellan 1988).

We also used a Mann Whitney U-Test to compare vegetation classes and habitat richness between sites occupied by globally threatened birds grouped and 100 randomly selected sites (on open habitat classes) in Aguapey river basin. This random sample of available habitat sites did not exclude sites where birds were recorded (Jones 2001).

Model development

We used an information-theoretic approach (Burnham and Anderson 2002) to develop a landscape model for the occurrence of each globally threatened bird in the Aguapey river.

We built a generalized linear model (GLM) to analyse the relationship between the presence of each globally threatened bird and a set of landscape predictors (see Landscape metrics). We performed a correlation analysis of the landscape variables to avoid autocorrelation between environmental factors. We considered the set of 10 variables uncorrelated because we found $r < 0.66$ in all cases. The response variable for this analysis was the presence or absence of a particular species. We used a binomial errors and logit link function and maintained equal weights on the presence and absence points to avoid prevalence (Manel *et al.* 2001).

We used Statistica 6.0 'GLZ-best subsets' module (StatSoft 2001) from a full model that included all variables because there was no *a priori* basis to eliminate any models. We used

Akaike's Information Criterion (AIC) to select best models. We followed the methodology proposed by Burnham and Anderson (2002) in that models were considered as competing if their AIC values were less than two points compared with the model with the lowest AIC. We applied the correction of AIC for small sample size, the AICc, and we calculated the ΔAICc (the difference in AICc with the best candidate model) and AICc weight as a measure of the relative model likelihood to look for the support of data after selecting the best model.

Results

Image classification

The overall accuracy of the two final images corresponding to 2002 was 70.2% and 69.2% respectively and the overall Kappa Statistic of the two images was 0.65 and 0.58 respectively. The producer's accuracy was 69–84% for the open habitat classes (including water and grassland) and it was between 47–55% for subtropical forest and the *Pinus* spp. and *Eucalyptus* spp. plantation classes.

Habitat associations at the local scale

We conducted 67 point counts in the five classes of open habitats. We recorded eight globally threatened or Near Threatened species during the point counts: Saffron-cowled Blackbird *Xanthopsar flavus* ('Vulnerable'), Strange-tailed Tyrant *Alectrurus risora* ('Vulnerable'), Black-and-white Monjita *Heteroxolmis dominicana* ('Vulnerable'), Chestnut Seedeater *Sporophila cinnamomea* ('Vulnerable'), Marsh Seedeater *Sporophila palustris* ('Endangered'), Dark-throated Seedeater *Sporophila ruficollis* ('Near Threatened'), Rufous-rumped Seedeater *Sporophila hypochroma* ('Near Threatened') and Sharp-tailed Tyrant *Culicivora caudacuta* ('Vulnerable'). The last two species were recorded fewer than six times during the point counts and were not included in this analysis. We also recorded the presence of Entre Rios Seedeater *Sporophila zelichi* ('Critically Endangered') and Ochre-breasted Pipit *Anthus nattereri* ('Vulnerable'), and two additional 'Near Threatened' birds, the Greater Rhea *Rhea americana* and Bearded Tachuri *Polystictus pectoralis* in previous surveys (October 2001).

All six analysed species were recorded in the point counts in lowland *Andropogon lateralis* wet grassland, flooded *Paspalum* spp. grassland and marshes (Table 1). Only a few individuals were recorded in the upland dry grassland dominated by *Aristida jubata* and *Elionurus muticus* (one individual of Black-and-white Monjita) and in a modified (overgrazed) grassland (five individuals of Saffron-cowled Blackbird).

Table 1. Abundance (mean number of individuals by point count \pm standard error) of globally threatened grassland birds recorded in point counts in the Aguapey River Basin IBA, Corrientes, Argentina. Birds were counted in seven grasslands dominated by *Aristida jubata*, and in 15 grasslands dominated by *Andropogon lateralis*, 15 dominated by *Paspalum* sp., 15 marshes and 15 modified. *P*-values correspond to the differences in the abundance of birds between different classes of grasslands.

Species	<i>Andropogon lateralis</i>	<i>Aristida jubata</i>	<i>Paspalum</i> sp.	Marshes	Modified	<i>P</i> -value
<i>Alectrurus risora</i>	1.33 \pm 0.46	0.00	1.33 \pm 0.61	0.47 \pm 0.27	0.00	0.010
<i>Heteroxolmis dominicana</i>	0.07 \pm 0.07	0.14 \pm 0.14	0.33 \pm 0.19	0.60 \pm 0.25	0.00	0.091
<i>Sporophila cinnamomea</i>	0.47 \pm 0.35	0.00	0.13 \pm 0.09	0.20 \pm 0.14	0.00	0.528
<i>Sporophila palustris</i>	0.00	0.00	0.47 \pm 0.27	1.33 \pm 0.46	0.00	0.036
<i>Sporophila ruficollis</i>	0.07 \pm 0.07	0.00	0.33 \pm 0.19	0.33 \pm 0.33	0.00	0.280
<i>Xanthopsar flavus</i>	0.00	0.00	0.00	2.40 \pm 0.91	0.33 \pm 0.33	<0.001

Strange-tailed Tyrant was the most abundant species in our point counts. It was seen regularly in the *Andropogon* and flooded grassland and to a lesser extent in the marshes. Marsh Seed-eater was more common in the marshes than in the flooded *Paspalum* grassland. Cinnamon Seed-eater was found in *Andropogon* and *Paspalum* grasslands and marshes, and Dark-throated Seed-eater occurred in *Paspalum* grassland and marshes, both without any significant differences in abundance between these two habitats. Black-and-white Monjita was seen in all types of grassland, except for the overgrazed grassland. Saffron-cowled Blackbird was mainly observed in marshes and the overgrazed grassland.

Habitat associations at landscape scale

We recorded a total of 174 observations of the six globally threatened and Near Threatened species over 125 points (67 from the point counts plus 58 other records along the roads). When the records of all species grouped together were considered, we found that there was a lower percentage of modified grassland among the occupied sites than in the available sites at 1,000 m buffer radius scale ($Z = -2.37$, $P = 0.018$). Similarly, we found that sites occupied by threatened species have a higher percentage of flooded grassland and marshes ($Z = 3.99$, $P < 0.001$). So, the threatened species tended to occur in areas with large amounts of flooded grassland and less modified grassland.

Strange-tailed Tyrants occupied sites with low cover of upland grassland and patches of subtropical forests corresponding to areas with more grassland habitat (Table 2). These variables were retained in the eight competing models but the selected model was strongly supported by its AIC weight value (0.22 vs 0.13 for first and second ranked models, respectively).

The best model for Saffron-cowled Blackbirds included RIV, FOR and AFF. Saffron-cowled Blackbirds occurred near the river, in landscapes with more natural forests and pine plantations that are usually located in the uplands. Five competing models retained such predictor variables and showed other components of the riverine landscape, such as marshes and flooded *Paspalum* grassland.

The best model for Black-and-white Monjitas showed a high value of AICc weight (0.75), but retained six predictor variables (RIC, WAT, BOG, UPG, FOR and AFF). This species occurred at sites with a high value for habitat richness that were associated with water near to the river and flooded *Paspalum* grassland surrounded with upland grassland, natural forests and pine plantations.

We found several models for *Sporophila* seedeaters with low support and a high number of parameters. The best model for Chestnut Seedeaters showed increased occurrence at sites near the river with low cover of tall grassland, natural forests and pine plantations. We found two models for Marsh Seedeaters with similar AICc values and low AICc weights, that included RIC, UPG, MOD, FOR and AFF as predictor variables. Sites occupied by Marsh Seedeaters tend to have high habitat richness and contained less upland grassland, modified grassland, natural forests and pine plantation. The best model for Dark-throated Seedeater, but with low weight, included WAT, MAR, LOW, FOR and AFF predictors. This species was associated with sites containing low water cover, marshes and lowland *Andropogon* grasslands, and also with low cover of natural forest and pine plantation.

Discussion

The occurrence of six species of threatened grassland birds in the Aguapey river basin was mainly associated with flooded *Paspalum* grassland and marshes. This pattern was confirmed at both spatial scales. The *Andropogon* grassland represents one of the most common elements of the landscape in the Aguapey river basin and is of great importance for some species. These threatened species avoided overgrazed grassland and forested areas and they were not found in upland dry grassland dominated by *Aristida jubata* and *Elionurus muticus*. Our results provide support for the hypothesis that regional extinctions of populations of some grassland birds, such

Table 2. Competing models for each species of globally threatened and Near Threatened birds of the Aguapey River basin, Argentina. For each model, the corrected Akaike's Information Criterion (AICc), the difference on AICc between the current model and the best model (Δ AICc), and the Akaike weights (w) are given. Abbreviations of variables are given in the Methods section. The variables retained in the best candidate model are in bold.

Species	Variables	AICc	Δ AICc	w	
<i>Alectrurus risora</i>	UPG+FOR	130.00	0	0.22	
	WAT+ UPG+FOR	131.05	1.04	0.13	
	UPG+FOR +AFF	131.08	1.08	0.13	
	RIV+ UPG+FOR	131.09	1.09	0.13	
	RIV+WAT+ UPG+FOR	131.41	1.41	0.11	
	FOR	131.59	1.59	0.10	
	BOG+ UPG+FOR	131.84	1.84	0.09	
	RIC+ UPG+FOR	131.89	1.88	0.09	
	<i>Xanthopsar flavus</i>	RIV+FOR +AFF	40.68	0	0.31
RIV +BOG+ FOR +AFF		41.54	0.86	0.20	
RIV +MAR+ FOR +AFF		41.78	1.1	0.18	
RIV +WAT+ FOR +AFF		41.81	1.13	0.17	
RIC+ RIV + FOR +AFF		42.16	1.48	0.15	
<i>Heteroxolmis dominicana</i>	RIC +WAT+ BOG + UPG + FOR +AFF	64.37	0	0.75	
	RIC +WAT+ BOG + UPG +MOD+ FOR +AFF	66.60	2.23	0.25	
<i>Sporophila cinnamomea</i>	RIV +BOG+LOW+FOR+AFF	32.48	0	0.25	
	RIC+ RIV +WAT+MAR+UPG+AFF	33.42	0.94	0.16	
	RIC+ RIV +BOG+LOW+FOR+AFF	33.46	0.98	0.16	
	RIV +BOG+LOW+FOR+AFF	34.07	1.59	0.11	
	RIC+ RIV +WAT+MAR+UPG	34.12	1.64	0.11	
	RIC+ RIV +WAT+BOG+LOW+FOR+AFF+	34.16	1.68	0.11	
	RIV +MAR+BOG+LOW+FOR+AFF	34.44	1.97	0.10	
	RIV +UPG+MOD+FOR+AFF	65.14	0	0.16	
	RIC+UPG+FOR+AFF	65.17	0.03	0.16	
<i>Sporophila palustris</i>	RIC+BOG+UPG+FOR+AFF	66.19	1.05	0.09	
	RIC+LOW+MOD+FOR+AFF	66.45	1.31	0.08	
	RIC+UPG+MOD+FOR	66.52	1.38	0.08	
	RIC+MAR+UPG+FOR+AFF	66.59	1.45	0.08	
	RIC+UPG+FOR	66.59	1.45	0.08	
	UPG+FOR+AFF	66.62	1.48	0.08	
	RIC+LOW+UPG+MOD+FOR+AFF	66.73	1.59	0.07	
	RIC+MOD+FOR+AFF	66.89	1.75	0.07	
	RIC+WAT+UPG+MOD+FOR+AFF	66.97	1.83	0.06	
	<i>Sporophila ruficollis</i>	WAT+MAR+LOW+FOR+AFF	38.20	0	0.12
		MAR+BOG+LOW+UPG+MOD	38.75	0.55	0.09
		WAT+LOW+UPG+FOR+AFF	38.87	0.67	0.09
		WAT+LOW+FOR+AFF	39.02	0.82	0.08
		AFF	39.14	0.94	0.08
RIC+WAT+MAR+LOW+FOR+AFF		39.36	1.16	0.07	
WAT+MAR+LOW+AFF		39.40	1.21	0.07	
LOW+AFF		39.41	1.22	0.07	
WAT+UPG+FOR+AFF		39.44	1.24	0.06	
LOW+FOR+AFF		39.51	1.31	0.06	
UPG+AFF		39.63	1.44	0.06	
UPG+FOR+AFF		39.80	1.60	0.05	
WAT+BOG+UPG+AFF		39.81	1.61	0.05	
RIC+MAR+BOG+LOW+UPG+MOD		39.84	1.64	0.05	

as Strange-tailed Tyrant, Saffron-cowled Blackbird, and Black-and-white Monjita, is due to agricultural intensification. However, habitat requirements at the local scale and landscape scale showed differences for individual species.

At the local scale, Strange-tailed Tyrants were most abundant in habitats dominated by tall grasses (0.5–1 m), such as *Andropogon lateralis* and *Paspalum* spp., which occur on plains or land with gentle slopes. At the landscape level, this species was also found in landscapes dominated by *Andropogon* and *Paspalum*. However, these grasses mainly occur in areas that are not close to the Aguapey river (3–15 km from the river). This explains why the percentage of upland grassland and forests was lower in areas where this species was recorded, as these habitats are found close to the river. This habitat association coincides with observations of the species in the provinces of Formosa (Di Giacomo and Di Giacomo 2004, Di Giacomo 2005a) and Corrientes (Giraudó *et al.* 2003, Di Giacomo and Di Giacomo 2004).

Historic records for Strange-tailed Tyrant show that it occupied dense, tall, lightly-grazed grassland in subtropical regions in the south of Paraguay and north of Argentina (Azara 1802–05, Hartert and Venturi 1909, Hayes 1995, Di Giacomo and Di Giacomo 2004). In regions further south, where the species has become extinct, this flycatcher was historically a summer visitor in the tall *Paspalum* grassland of Uruguay, and the provinces of Buenos Aires and Entre Ríos in Argentina (Collar *et al.* 1992, Di Giacomo and Di Giacomo 2004). At the present time this type of grassland has disappeared from the southern Pampas region as these habitats have been converted into cropping or are intensively grazed by cattle (Krapovickas and Di Giacomo 1998).

The presence of cattle does not appear to be a threat in the Aguapey river basin when the grass is between 50 cm and 1 m high and there is a low grazing regime. However, in this study we have shown that these birds do not maintain territories in modified grassland. Strange-tailed Tyrants disappeared from the heavily grazed Pilcomayo National Park, Formosa Province. This rare flycatcher has again been observed in the park after the cattle were removed (Di Giacomo 2005b).

Saffron-cowled Blackbirds were most common in close proximity to the marshes connected to the Aguapey river where there were natural forest patches and areas with extensive *Pine* and *Eucalyptus* plantations. These sites were quite diverse, with low lying grassland alternating with marsh and sandy hills and patches and corridors of riverine forest. This habitat association coincides with previous observations of Saffron-cowled Blackbirds found in undulating countryside with marshes surrounded by grassland, shrubs, agricultural crops, planted pastures and even patches forest or woods in Buenos Aires, Corrientes and Entre Ríos, Argentina (Fraga *et al.* 1998, Fraga 2005), in Uruguay (Azpiroz 2000), Brazil (Belton 1985, Dias and Mauricio 2002) and Paraguay (Fraga 2005).

The Aguapey river population of Saffron-cowled Blackbird might be threatened by a variety of land uses in sectors near to the river, although it seems that the species has a limited tolerance to moderate disturbance.

Black-and-white Monjitas in the Aguapey river occurred in a variety of habitats, mainly associated with marshes and their surroundings (Collar *et al.* 1992, Fontana and Voss 1995, Fraga 2003). However, in the Aguapey river basin, the monjitas are also seen in *Andropogon*, *Paspalum* and *Aristida jubata* grasslands 3–15 km from the river, where Saffron-cowled Blackbird is absent. Similar observations have been reported in the region of Concepción and Mercedes (Fraga 2003, Di Giacomo unpublished data). A relict population of monjitas lives in an area of coastal dunes and adjacent grassland in the province of Buenos Aires, coinciding with the presence of undulating land and wetlands in the depressions (Orians 1978, Fraga 2003). Monjitas also live in agricultural areas in the south of Entre Ríos (Fraga 2003) and there are populations that live in recently forested zones in Corrientes (Di Giacomo 2005b).

The habitat associations of the three species of seedeaters showed similarities and differences, which sometimes differed at different scales. At the local scale Cinnamon Seedeater was more common in *Andropogon* grassland, and Marsh Seedeater was more frequent in marshes, consistent with previous observations (Ridgely and Tudor 1994, Fontana *et al.* 2003, Birdlife International 2008). We found Marsh Seedeaters almost exclusively in patches of *Paspalum* spp.

or in areas of *Andropogon lateralis* containing ripe seeds, whereas these seedeaters were absent in nearby areas that contained plants with green seed or without seed. Dark-throated Seedeater did not show strong habitat associations at the landscape scale. This seedeater functioned as a habitat generalist, in agreement with previous observations (Filloy and Bellocq 2006, Birdlife International 2008).

Conservation and recommendations

Most of the Aguapey river basin consists of large private properties, often more than 10,000 ha, with traditional cattle production and usually cover the entire grassland gradient from low lying land with *Andropogon* and *Paspalum* to higher areas near the river. Drainage ditches have been dug in some estancias to drain the flooded *Paspalum* grassland and low lying areas of *Andropogon*. Improved pastures have been sown on higher, drier areas for cattle raising. Traditional cattle production does not appear to compromise the viability of populations of all globally threatened birds of the Pampas grasslands, although there is evidence of lower breeding success in some cattle raising areas (Fraga et al. 1998, Azpiroz 2000).

We documented the avoidance of overgrazed areas by some species. The increasing tendency towards intensification and pastures planted with exotic grasses is likely to have negative effects on these specialists in the Aguapey river basin. In addition, rice production on some estancias is likely to have an impact on some of these species, especially Saffron-cowled Blackbird, because these dams impede the flow of water to the marshes.

Large blocks of *Pinus* and *Eucalyptus* plantations threaten biodiversity conservation in this area because they occur on all types of grassland. This causes an impact on the undulating landscape near the river and also in low-lying areas at some distance from the river. The increase of forest plantations in Corrientes in recent years was strongly supported by government subsidies granted by National Law #25080 that distributed funds supplied by the World Bank. This law has been questioned on environmental protection issues (Di Giacomo and Krapovickas 2001). By comparing satellite images taken in 1995 and 2008, it is seen that more than 50% of the natural grassland in the Aguapey river basin has been planted with trees, reducing the available habitat and connectivity for threatened grassland birds (Di Giacomo 2005b). Given the increase in forestry and the intensification of cattle production in the Aguapey river basin, it is likely that there will be a continued adverse impact on biodiversity, affecting the breeding habitat of these globally threatened birds, and impeding their ability to disperse between habitat patches.

It is important to undertake future management actions at a landscape scale because our study found that landscape attributes affect the occurrence of threatened and Near Threatened birds. We recommend the following conservation measures:

- 1) Maintain the current connectivity of the grasslands in the Aguapey River with the Iberá Nature Reserve so that there is a functional corridor for all fauna.
- 2) Create one or more protected areas, whether governmental or private, including the better conserved habitats along the complete vegetation and topographic gradient from the Aguapey river to the interior of the plains.
- 3) Design and support a land use plan of the basin so that the remaining biodiversity can be maintained in conjunction with a variety of agricultural activities.
- 4) Avoid large blocks (>50 ha) of forest plantations to ensure connectivity between open habitats.
- 5) Halt government support for afforestation projects in Aguapey river basin without an adequate land use plan that includes the requirements for threatened species conservation and long-term monitoring of grassland bird populations.
- 6) Finally, carry out more detailed studies on the breeding biology, habitat use, and movements of populations of threatened grassland birds are necessary in the Aguapey river basin so that critical habitat patches can be identified.

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