Bird community changes associated with cattle raising management in the delta forests of the Paraná River

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Abstract

Riparian forests and environments close to watercourses support high biodiversity, which may be modified by human activities. In the Paraná River Delta region, cattle raising is one of the activities with the greatest impact, altering vegetation structure. These changes are reflected in bird communities that inhabit these environments. We hypothesize that the absence of large herbivores (whether cows or native deer) will produce an increase in the vegetation cover of the lower strata of forests, due to the greater height of the herbaceous stratum and greater coverage of the shrub stratum, and that these changes mainly affect the species of birds that use resources associated with these strata. Our objective was to understand the changes in richness and abundance of the bird community among different types of cattle management using a functional aggregation approach of bird species. In the areas with cattle, we found less coverage of the shrub layer, lower height of the herbaceous layer and fewer climbing vines. We found that changes in richness and abundance of bird community were strongly related to species associated with the lower vegetation strata (ground-feeding guild, shrub guild and low canopy guild), and that the responses of the different guilds were not homogeneous. Understanding the direction of changes in bird

communities occurring in response to modifications of the environment, allows us to optimize conservation efforts. If these efforts are based on conservation of the environment in its natural state, we should adjust the management of the herbivory to the pristine conditions of the environment. On the other hand, if conservation efforts are based on particular species or groups of species associated with certain resources, the correct management of herbivory by cattle can be essential to obtain successful results.

Keywords: *Anthropic impact, functional guild, riparian forests, vegetation structure.*

Introduction

Riparian forests and environments close to watercourses support high biodiversity but most of these environments are subject to anthropogenic processes, such as fishing, hunting, house construction, and navigation, extraction of firewood and trees, and cattle raising (Croonquist & Brooks 1991, 1993, Berduc et al. 2015, Kandus & Quintana 2016). The latter activity is considered one of the anthropogenic processes that changes the environment the most, because presence or absence of large herbivores like cows modifies vegetation structure (Jansen & Robertson 2001, McIntyre et al. 2003, Quintana et al. 2014). Spatial homogenization of the habitat is expected at very high cattle raising intensities, while low or moderate cattle raising levels may increase spatial heterogeneity of the habitat (Fuhlendorf & Engle 2001). This increase in spatial heterogeneity of the habitat is positively related to the overall diversity of bird species, both locally and at landscapes scales (Verdú et al. 2000, Frutos et al. 2016, Penteado et al. 2016).

Bird communities from around the planet have been reported to display differing responses to the presence or absence of cattle, and associated grazing pressures. For example, an Australian study has found with the majority of bird species declining with increasing grazing pressure (Martin & Possingham 2005). In the United States, bird response (negative or positive) may depended on the intensity of cattle raising (Fuhlendorf & Engle 2001). Similar results have been found in European regions (Laiolo et al. 2004). On the other hand, other studies have found negative responses of bird communities in terms of density and richness after cattle had been excluded (García et al. 2008). Apparently, the effect of cattle density on bird communities in the environment depends not only on the loads used, but also on the specific herbivory context of the region, possibly with a marked influence of the recent evolutionary processes of the environments in the presence or absence of large herbivores, and of the current populations of native herbivores (García et al. 2008, Okes et al. 2008, Kay et al. 2017).

Different species of birds may respond differently to changes or disturbances in the environment, so some species may be favored or harmed, and others not altered (Rotenberry & Wiens 1980, Weller 2003, Okes et al. 2008). The guild approach proposing supra-specific groups has been profusely applied in ornithological studies, as an alternative to the more complicated species-specific approaches (Croonquist & Brooks 1991, Farías et al. 2007, Bejarano et al. 2011). Species classification into guilds according to resource use, facilitates bird community studies, allowing comparisons regarding functional organization of the guilds (Terborgh & Robinson 1986, Gitay & Noble 1997, Wilson 1999, Blondel 2003). This is a functional approach because for species with similar habitat uses and food requirements (similar ecological function), a similar response to spatial-temporal variation in the habitats is expected, allowing to examine differences that may not be observed at the species level or in the structure of bird communities.

We hypothesized that absence of large herbivores (cows) would result in an increase in vegetation cover of the lower strata of the riparian forest, with greater height of the herbaceous layer and a denser cover of the shrub stratum, and that these changes would mainly affect guilds that use resources associated with these strata. Our aim was to understand changes in richness and abundances of the bird communities under different types of cattle raising management in riparian forests of the Paraná River delta, using a functional guild approach of bird species.

Materials and methods

Study area

The study was conducted in floodplain forests in the Pre-Delta region of the Paraná River, from Pre-Delta National Park (32 º 03 ' S; 60 º 38 ' W), south to Islas de Santa Fe National Park (32 º 25 ' S; 60 º 49 ' W), Argentina. The climate in the area is temperate/warm humid (Kottek et al. 2006). Annual average temperature is about 19 ºC and annual rainfall is ~900 mm, with warmer and rainier summer periods than in winter.

Sampling design

Data were collected in riparian forest under three different types of cattle-raising management ("type of management" hereinafter): riparian forest on islands with cattle (IwC); riparian forest in the Pre-Delta National Park on islands with > 20 years of cattle exclosure (NC); and riparian forest in the Islas de Santa Fe National Park on islands with recent cattle exclosure (RCE), approximately 4 years before this study began.

The sampling design consisted of four point counts location (separated from each other by at least 250 m) along each of three transects (every transect on a different island) in each of the types of management (9 transects, 36 total point counts location). Transects within the same management type were separated by at least 1,500 meters. Counts were conducted two times (with intervals of 45 days between counts within a season) in summer, autumn, winter, and spring, for three years (2014 - 2016). In total, we performed 864 counts (3 managements x

3 transects x 4 point counts location/transect x 8 times / year x 3 years). The forest structure was sampled in 15-m x 15-m plots of vegetation centered at each counting point during each visit. We estimated the percentage of arboreal and shrub layer cover (by visual estimation), the average height of the herbaceous stratum (taking five random samples with metric rods and averaging them) and presence or absence of the climbing vines (Matteucci & Colma 1982).

Bird samples

We counted all birds seen or heard during 10 min in a 75 m radius at each point count location. All counts were conducted during the first 4 hours after sunrise and the sampling order of the points within each type of management was alternated between the two samples in each season to reduce any bias associated with bird activity and time of day (Frutos et al. 2019). We followed Pearman and Areta (2020) for systematics, and categorized residency status of species based on Fandiño and Giraudo (2010): 1) residents (R): species that remain in the area throughout the year; 2) northern austral migrants (NAM): species that nest in Argentina in spring and summer and migrate northward outside of Argentina during the autumn-winter period; 3) southern austral migrants (SAM): species that nest in the south of Argentina in spring and summer and that disperse to the north and east of Argentina in autumn and winter; and 4) longitudinal migrants of the west (LMW): species that breed in western Argentina in spring and summer and that migrate eastward in Argentina during autumn-winter.

Data analysis

To evaluate the composition of the bird communities, species were grouped into six functional guilds. The guilds were defined on the basis of vegetation strata and their associated food resources, which are exploited by birds, and by the way the birds obtain food, using sections in the Handbook of the Birds of the World (del Hoyo et al. 1992, 1994, 1996, 1997, 1999, 2001, 2002, 2003, 2004, 2005, 2006, 2009, 2010, 2011) and personal notes. Defined guilds were:

- Ground-feeding guild: species that obtain their food mainly on the ground, resting on it.

- Shrub guild: species that obtain their food mainly in the shrub stratum or at the height of the herbaceous stratum (usually 0.5 - 3 m).

- Low canopy guild: species that obtain their food mainly in the lower part of the canopy or on upper levels of the shrub layer.

- Canopy guild: species that obtain their food mainly in the canopy or at the top of tall trees and shrubs.

- Trunk-dwelling guild: species that obtain their food mainly by climbing on tree trunks.

- Aerial-feeders guild: species that obtain their food mainly by hunting in flight, either by short maneuvers from a perch or by constant flights.

In order to obtain more representative samples of the bird community that inhabits forests with different management, we combined the observations made at each point count location in a given season. Thus, each sample included the results of six observation events: two observation dates per season in three years. We compared richness and abundance of each of the six functional guilds using Mixed Generalized Linear Models (MGLM), considering "Management", "Season" and first-order interactions ("Management x Season") as fixed effects, and "sampling point" (levels = 36) nested in "transect" (9 = levels) as random effect variables, recognizing the interdependence of point-count samples (samples repeated at the same point) and their proximity in space (points within the same transect were relatively closer to each other). "Point count" was not evaluated for possible elimination in the model (due to lack of associated variance), but was always part of the models in order to correctly model sampling design. To evaluate statistical significance of the fixed effects, we started with a general model with all variables included. We then used a process of stepwise and backwards selection of variables, by comparing nested models and calculating significance through the likelihood ratio test (LRT). When first-order interactions were significant, final models were made for each season, totaling four models for each response variable analyzed according to “Management” as a fixed effect variable, and samples nested in the “transect” random variable associated with sampling design.

In order to evaluate vegetation structure variables (canopy cover, shrub layer cover, herbaceous layer height) we considered "Management", "Season", "Year" and all the first and second-order interactions (Management*Year*Season; Management*Year; Management*Season; Year*Season) as fixed effects, and the same random effect variables mentioned in the previous paragraph. To evaluate statistical significance of the interactions and fixed effects, we started with a general model with all the variables included and the first and second-order interactions. We then used a process of stepwise and backwards selection of variables, by comparing nested models and calculating significance through the likelihood ratio test (LRT). When we found significant second-order interactions for vegetation variables, final models were made for each season of each year. Thus, we had twelve models (4 seasons x 3 years) for each dependent variable analyzed, with “management” as a fixed-effect variable, plus the random variables associated with the sampling design. If second order interaction were not found, but there was a significant first-order interaction, we analyzed the data using one model for each season of each year, as we mentioned in the previous sentence. In models where the variable "Management" was significant, we used Tukey test (HSD) to make comparisons between pairs of factor levels. These analyses were implemented in R

(Team 2017) using the "lme4" package, "glmmADMB" and the "multcomp" package to apply the Tukey test. In all cases, we report means ± Standard Deviation.

Results

Canopy cover was similar among the types of management throughout the three years of sampling (Fig. 1A; see Appendix A: Table 1). In IwC, we found fewer climbing vines, compared to NC and RCE forests. *Cortaderia selloana*, a tall herb, was included in the shrub layer due to its large size. This was the most abundant species in the shrub stratum in IwC. The shrub stratum only showed greater coverage in RCE with respect to IwC although these differences were not constant during the entire sampling period, with variations in the magnitude of the average differences between management, seasons and years and were only important during the autumn season in all years and in winter of 2014 (Fig. 1B, see Appendix A: Table 1). The height of the herbaceous stratum also showed variations in the magnitude of the average differences between management types, seasons and years, which was lower in IwC compared to NC and RCE, except during summer in all the years and during winter and spring of 2016, when heights did not differ among management types (Fig. 1C, see Appendix A: Table 1).

In the total study area we recorded 20,605 individuals belonging to 130 species, 33 families and 16 bird orders, of which 81 species (20,082 individuals) were grouped into six functional guilds (see Appendix A: Table 3). The remaining 49 species were not analyzed with respect to guild structure, because in many cases they were rare or occasional species (less than five detections during the entire sampling period), or species associated with grassland and/or marsh environments, which use the forests occasionally or exceptionally (for example, during periods of flooding).

The ground-feeding guild presented the greatest richness and relative abundance of birds in the total study area. The trunk-dwelling and aerial-feeders guilds presented the least richness and relative abundance of birds (Fig. 2A). In IwC, the ground-feeding, canopy and aerial-feeders guilds presented the highest relative abundance respect to others managements types (Fig. 2). In RCE, the shrub and low canopy guilds presented the highest relative abundance (Fig. 2).

Ground-feeding guild. The species richness by point count location was higher in IwC than in RCE and NC in all seasons. Total abundance of individuals by point count location was greater in IwC than RCE and NC in all seasons, except in the autumn where IwC was similar to NC, and RCE had lower values (Table 1; see Appendix A: Table 2).

Shrub guild. The species richness by point count location did not present differences between the different types of management in any of the four seasons. The abundance of individuals by point count location was lower in IwC than in RCE and NC in autumn and winter seasons, while in summer there were no differences and in spring it was higher in RCE than in IwC and NC (Table 1; see Appendix A: Table 2).

Low canopy guild. The species richness by point count location showed no differences between management types in summer, but was lower in IwC than RCE and NC during autumn and winter, while in spring it was higher in RCE than IwC and NC). The abundance of individuals by point count location did not differ between management types during the summer, but was lower in IwC than RCE and NC during autumn, winter, and spring (Table 1; see Appendix A: Table 2).

Canopy guild. The species richness by point count location did not differ between management types in any season. The abundance of individuals by point count location was lower in NC during summer and winter with respect to IwC and RCE, in autumn it was higher in IwC with respect to the other managements, and in spring it did not present differences between types of managements (Table 1; see Appendix A: Table 2).

Aerial-feeders guild. The species richness by point count location was lower in IwC than in RCE and NC only during the winter season, while there were no differences between management types in other seasons. The abundance of individuals by point count location did not differ between management types (Table 1; see Appendix A: Table 2).

Trunk-dwelling guild. The species richness and the abundance of individuals by point count location showed no differences between management types in any season (Table 1; see Appendix A: Table 2).

Discussion

The ground-feeding guild presented the greatest differences with respect to type of cattle raising management, and in general, species that make up this guild were positively associated with IwC. The shrub guild presented the higher abundance values detected during cold seasons (autumn and winter) in NC and mainly in RCE may respond to a greater supply of food resources associated with the lower strata, with higher values of shrub cover in RCE, and little developed in IwC. The low canopy species showed a strong association with RCE and NC. The main differences in richness and abundance values occurred in cold seasons, possibly due to the greater supply of food resources associated with climbing vine that colonized most of tree trunks in RCE and NC, which were not present in IwC. Many species of the canopy guild are migratory species that reside in the area during warm seasons. This explains the decrease in abundance of this guild during the cold seasons in RCE, as they migratory species were very abundant in that management during the warm seasons. The species of the aerial-feeders guild generated great changes in community at a temporal scale (among seasons), since most of them are migrant species that reside in the area during the warm seasons. The group of species of the trunk-dwelling guild was very stable with respect to their abundances in different types of management and different seasons. Our bird species classification into functional guilds reflected structural changes in vegetation strata, so we recommend their implementation in future studies that focus in structural changes of the environment.

Reactions of bird communities to different disturbances that modify access to soil resources and low vegetation strata, such as fire and cattle raising, have been studied in different regions of the planet (Laiolo et al. 2004, Powell 2008), where species that exploit ground resources generally benefit from herbivory, while species associated with shrubs and high grass are negatively affected. More complex studies have evaluated the response of communities to heterogeneity of patches with different fire and herbivory management, finding species that are favored by such heterogeneity, while others are preferentially associated with certain patches (Fuhlendorf et al. 2006, Isacch & Cardoni 2011).

A recent research concluded that, on an international scale, grazing causes a decrease in diversity at all trophic levels, except detritivores (Filazzola et al. 2020). However, researchers from different regions of the planet suggest that grazing exclusion may have negative consequences for biodiversity, mainly for organisms that have evolved in environments with high herbivory pressure and where populations of native herbivores have decreased or have become extinct (Fuhlendorf & Engle 2001; Laiolo et al. 2004; Fuhlendorf et al. 2006; Cingolani et al. 2008; Coppedge et al. 2008; Ahlering & Merkord 2016; Ferreira et al. 2020).

In areas with different types of cattle raising within the floodplain of the Paraná River, we found that changes in bird community composition were strongly related to species associated with low vegetation strata (ground-feeding guild, shrub guild, and canopy guild), and that responses of different guilds were dissimilar. Ground-feeding species showed a positive association with cattle raising, while shrub stratum and low canopy species showed a positive association with absence of cattle raising, mainly with recently excluded areas. On the other hand, guild species composed of species less strongly associated with vegetation strata modified by type of management showed little or no differences between sites. Understanding the direction of changes in biodiversity associated with environmental modifications allows us to optimize conservation efforts. If such efforts are based on conservation of environment in its natural state, we should adjust herbivory management to pristine conditions of the environment (for our study area it was discussed in Frutos et al. 2020). On the other hand, if conservation efforts are based on particular species or groups of species associated with particular resources, correct management of the herbivory may be fundamental to obtaining successful results.

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Ethics statement: This study complies with all Argentina laws and adheres to appropriate ethical standards.

Author contributions: A.E.F. and C.I.P conceived the project. A.E.F performed the data collection. A.E.F, P.M.L.L and C.I.P analyzed data and prepared the manuscript.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at XXXXX.

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Fig. 1. Mean values ± SE of canopy cover (A), shrub layer cover (B) and herbaceous layer height (C) per point count location in each of four seasons in 2014, 2015 and 2016 in albardón forests under three different types of cattle-raising management. In cases where there were differences between the different types of management, the letters indicate similarities (equal letters) and differences (different letters) between management types (Tukey test).

Fig. 2. Relative abundance [%] and total richness (in italics) for the different guilds in the total study area (A); Relative abundance [%] and total richness for the different types of cattle-raising management in albardón forests for Ground-feeding guild (B); Shrub guild (C); Low canopy guild (D); Canopy guild (E); Trunk-dwelling guild (F); Aerial-feeders guild (G).

Table 1. Mean values ± SE of total number of individuals and total richness of birds species for each guild per point count location in each of four seasons in 2014, 2015 and 2016 in albardón forests under three different types of cattle-raising management. Shadings represent differences between types of management (result of a posteriori comparisons by Tukey test); the gray triangle indicates that the value of this treatment did not show differences with the others. IwC: Island with Cattle; RCE: Recent Cattle Exclosure; NC: Non Cattle (> 20 years of cattle exclosure). Each count point was sampled 6 times per season (2 samples per season during the years 2014, 2015 and 2016).

		Summer			Autumn			Winter			Spring		
		IwC	RCE	NC	IwC	RCE	NC	IwC	RCE	NC	IwC	RCE	NC
Average abundance per sample	Ground-feeding guild	68.8 ± 3.0	42.7 ± 2.3	39.8 ± 1.3	57.3 ± 5.0	39.3 ± 3.2	47.8 ± 1.7	62.7 ± 3.9	45.6 ± 3.3	41.4 ± 2.1	82.9 ± 3.9	52.8 ± 2.3	52.7 ± 1.2
	Shrub guild	19.5 ± 1.1	21.8 ± 1.4	19.4 ± 1.1	17.0 ± 0.8	22.8 ± 1.5	22.0 ± 0.9	14.4 ± 1.0	25.7 ± 1.9	22.8 ± 1.4	19.1 ± 1.2	27.5 ± 1.8	20.8 ± 1.4
	Low canopy guild	18.5 ± 1.6	25.4 ± 1.7	23.8 ± 1.1	9.4 ± 1.0	23.9 ± 1.9	20.5 ± 1.2	11.1 ± 1.0	23.6 ± 2.4	22.3 ± 1.0	20.3 ± 1.4	33.9 ± 1.5	29.1 ± 1.6
	Canopy guild	26.5 ± 1.1	26.5 ± 1.1	17.9 ± 1.6	26.8 ± 2.1	19.1 ± 0.6	16.6 ± 2.0	26.3 ± 2.0	20.8 ± 1.3	14.7 ± 1.3	26.8 ± 2.4	28.8 ± 1.3	22.3 ± 1.2
	Aerial-feeders guild	9.0 ± 1.2	8.3 ± 1.3	9.3 ± 1.9	4.4 ± 0.7	4.3 ± 1.0	1.8 ± 0.5	10.6 ± 1.4	8.7 ± 1.3	5.9 ± 1.2	19.7 ± 2.0	13.6 ± 1.6	13.7 ± 1.2
	Trunk-dwelling guild	10.8 ± 0.9	10.7 ± 1.5	10.7 ± 1.2	11.9 ± 1.2	12.0 ± 1.7	13.2 ± 1.2	12.1 ± 1.1	12.5 ± 1.2	12.4 ± 0.9	10.7 ± 1.1	14.2 ± 1.4	12.2 ± 1.0
Average richness per sample	Ground-feeding guild	16.2 ± 0.4	11.1 ± 0.6	10.2 ± 0.5	12.4 ± 0.4	10.1 ± 0.4	10.4 ± 0.5	14.2 ± 0.4	11.4 ± 0.4	10.8 ± 0.6	17.1 ± 0.4	13.4 ± 0.4	13.0 ± 0.7
	Shrub guild	5.1 ± 0.4	4.9 ± 0.3	4.6 ± 0.4	3.7 ± 0.3	4.6 ± 0.3	3.4 ± 0.3	3.8 ± 0.3	5.1 ± 0.4	4.0 ± 0.2	5.6 ± 0.6	6.2 ± 0.3	4.6 ± 0.4
	Low canopy guild	5.0 ± 0.3	5.8 ± 0.4	5.5 ± 0.4	3.3 ± 0.3	5.4 ± 0.4	5.3 ± 0.4	3.8 ± 0.3	5.5 ± 0.2	5.1 ± 0.3	5.8 ± 0.3	8.1 ± 0.4	6.2 ± 0.4
	Canopy guild	6.2 ± 0.3	5.7 ± 0.3	6.2 ± 0.4	5.3 ± 0.4	5.3 ± 0.3	5.3 ± 0.3	5.6 ± 0.3	4.6 ± 0.3	5.0 ± 0.3	5.8 ± 0.3	6.3 ± 0.4	6.4 ± 0.2
	Aerial-feeders guild	3.8 ± 0.3	3.1 ± 0.4	3.4 ± 0.5	1.4 ± 0.2	1.8 ± 0.3	1.2 ± 0.2	1.3 ± 0.1	2.4 ± 0.1	2.1 ± 0.2	5.3 ± 0.5	4.7 ± 0.3	4.6 ± 0.3
	Trunk-dwelling guild	3.6 ± 0.2	3.8 ± 0.4	3.6 ± 0.2	3.9 ± 0.4	4.0 ± 0.3	4.7 ± 0.3	3.8 ± 0.2	4.1 ± 0.3	4.3 ± 0.3	4.0 ± 0.2	4.4 ± 0.3	4.3 ± 0.3